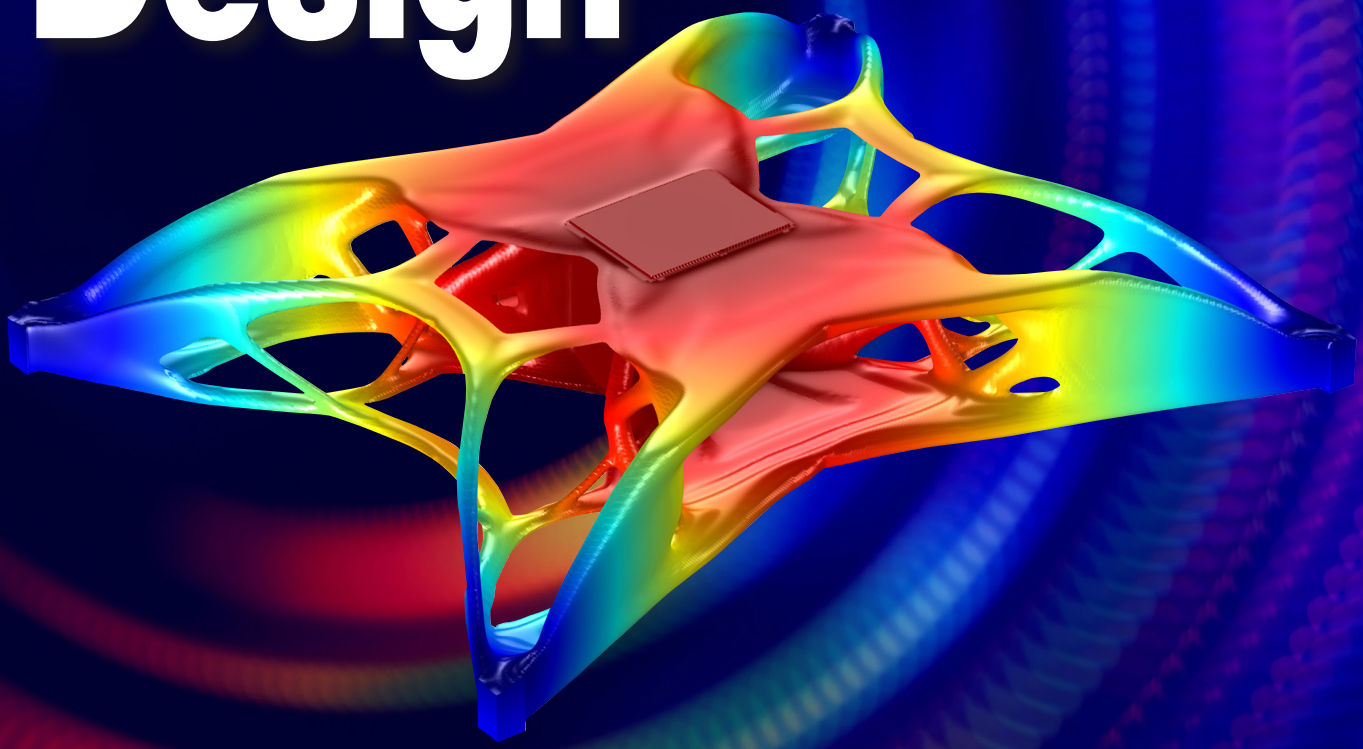
May 2021

DE247 Digital Engineering

- Get Ready for CAASE21 P.8
- Redesigned Supply Chain P.26
- Review: ThinkStation P620 P.36

Generative Design



DigitalEngineering247.com

Peerless MEDIA, LLC

By Brian Albright

A Second Look at Generative Design

GENERATIVE DESIGN CONTINUES to be a very promising technology that has not quite caught on yet. According to our own reader survey data from last year, just 15% were using the technology, while 17% had never even heard of it.

There are a variety of reasons for this, but I think part of the problem remains the way generative has been presented to the market and perceived by users: as a method of topology optimization best suited for lightweighting and additive manufacturing.

But generative is really a tool that should not be tied to any particular manufacturing process or optimization scheme. It is a way to take some of the trial-and-error drudgery out of initial design work and get the engineer to the best design faster. That only works if the engineer is able to feed the correct parameters into these solutions, and not every generative design software offering can provide that capability right now (at least not for every use case).

So in this issue, we are taking a look at how engineers can differentiate between generative design and topology optimization, as well as the evolution of easier-to-use simulation tools that can support this methodology.

Writer Beth Stackpole also walks us through the ways software providers and end users are applying generative design principles to other types of simulation and design problems (like flow) and traditional manufacturing processes. This is where the rubber really meets the road, as potential users need to be able to see how the technology can benefit them outside of simply finding the best way to pull weight out of a given part. The article also discusses how generative principles can help guide users to finding the most cost-effective manufacturing method that meets their design parameters.

Elsewhere in the issue, we take a look at how efforts to shore-up the U.S. manufacturing supply chain, and the role 3D printing and other technologies could play.

I also want to call your attention to two important events. First, *Digital Engineering* has launched a contest (in conjunction with the Advanced Product Developed Resource Center) to showcase our readers' innovative engineering projects. The Celebrating Engineering Innovation Contest will run through May. Entrants have a chance to win an NVIDIA Quadro RTX 6000 graphics card. Learn more here.

Generative is really a tool that should not be tied to any particular manufacturing process or optimization scheme.

We are also gearing up for the Conference on Advancing Analysis & Simulation in Engineering (CAASE21) virtual event on June 16. This is the fourth CAASE event we have produced in partnership with NAFEMS Americas. CAASE21 will feature a keynote on the development of autonomous vehicle technology, and four sessions highlighting advancements and use cases simulation technology, additive manufacturing, digital twins, and other technologies. Learn more about the event and register here.

Brian Albright, Editorial Director
E-mail me at balbright@digitaleng.news

GET NEWS OF FUTURE GPU ANNOUNCEMENTS

The advanced linework and visually rich imagery you see in your professional software is only possible because of the GPU you are using to display it. For today's resource heavy software, a modern GPU can mean increased performance and processing power. At AMD we are accelerating this further, and we can't wait to show you what we have been working on.

Register now for news of the newest AMD graphics cards as they're announced: amd.com/ProGPUsignup

AMD

© 2021 Advanced Micro Devices, Inc. All rights reserved. AMD, the AMD Arrow logo, Radeon, and combinations thereof are trademarks of Advanced Micro Devices, Inc.

DE247 Digital Engineering

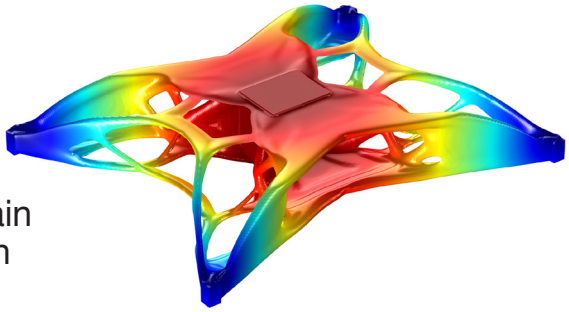
TECHNOLOGY FOR OPTIMAL ENGINEERING DESIGN

May 2021
Vol.27 • No.4

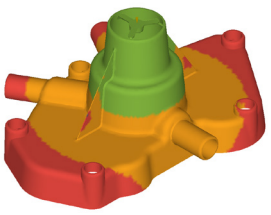
INSIDE

FOCUS ON GENERATIVE DESIGN

COVER STORY



10 Optimize or Generate?
Industry insiders explain the difference between the two approaches.
By Kenneth Wong

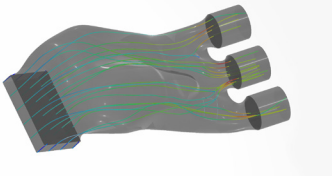


SIMULATION

14 Democratizing Simulation: A Progress Report
CAD-integrated FE, templates and UI changes pave way for wider adoption.
By Kenneth Wong

PROTOTYPE AND MANUFACTURE

18 Expanding the World of Generative Design
Additive manufacturing and generative design have been tied inextricably to lightweighting—but this tech combo can do much more for engineers.
By Beth Stackpole



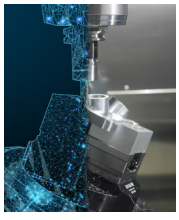
FEATURES

ENGINEERING COMPUTING

22 Dawning of a New Era in Data Science
New product development now incorporates machine learning, but lack of data science experts persists.
By Randall Newton

PROTOTYPE AND MANUFACTURE

26 Additive Manufacturing 2.0: Building a Resilient, Diverse, Secure Supply Chain
A new executive order and cybersecurity concerns shine light on the state of 3D printing.
By Jim Romeo



DIGITAL THREAD

30 Digital Twin Bridges Design and Manufacturing
Twin technology can aid product designers in pulling out vital information from both domains to improve development and production.
By Tom Kevan

REVIEWS

ENGINEERING COMPUTING

36 Lenovo ThinkStation P620: Powerful But Pricey

We review the first workstation powered by the AMD Threadripper Pro WX CPU.

By David Cohn

ENGINEERING COMPUTING

42 Getting Better All the Time: HP ZBook Studio G7 Mobile Workstation

HP makes their lightweight mobile workstation even thinner and smaller than previous versions.

By David Cohn

DEPARTMENTS

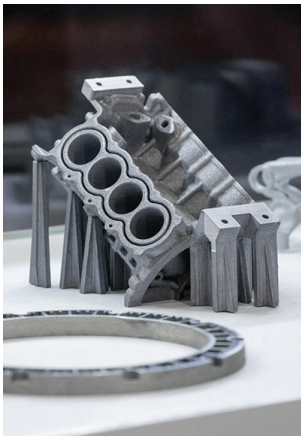
2 Degrees of Freedom
A Second Look at Generative Design
By Brian Albright

6 By the Numbers
Generative Design

8 News
- NAFEMS Americas, Digital Engineering Announce CAASE21 Virtual Conference
- Explore CAASE
- 3D Printing Meets Home Construction
- Celebrating Engineering Innovation

46 Editor's Picks

48 Next-Gen Engineers
Designing for Real-World Impact
Student Competition Profile: CWRU Global Health Design Collaborative
By Jim Romeo



Editor's Pick, Page 46

PUBLISHER
Tom Cooney

EDITORIAL
Brian Albright | Editorial Director
Kenneth Wong | Senior Editor
Stephanie Skernivitz | Associate Editor
Jess Lulka | Copy Editor

CONTRIBUTING EDITORS
Tony Abbey, David S. Cohn, Kip Hanson, Tom Kevan, Randall Newton, Beth Stackpole

ADVERTISING SALES
Len Pettek | Western U.S. Regional Sales Manager
Phone: 805-493-8297
lpettek@digitaleng.news

Mike Worley | Midwest/Eastern U.S. Regional Sales Manager
Phone: 630-834-4514
mworley@digitaleng.news

Tom Cooney | Group Publisher
Phone: 973-214-6798
tcooney@digitaleng.news

CREATIVE SERVICES
Wendy DelCampo | Senior Art Director
Polly Chevalier | Art Director
Kelly Jones | Production Director

A PEERLESS MEDIA, LLC PUBLICATION
Brian Ceraolo | President & CEO

EDITORIAL OFFICES
Peerless Media, LLC
50 Speen St., Suite 302,
Framingham, MA 01701
Phone: 508-663-1590
de-editors@digitaleng.news
www.DigitalEngineering247.com

SUBSCRIBER CUSTOMER SERVICE
Digital Engineering®
PO Box 677
Northbrook, IL 60065-0677
Phone: 847-559-7581
Fax: 847-564-9453
E-mail: den@omeda.com

Peerless MEDIA, LLC
peerlessmedia.com

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. Reproduction of this magazine in whole or part without written permission of the publisher is prohibited. All rights reserved ©2021 Peerless Media, LLC. Address all editorial correspondence to the Editor, Digital Engineering. Opinions expressed by the authors are not necessarily those of *Digital Engineering*. Unaccepted manuscripts will be returned if accompanied by a self-addressed envelope with sufficient first-class postage. Not responsible for lost manuscripts or photos.

BY THE NUMBERS | GENERATIVE DESIGN

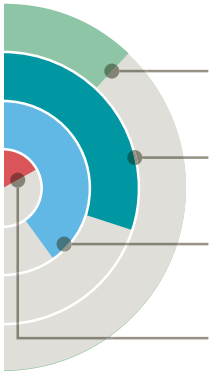
Digital Engineering Readers and Generative Design

Currently use generative design — **15%**

Plan to incorporate generative design within the next two years — **26%**

Were **extremely/very satisfied** with the ability of generative design to **discover new designs** — **52%**

How Familiar Are You with Generative Design?



- **12%** Very familiar
- **30%** Somewhat familiar
- **40%** Have heard of it, but not very familiar
- **17%** Never heard of it

63% of respondents said that **discovering new designs** was an extremely important objective in justifying generative design software.

The same number indicated **fostering innovation** in product development was an extremely important objective.

Respondents who believe generative design will **revolutionize** product design and development — **31%**

Source: Digital Engineering 2020 Technology Outlook Survey

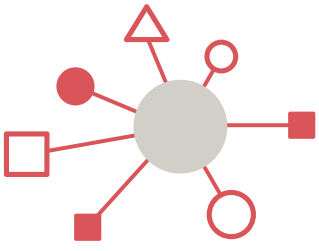
Incremental growth, 2018-2023

$124.58 MILLION

16% CAGR
Generative design market **forecast,** 2019 to 2023

35% of that growth will come from **North America**

14.7% YOY **growth rate,** 2019



The market is **MODERATELY FRAGMENTED** with **SEVERAL PLAYERS** occupying the market share

One of the **KEY DRIVERS** for this market will be the **GROWING DEMAND** from the automobile industry

Source: Technavio

ACCELERATE YOUR PRODUCT DEVELOPMENT WITH GENERATIVE DESIGN

Expand your ability to deliver innovative design and engineering solutions. Simultaneously generate multiple CAD-ready solutions based on real-world manufacturing constraints and product performance requirements.

LEARN MORE:
autodesk.com/generative-design

DESIGN:
2.5 AXIS GENERATIVE DESIGN MOTORCYCLE TRIPLE CLAMP DESIGN
BY MJK PERFORMANCE

AUTODESK.

NEWS

SIMULATION

NAFEMS Americas, Digital Engineering Announce CAASE21 Virtual Conference

The conference will explore the use of simulation and analysis across the design/development process.

NAFEMS Americas and *Digital Engineering* magazine will hold the second CAASE21 Virtual Conference on June 16, 2021. The one-day event will feature sessions conducted by representatives from Rolls-Royce, George Mason University, Purdue University, the National Institute of Standards and Technology (NIST), and University of Texas-Austin (UT-Austin).

DE and NAFEMS Americas launched the Conference on Advancing Analysis & Simulation in Engineering (CAASE) as a live event in 2018, and followed up with a virtual version of the conference in October 2019. A second live event was planned in Indianapolis for the summer of 2020, but the ongoing COVID-19 pandemic forced organizers to transition to a virtual conference.

CAASE21 will follow the same format as CAASE19, with the entire conference available live and online starting at 1 p.m. ET.

CAASE21 will provide a look at simulation-driven advances in design and product development, with presentations from leading experts and end users. Attendees will learn about the latest trends in engineering analysis and simulation, how industry leaders are using simulation, what lessons they've learned along the way and how the industry can democratize simulation to increase adoption.

The schedule includes a keynote session from George Mason University on development of autonomous navigation technology. The Rolls-Royce aerospace division will also be on hand to present their use of simulation-driven design techniques.

Purdue University will discuss a verification and validation framework for establishing trust in model predictions, while NIST will outline its efforts in leveraging computer simulation to help develop a broad-based additive manufacturing infrastructure. Attendees will also learn about predictive digital twins and their use in building an unmanned aerial vehicle from UT-Austin. DE

For more information and to register, visit:

- Digitalengineering247.com/caase21

Explore CAASE

Now in its fourth year, the Conference on Advancing Analysis & Simulation in Engineering (CAASE) has provided attendees at both live and virtual events with leading-edge content to help engineering professionals stay informed about the continued expansion of simulation and analysis activities across the design process.

The CAASE19 and CAASE20 virtual sessions are still available online. You can access the archived sessions and other content at the links below.

- **CAASE19**
  Digitalengineering247.com/caase19
- **CAASE20**
  NAFEMS.org/events/nafems/2020/caase20

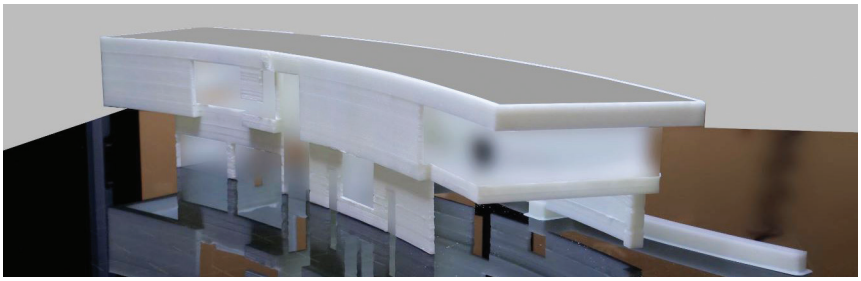
ADDITIVE MANUFACTURING

3D Printing Meets Home Construction

Forte Specialty Contractors is using 3D printed models to help customers understand building plans and layouts.

BY BETH STACKPOLE

We've gotten increasingly comfortable with the notion of 3D printing production-grade parts for automobiles and airplanes, and the technology is frequently tapped to create bespoke products—whether a fashion item or a custom-fit prosthesis. More recently, 3D printing played a huge role in address-



ing pandemic-induced shortages of personal protective equipment (PPE), including masks, swabs and face shields.

Now, 3D printing is taking root in the building industry as a way to help customers understand design layouts, to create custom job site pieces and even as a construction method as contractors and buyers seek more sustainable materials and building options. 3D printing's emergence in the construction and homebuilding industry appears poised for growth: A Markets and Markets report projects the concrete 3D printing market to be valued at $56.4 million by 2021.

A notable example of where this trend is heading is a 3D printed, zero-net-energy neighborhood being planned in Rancho Mirage, CA. According to a recent report on CNN, the Palari Group said it plans to build 15 eco-friendly 3D printed homes on a 5-acre spot; each single-story home will be 1,450 square feet and will be made from a fire-resistant stone composite material. The developer is working with Mighty Buildings on the project, using 3D printed modular panels that fit together like "Lego blocks."

Forte Specialty Contractors, a Las Vegas construction firm, is also bullish on 3D printing's role in residential and commercial building projects. Scott Acton, CEO and founder, says the firm isn't ready to build actual homes using the technology; however, it is tapping 3D printing in myriad other ways, for providing mockups of renovation and building designs and for creating custom theme park pieces.

Using the large-scale Massivit 1800 Pro 3D printer, the firm is outputting scale models of its new homes to help clients better understand design elements and to avoid misunderstandings that can lead to costly and time-consuming change orders. By building a large-scale model of a building or renovated room design, Forte can help clients understand things like what doors open which way and even how furniture would look in a room.

"It's a great communications tool for us and removes assumptions," Acton says. "3D printing provides a way to communicate spatially and affordably, to do redesigns in a controlled environment and not have a lot of change orders in the field. It's a way for us to mitigate risk on design and layout by doing things virtually."

The Massivit 1800 3D printer can produce pieces up to 5'9" high using a proprietary additive manufacturing gel technology that instantly cures to produce lightweight, hollow objects. One of the biggest use cases for the printer is producing super-size signage, displays and specialty pieces—the latter, an application also used by Forte for its hospitality, restaurant and entertainment clients. The build area is 57 inches wide, 44 inches in depth and 70 inches high.

In fact, it's the sheer size of the Massivit build plate that makes the technology particularly appealing to Forte Specialty Contractors. "Everything we do is really massive so the build plate size is important to do larger pieces," Acton says. DE

➜ **To learn more about the Massivit 3D printing technology used in Forte's building construction application, check out this link.**

CONTEST

Celebrating Engineering Innovation

Win an NVIDIA Quadro RTX 6000 GPU

Digital Engineering, in partnership with Dell and NVIDIA's Advanced Product Development Resource Center, will celebrate the engineering achievements of our readers via the inaugural Celebrating Engineering Innovation contest.

The APDRC is a repository of resources and information that can help design engineering teams capitalize on digital disruption through the use of advanced design and computing technologies. *DE* and the APDRC want to showcase how readers are using these technologies to create innovative products and designs. Winning entries will be featured on the APDRC website and newsletter, and the grand prize winner will receive an NVIDIA Quadro RTX 6000 graphics card.

Submissions should include a short description of the project, along with details about the hardware and software used, and the entrant's contact information. (Entries can also include images, screenshots and video, but these elements are optional.)

Submissions will be accepted now until May 31, 2021. For more information and to enter the contest, visit the registration page. DE

Optimize or Generate?

Industry insiders explain the difference between the two approaches.

BY KENNETH WONG

Currently, as a term of commercial appeal, generative design takes precedence over topology optimization. But before generative design's emergence, companies put the spotlight on topology optimization.

In certain stages, the geometry that results from generative design and topology optimization looks quite similar, for good reasons. Both approaches, as encapsulated in the design software packages with these labels, rely heavily on algorithms and known principles of finite element analysis (FEA).

Therefore, if the stress concentrations on a solid part are the same, the topological solution proposed by the software, whether generative design or topology optimization, will likely be the same. But most experts point out, increasingly, one approach is getting better at reconciling the mathematically ideal topology with the manufacturing requirements.

Chronological Order

The underlying principles for generative design and topology optimization have been around for some time, but as commercial design software programs go, topology optimization made its debut first, partly enabled by the faster processors that made it possible to run FEA in the background.

The Genius bottle cage for cyclists, optimized in Ansys Discovery. *Image courtesy of Ansys.*

Altair OptiStruct entered the market with a commercial version of topology optimization in 1992. solidThinking, then a division of Altair, added what is now called topology optimization in solidThinking Inspire as an automated lightweighting solution over a decade ago.

In its press announcement for 2012's Inspire 9.0, Altair wrote, "Inspire 9.0 provides design engineers and architects with an intuitive environment that enables the exploration of structurally efficient concepts in the earliest phases of the design process."

"Users can rapidly generate design spaces and arrive at efficient design concepts while improving both static and dynamic stiffness and reducing weight" Andrew Bartels, program manager for Inspire, explains. (For more, read "SolidThinking Inspire 9.0: Weight Loss Made Easy," September 2012, bit.ly/2PV7Rm9.)

The rapid rise of generative design software has a lot to do with Autodesk, which began exploring the technology's potential with Project Dreamcatcher.

In the company blog, Between the Lines, Autodesk blogger Shaan Hurley wrote, "The Dreamcatcher system allows designers to input specific design objectives, including functional requirements, material type, manufacturing method, performance criteria and cost restrictions. Loaded with design requirements, the system then searches a procedurally synthesized design space to evaluate a vast number of generated designs for satisfying the design requirements." (The blog excerpt was taken from the following: "Olympic Recurve Bow Created with Generative Design," January 2016, bit.ly/3dFDM2g).

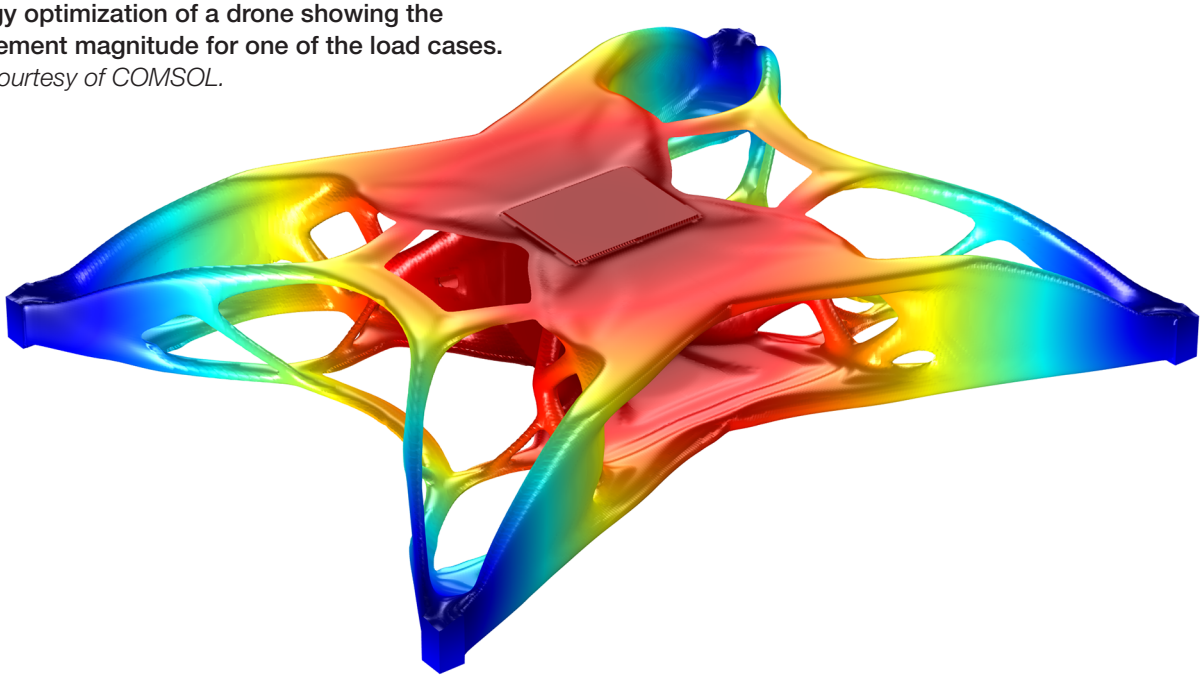
Eventually, Autodesk would package Dreamcatcher's components as generative design, and them in products such as Autodesk Fusion 360 and Netfabb.

A Hierarchy of Processes

In general, most industry experts think of generative design as the larger umbrella term, and topology optimization as one of the methods within.

"I think [of] topology optimization as one form of generative design," says Uwe Schramm, chief technical officer at Altair.

Topology optimization of a drone showing the displacement magnitude for one of the load cases.
Image courtesy of COMSOL.



Similarly, Michael Wakefield, Autodesk Fusion evangelist, says, "Generative design is a step beyond topology optimization. Topology optimization is part of generative design. Generative design uses topology optimization as the starting point."

And Justin Hendrickson, director of product management at Ansys, says, "Topology optimization is a key building block to deliver generative design."

Colin Swearingen, solution consultant at Dassault Systèmes, says, "Topology optimization is one method of generative design, a subset of generative design. So if I'm using generative design to design a part, it might incorporate some topology optimization." But he also pointed out topology optimization is usually aimed at removing materials to create lightweight parts.

"The fundamental difference between topology optimization and generative design is that topology optimization is driven by the physics of the problem, while generative design is more directly controlled by the designer's own choices and requirements," says Kristian Ejlebjærg Jensen, product manager for optimization module, COMSOL.

For many, generative design is the next phase in the evolution of topology optimization, a refinement of the technology with more automation. This matches Autodesk's implementation of the technology.

"We give you the option to get Unrestricted topology in Autodesk Fusion when you do generative design," says Wakefield. "That's essentially topology optimization without manufacturing constraints."

With the Unrestricted option in Autodesk Fusion, the topology you get is theoretically optimal based on algorithms and FEA results, but it may be impractical or impossible to manufacture. In contrast, the software will propose topology ideal for specific manufacturing methods if you choose it as a requirement.

"With topology optimization, normally you get a design approach, a proposal of where to add materials and where to remove them, but you may still need to work on it to finalize it," notes Thomas Reiher, director of generative design, Hexagon. "With generative design, the goal is to get something that's ready to use."

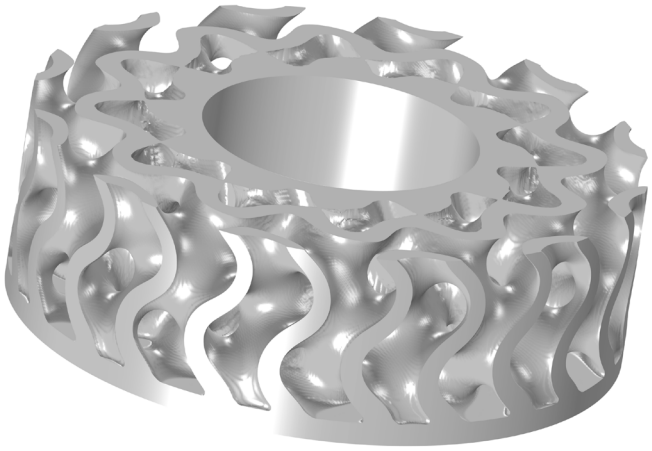
Swearingen urges users to think of generative design as a design exploration tool.

"With generative design, you may ask the software for a design variant perfect for AM, another variant for casting and another for milling," he explains. "You might be able to do that with some topology optimization software, but topology optimization is traditionally an analyst's or expert's tool."

Topology optimization's FEA-driven approach "comes at the cost of explicit control for the designer, making it difficult to prohibit things like the formation of internal voids, floating parts or structures that are too slender and thereby prone to buckling. It may also influence aesthetics," says Jensen. "Alternatively, generative design is a bit less focused on performance and more on aesthetics and manufacturability, which are controlled through the generative design methods or algorithms."

Schramm points out that in Altair's implementation of topology optimization, it's also possible to add manufacturing constraints as part of the optimization strategy.

"If you want to optimize a part for 3D printing, you care about AM constraints, so you want to look at overhangs and print direction, for example," he explains. "These can all be formulated as topology optimization problems. You can even optimize for different manufacturing considerations: one for casting, another [for] 3D printing."



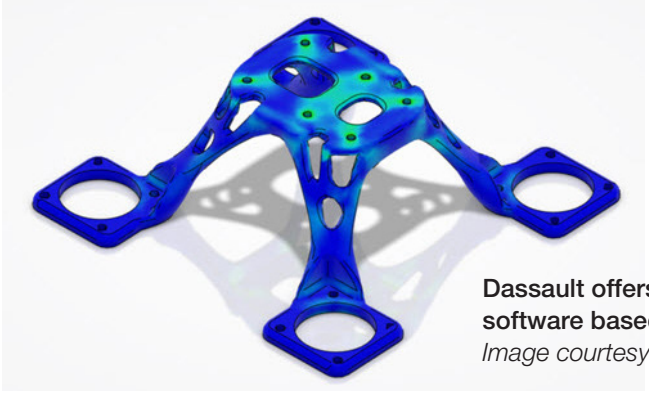
Generative design for a gyroid geometry with decreasing wall thickness in the z-direction.
Image courtesy of COMSOL.

Different Approaches

Most, if not all, generative design and topology optimization software packages run on top of time-tested FEA solvers. Altair Inspire, for example, runs on the company's high-end OptiStruct solver, developed to handle static and dynamic vibrations, acoustics, fatigue, heat transfer and multiphysics scenarios. MSC Software, part of Hexagon, uses MSC Apex as the basis for its MSC Apex Generative design software combined with a specialized FE solver.

This is why topology optimization and generative design's basic setups are instantly familiar to FEA software users. From selecting surfaces to applying stress loads, the generative design and topology optimization software user interfaces closely mimic simulation software setups.

The difference is in the degree of automation involved, which reduces the complexity for the users. The more automation it offers, the less the user needs to do to formulate the simulated event in numerical terms (as stress loads, pressure directions, joint types and mesh types). This has implications on the learning curve.



Dassault offers topology optimization and generative design software based on its Tosca solver, part of Dassault SIMULIA.
Image courtesy of Dassault Systèmes.

"Tosca from Dassault SIMULIA is for experts and analysts, but our generative design package makes the same workflow easier and it is intended for the designers," says Swearingen.

Similarly, for Hexagon customers, "it's easier to learn generative design because you can ignore the mathematical formulas. Hiding the complexity is an accomplishment in itself," says Reiher. "We do optimization quite differently. We do it based on stress, so you can use a certain stress level as the threshold not to exceed. MSC Apex generative design offers ease of use for people who don't want to know the mathematics involved."

"Emerging trends involve the combination of topology optimization with generative design as well as the use of the tools for applications outside the field of structural mechanics, such as heat transfer, CFD [computational fluid dynamics] and acoustics," says Jensen. "Thus, there is a demand for flexible tools as well as prepackaged functionality for entry-level users."

In the largely FEA-driven topology optimization packages from different developers, the software proposed topology, usually a mass reduction strategy, is bound to be similar because it's determined by stress distribution and material characteristics.

But generative design packages function differently. Though almost all allow stress and mass reduction targets as inputs, the additional allowable parameters are not identical. Some products offer cost, carbon emission or manufacturing methods as parameters; others may not.

To Cut or Grow

The basic optimization strategy—especially in lightweighting projects—is to remove as much materials as possible without compromising the part's strength. That means cutting away materials in the regions unaffected by stress loads, as the FEA results indicate. But there's a weakness to this approach, according to Wakefield.

"Most software only removes geometry," says Wakefield. "But with Autodesk Fusion, we are able to add geometry as well as remove it." This makes a difference if you want to know, for example, the most economical way (in terms of material usage) to connect two disparate mechanical components.

Hendrickson says users can set up multiple optimization sessions using the high-end Ansys Mechanical software, powered by on-demand cloud resources from Ansys Cloud. "Users might think of it as generative design but we don't market it as such," he says.

Similarly, Autodesk allows Fusion 360 users to use cloud credits (purchased separately from the software license) to speed up generative design sessions. Hexagon's MSC Apex Generative design and Altair's OptiStruct are parallelized, and therefore can be accelerated with distributed computing.

An appeal of generative design is that the software can offer scores—even hundreds—of design options. This is especially true of cloud-powered generative design software. But the more, the merrier doesn't necessarily apply here, cautions Reiher.

"If you get too many results, it makes it harder for the engineers to determine which is the best one. They will be overwhelmed," he says. "Most likely they will throw away most of the answers. It's a waste of computing power."

Accidental Lattice

Engineers have lately turned to lattice structures for lightweighting parts. The complex nodes and beams support one another, offering strength. Yet, it remains porous, weighing much less than the solid part it replaces.

But such designs are nearly impossible to model manually in typical 3D CAD software. The best approach is to use a program or algorithm to automatically generate them. Generative design offers tantalizing possibilities to explore efficient ways to model lattice fills.

"Today's generative design solutions may sometimes give you lattice-like answers, but they are not true lattice structures," says Wakefield. "Pure lattice structures are not generative design or topology optimization, but structures generated based on constraints."

"Some software uses precook lattice forms to fill a volume, but that's not optimal design," warns Schramm. "If your lattice structures are in the wrong orientation, you don't get optimal resistance for your stress loads."

Unquantifiable Parameters

For the most part, generative design packages have evolved to include manufacturing constraints, allowing engineers to limit the design options to only those suitable for their desired manufacturing method. In some, you also may use cost and carbon emission as input, which gives you a way to stay within your budget and explore greener products. However, certain design criteria may never be automated.

"The aesthetic element of design is not quantifiable or constant over time, so it is somewhat incompatible with topology optimization, yet aesthetics is the primary consideration for many design problems," observes Jensen.

"The aesthetic appeal of the shape, for example, is not something we can quantify as a set of parameters," Hendrickson adds.

Often, the judgment is based on the engineer's own personal views and his or her understanding of the marketplace. This led Hendrickson to propose engineer-in-the-loop generative design.

Dassault offers topology optimization and generative design software based on its Tosca solver, part of Dassault SIMULIA. *Image courtesy of Dassault Systèmes.*

"This is where the engineer is changing the inputs, learning from the output topologies, and reiterating. Think of it as the software working hand-in-hand with the engineer," he says.

Generative design and topology optimization have become well-established industry terms; therefore, users should be able to expect certain things from software marketed under these labels. But rather than relying on the term, it's best to test out the software to see if it's a good fit for the project.

"We used to call topology optimization morphogenesis in our old website," says Schramm. "It didn't stick." 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

- **Altair:** Altair.com
- **Ansys:** Ansys.com
- **Autodesk:** Autodesk.com
- **COMSOL:** COMSOL.com
- **Dassault Systèmes:** 3DS.com
- **Hexagon / MSC Software:** MSCSoftware.com

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

Democratizing Simulation: A Progress Report

CAD-integrated FE, templates and UI changes pave way for wider adoption.

BY KENNETH WONG

The CAE software market's value stands at U.S. $6.1 billion in 2020, according to the analyst firm Cambashi's "CAE Observatory Report." Out of the 480 vendors the firm has been tracking, five emerged as the top vendors between 2016 and 2020: Ansys, Siemens, Dassault Systèmes, Altair and Hexagon. In 2020, the top three accounted for 47% of revenues.

Despite a dip in the growth rate during the COVID-19 shutdown, the CAE market is expected to bounce back and follow an upward trajectory with a compounded annual growth rate of 11.1% from 2019 to 2024, predicts Cambashi.

The numbers suggest the software vendors' drive to democratize simulation—to push for wider adoption among designers and engineers with limited simulation expertise—is paying off, quite literally.

To better understand how and why the nonexperts are embracing the technology, we spoke to various simulation software users on the frontier of the movement for democracy.

Identifying the Correct Adoptee

Ricardo Espinosa, R&D engineering manager for the furniture manufacturer Kimball, has been using Siemens' Solid Edge CAD for nearly two decades now, but he began using simulation only during the last 6 years, he recalls.

In his experience, the successful simulation rollout had to do with identifying the appropriate group of users. In the case of Kimball, that pool was not all CAD users but only a portion of them.

"Even if the software is easy to use, it's difficult for some designers to understand the structural calculations involved," Espinosa says. "Only those who understand loads and assembly joints can use them. So we decided to train only those with a good foundation in structural engineering."

Stress loads and boundary conditions on furniture are not exactly rocket science, Espinosa admits, but they still demand a good grounding in structural engineering and the physics involved.

"We need to simulate people sitting on furniture or pushing it. We also simulate draws and shelves opening. It gets more complicated when we simulate how the human body interacts with the furniture," says Espinosa. "So I wrote a manual that explains the correct mesh size to use, how to define the joints and how to apply the loads."

These calculations were previously done by the engineering group, not the designers. So the engineers became the target group for simulation software training, provided onsite by a Siemens value-added reseller. The collaborative workflow occurs inside Teamcenter, a data management product by Siemens.

"Simulation is only about 1% to 2% of our design workflow," estimates Espinosa. With Solid Edge's tiered licensing scheme (Foundation, Classic and Premium editions), Espinosa's team was able to secure just a handful of licenses that include simulation features, and keep the rest of the team on regular design-centric licenses.

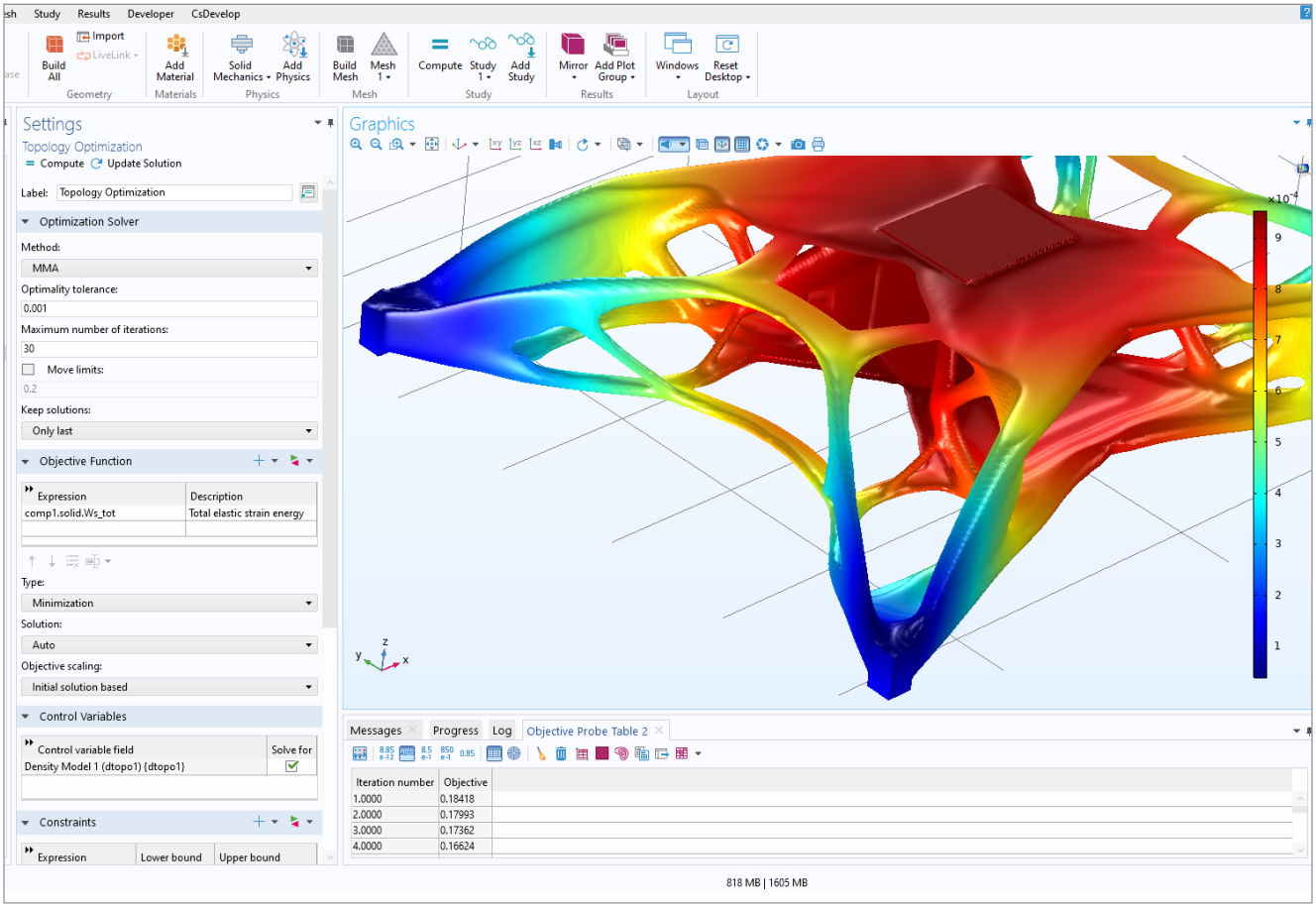
Large furniture makers in the hospitality industry are more likely to adopt simulation, because they benefit the most from a reduction in physical testing, Espinosa reasons.

"The rest—the little shops with a few employees—don't have the human resources to train and learn the software," he adds.

Learn This in Two Weeks

Theodore Chortatsos, mechanical engineer/simulation engineer at Solidize, is also the Hellenic SolidWorks User Group Leader and a SolidWorks Champion. He still remembers his first encounter with simulation vividly.

Someone handed him a CD and said, "This is FEA [finite element analysis] software, and we must have the results in 15 days," he recalls. "I had to model the entire structure with all its details inside an unfamiliar and unfriendly 3D software. I had



COMSOL Multiphysics software includes an app publisher, allowing users to publish complex simulations as guided workflows with only a few variables. *Image courtesy of COMSOL.*

only hand calculations as reference to solve the simulation."

Somehow Chortatsos did manage to finish the assignment and was impressed with what was possible with FEA.

"I could visualize on my screen things that I was unable to even imagine at the time—stress areas, weak points and structural deflections with cool color plots," he says.

Chortatsos puts potential simulation users into three categories: designers, engineers and analysts. The analysts are undoubtedly capable of sophisticated simulation as they are experts in the product's physics.

"Dassault's products have a user-friendly environment. I believe these manage to reach the average designers and engineers," Chortatsos remarks. "The integrated 3D modeling and simulation environment offers flexibility with advanced simulation capabilities to fulfill the designers' and engineers' needs."

Chortatsos says he now uses simulation almost daily. His preference is to work with simulation tools embedded inside CAD.

"The seamless transition between the two environments let me alternate without having to set up analysis from scratch," he says.

But as he takes on more simulation tasks, he notices that model complexity is growing—as well as the data output.

"The time required for analysis is proportional to the complexity of the model and assembly details involved," he says. "The amount of data needed to be stored locally is huge. Both are becoming barriers to solving models."

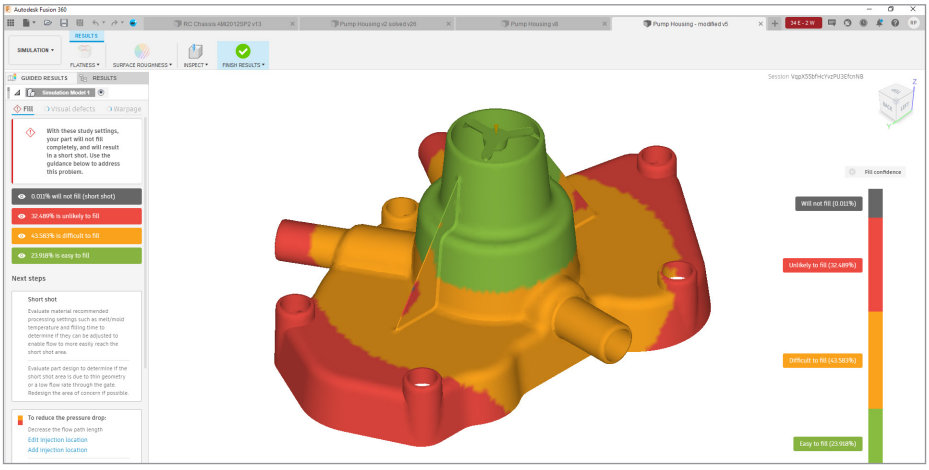
Chortatsos has begun exploring Dassault's 3DEXPERIENCE, with more cloud features to address computing power shortage and storage needs.

Template-Driven Simulation

Christopher Hopper, senior radiofrequency (RF) systems engineer at ITW, is a COMSOL Multiphysics simulation software user. As a simulation expert, he must figure out ways to facilitate simulation usage among his less knowledgeable colleagues. That's where apps play a role.

COMSOL Multiphysics includes functions to build and publish apps or guided simulation workflows. This feature lets experts like Hopper create simulation apps with only a few variables exposed as inputs, allowing novices and nonexperts to use them without learning the software. But creating the app requires time, so Hopper needs to consider the return on investment.

"If I have to put in three hours to build an app, and in the long run it will help me save more time than what I put in, then it's worth doing," he says.



Autodesk Fusion 360 includes injection molding simulation to let users preview mold operations. *Image courtesy of Autodesk.*

Certain features of the design, such as heat wave guide placement or the tray height inside the cavity, are determined by experts like Hopper, so these are not open to experimentation.

On the other hand, "I give users a lot of freedom in the size, shape and cavity dimensions. These are all up to the designers," Hopper says.

Hopper has built apps not just for his colleagues but also for customers, to show why ITW's RF technology yields better results compared to the competition.

"We use solid-state RF, so I made an app to let the customers see why solid-state RF always gives better results," he explains.

Hopper's expertise, in the physics of RF and in COMSOL software, allows him to build apps but he also recognizes, for smaller firms without experts, this may not be possible. That's why he thinks prebuilt cloud-hosted apps from vendors is a fascinating idea.

"I would like to see vendors producing more of these," he says.

Leading simulation software developers such as Ansys and COMSOL offer app marketplaces within their ecosystems. But pioneering vendors, such as simulationHub, have also emerged to offer cloud-hosted simulation apps for specific tasks, accessible from standard browsers for a subscription fee.

A UI Revolution is Needed

Collected data of Autodesk's software users shows "Autodesk Fusion 360 users use twice as much simulation as Inventor users," reports Seth Hindman, senior manager of product management & strategy at Autodesk.

He thinks it has something to do with how simulation problems are presented to the users in the software's user interface (UI).

"We need to focus more on the user's desired outcome," he reasons. "All these contact points, where to put the loads, how to mesh—they require so much cognitive burden. We can automate a lot of these. Take, for example, simulation of injection molding a design. What if, instead of asking you for boundary conditions, we just tell you based on your design whether the mold will fill, or whether it will be aesthetically pleasing?" he says.

This will be a significant departure from the standard simulation software UI, which asks the users for a series of inputs.

"The hidden aspect of making the UI strategy work is automation under the hood. By helping to set up, interpret and recommend changes to the problem, a different UI experience is possible. We think Fusion 360 is a leading candidate for this type of UI change," says Hindman.

Almost all mainstream CAD packages now include basic simulation tools; therefore, access to simulation is no longer a barrier. The integrated CAD-CAE environment is more desirable to the designers with limited FE expertise, as indicated by the users we interviewed.

But by the nature of their work, designers aren't expected to wrestle with simulation problems day in, day out. Unlike a simulation specialist, they tend to use it only when they need to verify the function and performance of the design.

"The key is to allow people to use simulation on an infrequent basis with confidence," Hindman says. 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

- **Autodesk:** Autodesk.com
- **Cambashi:** Cambashi.com
- **COMSOL:** COMSOL.com
- **Siemens Solid Edge:** SolidEdge.Siemens.com
- **simulationHub:** simulationHub.com

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

ACCELERATE YOUR PRODUCT DEVELOPMENT WITH GENERATIVE DESIGN

Expand your ability to deliver innovative design and engineering solutions. Simultaneously generate multiple CAD-ready solutions based on real-world manufacturing constraints and product performance requirements.

LEARN MORE:
autodesk.com/generative-design

DESIGN:
2.5 AXIS GENERATIVE DESIGN MOTORCYCLE TRIPLE CLAMP DESIGN
BY MJK PERFORMANCE

AUTODESK.

Expanding the World of **Generative Design**

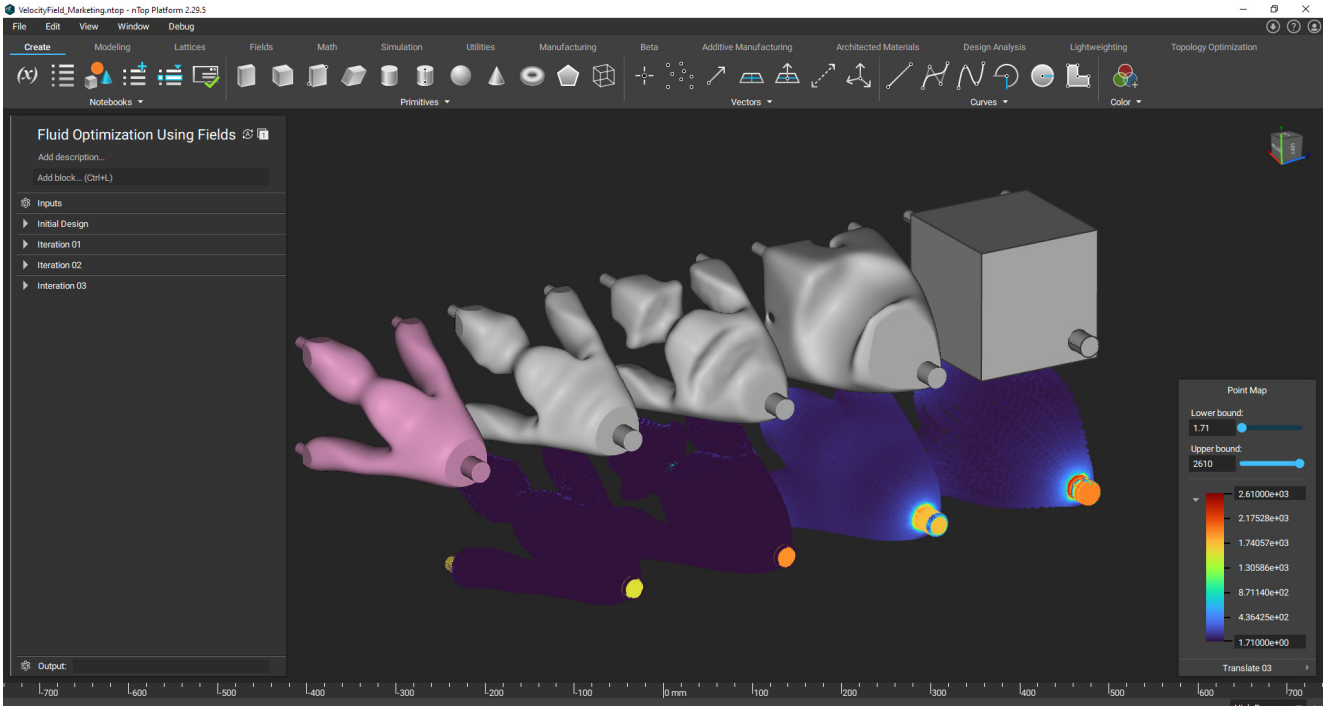
Additive manufacturing and generative design have been tied inextricably to lightweighting—but this tech combo can do much more for engineers.

BY BETH STACKPOLE

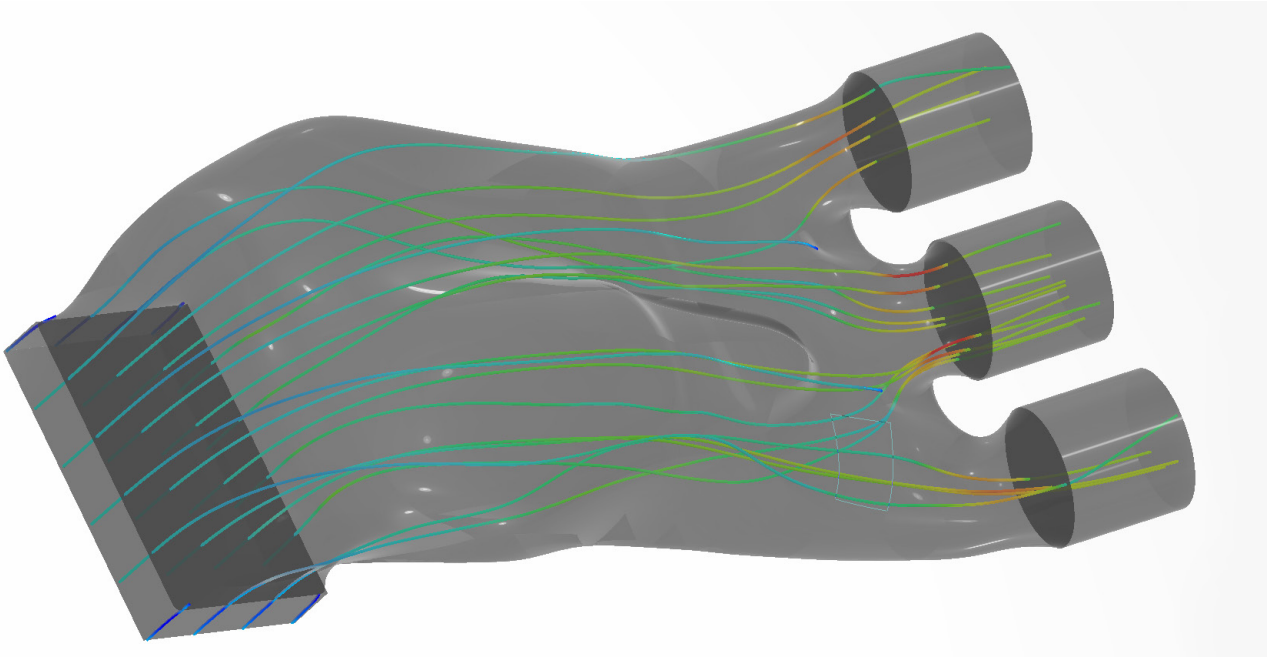
A few years into the debut of generative design software and the mainstreaming of 3D printing technology, it's now a bit hard to think about one without the other.

The symbiotic nature of the technologies has led to a wave of early use cases focused on creating organically-shaped designs aimed at consolidating or lightweighting parts that couldn't be produced with traditional manufacturing methods.

Though engineering teams have scored notable wins leveraging the dynamic duo for specific projects, generative design software has capacity to solve for other design challenges in areas such as fluid flow and design for manufacturing (DfM). With the benefits so heavily fixated on lightweighting, engineers could miss out on opportunities to leverage gen-



By coupling design and simulation together using Field-Driven Design, nTopology enables the power of implicit geometry to be unlocked in ways that were not previously possible. *Image courtesy of nTopology.*



Flow-Driven Generative Design streamlines the user experience and automates generation of flow-driven shapes, removing bottlenecks that make it cost-prohibitive to explore optimized parts.
Image courtesy of Dassault Systèmes.

erative design's full potential to unlock design freedoms and transform workflows in pursuit of highly-optimized products.

"Generative design is way bigger than what's now mostly understood as it being a design tool for additive manufacturing," says Thomas Reiher, director of generative design for MSC Apex at MSC Software, a division of Hexagon. "Both produce these organic shapes so it's a perfect way of working together. But the real promise is bringing the power of computing and the knowledge of multiple systems (such as different physics and manufacturing methods) into an automated way to get to a final design solution."

Driving Design for Manufacturing

Until now, generative design's sweet spot has been lightweighting parts such as brackets or casings for output with additive manufacturing (AM). However, the software also can be trained on lightweighting objectives for conventional manufacturing technologies such as computer numeric control milling or casting—a use case often overlooked as engineering teams get caught up in the generative-plus-AM hype.

PTC, which acquired Frustum in 2018 to fold into its Creo portfolio, and zeroed in on that flavor of generative design software primarily because of its capabilities for optimizing manufacturing processes outside of AM, including five-axis milling, as well as a range of physics, says Brian Thompson, CAD division vice president and general manager at PTC.

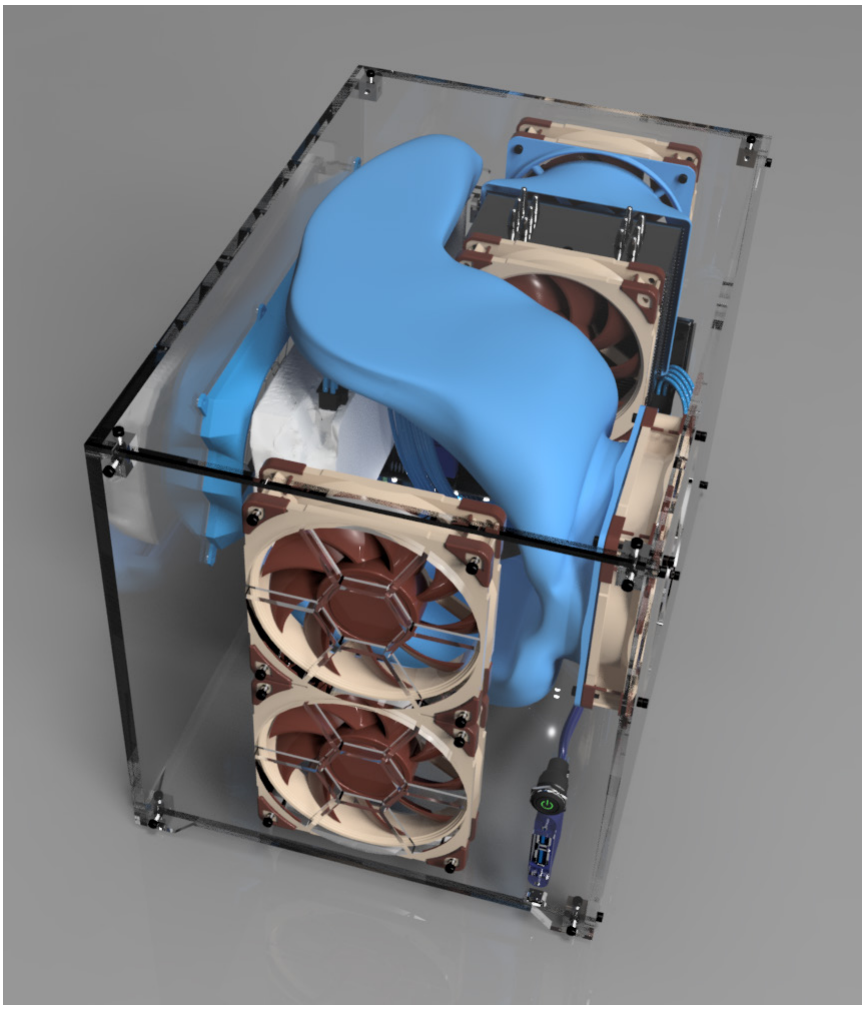
"We can accommodate manufacturing processes that require a parting line like casting or molding, we can optimize for undercuts for extrusion processes, and ensure the required clearances are there so a design can be machined," Thompson says. "Not only do we provide the optimal geometry based on structural FEA [finite element analysis] input, we provide that with feedback on manufacturing constraints."

Jacobs Engineering, a contractor on NASA's Exploration Portable Life Support System (xPLSS), used Creo Generative Design to come up with optimized and lightweighted designs for brackets, housings and face plates for the space suite, but also to rapidly explore hundreds of combinations of materials and manufacturing processes.

Using Creo 7's generative design functions, the team was able to explore a full suite of manufacturing methods and apply whichever one was best suited to any given part, says Russell Ralston, xPLSS design manager at NASA's Johnson Space Center. Not only does the generative design function allow NASA and other engineering teams to challenge basic design biases, it can serve as a way of training and evolving engineers.

"It's about building muscle memory about how to be a better engineer," says Jesse Blankenship, PTC's senior vice president of technology.

At Autodesk, the vision is to promote generative design as an exploration tool for multiple manufacturing methods and physics, according to Brian Frank, senior product line man-



Generative design was applied to fluid flow optimization, helping to create cooling ducting to optimize a tower computer. *Image courtesy of Autodesk.*

ager, generative design and simulation at Autodesk.

Take material changes as one example: Sometimes the materials used in a design are no longer available or there are recyclability concerns, and generative provides a way to explore how to optimize design changes to accommodate new material choices. Generative design can also come into play to help guide the evolution of a part from concept to volume to determine the best production processes.

"With one design definition in the generative workspace, you can explore how to optimize a design first for AM for prototyping and small production runs, then move to a subtractive or milled process as you enhance capacity, and then to casting for volume production," Frank says. "Fine-tuning the design to the manufacturing process always gives you the best results."

In the broadest sense, generative design should serve as a guide to augment engineering expertise, not replace actual engineer decision-making. The system should steer users through the process of identifying whether a lightweight design would work better as casted part or if it would require too much expensive material and work better with a molding process.

"The system should give you different ideas and guide you through the process to achieve your goal," Reiher says. "It should be able to supervise what the engineer is doing and provide hints on how to improve results and avoid producing parts that are too expensive."

Generative Design Goes for Flow

Moving forward, MSC Software is exploring how to apply these concepts to new use cases, promoting generative design for fluid flow applications such as optimizing pressure forming molds or cooling channel integration.

The company is also cooperating with an as-for-now unnamed software company to develop the next stage of generative engineering by combining structural generative design with additional engineering disciplines and workflows, Reiher says.

For example, the two companies have collaborated on the redesign of a packaging machine gripper, invoking generative capabilities to create an optimal structure, which in turn was used to drive optimization of a design for internal channel routing.

"Optimal fluid flow was achieved in the most direct and efficient way by coming up with an optimal mechanical geometry and fully automating the process," he says. "This workflow can be adapted to many other use cases such as pneumatic grippers, oil routing for clamping devices or cooling fluid through fixtures exposed to conventional machining areas of operation."

Dassault Systèmes also sees potential for flow-driven generative design. Leveraging technology like Abaqus CFD, Tosca Fluid and CATIA, Dassault has built up capabilities on the 3DEXPERIENCE platform to help engineers solve such problems as minimizing pressure drops in ducting or finding

feasible flow paths in parts associated with jet propulsion.

In lieu of traditional workflows that require a back-and-forth workflow and handoffs between siloed tools like CAD and computational fluid dynamics, Dassault's Flow-Driven Generative Design streamlines the workflow and makes flow optimization capabilities more accessible to mainstream engineers.

"Knowing the inlets and outlets and boundary conditions on each end, you can set up the problem and get an optimal flow path," says Colin Swearingen, industry process consultant at Dassault. "There are plenty of use cases out there and they're gaining more in popularity."

Autodesk recently demonstrated a new fluids solver for its Fusion 360 platform, which enables generative applications to include things like pumps and valves. With proper inlet and outlet definitions that pass through a cooling chamber, Fusion 360 can zero in on the best solution for minimizing pressure drop in a pump design.

From there, engineers can move directly into Fusion 360's manufacturing workspace to set up the optimal build, resulting in a design that ensures a smooth, continuous flow rate with virtually no turbulence, according to Stephen Hooper, vice president and general manager for Fusion 360 at Autodesk.

Making Generative More Accessible

To ensure generative design capabilities are applicable to other design problems outside of lightweighting and AM production, vendors must lean in to educate the broader audience and make functionality far more accessible to everyday engineers.

For its part, MSC Apex Generative Design focuses on streamlining the process of model setup so designers can make use of the technology. There is also a capability for setting up a "complexity" value that defines how complex a structure should get, which makes it possible to yield more straightforward shapes that lend themselves to traditional manufacturing methods such as casting.

"The designer doesn't have to set up a specific mathematical value where they need to know what is happening in the background, but can vary the designs based on [a] gut feeling on how they want the design to look or by secondary requirements like cleanability," Reiher says.

MSC Apex also includes a capability for inputting multibody simulations from tools such as MSC Adams to simplify the specification of complex loading conditions along with features for producing manufacturing-ready files.

Autodesk is also taking steps to make generative design capabilities more consumable and applicable for other use cases. To make generative output useful and deployable for downstream processes, it's integrated into the Fusion 360 platform and creates editable geometry to ensure what is produced from generative can be used in CAD or simulation processes without any extra conversion steps.

The Autodesk platform also supports a decision framework, which allows the problem to be defined once and reused for additional exploration as well as for supporting trade-off studies.

"We've spent a lot of time to make sure that from an engineering perspective, if you're leveraging generative design, it's a productivity enhancer, not a productivity detractor," Frank says. "If you want mass adoption across the industry, you have to make these things low friction for users."

Unlike other applications that bake generative capabilities into existing CAD and design packages, nTopology provides a platform that helps engineers create and define their own generative processes for new design creation.

The nTopology platform accomplishes this through capabilities like implicit modeling, which allows you to generate a design regardless of complexity; field-driven design, which ingests real-world physics data to control design parameters; and reusable workflows for building off of previous work.

nTopology's approach broadens the applicability of the technology and doesn't pigeonhole generative as the long-time partner for AM.

"The black box approach limits the innovation in the industry—it's basically saying generative design is just a feature in a CAD tool, not a shift in the way we make parts," says Bradley Rothenberg, CEO, nTopology. "The key is generative design is a new way to think through how to produce a design object. It's not replacing the way we design everything, but for certain applications, it can solve the design problem in a better way." DE

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

MORE INFO

- **Autodesk:** Autodesk.com
- **Dassault Systèmes:** 3DS.com
- **MSC Software:** MSCSoftware.com
- **nTopology:** nTopology.com
- **PTC:** PTC.com

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

Dawning of a New Era in **Data Science**

New product development now incorporates machine learning, but lack of data science experts persists.

BY RANDALL S. NEWTON

The use of data science and machine learning (ML) continue to grow in product development. Manufacturers have found new ways to gather and use the vast amounts of data now available. Not only do new products benefit from the use of ML during R&D, some even have ML added as a new feature within the product.

When we last looked at data science for product development (bit.ly/2PYbSWW), we found that the hardware and software for conducting data science work were available, but there was a lack of trained personnel. In the time since that report, the situation has not changed much. Gartner calls the situation one of using "citizen data scientists,"—people without an academic background in computer science but who have been drafted into being the local data science expert.

"It would be good to combine the two," says Seth DeLand, product marketing manager, data analytics at MathWorks. "There are many certification programs out there. An engineering-savvy person can pick up data science techniques quickly. The field is 'mathy' and similar to the way engineers think."

Yet, DeLand thinks companies with large enough R&D budgets should still hire data science experts.

"They see the big picture. With both practical and academic experience, they can understand the end-to-end lifecycle pipeline," DeLand adds.

Data Science and Autonomous Vehicles

Autonomous vehicle (AV) R&D relies on data science as it moves closer to the dream of truly driverless vehicles. AVs are also a use case where engineers need the insights of data science beyond development.

"If there is uncertainty around the vehicle, the related data must be analyzed," says Leslie Nooteboom, chief product officer at Humanising Autonomy, an artificial intelligence (AI) R&D firm specializing in the interaction of people and machines. "In our models, we don't simply provide a prediction of what people think is happening around the car. We also provide an accurate prediction of what will happen."

Humanising Autonomy creates intelligent software that embeds into the sensors and the main "brain" of an AV. The software enables a pipeline for learning from real-world

Researchers developed a supervised machine learning model as a proof of concept. Despite having little previous experience with ML, in just three weeks BMW completed a working ECU prototype capable of detecting oversteering with over 98% accuracy. *Image courtesy of MathWorks via BMW.*

NVIDIA is investing in various data science initiatives for product development, including robotics. Training and testing AI-based robots such as R.Eva, shown here, require physics-accurate simulated environments. *Image courtesy of NVIDIA.*

deployments. Data is analyzed on the vehicle—an example of edge computing—and from a central cloud-based location.

Nooteboom says this allows for real-time information informing decisions, and an overall data analytics model for the AVs based on continuous learning that comes from outside the vehicle.

In real-time operation inside the vehicle, the software from Humanising Autonomy divides unexpected external behavior into four categories: True Positive, False Positive, True Negative and False Negative.

"These are the situations where the software did not function as it should. This is the data required for data model performance," Nooteboom says. The results update the vehicle's deep learning decision process, and add to the knowledge base of all other vehicles and new vehicles that are not yet built.

A Challenge to the Business Model

This bifurcated use of data within and outside the vehicle raises an important business model issue. Automotive manufacturing is based on the purchase as a final transaction. Traditionally, there is no added value on the part of the manufacturer beyond supporting its warranty. AVs require near-constant updates of their deep learning model. Either the manufacturer will host the continuously updating model or they must assign it to a third party.

"The old model is 'ship and forget,'" says Nooteboom. To succeed with AVs, automotive companies must become more like software companies, and offer more of a subscription model approach to sales and customer relations.

The autonomous vehicle AI data model must be able to cope with unforeseen circumstances. Nooteboom tells the story of a client getting unusual readings that the AI could not interpret, so it displayed them as "flying people without any body movement."

The development team and the vendor figured out the data was from people using electronic scooters in traffic, a class of behavior that was previously unaccounted.

"So we created a new class of object, a mobility class that behaves differently from bicycles or walking," Nooteboom explains.

Creating a New Product Feature

Data science and ML are changing product development in two ways, says DeLand. The first is use of real-world data to inform product design and engineering. The second is the integration of ML into products, which makes the ML model a new product feature.

DeLand cites a new initiative at Ford as an example of the first use. They are logging data from vehicles driving in the real world, and uploading it to computing clusters for analysis.

"To us, this is traditional data analysis," DeLand notes. In this use case, Ford notes how equipment is used, and they use the data for simulations to see how a component behaves.

For the second change—integrating ML into products—DeLand cites use cases from two more automotive companies, BMW and Mahindra. BMW is using a ML model to understand when a vehicle is in an oversteer/drift situation.

"There are many variables to determine traction," DeLand notes, "so they hired professional drivers to do drifts."

Based on the accumulated data, BMW not only tested various drift scenarios in simulation, but engineers created a ML model that predicts oversteer, and made it part of an electronic control unit (ECU).

Mahindra has created a ML model to estimate road conditions. The model assesses vehicle data in real time and makes adjustments. An example would be a truck that has to leave the interstate highway and drive on a dirt road.

DeLand says MathWorks has invested in software to connect to data sources, which is often not found within the computer running MathWorks software.

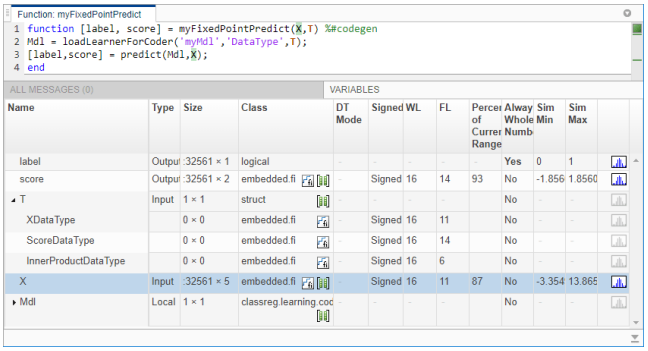
"Event data is the key," DeLand says. "These repositories of in-field data are often huge; petabytes of real-world data."

An engineer doesn't care about all the data, but seeks something specific.

"We help users understand how to write expressions to study all their data and get back the subset they need," DeLand explains. "The analyses are complex. Getting only the subset they need is essential to keeping the compute manageable."

But ML principles come out of university math and computer science departments, not engineering schools.

"So we build apps for training machine learning models," says DeLand. MathWorks often recommends best practices and offers "guide rails" to their users to help apply ML to product development.



MATLAB has tools for converting ML models into lower-level C/C++ code to run in products with embedded processors. *Image courtesy of MathWorks.*

Simulation and Data Science

Simulation makes large data repositories available for product development teams. The rise of real-world data and ML results makes for a second category of data. DeLand of MathWorks says the new way to think about simulation is, "data science informs simulation, and simulation informs data science."

MathWorks sees more customers taking time to extract "interesting" data from on-board machine learning apps, which they then use in a simulation.

"They are simulating on real-world data as part of the design process," says DeLand. This is more than testing correct behavior, but is a simulation of what happens when something goes wrong.

"You can build failure prediction into the model," he says. This cutting-edge application of real-world data is especially valuable in situations where failure data is either lacking or not gathered because it is too expensive, as in jet engine design.

Keeping Hardware Up to Data

Computer vendors were quick to provide workstations for data science as soon as NVIDIA announced its Data Science Workstation specification in 2019.

"We see machine learning and deep learning impacting every industry, not just product development," says Matt Allard, an industry strategist for Dell Technologies. "We break down product design into distinct phases of design, validation and operations. We see artificial intelligence, machine learning and deep learning applied across all phases."

Dell is also noticing use of data science in manufacturing operations.

"Manufacturing lines are increasingly rigged with IT devices generating piles of process control data," Allard says. "Pure data science can be useful there to draw inferences from processes."

This data is unstructured, so it needs AI to "tease out from the noisy data the information needed," he says. "This requires heavy compute platforms."

"This truly is the golden era of AI, the confluence of affordable hardware at every level," adds Kyle Harper, data science workstation strategist for Dell Technologies. "The economics make sense for both the hardware and the algorithms. They were once only theoretical but are now practical."

When NVIDIA defined a workstation-class data science computing platform, it brought a new level of democratization for the use of data science in product development. NVIDIA continues to support data science with its hardware and software. There is new work in embedding predictive techniques into products, notes Scott McClellan, senior director of the data science product group at NVIDIA.

"Engineering has been data-driven for a long time," McClellan says. "What is new is applying more probabilistic techniques, instead of just rule-based or deterministic techniques."

The difference between R&D testing and real-world performance is huge.

"It requires a rigorous end-to-end lifecycle regarding training, data sets and the models used for training," adds McClellan, who notes that NVIDIA is seeing a rise in a three-step approach: data management; experiment management and model management. 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

- **Dell Technologies:** DellTechnologies.com
- **Humanising Anatomy:** HumanisingAutonomy.com
- **MathWorks:** MathWorks.com
- **NVIDIA:** NVIDIA.com

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

A New Way to View and Fix the World

When your experts and technicians cannot travel, AR/VR applications could be their eyes and ears.

During the height of the COVID shutdown last year, the use of remote experts—virtual expert visits enabled by AR/VR technologies—emerged as a solution to address the shortage of technical experts due to travel restrictions. In a March 2020 report titled "Transforming Frontline Operations with Augmented Reality Technology," the research firm LNS wrote, "AR enables a variety of high-value use cases such as remote expert access, digital work instructions, and in-context training that not only contribute to operational performance improvement, but also directly help to address the workforce skills gap challenges that threaten to hold back manufacturing and other industrial sectors."

Thomas Unterluggauer, Creative Manager CGI, KIA Design Center Europe, using Varjo's XR device to perform automotive design review. *Image courtesy of Varjo.*

Remote Viewing

Epson, a household name in the printer business, has also entered the AR/VR market. In 2019, it launched the Epson Moverio smart glasses with the AR software Moverio Assist. The company probably didn't anticipate how the package might find new uses during the pandemic a year later.

Targeting the field technicians, the company wrote, "by 'seeing what the field technician sees' in real time, remote experts can provide the appropriate audio or text instructions, PDF service manuals or tutorial video links to help expedite repairs."

AR-powered applications like Moverio Assist let the expert remotely guide a field technician with real-time instructions and advice, allowing them to render services without travel. The use case is particularly helpful for engineering and manufacturing, where repair and assembly operations often involve intimidating knowledge of the assemblies and access to 3D CAD documents.

Lightweight 3D model viewers, a regular feature of Product Data Management (PDM) and Product Lifecycle Management (PLM) solutions, are also gradually moving toward AR/VR. In 2019, Terex, a U.S. manufacturer of drilling machines and construction equipment, partnered with the 3D collaboration software developer Vertex to improve collaboration with its customers.

"We've given the ability to view and interact with 3D models to a more diverse group of users within our customer base to satisfy their needs for design reviews," said Ryan Kloos, Sales Application Supervisor, Terex. "By providing more detailed information for customers to review, that minimizes confusion and rework. We've found that with Vertex, the customer experience has vastly improved and we can accelerate our cycles."

These use cases exemplify how engineering data, maintained as detailed CAD models, are now finding new uses among the frontline technicians with limited exposure to CAD. The use of AR/VR-powered remote applications have been gradually replacing the paper manuals and PDF instructions, but the pandemic appears to have accelerated the shift. The trend is of interest to software developers like PTC, Autodesk, Dassault Systèmes and Siemens, which offers CAD and PLM products.

Varjo's latest generation hardware XR3 and VR3 requires NVIDIA RTX GPUs to run. For software developing interactive VR content, Dell offers VR-ready workstations in its Dell Precision product line featuring NVIDIA RTX GPUs. VR-ready products are configured to ensure optimal VR experience with low latency, high refresh rate and high memory.

Advanced PRODUCT DEVELOPMENT Resource Center
In Partnership with DELL NVIDIA

For the full version of this article and more information about the Advanced Product Development Resource Center, visit APDRC.com.

Additive Manufacturing 2.0: Building a Resilient, Diverse, Secure Supply Chain

A new executive order and cybersecurity concerns shine light on the state of 3D printing.

BY JIM ROMEO

In February 2021, President Biden issued an executive order (bit.ly/3dsm1U5) to specifically address United States supply chains, stating:

"More resilient supply chains are secure and diverse—facilitating greater domestic production, a range of supply, built-in redundancies, adequate stockpiles, safe and secure digital networks, and a world-class American manufacturing base and workforce."

This is in response to manufacturing supply chain snags due to the pandemic. Suppliers and their workers, in many cases, had been unable to supply according to demand signals due to multiple factors.

Such factors included everything from the safe presence of workers in the workspace, to the unavailability of supplies, and a sluggish—if not halted—transportation pipeline that would allow parts, commodities and materials to be transported.

Self-Sufficiency in a "Make it Yourself" Supply Chain

3D printing and additive manufacturing (AM) aren't what they once were—they're getting better every year. 3D printers are fast, quite accurate and can accommodate feed-

With 3D printing and AM technique advances, there's a newfound self-sufficiency for manufacturers to fabricate parts organically without relying on a tier 1, 2 or 3 supplier—who may face challenges with their own labor, transportation and material availability during the pandemic. *Images courtesy of Desktop Metal.*

This clutch plate was fabricated using 3D printing and additive manufacturing techniques. It exemplifies the detail and complexity or direct parts that may be fabricated in lieu of relying exclusively on a supplier to fabricate the same.

stocks with materials and different composites that possess unique properties for finished products that you might not think possible to be fabricated from a 3D printer. With a high-quality 3D printer and reliable materials, you can make parts yourself.

"All companies are going to change the way that they view how they manufacture products and what their internal corporate plans are around this," says Jonah Myerberg, CTO and co-founder of Desktop Metal. "I think we saw a lot of that with this pandemic.

"When companies, even hospitals, were kind of strapped, they were putting a very tough position on how they would get spare parts or converters, or how they would remain flexible when they had certain pieces of equipment and other pieces of equipment that didn't fit the pieces of equipment. And they were able to very quickly create parts that they needed either themselves or with local 3D printing suppliers," he says.

The self-sufficiency that fabrication via 3D printing affords doesn't just come in handy during the pandemic. It's also on the brink of becoming a major strategic advantage in helping manufacturers be more competitive.

"Advanced technology such as 3D printing, robotics, advanced machine tools, artificial intelligence, IoT and new software and sensors are all key technologies to expanding manufacturing in the U.S. Through leveraging technology, companies can extract labor costs and improve efficiency and productivity," says Rosemary Coates, founder and executive director of the Reshoring Institute.

"In this way, factories in the U.S. are again competitive with low-cost countries," Coates says. "Most executives will consider cost as a first step in making manufacturing and sourcing location decisions, but the pandemic has introduced risk in global supply chains. Now executive decisions are based on cost and risk. Executives are thinking more strategically about multiple manufacturing and sourcing locations."

With a challenged supply chain, 3D printing speed and accuracy, as well as its ability to print from metal and composite feedstocks, translate into new viable possibilities to produce finished goods and deliver them to market despite the most austere circumstances.

Douglas Krone is the CEO of Dynamism Inc., a company that focuses on 3D printing advisory, hardware, software and training. Krone says that building 3D printing capacity will benefit manufacturers in many ways. Not only can building up printing capacity alleviate some of the dependence on a downstream supply chain, but it also can help reduce cost of goods.

"By identifying components within the supply chain that can be produced in-house using 3D printing, companies cut lead times, overstock and the reliance on third-party outsourcing for hard-to-find or obsolete components," says Krone. "When the specific components cannot be moved to 3D printing, sometimes the tooling used for manufacturing those components can be. That also saves on speed and expense of 'tooling costs' for manufacturing. So, there are two separate points of significant added value that come from 3D printing."

Brent Stucker is a distinguished engineer in additive manufacturing at Ansys. He points out the added advantage of using simulation and modeling in tandem with AM to arrive at solutions using iterative processes. AM, given its fast and flexible features, make it an ideal complement to simulating designs to arrive at a better part solution. This was not readily available in the past.

"The ability to produce components directly from digital data is a huge benefit to companies becoming more self-sufficient," says Stucker. "This is especially true if simulation is used to validate the digital design, material choices and manufacturing plan prior to production.

"The value of a holistic digital supply chain is that it enables low-quantity manufacturing, rapid product changes and the ability to shift production between any location that has capacity to produce just by sending digital information," he adds. "As a result, digital supply chains are more resilient to disruptions than non-digital supply chains."

Digital Information and Intellectual Property

A unique attribute of 3D printing is the capability to digitally scan an object and reverse engineer it, digitally, with relative ease. This poses a problem that hasn't shifted to the forefront in a discussion regarding the benefit of 3D printing: Do 3D printing capabilities, now more prevalent than ever, make a designed and finished good more vulnerable to copying? Can the intellectual property of a design be more easily hijacked with the ease and flexibility of AM?

Companies have used reverse engineering for a long time. Fabricated parts, objects and forms were always vulnerable to being copied and produced, even though the digital details and plans for such a form may be proprietary. The biggest change is that now, it's easier.

"I think we've always had a problem with counterfeiting," says Myerberg. "We've always had problems and challenges with authenticity. And if you look at counterfeit product that comes into the country, it's super fascinating. It's an amazing case study to look at."

Myerberg recounts a scenario when he worked for Bose, an audio speaker and sound accessory manufacturer. "Counterfeit wave radios would come into the country and we would deconstruct the wave radio and pull the plastic parts apart," he says.

And we would say, 'these are plastic components that we didn't make.' We didn't injection mold this. But there were details in that plastic component that only existed in the authentic components that Bose did make."

As Myerberg explains, companies such as Bose are gathering competitive intelligence from a like-kind product that had been copied. But the products were copied without the intrinsic quality organizations instilled in their own product lines.

"There were errors," he says. "There were defects in the part that existed in the tools that Bose owned that a company in China duplicated exactly when they scanned it. They built the part exactly to the way that they saw it. And there were knit lines and parting lines that had no functionality whatsoever, but they were just copied."

Myerberg says this has always been a problem of counterfeiting parts.

"3D printing allows people to scan and reproduce faster,"

Myerberg notes. "But I think that what we're going to start to see are more powerful tools to protect digital data, because one thing that additive manufacturing does, is it bridges that gap between the digital world, which may be the scanned files that you create in the physical world, ... the actual product. And it makes it a whole lot easier."

Coates says the biggest issues in intellectual property (IP) protection stem from China.

"Your Chinese factory and suppliers are going to remember how to produce your product long after you are gone and will most likely continue to do so," Coates says. "They know who your suppliers are, they have your drawings and your molds, they have learned how to make a quality product, and they will most likely manufacture it and sell it on the world market.

"If you have not registered your trademark in China or any foreign country where you manufacture, they may even use your brand name and logo," Coates adds. "To protect your IP, you need to plan well in advance of leaving, and seek the help of an experienced consultant or attorney."

Ansys' Stucker advises that IP protection requires carefully considered and broadly followed security protocols within the supply chain.

"Other digitally-driven industries such as film production, book publishing [and] espionage agencies, have learned to protect their data until the time when they want to release it," he says. "Digitally-enabled manufacturing needs to use secure methods of storage and transfer of information to help ensure intellectual property protection. Unprotected email, chats and file-sharing services are potential security breach locations. But by appropriate use of widely available secure transfer and storage protocols, a digital supply chain can be flexible and resilient."

Though 3D printing can be a boon to self-sufficiency and a boost to the extended supply chain, it does require cybersecurity measures to protect access and capture of digital assets. Today, there's ample authentication and detection, but cybersecurity is always an area that remains vulnerable.

When one risk is crossed off, it seems another risk opens up. Thus, digital engineering, especially in the age of 3D printing, must be accompanied by a thought-out cybersecurity policy and plan that specifically addresses the risk of intellectual property, digital files and assets, and their vulnerability in a globally competitive manufacturing environment.

Supply Chain-Ready 3D Printing

The very prevalence of 3D printing is in the earlier stages of an industrial revolution within an existing revolution, where shortcuts, cost-cutting and useful hacks are being employed to adequately compete; yet things changed with the arrival of a global pandemic.

The pandemic has become a force to find function for different technologies. It helps bring about a better use of technology to overcome obstacles and face challenges. 3D printing is such a technology that has flexed its muscle in bringing solutions to supply chains.

"So this AM 2.0, which we call it, is the next generation of AM," says Myerberg. "It's bringing 3D printing into the mass production with Industry 4.0 and digital factories of the future. That requires flexible manufacturing processes, like 3D printing. So that's just going to pull the development and expand the development.

"High-quality metal powder production is popping up all over the globe," Myerberg adds. "And that's allowing mass kind of distribution of AM machines around the globe as well. So you can enable this kind of file transfer that you're describing, and you're going to have 3D printers massively distributed everywhere. So manufacturing is evolving quickly, and it's really a great opportunity for everybody."

This has happened against a backdrop of a domestic manufacturing supply chain whose resiliency has been tested. 3D printing syncs well with President Biden's overarching objective in issuing an executive order that aims to make supply chains resilient, diverse and secure. DE

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

MORE INFO

- **Ansys:** Ansys.com
- **Desktop Metal:** DesktopMetal.com
- **Dynamism:** Dynamism.com
- **Reshoring Institute:** ReshoringInstitute.org

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

Digital Twin Bridges Design and Manufacturing

Twin technology can aid product designers in pulling out vital information from both domains to improve development and production.

BY TOM KEVAN

A digital twin, by definition, provides a comprehensive picture of an asset or product, documenting its state as it moves through the various phases of its lifecycle. If the system works properly, all lifecycle stages contribute valuable insights. There are, however, exceptions.

A synergy exists between design and manufacturing that promises significant benefits for product developers, making this combination of forces worthy of closer inspection. Digital twin technology can help product designers extract key insights from the interdependencies between the two domains. This, in turn, allows the engineers to perfect their designs early in the development process, reduce costs and shorten the time required to introduce new products (Fig. 1).

A powerful mechanism that contributes to this process is the feedback loop that links the design and manufacturing worlds. Leveraging industrial internet of things (IIoT) data, developers can work across engineering domains, continuously refine and enhance their designs, and respond to increased product complexity (Fig. 2).

Touch Points and Catalysts

Getting full value from a digital twin, therefore, can be about making the right connections between design and manufacturing. The benefits of this union stem from recognizing the interdependencies between the two worlds and understand-

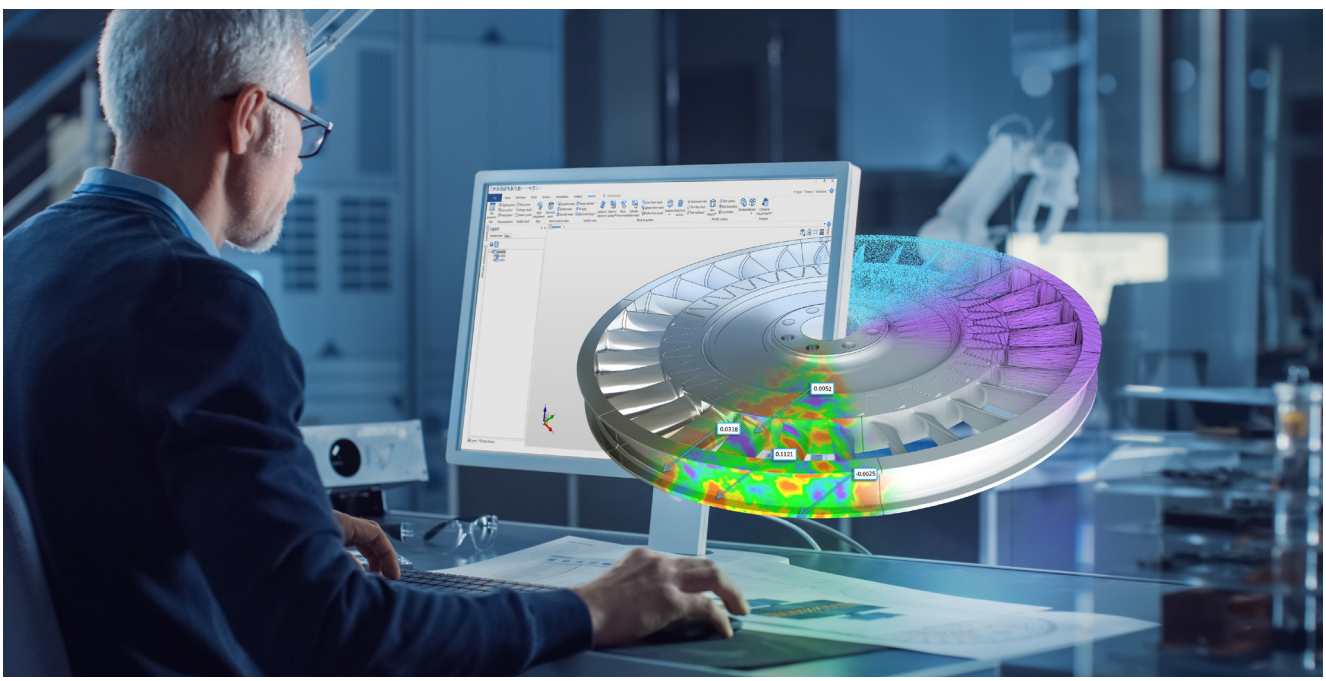


Fig. 1: By combining design and manufacturability insights gleaned from digital twins, product developers can avoid delays and costly modifications when the product goes into production. *Image courtesy of Hexagon.*

ing how choices and trade-offs in one domain affect the other.

"Product designers make many choices during product development, some of which are driven by product requirements, but many of which are arbitrary—just based on the designer's preferences," says Jonathan Scott, chief architect at Razorleaf.

"For each of those arbitrary decisions, if valuable information exists to influence the engineer's decisions—say from manufacturing simulation—the design can be enhanced based on that data. Information from the digital process twin can also be used to provide that added data to the designer at the right time—when they are making key decisions and moving the product design forward," he adds.

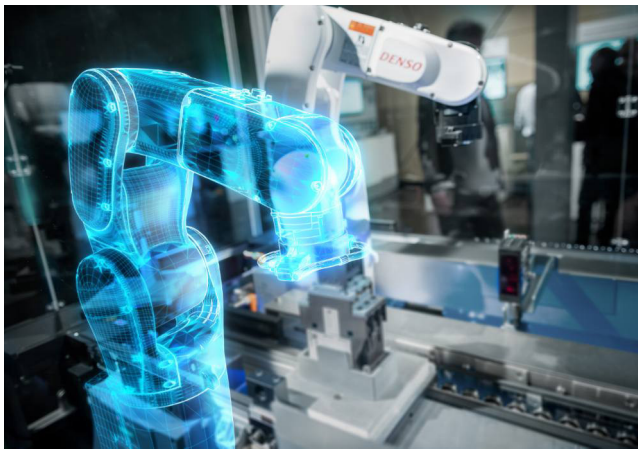


Fig. 2: Closed-loop digital twin technology aims to feed operational data back to design and automation engineers, creating an opportunity to continuously optimize product design and production activities in a feedback-enabled decision-making process.
Image courtesy of Siemens Digital Industries Software.

One such example is when a development team adjusts material thickness to achieve a particular appearance or to reduce weight. In manufacturing, however, these same choices can cause problems in assembly or as material moves on conveyorized systems. The ability to quantify the impact of downtime and related defects can provide valuable feedback to the product design.

Design teams can extract these insights through the analysis and simulation of an array of manufacturing processes in the design environment—processes that range from component machining and sheet metal forming to injection mold filling.

In another example—this time from the consumer goods sector—marketers may try to use unusual bottle and container shapes to differentiate their products. Sometimes the unusual shapes can pose real problems for manufacturing.

"Being able to correlate design characteristics with assembly fit characteristics can lead to a design that is both marketable and manufacturable," says John Oskin, president of Sage Clarity Solutions.

A Window on Manufacturing at Scale

The nexus between design and manufacturing is particularly significant when considered in the context of manufacturing at scale, where the goal isn't to make one part right the first time, but to make many well.

In these situations, design engineers must account for small changes on the factory floor that are difficult, if not impossible, to replicate. Although small, these variations can greatly affect a design's effectiveness.

"At scale, quality issues can arise from environmental changes or tools simply wearing, leading to statistical deviances in manufacturing processes," says Keith Perrin, industry director, manufacturing intelligence division, at Hexagon. "Somehow, we must capture these changes and feed them back into the design process. Manufacturers that can digitize the real world and compare it to the digital world have a unique advantage, particularly in large-volume production and assembly."

Broad Application of Manufacturability

A closer look at the impact of manufacturability issues on designs reveals that such factors spans all industries and production processes.

A subtractive process digital twin can influence product development that can be seen in any lightweighting process.

In this case, a designer identifies the spatial requirements of a part (e.g., envelopes and keep-out zones) as well as interface points (e.g., connections and joints) and then explores how to efficiently remove or add material to generate the lightest possible design based on the manufacturing processes available.

"Simulating the tool paths of subtractive machining gives engineers a unique capability to explore the tradespace of weight, performance and cost," says Scott.

The same kinds of benefits also can be found in additive manufacturing (AM) applications, although the touch points sometimes differ, depending on the building materials used.

The suitability of AM materials for specific use cases strongly depends on the selected manufacturing process. This requirement is true for applications that use metals, where engineers must consider building direction, surface roughness and porosity.

The link among these factors, however, is even stronger for composite 3D printing. In these cases, the toolpath drives the fiber orientation and largely determines the mechanical behavior of the part.

This can be seen in a technique adopted by Danfoss Power Solutions, a producer of hydraulic and electronic solutions for mobile off-highway equipment. The Danfoss process applies integrated computational materials engineering to create and test a lifting bracket used to transport heavy cast housings in its factories. The company uses a Markforged 3D printer and composite material for fabrication.

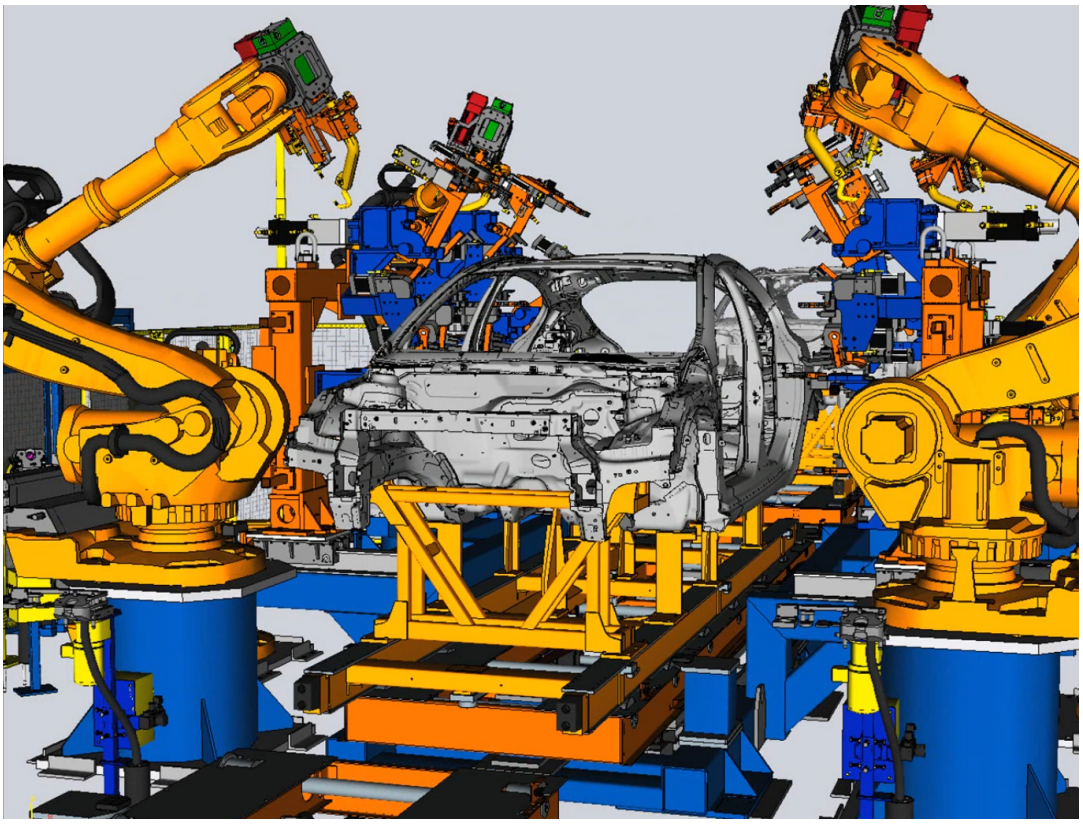


Fig. 3: Increasingly, process digital twins make manufacturing modeling and simulation information more accessible for designers, allowing them to use these complex tools in more instances to influence more designs. *Image courtesy of Siemens Digital Industries Software.*

Empowered by data extracted from these processes, engineers glean insights that enable them to create better designs.

"By embedding a multi-scale material model in Danfoss' design engineering tools that accounts for the proprietary print process, engineers can predict the performance of the part, accounting for the fiber alignment and composite properties at a given zone of the structure," says Hexagon's Perrin.

Manufacturing Tools Provide Design Info

In broadening the search for resources to enhance the design process, product development teams should not limit themselves to digital twin data provided by traditional design tools. Increasingly, process digital twins make manufacturing modeling and simulation information more accessible for designers, and this data can prove to be invaluable (Fig. 3).

"Individual tools for different types of manufacturing will help when designers apply them upfront during the design process," says Scott. "Generally speaking, the industry trend toward model-based approaches will make many types of manufacturing simulations more accessible.

"If a complex process simulation tool used only by an experienced manufacturing engineer can be encapsulated in a digital process twin with a small number of input/output parameters, designers can use these complex tools in more instances to influence more designs," Scott adds.

Toolpath simulation software is an example of this. These programs tell engineers whether the relevant machine tools will cut parts quickly and accurately.

This software offers designers multiple perspectives of the cutting process, with varying degrees of resolution. Currently, most CAD/CAM systems offer basic simulation capabilities, using plug-in modules that simply use cutter-location data. CAM users requiring higher resolution simulations, however, can turn to third-party numerical-control simulation programs, such as CGTech's VERICUT or Hexagon's NCSIMUL. These applications offer G-code simulation of all parameters used in the cutting process, to help avoid costly mistakes (Fig. 4).

Today's toolpath simulation software promises to deliver richer data to designers. One of these programs might identify how a particular strategy could minimize tool changes or reduce costly features, which improves a design's prospects for success.

Another manufacturing software type that benefits designers is sheet metal formation simulation. Companies such as Ford and Toyota use this simulation software to assess whether a part is formable, to define trimline modifications that maximize material use, and to identify opportunities to downgauge materials.

"Historically, this was the basis for concept sign-off and budget creation so that design and engineering could get started," says Perrin. "What we've found in recent years is that increasing

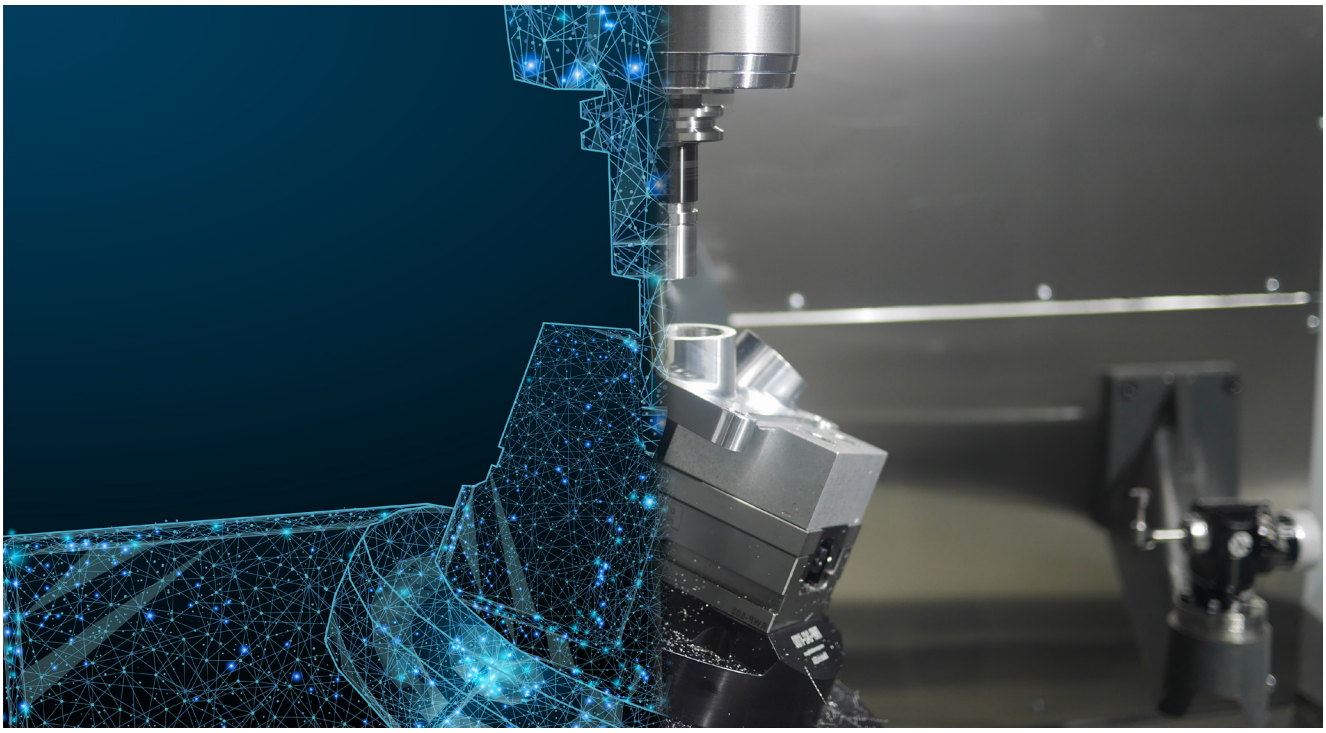


Fig. 4: By predicting the lines of code that may present problems with vibrations and surface quality, high-resolution toolpath simulation software like NCSIMUL can simulate, verify and optimize computer numeric control machining by modifying cutting strategy parameters. Aided by these insights, product development teams can avoid costly features in their designs. *Image courtesy of Hexagon.*

numbers of automakers are scrutinizing the material gauge and usage to squeeze performance into a 'weight budget.' Automakers are seeking upfront virtual manufacturing tools to better assess the cost and manufacturability of lighter materials."

Material Insights

A relatively new genre of manufacturing modeling and simulation software is emerging that examines the effect that materials have on production processes. The data generated by this software promises to shed new light on key design considerations.

"Process simulation is a key element of the development stage and makes it easier for the designer, forming specialist or advising team to identify how to use new materials, such as advanced high-strength steels, magnesium and aluminum alloys, which require new techniques and associated process plans," says Perrin. "New materials have different processes and unique behaviors that can influence styling and design."

Multi-scale material modeling, which describes the behavior of a material by bringing together data from various sources, is the software for this specialty. This software can be used for different types of simulation that can provide insights into the efficacy of a product's design and its manufacturing processes.

For example, engineers can use multi-scale material modeling tools to better use reinforced polymers and advanced composites in production by accounting for their performance as they are manufactured.

In many instances, materials aren't used to their full potential because manufacturers don't have the knowledge, resources and processes in place to efficiently and cost-effectively determine how to maximize their potential.

By embedding material-modeling technologies within simulation software, the technology can help companies achieve lightweighting goals and avoid overengineering products made with expensive materials.

Most recently, multi-scale material modeling and simulation software has proven valuable in AM applications, but AM is only one of the areas engineers can apply these technologies. The software also supports a wider array of discrete manufacturing processes, such as stamping, die, mold, numerical control, drilling, milling, turning, rolling, casting, welding, wintering, forging and composites.

PLM's Challenges

Although specialized modeling and simulation tools provide valuable insights that enable greater symbiosis between design and manufacturing, the foundation upon

which digital twin and the interaction between the two engineering domains remains the product lifecycle management (PLM) system.

That said, a few nagging questions haunt efforts to increase the use of manufacturability in the design and development processes: Are PLM platforms equipped to break down the barriers that separate the design and manufacturing data silos? Can PLM software open the door for greater symbiosis and enhance the product development efficiency?

PLM software vendors contend their technologies are up to the task.

"PLM brings together the two worlds of engineering and production, providing a common view of the data," says Kevin O'Brien, divisional general manager of the PLM segment at PTC.

This is not to say that the task of tearing down the data silos is going to be easy.

"While there are many point solutions that create and capture dimensions of the digital twin, companies are challenged to create a holistic, closed-loop digital twin," says Andy Macleod, director of strategic marketing and branding at Siemens Digital Industries Software.

"The best way to bring a closed-loop digital twin together is to invest in a seamless digital thread that can connect product development, manufacturing and real-world performance information. This requires a PLM system to manage the virtual product development and manufacturing information, then connect it with a high-volume IIoT system that collects real-time information from physical products and feeds it back to product development and manufacturing," he says.

Gathering the information, however, is only the first step. Companies then need the PLM system to manage the complexity of relationships and processes such as configuration and change management. For the more traditional PLM systems, it means enhancements and accommodations are required.

"Improved connectedness between design and manufacturing can help organizations increase shop-floor visibility," says Richard Howells, vice president of solution management for digital supply chain, SAP America.

Connectivity, however, is a many layered challenge. Some hurdles directly relate to the links between design and manufacturing.

"PLM tools are well suited to manage manufacturing planning data, but less well-equipped to manage the transactional data associated with operations on the shop floor," says Scott. "The digital process twin should be born out of an interface between PLM and MES/MOM [manufacturing execution system/manufacturing operations management] systems because it needs to come to life using live data and feedback from the shop floor. This is the data that MES and MOM systems provide through IIoT."

Other challenges, however, are general, but call for fundamental changes in the way PLM platforms handle data, focus on openness and flexibility. In response to these new demands, some software providers look to emerging technologies for solutions.

"If you look at modern, cloud-native product-development practices, most enterprises are adopting open, flexible development systems that enable them to use the best of what's available and drive the dynamic, adaptive, autonomous systems and processes they need," says Perrin.

"They're a combination of Agile services, connected through APIs that enable interoperability," Perrin adds. "When we look at the future of PLM, this is what we see, not a rigid set of dogmatic ideas around a single source of truth and old-school ideas of process management."

Advocates of this open approach contend that companies, armed with more flexible systems, will see mechanical product development that's more analogous to the continuous-development techniques used for software. They assert that the digital twin is nothing more than a software artifact that represents a physical product. So why can't companies develop digital twins with modern development ideas?

Looking at the shape and substance of PLM from the varied industry perspectives, it is clear that the technology—much like the emerging digital twin—is being reinvented seemingly on a daily basis. The few constants are change and adaptation. DE

Tom Kevan *is a freelance writer/editor specializing in engineering and communications technology. Contact him via de-editors@digitaleng.news.*

MORE INFO

- **Hexagon:** Hexagon.com
- **PTC:** PTC.com
- **Razorleaf:** Razorleaf.com
- **Sage Clarity Solutions:** SageClarity.com
- **SAP America:** SAP.com/index.html
- **Siemens Digital Industries Software:** SW.Siemens.com/en-US

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

Do you have a design engineering project you are particularly proud of?

Have you had a technology product development break-through worthy of celebration?

We want to share your story!

Celebrating Engineering Innovation Contest

Digital Engineering, in partnership with Dell and NVIDIA's Advanced Product Development Resource Center, wants to celebrate these achievements and share them with the *DE* and APDRC audiences. We will profile the top submissions so the rest of the design and simulation community can benefit from your breakthroughs.

CLICK HERE TO ENTER!

Sponsored by:

DE247 Digital Engineering

Advanced PRODUCT DEVELOPMENT Resource Center
In Partnership with DELL NVIDIA

Lenovo ThinkStation P620: **Powerful But Pricey**

We review the first workstation powered by the AMD Threadripper Pro WX CPU.

BY DAVID COHN

Regular *DE* readers may have noticed that mobile workstations have received all the attention lately.

In fact, it has been more than a year since we last reviewed any tower-based systems (see "Performance without Breaking the Bank;" bit.ly/2NyvUXo). It has been even longer since we last received a tower workstation from a major vendor (see "Lenovo ThinkStation P520: Affordable Power;" bit.ly/37Mx08J).

Fig. 1: The Lenovo ThinkStation P620.
Images courtesy of Lenovo.

So, when Lenovo asked if we wanted to review its new ThinkStation P620, the first workstation powered by the AMD Threadripper Pro WX CPU, we jumped at the opportunity.

The WX designation for the new Threadripper Pro processors is AMD's way to denote that these CPUs are designed specifically for the professional workstation market. The series consists of four processors. All four support 3200MHz DDR4 error-correcting code (ECC) memory with eight memory channels, 128 PCIe lanes and support for PCIe 4.0.

When first launched in July 2020, Lenovo was the exclusive workstation vendor to offer systems based on the new CPU, although ASUS and Gigabyte have more recently announced several motherboards that support the Threadripper Pro.

The Lenovo ThinkStation P620 we received came housed in a black aluminum tower chassis similar to other P-series workstations, measuring 6.5x17.94x17.62-in. (WxDxH) and weighing 32 lbs. Handles at the top and rear, identified with red touch points, make it easy to move the system.

The base price of $2,099 ($3,619 before discounts) gets you a ThinkStation P620 system equipped with an AMD Ryzen Threadripper Pro 3945 WX CPU, Windows 10 Pro for Workstations, 16GB of 3200MHz DDR4 ECC memory, an NVIDIA Quadro P620 graphics processing unit (GPU), a 256GB M.2 Gen 3 PCIe solid-state OPAL drive, a 1,000-watt power supply, a keyboard and a mouse, all covered by a three-year on-site warranty. But that is just the starting point.

Lenovo ThinkStation workstations feature a Flex module that offers optional storage in front-panel accessible drive

Tower Workstations Compared

	Lenovo ThinkStation P620 workstation (one 2.7GHz AMD Ryzen Threadripper Pro 3995WX 64-core CPU, NVIDIA Quadro RTX6000, 32GB RAM, 512GB SSD	**Velocity Micro ProMagix** HD60 ATX AMD workstation (one 3.5GHz AMD Ryzen 9 3950X 16-core CPU, NVIDIA Quadro RTX 4000, 32GB RAM, 1TB SSD, 2TB SAT	**Velocity Micro ProMagix HD60** one 3.6GHz Intel Core i9-9900K 8-core CPU over-clocked to 5.1GHz, NVIDIA Quadro RTX6000, 32GB RAM, 512GB SSD, 2TB SATA HD	**@Xi MTower PCIe** one 3.5GHz Intel Core i9-9920X 12-core CPU over-clocked to 4.3GHz, NVIDIA Quadro RTX5000, 32GB RAM, 512GB SSD	**Lenovo ThinkStation P520** one 4.0GHz Intel Xeon W-2125 quad-core CPU, NVIDIA Quadro P4000, 16GB RAM, 512GB SSD	**Dell Precision 7820** two 3.0GHz Intel Xeon Gold 6148 20-core CPU, NVIDIA Quadro P4000, 96GB RAM, 500GB SSD, 2TB SATA HD
Price as tested	$12,878	$4,733.00	$6,328	$6,400	$2,825	$12,582
Date tested	12/18/20	12/11/19	4/21/19	2/28/19	7/18/18	7/15/18
Operating System			Windows 10 Home	Windows 10 Home	Windows 10 Home	Windows 10 Home
SPECviewperf 13 (higher is better)						
3dsmax-05	277.80	189.84	290.23	229.42	132.29	130.53
catia-04	375.67	264.39	394.33	325.82	244.08	193.52
creo-01	385.90	246.92	388.38	311.19	201.97	125.77
energy-01	78.48	37.38	76.95	53.76	12.50	12.88
maya-04	387.76	264.91	440.31	347.30	223.91	193.32
medical-01	160.60	81.12	123.16	104.42	45.69	31.97
showcase-01	190.35	114.26	192.20	150.04	74.51	74.98
snx-02	985.51	316.07	497.17	574.11	470.02	227.67
sw-03	195.02	154.34	220.40	179.19	164.24	123.04
SPECapc SOLIDWORKS 2015 (higher is better)						
Graphics Composite	4.63	4.27	6.26	5.09	4.55	4.38
Shaded Graphics Sub-Composite	2.83	2.55	4.09	3.40	3.07	2.90
Shaded w/Edges Graphics Sub-Composite	3.47	3.37	5.03	4.26	3.79	3.73
Shaded using RealView Sub-Composite	3.34	3.08	4.64	3.83	3.43	3.27
Shaded w/Edges using RealView Sub-Composite	4.03	3.83	5.24	4.25	3.83	3.85
Shaded using RealView and Shadows Sub-Composite	3.84	3.42	5.33	4.36	3.95	3.71
Shaded with Edges using RealView and Shadows Graphics Sub-Composite	4.27	3.92	5.56	4.47	4.05	4.02
Shaded using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	12.86	11.30	17.29	13.58	11.50	10.57
Shaded with Edges using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	12.60	11.13	15.95	12.57	10.93	10.56
Wireframe Graphics Sub-Composite	3.60	3.91	4.61	3.66	3.45	3.25
CPU Composite	5.46	3.76	4.44	4.50	2.95	3.75
SPECwpc v3.0 (higher is better)						
Media and Entertainment	5.92	3.89	3.55	3.69	n/a	n/a
Product Development	4.78	3.50	3.24	3.37	n/a	n/a
Life Sciences	4.21	3.70	2.92	3.09	n/a	n/a
Financial Services	9.43	5.84	3.12	3.23	n/a	n/a
Energy	5.15	2.72	1.96	2.38	n/a	n/a
General Operations	2.14	2.45	2.51	2.36	n/a	n/a
Time						
Autodesk Render Test (in seconds, lower is better)	25.00	23.9	24.10	23.80	61.60	28.30

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

Fig. 2: The Lenovo ThinkStation P620 can support up to two NVIDIA Quadro RTX 8000 GPUs, 5212GB of DDR4 3200MHz ECC memory and up to 20TB of storage.

bays. In addition to the power button, headphone jack, a pair of USB Type-A 3.2 Gen 2 ports and a pair of USB Type-C 3.2 ports, the Flex module in the system we received housed a slim DVD-RW drive and a 15-in-1 media card reader, options that added $25 and $40, respectively.

The rear panel provides three audio ports (microphone-in, audio-out and audio-in), PS/2 keyboard and mouse ports, a pair of USB Type-A 2.0 ports, four additional USB Type-A 3.2 Gen 2 ports and a single RJ45 network jack. There is also space on the rear panel for an optional nine-pin serial port. The NVIDIA GPU in our evaluation unit provides four full-size DisplayPorts plus a miniDisplayPort.

Lots of Options

Like other ThinkStation P-series workstations, red touch points indicate where to grasp components that require no tools to remove. For example, to access the interior of the P620, you simply press and then lift a red lever, which releases an entire left side panel.

Inside, red touch points let you remove fans, drive bays, the power supply and other components. Drive bay trays accommodate either a 3.5- or 2.5-in. drives. Additionally, blind connections enable drives to connect directly to the system's backplane, which eliminate the need for cables.

The single air-cooled CPU is concealed beneath a custom-designed heat sink, which is flanked by two banks of four registered dual-inline memory module (RDIMM) sockets, each of which has its own small cooling fan. The ThinkStation P620 supports up to 512GB of RAM using eight 64GB registered RDIMMs.

Lenovo currently offers 16GB, 32GB and 64GB 3200MHz ECC memory modules priced at $267, $770 and $1,315, respectively. Our evaluation unit came with a 32GB of RAM, installed as a pair of 16GB RDIMMs. Since the base price already included one 16GB module, the extra memory added just $267.

In addition to the 4.0GHz 12-core AMD Ryzen Threadripper Pro 3945WX included in the base configuration, you can choose any of the other three CPUs in the new AMD Threadripper Pro WX series. Just be prepared for some sticker shock.

The 3.9GHz 16-core 3955WX adds $1,010, while the AMD Ryzen Threadripper Pro 3995WX in the system we received added a whopping $10,675, before discounts (see sidebar). That processor has a 2.7GHz base frequency and a maximum single-core boost speed of 4.2GHz. It features 64 cores for a total of 128 threads—which actually makes it a cost-effective alternative to dual-socket systems—and a total L3 cache of 256MB. All four Threadripper Pro WX processors have a thermal design power (TDP) rating of 280 watts.

The motherboard in the P620 provides six PCIe Gen 4 expansion slots, two X8 and four X16. Lenovo offers a choice of 11 different GPUs, ranging from the NVIDIA Quadro P620 in the base configuration to the NVIDIA Quadro GV100. Choices even include several AMD Radeon Pro graphics boards. The four X16 slots means that the ThinkStation P620 can accommodate up to four NVIDIA RTX 4000 GPUs or up to two RTX 8000 boards.

Our evaluation unit came with a single NVIDIA Quadro RTX 6000 GPU with 24GB of dedicated GDDR6 memory. With 4,608 compute unified device architecture cores, 576 Tensor cores and 72 RT cores, the 384-bit interface delivers

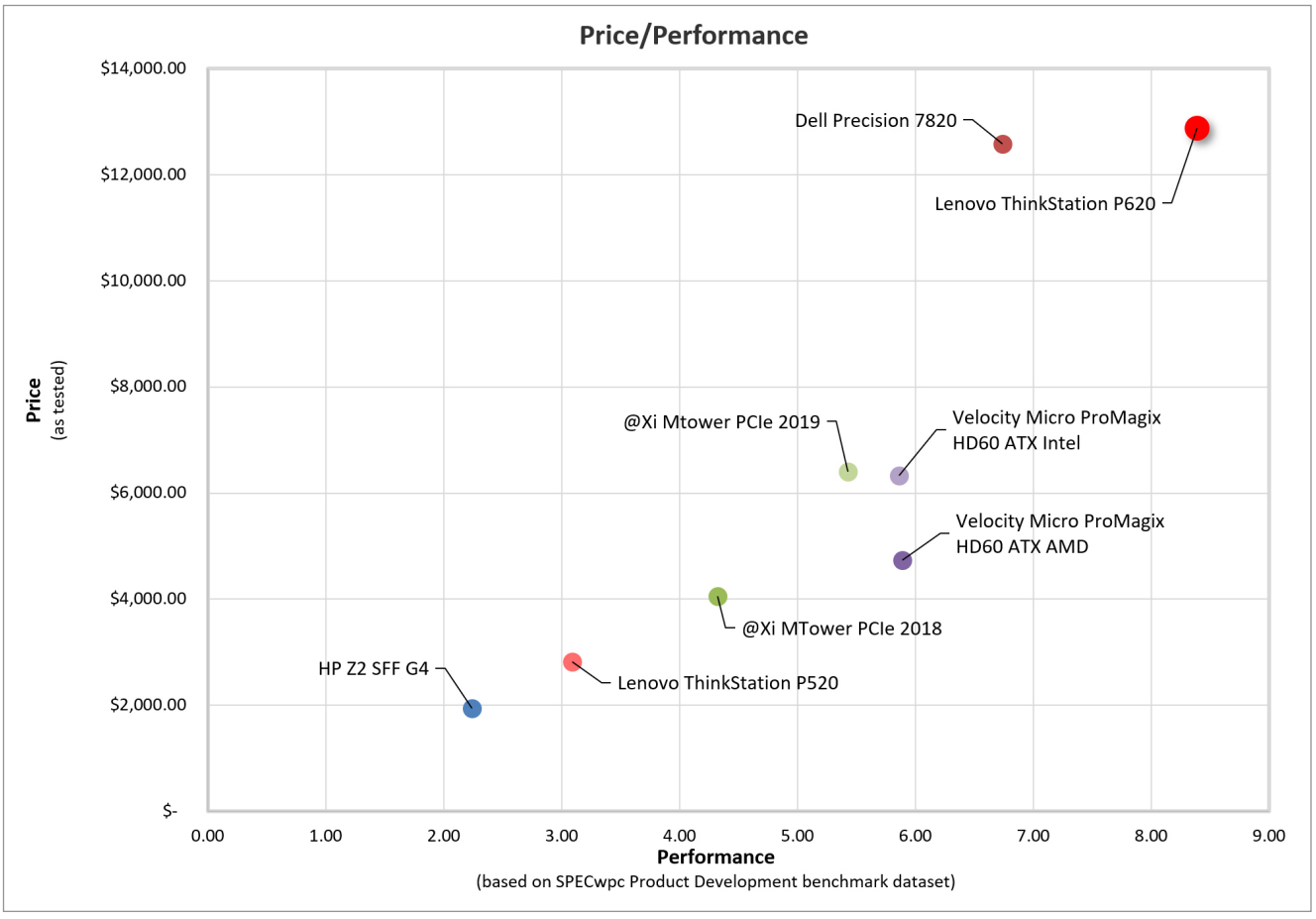


Fig. 3: Price/Performance chart based on SPECwpc Product Development benchmark dataset.

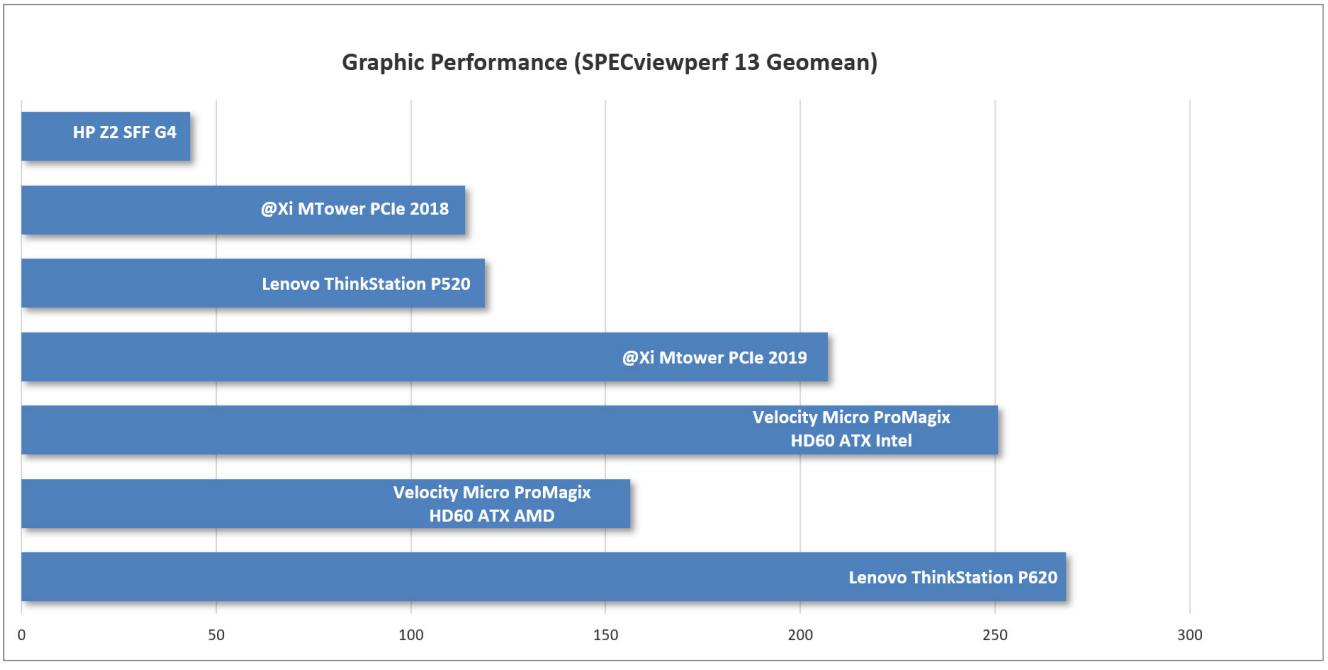


Fig. 4: Graphic Performance chart based on SPECviewperf 13 Geomean.

Playing the Numbers

We have always noted that the actual cost of a Lenovo workstation gets reduced after applying whatever discount is available at the time of purchase. We never thought much about that statement, however, until reviewing the new ThinkStation P620.

As you read through the review, if you add the additional cost for each upgraded component, the total cost of the ThinkStation P620 we reviewed comes to $22,211. But after applying a $9,333 discount, the final purchase price is $12,878. What's up with that?

It appears that Lenovo's sales department has taken buyer psychology to a new level. The discount—only available if you buy now and enter the special coupon code in the cart at checkout—makes it look like the purchaser is getting a great deal that may not be available if they wait too long.

In reality, it appears that Lenovo may be inflating the initial add-on cost, and then reducing it at the time of purchase, but only if the buyer enters the proper code. Those who neglect to enter that code—there will likely be some—pay full price. And the math itself can get very confusing.

For example, Lenovo states that the ThinkStation P620 starts at $2,099, but that is after applying a $1,520 discount. On the big-ticket items, the before and after price is even more glaring. The NVIDIA Quadro RTX 6000 GPU in the system we received added $7,195 (which on the Lenovo website appears to be a discount from a $8,220 initial price), while the top-of-the-line AMD Ryzen Threadripper Pro 3995WX CPU increased the system cost by $10,675 (rather than $12,200, which appears in a smaller font below with a line through it). Those two components alone total $17,870 before the discount code is applied.

But as a quick online search reveals, you can purchase that same graphics board from numerous vendors for around $4,300, and the AMD Threadripper Pro 3995WX has a suggested retail price of $5,489.

On the Lenovo website, when we configured our own ThinkStation P620 and added the 3995WX CPU to the base configuration, it increased the as-configured price from $3,619 to $14,294. But then the discount brought it back down to $8,291.

Although that makes it look like the customer is saving $6,003 ($4,483 on the CPU and $1,520 on the rest of the workstation), in reality you would still be paying $703 more than the manufacturer's retail price for that CPU. But even that is a bit misleading, because the base system price already includes a Threadripper Pro 3945WX, which has a retail price of $2,385. So, you would actually be paying $3,088 over the retail price of that CPU.

The situation is not the same for the GPU, however. The upgrade from the NVIDIA Quadro P620 in the base configuration to the RTX 6000 we received added $7,195 to the system cost. The discount then reduced the purchase price by $3,022, resulting in $4,173 to upgrade from the Quadro P620 to the RXT 6000. But since the base price already included the Quadro P620 (which retails for $190), you would actually be paying $4,363 for the RTX 6000, nearly matching the GPU's suggested retail price.

This numbers game is certainly confusing and requires a bit too much detective work to figure out how much each upgrade actually costs.

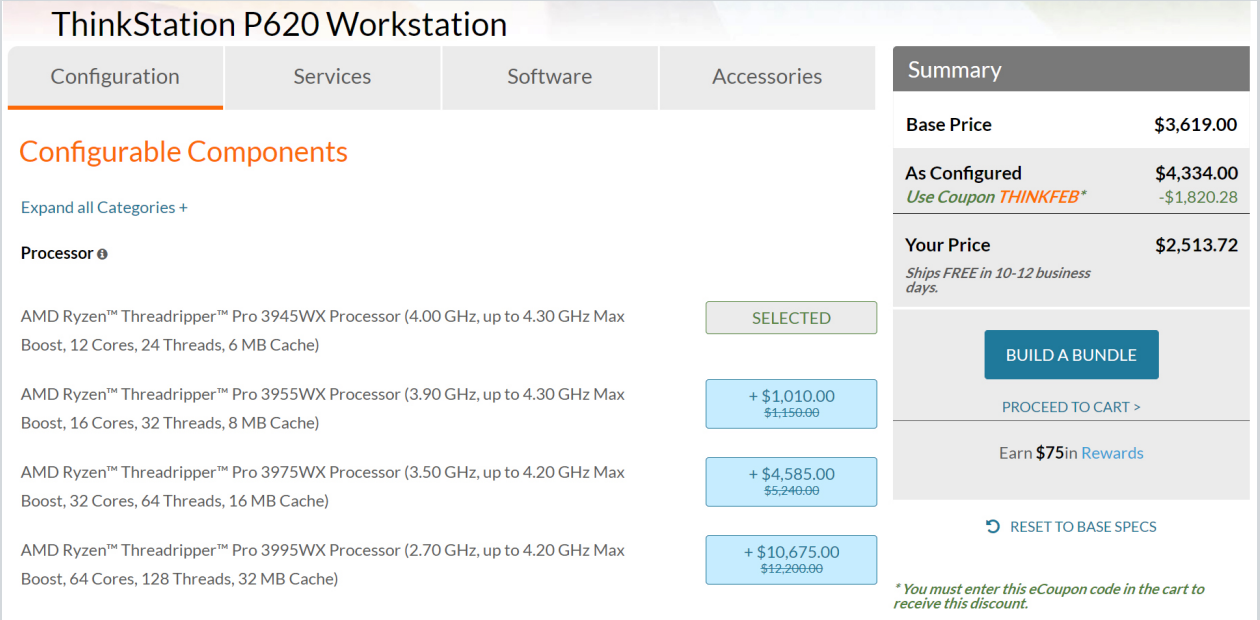


Fig. 5: Pricing on the Lenovo website can be confusing, with all costs subsequently reduced after applying a coupon code.

a bandwidth of 672 GB/second while consuming 295 watts. That board increased the cost by an additional $7,195, again before applying any discounts.

The ThinkStation P620 can be equipped with up to two M.2 drives plus up to four SATA drives. Lenovo offers a choice of solid-state OPAL drives ranging from 256GB to 2TB as well as 7200rpm SATA drives from 1TB to 4TB capacities, enabling the P620 to support up to 20TB of storage. Matched pairs of drives can also be configured in RAID arrays. Our evaluation unit came with a single Western Digital 512GB M.2 Gen 3 PCIe solid-state drive, which added $390.

Record-setting Performance

With its massive number of CPU cores and ultra-high-end GPU, we expected the Lenovo ThinkStation P620 to deliver optimum performance, and it definitely delivered. On the SPECviewperf benchmark, which focuses solely on graphic performance, the P620 equipped with an NVIDIA Quadro RTX 6000 scored at or near the top on every dataset.

Although the Intel-based system from Velocity Micro that we reviewed last year beat the Lenovo workstation on some individual tests, overall, the Lenovo ThinkStation P620 was the clear winner. Its test results were also quite good on the SPECapc SolidWorks benchmark, but here the overclocked eight-core Intel CPU in the Velocity Micro workstation gave it a distinct edge.

On the very demanding SPECwpc workstation performance benchmark, however, there was no contest. The Lenovo ThinkStation P620 delivered the top scores on the majority of the individual tests, often by a very wide margin. It also garnered the best subsystem results for all but storage.

And on our AutoCAD rendering test, where the advantage goes to systems with fast, multi-core CPUs, the ThinkStation P620 averaged 25 seconds, a mere 1.2 seconds behind the @Xi MTower PCIe, which still holds the record on this test.

Lenovo preloaded Windows 10 Professional. Ubuntu is also available and Red Hat Enterprise Linux 8.3 is supported. The system comes with a three-year warranty that covers parts and labor and includes Lenovo Premier Support with next-business day onsite labor and parts prioritization. Warranty coverage can be extended for up to five years.

The system is independent software vendor (ISV) certified for applications from companies including Adobe, Altair, Ansys, Autodesk, Avid, Bentley, Dassault Systèmes, Esri, PTC, Schlumberger, Siemens and Vectorworks. And systems are protected by Lenovo ThinkShield, a suite of security solutions, as well as Lenovo's self-healing BIOS.

As configured, the ThinkStation P620 we received priced out at $12,878 after discounts. Although its performance places it firmly at the head of the pack, its price also makes the P620 the most expensive single-socket workstation we have ever tested.

That price likely precludes this Lenovo workstation from consideration for all but the most demanding applications. But for analysis and simulation, the Lenovo ThinkStation P620 may be the perfect solution. DE

David Cohn *is the senior content 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

- **Lenovo:** Lenovo.com/thinkstation
  Lenovo ThinkStation P620
- **Price:** $12,878 as tested ($2,099 base price)
- **Size:** 6.5x17.94x17.62-in. (WxHxD) tower
- **Weight:** 32 lbs.
- **CPU:** 2.7GHz AMD Ryzen Threadripper Pro 3995WX 64-core w/256MB L3 cache
- **Memory:** 32GB DDR4 ECC at 2666MHz
- **Graphics:** NVIDIA Quadro RTX 6000 w/24GB GDDR6
- **Storage:** 512TB Western Digital M.2 Gen 3 PCIe SSD, OPAL
- **Optical:** 24X DVD+/-RW
- **Audio:** Built-in Realtek HD 5.1 with internal speaker, front panel headphone jack and rear panel line-in, line-out and microphone-in
- **Network:** Marvell AQC107 10G ethernet with one RJ45 connector
- **Ports:** six USB 3.2 Gen 2 Type-A, two USB 3.2 Gen 2 Type-C, two USB 2.0 Type-A
- **Other:** 15-in-1 media card reader
- **Keyboard:** Lenovo 104-key USB keyboard
- **Pointing Device:** Lenovo USB optical mouse
- **Standard Warranty:** Three-year parts and labor

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

Getting Better All the Time: HP ZBook Studio G7 Mobile Workstation

HP makes their lightweight mobile workstation even thinner and smaller than previous versions.

BY DAVID COHN

The HP ZBook Studio mobile workstation has been a favorite since its introduction. Earlier this year, HP revamped its entire ZBook portfolio, and we jumped at the opportunity to review the latest version of what the company claims is the "world's most powerful mobile workstation of its size."

Now in its seventh generation, the redesigned HP ZBook Studio G7 is thinner, smaller, lighter and more powerful than its predecessor, and features an improved thermal design, faster performance and increased battery life.

Based on a 10th-generation Intel processor, the HP ZBook Studio G7 comes housed in a satin-finished, aluminum unibody chassis with a polished Z-logo etched into the lid and triangular rubber strips across the bottom. These strips keep the system from sliding around on your desk and raise it slightly to aid airflow.

Fig. 1: The HP ZBook Studio G7. *Image courtesy of David Cohn.*

The new ZBook Studio G7 measures 13.94x9.31x0.66-in. and our evaluation unit weighed just 4.28 lbs., a footprint that is 22% smaller and considerably lighter than the G5. The 200-watt power supply (6x2.87x0.94-in.) is actually thicker than the laptop itself. Its 1.28-lb. weight brings the total travel weight to 5.56 lbs., which is similar to the G3, the last version we reviewed (see *DE*, September 2016; bit.ly/3rIBW5q).

Raising the lid reveals a spill-resistant 85-key backlit keyboard with 1.3-mm of travel, a bit shallow for some touch-typists. Most keys are full size, with the exception of a row of half-height function keys above the number row and small arrow keys in the lower right corner. There is no separate numeric keypad.

A fingerprint reader (a $12 option) is positioned to the lower right of the keyboard. A pair of speakers connected to a Bang & Olufsen sound system flank the keyboard, while the responsive 3.5x2.75-in. touchpad is centered below the spacebar. The touchpad lacks dedicated buttons, but it does support gestures for zooming and scrolling. You can also tap near the touchpad's lower-right corner to right-click.

Function keys enable you to control screen brightness, adjust volume, toggle keyboard backlighting and mute the built-in microphone. You can also toggle HP Sure View, an integrated privacy screen that makes the display unreadable to those around you. Several keys have their own LEDs to indicate when they are selected. One of those small function keys is actually

Mobile Workstations Compared

	HP Zbook Studio G7 15.6-in. mobile workstation (2.7GHz Intel Core i7-10850H 6-core CPU, NVIDIA Quadro RTX 3000, 32GB RAM, 1TB NVMe PCIe SSD)	**Lenovo ThinkPad P1 Gen 3** 15.6-in. mobile workstation (2.7GHz Intel Core i7-10850H 6-core CPU, NVIDIA Quadro T2000, 32GB RAM, 1TB NVMe PCIe SSD)	**MSI WS66 10TMT** 15.6-in. mobile workstation (2.4GHz Intel Core i9-10980HK 8-core CPU, NVIDIA Quadro RTX 5000, 64GB RAM, 1TB NVMe PCIe SSD)	**Eurocom Nightsky ARX 15** 15.6-in. mobile workstation (3.5GHz AMD Ryzen 9 3950X 16-core CPU, NVIDIA GeForce RTX 2070, 64GB RAM, 2x 4TB NVMe PCIe SSD)	**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)
Price as tested	$3,737	$2,795	$3,999	$8,512	$5,219	$4,355
Date tested	12/22/20	11/2/20	10/1/20	9/2/20	8/28/20	6/24/20
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	136.98	84.10	174.60	183.08	132.73	91.74
catia-05	187.62	140.38	256.00	109.70	173.75	147.96
creo-02	162.14	113.82	233.21	178.81	159.58	116.59
energy-02	26.80	17.60	40.50	19.94	29.78	17.31
maya-05	159.19	115.32	228.70	249.96	153.66	112.25
medical-02	68.57	50.96	103.67	53.19	73.08	51.11
showcase-02	63.54	44.65	95.62	101.02	74.54	43.99
snx-03	188.18	147.97	291.91	15.25	189.01	144.50
sw-04	132.38	105.23	156.49	87.13	110.18	100.81
SPECapc SolidWorks 2015 (higher is better)						
Graphics Composite	4.64	2.82	5.43	n/a	3.82	3.43
Shaded Graphics Sub-Composite	2.65	1.43	3.36	n/a	1.94	1.77
Shaded w/Edges Graphics Sub-Composite	3.61	2.04	4.25	n/a	2.88	2.67
Shaded using RealView Sub-Composite	3.34	1.92	3.92	n/a	2.62	2.42
Shaded w/Edges using RealView Sub-Composite	4.05	2.54	4.69	n/a	3.47	3.28
Shaded using RealView and Shadows Sub-Composite	3.83	2.21	4.49	n/a	3.04	2.85
Shaded with Edges using RealView and Shadows Graphics Sub-Composite	4.26	2.70	4.94	n/a	3.67	3.45
Shaded using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	12.92	7.35	15.06	n/a	9.86	7.51
Shaded with Edges using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	12.67	7.82	14.68	n/a	10.68	8.64
Wireframe Graphics Sub-Composite	3.74	3.08	4.08	n/a	3.85	3.53
CPU Composite	3.73	3.45	7.13	n/a	3.55	3.09
SPEC Workstation v3 (higher is better)						
Media and Entertainment	1.64	1.72	2.33	3.43	2.20	1.93
Product Development	1.76	1.80	2.38	1.56	2.29	2.09
Life Sciences	1.63	1.52	2.35	2.91	2.15	1.59
Financial Services	1.26	1.31	1.76	4.72	2.13	1.54
Energy	1.14	1.02	1.50	2.33	1.43	1.30
General Operations	1.53	1.96	2.07	2.15	1.92	1.96
GPU Compute	3.00	1.85	3.61	3.77	3.09	1.91
Time						
AutoCAD Render Test (in seconds, lower is better)	45.70	43.70	28.70	27.10	35.60	38.9
Battery Life (in hours:minutes, higher is better)	8:53	7:04	9:50	0:55	10:30	10:22

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

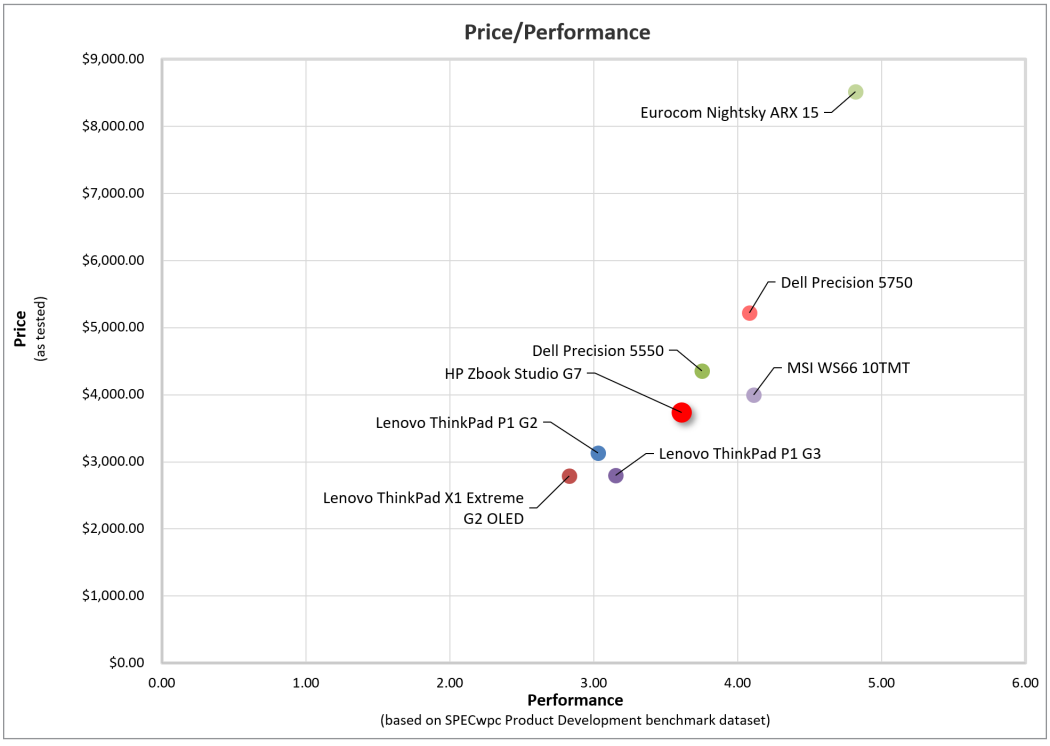


Fig. 2: Price/Performance chart based on SPECwpc Product Development benchmark dataset.

the power button, but you will seldom press it, because the computer automatically turns on when you lift the lid.

A 720p webcam is centered above the display, flanked by a pair of microphones and infrared cameras as well as an LED that glows white when the webcam is active. The 15.6-in. display appears larger, thanks to a much thinner bezel (73% thinner along the top and 52% thinner along the sides, compared to the ZBook Studio G5). Ports are at a bit of a premium in this new ZBook—it's a trend we have seen in other recent thin mobile systems. Along the right side is an SD media reader slot, a mini-DisplayPort, a pair of USB-C Thunderbolt ports, a 4.5-mm power adapter port and an LED charging indicator light. Ports along the left side consist of a microphone/headphone combo jack, a single USB 3.1 port with charging capability and a security lock slot.

Choose Your Combo

Prices for the HP ZBook Studio G7 start at $1,789 for a system based on a 2.6GHz Intel Core i5-10400H quad-core CPU, 8GB of RAM, integrated Intel UHD graphics and a 256GB M.2 solid-state drive (SSD), backed by a 1-year warranty. But that is just the starting point.

HP offers a choice of CPUs, including several six- and eight-core Intel i7 processors, as well as the 2.4GHz 8-core Intel Xeon W-10885M. There is also a choice of NVIDIA graphics boards, ranging from the Quadro T1000 to the RTX 5000.

Interestingly, rather than selecting a CPU, a graphics processing unit (GPU) and RAM, you must choose one of 14 configurations that combine a processor, graphics card and a select amount of memory (which is soldered to the motherboard).

The system we received included an Intel Core i7-10850H CPU, an NVIDIA RTX 3000 GPU and 32GB of 2666MHz RAM. That six-core Comet Lake CPU has a 2.70GHz base speed, with a maximum turbo speed of 5.1GHz and a 12MB Smart Cache as well as integrated Intel universal high-definition graphics, while attaining a thermal design power (TDP) rating of just 45 watts.

The NVIDIA virtual-reality-ready GPU includes 6GB of discrete GDDR6 memory and features 1920 compute unified device architecture cores, 30 RT cores and 240 Tensor cores. That particular graphics card has a 192-bit interface and 336GB/second bandwidth, while consuming 60 watts.

HP offers a choice of four displays. The base configuration includes a 1920x1080 LED anti-glare panel with a brightness of 400 nits. Our evaluation unit came with a much brighter (1000 nits) full high-definition panel that included HP Sure View technology, adding $169. Other choices include a 3840x2160 DreamColor display and a 3840x2160 OLED panel.

The new ZBook Studio G7 also supports just a single M.2 storage device. Choices range from the 256GB included in the base configuration to 2TB. Our system came with a 1TB PCIe NVMe TLC SSD, which added $365.

All ZBook Studio G7 systems include an Intel AX201 WiFi6 network adapter plus Bluetooth 5.0 and an HP Long Life 6-cell 83 Watt-Hour battery. That battery kept our system running for nearly 9 hours, more than 3.5 hours longer than its predecessor. The ZBook Studio G7 remained cool and nearly silent throughout our tests, thanks to new venting and cooling technologies, including a vapor chamber heat sink and advanced fan control methodologies.

Great Performance

Despite its light weight and diminutive size, the HP ZBook Studio G7 still delivers the kind of performance one would expect from a mobile workstation. On the SPECviewperf

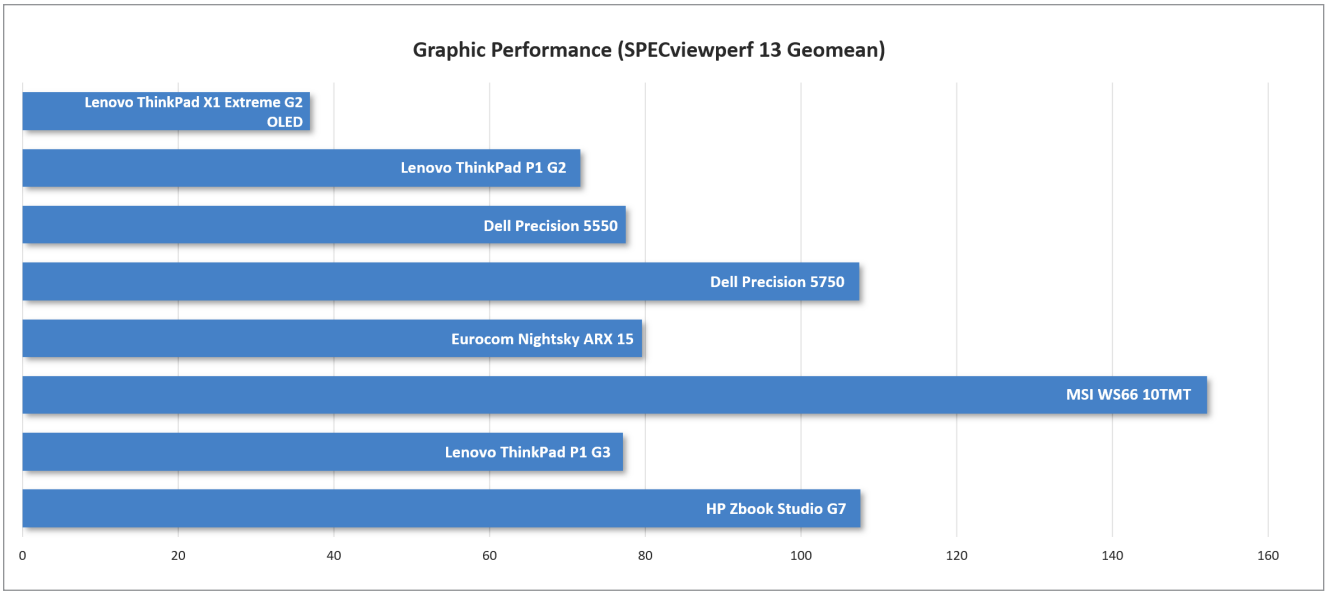


Fig. 3: Graphic Performance chart based on SPECviewperf 13 Geomean.

test, which focuses on graphics, the new ZBook Studio outperformed systems costing considerably more. The same proved true on the SPECapc for SolidWorks benchmark.

On the very demanding SPEC workstation benchmark, the ZBook Studio easily surpassed the results of the previous generation, with results on par with those of other thin, lightweight mobile workstations we have tested recently. Its 45.7-second average to complete our AutoCAD rendering was 2 seconds slower than the Lenovo ThinkPad P1 Gen 3, which was based on the identical CPU.

The HP ZBook Studio G7 came with Window 10 Pro pre-installed. FreeDOS and Ubuntu Linux are also available. Optional accessories include a USB-C mini dock ($92) and a Thunderbolt Dock ($262).

The HP ZBook Studio G7 is independent software vendor certified for a wide range of applications from Autodesk, Dassault Systèmes, PTC and Siemens. It has also passed military certification tests and other quality checks to ensure it can perform in extreme conditions. Although the standard warranty covers the system for just 1 year, our $3,737 price as tested includes $259 to extend coverage for three years.

After having tested several generations of this system, we remain impressed. The HP ZBook Studio G7 is one of the best thin, lightweight mobile workstations made today, offering a perfect combination of performance, portability and features. DE

David Cohn *is the senior content 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

- **HP:** HP.com
- **HP ZBook Studio G7 mobile workstation**

Price: $3,737 as tested ($1,789 base price)

Size: 13.94x2.87x0.69-in. (WxDxH) notebook

Weight: 4.28 lbs. (plus 1.28-lb. external 200-watt power supply)

CPU: Intel Core i7-10850H 2.7GHz (5.1 max turbo) six-core w/ 12MB cache

Memory: 32GB DDR4 2666MHz

Graphics: NVIDIA Quadro RTX 3000 w/6GB GDDR6

Display: 17.3-in. UHD (3840x2160) Dream Color

Camera: 720p plus infrared

Storage: 1TB M.2 PCIe NVMe TLC SSD

Audio: Built-in Bang & Olufsen speakers, microphone/headphone combo jack, built-in microphone array, noise cancellation

Network: Intel AX201 WiFi 6 802.11AX 2x2 and Bluetooth 5.0

Ports: Mini DisplayPort, two USB-C Thunderbolt, USB 3.1 Gen 1 with charging

Other: Fingerprint reader, SD 4.0 Media Reader slot

Keyboard: 85-key backlit spill-resistant backlit keyboard

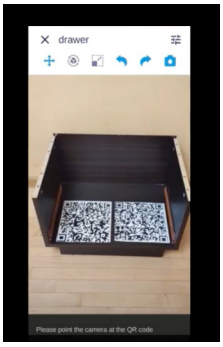
Pointing device: Touchpad

Standard warranty: 1-year parts and labor (as-tested price includes 3-year warranty)

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.



View 3D CAD Models in Mobile Augmented Reality

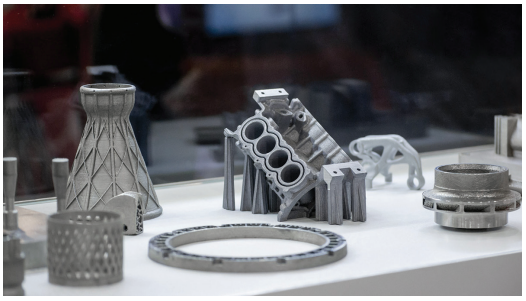
Mobile demo shows how 3D CAD models can be in a mixed reality environment.

Software developer AMC Bridge releases a CAD-based augmented reality (AR) mobile application as a tech demo. The demo links several distinct technologies: CAD; cloud storage; the Unity real-time 3D display engine; Google's Android smartphone operating system; and AR courtesy of the EasyAR software development kit from VisionStar Information Technology. The app allows users to upload a 3D model from either local or external cloud storage drawers and a lid.

MORE ➜ digitalengineering247.com/r/24983

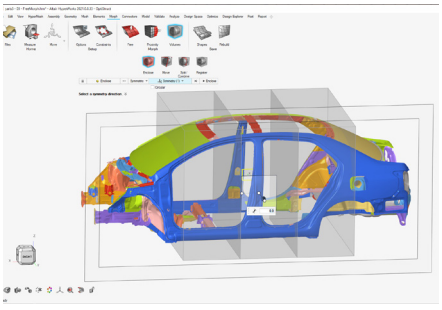
New Platform for Part Deviation Review

Riven 3D validation of new part introduction is bundled—a 3D scanner and software.



Riven part testing and validation platform can streamline part analysis as part of new product introduction (NPI) workflows by reducing iterations, validating part integrity and improving NPI collaboration. Riven says increased use of metal additive manufacturing for creating final parts is creating challenges for the NPI workflow. The Riven platform can quickly identify issues, such as deformation and warping, making it easier to solve manufacturing issues and validate new parts.

MORE ➜ digitalengineering247.com/r/24963



Simulation Toolkit for Complete Electronics Design

Altair Simulation 2021 enables users to develop complex products that use 5G.

Altair Simulation 2021 adds a new robust end-to-end electronic system design toolset. The company says the new electronic design system toolset will allow engineers to fully collaborate on "smart, connected products" for all aspects of physical, logical, thermal, electrical and mechanical design. The company notes there is expanded modeling and visualization, including workflows that support the entire topology modeling and meshing process.

MORE ➜ digitalengineering247.com/r/24938

Customer Input Drives Updates

IronCAD Mechanical 2021 add-on productivity module built on customer requests.

IronCAD Mechanical 2021 includes new features such as import/export. Export Unfolded Part has new settings options, including thickness and material settings. View Manager new features include simplification of the ability to set an export image size. The Steels tool adds an option for the replacement of Profiles equal to the one being modified. Face to DXF offers more options for settings, and adds the use of right-click selection of parallel or coplanar faces. There's also an ability to export DWG drawings for each record in a table.

MORE ➜ digitalengineering247.com/r/24917

DE247 Digital Engineering

NAFEMS

Digital Engineering and NAFEMS Americas are teaming up to present CAASE21, a one-day Online Event.

CAASE21

The Conference on Advancing Analysis & Simulation in Engineering

Online Event • June 16, 2021

Keynote: *Challenges of Fully Integrating Sensor, Vehicle ADS, and 5G Technologies to Achieve Reliable and Safe Transportation Systems*

TRACK 1: Simulation Driven Design
TRACK 2: Verification & Validation
TRACK 3: Manufacturing Processes & Additive Manufacturing
TRACK 4: Business Strategies & Challenges

Visit: Digitalengineering247.com/caase21 to view presentations from George Mason University, Rolls-Royce Corporation, Purdue University, The National Institute of Standards and Technology (NIST), The University of Texas at Austin. **REGISTER HERE!**

ROLLS ROYCE

NIST National Institute of Standards and Technology U.S. Department of Commerce

PURDUE UNIVERSITY

GEORGE MASON UNIVERSITY VIRGINIA 1957 FREEDOM AND LEARNING

THE UNIVERSITY OF TEXAS AT AUSTIN

Next-Gen Engineers

Student Competition Profile: CWRU Global Health Design Collaborative

Designing for Real-World Impact

BY JIM ROMEO

The Global Health Design Collaborative (GHDC) evolved from an initiative between social scientists and engineers working together on global health projects in Uganda. The goal is to combine medical anthropology expertise through working in local communities with the design expertise of engineers in developing solutions for global health problems.

Andrew Rollins is a professor of biomedical engineering at Case Western Reserve University (CWRU) in Cleveland, OH. We spoke to Rollins to learn more about the program.

Digital Engineering: **Can you provide an overview of the Global Design Collaborative?**

Professor Andrew Rollins: Our goal is to blend the expertise of medical anthropology in working in local communities with the design expertise of engineers in developing solutions to global health problems. The initiative is specifically working in Uganda, where Case Western Reserve has a 32-year collaboration in health research. This project is a unique blending of social science and engineering, which provides students—at CWRU and at Makerere University in Uganda—the opportunity to work together in interdisciplinary teams to address real-world problems.

GHDC's founders came together in 2014 to work on two health projects in collaboration with engineering students in Uganda. To date, eight cohorts of students have traveled with us to Uganda to visit rural health centers with the Ugandan students and get critical input from stakeholders on solutions in progress. The GHDC has grown and expanded its membership base and is now a large ongoing student design club.

Backpack designed by participants at Case Western Reserve University. For healthcare workers and others in Uganda, teams designed a comfortable, versatile backpack that accommodates their needs. *Images courtesy of CWRU.*

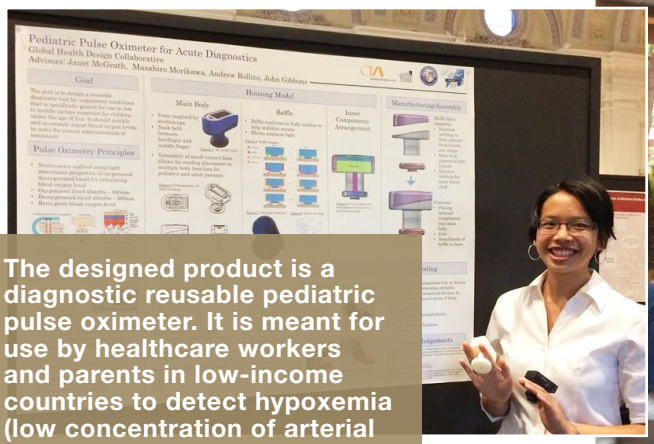
The program benefits Case Western Reserve engineering students by providing real-world design opportunities in a team setting with healthcare, engineering and anthropology mentors in the U.S. and in Uganda.

As a broader impact, this program provides collaborative team design experience to other (non-engineering) CWRU students as well as engineering students at Makerere University in Uganda (MAK), as well as building capacity in the emerging biomedical engineering (BME) program at MAK. Last year a graduate of the MAK BME undergraduate program who is doing her graduate work in BME here at CWRU joined the team to provide additional mentoring and further the collaboration with MAK.

The group has continued its substantial momentum over the last year, even under the difficult circumstances of the COVID-19 shutdown and the cancellation of travel. There are currently six active design teams, and student engagement has remained high, despite current restrictions, with many new students joining the teams.

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

Rollins: Active design projects include: A handheld pediatric pulse oximeter. This project was initiated at the request of the previous head of the global health residency program at University Hospitals. He had experienced the need for such a device to help diagnose and treat babies with pneumonia in low-resource clinics around the world.



The designed product is a diagnostic reusable pediatric pulse oximeter. It is meant for use by healthcare workers and parents in low-income countries to detect hypoxemia (low concentration of arterial oxygen supply).

The GHDC evolved from an initiative between social scientists and engineers working on global health projects in Uganda.

Two teams are working on devices to aid health outreach workers in rural Uganda, who travel to rural villages to provide healthcare and vaccinate children. These teams are working on an improved vaccine carrier and a specialized backpack to help workers manage their gear. These needs were identified in the Luweero District in Uganda, where the club conducts fieldwork in collaboration with MAK.

Single-use injectable depot medroxyprogesterone acetate (or DMPA) is a contraception option for women in Uganda. One concern identified by local partners is safe disposal of the device after use. This GHDC team is investigating the environmental effects of in-home use as well as envisioning safe disposal methods. This project was identified by the Uganda Country Office of PATH, with whom GHDC consults.

Another team is designing a small incinerator specifically for disposable sharps boxes. These safety boxes are commonly used in small clinics and by outreach workers, but small clinics rarely have access to incinerators for appropriate hazardous medical waste disposal, where needles constitute a significant portion.

The GHDC design teams have developed numerous prototypes for field testing and design iteration. The photographs show examples of prototype backpacks, vaccine carriers and pulse oximeters. Teams regularly participate in student design competitions, and win or place in several cases.

Teams are aware that designs only make a real-world impact if a product reaches the users. They, together with their MAK collaborators, are investigating pathways to product development.

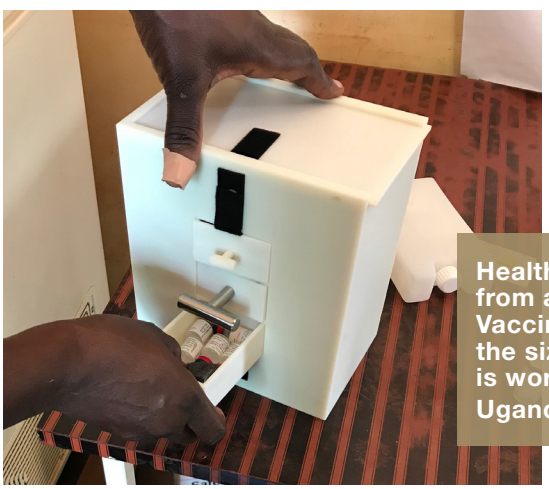
DE: **Anything else you'd like to tell us about the event that the above questions haven't given you the opportunity to express?**

Rollins: The Case Alumni Association (CAA) has been the major sponsor of GHDC activities. Institutional support has also come from the Case School of Engineering, the Department of Biomedical Engineering, the Center for International Affairs and the Social Justice Institute. DE

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

➜ MORE INFO

- **Global Health Design Collaborative:** Facebook.com/CaseGHDC



Healthcare workers in rural parts of Uganda transport vaccines from a central care facility to villages on foot or via motorcycle. Vaccines are stored in large containers to accommodate for the size and number of vials required for each trip. One team is working on an efficient, affordable vaccine carrier for rural Ugandan healthcare workers.