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DE247 Digital Engineering

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Generative Design Arrives

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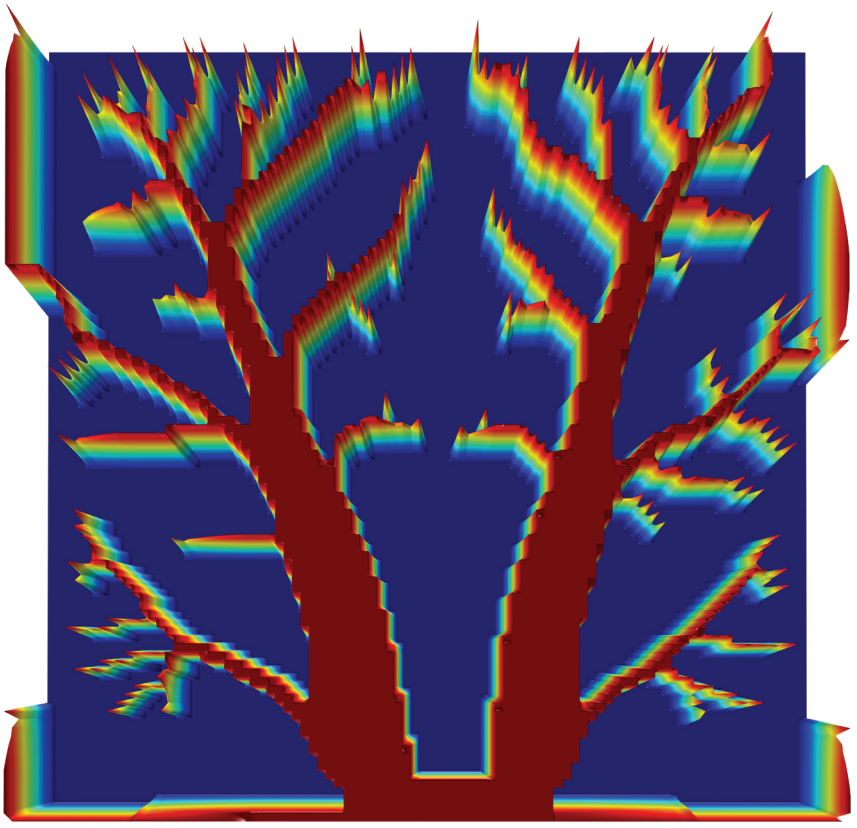

Topology optimization of a heat sink.

Engineers from Fraunhofer IAPT used topology optimization and additive manufacturing to design a heat sink, a common component in many electronic devices. The topology-optimized design was then transformed into a simulation application to automate and customize certain design tasks. Now, engineers, designers, and manufacturers companywide are able to efficiently optimize intricate heat sink geometries and prepare them for 3D printing.

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Read the blog post

COMSOL

By Brian Albright

Technology, Culture and Innovation

While the global pandemic has certainly slowed down large swaths of the economy, the push for digital transformation has continued. IFS released a study earlier this year that found 70% of companies still plan to increase or maintain their digital transformation spend, with an eye on recovering in the post-pandemic economy.

IFS released another study in September that looks at these efforts from a slightly different perspective: a growing number of those companies want to spend their transformation dollars with vendors that align with their ethics and culture.

In fact, ethics and culture topped more traditional factors like innovation in the survey when it came to choosing a partner. Why? Poor advice from vendors was listed as a top reason for the failure of digital transformation projects. In many cases, senior management forced implementations with vendors that were a poor technological fit.

"The fact that a non-tangible such as ethics is ranked among the top three vendor traits is inextricably linked to the fact that poor advice from vendors was rated as the top reason for failure," IFS Chief Customer Officer Michael Ouissi said. "Companies investing in technology should expect their vendors to adhere to sound sales and marketing practices based squarely in actual customer value."

I bring this up because I think it ties into our focus in this issue—generative design solutions. While vendors like Autodesk have been promoting the capabilities of these systems, adoption is still in the earliest stages, in part because a lot of end users have not been able to align the capabilities of these solutions (which I think can potentially unlock some pretty amazing innovations) with their own goals.

For vendors offering generative design solutions, it is going to be critical to ensure a good fit with the needs of their engineering customers. Likewise, companies that are investigating these solutions should be aware that they will require a new type of approach to the design cycle, and a better understanding of their own design goals.

Early demonstrations of generative design have focused on feeding strength and weight parameters into the solution, and then gasping at the frequently wild-looking shapes that emerge. Practical adoption of these systems will require users to take a more holistic approach to setting up the problems they need to solve. Generative design needs to provide solutions that address the entire workflow, and do so in a way that will not always require additive manufacturing.

Generative design needs to provide solutions that address the entire workflow, and do so in a way that will not always require additive manufacturing.

In this issue, our writers have talked to experts in the field of generative design to examine the current market for the technology, and how these solutions can potentially help engineers get to the best design in the most efficient way possible.

As IFS found, however, innovative technology alone is not enough. Vendors and their customers will need to openly and honestly evaluate their needs and capabilities, and craft technology solutions that truly address real-world design problems in an efficient and affordable manner. DE

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DE247 Digital Engineering

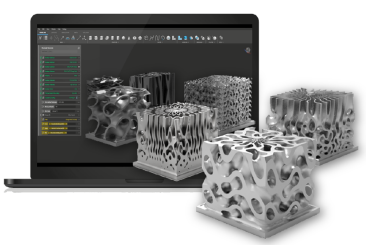
TECHNOLOGY FOR OPTIMAL ENGINEERING DESIGN

October/November 2020
Vol.26 • No.8

INSIDE

COVER STORY

FOCUS ON GENERATIVE DESIGN



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ENGINEERING COMPUTING

SIMULATION

How plant simulation and modeling technologies help enforce social distancing and safety practices.

By Kenneth Wong

REVIEW

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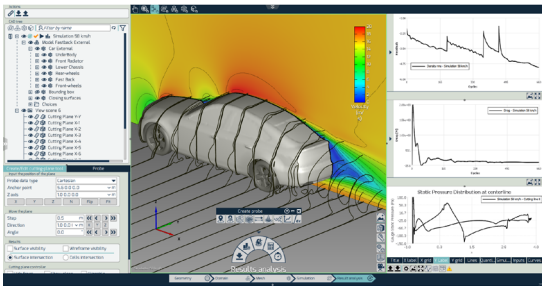
DEPARTMENTS



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Digital Engineering® (ISSN 1085-0422) is published 9 times per year (Jan/Feb, Mar, Apr, May, Jun, Jul/Aug, Sep, Oct/Nov, Dec) by Peerless Media, LLC, 50 Speen St., Suite 302 Framingham, MA 01701.

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Remote Work is Here to Stay

Engineering recruiting firm Andela found in a recent survey that

74% of engineering leaders said that their teams had **transitioned to fully remote** as a result of COVID-19

66% indicated that they plan to **continue allowing remote work** after the pandemic subsides

13% of engineering teams were **fully remote** prior to COVID-19

22% of engineering leaders express a **preference for engineers working in an office environment** following the pandemic

SOURCE: Andela

Digital Twin Market to Grow 30%

The digital twin market is set to grow from more than **$4 billion** currently **(2019)** to more than **$35 billion** by **2026**, according to a recent study from market research firm Global Market Insights.

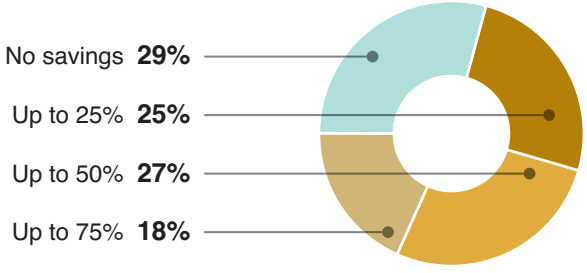
SOURCE: Global Market Insights

>34% Machines and equipment health monitoring application CAGR **(2026)**

European market share **(2026)** **>26%**

3D Printing Cost Savings

On average, how much were costs reduced per project when using 3D printing compared to your previous method?

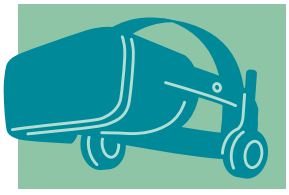


MakerBot's 3D Printing Trends Report found that nearly **74%** of respondents plan to invest in 3D printing in **2021**, with **50%** planning to spend up to **$100,000**. The majority of respondents (**77%**) use Fused Deposition Modeling/fused filament fabrication 3D printers, and plastics and resins are the main materials in use.

SOURCE: MakerBot

$4.6 Billion

The size of the virtual reality (VR) market in **2020**, according to ABI Research. While the COVID-19 pandemic has presented some supply chain challenges to the VR industry, the technology can provide enhanced remote collaboration benefits for companies that have shuttered offices and reduced travel.



SOURCE: Virtual Reality Market Data: Devices, Verticals, and Value Chain. ABI Research, September 2020

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AMD ALTAIR

[1] RPW-320: Testing as of April 29, 2020 by AMD Performance Labs on a production test system comprised of an Intel® Xeon® W-2125, 32GB HBM2 RAM, Windows® 10 Pro for Workstations, 64-bit, System BIOS 1.11.1, AMD Radeon™ Pro VII, AMD Radeon™ Software for Enterprise 20.Q2 Pre-Release version /NVIDIA Quadro RTX™, NVIDIA Quadro® Optimal Driver for Enterprise (ODE) R440 U6 (442.5) using AMD Internal Benchmark for ALTAIR EDEM™. Results may vary. RPW-320

ROAD TRIP

Open Design Alliance Developers Conference

Autodesk Surprises Industry and Joins ODA

BY RANDALL S. NEWTON

In an unusual turn of events, big news about the Open Design Alliance (ODA) was not announced at ODA's recent developers conference—but afterward by its newest member and former antagonist Autodesk.

It is understandable if you reread the previous sentence to believe those words. Since its creation more than 20 years ago, the ODA has served its members through creation and support of a reverse-engineered version of the DWG file format that Autodesk AutoCAD popularized.

So why the change of heart? Autodesk is under considerable pressure from its Revit user base in architecture, engineering and construction (AEC) to improve interoperability for Building Information Modeling (BIM). When AutoCAD was the leading tool for architecture and construction, the ODA's version of DWG filled the interoperability gap.

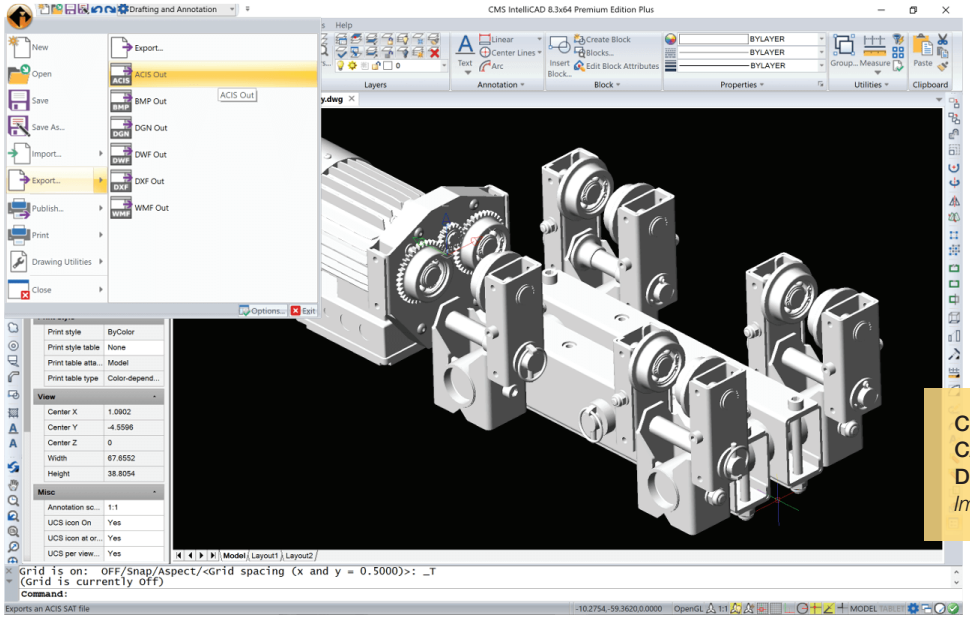
For the sake of accuracy, AEC firms have turned to directly sharing Revit files, even at the cost of shutting out users who prefer other software products. Revit has proprietary file formats and have started to become a de facto file format for construction the way DWG did a generation ago.

Revit can also import/export to a vendor-neutral data format called Industry Foundation Classes (IFC). Users have always complained that Autodesk's support of IFC for Revit was tepid. Updates came late, and conversions almost always needed more editing.

In 2018, ODA started shipping a Software Development Kit (SDK) for Revit compatibility. Last year ODA announced a partnership with the nonprofit behind IFC, buildingSMART International, and is now shipping the first iteration of its new IFC support. It now seems Autodesk decided it would be better to join the IFC interoperability effort than continue to swim upstream against the wishes of its users.

The agreement between Autodesk is very specific; it covers only IFC. Standard ODA membership terms require member companies to share any code they develop for DWG compatibility with ODA for the benefit of all members; Autodesk was granted an exception.

Autodesk and the ODA are not commenting beyond the initial announcement, which



CMS IntelliCAD is one of many CAD products built using Open Design Alliance technology. *Image courtesy of CMS.*

was published in an Autodesk blog as a statement from Autodesk VP Amy Bunszel. "This decision demonstrates our commitment to take meaningful steps towards improving our customers' experience in the AEC space," Bunszel wrote.

The comments of Dr. Stefan Boeykens, a guest professor of BIM at KU Leuven, Belgium, and a practicing architect, are typical of what users are saying on social media about the announcement.

"So alongside the internal C++ and C# code bases, which both still exist in Revit, [Autodesk] will now add a third attempt to properly support IFC. Maybe this time they can show their competitors that Revit can play nicely in IFC exchange after all. The underwhelming IFC support by Revit is costing the industry a lot, although it does bring business to countless BIM consultants trying to get things to work more or less in projects. But I prefer better IFC support over the whole industry being forced to adopt the RVT format," he notes.

Meanwhile in DWG

Although the Autodesk announcement overshadowed any news from the conference, ODA still had plenty to say about the value of its work to make DWG more than a file format.

"For us, DWG is a powerful framework for application development," says Neil Peterson, ODA president.

With hundreds of products in all CAD disciplines based on ODA technology, the ODA has become a primary development partner for a variety of software companies. Using ODA technology allows software makers to add version control and support for cloud technologies.

By comparison, Autodesk does not offer version control in AutoCAD. An independently produced white paper that compares AutoCAD Web against a product made using ODA technology (Graebert Ares Kudo) concludes the ODA-based product "significantly outperforms AutoCAD Web in almost every category."

Open Cloud SDK, ODA's stack for cloud is not a turnkey Software-as-a-Service product, Peterson says. "We give you tools to host your own applications and control your own IP," he says. The customizable platform works with both Microsoft Azure and Amazon Web Services. The most recent release includes new options for working with a range of mechanical CAD formats including data from SolidWorks, CATIA and products using the JT open data format from Siemens.

Specific recent improvements to ODA SDKs of interest to mechanical CAD include:

- Improvements to PDF Import into a DWG database: users can import full lines of PDF as MTEXT; linetypes; and support for clipping regions during import.
- The ODA Solid Modeler now supports Boolean operations in the DWG database.
- ODA's native revision control for DWG is now refactored to allow easier integration into real-world client applications. The new implementation allows clients to more easily implement revision history for groups of related files, including non-DWG files.
- PDF export can now use graphics caching to improve performance in cases where multiple views of a model are exported to the same PDF file.
- New DGN export from a DWG database. ODA now supports DGN-to-DWG conversion and DWG-to-DGN conversion.
- Automatic level of detail selection for RCS point cloud visualization supports fast visualization and manipulation of large RCS point clouds. Users can also convert point cloud data to RCS format.
- Improvements to model documentation view support now include new VIEWSECTION, VIEWBASE and VIEWPROJ commands for convenient creation of model doc views. Features in progress are saving model document views to standard DWG files and precision hidden line removal support.

"The ODA technology stack is our value proposition," says Peterson, "and our stack is ready for prime time."

ODA is also working on extending its solid modeler SDK to be a multi-user application, taking advantage of its previous work in version control and cloud CAD. No specific availability date was provided. DE

Randall S. Newton *is principal analyst at Consilia Vektor, covering engineering technology. He has been part of the computer graphics industry in a variety of roles since 1985. Contact him at DE-Editors@digitaleng.news.*

MORE INFO

- **Autodesk:** Autodesk.com
- **Open Design Alliance:** OpenDesign.com

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

A Glimpse of the Generative Design Market

Analysts speculate market impacts of COVID-19, and find ways to evaluate software efficiency.

BY KENNETH WONG

In early 2019, the analyst firm ABI published the "Generative Design Vendor Ranking" report, described as a competitive assessment study. The top spot went to Autodesk, giving it bragging rights over rivals such as Siemens, PTC and Dassault Systèmes.

"The market for software with generative design tools will grow at a compound annual growth rate of 24% to reach US$44.5 billion for over 16 million seats in 2030," according to ABI. "These sales include licenses and subscription revenues for computer-aided design [CAD] products with generative design tools or standalone generative design software products."

"The automotive industry represents the largest opportunity globally with US$18.5 billion in generative design software revenues forecasted for 2030," Pierce Owen, principal analyst at ABI Research, noted.

Since the report's publication, COVID-19 and supply chain disruptions have emerged, putting many positive trends in jeopardy. Digital Engineering spoke to industry watchers to understand if generative design (GD) adoption and deployment are slowing down or holding up in the pandemic.

A Blurry Picture for Now

Before his role as an analyst, Stan Przybylinski was manager of Market and Competitive Intelligence for Dassault Systèmes, one of the key players in the CAD and simulation software market. This gives Przybylinski, VP of CIMdata, not just an analyst's perspective, but also an insider's view.

"I don't think that COVID-19 is really blunting GD adoption, other than perhaps slowing some expenditures. On the other hand, many companies see this disruption as an opportunity to make important changes in their operations and enabling technologies," observes Przybylinski.

Frustum, a new startup in generative design, was acquired by mainstream CAD and PLM software supplier PTC in 2018. *Image courtesy of Frustum.*

Simon Hailstone, principal consultant at Cambashi, believes the fate of GD is invariably linked to the fortunes of heavy simulation users. "The current downturn has huge impacts on certain industries, like aerospace, automotive and oil & gas. With aerospace, we're talking impact across the supply chain. Other industries, like health care, seem to be holding up. The high-tech industry is also showing resilience."

When upper management tightens its belt in response to an economic downturn, emerging technologies such as GD are on shaky ground.

"GD gives you fantastic cost optimization opportunities. On the other hand, it also represents a significant investment. We may not really know how things look until next year. 2021 is a more critical year for us to look at the market," Hailstone says.

At the recent virtual Autodesk Advanced Manufacturing Summit, Autodesk highlighted its customer's (Briggs Automotive Company) use of generative design to reduce weight in its wheels. *Image courtesy of Autodesk.*

"My intuition is the graphs for GD's growth should be similar to or slightly better than the design space exploration and automation segments," Joe Walsh, CEO of IntrinSIM, observes.

Design space exploration and simulation encompass classic CAD and simulation programs. GD, in many analysts' view, is an offshoot of these markets.

"But there isn't enough data, and there's not an easy way to get the data," Walsh says. "Maybe the product managers might have that information, but usually it's included in something else."

The challenge in assessing the generative design market is twofold: Because GD is a relatively new branch of simulation, the financial data, licensing models and seat counts are too limited to offer a historical perspective. Furthermore, GD is sometimes offered as an integrated part of CAD, sometimes as an independent tool of its own and sometimes as part of geometry preparation tools for 3D printing. This leaves the analysts with scrambled pieces of a jigsaw puzzle.

Benchmarks for Generative Design

In the report titled "A Vision for Generative Design," released in February 2019, IntrinSIM proposes a checklist for evaluating GD tools.

The firm proposes that, based on the software's ability to consider a wide range of design parameters—such as weight, mass, temperature, fatigue, manufacturing process—as constraints, the solution can be graded as (1) Limited, (2) Basic, (3) Functional, (4) Advanced or (5) Comprehensive.

The firm further proposes that the tool be subjected to these benchmarks on a number of contexts: Handling all appropriate objectives and constraints; handling multiple load conditions; handling multiphysics; and so on.

"Every six months or so, a major release of GD software will come out, and I'd see dramatic improvements," says Walsh. "In my opinion, nobody gets a Comprehensive grade right now across the spectrum. There are a couple of tools that get Advanced grade on several fronts."

For example, Walsh would place Autodesk Fusion 360's GD between Functional and Advanced in terms of cost-based optimization. On the other hand, due to a lack of assembly-level GD, he would give the software a Basic grade in the assembly context.

"If someone just needs component-level GD with costing considering, Fusion 360 is an excellent fit. For someone who needs assembly-level GD, maybe not," Walsh says.

Space Allocation in COVID

Cambashi's Hailstone believes GD may have a role to play in the COVID-era space management crisis, brought on from social distancing requirements. Enclosed spaces such as train stations, bus terminals and bus interiors, for example, may need to be reconfigured and sectioned off to keep people 6 ft. apart. The airflow within public spaces may need to be controlled to minimize pathogen transfer. Applying GD to these problems would allow engineers to consider a range of options simultaneously.

"In the context of public health, this could be a real game changer," says Hailstone. "Much of it has to do with using simulation to figure how to redesign the existing spaces. We know, for example, office spaces need to change significantly."

Though GD relies heavily on artificial intelligence-like algorithms, Hailstone believes the role of the human expert is indispensable.

"We have to make it easier for the engineers to define a problem, then let them make the final decision. The decision-making tools should give them enough information to show how the software gets to the answer. That workflow would work quite well," he says.

Newcomers and Household Names

Autodesk Fusion 360, Altair's solidThinking and their rivals in the mainstream CAD segment represent established players with GD offerings. Newcomer Frustum was acquired by PTC in 2018, leaving a handful of startups (nTopology, ParaMatters and SciArt) in the pool.

For those on a quest for a GD solution, Walsh says the goal is not necessarily to search for a tool with a Comprehensive rating, but to find one that offers the desired features.

"Nobody needs everything," he says. "Someone might need support for assembly contact as a constraint, but they may not need lattice structures."

The GD software sector as a whole, Walsh reasons, is presently somewhere between Basic to Functional, poised to cross the threshold. He predicts some vendors may eventually choose to specialize in specific GD applications rather than offer generalized solutions, which could be too complex to learn or use for average design engineers. 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

- **ABI:** ABIResearch.com
- **Cambashi:** Cambashi.com
- **CIMdata:** CIMData.com
- **IntrinSIM:** IntrinSIM.com

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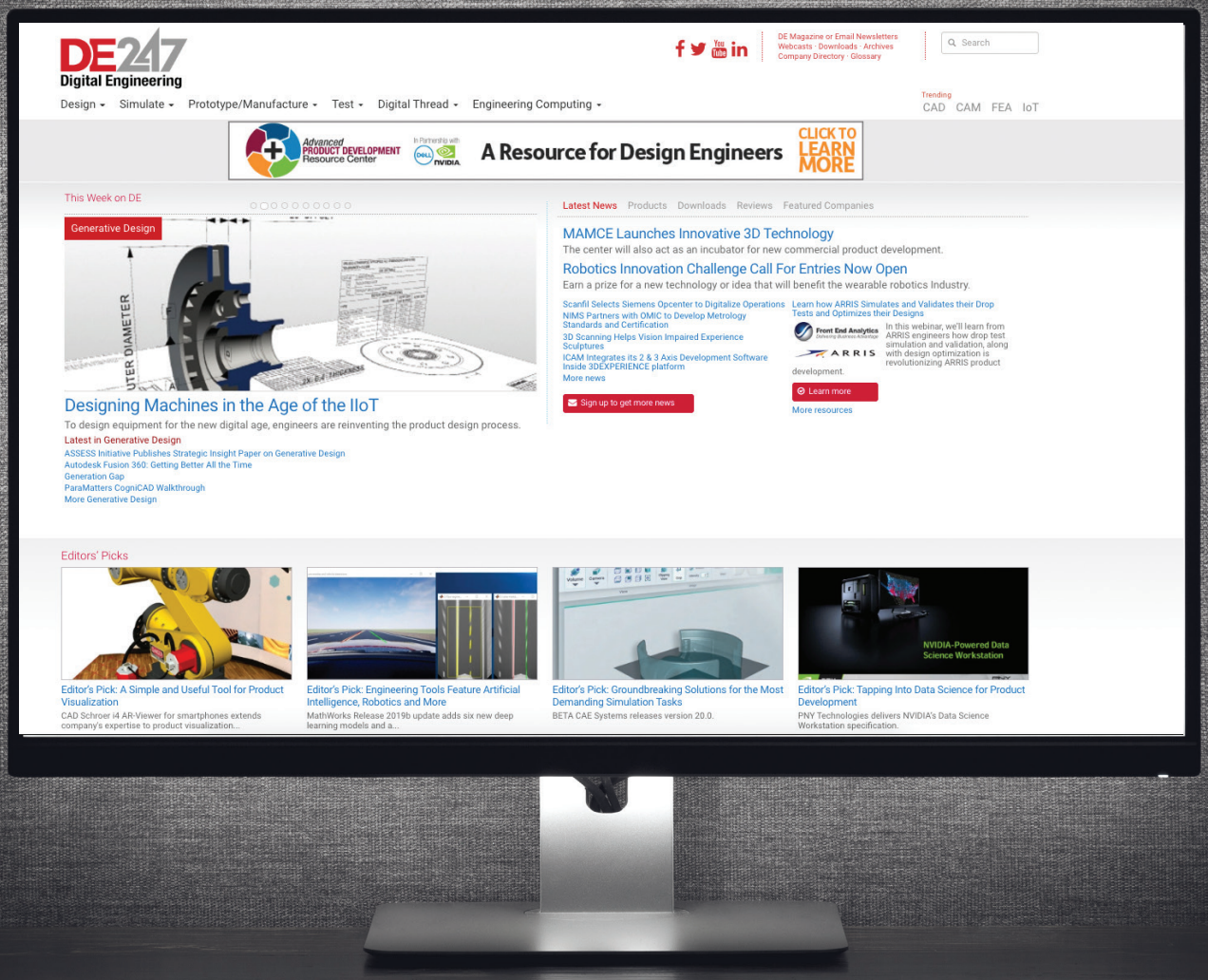

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Lighter **by Design**

Generative design can help engineers meet new lightweighting requirements.

BY JIM ROMEO

The Harley-Davidson LiveWire electric motorcycle was designed to improve its energy capacity by 90% while boosting this capacity relative to vehicle mass (kWh/kg) by an increase of 60%. At the same time, its chassis stiffness increased 143% and 97% in two primary directions of interest. Its rolling chassis mass reduced 2.3 kg.

It's lighter by design. And when it revs its engine, it delivers sufficient rolling power, consuming a minimum of energy and delivering a relatively green footprint to the world.

Today's design is demanding, calling for lightweight designs to boost characteristics that aid efficiency and speed, and enable things like electric power. Generative design is being employed in full force to meet design goals such as lighter materials. Lighter materials provide more capability in design performance and capability. The complexity of machines and parts is getting lighter by design.

"Design engineers in the auto and aviation industries favor lightweighting as a way to increase fuel economy (the less something weighs the less energy it takes to operate), while increasing product performance," says James Dagg, chief technology officer of Altair.

Marelli's new advanced sheet compression-molded suspension steering knuckle has 25 percent mass savings compared to the aluminum version used on the Jeep Compass and a 50% savings compared to the cast iron version.

"By leveraging simulation-driven design software utilizing topology optimization, manufacturers can make timely decisions around design exploration that lead to an optimal balance of improved product development, lighter weight and better performance at lower cost while also ensuring safety," Dagg adds. Applying simulation upfront in the product development process enables design teams to meet performance targets by integrating a lighter weight design earlier in the process, rather than working to take mass out later."

Safe and Efficient

Dagg says they use a proprietary optimization solution, Altair OptiStruct. It provides the best possible starting point for designing a structure and generating a conceptual design that withstands all real-world conditions and loads to ensure a safe and structurally efficient result.

"Similar to the way human bones naturally take shape, some thick and strong where needed and light and flexible in other places, our software can be applied to countless materials and structures at semiconductor speed until an engineer arrives at a design that meets the need without any excess material," he explains.

New generative design software tools are enabling manufacturers to achieve lighter weights for components without sacrificing durability, safety and performance. Sierra Turbines, for one, uses additive manufacturing technology from VELO3D to design and fabricate components that fulfill multiple functions. This leads to a reduced overall part count while eliminating interfaces between traditionally separate parts.

"All internal lubrication and fuel circuits are integrated into our unique single-piece core engine," explains Roger Stone, CEO of Sierra Turbines. "This way, potential points of failure and sources of leakage are avoided, thus increasing safety and engine efficiency while enabling a

Vehicle formed by students from the Barcelona School of Industrial Engineering (ETSEIB) and the Barcelona School of Telecommunications Engineering (ETSETB). The ETSEIB Motorsport team focuses on designing and building two cars that they use to compete in the Formula Student tournament against other teams worldwide. Both of their vehicles are 100% electric, one driven by a pilot and the other one driverless.

high-performing, lightweight design."

Increased efficiency is one of the primary benefits of lightweighting, explains Dagg. He notes that this is especially true in the automotive industry where automakers need a multi-pronged approach to achieve many criteria: fuel efficiency, lighter structures and aerodynamic performance.

"Lightweight automotive structures paired with high-efficiency engines or even fully electric powertrains, which can also benefit from lightweighting, will play a critical role in meeting climate goals" he predicts. "Lighter cars require less battery power for accelerating and maintaining speed, allowing a single charge to go further."

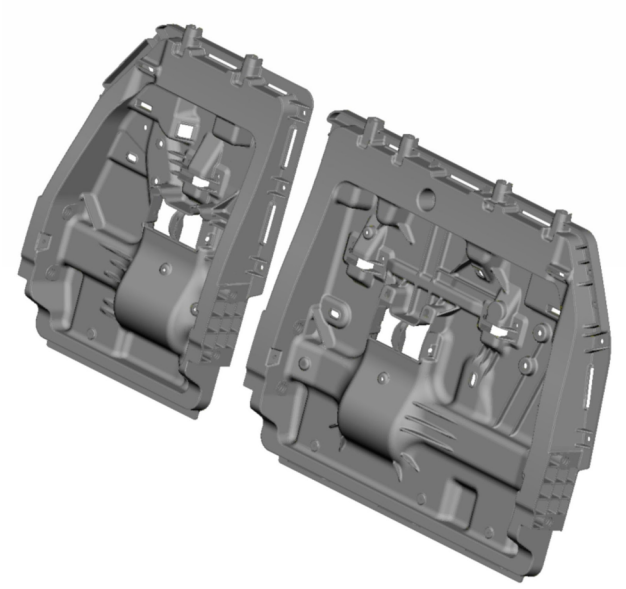
This will be even more important as electric propulsion becomes more mainstream in transportation design. "As OEMs begin to create battery-electric vehicles (BEV) for their mainstream customers to address issues like range, drivetrain efficiency and charging times, design becomes an even more vital component of the development process," adds Dagg. "This requires fast exploration of higher system voltages, innovative cooling implementations and the ongoing race to reduce vehicle weight."

Dagg says lightweighting not only decreases fuel consumption, but also lowers the carbon footprints of these vehicles. He cites a 3% to 5% decrease in carbon emissions per 220 lbs. of weight dropped. The benefits of lightweighting are not only economical, he says, "but also environmental."

Innovations in Automotive Lightweighting

Dagg cites Altair's Enlighten Awards, where firms compete to specifically address the auto industry goal to reduce vehicle weight and meet emissions targets. Several innovative designs were recognized with awards:

- Harley-Davidson Motor Company used electrification to improve energy capacity of its aforementioned LiveWire electric motorcycle by 90% while increasing the ratio of energy capacity to vehicle mass by 60%. In addition to further improvements, this initiative established mass and stiffness design and optimization practices for future motorcycle programs.
- For its new Sentra 2020 platform, Nissan dramatically improved safety and dynamic performance without increasing weight by using simulation to place the right materials in the right locations.
- Toyota created a free-standing, two occupant injection-molded back-frame with no molded reinforcement for the 2021 Sienna. It consolidated 15 components into one part with one injection, driving down costs by 15%, reducing mass by 30% and improving safety performance by two times. This was an industry first.
- ZF created the first-to-market electric parking brake



CAD rendering of the 2021 Toyota Sienna resin third-row seat-back panels developed by Toyota Motor North America Research & Development with supplier partner BASF and manufactured by Flex-N-Gate. The design and materials met lightweighting and improved customer performance targets while still achieving a lower cost.

(EPB) with more than 75 million vehicles fitted with EPB for world roadways. The Heavy-Duty EPB offers a weight savings of 25 pounds or more for large trucks and SUVs compared to conventional drum-in-hat park brakes.

• Marelli developed a new advanced sheet compression-molded suspension steering knuckle that ensures a 25% mass savings compared to the aluminum version used on the Jeep Compass and a 50% savings compared to the cast iron version.

• Nissan's ultimate lightweight aluminum/carbon fiber reinforced polymer (CFRP) body side panel using topology design reduced weight by using a multi-material structure of aluminum and short fiber carbon fiber reinforced thermal plastic (CFRTP). Compared to conventional steel body side panels, it can reduce weight by approximately 50%.

Lightweighting in Aerospace

Lightweight design has become paramount in finding ways to shave off weight and equivocate the lighter weight into direct benefits. Lighter weight comes from less material. This translates not only into performance, but also material cost, as well as fuel savings. This is not only true for the automotive industry, but also for the aerospace industry.

"For aerospace applications, every ounce of reduced weight converts directly to dollar savings, and performance increases," says Stone. "Looking lower down the value chain, if less material is used and fewer steps are required during manufacturing and assembly, this equates to a more sustainable and profitable business model for Sierra Turbines.

"Our patent-pending 360° fuel-injection system, where atomized fuel is delivered uniformly along the entire circumference of the combustion chamber, enables unprecedented burn-efficiency across a broad spectrum of operating conditions," Stone adds. "Here, more power is extracted per unit of fuel with a single lightweight part, replacing what has traditionally been made of a heavier assembly of 61 separate parts."

Airbus, for example, uses generative design to develop a 3D-printed partition for its air frame cabins, according to an article in Fast Company.

The article cited it as "45% lighter yet 8% stronger than anything it's used to date. But the company is pushing further. It's now applying generative design tools to reengineer many more parts of its planes, from the vertical stabilizer (that tall fin that's on the back of a jet, now 20% lighter than ever before), to the legs of its seats, to the interior layout of the cabin, to how its factories are built for optimal production and cost-effectiveness."

Fusing AM and Generative Design

Additive manufacturing and 3D printing unveil new and lucrative channels for lightweighting. Combine this with topological optimization and there are numerous paths to lighter designs and overall product improvement.

"More and more manufacturers are using topological optimization to reduce the volume of their parts by making them much lighter while maintaining or even improving their performance," says Toni Aranzana, an engineering manager with BCN3D, a 3D printer and manufacturer in Spain. BCN3D produces desktop and workbench 3D printers that use fused filament fabrication (FFF) technology.

"These types of designs present organic shapes that are not only optimal for operation but visually much more attractive and innovative. Additive manufacturing brings a lot of value to this type of design as these geometries are often impossible to achieve with other manufacturing methods. The appearance of new materials composed of carbon or glass fibers in technologies such as FFF, thermoplastic materials for end use parts with very low densities that in more than one case can be substituted for metal parts (thus reducing weight and manufacturing costs), must also be taken into account."

Lightweight Ammunition?

Lightweight design is welcome in many different industries and applications, not just automotive and aerospace, but also in industries like construction and defense.

Recently, the U.S. Army, U.S. Marines and UK defense forces aligned to collaborate on design for lighter ammunition. The need arose from a growing concern about soldiers carry-

To meet targets for range, acceleration and handling, the Harley-Davidson LiveWire electric motorcycle energy capacity was improved 90% while the ratio of energy capacity to vehicle mass (kWh/kg) was increased by 60%. Chassis stiffness was increased 143% and 97% in the two primary directions of interest, with rolling chassis mass reduced 2.3 kg.

ing much too heavy loads while moving into operational battle.

The debate over how much weight we expect our soldiers and warfighters to carry has been brewing for some time. It has sparked the design spirit of many material developers to prioritize lightening the load of the ammunition they carry. The development community across the services took a hard look at each piece of equipment carried by warfighters to reduce ounces or pounds.

The U.S. Army and the U.S. Marine Corps formed a Joint Lightweight Ammunition Integrated Product Team to synchronize these efforts with the goal of decreasing the weight of ammunition by at least 10%. This approach will ensure collaboration during development that will yield a better, faster, cheaper solution for the future warfighter.

The Joint Lightweight Ammunition Integrated Product Team studies the practice and investments across programs of different warfighting services to achieve lightweight ammunition goals. The mission of the team is to collaborate on combat requirements, material developer solutions and joint qualification of lightweight ammunition using alternative case materials that would meet or exceed the performance of current brass-cased ammunition in standard service weapons.

Staying Agile and Light

Lightweighting ammunition is another example that adds to the efforts of designers in the automotive, aerospace and other industries to boost performance and achieve more overall agility.

Luis Rodriquez is an application engineer with Ultimaker. He also notes the impact that topology optimization and generative design are having on fabricating lighter products with more uses.

"This analysis-based design approach finds the most optimized regions to place material based on the loads applied to a given approach," says Rodriquez. "A computer program is used to do this. It has gained popularity particularly in the last 5 years, thanks to advancements in manufacturing methods capable of producing these shapes."

Roger Stone of Sierra Turbines says his company collaborates proactively, using topology to remain agile, without sacrificing data or product integrity. Like the Harley-Davidson electric LiveWire design, engineers are using generative design tools combined with other technology such as additive manufacturing to blaze new trails and design better, more efficient, lightweight products.

"Do not be afraid to embrace new design tools and discard established norms when designing for additive," advises Stone. "For example, why design with STL files when the native CAD file is infinitely better to use? Tools like nTopology allow you to manage layers (slices) extremely efficiently and have allowed us to generate complex geometry files with much smaller file sizes. This streamlines collaboration with our partners, allowing Sierra Turbines to remain agile." DE

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MORE INFO

- **Altair:** Altair.com
- **BCN3D:** BCN3D.com
- **Sierra Turbines:** SierraTurbines.com
- **Ultimaker:** Ultimaker.com

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

Winners of **Altair Awards** Are No Lightweights

Companies representing automotive industry share lightweighting recipes for success.

BY STEPHANIE SKERNIVITZ

Lightweighting is more than just a fleeting trend in the automotive industry. Employed properly in automotive manufacturing, it has the potential to lead to enhanced fuel efficiency, lower carbon emissions, streamlined aerodynamics and more. It's the result of design or materials modifications within the interior parts of a vehicle, such as the engine, chassis, etc. And, it's a significant enough approach that Altair annually highlights notable lightweighting achievements via its Enlighten Awards. This year's examples, hailing from big-name car and motorcycle manufacturers to automotive parts manufacturers, were no exception.

Altair announced winners of its 2020 Altair Enlighten Awards back in August. The 8th annual awards, which are a collaborative effort with the Center for Automotive Research, represent the global best of the best in efforts to cut vehicle weight while still meeting/exceeding emissions goals. *DE* reached out to the winners to collect a behind-the-scenes perspective on the standout work that earned accolades in this year's competition.

And the Winners Are...

Full Vehicle winner, Harley-Davidson, used electrification to enhance energy capabilities in the electric motorcycle by 90%. Unfortunately, officials from H-D were unavailable for comment due to company restructuring.

Marelli Suspension Cross-Member. *Image courtesy of Marelli.*

So Full Vehicle runner-up, Nissan's Tom Mally, associate chief vehicle engineer, Nissan Technical Center North America, stepped in to share details of its project, the new Sentra 2020 platform, built to enhance safety and performance without added weight.

Mally explains that the primary lightweight concept was intended to use common platform components, for example, seat frame, radiator, fuel tank and steering member.

"By applying these weight reduction ideas, we were able to achieve a lower and wider exterior design, [and] provide enhanced dynamic performance and improved fuel economy and acceleration," says Mally. "Compared to the previous generation Sentra, we were able to reduce approximately 100kg of weight, which then allowed us to add 200kg in performance improvement items."

The project was not without obstacles though. Whenever common parts from a previous model are integrated into a new model, Mally explains, "a creative approach is required to incorporate them, while still providing a fresh and unique new vehicle."

Another obstacle was the safety structure reinforcement. In the compact vehicle segment, Mally says it can be more

The primary lightweight concept for Nissan in Altair Enlighten Awards Full Vehicle runner-up category was intended to use common platform components, for example, seat frame, radiator, fuel tank and steering member, according to company officials. *Image courtesy of Nissan.*

difficult to absorb additional sheet metal weight compared to the proportions of larger vehicles. Nissan found it was necessary to use Ultra High Strength Steel (UHSS) mostly in the cabin area for a stronger passenger room. UHSS, according to Nissan, accounts for 30% of the metal usage to help offset as much of the weight increase as possible.

Looking back, Mally shares some tips for engineers who may be seeking creative ways to reduce weight in parts. He recommends evaluating the hot stamping process. "Utilization of the hot stamping process on key structural components can contribute not only to weight reduction, but also provide cost reduction opportunities. Hot stamping has very high strength and formability freedom," Mally explains. These characteristics enabled Nissan to take complex shapes that are often constructed with a number of component parts in complex assemblies and cut down raw materials costs, stamping and assembly methods with use of thinner panels and combining into single, bigger parts.

Another household car name, Altair Enlighten Awards **Module category winner**, Toyota, built a freestanding two-person injection molded back frame without any molded reinforcement for its 2021 Sienna model. The project reduced 15 components down to one, lowering costs and mass and boosting safety.

Todd Muck, senior principal engineer Body Design for Toyota, expounded on the company's winning efforts. He credits Chief Engineer (CE) Monte Kaehr for the award-winning Lightweighting challenge for the 2021 Sienna.

"CE Monte wanted the lightweighting on the new Sienna to be directly beneficial and noticeable to the customer. For instance, in the seat back article … referenced, this lowers the effort to lift the seat substantially for the direct impact to the customer," Muck says.

One of the greatest challenges for the Toyota team was temperature performance of the composite materials.

"The team had to rely significantly on the digital finite element analysis or computer-aided engineering for all temperature conditions that the vehicle may endure," Muck explains.

It's fitting that there's a saying at Toyota, "Start Your Impossible," that, according to Muck, helps team members overcome its challenges. The resin seat back was the Seat

Marelli ASMC steering knuckle.
Image courtesy of Marelli.

Team's "Start Your Impossible" moment, he notes.

Muck challenges engineers faced with lightweighting challenges to "push the status quo, push to make lightweighting without increasing cost. How can you make a design that improves mass, cost, and performance?"

For the **Enabling Technology category**, winner Mubea created a glass fiber-reinforced polymer Tension Leaf Spring that realized 75% weight savings, which would replace a traditional multi-layer steel spring.

"This lightweight product can easily be implemented in all rigid axle suspension systems, which mainly includes pickup trucks, light commercial vehicles (LCVs) and busses. The current potential worldwide market includes about 6M vehicles/year," according to Clemens, who commented as part of a team involved with the project (which included Stefano Rosta, Mubea head of research & development, and Felix Beste, project manager of Customer Projects).

Looking back, Clemens says a key takeaway from the efforts for Mubea was not to substitute 1:1 steel by composite

Comparing Common Steel Leaf Spring and Mubea's Tension Leaf Spring

The Mubea team explains how the common steel leaf spring and Mubea's invention work:

"The common SLS is a statically determined mechanical system, with a main leaf, one or more helper leafs and a shackle. Each leaf is designed to have a specific structural stiffness.

"Under the vehicle loads (static and dynamic), the main leaf deflects and changes its curvature. Because of the leafs changing their shape under load, the distance between front and rear leaf eye changes.

"In order to compensate this length change, the rear spring eye is connected to a shackle, which rotates around the rear attachment point to the frame (this is why the system is statically determined). At a specific load, the helper leafs come into contact with the main leaf, causing the system stiffness to increase suddenly.

"This concept is used to ensure that target vehicle trim heights and body frequencies are met."

Mubea's winning Tension Leaf Spring is a single-layer leaf made out of glass fiber reinforced plastic.
Image courtesy of Mubea.

Disadvantages to such a system include that it's heavy, has a high amount of unsprung mass, sudden spring rate change, and noise vibration harshness issues, to name a few.

"The Tension Leaf Spring is a single-layer leaf made out of glass fiber reinforced plastic (GFRP) and it integrates the shackle function (no additional shackle needed). By doing so, the system becomes statically overconstrained. This characteristic leads to a superposition of tension forces on top of the bending forces when the spring is deflected. Because of this behavior, it is possible to achieve the same rates and trim heights as the SLS, but with a continuous progressive force-displacement curve, resulting in greatly improved ride comfort," the team explains.

The main advantages of this Tension Leaf Spring concept, according to Mubea officials, include the following:

- "extremely light" (up to 75% weight reduction)
- reduced unsprung mass
- increased payload capacity
- no rate transition during spring deflection
- no body frequency discontinuity
- no interleaf friction, which meant no noise or uncontrolled damping
- safe fail behavior
- improved lifespan, and
- reduction of assembly parts.

"The structural behavior of a [glass fiber reinforced plastic] Tension Leaf Spring is not only relevant in terms of component behavior (stiffnesses and durability) but also in its impact on the vehicle ride & handling performance," reports Stefan Clemens, spokesman on behalf of Mubea.

The 2020 Nissan Sentra was reportedly designed with safety and performance in mind—without added weight. The company's lightweighting approach opened up a lower and wider exterior design, as well as improved fuel economy, according to Tom Mally, vehicle engineer at Nissan Technical Center North America. *Image courtesy of Nissan.*

but to design a product by using the material's properties.

Future of Lightweighting category winner, Marelli, and its Ride Dynamics team specifically, have traveled a 10-year journey in the lightweighting space, having launched research projects with advanced metal alloys and composite materials along the way, according to Lisa Van Giesen, head of marketing and communications, North America, Marelli.

"We scouted, through benchmarking activities, different process technologies and materials in cooperation with academic partners and suppliers," she says. "The goal was to find solutions to reduce weight, including identifying structural mechanical properties that could replace metal or be coupled with it."

In the last decade, Marelli has homed in on metal replacement projects for the majority of its suspension product portfolio, having tested alternative materials for control arms, knuckles, subframe, twist beam axles and spring seats. The goal? To achieve functionality and lighter weight, according to Van Giesen.

"In addition, we have focused deeply on advanced sheet molding compression (ASMC) using carbon fiber sheet molding compound (CF-SMC) materials. We believe this to be one of the most promising technologies for structural suspension part design and manufacturing," Van Giesen adds.

The advanced compression molded suspension steering knuckle—winner of the 2020 Altair Enlighten Award in the Future of Lightweighting category—does not represent Marelli's first foray in ASMC process technology. "Encouraged by successful experiences with larger parts such as our suspension cross member (see figure 2), we further challenged ourselves to push technological limits and support complex structural SMC shape manufacturing," she says. DE

MORE INFO

- **Altair:** Altair.com

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

A **Match** Made in **Heaven**

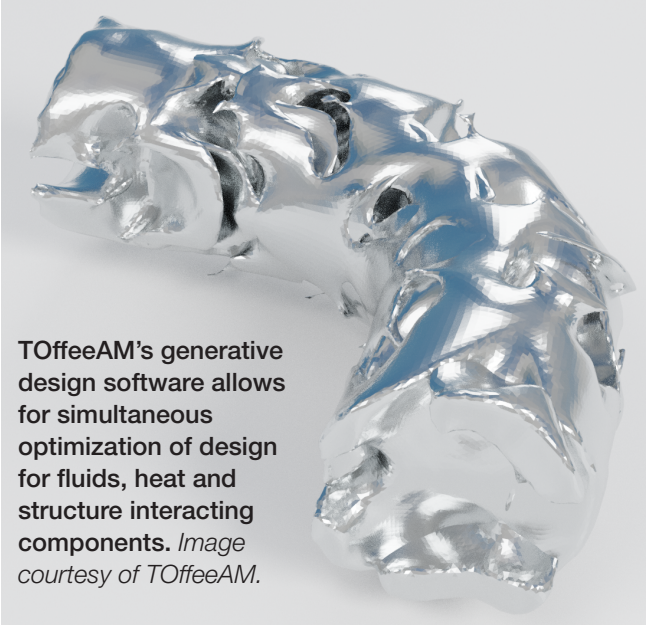
Additive manufacturing and generative design tools can be tapped as a dynamic duo to create and build parts fully optimized for weight and cost.

BY BETH STACKPOLE

There's a long history of iconic pairings. Fred Astaire and Ginger Rogers still reign in the dance world, while peanut butter and jelly remains a favorite sandwich pairing for folks of all ages. In the digital world, relative newcomer generative design technology is increasingly being eyed as a complement to additive manufacturing (AM) with the outcome being new workflows that turn out game-changing products.

Generative design tools, which include topology optimization and other artificial intelligence-based modeling techniques, burst on the scene these last few years as less expensive and more accessible computing power gives way to new algorithmic-driven design approaches.

These design tools provide a whole new level of design freedom by automating the ideation of hundreds of possibilities based off of specified parameters and constraints. The approach helps engineering teams zero in on parts and products that are fully optimized to meet weight, cost or thermal dynamic targets and that are simply not possible using traditional CAD tools and human brain power.



TOffeeAM's generative design software allows for simultaneous optimization of design for fluids, heat and structure interacting components. *Image courtesy of TOffeeAM.*

Just as mainstream CAD tools are not fully equipped to solve these novel design challenges, conventional manufacturing methods such as computer numerical control (CNC) milling and injection molding are not cut out to produce many of these new generative-designed parts due to the inherent limitations of the technologies. Yet coupling generative design tools with AM processes in a fully integrated workflow, engineering groups can achieve exponential benefits by leveraging the power of the combined technologies.

"If you're going to take advantage of the advanced design freedoms that AM can enable, you need to have a design tool that can harness them," says Jesse Blankenship, senior vice president of technology, advanced development for PTC. "Generative design fits the AM paradigm really well. It's not limited by the typical drafting tools humans are accustomed to, like a ruler and compass."

Two is Better Than One

Unlike traditional CAD tools that churn out detailed, solid 3D geometry, generative design tools employ algorithms to create faceted, non-orthodox shapes, that often take cues from nature. These designs, created through use of algorithms and simulation technologies, are proving to be instru-

The design of metal 3D printed bottle opener demonstrates how tubular structurally-optimized algorithms can reduce mass. In this case, the tubular structure is hollow, and mass is reduced by 64% compared to the solid model. *Image courtesy of 3D Systems.*

mental in helping engineering teams achieve critical design goals such as lightweighting, part consolidation and flexible foundation development for mass customization.

Given their unique characteristics, many of these generatively designed parts can be difficult to produce in volume using traditional production methods. But AM technologies aren't limited by the same constraints.

In fact, AM technologies' support for advanced materials and ability to control material placement at a voxel level makes the genre especially well-suited to producing the organic shapes and complex lattice structures that define a new generation of algorithmic-built designs.

"Engineers designing something for a particular manufacturing process have had to abide by certain design rules they've learned over the years and [that] are well understood," explains Brian Thompson, divisional vice president of technology, advanced development at PTC. "But the fact is, a lot of the work they're doing is putting a design together to achieve a particular function while accommodating the rules of the manufacturing process. AM provides more freedom—it gives you this ability to think almost exclusively about the function of the design and what you are trying to achieve."

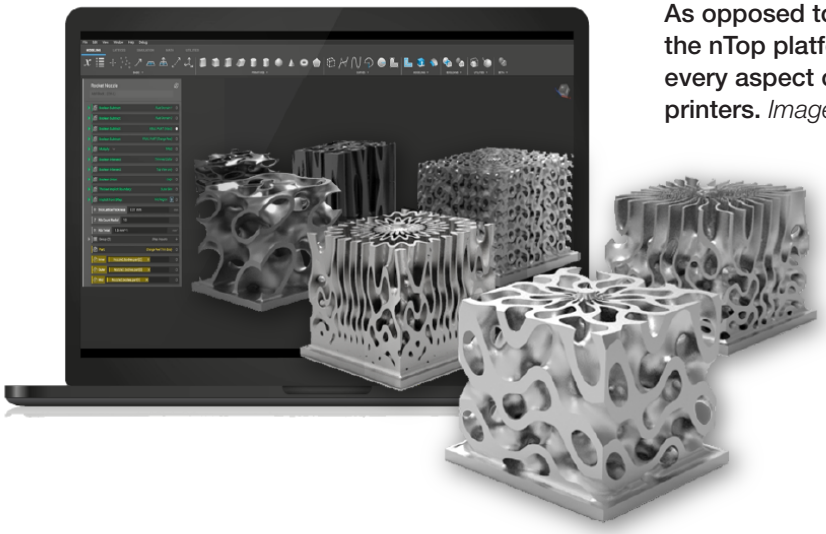
Patrick Dunne, vice president of advanced application development for 3D Systems, goes further, and describes the relationship between the two technologies as symbiotic. The coupling lets engineers achieve better performance of their end product, whether that's the structural integrity of load-bearing structures such as brackets or getting better fluid flow dynamics for a fuel injection system.

"Ultimately what it boils down to is making a piece of metal maintain its goal of supporting a structure while being 'x' percent lighter, generating fuel savings for an airliner, faster acceleration for a Formula One car, or less wear and tear on a robot," Dunne explains. "At the end of the day, these algorithms can yield significant step changes in performance and, ultimately, what it boils down to is a better performing product."

Sierra Turbines gained these results after it turned to AM and generative design technologies to reimagine its Aurelius Mk1 microturbine; the company's main objectives included increased thrust-to-weight ratios and decreased unit cost.

Using the nTop generative design platform from nTopology in concert with VELO3D's Sapphire metal 3D printer, the design team was able to consolidate 61 parts into a single part, reducing the number of joints between parts, thus minimizing the number of seals and fasteners and extending service life as well as flaws that could degrade engine performance.

Sierra Turbines could never have achieved this level of performance benefits using traditional design and manufac-



As opposed to black box generative design tools, the nTop platform enables complete control over every aspect of optimization and output to 3D printers. *Image courtesy of nTopology.*

turing processes, contends Brad Rothenberg, nTopology's CEO. "When you're implementing advanced manufacturing, you don't get value from taking a design meant for traditional manufacturing processes and simply trying to 3D print it," he explains.

Instead, organizations need to update the design, or start from scratch, to achieve the performance benefits possible with 3D printing, he says.

In the case of Sierra Turbine, the nTop software drove the effort to reduce the 61-part count into a single component via its ability to address the end-to-end engineering problem to develop optimized design options as opposed to focusing on a single parameter such as strength characteristics.

"With the generative process, you're able to capture and get control over thousands of different requirements like material properties to explore a bigger design space and get a better part," he explains. "Engineers needs to be thinking about their specific requirements, the outputs they are trying to get, and how they can make this part meet certain objectives."

Putting Generative Design Within Reach

Newcomers like nTopology and TOffeeAM position their platforms as generative design tools especially designed for AM processes. The nTop platform claims to be highly customizable and adaptable to engineering workflows as opposed to the "black box" paradigm adopted by most others in the emerging software category.

With the nTop Platform, engineers can capture custom logic and unique design requirements in functionally and fully customizable blocks. Other capabilities include "unbreakable" modeling features for designing complex lattice structures, multi-objective optimization, topology optimization and reusable design workflows.

TOffeeAM is an automated design platform that works through simultaneous optimizations, including those for fluids, heats and structure, along with a specified design space and performance objectives to create best-in-class design choices. Using TOffeeAM's generative design approach, organizations can bridge the gap between what's possible with AM and what is likely given the relatively high learning curve and lack of AM expertise at many companies, according to TOffeeAM CEO and co-founder Francesco Montomoli.

"Today you have the computing power for designing any kind of crazy geometry, but you have to be able to output that crazy geometry," he says. "Traditional design software is simply not capable without human intervention, and humans can't possibly come up every possible solution. If it's just trial and error, you just have stepped iteration and you're not fully exploiting what AM can do."

Mainstream CAD vendors are also stepping in with their own generative design solutions designed to exploit AM's potential; however, their approach is to meld the capabilities into existing platforms to simplify the learning curve. Autodesk's generative design capabilities are folded into the Fusion 360 platform, and the technology can be tapped to create optimized designs for AM along with traditional CNC machining, casting and injection molding processes.

Siemens Digital Industries Software has incorporated generative design and topology optimization capabilities into its NX platform to make the capabilities more accessible while adding an array of features designed to help teams optimize AM output. NX's convergent modeling technology delivers unified 3D modeling, allowing engineers to easily collaborate and work between facet and B-rep data, creating a more integrated design workflow that results in lighter weight components that don't sacrifice design intent or integrity.

Additionally, the company's Simcenter 3D AM Process Simulation suite and the AM Path Optimizer integrated into NX helps customers solve challenges related to AM production, including reducing systematic failures due to overheating or analyzing material behavior to avoid deformation.

It's a similar story at PTC, where the acquired Frustum

Creo Generative Design creates optimized designs using the power of the cloud from the familiar Creo design environment. *Image courtesy of PTC.*

technology is now Creo Generative Design. Creo also includes various capabilities to facilitate AM output, from visualizing and calculating support structures to the proper organization of parts on a print tray.

"We do not require users to learn a new environment," says PTC's Thompson. "Users expect to access generative design directly from the same interface they are used to and aware of—it's a key piece of the puzzle."

Gearing Up for a New Mindset

Though generative design tools and AM technologies have the potential to advance product design, it requires a completely new mindset to fully exploit the benefits of combined platform. To ensure the technologies are paired for the most effective results, organizations need to discourage silos in which different groups rely on different software, creating a lot of manual work to share files and slowing the iterative and creative design process.

Given the relative newness of both technologies, especially for production of parts, organizations also need to get people comfortable with algorithmic-driven design results—a feat that requires small wins that are widely communicated and promoted across the broader team.

Nonetheless, not every generative-designed component should be produced with AM technologies and there are pitfalls associated with the over-optimization of geometries—specifically, the possibility of approaching catastrophic failure modes. "There is still a lot of debate going on about how and where it's smart to apply highly optimized geometries," says 3D Systems' Dunne. "There are some instances where it doesn't make sense unless the algorithms get better and are able to anticipate outlier events or environmental exposures."

Most important is elevating engineers' ability to not only understand their requirements and design objectives, but to be able to communicate those design objectives to the system so the optimizations and output are viable as real, working products.

"It's a mindset change—with traditional design, you're designing a part that fulfills a set of requirements with your head," says Kevin Carr, president of MasterGraphics, an AM value-added reseller and system integrator. "With generative design, you're designing the problem and letting the cloud and the tool come up with the solution and then you pick the one that works best." DE

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MORE INFO

- **Autodesk:** Autodesk.com
- **MasterGraphics:** MasterGraphics.com
- **nTopology:** nTopology.com
- **PTC:** PTC.com
- **Siemens Digital Industries Software:** SW.Siemens.com
- **Sierra Turbines:** SierraTurbines.com

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

A Window Into Tomorrow's Shop Floor

The transformation to digital manufacturing requires a combination of technology, processes and people.

BY TOM KEVAN

Digital technology is poised to transform tomorrow's factory, and open the door for manufacturers to quickly detect problems in individual machines and entire assembly lines. In this new work environment, plant engineers can easily adapt production processes to changes in customer demand or supply chain conditions, and manufacturers can optimize for cost, throughput or other relevant business metrics (Fig. 1).

If you think that new technology adoption will drive these changes, you are only half right. A deeper look at the forces that will come into play on tomorrow's shop floor reveals a parallel force that will assume an equally important role in determining the form and function of manufacturing. This element amounts to a cultural revolution that promises to trigger nothing short of a holistic change in the way manufacturers view production processes and develop business models.

"The journey of transforming businesses from manual to digital workplaces will require changes across people, processes and technology," says Colin Parris, senior vice president and chief technical officer at GE Digital. "It will require an evolution to a data culture, where data discipline and its integration into all business processes as standard practice are embraced and continuously improved by the workforce."

Data in Tomorrow's Factory

How will digitization and the data culture translate to manufacturing operations? To answer this, consider the key forces that will shape the shop floor of tomorrow.

For instance, technologists see the digitization process drawing together different elements to create a rich, intuitive and insightful user experience for the management, workforce and supply chain partners.

This requires manufacturers to draw data from myriad sensors, business systems and virtual reality platforms to create a complete picture of the product being manufactured, as well as the assets and processes used in the production process (Fig. 2). This will require that engineers take integration to a new level.

Making the transition to greater data integration, for example, will call for production facilities to more tightly interweave business and operational data.

"Digital factories will connect IT and OT [operations technology] for manufacturing governance," says Jonathan Scott, chief architect at Razorleaf. "IT—technology and data coming from the front office—will define the nominal operating parameters for manufacturing processes. Think of a computer-aided machining model. On the other hand, OT—controls at the machining center and monitoring on the shop floor—will identify and correct abnormal operations and let humans know when intervention is necessary."

To extract value from the data, manufacturing engineers will have to create an end-to-end infrastructure for handling unprecedented amounts of data. This means enhancing their ability to capture, tag, store, mine and analyze data.

Aggregating Manufacturing Data

A first step toward implementing these changes is a digital thread deployment. This technology helps manufacturers to acquire much more data from a greater variety of sources, including customers and other third-party sources. This will allow plant managers to more accurately forecast current and future demand.

Additionally, the digital thread promises to give all stakeholders access to richer data pools, which will help them to better understand the current state of their assets, such as which machines are up and which are down. Manufacturers also will use the data to determine what future actions they should take to achieve desired business results.

To make these functions possible, digital thread promises to deliver enough data to provide manufacturers with the foundation needed to understand the current state of their operations. This should give plant managers the means to optimize processes to better meet market demands.

Fig. 1: Digitization of tomorrow's factories will be driven by technologies like digital thread, machine learning, digital twin and simulation. The aim of this process is to achieve unprecedented levels of visibility, giving all stakeholders a detailed, accurate and timely picture of not only products but also the manufacturing processes that build them. *Image courtesy of Siemens Digital Industries Software.*

Spinning a Better Thread

Keep in mind that digital thread technology is not static. Developers of these systems are continually refining the technology, with an eye toward expanding its ability to handle the challenges presented by big data on the shop floor.

One such refinement harnesses the power of machine learning (ML). This enhancement aims to enable engineers to quickly capture only the most useful data, enabling ability to achieve more visibility.

For example, using ML, OT will increasingly learn to correct for abnormal situations with reduced human intervention. "The farther we get into the future, the more advanced OT becomes as it learns to correct for abnormal situations with reduced human intervention, and the more OT learns from IT as they communicate on shared models rather than translated parameters," says Scott.

In the same process, digital thread improves the performance of ML systems. As artificial intelligence (AI) platforms are trained on simulation data, auxiliary data streams can be correlated to tease out the subtleties that ML can identify.

"An engineer today may be looking for failure modes via simulation results, but ML may notice trends in material usage or energy consumption while analyzing the same data," says Scott. "Thread technology is key to this because it provides the rich data set needed for training ML algorithms, as well as provide the context and connections needed to extend automation."

For example, by connecting requirements (e.g., load constraints), design solutions (e.g., tolerance geometric models), manufacturing planning (e.g., additive simulations) and product performance simulations can be conducted on as-manufactured state products to predict performance. If closed-loop automated simulations can identify failures in the as-manufactured virtual product, these data tools can shrink cycle times and eliminate scrap.

A View of the Physical World

Using the data provided by digital thread frameworks, digital twins provide engineers and plant managers with conceptualizations of physical objects and operations found on the shop floor. The digital conceptualization, or model, is regularly modified and upgraded with new data.

These models highlight one of the key benefits of the digital twin: It acts as a near-real-time bridge between the physical and digital domains, acting as a vehicle for all the data required to create a complete, up-to-date digital replica.

Plant managers and engineers can use digital twin models to simulate equipment performance and manufacturing processes to predict and optimize production quality and efficiency before large investments are made in setting up plants, assembly lines and fabrication work cells. Capturing performance in production and post-production phases, engineers can use the feedback to generate a continuous improvement loop with design and engineering departments.

When they get feedback from manufacturing operations, digital twins enable manufacturers to act on the feedback, compare the predicted performance against the actual per-

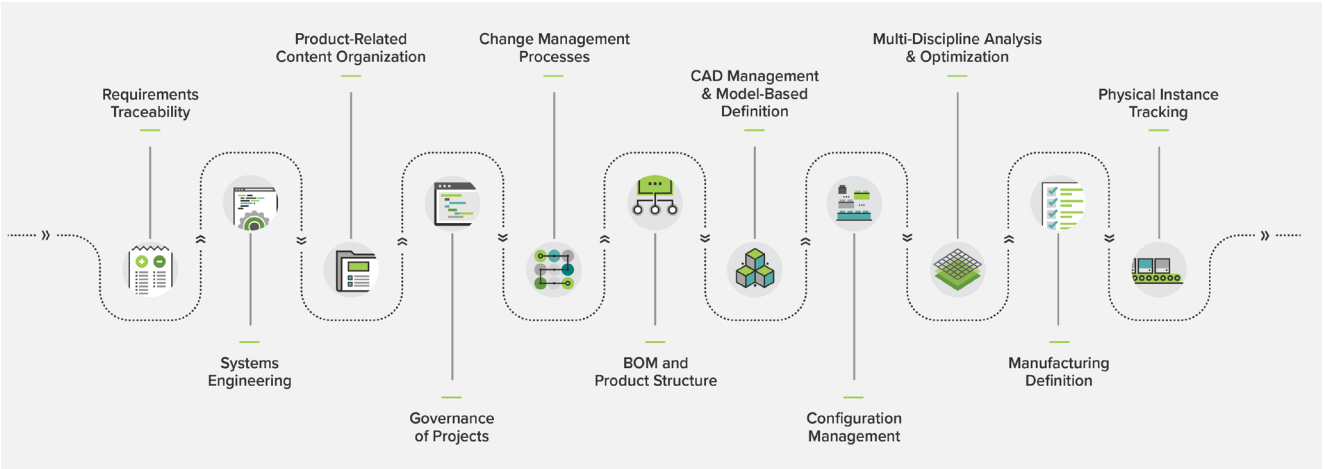

Fig. 2: The digital thread provides a complete record of a product or system, extending over its entire lifecycle. The framework collects data from a diverse variety of systems, ranging from sensing, control and business platforms to third-party supply chain sources. Thread systems provide accurate, up-to-date details as well as relevant contextual information, on industrial parts and systems, documenting how they are produced, maintained and retired. *Image courtesy Razorleaf Corp.*

formance, and based on that insight, adjust the equipment design or the manufacturing processes. Engineers can create the virtual model in advance, long before the equipment is fabricated or the assembly line is deployed.

"Digital twin technologies can be leveraged by manufacturers to analyze real-time performance, optimize operations or refine control of its assets," says Philipp Wallner, industry manager for industrial automation and machinery at MathWorks. "The technology can help product development teams capture a physical asset's history to help understand its behavior, improve maintenance strategies and help inform decision making."

All of these capabilities mitigate risk in the systems, reduce accidents and avoid unplanned downtime.

Painless Testing and Validation

You can't talk about digital thread and digital twin without also considering simulation because thread and twin systems open doors for manufacturers to leverage simulation in new ways, creating new opportunities to enhance business and operational processes.

For example, digital twins offer engineers the ability to simulate scenarios and "gaming" to test new business models.

"Twins can be used to model, simulate and optimize assets for new business strategies that involve near-shoring and product-mix variability," says Eric Green, vice president, DELMIA, at Dassault Systèmes. "The benefits impact every category of the factory profit and loss, from accelerating production volumes and revenue to cost reduction, worker safety, and sustainability improvement."

Armed with these capabilities, manufacturers can use twin simulations to determine the weaknesses of systems or the strengths that can be exploited in the future.

"These simulations allow you to plan the path forward, and as you improve your twin with current real-world data, your simulations will also improve," says GE Digital's Parris.

In terms of operational opportunities, manufacturers can use simulation to perform virtual commissioning of modularized mechatronic components, equipment and entire production lines. This allows engineers to counter the growing software complexities that make the designing and testing of physical machines more complicated. This allows manufacturers to verify that their requirements are met based on simulations prior to establishing physical production.

"Companies like Metso in Finland are already using models of its equipment for testing its controls software before deploying it on the industrial controllers of the machines," says Wallner.

The Problem with Data

Two of the biggest challenges confronting manufacturers seeking to digitize their operations are the heterogeneity of the data and when attempting to configure and manage the data. Even if data heterogeneity is managed and reduced, manufacturers will still have to be able to configure and manage the data set. As a temporary fix, interchangeability rules do provide a shortcut in manufacturing to reduce waste, but these rules will not age well as digital twin adoption grows in the coming years.

"It will not be enough to know that an assembly is made from the latest version of a certain part," says Scott. "It will become essential to know, for example, that you want to simulate the third version of an assembly that uses revision 7 of a part, and that you want to simulate the assembly's performance against the requirements defined for customer X in

Fig. 3: Plant engineers can capture performance of parts and systems in post-production phases. The engineers can then use the feedback to generate a continuous improvement loop with design and engineering departments. With feedback from manufacturing operations, twins enable manufacturers to compare the predicted performance against the actual performance, and based on that insight, adjust the equipment design or the manufacturing processes. *Image courtesy of Siemens Digital Industries Software.*

May 2015. This type of configuration management will require rules and systems that don't exist today, but which will be built on today's product data management and product lifecycle management systems."

Culture Change Challenges

Because cultivating a data culture is so important to the success of factory digitization, manufacturers must come to terms with the most nebulous of factors: human nature.

The question becomes how best to create a culture that sustains a data-focused approach and drive continuous improvement in both the data journey and business transformation.

"Transformation is always difficult, and it is very easy to provide a reason not to transform—it will take too much money, it takes too long, it takes away jobs," says Parris. "This is always the case with a fear of something new or not validated by the industry. Using lean processes can be beneficial for greater cultural acceptance because lean has broad acceptance as a mindset and a tool that can deliver operational and financial value."

That said, human resistance to change may be the greatest challenge to the creation of a data-focused culture, and as such, one of the biggest hurdles facing factory digitization.

In Search of Better Visibility

As key elements in the digitization of the factory of the future, digital thread and digital twin promise to significantly help in the design and production of products. The aim of the digital thread is to capture high-value data from the plant floor and the supply chain. This opens the door for manufacturers to use digital twin platforms to gauge the current state of assets, track the evolution of the parts, equipment and systems as they move through their lifecycle and optimize their performance and design (Fig. 3).

If manufacturers correlate manufacturing/production and design data with the data from the field, they can begin to see patterns, with points of weakness in products.

"It may be that specific conditions and specific environments can cause great current and future damage to a part," says Parris. "This gives engineers direct insight into the possible redesign of that part for those conditions and environments. It can also provide manufacturers insight on the choice of materials or manufacturing process to use to build stronger parts."

The digital twin also can be used to create a simulator of plants or a system in actual use. This allows manufacturers to run various scenarios on that twin to determine the best products to build at specific cost points or use case scenarios.

To ensure the visibility cultivated in the digitized factory delivers optimum value, manufacturers must develop connected visibility, which comes from the use of comprehensive digital twins.

"Manufacturers need a solution that can share information efficiently between multidisciplinary teams so errors can be avoided and better-informed decisions can be made to produce high-quality product," says Frans Adamowicz, solutions director, industrial machinery industry, at Siemens Digital Industries Software. DE

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➜ MORE INFO

- **Dassault Systèmes:** 3DS.com
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- **Siemens Digital Industries Software:** SW.Siemens.com
- **Razorleaf:** Razorleaf.com

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GPUs Are Workstation Essentials

Graphics, AI and parallel processing tasks have made GPUs a key enabler of engineering productivity.

BY RANDALL S. NEWTON

There has been a shift in recent years regarding performance expectations inside engineering workstations. For many years, the capabilities of the central processing unit (CPU) were the primary consideration. Then, in order of descending importance, there was RAM, storage and finally the graphics processing unit (GPU).

In 2020, the order has flipped. GPU performance has been on the exponential growth equivalent of a rocket ride. The other components are still important, but by comparison they are commodities within the typical engineering workstation, and not the premium anchor component of the system's value.

The value shift is summarized as going from throwing graphics on the screen to calculating the design and engineering issues behind the objects.

"The GPU is constantly evolving, and not just for gaming, but constantly being refined to provide much more than conventional raster-based 3D graphics for product design, with emerging innovations notable in uses from rendering to simulation to machine learning," notes Alex Herrera, senior graphics industry hardware analyst with Jon Peddie Research (JPR).

This is not an apex moment, Herrera adds. "Expect your GPU to increasingly be tasked with supporting machine learning, whether as a task the designer might explicitly invoke, like generative design, or [while] the application runs in the background, like sanity-checking design rules."

There are three main categories where the increased use of GPU technology benefits engineering, says Brian Hillner, senior product portfolio manager at Dassault Systèmes' SolidWorks:

The first is graphics fidelity for increased rendering speed and improved visualization. "A set of images that once took months to render with complete fidelity and no noise can now be created in weeks or days," Hillner says.

All GPUs come with the equivalent of a CPU on the board to manage the graphics processing. The AMD Radeon Pro W5700 uses AMD's 7nm circuit etching technology. *Image courtesy of AMD.*

The second is parallel processing, also known as the ability to simultaneously calculate multiple computations. Simulation and analysis tools are the big winners here. "Doing the same math over and over is perfect for GPUs," says Hillner. Depending on the physical process being analyzed, GPUs can offload some or most of the computation. Most CAE vendors are now either converting their solvers to run primarily on GPUs, or adding that capability to their CPU-based products.

The third is the application of artificial intelligence called design guidance. "Instead of sketching what might be the right shape, use AI and crush all the possible scenarios on the

NVIDIA makes desktop and mobile versions of its RTX line of GPUs. *Image courtesy of NVIDIA.*

GPU," says Hillner. A variety of software products now use generative design or other AI-enhanced methods to bring the "what if" CAE experience into design.

Pandemic Changes the Market

The annual sales cycle for GPU hardware generally has a lull in Q2 of the year. But this year COVID-19 changed things. There was a significant increase in demand for better work-from-home products, including engineering workstations. GPU sales overall—both by themselves and as sold within a workstation—rose in the quarter.

"The pandemic has been disruptive and had varying effects on the market," notes Jon Peddie, JPR president. "We believe the stay-at-home orders have continued to increase demand in spite of the record-setting unemployment levels."

Varying Workloads, Multiple Markets

Analysts break the workstation market into three distinct segments: entry level, mid-level and high-end, for desktop and mobile computers. For workstation vendors, the market is more nuanced. Which GPU engineers should select for any particular workstation model is never taken for granted.

"I think our GPU partners have done a great job with cost-effective base models," notes Chris Ramirez, engineering industry strategist for Dell. "3D CAD today works well within the minimum GPU."

Once the workstation user moves beyond using only one CAD package (2D or 3D), things get interesting. "It is interesting to see workloads evolve from being CPU-only to wholeheartedly embracing the GPU for compute," notes Ramirez. He uses the popular engineering rendering/visualization software KeyShot as an example. "KeyShot went from being completely CPU dependent to being able to leverage the GPU. [As a result] we are seeing demand for KeyShot skyrocket."

Some engineering workflows still use software tools that have minimal reliance on GPUs, such as 2D CAD. Dell, for example, uses three vendors for workstation graphics. The Intel ultra-high definition (UHD) 630 graphics subsystem is offered for entry-level users on mobile and deskside workstations. Mid-range and high-end users can select between various AMD and NVIDIA models, starting with the AMD Radeon Pro WX3200 or the NVIDIA Quadro P620 as base models, and working up into the high-end products from each vendor.

AMD Emphasizes Power Consumption

AMD sees the market for its GPUs as a combination of performance and power requirements. The better the performance, the higher the power requirements. If a company buys a thousand workstations, and there is a choice between a GPU that runs at 200W and another at 300w, there will be a considerable total cost of operations (TCO) difference.

"Is power consumption really that important?" asks Scott Jackson, who runs the workstation product team at AMD. "Larger enterprises tell us, when they multiply the savings across thousands of systems, they see real benefit." That benefit might be longer battery life on a mobile workstation, or TCO on workstations in the office.

Companies who need top GPU performance have to de-prioritize power consumption. "The higher end of the market wants the cutting-edge features, which then waterfall to the rest of the market over time," Jackson says, an action typical of technology democratization.

The AMD Radeon Pro VII GPU, for example, includes Infinity Fabric Link, a high-bandwidth low-latency direct connection between two Radeon Pro units for much higher throughput than can be achieved using the PCIe connectivity available in the workstation. The Infinity Fabric Link was invented by the AMD team working on supercomputer technology, then currently moved to the high-end GPU.

Building the GPU board is more than just serving the workstation market, Jackson notes. There is a complete soft-

ware stack to take into consideration as well. "We are seeing increased use of our remoting software; there is a shift because of the pandemic. Video conferencing will become more comfortable, which means improvements in GPU video encoding and decoding is important."

NVIDIA's Broad Product Line

NVIDIA is the heavyweight in the GPU industry. JPR says NVIDIA market share in the second quarter of 2020 was 78%, with AMD and Intel dividing up the rest.

Total GPU sales were up 36% from Q2 of 2019, a jump JPR attributes to two factors: increased interest in artificial intelligence (AI) and neural nets; and a rise in workstations purchased for work-from-home setups.

NVIDIA also sees the mission as more than building a graphics engine, and offers software and services to complement their hardware. Major GPU technology advancements introduced by NVIDIA in the last two years are real-time ray tracing and tensor cores, which are processors within the GPU that specialize in matrix mathematics.

"You can't just toss hardware out there and start taking market share," says NVIDIA's Allen Bourgoyne, a senior product marketing manager. "Our boards are now more than graphics accelerators; we have built a complex ecosystem of

Top Engineering GPUs Specs

Here are the primary specs for the AMD and NVIDIA GPUs used in engineering workstations. AMD and NVIDIA have different names for their primary pixel-processing pipelines; AMD calls them Stream Processors while NVIDIA calls them compute unified device architecture (CUDA) cores.

For each vendor, models are listed in order of feature set from high to low and current generation technology before previous generation. GPUs primarily marketed to the gaming community are not included.

AMD

Radeon Pro W5700: 2304 Stream processors; 36 compute units; 8.89 TFLOPS FP32; 8GB GDDR6 RAM; double-slot connection; maximum power consumption 205W.

Radeon Pro W5500: 1408 stream processors; 22 compute units; 5.35 TFLOPS FP32; 8GB GDDR6 RAM; single-slot connection; maximum power consumption 125W.

Radeon Pro WX9100: 4096 stream processors; 64 compute units; 12.3 TFLPS FP32; 16GB HBM2 RAM; double-slot connection; maximum power consumption 230W.

Radeon Pro WX 7100: 2304 stream processors; 36 compute units; 5.73 TFLOPS FP32; 8GB GDDR5 RAM; single-slot connection; maximum power consumption 130W.

Radeon Pro WX 5100: 1792 stream processors; 28 compute units; 3.89 TFLOPS FP32; 8GB GDDR5 RAM; single-slot connection; maximum power consumption 75W.

NVIDIA

Quadro RTX 8000: 4608 CUDA cores; 576 tensor cores; 72 RT (ray tracing) cores; 48GB GDDR6 RAM; rated at 16.3 TFLOPS FP32 (32-bit floating point); double-slot connection; maximum power consumption 295W.

Quadro RTX 6000: Primary specs equal to the RTX 8000 except for 24GB RAM; double-slot connection; maximum power consumption 295W.

Quadro RTX 5000: 3072 CUDA cores; 384 tensor cores; 48 RT cores; 16GB GDDR6 RAM; 11.2 TFLOPS FP32; double-slot connection; maximum power consumption 265W.

Quadro RTX 4000: 2304 CUDA cores; 288 tensor cores; 36 RT cores; 8GB GDDR6 RAM; 7.1 TFLOPS FP32; single-slot connection; maximum power consumption 160W.

Quadro GV100: 5120 CUDA cores; 640 tensor cores; no RT cores; 32GB HBM2 RAM; 14.8 TFLOPS FP32; double-slot connection; maximum power consumption 250W.

Quadro GP100: 3584 CUDA cores; no tensor or RT cores; 16GB HBM2 RAM; 10.3 TFLOPS FP32; double-slot connection; maximum power consumption 235W.

Quadro P6000: 3840 CUDA cores; no tensor or RT cores; 24GB GDDR5x RAM; 12 TFLOPS FP32; double-slot connection; maximum power consumption 250W.

Quadro P5000: 2560 CUDA cores; no tensor or RT cores; 16GB GDDR5x RAM; 8.9 TFLOPS FP32; double-slot connection; maximum power consumption 180W.

Quadro P4000: 1792 CUDA cores; no tensor or RT cores; 8GB GDDR5 RAM; 5.3 TFLOPS FP32; single-slot connection; maximum power consumption 105W.

AMD markets the mid-range Radeon Pro W5500 as a general-purpose GPU suitable for most engineering graphics workloads. *Image courtesy of AMD.*

hardware, software and third-party developers."

The days of "one app, one workstation" are gone, Bourgoyne says. "We have to hit a range of technologies" with a single GPU. "Five years ago, no one was doing AI except in a lab on a server in a dedicated research environment. Today, many companies have neural nets at work, even if they don't know it."

The Intel Xe Factor

Intel is the undisputed champion of CPUs, but it is an also-ran in graphics. Its current offering, Intel UHD graphics, is embedded into selected CPUs and only used in entry-level workstations as well as consumer and enterprise products.

In 2018, Intel announced a new initiative to create next-generation graphics processors, project Xe. To date, Intel has four Xe products in various stages of development. Xe LP is similar to UHD, an integrated graphics solution. Xe HP is for high-end compute and data center workloads. Xe high-performance computing (HPC) is an extended version of Xe LP for supercomputing applications. Xe HPG is a variation that includes ray tracing and removes tensor cores. The HP and HPC offerings are probably the models Intel will pitch to engineering workstation manufacturers.

The NVIDIA Quadro RTX 8000 features specialized circuits for real-time ray tracing and artificial intelligence R&D. *Image courtesy of NVIDIA.*

The Xe initiative received a big boost when Intel hired former senior AMD executive Raja Koduri. Many industry watchers who know Intel's past lack of market dominance in graphics are giving Koduri the benefit of the doubt and taking a wait-and-see attitude about these new subsystems. Nothing in the Xe line will be on the market until sometime in 2021.

Intel declined an interview invitation for this article. The representatives of AMD and NVIDIA interviewed for this article did not want to comment specifically on Intel's place in the market. It is safe to summarize that both companies believe Intel's past performance is not necessarily a predictor of the future; Intel could become a formidable competitor in engineering graphics in the near future.

A New Embedded Player

A growing part of the GPU market is embedded systems graphics. A new player is Cincoze, an established manufacturer of embedded compute systems who is now adding GPU compute capabilities to their line.

Their new GM-1000 is a ruggedized embedded processor designed for Internet of Things-type compute environments. There is no indication from either the manufacturer or the analyst community that Cincoze will be a player in workstation graphics in the near future. DE

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MORE INFO

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- **Dassault Systèmes:** 3DS.com
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- **Jon Peddie Research:** JonPeddie.com
- **NVIDIA:** NVIDIA.com

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Factory Digital Twins Enhance Worker Safety and Supply Chains

How plant simulation and modeling technologies help enforce social distancing and safety practices

BY KENNETH WONG

In September, the analyst firm Tech-Clarity published the outcomes of its survey, titled "Business Sustainability and Survival Strategies 2020." Though the pandemic is certainly on most respondents' minds, the survey points out "disruption could also apply to other world events such as earthquakes, tsunamis, volcanic activity, hurricanes, and human-created events like terrorism or armed conflict."

The survey reveals "almost one-half of businesses (46%) have increased focus and/or accelerated digital transformation due to the pandemic."

"I've spoken to a few companies that modeled their factories to figure out how to put people back to work safely—specifically, to figure out how to practice social distancing, or to implement air quality control," says Julie Fraser, VP of manufacturing software research at Tech-Clarity.

Although quick fixes, such as installing plexiglass barriers and routine temperature checks, will likely go away as the pandemic's threat fades, other types of supply chain disruptions, natural disasters and warfare are sadly a fact of life; they always have been. Therefore, the use of simulation, digital twins and sensor-driven monitoring to address those disruptions is expected to draw more attention.

"Digital twins of factories and simulation technologies enable companies to better understand the restart requirements and interdependencies," observes Fraser, "so they can respond better as issues and restrictions change."

Humans and Facilities

The simplest way to track and enforce social distancing in a factory or a plant might be through wrist-worn devices. Equipped with Bluetooth technology, they run on low energy and can buzz when two devices come within a close range, indicating that the individuals wearing them may be violating the required 6-ft. distancing rule.

Aside from device cost, they require no complicated infrastructure. But they also have many shortcomings, according to Adrian Jennings, VP of real-time location systems at Ubisense.

"For example, when people are turning their backs toward each other, the devices may overestimate the distance between them. Their signals could be blocked by human bodies. And [the devices] don't recognize barriers, like walls," he observes.

When two people are standing 3 feet apart with a wall between them, the barrier prevents pathogen transmission. But the wrist-worn devices may still trigger a warning buzz due to their proximity violation.

Jennings believes monitoring efforts need to encompass both human-centric and facility-centric measures. Doing one at the exclusion of the other undermines all efforts.

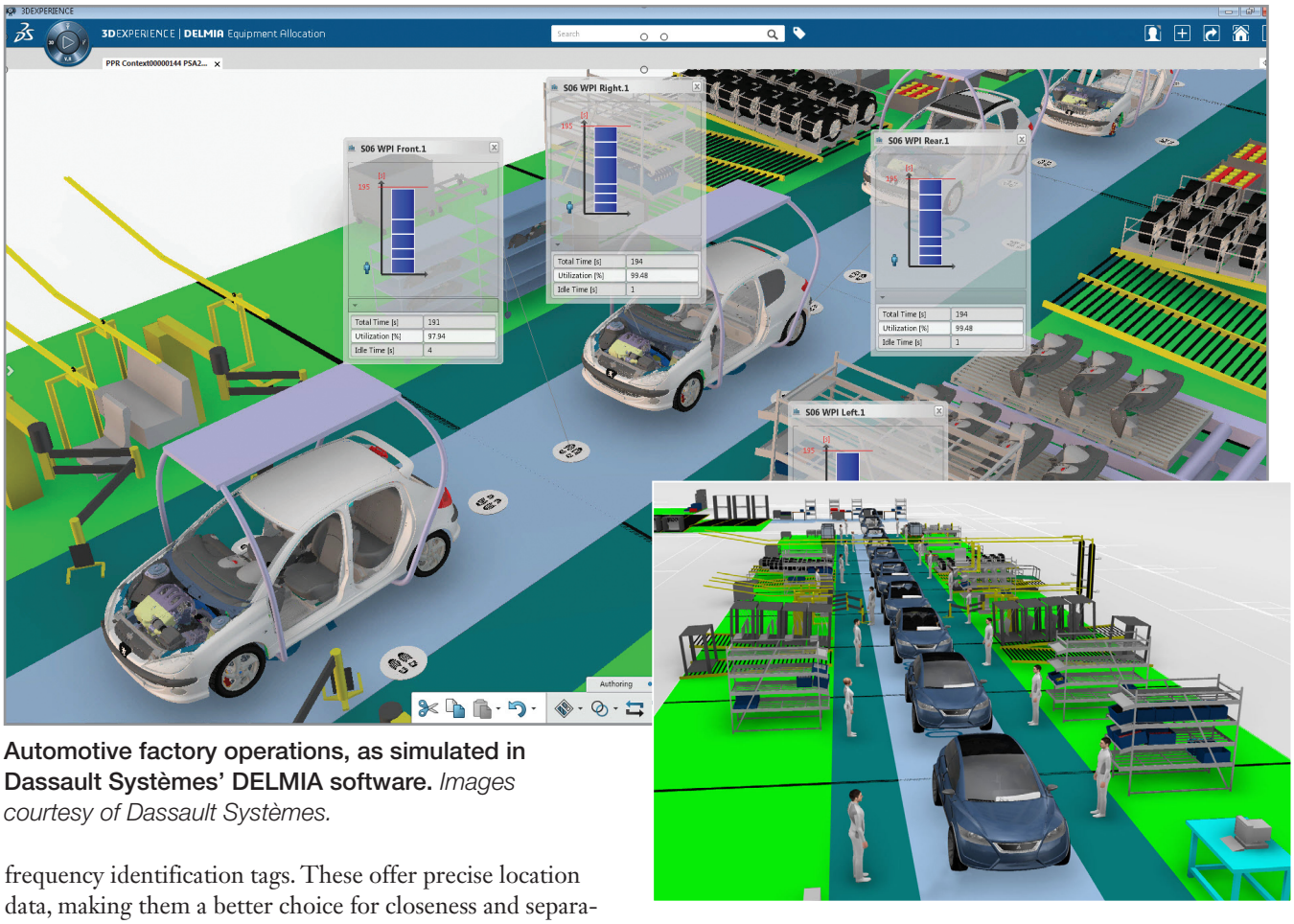
"On the people-centric side, you help people understand whether their behavior is causing a risk, and warn them when they are too close to each other and when too many of them are occupying the same space," he explains.

"On the facility-centric side, you need to understand how and if the building or the processes are creating risks. If two employees share the same tool or workspace, they may never come in contact with each other but they still risk passing infection," Jennings adds.

For the facility-centric view, a 3D model of the environment is crucial. "The building is itself a thing that helps people maintain social distancing, so you need the context of the building," he says. But the detailed CAD file may first need to be stripped down to barebones geometry to be efficient.

Jennings believes technology's role is indispensable in the new normal. "No supervisor can supervise that many people 24/7. But computers have infinite attention span so they can monitor people's movements 24/7," he says.

Ubisense relies on people to carry ultra-wideband radio-



Automotive factory operations, as simulated in Dassault Systèmes' DELMIA software. *Images courtesy of Dassault Systèmes.*

frequency identification tags. These offer precise location data, making them a better choice for closeness and separation monitoring in the pandemic, according to Jennings.

The company offers SmartSpace software and Dimension4 sensors, which serve as the basis for its Real-Time Location Systems (RTLS). Jennings is not surprised to be getting inquiries from engineering firms during the pandemic, but he noticed the company is now also drawing interest from cosmetic producers, food producers and even culinary training schools, which suggests that new markets are opening up.

Different Strokes for Different Folks

RTLS customers are typically large enterprises. "Larger facilities with complex processes benefit the most from RTLS. In smaller companies with simpler workflows, it's easier to manage separation by policy and process," Jennings says.

"In my experience, companies that use and benefit from digital twins of factories are usually large companies," TechClarity's Fraser also observes. "In a small company, processes are pretty straightforward, and people know one another's history. In a big company, the same camaraderie doesn't exist, and they have more complexity when changeover happens."

One of the headaches for digital twin implementation at the factory or plant level, Fraser points out, is data incompatibility. Newer equipment tends to come with onboard sensors, easy connectivity and monitoring software. Legacy machines don't have the same setup, thus must be retrofitted for Internet-of-Things-style monitoring. Synchronizing the two equipment types to get a clear picture of the plant's operations as a whole is no small feat.

"A company also has to deal with various manufacturing execution systems [MES], schedulers, maintenance and quality assurance (QA) systems. These don't necessarily talk to each other, but they all have data that the digital twin needs," she notes.

In theory, industries such as automotive and aerospace are much further ahead than others in digital transformation, thus are better positioned to take advantage of digital twins to deal with the fallouts from the pandemic, but Fraser isn't so sure.

"They tend to have digital twins of products [for example, digital models of the latest Audi or a new jet engine], but in terms of full-scale plant-level digital twins, process and plant industries are in much better shape, because they usually work with a centralized control system," Fraser reasons.

Catalysts for Digital Twins

Eric Green, VP and managing director for DELMIA at Dassault Systèmes, calls the pandemic another catalyst driving people to adopt more digital modeling and simulation tools. The need to enforce social distancing, install safety barriers on-site and analyze airflows to minimize pathogen transmission are among the top reasons, he observes.

"Some of our customers are trying to figure out how to reconfigure their factories, or add capacity, so they can produce personal protective equipment on-site rather than source them from elsewhere," Green says.

Even before the pandemic, the tariff war, political upheavals and natural disasters have already exposed the fragility of

The use of AR/VR to remotely monitor and analyze factory operations and space allocation is one way to meet the social-distancing requirements for the restart. *Image courtesy of Autodesk.*

supply chains, and prompted many manufacturers to rethink their workflows. New trends, such as near-shoring and onshoring, are reversing the processes and practices of offshoring.

Therefore, manufacturers now need to find ways to juggle production across different geographies: for example, adding production capacity to the U.S. site to make up for the Asia site that needs to shut down indefinitely.

"People are using our simulation technologies to figure out how to change their factory layout to add another machine, or a new product mix," Green says. "Most firms don't really have idle assets or unused space in their locations. And when you shift production to a new geography, you still need to address social distancing as required by the local agencies, and ensure quality control, so it goes beyond space modeling and allocation. The simulation and modeling get very complex."

Companies that have mature, well-established digital technologies are able to take advantage of augmented reality and virtual reality (AR/VR) technologies to reconfigure their operations, he notes.

"There are situations where you can solve problems by conducting a virtual walkthrough of the factory to understand what's happening," he says, "but it depends on the maturity level of the company."

High Variability, Low Volume

Companies with two main characteristics seem to benefit more from factory and plant simulation technologies.

"This might be a gross generalization but in discrete manufacturing, high variability and low volume tend to be the key [characteristics]," says Srinath Jonnalagadda, VP of strategy, design and manufacturing, Autodesk. "They require a lot of configurability and dynamism."

The basic needs for factory simulation remain the same: "This is nothing new: Manage the configurations of the factory. Manage the flow of operations. Streamline the path of the work. Reconfigure the factory layout based on whatever new demand comes up," observes Jonnalagadda.

But the pandemic adds extra burdens on top of these requirements.

"Now you also need new processes and tools to keep the staff safe, manage risks while maintaining business continuity, maintain a line of sight and make sure the plant is ready to react and respond to shocks from the supply chain," he says.

With the pandemic and travel restrictions, many factory and plant operators are finding that physical access to the site is severely limited. "So they're looking to keep the productivity at pre-pandemic level while observing the factory operations remotely," notes Jonnalagadda.

Autodesk offers Factory Design Utilities, described as a set of software tools to plan, design and install an efficient factory layout. It's part of the Product Design & Manufacturing Collection, integrated with Inventor, AutoCAD, Navisworks and other Autodesk titles.

BASF found an efficient way to inspect its facilities using AR/VR. "They recently came to us and asked for a way to combine our technology with HoloLens, so that they can use the digital model of the factory and plant in situ onsite, so the maintenance workers can do inspections in HoloLens, compare it to the design model to identify problems and suggest repairs," says Jonnalagadda.

On the use of AR/VR, Fraser cautions, "Most people don't want to wear goggles all day, so the key is to identify the right use case and strategically deploy them."

The use of AR/VR for remote expert, as exemplified by BASF's case, can help minimize contact. On the other hand, for on-site deployment of AR/VR, the need to sanitize shared goggles is an important factor during the COVID era.

For more on this topic, read "Simulation Charts Course to 'Next Normal' Manufacturing," June 2020, by Beth Stackpole. 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

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- **Ubisense:** Ubisense.com

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Dell Precision 5750: The Smallest 17-in. Workstation

Dell's new Precision mobile system is small but pricey.

BY DAVID COHN

After recently reviewing the Dell Precision 5550 (*DE*, September 2020; https://bit.ly/31fGUfZ), the newest 15-in. addition to the company's mobile workstation offerings, Dell sent us its larger sibling. Dell touts the Precision 5750 as "the world's smallest and most intelligent 17-in. workstation," a claim that we quickly put to the test.

Like the Precision 5550, the Precision 5750 comes housed in a silver-colored case, and is less than an inch thick. The system measures at just 14.75×9.54×0.87 in. (W×D×H) and weighs a mere 5.5 lbs., plus 0.98 lb. for its 130-watt power supply (5.63×2.63×0.87 in.).

No Numeric Keypad

Lifting the lid reveals a beautiful 17.3-in. display with a 16:10 aspect ratio surrounded by Dell's new Infinity Edge bezel. This feature, also found on the 15-in. Precision 5550, measures just over 1/8-in., resulting in a near borderless screen. Yet, Dell still managed to place an RGB-infrared webcam centered in the top edge of the bezel, flanked by a pair of infrared emitters, an ambient-light sensor and a camera-status light, while a pair of microphones are located on the top edge of the case. As was true for the Precision 5550, there is no webcam privacy shutter.

Fig. 1: The new 17.3-in. Dell Precision 5750 packs power and a gorgeous display into a thin, lightweight chassis with minimal ports.
Image courtesy of David Cohn.

The Dell Precision 5750 incorporates the same 79-key backlit keyboard as its smaller sibling. This keyboard provides a very good feel and ample 1.3-mm key travel and includes an additional key in its upper-right corner that serves as the power button.

The keyboard is flanked by a pair of top-firing stereo speakers, with slots along the bottom edge on either side of the case for left and right woofers. Although the speakers provide very good sound, the configuration fills the available space, leaving no room for a separate numeric keypad, a curious omission on a 17-in. system.

A large (5.94×3.56 in.) gesture-enabled touchpad is centered in the palm rest below the keyboard. This is identical to the Precision 5550, and like that system, it lacks any dedicated buttons but recognizes the difference between left- and right-clicks. Only the Caps Lock key includes an indicator light. An LED diagnostics light is located on the front edge of the case, centered below the touchpad.

Proximity Sensor Concerns

Although the size of the Dell Precision 5750 is a welcome change from bulky 17-in. systems, the thin chassis leaves limited space for external ports. The left side provides a wedge-shaped security lock slot and a pair of USB 3.2 Gen 2 Type-

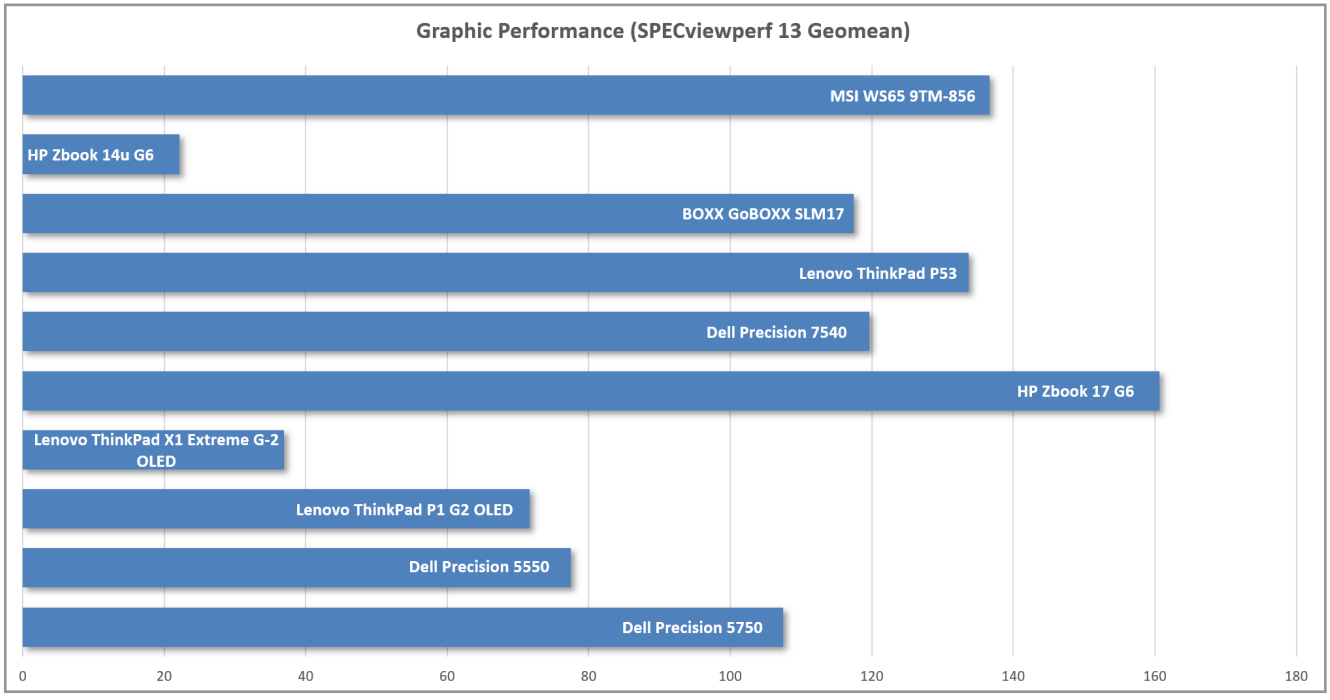


Fig. 2: Graphic performance of recent mobile workstations, based on the SPECviewperf 13 geomean results.

C ports. The right side hosts two additional USB 3.2 Type-C ports, an SD-card reader and a 3.5-mm audio port.

All four USB Type-C ports are charging ports and also support Thunderbolt 3 and DisplayPort 1.4. One of the Type-C ports must be used to connect the external power supply. There are no other ports.

Like the Precision 5550, the Dell Precision 5750 comes with a small adapter that, when plugged into a USB Type-C port, provides a single HDMI port and a single USB Type-A port. But it's still our opinion that modern systems require a minimum of two USB Type-A ports, one for a mouse and one for an external hard drive or thumb drive. Some users might also want an RJ-45 jack to connect to a gigabit network.

Dell sells several adapters, including a USB-C mobile adapter ($70) that provides six ports (USB-A, USB-C, HDMI, VGA, DisplayPort and RJ-45) and a Thunderbolt Dock ($275) that houses 11 ports (three USB-A, two USB-C, HDMI, two DisplayPorts, two audio combo jacks and a power connector). There are also a number of third-party adapters that would work, or you could purchase several USB Type-C to Type-A adapters. Either way, you may want to factor this into your purchase.

More troubling, however, was a feature we did not initially know existed. The Dell Precision 5750 includes a proximity sensor, located just to the left of the webcam. When you raise the lid, the system immediately boots up; there is no need to touch the power button. But we were puzzled by the fact that during our initial testing, the screen would turn off and the system would hibernate after 1 minute, despite the fact that we had changed the power settings to one in which this should never happen.

It turns out that the latest version of the Dell Optimizer software—designed to dynamically optimize the system's performance using artificial intelligence and machine learning—is set to do this by default, to enhance privacy when you walk away from your desk. However, there was nothing accompanying the system to let a new user know that this feature existed. An email to our contact at Dell provided the solution before we resorted to calling tech support. We feel that Dell should either include some sort of hard-copy document prominently explaining this or not have this feature automatically enabled.

Lots of Options

Although external connections are limited, Dell offers quite a few internal options. With a starting price of $2,399, the base configuration includes an Intel Core i5-10400H 2.6GHz 4-core CPU with integrated Intel HD Graphics 630, a 1920×1200 display, 8GB of DDR4 2933MHz RAM, a 256GB M.2 PCIe NVMe Class 35 solid-state drive (SSD), a 3-cell 56Whr lithium-ion battery and a 90-watt power supply, essentially identical to the base model of the Precision 5550. But again, that is just the starting point.

Dell offers a choice of seven different Intel processors. In

Mobile Workstations Compared

	Dell Precision 5750 17.3-in. mobile workstation (2.40GHz Intel Xeon W-10885M 8-core CPU, NVIDIA Quadro RTX 3000 w/Max-Q Design, 32GB RAM, 1TB NVMe PCIe SSD)	**Dell Precision 5550** 15.6-in. mobile workstation (2.30GHz Intel Core i7-10875H 8-core CPU, NVIDIA Quadro T2000, 32GB RAM, 1TB NVMe PCIe SSD)	**Lenovo ThinkPad P1 G2 OLED** 15.6-in. mobile workstation (2.80GHz Intel Xeon E-2276M 6-core CPU, NVIDIA Quadro T2000, 32GB RAM, 1TB NVMe PCIe SSD)	**Lenovo ThinkPad X1 Extreme G2 OLED** 15.6-in. mobile workstation (2.60GHz Intel Core i7-9850H 6-core CPU, NVIDIA GeForce GTX 1650, 32GB RAM, 1TGB NVMe PCIe SSD)	**HP Zbook 17 G6** 17.3-in. mobile workstation (2.40GHz Intel Xeon E-2286M 8-core CPU, NVIDIA Quadro RTX 5000, 32GB RAM, 512GBB NVMe PCIe SSD)	**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)
Price as tested	$5,219	$4,355	$3,133	$2,794	$5,654	$3,646
Date tested	8/28/20	6/24/20	2/16/20	2/16/20	1/24/2019	10/25/2019
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	132.73	91.74	76.32	85.73	185.09	155.08
catia-05	173.75	147.96	126.46	56.36	279.31	209.89
creo-02	159.58	116.59	101.20	75.12	243.95	187.29
energy-02	29.78	17.31	17.11	6.37	42.15	31.69
maya-05	153.66	112.25	102.12	100.62	272.88	183.66
medical-02	73.08	51.11	47.95	24.57	91.59	63.63
showcase-02	74.54	43.99	36.50	36.83	93.46	78.72
snx-03	189.01	144.50	191.81	11.29	361.04	217.45
sw-04	110.18	100.81	86.57	53.45	158.92	130.57
SPECapc SolidWorks 2015 (higher is better)						
Graphics Composite	3.82	3.43	2.81	n/a	5.24	4.27
Shaded Graphics Sub-Composite	1.94	1.77	1.41	n/a	3.23	2.55
Shaded w/Edges Graphics Sub-Composite	2.88	2.67	2.03	n/a	4.21	3.37
Shaded using RealView Sub-Composite	2.62	2.42	1.91	n/a	3.90	3.08
Shaded w/Edges using RealView Sub-Composite	3.47	3.28	2.60	n/a	4.54	3.83
Shaded using RealView and Shadows Sub-Composite	3.04	2.85	2.23	n/a	4.48	3.42
Shaded with Edges using RealView and Shadows Graphics Sub-Composite	3.67	3.45	2.76	n/a	4.85	3.92
Shaded using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	9.86	7.51	6.92	n/a	13.41	11.30
Shaded with Edges using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	10.68	8.64	7.79	n/a	13.20	11.13
Wireframe Graphics Sub-Composite	3.85	3.53	3.13	n/a	4.00	3.91
CPU Composite	3.55	3.09	3.19	n/a	3.06	3.76
SPEC Workstation v3 (higher is better)						
Media and Entertainment	2.20	1.93	1.63	1.70	1.87	1.88
Product Development	2.29	2.09	1.62	1.57	1.81	1.91
Life Sciences	2.15	1.59	1.54	1.31	1.94	1.67
Financial Services	2.13	1.54	1.53	1.17	1.96	1.75
Energy	1.43	1.30	0.99	0.99	1.32	1.36
General Operations	1.92	1.96	1.90	1.84	1.55	1.72
GPU Compute	3.09	1.91	1.79	1.84	3.34	3.20
Time						
AutoCAD Render Test (in seconds, lower is better)	35.60	38.9	49.00	44.10	35.40	34.80
Battery Life (in hours:minutes, higher is better)	10:30	10:22	7:14	6:45	4:45	7:51

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

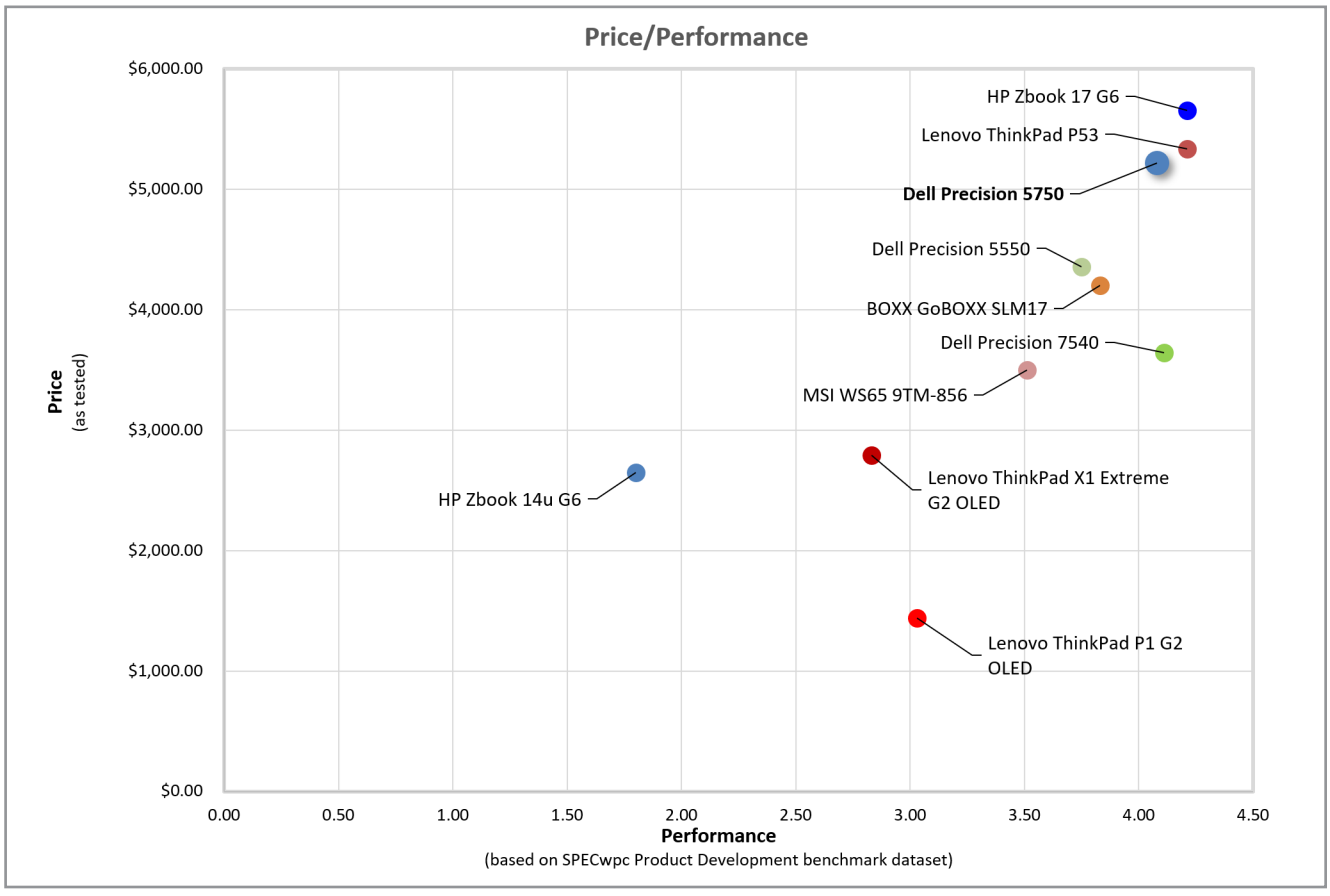


Fig. 3: Price/Performance chart based on SPECwpc Product Development benchmark dataset.

addition to the base 4-core i5 CPU, you can opt for one of two Intel Core i7 6-core variants (the 2.6GHz i7-10750H or 2.7GHz i7-10850H), one of two 8-core i7s (the 2.3GHz i7-10875H or 2.4GHz i7-10885H), or one of two Intel Xeon CPUs (the 6-core W-10855M or 8-core W-10885M).

All of these Comet Lake CPUs offer increased core counts and faster clock speeds than the previous generation, but the highest numbers are only achievable with what Intel calls its Thermal Velocity Boost. This means the additional speed is only available periodically when the processor is operating below its maximum temperature.

Our evaluation unit came with the Intel Xeon W-10885M CPU, an 8-core processor released in the spring of 2020. This CPU features a 2.4GHz base frequency, 5.3GHz max turbo, 16MB of Smart Cache and a thermal design power rating of 45 watts adding $448 to the base price.

In addition to the integrated Intel graphics, Dell offers the Precision 5750 with a choice of two NVIDIA discrete graphics processing units (GPU): the Quadro T2000 ($266) or the Quadro RTX 3000 with Max-Q ($426), which was included in the system we received. This GPU incorporates 6GB of GDDR6 memory, 1920 compute unified device architecture cores, 30 RT cores and 240 Tensor cores.

Based on NVIDIA's Turing architecture, the RTX 3000 has a 192-bit interface, enabling it to deliver a bandwidth of 288.05GB/second while consuming 80 watts. The discrete graphics card requires a larger (130-watt) power supply, adding $17.

Dell also offers a choice of two displays. Our evaluation unit included the same gorgeous 3840×2400 touch-enabled display as the one in the Precision 5550, which covers 100% of the Adobe color gamut. On the Precision 5750, this display added $348 to the total cost.

Although the new 10th-generation Intel CPUs can support up to 128GB of memory, the Dell Precision 5750's two memory sockets limit the total memory to 64GB. The system we received came with 32GB of non-error-correcting code (ECC) RAM, installed as two 16GB DDR4 2933MHz modules, adding $420. Systems like ours, equipped with a Xeon CPU, can also use ECC memory. Dell's ECC memory costs a bit more ($459 for 32GB) and is slightly slower (2666MHz) than the non-ECC RAM.

The Dell Precision 5750 also supports up to two M.2 solid-state drives—with optional RAID 0 and RAID 1 on systems equipped with two identical drives. Capacities range from 256GB to 2TB. The system we received came

with a 1TB PCIe NVMe Class 50 SSD, which added $735.

Although a 3-cell 56Whr battery comes standard, our system included a 6-cell 97Whr lithium-ion battery with ExpressCharge ($56 extra), which enables the battery to reach 80% in 60 minutes. That battery kept our Dell Precision 5750 running for an impressive 10.5 hours, slightly longer than the 5550.

The computer was nearly silent during even the most demanding tests, reaching just 56dB under heavy compute loads. But the underside reached 108°F at times and we measured a temperature of 123°F around the function keys when running some of our benchmarks.

Great Test Results

With its more powerful components, we expected the Dell Precision 5750 mobile workstation to outperform the Precision 5550, which it did quite handily. On the SPECviewperf test, which measures pure graphic performance, the Precision 5750 equipped with the NVIDIA Quadro RTX 3000 GPU turned in great results, lagging only behind mobile systems equipped with the even more powerful RTX 5000. Scores for the SPECapc SolidWorks benchmark were equally impressive.

On the very demanding SPEC workstation performance benchmarks, the Dell Precision 5750 also delivered excellent results. It turned in the top scores for four of the seven use cases (media and entertainment, product development, life sciences and energy) and scored near the top in the other three.

The 5750 also delivered the best results for CPU-dependent operations. The Dell Precision 5750 completed our multi-threaded AutoCAD rendering test in less than 36 seconds, among the fastest among all mobile workstations we have ever tested and more than 3 seconds faster than the Precision 5550.

All Dell Precision 5750 systems are independent software vendor certified for major CAD, digital content creation and scientific applications and include a copy of the aforementioned Dell Precision Optimizer. Since our system included a Xeon CPU, Windows 10 Pro for Workstations came preloaded, adding $154. Systems based on Intel Core processors come with Windows 10 Pro. Windows 10 Home and Ubuntu Linux are also available.

Like several other vendors, Dell's standard warranty has been reduced to just 1 year of basic service. Warranties of up to 5 years are also available. Since we base our as-reviewed price on systems with a 3-year warranty, our cost includes the extra $216 for the longer warranty. Note that the exact cost to extend the warranty will vary depending on the specific system configuration.

As configured, the Dell Precision 5750 priced out at $5,219, making it one of the more expensive mobile workstations we have recently tested. Although it is several pounds lighter than other 17-in. laptops, just remember that it sacrifices a separate numeric keypad and extra ports to achieve its svelte form. There are certainly faster, less expensive 17-in. systems out there, but none as thin or lightweight as the Dell Precision 5750. DE

David Cohn *is the technical publishing manager at 4D Technologies. He also consults and does technical writing from his home in Bellingham, WA and has been benchmarking PCs since 1984. He is 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 www.dscohn.com.*

MORE INFO

- **Dell:** Dell.com
- **Dell Precision 5750**

Price: $5,219 as tested ($2,399 base price)

Size: 14.75×9.54×0.87 in. (WxDxH)

Weight: 5.5 lbs. plus 0.98-lb. 130-watt power supply

CPU: 2.40GHz Intel Xeon W-10885M 8-core w/16MB Smart Cache

Memory: 32GB DDR4-2933MHz non-ECC

Graphics: NVIDIA Quadro RTX 3000 Max-Q w/6GB GDDR6

LCD: 17.3-in. UHD+ 3840×2400 anti-glare touch-enabled

Camera: 1 megapixel RGB+infrared webcam

Storage: 1TB KIOXIA America M.2 PCIe NVMe Class 50 SSD

Audio: Realtek ALC3281-CG with built-in speakers, built-in microphone, universal 3.5-mm audio jack

Network: Intel Wi-Fi 6 AX201 plus Bluetooth 5.1

Ports: Four USB 3.2 Gen 2 Type-C with Thunderbolt 3 and DisplayPort 1.4

Other: SD-card slot

Keyboard: 79-key backlit keyboard

Pointing device: Gesture-enabled 5.94×3.56-in. touchpad

OS: Windows 10 Professional for Workstations 64-bit

Warranty: One-year basic onsite (three-year warranty included in as-tested price)

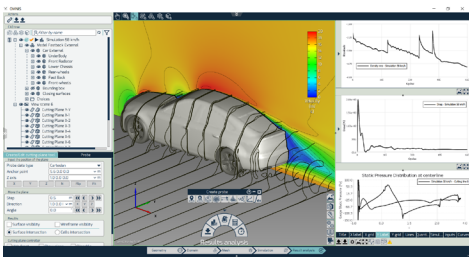
For more information on this topic, visit DigitalEngineering247.com.

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.

Debuting a CFD solver for incompressible flows

A variety of updates to existing modules are in the rest of the OMNIS platform.



Numeca International introduces OMNIS Release Candidate 4.2, the new update to the modular computational fluid dynamics (CFD) solution. This update features the first release of Open-PBS, a new solver for low-speed and incompressible flows.

Applications recommended for Open-PBS include heat exchangers, automotive thermal management, cooling systems and low-speed rotating machinery.

MORE ➜ digitalengineering247.com/r/24366

Monitor 3D printer activity from your smartphone

App can deliver push notifications to smart devices about job status and more.

ExOne introduces Scout, a smartphone app that provides real-time monitoring of 3D print jobs. The Scout app is part of a feature-rich web-based program that can deliver push notifications to smart devices about job status, printhead speed, fluid levels, temperature, humidity and other actionable manufacturing data. Scout uses Siemens MindSphere, an IoT operating system designed for industrial operations. Versions of the app work on Google Android and Apple iOS mobile platforms.

MORE ➜ digitalengineering247.com/r/24348

Reduce complexity of advanced tolerance analysis

Features clean, organized and highly interactive Modeler and Analyzer interfaces.

Sigmetrix has released CETOL 6 σ Version 10.4, the latest release of this solution for 3D tolerance analysis. Versions are available for PTC Creo, Dassault Systèmes Catia V5/6 and SolidWorks, and Siemens NX. Sigmetrix says CETOL 6 σ provides a comprehensive set of geometric dimensioning and tolerancing tools to analyze the precise assembly modeling process, resulting in more accurate prediction of critical variation impact early in the development process.

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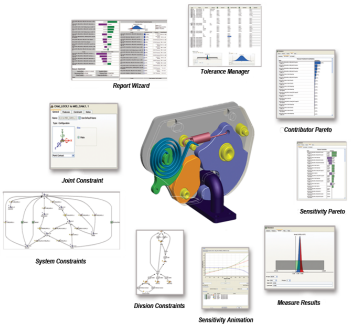
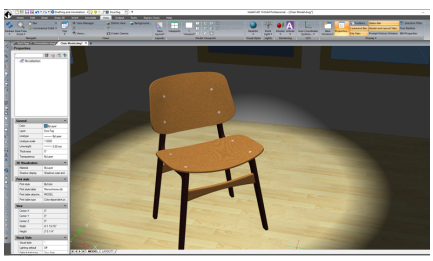




Major update from leading .DWG editor

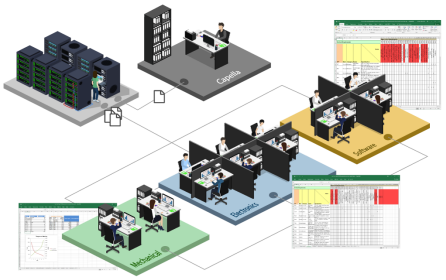
IntelliCAD 10 adds OpenGL ES graphics device, a new materials library and more.

The IntelliCAD Technology Consortium (ITC) introduces IntelliCAD Release 10, a major update of its drafting solution. IntelliCAD is a standalone drafting solution that is also used as the foundation for CAD products from several vendors. ITC is a founding member of the Open Design Alliance, and uses ODA solutions extensively in the CAD product. New import file formats include popular 3D data formats .OBJ and .STL.

MORE ➜ digitalengineering247.com/r/24293

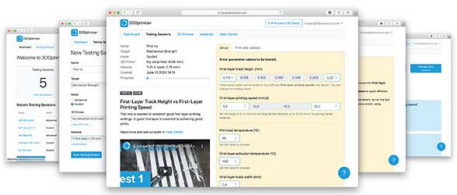
Gain task-specific access to the systems model

MapleMBSE uses Microsoft workflow to enable optimized views for editing.



Maplesoft introduces a release of MapleMBSE software to enable use of model-based systems engineering (MBSE) without requiring all project stakeholders to directly access the model. MapleMBSE keeps the central model updated for use by all team members. Because it eliminates the need to funnel all MBSE tasks through a small number of engineering experts, the workflow becomes a more democratized process. MapleMBSE supports several MBSE platforms.

MORE ➜ digitalengineering247.com/r/24265



Online software to develop 3D printer settings

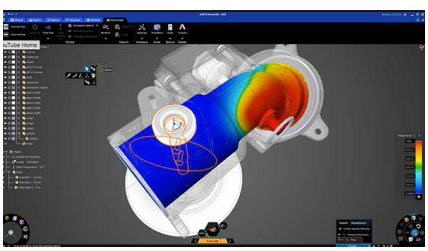
3DOptimizer works with most FFF/FDM 3D printers.

FabControl introduces 3DOptimizer, an online software tool for developing 3D printer settings. FabControl says the software addresses a "major issue" in additive manufacturing, the trial-and-error outcome that results from imprecise printer settings as a company moves from one material to another for various print jobs. 3DOptimizer works with most FFF/FDM 3D printers, including customized and self-built machines.

MORE ➜ digitalengineering247.com/r/24236

Refine design faster with upfront simulation

Release builds on the advancements made by the original Ansys Discovery Live.



Ansys has released a significant update to its simulation-driven design tool, Ansys Discovery. Discovery combines instant physics simulation, accurate high-fidelity simulation and interactive geometry modeling into a single, easy-to-use interface. Conducting real-time, rapid iterative design explorations, Ansys says engineers can explore larger design spaces and quickly answer critical design questions earlier in the product design process. This update offers a completely redesigned user interface.

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Xometry Launches 2D Tech Drawing Marketplace

Custom manufacturing company provides U.S. shops with more access to jobs.

Xometry unveiled its 2D Technical Drawing Marketplace, a platform to expand access to prospective job orders for 3,000+ American machine shops. The marketplace offers engineers and designers the ability to get quotes from Xometry's network of qualified U.S. shops for projects that lack 3D files. These files are often used for legacy parts and in sectors where diminishing manufacturing sources and material shortages issues are common. Xometry will guarantee the work quality.

MORE ➜ digitalengineering247.com/r/24162

Next-Gen Engineers

Student Design Competition: PTC's "Robots to the Rescue"

How to Host a World-Scale Design Competition During a Pandemic

BY JIM ROMEO

"Robots to the Rescue," is an entirely virtual CAD design competition using Onshape, where students identify a problem and design a robot to help solve the issue. Competitors in the FIRST Robotics Challenge and FIRST Tech Challenge were invited to compete and practice their skills over a 6-week period.

All teams were provided with Onshape Education plans (free for all students and teachers), along with training materials, live webinars twice a week and plenty of community support.

In total, 460 teams (including more than 1,000 students) from 10 countries participated. At the end of the 6 weeks, 151 of those teams submitted robot designs along with written documentation explaining the problem and how their robot was designed to solve it. Approximately 72% of teams were using Onshape for the first time, and for many it was the first time using CAD at all. They spent nearly 6,200 hours working on Onshape to develop their submissions.

A total of 460 teams from 10 countries competed in "Robots to the Rescue." *Images courtesy of Argenis Apolinario.*

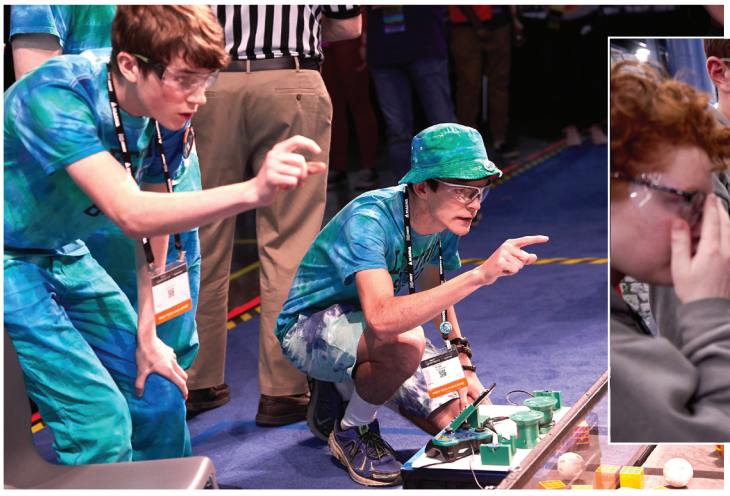
Jordan Cox is the senior vice president of PTC Academic Programs. We spoke to him to find out more about the competition.

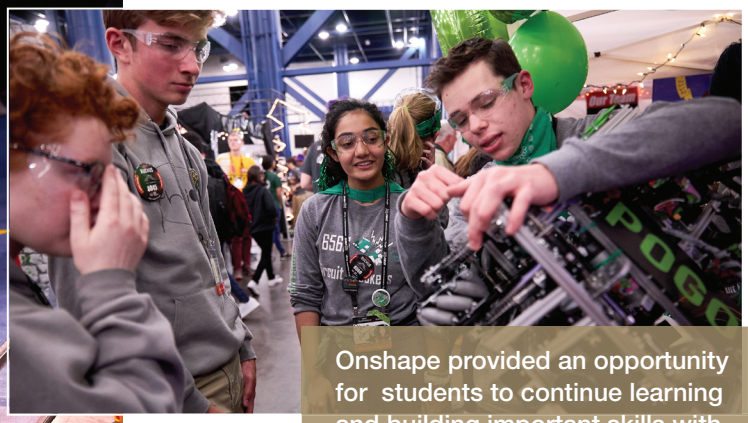
Digital Engineering: **Can you provide an overview of the PTC's "Robots to the Rescue" competition?**

Jordan Cox: PTC has been a long-time sponsor of the FIRST organization and has built close relationships with the community for the past decade. With the onset of COVID-19, the FIRST season was cancelled, and we really felt for the kids who were not going to get the valuable experience that FIRST normally provides them.

Not only was the competition cancelled, but teams could no longer meet due to social distancing policies. So, we set out to provide an alternative that was entirely remote and would still allow students to have some of the

"Robots to the Rescue," is an entirely virtual CAD design competition using Onshape, where students would identify a current world problem and design a robot to help solve that problem.





Onshape provided an opportunity for students to continue learning and building important skills with tools otherwise not available (left). A total of 72% of teams were using Onshape for the first time, and for many it was the first-time using CAD at all (right).

critical problem-solving and collaboration experiences that FIRST is so great at providing.

DE: **Can you tell us about some of the designs that are part of the event and how they came to be?**

Cox: The winning team of the competition was team FRC 6025—"R Factor" from Mumbai, India, that created an autonomous robot capable of filling in potholes. In their documentation, the team cited how much of a problem potholes are in India, and how much damage they cause on a yearly basis. In their design, they put a lot of effort into ensuring that their robot would be capable of bearing a load of 300 lbs. of asphalt, an impressive feat given the constraints of the competition.

We also had teams who chose to work together in alliances, who connected with other teams to design robots that worked in concert to solve the identified problem. One of these alliances designed a system of robots to select and deliver groceries autonomously and without human contact. One team designed a robot to grab items off the shelf, another robot transported those items in a crate and the final robot grabbed and moved the crate for curbside delivery. What's most impressive about this is that these teams had not worked with each other before the competition—they found each other on social media and started building collaboratively. The three teams involved received the "Amazing Alliance" award.

Another robot was a package delivery robot that could go up and down stairs, using a similar mechanism to Dean Kamen's iBOT wheelchair, but had large, friendly eyes on the front. In their write-up, they talked about how robots like theirs would need to move around alongside people and would need public trust—and the eyes they designed were an important aspect of gaining that. Although it may seem like a small thing, there was a lot of thought put into it. We gave that team the "Friendliest Robot" award.

DE: **Can you provide some examples of what the event has produced or what you expect it to produce?**

Cox: One of my favorite parts of this competition has been how the community has rallied together in Onshape to help each other out. In particular, Onshape has a capability to publish parts or assemblies to a "public documents" section, so that any other user on the platform can access them. With Robots to the Rescue, the number of public documents exploded! You can find just about every gear, wheel, bracket and frame from almost every FIRST supplier within seconds. The community has even banded together to establish review processes to ensure that the parts being shared are within specifications and accurate. This "coop-etition" as FIRST calls it, is so great to see.

Another aspect of the competition was just how advanced these teams are. When you think about a team of students in high school you might expect that they wouldn't be as advanced as some of our professional users, or they wouldn't follow CAD modeling best practices. But that was certainly not the case.

We had teams building out entirely parametrically configured gear trains, so that the gear ratios could all be changed with a single click of a button. We had other teams using FeatureScript, an open-source programming language within Onshape that allows users to add functionality and custom CAD features to the platform, to automatically create brackets for connecting structural components. Many of the teams used proper sheet metal techniques to design their robots.

Most importantly, Onshape enabled us to provide an opportunity for these students to continue learning and building important skills that we would not have been able to provide otherwise, and we hope to provide similar opportunities in future. DE

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

MORE INFO ➜

➜ **Robots to the Rescue:** Onshape.com/robots-to-the-rescue