July/August 2021

DE247 Digital Engineering

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Design in the Fast Lane

DigitalEngineering247.com

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| DEGREES OF FREEDOM |

By Brian Albright

Trucks, Toilets and Innovation

A COUPLE OF RECENT headlines caught my eye, and although they are not directly connected, I think they are related in many ways. Together, they got me thinking a lot about how the technology we write about is being used, the ways in which innovation is applied, and how we prioritize our coverage of it. The first story comes from my home state of Ohio, where Lordstown Motors has warned that it may be teetering on the verge of collapse. The Lordstown facility was originally a GM plant, and a much vaunted one at that. When the automaker announced in 2019 that it would close the plant (in operation since 1966), it threatened the local economy and drew the attention of then-President Trump, who lambasted GM for the decision.

The plant was purchased by electric vehicle startup Lordstown Motors (with some help from GM). The company has since been accused of overstating its order book, and its share prices have plummeted.

The company's initial vehicle is set to be the Endurance, an all-electric, full-size pickup truck with a base price of around $52,000.

The second item was a story about the need for better sanitation solutions around the world. The story mentioned the Gates Foundation's Reinvent the Toilet Challenge, a decade-long project to spur creation of innovative ways to dispose of waste that do not rely on elaborate infrastructure. Author Chelsea Wald wrote a book on the topic, "Pipe Dreams: The Urgent Global Quest to Transform the Toilet," which is now on my summer reading list.

Why have these two stories been blended together in my admittedly addled brain? Because while both involve engineering innovations, the latter is targeted at creating solutions that could make an enormous difference in global health outcomes, the former involves millions in investment to create a pricey electric truck that may never actually exist. And our engineering coverage tends to lean more toward the pricey electric trucks rather than the practical (but unpleasant).

That is not to say there is no value in covering flashier projects. The importance of the Mars Rover goes beyond just the immediate thrill of landing the thing and marveling at the photos it takes. Over-priced electric vehicles will lay the groundwork for more affordable ones down the line.

My mid-year resolution, though, is that I want to make a better effort to highlight the work our readers are doing to solve important problems that pay big societal dividends. If you are working on such a project, or know of one, please feel free to send it our way via email or social media.

On a related note, check out our online coverage of how simulation and digital twin technology can help redesign our aging power grid. You can access the stories here and here.

Have a great summer.

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


SOME ENGINEERING PROJECTS WON'T MOVE AHEAD WITHOUT YOU
The AMD Radeon™ PRO W6800 GPU offers superior Hardware Raytracing performance of previous AMD professional graphics and the NVIDIA Quadro RTX 5000 in Dassault Systèmes' SOLIDWORKS® Visualize 2021. (It even has twice the dedicated RAM of the RTX 5000.)
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Source of Nvidia specifications is nvidia.com as of 01 June 2021.
Testing as of March 23, 2021 by AMD Performance Labs on a test system comprised of an AMD Ryzen™ 9 5950X with AMD Radeon™ PRO W5700 / AMD Radeon™ PRO WX 9100 / AMD Radeon™ PRO W6600 (pre-production sample) / AMD Radeon™ PRO W6800 (pre-production sample) / Nvidia® RTX 5000. Benchmark Application: Dassault Systèmes SOLIDWORKS® Visualize 2021 SP3 (time to complete, seconds) measuring rendering test time of the Camaro default angle (ProRender low sample) test. Performance may vary based on factors such as driver version and hardware configuraton. RPW-383

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Cover by Wendy DelCampo. Images: from Getty Images and courtesy of Autodesk.

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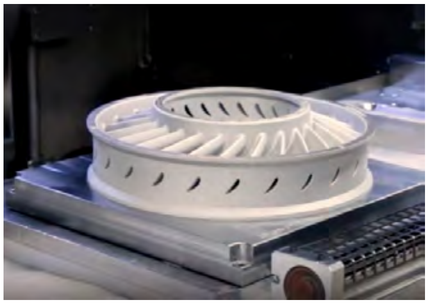

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Autonomy Accelerates

The COVID-19 pandemic has kickstarted additional autonomous vehicle testing. That, combined with **falling sensor prices**, could accelerate the advancement of autonomous driving, according to IDTechEX. Based on existing data from tests in California, IDTechEX predicts that within three years, autonomous vehicles will be performing **more safely** than the average American driver, and that **within 25 years** autonomous vehicles will be able to travel the **same annual distance** as the entire U.S. fleet without a single disengagement.

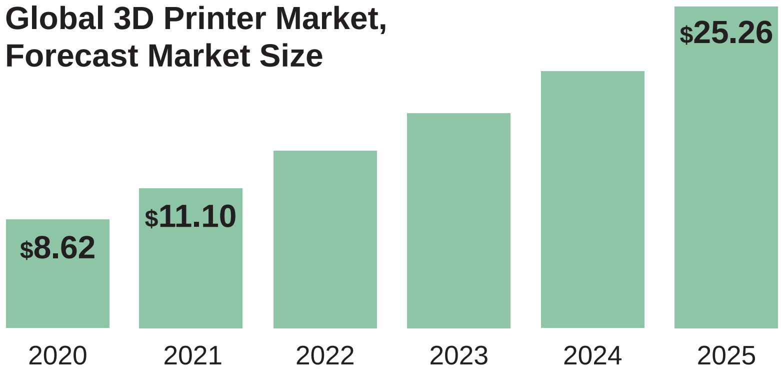
2020 American drivers average **480,000** miles between crashes. Top autonomous vehicles manage **30,000** miles between disengagements

2024 Autonomous vehicles will perform with the **same safety** as the average American

2046 Autonomous vehicles will be able to cover the same distance as the entire U.S. fleet (3 trillion miles) between disengagements

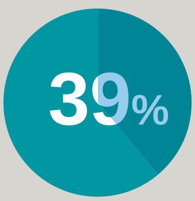
Source: IDTechEx

Global 3D Printer Market, Forecast Market Size

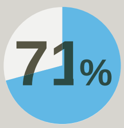


$11.1 BILLION The estimated size of the **global 3D printer market**, up from **$8.62 billion** in **2020**. The market could reach **$25.26 billion** in **2025**, largely driven by **demand** in the **automotive sector**.

Source: The Business Research Company, June 2021

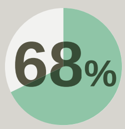


The number of **automotive manufacturers** planning to implement **augmented/virtual reality (AR/VR)** technology in the next 12 months



Executives planning to start or **fast-track** AR/VR deployments because of the COVID-19 pandemic

Planning to use AR/VR for virtual design



Source: online survey commissioned by Grid Raster, August 2020

ROAD TRIP

CAASE21 Highlights

Autonomous Vehicles, Digital Twins and Simulation-Led Design In the Spotlight at CAASE21

BY STEPHANIE SKERNIVITZ, KENNETH WONG

In June the Conference on Advancing Analysis & Simulation in Engineering (CAASE21), cohosted by *DE* and NAFEMS, went online with a live keynote, accompanied by four sessions.

CAASE21
The Conference on Advancing Analysis & Simulation in Engineering
Online Event • June 16, 2021
Co-hosted by: NAFEMS DE247 Digital Engineering

In the keynote, Professor Cing-Dao (Steve) Kan and Professor Duminda Wijesekera, both from George Mason University, discussed the challenges of integrating sensor, vehicle automated driving systems and 5G technologies to create an autonomous driving experience. A successful fusion of these elements will lead to "improving roadway throughput and reduction in greenhouse gas emission, traffic congestion, and traffic fatality and injury suffered from traffic accidents," predicted Kan and Wijesekera. However, perfecting the way the car "sees" its surroundings and makes navigation decisions is no easy feat.

Sensors and Dummies Critical to Self-Driving Cars

The vehicle's autonomous functions, such as automated parking, road sign recognitions and lane changes, are enabled by the onboard sonar, camera, radar and electronics equipment.

"This is exactly like our ears, eyes and nose," said Wijesekera. "We get all the information from these, our brain puts it together and we get a picture of what's around us." But some sensors are "sensitive to reflective light rays," making the vehicle's vision imprecise when dealing with glares, in foggy weather and on rainy days.

In standard cars, passengers sit facing the car's front view. But in an autonomous car, the configuration may be different. It suggests more safety tests need to be conducted to understand what setups are acceptable and what are not.

"Traditionally we use what is known as ATD [anthropomorphic test dummies]. But the limitation is they can only be tested in the regular seated position … and it can only address a unidirectional impact," said Kan.

For self-driving cars where passengers may lie down or turn the seat completely around to interact with other passengers, this could present a problem in safety tests. A better alternative under consideration, Kan said, is the human body model (HBM), which can address omni-directional loading, and has features that resemble joints, muscles and ligaments. As the HBM is relatively new, the test data is limited, presenting a different challenge for early adopters.

The issue with sensor-based driving is the wide range of scenarios involved, Wijesekera pointed out. "Some corner cases that deserve more attention, are electric scoopers, which have much greater agility than typical pedestrians in the path, and also children, disabled people, and various kinds of carts," he added. "So we need to train the sensors to recognize all these incidents."

Kan encouraged autonomous car developers to incorporate the human driver's behaviors in the self-driving training process. Based on accident data and diagrams, "perhaps we can recreate the scene using a drive simulator. Then we can learn from it, and feed the data back into the self-navigation system," he said.

Backbone of Simulation-Driven Design

In another track, Alexander Karl, associate fellow at Rolls-Royce, Indianapolis, discussed the need for stochastics, robust design and systems engineering to support simulation-driven design.

Karl said one of the challenges Rolls-Royce, a company of 48,000 people globally across 45 countries, is faced with at present is that in order to meet the demands of a growing, more connected society, "the power that matters must be sustainable power. Our technology will play a fundamental role in enabling the transition to a low carbon global economy." Rolls-Royce has three core businesses, according to Karl: civil (which makes up about 50% of the business); power systems (18%); and defense (20%).

Diving into simulation-driven design, Karl started with what he referred to as a "backbone" of structured hierarchical models. "These models are necessary because most of the physical simulations today cannot address all of the physics in their given timeframes," Karl explained.

The models, according to Karl, start with the SysML model, followed by the Physical System Model, then 1D, 2D and 3D simulation models. All these models require test data, manufacturing data and service data. And all models are built with design and analysis knowledge.

As he explained, "Simulation-Driven Design is actually an extension of the classical Systems Engineering V." He says this type of design is built with design models that are typically simplified and used to determine product design. The models are grounded with sophisticated analysis models before real-world data is available. All models are grounded in experiments via the Verification, Validation, and Uncertainty Quantification process.

Certain About Uncertainty

Uncertainty Quantification (UQ) is also on the minds of other presenters such as Jakob Hartl, Ph.D. student, Aerospace Systems, Purdue University; and Karen E. Willcox, director of the Oden Institute for Computational Engineering and Sciences, University of Texas at Austin.

In the talk on simulation credibility, Hartl revisited a topic he has presented previously but with an update, to answer the question "are we there yet?" A key part of his talk was a review of the results from a rigorous UQ analysis of a 3D centrifugal compressor aerodynamic model, part of a collaboration between Purdue University and Rolls-Royce. In talking about digital twins, Willcox emphasized the need for physics-based models to be reinforced with machine learning.

"Quantifying the uncertainty associated to a digital twin is crucial," said Willcox. "We have to recognize that the digital models are inherently incomplete, and the data is noisy, but we can't throw up our hands and say we can't predict anything until our model is perfect. Instead, we have to think about the uncertainty involved, then make predictions while factoring in the risks."

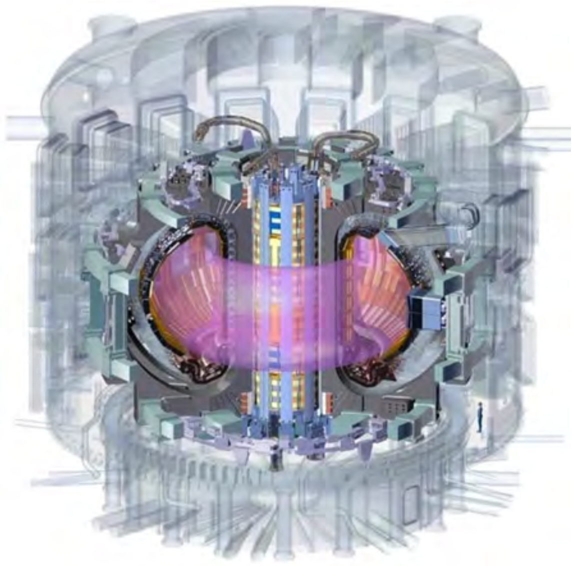
To watch the recorded talks, please visit www.digitalengineering247.com/caase21. DE

Simulation to Help Harness Nuclear Fusion

The ITER Organization is collaborating with Ansys to optimize electromagnetic (EM) structure design and performance for the ITER, the largest nuclear fusion plant created to deliver net energy and maintain fusion for long durations. Through a new multiyear agreement, Ansys will work with ITER engineers to improve project risk management, streamlining system development and meeting critical safety requirements, the company said in a press release.

Producing a self-sustaining fusion reaction requires an ionized plasma of hydrogen isotopes to be heated to approximately 150 million °C. To sustain this extreme temperature while containing the plasma, the ITER tokamak (a plasma confinement structure) uses an array of massive superconducting magnets, which creates an invisible magnetic cage inside the metal vacuum vessel of the tokamak. ITER engineers leverage Ansys simulation solutions to design the EM structures.

The company uses Ansys Fluent to validate the extreme cooling system and build the documents that ITER engineers will use to ensure the system design is robust and complies with strict project and industry safety standards. Additionally, Ansys Mechanical is used by the engineers who build the structural supports that secure the ITER's base.



"Ansys simulation solutions will continue to help our team to satisfy the required safety and accuracy levels for this first-of-a-kind initiative," said Bernard Bigot, director-general of the ITER Organization. "For ITER to achieve hydrogen fusion at industrial scale requires unprecedented levels of engineering precision, so it is incredibly important that our simulation software is highly reliable and efficient. Ansys has consistently delivered that capability to us for many years, enabling our team to safely push boundaries, dream bigger and deliver Earth's biggest fusion reactor."

"To power the sun and the stars, light atoms fuse at very high pressures and temperatures. Replicating this process on Earth with ITER will help solve the world's energy demands, however, engineers must overcome extremely difficult design challenges," said Prith Banerjee, chief technology officer at Ansys. "Using Ansys simulations, ITER engineers are rapidly building a structurally sound fusion power reactor, drastically reducing the EM structures' material content and substantially decreasing the plant's development cost—driving the delivery of clean, sustainable energy for our planet." DE

The Simulation Risk-Free Space of Vehicle Design

As vehicle design increases in complexity, so does simulation, allowing design teams to safely simulate designs before they become road-ready.

BY JIM ROMEO

When talking transportation and mobility, traditional automobiles are no longer the only focus. For innovators, an entirely new genre of autonomous vehicles (AVs) and smart vehicles incorporates new and advanced technologies.

Such technology trends include AVs, connected vehicles, smart infrastructure and new types of mobility applications that are disrupting the automotive sectors in unprecedented ways.

As such technologies become more complex, engineering design teams turn to simulation solutions during the design and development process to incorporate mechanical, flow, electrical and sensor simulations—and do so in ways that can help predict performance of self-driving and electric vehicles made of new materials, as well as incorporate data collected from sensors and connected vehicles.

Tools need to be accurate, easy to use and very efficient. In addition, people have traditionally worked in silos, working on specific physics with less familiarity of multiphysics coupling to solve complex real-world problems. *Image courtesy of MSC Software.*

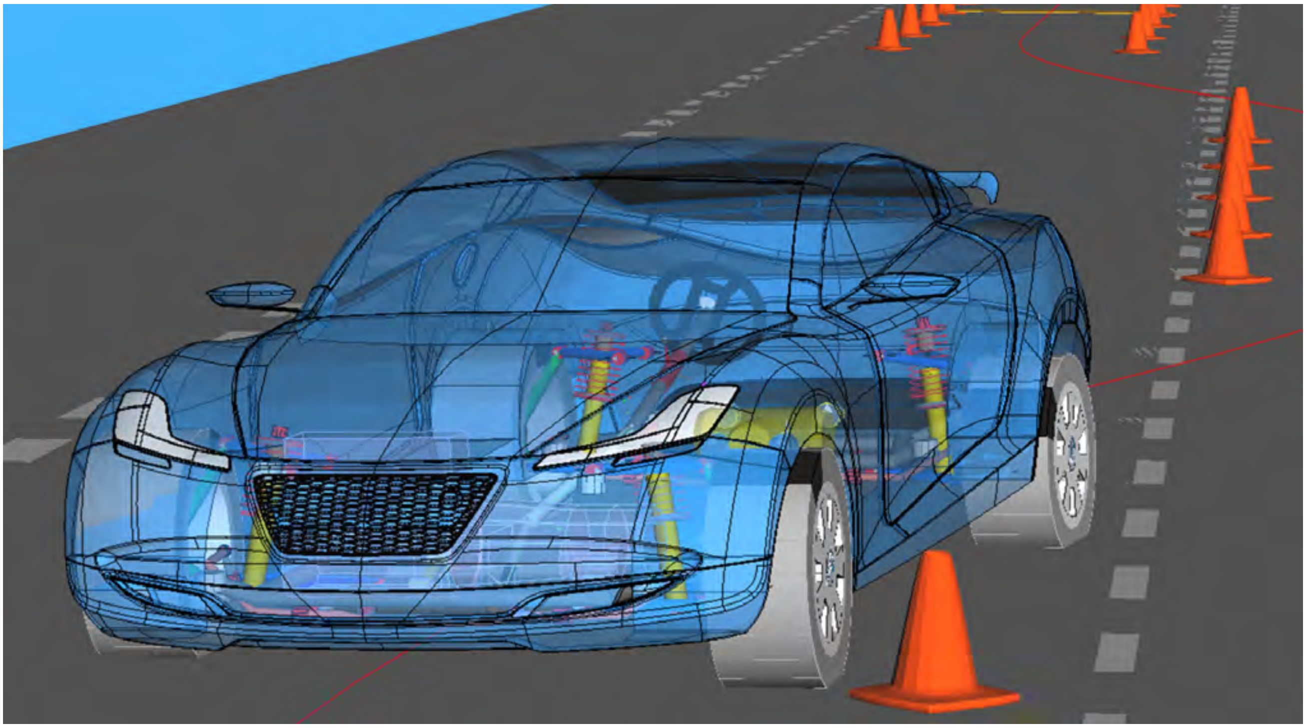
Win on Sunday, Sell on Monday

An automobile, in any form, is a complex assembly of systems, parts and technology. To interweave all parts of an automotive design is a challenge.

"A maxim in the auto industry is 'win on Sunday, sell on Monday,'" says Ed Tate, senior director, SIMULIA, Transportation and Mobility Industry Processes, Dassault Systèmes. "The auto industry has always been about speed, especially the speed of getting to market. But getting the most complex consumer product into production is a tough job.

"An automaker needs to integrate tens of thousands of parts with millions of lines of code while satisfying thousands of regulations to make a car that operates for decades in the harshest environments on earth," Tate adds. "Thirty years ago, it was common to take four years to go from concept to production."

Today, Tate says, most automakers get to market in under two years.



The potential for modeling and simulations is that every step from concept to final design release will be done virtually with larger quantities of higher quality information available than possible today, supported by robust decision analytics. *Image courtesy of Dassault Systèmes.*

"Amazingly, even though cars are increasing in complexity, they are objectively more efficient, durable, clean and subjectively better looking and fun. This improvement is possible because designers and engineers can escape the tyranny of physical prototypes that previously drove development schedules," Tate says.

Tate says that an ability to work at the scale and complexity of a full vehicle enables design and engineering teams to collaborate on simulation models. He points out that Dassault's computational fluid dynamics (CFD) solutions enable designers and engineers to "talk the same language so they can find beautiful and efficient car shapes without clay or wind tunnels."

Simulation: The Risk-Free Space

Simulation is an exploratory space for vehicle design and simulation.

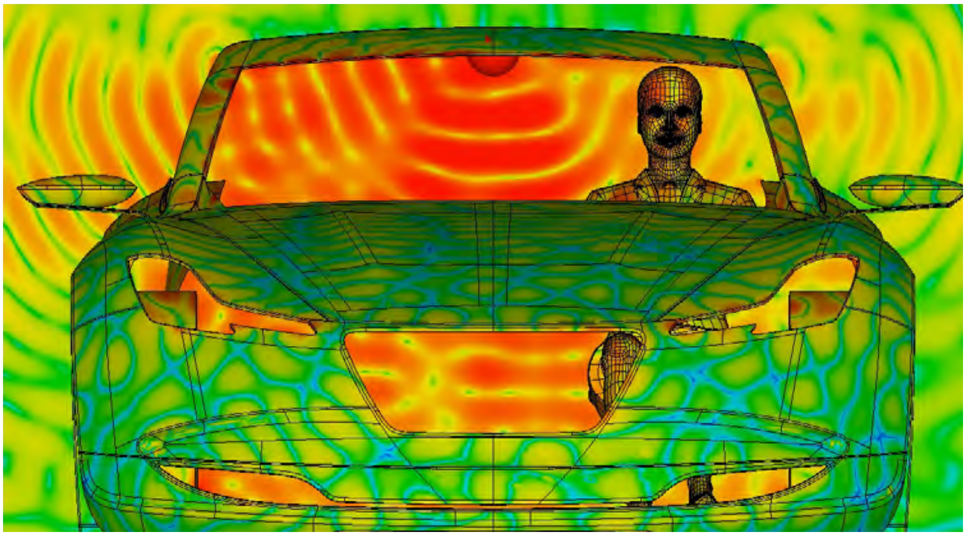
"The benefits of simulation are widespread," says Catherine Neubauer, research psychologist and lecturer in the Master of Science in Applied Psychology Program at the University of Southern California and the Army Research Lab, in Fort Lauderdale, FL.

"I for one like to utilize simulated driving scenarios for several reasons mainly because they're contexts that can reproduce cognitive and emotional states—stress and fatigue—that we wish to study," Neubauer adds. "Additionally, simulated technologies, such as driving simulators, can implement, then test new technologies in a safe space. In other words, we're able to use simulation to test various human responses and behaviors such as reaction time, lane-keeping and other important performance responses all while in a safe environment. There is essentially no risk to the human driver."

Simulation ultimately provides options. "The key benefit of simulation is improving the number of design options engineers can explore," says Tate. "The more design options evaluated and understood the better the fit and function can be refined between the limits of physics and the demands of the customer."

Mike Bartels is the director of marketing research and user experience with Tobii Pro headquartered in Stockholm, Sweden, and with offices in Reston, VA. Tobii's eye-tracking technology has been used by some of the biggest auto manufacturers in the world, such as Toyota, Nissan and Honda to help understand driver attention and vehicle design. While much of their research takes place in the real world, their technology is also simulated as testing prototypes that are not yet road-ready.

"With most consumer products, a cluttered design or poor usability does not run the risk of resulting in death," says Bartels. "Automobiles are an exception to that rule. Every second spent fiddling with the stereo or adjusting the AC [air-conditioning] is a second that the driver is not looking at the road. This, automotive com-



Though cars are increasing in complexity, they are objectively more efficient, durable, clean, and subjectively better looking and fun. *Image courtesy of Dassault Systèmes.*

The challenge of simulation presents risk. However, with risk, there's reward. Such reward shows some of the biggest benefits of simulation in vehicle design.

"One of the biggest benefits has been to cut development lead times," says Peter Fintl, director, technology and innovation at Capgemini Engineering. "Thanks to novel engineering methodologies like virtual development and digital twins and the extensive use of simulation, development lead times for new vehicles have been cut from 45-plus months to around 20-plus months. Those dramatic gains in development efficiency must be seen in the context of a significant rise in vehicle complexity and legislative demands as well as growing quality requirements."

Fintl adds that another major benefit more recently has been the ability for original equipment manufacturers (OEMs) developing self-driving cars to simulate the driving of miles in cars to test different traffic or weather conditions. Fintl emphasizes that no OEM can afford to drive real cars for so long and experience so many different conditions.

panies take very seriously—the need to study the behavior of drivers in a safe way.

"Simulation provides a consequences-free environment to test and retest every innovation before it goes to market," Bartels adds. "As the fidelity of simulators and the accuracy of attention measurement tools improves, automotive manufacturers have more insight into the relationship between design, experience and safety than ever before."

Simulation Challenges and Benefits

The use of modeling and simulation software for engineering design in our present environment has its challenges, however.

"The challenge is making engineers and designers comfortable with using new technology to enhance the design and engineering processes," says Roger Assaker, CEO of MSC Software, which is part of Hexagon's Manufacturing Intelligence division. "The tools need to be accurate, easy to use and very efficient. In addition, people have traditionally worked in silos, working on specific physics with less familiarity of multiphysics coupling to solve complex real-world problems.

"Designers don't traditionally communicate with the people in manufacturing," Assaker adds. "This technology encourages a more inclusive, collaborative environment which inevitably results in superior products, delivered quicker and more efficiently."

Vehicle Simulation: A Glimpse Forward

In the future, engineering teams will get smaller. "The development cycle will get faster," Dassault's Tate says. "To

OEMs and suppliers will collaborate more securely on concepts, detailed models and multiphysics simulations to develop and integrate the best components. *Image courtesy of Dassault Systèmes.*

squeeze more performance from their products, OEMs and suppliers will collaborate more closely and more securely on concepts, detailed models and multiphysics simulations so they can develop the best components and integrate them as expected into the best performing, faster than previously possible."

He emphasizes that modeling, simulation and other support technologies will enable all of this. Simulation enables replacement of routine decisions with machine decisions, which frees up time. Simulation can provide insight into what happens in a vehicle in a way that is not possible with physical testing.

"With physical testing, an engineer can only see the physics of an electromagnetic wave, stress, pressure or any number of invisible quantities, in relation to specifically placed test sensors, or using their imagination tempered by a lifetime of experience and the limited data available from instrumented tests," says Tate. "With accurate simulation, the designer, engineer and executive can all see everything in the model. Realistic images and animations, allow them to share the results with all stakeholders, speak a common language, gain detailed insights and collaborate on improving a design."

Tate adds that the potential for modeling and simulations is that every step from concept to final design release will be done virtually with larger quantities of higher quality information available than possible today, supported by robust decision analytics. Every engineer will have on their desk the whole world to test and prove their designs.

"Inventiveness is trapped behind the expense and time of physical testing with limited prototypes in expensive and exotic locations," he says. "Modeling and simulation will continue to unleash pent up creativity and accelerate learning to help improve vehicles further. We are at an early phase in this process, but the effects are already evident. Smaller development teams are proving that they can develop more complex vehicles in less time. Yet, there is much more to come."

Nowadays, says Maurice Liddell, principal and senior client executive at BDO Digital, many things are simulated. This includes vehicle components as well as the entire vehicle-based on design and material specifications.

"This approach further shortens the product development lifecycle, as design changes can be tested almost instantaneously, thus providing a model-validated design prior to prototype development," says Liddell. "With the advancements in technology and application to vehicles simulation is even more valuable to validate software logic for safety, performance and efficiency. As auto manufacturers increasingly look to build these new vehicles, they're investing in technology like AI and machine learning and virtual and augmented reality to properly simulate real-world conditions for AVs and [electric vehicles] EVs." DE

Virtual testing validates the designs at much lower costs, and more rapidly than older validation methods. This frees up significant staff hours and enables manufacturers to focus more on design and production instead of prototyping and testing for validation, as well as helping companies produce more sustainably through more efficient designs. *Image courtesy of MSC Software.*

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

→ MORE INFO

- **BDO Digital:** BDO.com
- **Capgemini Engineering:** capgemini-engineering.com
- **Dassault Systèmes:** 3DS.com
- **MSC Software:** MSCSoftware.com
- **Tobii Pro:** tobiipro.com

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

Body Painters and **Test Drivers Wanted** in Mixed Reality

Training and design review fuel use of AR/VR in automotive.

BY KENNETH WONG

With vaccinations picking up momentum in the United States, schools and universities in many states are once again reopening. But Bharanidharan Rajakumar, CEO of TRANSFR, believes many of his clients who have discovered the convenience of virtual reality (VR) may choose to continue their education in pixels and bytes.

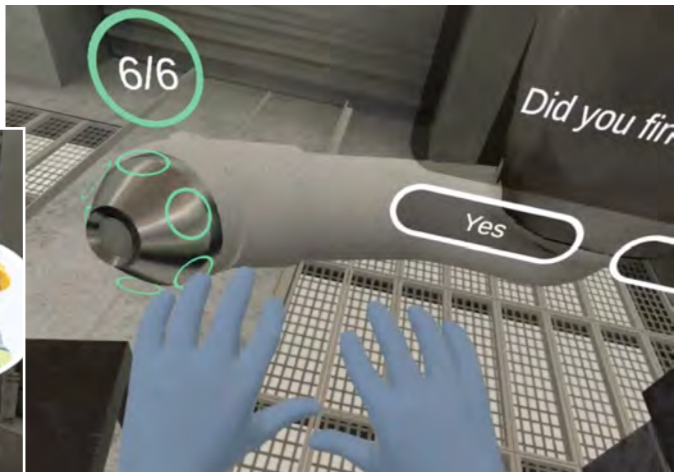
Rajakumar founded the startup TRANSFR in 2017 with the idea to deliver training in VR. At the time, VR and its sibling augmented reality (AR) had found audiences in the game and entertainment market, but both struggled to find adoption in the professional sector.

He never anticipated that, in a few years, a pandemic would shut down schools and business and social distancing would become mandatory. During the COVID-19 pandemic, remote teaching and learning was the safest possible option, creating new markets for TRANSFR products and services.

"COVID-19 may have been the instigator for VR-based training, but for a lot of people, there's no going back. VR's value over PowerPoint-based training and classroom lectures has been established," he says.

Cognitive Training

At the [Mazda Toyota Manufacturing USA (MTMUSA) factory in Huntsville, AL](), when newly hired employees in the paint department come to get trained on operating the paint



TRANSFR developed a VR-based training for operating a paint robot, now used in the Mazda Toyota Manufacturing USA in Huntsville, AL, to train new hires. *Images courtesy of TRANSFR.*

Example of a mix of physical and digital assets for design review. A seat bucket that replicates a car's interior is used along with Autodesk VRED digital models, delivered to the driver via VR. *Image courtesy of Autodesk VRED and Italdesign Giugiaro S.p.A.*

robot, they will likely put on a VR headset before they go into the auto painting facility.

The VR-based training modules are the outcome of a private-public partnership involving MTMUSA, Alabama Industrial Development Training (AIDT; part of the Alabama Department of Commerce) and TRANSFR.

The program was piloted with two groups of 31 participants, made up of trainers, paint booth users and trainees. Booting up the VR program, the participants first saw a digital replica of the factory site that housed the paint robot. In this virtual environment, they learned to perform safety checks, and handle, measure and calibrate the tools.

"There was a significant increase in performance for both groups overall (from 53% to 82%) … this was an indication that the trainees gained knowledge from the simulations," TRANSFR notes in the published case study.

"The value in simulation-based training is, it helps the trainee acquire procedural knowledge. So when they get to the job site, they know where everything is, what every device does," Rajakumar says.

The VR training boosts confidence in the new hires, but it also works to the training provider's advantage. "It's easier to standardize the training and scale up the capacity," he says. "If you have good trainers in one region, but have a shortage in another, you can solve it with VR. Before, you might be training 20 students with four trainers. In VR, you could train 80 with the same trainers."

Some VR-based training application developers like

Simulating the Six Senses

Certain haptic gloves exist to simulate feedback when interacting with digital objects. However, the feedback is usually powered by hydraulic pipes and cables, making the glove bulky. In addition, the feedback is confined to temperature and vibration. Simulating texture sensation (such as the feel of a leather seat or the smoothness of a vehicle's hood) exits almost exclusively in research labs, not yet in the mainstream commercial AR/VR hardware.

There are, however, technologies like Olfactory Virtual Reality (OVR) Architecture of Scent to deliver artificial aroma using an additional piece of wearable hardware. The company offers Scentware, a library of artificial scents in cartridges. (For more, listen to the podcast "OVR: Stop and Smell the Roses in VR," June 2020, bit.ly/3AGrwZQ.)

Some automakers use Varjo's XR-1 headset in conjunction with real cars to understand the driving experience of new models. *Image courtesy of Varjo.*

Sixense incorporate physical props, such as replica paint cans and weld guns into the setup, allowing the trainees to build muscle memory and get used to the shape and weight of the tools.

TRANSFR applications uses the standard game controllers, which do not match the shape of the real tools.

"For the instances we work in, the added value from the prop is not a must have," Rajakumar says.

TRANSFR caters to not only the industrial sector but also to the education and government sectors. Of these, Rajakumar feels automotive is an area of growth.

"They are moving from traditional cars to electrical and autonomous vehicles, so there's a lot of room for new training materials to be created," he says.

Mixing Physical and Digital Assets

The best driving simulation is a mix of physical assets, which provide the basic frame of a car, with VR-based digital view, which shows what a yet-to-be-built model looks like from the inside out. One of the best examples of the physical-digital combo comes from Varjo, an AR/VR application developer that counts Volvo among its customers.

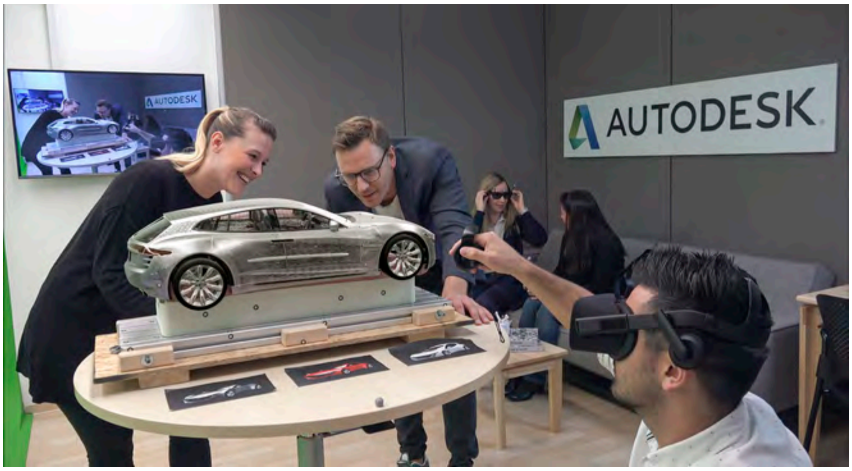
Volvo engineers have been test-driving a real Volvo XC90 while wearing Varjo's VR headsets.

AR-Powered Task Guidance Market

Many tasks once done by experts onsite will likely shift to augmented reality (AR), according to the analyst firm Greenlight Insights. In its report titled *RealityCheck: Augmented Reality Task Guidance Solutions*, it identifies PTC's Vuforia as a leading solution in the market. J.C. Kuang, managing director and principal analyst at Greenlight Insights, predicts the market segment will reach $3.5 billion in value by 2025.

"As we've seen over the last few years, enterprise applications for frontline workers continue to be the most compelling market for both hardware and software providers. Companies like Magic Leap and Bose tried and failed to find a market in consumer products despite their impressive technology stacks. And only now are we seeing potentially scalable consumer-oriented deployments from major stakeholders like Snapchat," observes Kuang.

In May, PTC launched Vuforia Instruct, a mobile device-powered work instruction publishing and viewing application. In doing so, PTC joins Epson with Epson Moverio Assist and RealWear with RealWear HTM, which leverages AR technology for remote assistance and frontline operations.



The use of VR and AR technology allows automotive designers to rely less on physical models. *Image courtesy of Autodesk.*

The purpose is "to perform [automotive] UX [user experience] studies by keeping as much as possible of reality—the real road, nature, road signs and more—and only exchange the things they want to evaluate, for example, a new display or interior, during the virtual and mixed reality test drive," according to the case study by Varjo.

Varjo found that test drivers instinctively stepped on the brake when they saw a virtual moose crossing the road, and reacted to virtual cars overtaking the test car, according to the case study.

Because of the partnership between design software maker Autodesk and Varjo, Autodesk VRED and Alias software users can view their detailed vehicle models with Varjo hardware. Such applications push the automotive design discipline to rely less on traditional clay models and more on digital models.

"Bringing the clay model experience into the virtual space is the holy grail in automotive design," says Thomas Heermann, vice president of automotive, concept design and XR at Autodesk.

One aspect of the clay model that cannot yet be simulated is the tactile sensation. You can run your hands down a clay model to examine the surfaces and curvatures of the vehicle, but tactile or haptic feedback in AR/VR is still a long way from such interactions.

"It will take a few more steps in innovation to get there. Getting rid of the controllers is the first step," Heermann says. "Also, finger recognition needs to get granular enough to recognize the joints."

The latest devices like Microsoft HoloLens 2 include finger recognition, allowing a user to use their fingers to push a virtual button or play a virtual keyboard, for example. However, such features are not yet the norm in AR/VR hardware.

Create, Review, Experience

During the shutdown, the use of AR/VR for collaborative design review became the norm, Heermann notes.

"In rough concept models, the shape and form are more important, but in the later design phases, you want to see shadows and reflections, so this requires high-resolution graphics," he says. "Imagine seeing objects behind you in your [virtual car's] side and rearview mirrors."

It suggests that the use of graphics processing units (GPUs) with real-time interactive ray tracing may become part of AR/VR hardware architecture.

Automakers have also been using mixed reality or extended reality (XR) to boost sales, Heermann says. "So you can use your iPhone's XR function to put your new car in your driveway, for example," he says. While design creation in AR/VR is not yet the norm, Heermann predicts, "design review and creation will converge in VR."

This June, Autodesk added the USDZ file export feature in the Autodesk Fusion 360 software, giving users an easy way to bring 3D CAD models into AR/VR environments for viewing and interaction. **DE**

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

→ MORE INFO

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- **Epson:** Epson.com
- **Greenlight Insights:** Greenlightinsights.com
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- **PTC:** PTC.com
- **RealWear:** Realwear.com
- **Sixense:** Sixense.com
- **TRANSFR:** Transfrvr.com

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Digital Thread Accelerates **Connected Car** Development

Digital transformation of the automobile will require a new design approach.

BY TOM KEVAN

The emergence of the connected car marks a key stage in the evolution of the automobile, putting digitization squarely in the driver's seat. To successfully make the transition, however, the automotive designer must bring the full power of digital thread to bear (Fig. 1).

From the beginning, the main challenge confronting designers of connected cars has been the formulation of a clear picture of what they were creating. Connected car technology has made vehicles much more than transportation platforms. By adding connectivity and extensive data collection to the mix, carmakers have created an opportunity to spark the same level of consumer enthusiasm that electronics companies have done with their smart products.

To deliver on this promise, however, the designer must fundamentally rethink the automotive environment. In-car features have shifted from hardware-based functionality to software-defined capabilities. These software-based features increasingly take the form of rich web services.

To complete this digital transformation, carmakers must modify their processes and operations, and tailor the changes to produce vehicles that better meet the evolving demands of today's consumers. This means that engineers must be able to identify and understand the usage patterns and preferences of vehicle occupants, with an eye on delivering the optimum user experience.

Engineers now have a better chance of achieving this because of the increasing availability of location- and time-specific sensor data. The challenge here is to create an infrastructure that can aggregate and refine data, allowing globally distributed stakeholders to leverage data that comes in a broad spectrum of formats, from a plethora of sources and engineering domains. This is where the digital thread comes into its own.

Creating a Window for Designers

By harnessing digital thread, automotive engineers gain access to vast pools of information associated with the connected car, allowing them to evaluate different configurations of the software, and mechanical and electrical parameters.

As the vehicles operate, the thread collects and filters information, constantly tapping the changing data streams as the cars mature and the mobility environment changes. This can be done for thousands, even millions, of vehicles.

"This operating history of every connected car is a treasure trove of information to support next-generation product development," says Jason Kasper, product marketing manager at Aras. "The information can provide insight into such things as driving habits, quality issues, service history and maintenance considerations."

In the past, carmakers attempted to compile similar histories by performing time-consuming usage studies, called customer correlation studies. Now, with the digital thread, development teams gain access to information that enables them to enrich, analyze and sanitize data much more quickly (Fig. 2).

"We are doing this for a major [original equipment manufacturer (OEM)] in Germany to extract usability information and useful insights into energy management, performance optimization and remaining useful life," says Nand Kochhar, vice president, automotive and transportation industry, at Siemens Digital Industries Software.

New Points of Interest

As connected car technology has matured, three types of data have grown in importance, capturing the attention of automakers. These are categorized as remaining useful life, energy management and advance driver-assisted systems

Fig. 1: Building a digital thread for a connected car means tapping into multiple data streams from vehicles, transportation infrastructure and a raft of mobile devices and services. *Image courtesy of Siemens Digital Industries Software.*

(ADAS) and automated vehicle (AV) systems.

In this context, remaining useful life data helps engineers to understand the dynamic use cases. An example of this might be: "When will the suspension system fail?"

Energy management information, on the other hand, allows the design team to improve battery consumption, optimize power versus range tradeoffs and maximize overall power management and efficiency. This type of data is especially important now that the industry is making the transition to electric vehicles.

Furthermore, ADAS and AV data helps development teams account for new regulatory requirements, such as automatic braking, which is becoming compulsory for U.S. vehicles in 2022.

"Analyzing this data enables teams to discover the causes of issues like phantom braking," says Kochhar.

Richer Details, Living Designs

To ensure that engineers reap the full benefit of the digital thread, data must be collected across the vehicle's entire lifecycle, beginning at the earliest stages of design and development and continuing through the production, service and usage phases. Each lifecycle phase delivers unique and essential data, which contributes to the richness of the resulting digital twin (Fig. 3).

For example, engineering data describes the product's structure, its variants and dependencies, and software and sensor requirements—all of which describe the product and its functionality. Similarly, manufacturing data defines the concrete instance and configuration of the built product, including the individual parts used during manufacturing.

The digital thread combines and links these data streams so that they work in tandem. This enables more comprehensive coverage of the design.

Making Smarter Choices

The data provided by the thread is the material from which models and simulations of connected cars and services are made. Parameter inputs come from an increasing number of sources, all made available through the digital thread.

As the connected data pool grows, analytics can better guide the setting of tolerance limits, improving the accuracy of models and simulations.

"Teams create their designs based on assumptions, but the digital twin enables them to replace those assumptions with real-world facts," says Mark Taber, vice president of go-to market and marketing at PTC. "This enables them to test their designs against the actual conditions the vehicles see in the real world and to better refine their design choices."

The attraction of digital thread lies in the fact that it promises engineers access to the data they need, when they need it. The challenge, however, is getting the quality of data required.

The biggest obstacle here is the sheer amount of data to be processed and analyzed. A connected car produces a tremendous amount of data every second. This makes it

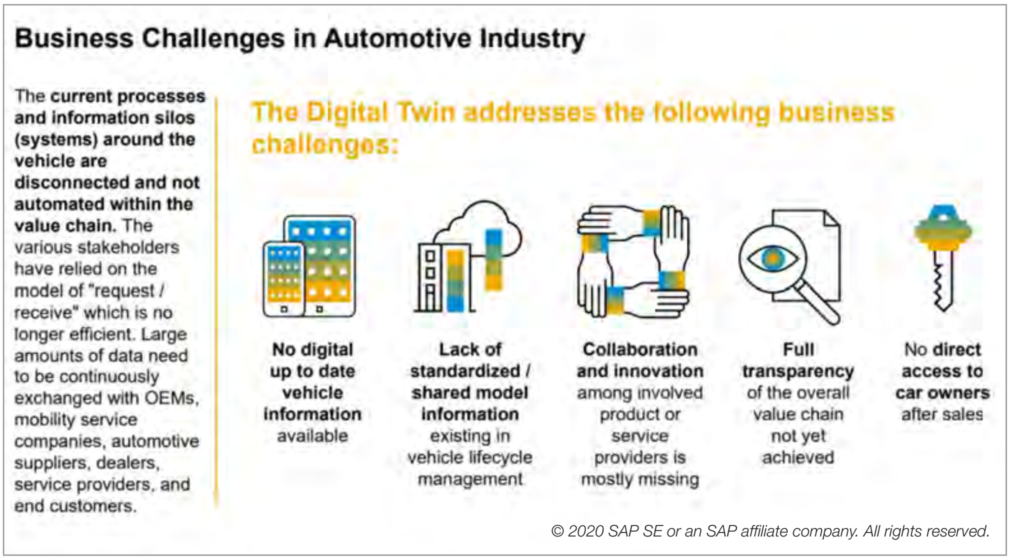

Fig. 2: Digital thread technology provides connected car designers and manufacturers with the means to break away from and move beyond the obstacles inherent with traditional automotive design, manufacturing and data management practices. *Image courtesy of SAP.*

critical to sanitize and filter data.

For example, some types of data are easy to manage. For instance, basic vehicle performance data can be event-based, and this makes it easy to identify.

On the other hand, to create useful information from specific interactions between a connected car and other factors (e.g., vehicles, infrastructure and web services) is another matter. This requires a system that can cull out and integrate useful information from diverse systems. To accomplish this, significant computing power must be available at the edge.

All of this may seem doable, but there's a catch. As automotive companies digitize their processes and operations, they have encountered bottlenecks. These often stem from homegrown software, spreadsheets and data management systems designed decades ago to be completely independent of external platforms. This is where a division of labor between edge and cloud systems provides a solution.

Cloud and Edge Collaboration

These two systems working together provide the muscle required to break down data silos, deal with the data deluge and extract useful information continuously.

For example, edge computing resources on the connected car—enhanced with artificial intelligence—can filter incoming data, identifying and isolating useful or relevant information. This translates into pushing out performance, usage and condition summaries. By doing this, edge systems reduce the volume of data to be analyzed and lessen the demands placed on communications infrastructures.

"Edge technology enables decentralized processing and analysis of data, such as data produced by vehicle sensors, to reduce the volume of data that must be transferred," says Hagen Heubach, global vice president and head of the automotive industry business unit at SAP. "Consequently, transfer times for a connected car's data are shortened, and this raises service quality significantly."

Upon receiving partially processed data from edge devices, cloud systems can further scrub and enhance the data as needed. Cloud systems also provide the network and platforms that vendors and product designers use to collaborate as they develop, launch and update the vehicle and supporting services.

An example of this can be seen in the freight industry, where companies have discovered that driving style greatly determines tire wear and tear. Aided by the insights enabled by digital thread and digital twin, these companies now access data that helps them to schedule predictive maintenance and preemptive repairs.

Security Becomes a Real Concern

As connectivity and big data become integral parts of this generation of vehicles, carmakers, their supply chain partners and connected car development teams must contend with a new issue: cybersecurity.

The majority of cars today are very communicative, with each vehicle producing an enormous amount of data from interior and exterior sensors. Bundling technical and personal usage data can greatly help connected car designers, providing detailed insights about the occupants and their behavior, as well as the success or failure of the vehicle's design.

Car companies and consumers, however, can pay a high price for these insights. The increased accessibility to these large pools of data exposes connected car control systems and their owners' personal data to cyberattacks. In addition, penetrations of the digital twin during the product development phase can affect the long-term profitability of the OEM through the disclosure of intellectual property to a competitor.

"When I worked for a previous employer, an innovative engine design was disclosed to our competitors a few years before launch, allowing them to respond in the market, causing an estimated $1 billion loss," says Rick Sturgeon, senior director of transportation and mobility at Dassault Systèmes. "During the development of the product and especially the field service, we need to both protect and be prepared to respond to security breaches. A system monitoring all the other systems for out-of-range conditions or actions is a good first step beyond conventional firewall prevention."

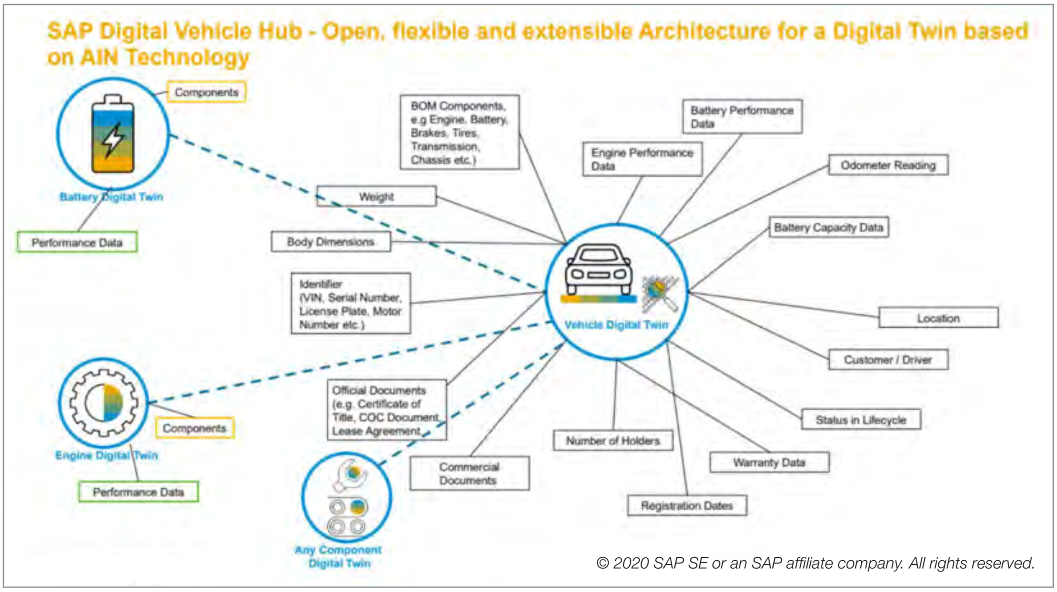

Fig. 3: The digital thread aims to intertwine and make available a broad spectrum of data sources, providing the means for connected car manufacturers and their development teams to glean insights into the viability of designs, technical status of an asset, usage of the vehicle and preferences of its occupants. *Image courtesy of SAP.*

In addition to system monitoring, the industry is working to expand established security enhancement measures to protect connected vehicles.

"To ensure that user privacy is respected, the use and further development of technologies for anonymization, integrated encryption and authentication will be key offerings from manufacturers and brands," says SAP's Heubach.

Paralleling these efforts is the industry's drive to cultivate standards and a stronger regulatory environment. Having a common trusted platform is critical. Standards bodies have already done a lot of work on security standards and a common industry model. An example of this is in ISO/SAE 21434, which addresses road vehicle cybersecurity engineering through the improvement of software lifecycle management.

Driving the Digital Thread Forward

In the past, cars were primarily a mechanical device that you could take apart and put back together, confident that it would work. Connected cars, on the other hand, represent an amalgam of hardware, software, communications and cloud components, making them much more complex.

Creating a digital thread of the connected car, including data from its mobility environment, allows carmakers and development teams to test many options and optimize the vehicle and associated services as they mature. This minimizes development costs and rework. It also provides a significant reduction of the product's development cycle and boosts customer acceptance.

User requirements are also validated early in the development process, ensuring an optimized customer experience. Even after the vehicle enters service, the thread enables car manufacturers to improve maintenance and continually upgrade the product and introduce new services. DE

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MORE INFO

- **Aras:** Aras.com
- **Dassault Systèmes:** 3DS.com
- **PTC:** PTC.com
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3D Scanning in a New Light

Advanced 3D scanning software is enabling large-scale digital twin applications and new types of reality capture.

Recent innovations in 3D scanning workflows are transforming the workflow for reality capture. 3D scanner companies have developed a new generation of lightweight, highly portable scanners that can be used by operators with little or no scan experience. There are also automated and robotic scan solutions. Together, these improvements have enabled scanning of very large parts and assemblies, as well as entire buildings and campuses for architecture applications. In addition, the scanners are being used for historic preservation, reverse engineering, quality control, measurement and other applications.

Combined with additive manufacturing, 3D scanning has enabled the recreation of obsolete parts for legacy machinery and vehicles, advanced reverse engineering uses and even some novel applications.

These scans of more complex assemblies and larger physical areas create ever more expansive volumes of scan data. The scan data can be exported into CAD and building information modeling (BIM) applications, and can be used to create high-resolution renderings. Increasingly, the software used to process the data from these high-performance 3D scan solutions relies on more powerful GPU compute resources in workstation-grade computers.

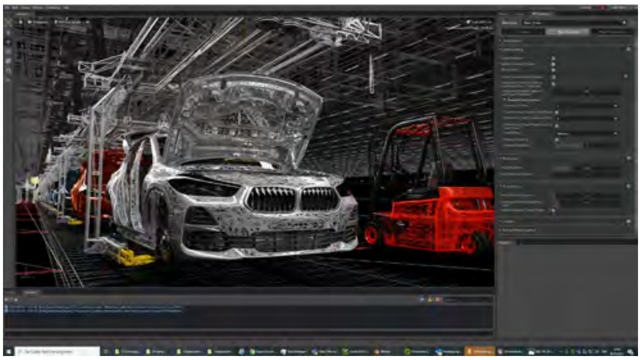
FARO provides 3D SCENE software that turns 3D scans into 3D visualizations that can be imported in various point cloud and CAD formats. Users also can create virtual reality views. The software requires a dedicated graphics card with at least 8G of memory. For stereo rendering and viewing, users need NVIDIA graphics; VR rendering requires an NVIDIA 1080GTX or similar GPU. The software supports Oculus Rift S and HTC Vive VR headsets when SteamVR is installed.

Large-Scale Digital Twins

At the recent NVIDIA GTC conference in April, the company announced that the cloud-based collaborative design platform Omniverse had emerged from Beta and was being applied to enterprise and manufacturing applications. Omniverse allows users from different locations to meet in virtual space and collaborate on designs or solve engineering issues using raytraced 3D objects.

BMW uses the Omniverse to build digital twins of its automotive plants. Dr. Milan Nedeljkovic, a member of the BMW board of management, participated in the GTC keynote.

"For the first time, we are able to have the entire factory in simulation. Global teams can collaborate using different



BMW and NVIDIA are partnering to use Omniverse to build a virtual factory. *Image courtesy of NVIDIA.*

software packages, using Revit, CATIA and point clouds," he says. "BMW regularly reconfigures its factory to accommodate new vehicle launches . . . An expert 'wormholes' [travels virtually] into the Omniverse using a motion capture suite, records task movements, and another expert can adjust the line design in real time. Two planning experts can work together to optimize the line in Omniverse. We want to be able to do it at a scale in simulation."

Another company that is enabling factory digital twins is a recent startup called Prevu3D (based in Montreal). Nicolas Morency, founder and CEO of Prevu3D, launched the company four years ago. With a background in mechanical engineering, Morency wanted to create a solution to easily create digital models of machines and factories.

To efficiently document a facility, he knew that 3D scanning/reality capture would be critical. "But 3D scanning is so massive that few people use it efficiently," Morency says. "How could we make this high-value data accessible to more engineers and project managers? We looked at how to process files into high-fidelity mesh textured models."

With a full facility scan, the Prevu3D software allows users to navigate 3D models, measure and annotate the models; cut, move, duplicate and export parts from the model; simulate new machinery installations; and share the models with other stakeholders via the cloud.

The Do's and Don'ts of Metal 3D Printing

The No. 1 rule for optimizing value: redesign parts specially for metal AM while following materials and post-processing specs.

BY BETH STACKPOLE

Star Trek aficionados are well versed in the wonder of the "Replicator," a machine that initially synthesized meals on demand, but eventually evolved to magically produce any number of complex objects, from clothing to the USS Enterprise's spare parts.

3D printing, and in particular, recent advances in metal additive manufacturing (AM), have many likening what's possible with the technology to the sci-fi promises of the Star Trek universe. Proponents of metal 3D printing are bullish on the potential, touting the ability to accommodate complex structures, decrease materials waste and reduce lead times for specific classes of traditionally manufactured metal parts.

However, the general lack of understanding of the process, especially the need to redesign parts to achieve the true benefits, remains a significant hurdle to adoption as well as an ongoing inhibitor to metal AM return on investment (ROI).

While metal 3D printing is indeed a game changer, most companies haven't fully capitalized yet because they aren't taking the opportunity to redesign parts, contends Tom Houle, director of LUMEX NA for Matsuura USA.

"When we see parts that are designed to be metal 3D printed instead of converted to metal 3D printing then the result is a part that is lighter, uses less materials, creates less scrap and waste and runs on a machine 24/7,

As a service bureau offering multiple 3D printing technologies, including metal AM, Protolabs helps customers consider key design considerations and improve part manufacturability. *Image courtesy of Protolabs.*

Matsuura USA's LUMEX printers combine a powder bed metal AM platform with machining capabilities into a single hybrid platform and process. *Image courtesy of Matsuura USA.*

lights out," he explains. "Those are four game-changing aspects of metal 3D printing and why the technology will eventually be commonplace."

Designing for Metal AM is Key

For now, metal AM is not exactly a manufacturing floor or engineering department staple, but it is making headway. A recent survey from Market Reports World projects the metals 3D printing market to grow at a compound annual growth rate (CAGR) of almost 22% from 2021 to 2025, increasing revenue by $1.3 billion. Grandview Research is projecting 27.8% CAGR growth between 2020 and 2027, fueled by increased adoption in the medical, automotive, and aerospace and defense sectors.

Despite the uptick, the high-cost and complex nature of traditional metal 3D printers have put them out of reach for a large segment of manufacturers and engineering shops. That dynamic has shifted over the last few years as prices have declined and a spate of next-generation models have made the technology more accessible.

Yet, as companies start to test-drive metal 3D printing, they encounter an array of challenges that leave many disappointed with results.

"The core challenge of metal 3D printing is education and expectation setting," says Lishan Mu, product manager at Markforged. "Because of the novelty of metal 3D printing, the manufacturing world doesn't know what to print or how to design for the metal AM process. They are taking parts meant for [computer numerically controlled] machining and expecting the same results from metal 3D printing. It just doesn't work that way as metal 3D printing is a completely new fabrication process that has its own capabilities, strengths and shortcomings."

To help counter that scenario, Markforged advises engineering teams to embrace a redesign approach, reevaluating parts by drilling down into why a particular feature was designed the way it was.

"Ask yourself, 'Why is the hole round? Is it because it's a through hole for a screw or because the drill to create the hole is round? Does it actually need to be round?'" asks Mu. "Most conventionally-designed parts are concepted to require as little material removal as possible, which is the exact opposite of what Design for AM (DfAM) suggests. If you ask enough of the right questions, you'll quickly find areas to optimize for a successful output with metal 3D printing."

To assist customers in this process, the Markforged

This 0.5-m diameter HexiLOX manifold was produced on 3D Systems' DMP Factory 500 as a seamless monolithic part using NoSupports advanced build mode. *Image courtesy of 3D Systems.*

University program helps identify the right parts to print as well as how to implement DfAM techniques to ensure print success.

Best Practices for Metal AM

Beyond the No. 1 best practice of redesigning parts for metal AM, experts in the field have various recommendations for what measures to avoid along with guidelines to ensure the best value and to optimize printed parts. Among them are:

Don't underestimate post-processing. Because it's still relatively unknown in broad market circles, many companies tend to look at 3D printing, and metal AM in particular, as a black box. Experts say it's a misconception to assume most offerings are a plug-and-play machine and that there won't be significant machining and finishing work required to ensure a part comes out finished as intended.

Companies diving into metal AM need to cultivate an understanding about how particular materials operate in terms of structural integrity as well as gain a clear picture of what's required for surface finishing and heat treatment to ensure there is no deformation and that parts will meet required tolerances. Often, companies don't factor in the need for machine shop capabilities as an integral part of the metal AM process.

Those firms that go into metal AM with a strategy that starts with design and goes all the way through inspection and testing have better results with implementation, Houle says.

"Those that have a plan from the ground up for implementing metal 3D printing have a strong track record of ROI," he says. "Those that bring in the technology and try to find different parts or applications they can convert do not."

Matsuura's LUMEX Avance-25 and Avance-60 metal laser sintering system focus on a hybrid approach, which streamlines post-processing work, Houle contends. The systems combine a powder bed metal AM platform with subtractive machining capabilities to ensure quality parts are finished with maximum precision.

SPEE3D's supersonic 3D powder deposition (SP3D) process also helps defray post-processing challenges while operating up to 100 to 1,000 times faster than traditional 3D metal printing processes, according to Bruce Colter, vice president and general manager for the Americas region of the company.

SPEE3D is based on cold spray technology, typically used for parts repair and coating, which combines high-pressure carrier gas with metal powders and operates below the melting point of the metal in use so it achieves a high density of deposits and low residual stresses. The resulting process requires far less heat treatment or post-processing work to get a quality finished result.

"The dirty little secret of metal AM is that often 60% of the process time is spent at the back end, de-stressing, heat treating or HIP (Hot Isostatic Pressing) parts as part of the finish work," Colter says. HIP refers to a process that exposes components to simultaneous application of heat and high pressure to help form the part by compacting the metal powder and eliminating porosity.

Make use of simulation to help optimize print processes. As companies expand use of simulation, simulation can also play a role in helping companies understand the metal AM process, specifically to optimize the printing process. SPEE3D just released SPEE3D Craft, a 3D printing simulator that takes users through the entire process, from part design to picking materials and removing parts from the build plate. It also provides instruction for use of the equipment.

Desktop Metal also sees simulation as a critical step for successful metal AM. The company's Live Sinter software simulates the complex forces and deformation of parts during sintering, helping users with limited experience with the technology to achieve defect-free parts. To foster better parts design for metal AM, the company offers Live Parts generative design software.

"We focus on simulation before and during the simulation process," says Jonah Myerberg, Desktop Metal CTO. "We want the designer to only put materials where they need to be and design the part around the manufacturing process, and Live Sinter shows how parts distort and change so engineers can make minor tweaks and get better results."

Don't forget metal AM is an end-to-end process, not just a machine. The specific features and functions of a metal AM system are important, but it's critical to look at how the platform addresses the entirety of the process to ensure the best results. At Velo3D, for example, the Sapphire 3D printer is integrated tightly with Flow print preparation software and Assure, a quality assurance and control system. Flow employs simulation to ensure predicable print outcomes directly from a native CAD workflow.

The software also features standardized recipes for parts, negating the need to develop new process parameters for every print job, saving time and reducing the need for 3D printing specialists. Assure uses a multi-sensor defect detection system to predict bulk material properties for each part and to determine print health in real time, ensuring companies can move to production with verifiable part-to-part consistency.

"Historically, engineers have had to wait for something to be printed to scan and check results," says Zach Murphree, vice president of technical partnerships at Velo3D.

Do embrace an iterative approach to design and manufacturing. That's at the heart of the benefits of 3D printing of all types. "Don't be afraid to put something on the machine," says Patrick Dunne, vice president of advanced application development at 3D Systems. "Maybe it doesn't work, maybe it breaks, but it's the ability to iterate at a high frequency and embrace Agile as a design approach that's so interesting."

Do get your feet wet with a service bureau. To determine whether metal AM makes sense for your applications, consider enlisting the help of a service bureau that has already gone through the learning curve and codified best practices to address complexities like part orientation or how to best plan for supports.

"We've already been through the growing pains," contends David Bentley, senior manufacturing engineer for 3D printing at Protolabs, a contract manufacturer. "Right now metal 3D printing isn't a dark art, but there's definitely some art to it. We can look at a part and come up with a solution that works on the first print and avoid a lot of that trial and error." **DE**

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→ MORE INFO

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- **LUMEX:** Matsuuraausa.com/series/lumex-series
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- **SPEE3D:** SPEE3D.com
- **Velo3D:** Velo3D.com
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Preparing for **Predictable** and **Unforeseen Events**

Pie Aeronefs discusses the decision-making process in aircraft design for an aerial race.

BY KENNETH WONG

Marc Umbricht and his colleagues founded Pie Aeronefs SA in 2020 with an ambitious goal: to design and make lightweight and zero-emissions aircrafts by 2026.

"When you are lightweighting, you target the forces you know you need to resist," says Umbricht, CEO and CTO of Pie Aeronefs. "But the risk is, there are also forces you aren't considering."

This is, in essence, the dilemma in all lightweighting projects. How do you retain sufficient structural muscles in the design to ensure it can survive not only routine events but also the unlikely but probable events? A smartphone designer must make sure the phone can survive not only the day-to-day operations but also the occasional mishaps, such as the user dropping the phone onto a concrete floor or into a water-filled bathtub.

Similarly, Umbricht and his engineers need to prepare their plane not only for the known forces but also for the dreaded scenarios, such as a midair collision or a crash landing.

If lightweighting is the remedy to over-building, it's also a doorway to the danger of under-building. As he recounted the decision-making process in the construction of Pie Aeronefs' (Team Pie Aeronefs) UR-1 plane for the Air Race E Challenge, Umbricht revealed ways to add safeguards in lightweighting to avoid under-building.

Motorsports for Electric Planes

Described as "the first ever all-electric airplane race," Air Race E pits eight planes against one another in a race around an oval circuit.

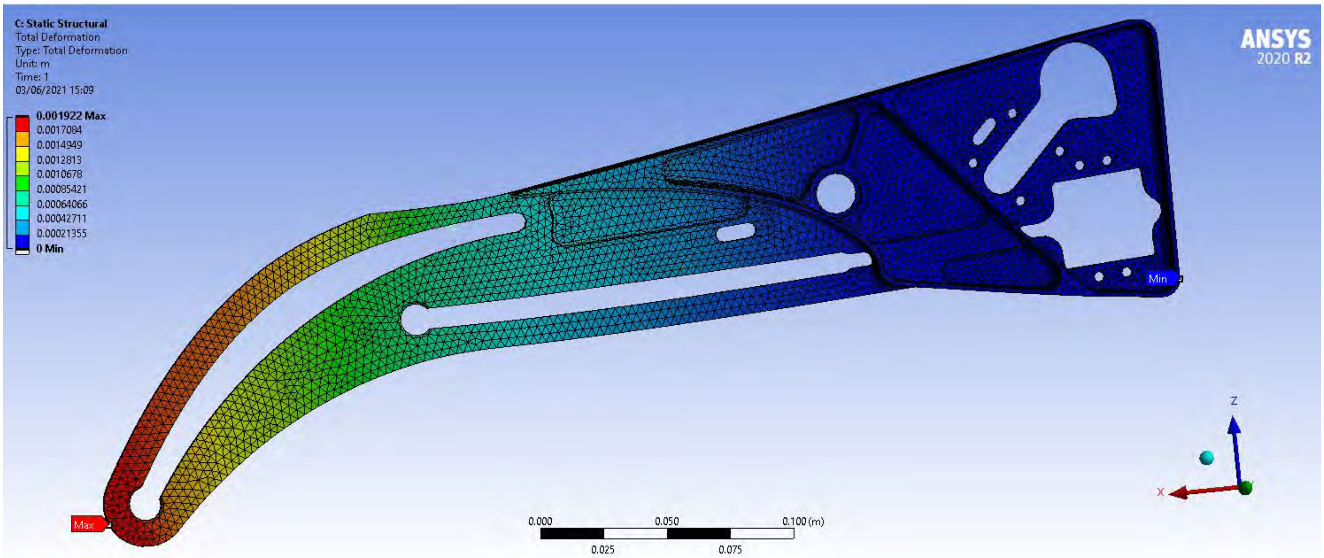
"The spectacular, quick, action-packed race will see speeds of 400 km/h [250 mph] around a tight circuit just 1.5 km end to end. The first race series will go ahead in 2022," the organizers promise on their website.

"When you're in flight, you deal with the four forces of flight: thrust, drag, lift and weight. A good balance of these four gives you a steady flight," explains Umbricht. "If you were to suddenly increase the rudder input, the aircraft would yaw at a certain rate, causing a torque between the wing and the fuselage. This is not a particularly important consideration in most planes, but in ours, the mass includes the batteries in the wings, so it was a major factor."

Traditional aircrafts do not have wings loaded with battery packs. But Team Pie Aeronefs' UR-1 does. The added weight also affects the landing gear's operations. Such design elements present additional challenges to the simulation and lightweighting tasks.

Preparing for the Surprises

Team Pie Aeronefs' UR-1 is designed to meet the European Union Aviation Safety Agency's (EASA) CS-23 regulations for normal, utility, aerobatic and commuter



Analysis results showing displacements in smooth gradient in the flap mechanism of Team Pie Aeronefs's UR-1 plane. Analysis done in Ansys Mechanical. *Image courtesy of Pie Aeronefs.*

aeroplanes. The rules stipulate the planes must be able to handle "gust upsets, inadvertent control movements, low stick force gradient in relation to control friction, passenger movement," and a host of other events.

"At low altitude [where the race will take place], gust speed tends to be much lower than at high altitude," says Umbricht. That was another design consideration.

The team also had to consider flight collision events. "These are violent events where 400 to 600-kg objects crash into each other at high speed," says Umbricht.

In a race where all planes are flying in the same direction, the accidents "probably won't be head-on collisions," he reasons.

In theory, an airframe could be designed to survive such an event with robust internal ribs and reinforcements, but the weight of it would make the design impractical, especially for a racing aircraft.

Measuring Risks

In aircraft design and engineering, assigning certain safety risks as "acceptable" or "tolerable" based on probability is routine; though the thought might make a frequent flyer queasy.

"We have to characterize probable events as very likely, unlikely, very rare and never going to happen," says Umbricht. "So we design the aircraft to have no degradation in performance when it encounters a likely event. But we also have to accept that in case of a highly unlikely event, the result might be hull loss and fatality."

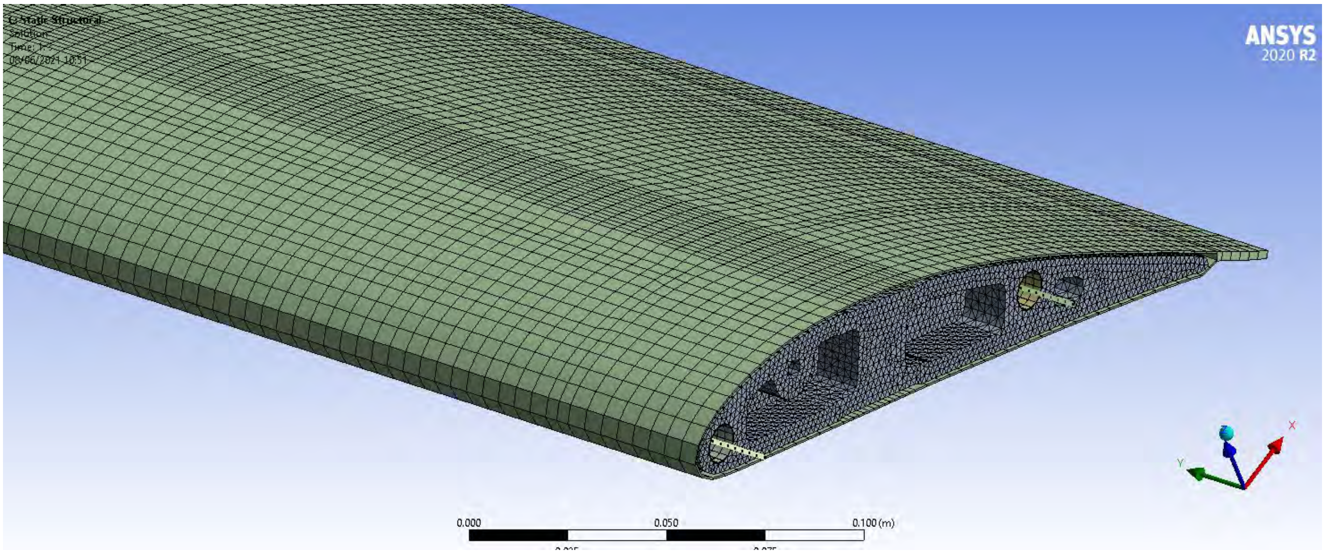
To offset the risk accepted, engineers included certain mitigation strategies, such as a crash helmet, a quick-detaching canopy and a parachute.

Topology vs. Material

In seeking opportunities to reduce the weight of the craft, engineers chose to exclude the airframe protecting the pilot. This leaves the wings as the obvious target regions. However, the battery-mounted wings have limited options in topology-driven lightweighting.

"So our lightweighting method was based on materials. We made the ribs out of woods—specifically, birch plywood," says Umbricht. "Because these are natural materials, [finite element analysis (FEA)] programs couldn't adequately characterize them. So we had to conduct a series of destructive tests."

Most FEA software includes steel, aluminum, plastic and other standard materials in a dropdown menu to choose from. But the library rarely includes natural materials, such as wood, due to the available variety. Furthermore, the strength, bending behaviors and breaking modes



Mesh model of the rib side of the flap assembly in Team Pie Aeronefs's UR-1 plane. Analysis done in Ansys Mechanical. *Image courtesy of Pie Aeronefs.*

of birch plywood could be specific to the supplier and the source region; therefore, physical testing remains the best approach to understand its character.

Digital vs. Physical

Team Pie Aeronefs used Ansys Mechanical, a structural analysis software package for modeling complex materials, large assemblies as well as linear and nonlinear behaviors. The software allows the team to find the optimal layup of the composite laminates that function as the skin covering the wings. It also lets them simulate the wings' reaction to the various critical stress loads.

A comparison of the failure modes predicted by the FEA software and those discovered in the physical tests of the wing assembly's mockup, gave the engineers confidence in the design.

"In one of the destructive tests, the rib broke on the opposite side of the applied load, which made no sense," Umbricht says. "Most likely, it was because the stress flowed through the fixtures to the opposite side."

In Team Pie Aeronefs' experience with the UR-1, FEA software correctly predicted the global region of the failure, but the physical tests revealed the micro regions and specific modes of the failure.

Umbricht believes the key to lightweighting is the ability to accurately describe the operating conditions of the craft in the FEA software. The simulation is relatively simple for fixed-wing airplanes, as the operating conditions are well understood. Even edge cases, such as bird strikes, are well-known.

"For us, it came down to doing due diligence to find all the edge cases that are applicable to us, and designing the craft that can react to them," says Umbricht. 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

- **Air Race E:** airracee.com
- **Ansys:** www.ansys.com
- **Pie Aeronefs:** pieaeronefs.ch/en

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Match the **Workstation** to the **Workload**

As engineers return to the office, many firms are re-evaluating their computing requirements.

BY RANDALL S. NEWTON

When the pandemic first caused companies to shift to work from home, many engineering groups responded by deploying mobile workstations. Now that companies begin the shift back to office-based work, engineering teams are again evaluating what performance specifications they need as they upgrade or expand their workstation deployments.

"Everything has changed, and yet nothing has changed," says Christopher Ruffo, workstations segment lead at Lenovo for manufacturing and architecture. "What has happened in the past year is evolving into the new normal."

"Last year, laptop sales were higher," says Phil Lowrey, technical marketing manager at Boxx. "We resurrected remote power workstations. We didn't see a huge dip; customers still needed the power. Just more buys were put on hold for uncertainty."

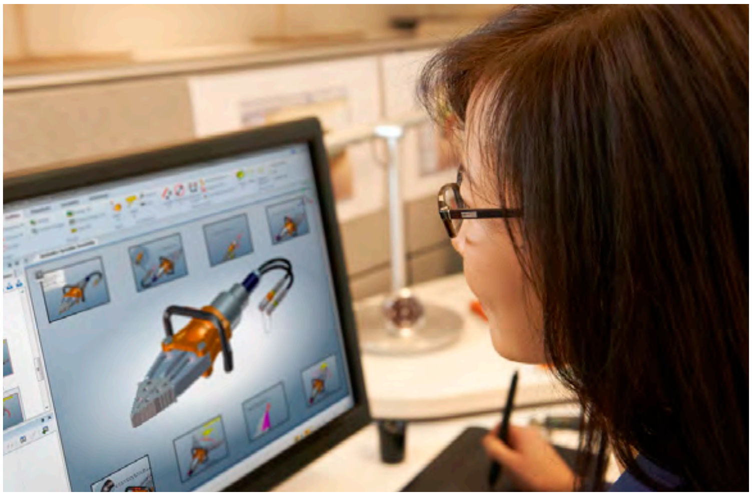
One trend that began before the pandemic and continues now is the increased use of simulation early in design. "We see users running complex simulations early in design," says Ruffo.

But not all simulation solutions need the same hardware specs. While most solvers rely on the CPU for most calculations, a few are now using graphics processing units (GPUs). Ansys Discovery Live, for example, uses NVIDIA RTX-enabled GPUs, while Ansys Mechanical is CPU based, and can use the larger amounts of memory only a CPU can handle.

Boxx's Lowrey sees the same trend in simulation. "We have a configuration of four GPUs into a dual-socket Intel Xeon, to run live simulations. It isn't a huge part of the market, but we have it and we understand the workflow."

"It is too early to know if desktops will be selling in the same volume [as before the pandemic]," says Matt Allard, industry strategist for manufacturing, engineering and media at Dell. "It is clear to us business has shifted to the mobile side. There is a dynamic in the industry; mobiles are now so powerful they are changing the nature of what can be accomplished. We are talking about the compute-heavy tasks previously reserved for desktop units."

Workstations with a high CPU core count are a better fit for complex simulations using products like Ansys Mechanical, than using clock speed as a power metric. *Image courtesy of Ansys.*



Workstation components should be matched to their primary task. Design work, such as in SolidWorks, does better with a faster CPU. Computational work, such as running simulations, benefit more from a CPU with many cores than from a high clock speed. *Image courtesy of Dassault Systèmes.*

"Our view is you align the machine with the workflow. That can be defined by software, but more often by the specific functions inside the software."

Rise of Threadripper

"Some solvers are very hash dependent, others are memory dependent," Ruffo notes. Lenovo says recent benchmarking with the new 64-core Ryzen Threadripper Pro CPU from AMD shows speed increases of around 25% for engineering solvers requiring multiple CPU cores.

Lenovo was the first major workstation vendor to offer a model that runs AMD's Threadripper Pro (3000WX Series). A few other vendors, including Supermicro, Velocity Micro and Puget Systems, are also offering workstations using this new CPU. Threadripper is based on AMD's Epyc server CPU, but designed for use in a single-CPU workstation. AMD says Threadripper Pro is the first workstation-specific CPU to support PCI3 4.0 for I/O, with 128 PCIe data lanes from the CPU.

The general availability of CPUs running NVIDIA RTX technology is also changing how workstations are deployed.

"It took a while for software vendors to fully support RTX," notes Allard.

Now that more professional products are supporting the accelerated raytracing in RTX, and taking advantage of its specialized cores for artificial intelligence and machine learning, sales of workstations with RTX technology are on the increase. RTX is now available on mobile workstations, further increasing demand.

Despite the unique nature of working during a pandemic, the larger trends around workstation use have not changed, says Scott Hamilton, a senior marketing operations manager at Dell.

"This happens [with] every generation of hardware we release. New platforms become more capable, lowering the barrier to entry," he says.

Three years ago, Hamilton says, Dell's Precision 3000 series mobile workstations were not popular for engineering. Today Dell's 3150 offers the NVIDIA RTX A5000 as a GPU option. "It becomes a very capable workstation for CAD and Ansys Discovery Live," says Hamilton. "What can be done on an entry-level workstation three years ago is very different from what can be done today."

It is not uncommon in smaller engineering firms that the most powerful computer goes to rendering, including augmented or virtual reality. The 64 cores available in the Threadripper Pro may attract such users, but what GPU should be matched with it? Is it only AMD or can it play nice with NVIDIA? Lenovo's Ruffo says they sell Threadripper Pro workstations equipped with either AMD Radeon Pro or NVIDIA RTX-enabled GPUs. NVIDIA's Ampere generation of GPUs offers PCI3 Gen 4, making it a powerful match for Threadripper.

The goal, Ruffo says, is to offer their customers "a graduation of power and price, from three to eight GPUs in a unit, as needed." Customers looking at such a workstation need to talk to their key software vendors to be sure they are getting the right hardware configuration for their needs.

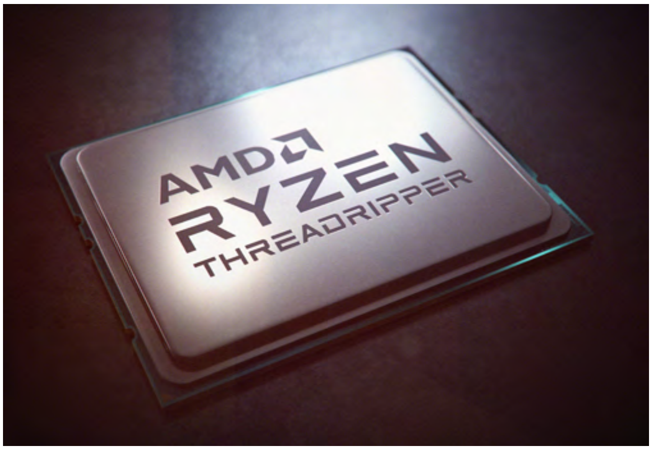
"Mixed reality rendering places tremendous demands on hardware," adds Ruffo, citing the popular Varjo mixed reality headset with its 20/20 eye tracking technology as an example of "driving the need for a powerful workstation."

More Cores or More Speed?

There are times when the purchasing decision swings on how many compute cores are required. Applications including Autodesk AutoCAD and Dassault Systèmes' SolidWorks are examples where clock speed is more important than many cores.

"We talk to our customers," says Dell's Hamilton. "We ask, 'Do you really need all those cores?' They might need super-fast single-threaded performance instead."

"We look at [engineering workload] as being in two main camps," Hamilton explains. Workloads are either interactive or computational.



AMD Ryzen Threadripper Pro is a 7nm CPU and the first workstation CPU to offer up to 64 cores. *Image courtesy of AMD.*

Interactive would include using drafting or modeling software, where there is constant user interaction with the software. Computational workloads include simulation and rendering, where the user sets up the job and it runs.

"These two usage scenarios help define the system you need," Hamilton says. Interactive workloads do better with low thread count and high clock speed; computational workloads do better with more cores. Hamilton says computation users can sacrifice a high clock speed for more cores.

"When someone does both, they have to balance it. Get a good base clock speed and match it with good turbo speed," he adds.

Workstation buyers need to be aware of instructions per cycle (IPC), notes AMD's Chris Hall, director of software performance engineering. "It is a measurement of how efficient a core is." Two competing CPUs running at 4 Mhz will not perform identically on standard benchmarks due to variations in IPC. "If you look at the frequency only, you miss the whole story."

Lenovo was the first major workstation provider with a model running AMD's Threadripper Pro. *Image courtesy of Lenovo.*

CAM toolpath calculations are another area where matching components in a workstation can make a big difference, Hall adds. "People don't think of toolpath generation as a pain point. But if you only have two days, can you look at 10 toolpath runs or 20?"

A more optimized production run saves CAM bit wear and improves tolerances. "The more time your computer gives you to do toolpath calculations, the more profitable your company will be," he says.

Despite the availability of powerful GPUs, CPUs are still popular for rendering. "You can't put a gig of memory on a GPU," notes AMD's Hall. Media companies still use CPUs for rendering because they need large amounts of memory. In product development, the beauty shot you render might run out of memory, which causes a performance drop. 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

- **AMD:** AMD.com
- **BOXX:** Boxx.com
- **Dassault Systèmes:** 3DS.com
- **Dell:** Dell.com
- **Intel:** Intel.com
- **Lenovo:** Lenovo.com
- **NVIDIA:** NVIDIA.com

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Lenovo ThinkPad P15 Gen 1: A High-End Price/Performance Leader

Lenovo's new 15-in. mobile workstation offers Ultra Performance Mode.

BY DAVID COHN

Last year, Lenovo launched the next generation of its ThinkPad P Series mobile workstations. While we have already reviewed several of the thin, lightweight computers in the new lineup, we recently received one of Lenovo's new ThinkPad P15 systems. The successor to the ThinkPad P53 (digitalengineering247.com/r/22766), the new P15 Gen 1 represents a complete re-engineering of many aspects of the company's full-size 15-in. laptop.

With enhanced thermal design, including a 30% larger CPU heat sink, larger vents and a new thermal mesh to dissipate heat faster, Lenovo claims that users can take full advantage of Ultra Performance Mode to harness more power from a ThinkPad P Series mobile workstation than ever before.

The new Lenovo ThinkPad P15 Gen 1 comes housed in a charcoal gray case with a top cover constructed of a mix of polyphenylene sulfide and glass-fiber material. The system measures 14.75x9.94x1.44-in. and our evaluation unit weighed 6.11 lbs., over 2 lbs. heavier than the ThinkPad P1 G3 we recently reviewed (DE; January/February 2021). The P15 system we received included a 230-watt power supply, which measures 6.62x3.44x1.0-in. and weighs 1.95 lbs. And of course, the lid features the Lenovo ThinkPad logo with its glowing red dot over the "I."

The base configuration of the ThinkPad P15 Gen 1 has a starting price of $1,420. That base system includes a 10th-generation Intel Core i5-10400H 4-core 2.6GHz processor, 8GB of DDR4 2933MHz RAM, a 256GB PCIe OPAL solid-state drive (SSD), an NVIDIA Quadro T1000 graphics processing unit (GPU), a full-high definition (FHD; 1920x1080) in-plane switching 300 nits display, a 720p webcam, a fingerprint reader, a backlit keyboard, Wi-Fi and Bluetooth 5.1, a 170-watt power supply and a copy of Linux, all backed by a one-year warranty. The same system with Windows 10 Home preinstalled starts at $1,507.

User-Friendly Keyboard and Dazzling Display

Lenovo keyboards have always offered perhaps the best typing experience available in any laptop, and the ThinkPad P15 is no exception. Raising the lid reveals a spill-resistant keyboard with 105 mostly full-size keys, including a separate numeric keypad. Two levels of backlighting can be toggled by pressing the Fn key and spacebar.

A round power button is located to the upper right of the keyboard and a 3.94x2.75-in. touchpad with three buttons is centered below the spacebar. There is also the familiar red Lenovo pointing stick nestled between the G, H and B keys. The caps lock key has its own LED, as do the keys dedicated to the speakers, microphone and number lock. A fingerprint reader is positioned below the cursor keys, while the Dolby Atmos speakers are located below a grille above the keyboard.

A narrow bezel surrounds the display panel, yet still provides space above the panel for the webcam, which includes a privacy shutter. Lenovo offers a choice of four different display panels, including a brighter (600 nits) FHD display and two different ultra-high-definition (UHD; 3840x2160) displays. All three higher-priced panels include Dolby Vision HDR. Systems equipped

Fig. 1: The Lenovo ThinkPad P15 Gen 1. *Image courtesy of David Cohn.*

with UHD panels also come with infrared cameras, and the top-of-the-line display uses OLED technology and is touch-enabled.

Plenty of Options

Lenovo offers eight different CPUs, including 2.6Ghz and 2.7GHz 6-core Intel Core i7 processors, two different 2.4GHz Core i9 processors, a 2.8GHz 6-core Xeon CPU and a 2.4GHz eight-core Xeon processor. The system we received came with an Intel Core i9-10885H, an eight-core 2.4GHz Comet Lake CPU with a maximum turbo speed of 5.30GHz, 16MB SmartCache and a thermal design power rating of 45 watts, which added $935 to the base price.

While the base configuration comes with just 8GB of RAM, the ThinkPad P15 Gen 1 can accommodate up to 128GB of memory. Our evaluation unit included 32GB, installed as a pair of 16GB 2933MHz small-outline dual in-line memory modules, which added $430. Systems equipped with a Xeon CPU can support error-correcting code (ECC) or non-ECC memory. A similar amount of ECC memory would cost $555.

The Lenovo ThinkPad P15 Gen 1 supports up to two solid-state hard drives. In addition to the 256GB OPAL SSD in the base model, Lenovo offers three other choices—512GB, 1TB and 2TB—for a maximum storage capacity of 4TB. The system we received included a single 1TB PCIe NVMe M.2 OPAL drive, which added $395.

Though the base configuration includes an NVIDIA Quadro T1000 with Max-Q, that is just the starting point. Lenovo offers four other NVIDIA GPUs, including the Quadro T2000 as well as three virtual reality-ready NVIDIA RTX graphics boards: the RTX 3000, RTX 4000 and RTX 5000. Our evaluation unit came with an NVIDIA Quadro RTX 5000 with Max-Q, a GPU with 16GB of discrete GDDR6 memory. This board features 3072 compute unified device architecture cores, 384 Tensor cores and 48 RT cores. Its 256-bit interface enables the GPU's 384GB/second bandwidth, while consuming 90 watts of power. This high-end board added $3,145 to the total system cost.

Because the ThinkPad P15 is a full-size mobile system, Lenovo is still able to include an ample assortment of ports. The right side includes a security lock slot, a USB 3.2 Type A port and a SD card slot. There is also space for a Smart card reader, a $10 option not included on our system. The left side

Mobile Workstations Compared

	Lenovo ThinkPad P15 Gen 1 15.6-in. mobile workstation (2.4GHz Intel Core i9-10885H 8-core CPU, NVIDIA Quadro RTX 5000, 32GB RAM, 1TB NVMe PCIe SSD)	**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)
Price as tested	$4,750	$3,737	$2,795	$3,999	$8,512	$5,219
Date tested	3/11/21	12/22/20	11/2/20	10/1/20	9/2/20	8/28/20
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	184.60	136.98	84.10	174.60	183.08	132.73
catia-05	302.43	187.62	140.38	256.00	109.70	173.75
creo-02	281.58	162.14	113.82	233.21	178.81	159.58
energy-02	42.73	26.80	17.60	40.50	19.94	29.78
maya-05	285.55	159.19	115.32	228.70	249.96	153.66
medical-02	114.71	68.57	50.96	103.67	53.19	73.08
showcase-02	100.73	63.54	44.65	95.62	101.02	74.54
snx-03	637.86	188.18	147.97	291.91	15.25	189.01
sw-04	185.32	132.38	105.23	156.49	87.13	110.18
SPECapc SolidWorks 2015 (higher is better)						
Graphics Composite	5.83	4.64	2.82	5.43	n/a	3.82
Shaded Graphics Sub-Composite	3.84	2.65	1.43	3.36	n/a	1.94
Shaded w/Edges Graphics Sub-Composite	4.67	3.61	2.04	4.25	n/a	2.88
Shaded using RealView Sub-Composite	4.40	3.34	1.92	3.92	n/a	2.62
Shaded w/Edges using RealView Sub-Composite	5.10	4.05	2.54	4.69	n/a	3.47
Shaded using RealView and Shadows Sub-Composite	5.03	3.83	2.21	4.49	n/a	3.04
Shaded with Edges using RealView and Shadows Graphics Sub-Composite	5.34	4.26	2.70	4.94	n/a	3.67
Shaded using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	14.87	12.92	7.35	15.06	n/a	9.86
Shaded with Edges using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	14.50	12.67	7.82	14.68	n/a	10.68
Wireframe Graphics Sub-Composite	4.16	3.74	3.08	4.08	n/a	3.85
CPU Composite	3.62	3.73	3.45	7.13	n/a	3.55
SPEC Workstation v3 (higher is better)						
Media and Entertainment	2.51	1.64	1.72	2.33	3.43	2.20
Product Development	2.52	1.76	1.80	2.38	1.56	2.29
Life Sciences	2.41	1.63	1.52	2.35	2.91	2.15
Financial Services	1.92	1.26	1.31	1.76	4.72	2.13
Energy	1.62	1.14	1.02	1.50	2.33	1.43
General Operations	1.88	1.53	1.96	2.07	2.15	1.92
GPU Compute	3.55	3.00	1.85	3.61	3.77	3.09
Time						
AutoCAD Render Test (in seconds, lower is better)	32.00	45.70	43.70	28.70	27.10	35.60
Battery Life (in hours:minutes, higher is better)	4:42	8:53	7:04	9:50	0:55	10:30

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

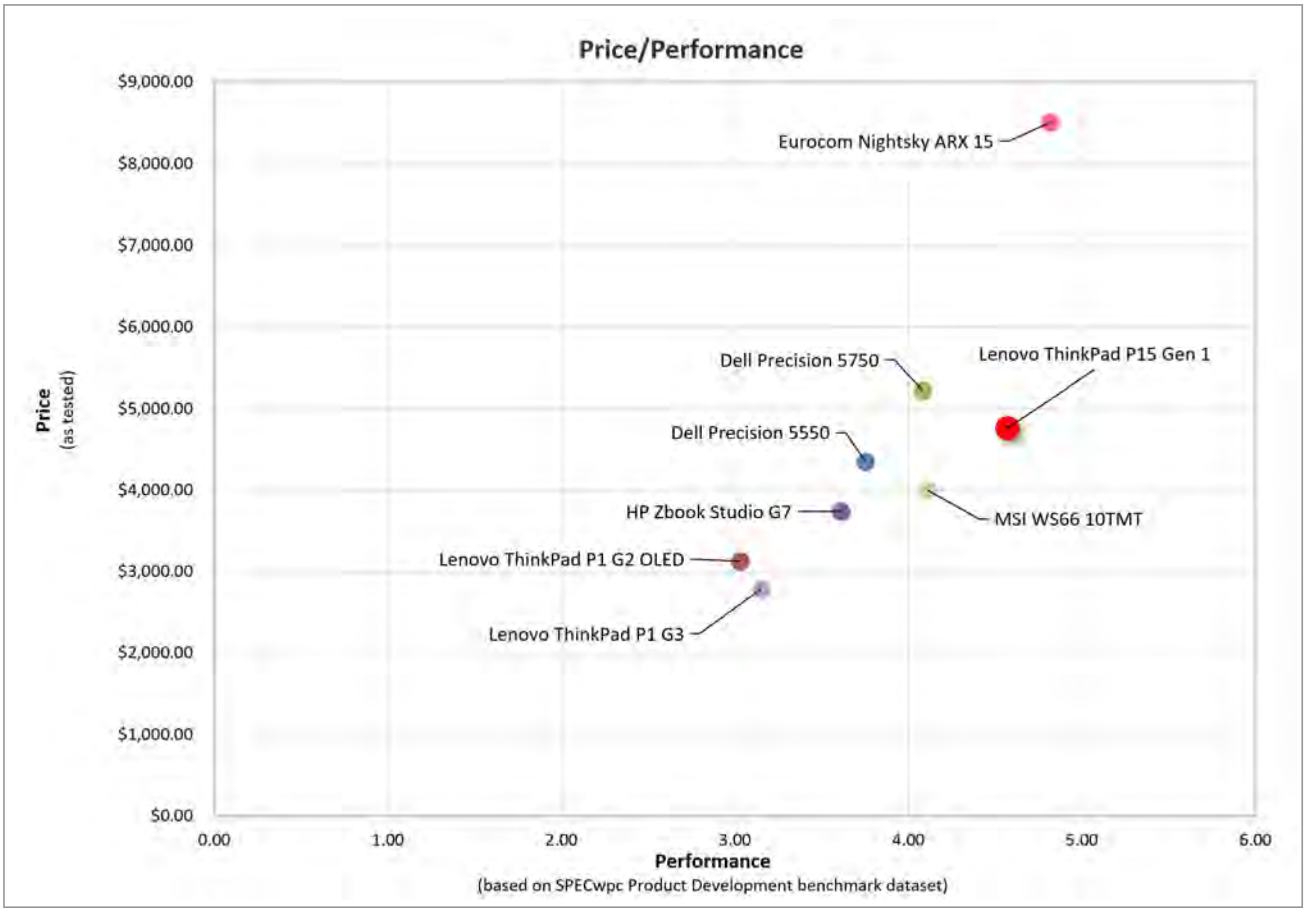

Fig. 2: Price/Performance chart based on SPECwpc Product Development benchmark dataset.

provides an HDMI port, an always-on USB 3.2 Type A port, a headphone/microphone combo audio jack and space for an optional Nano-SIM card. The rear of the case includes a full-size RJ-45 Ethernet port, a USB 3.2 Type C port, a pair of Thunderbolt 3 USB-C ports and the power input.

All Lenovo ThinkPad P15 Gen 1 systems include an Intel Wi-Fi AX201 802.11ax adapter plus Bluetooth 5.1 and a 6-cell 94Whr battery with Lenovo's Rapid Charge technology that can bring the system back up to 80% capacity in just an hour. The battery kept our evaluation unit running for 4.7 hours on our battery run-down test, while running entirely on the discrete graphics. Better battery life can be achieved by using a combination of discrete and integrated graphics (which must first be toggled on in the BIOS). The system remained cool and relatively quiet throughout our tests, reaching 55dB when under heavy compute loads.

Record-Setting Performance

We have come to expect excellent performance from Lenovo mobile workstations, and the ThinkPad P15 Gen 1 continues that tradition. On the SPECviewperf test, which focuses almost exclusively on graphic performance, the ThinkPad P15 Gen 1 outperformed every other mobile workstation we have tested to date on nearly every dataset. Although it did not set top marks on the SPECapc SolidWorks benchmark, the P15 Gen 1 still ranked near the top on every aspect of this test.

The Lenovo ThinkPad P15 Gen 1 also performed very well on the SPEC workstation benchmark, including delivering top scores in the Product Development category, most important for most DE readers. While the 32-second average to complete our AutoCAD rendering could not beat the 27.1-second mark set by the Eurocom Nightsky ARX 15 (digitalengineering247.com/r/24769), the Lenovo ThinkPad P15 Gen 1 ranks as one of the fastest mobile workstations we have ever tested.

Our evaluation unit came with Window 10 Pro preinstalled, which added $70 over the cost of Windows 10 Home. Since the standard warranty only covers the system for one year, with depot carry-in service, our as-tested price of $4,750 includes an additional $93 to extend the warranty for an additional two years. Other

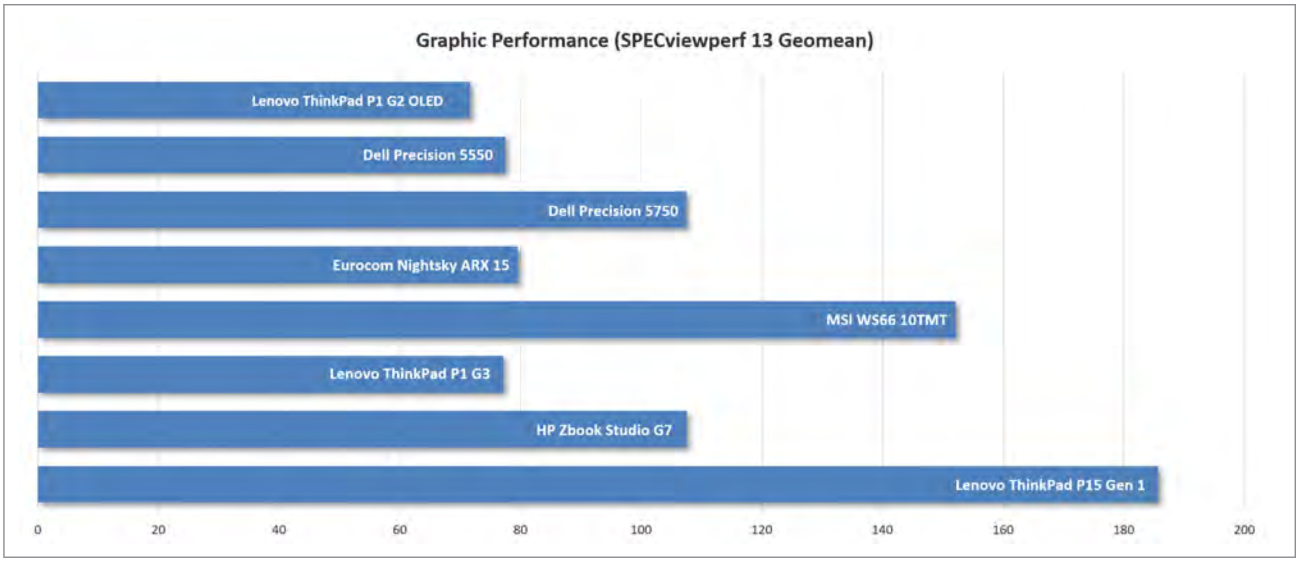

Fig. 3: Graphic performance chart based on SPECviewperf 13 Geomean.

warranty options include warranties of up to five years as well as onsite repairs and premier support for one to five years. Lenovo also offers accidental damage protection and battery replacement warranties.

The Lenovo ThinkPad P15 Gen 1 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. Though its high-end RTX 5000 GPU makes this one of the more expensive mobile workstations we have tested recently, it outperformed systems costing thousands of dollars more. Once again, Lenovo has delivered a system offering a portable solution for engineers needing a high-end, full-size mobile solution. DE

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→ MORE INFO

- Lenovo.com/thinkstation
- **Lenovo ThinkPad P1 Gen 3 OLED**

Price: $4,750 as tested ($1,507 base price)

Size: 14.75x9.94x1.44-in. (WxHxD) notebook

Weight: 6.11 lbs. (plus 1.95-lb. external 230-watt power supply)

CPU: Intel Core i9-10885H 2.4GHz 8-core w/ 16MB cache

Memory: 32GB DDR4 at 2933MHz

Graphics: NVIDIA Quadro RTX 5000 w/16GB GDDR6 and 3072 CUDA cores

Camera: 720p with infrared

Storage: 1TB Toshiba M.2 PCIe NVMe

Audio: Built-in Dolby Atmos speakers, microphone/headphone jack, built-in microphone array

Network: Intel Wi-Fi 6 AX201 802.11ax plus Bluetooth, full-size RJ45 Ethernet port

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

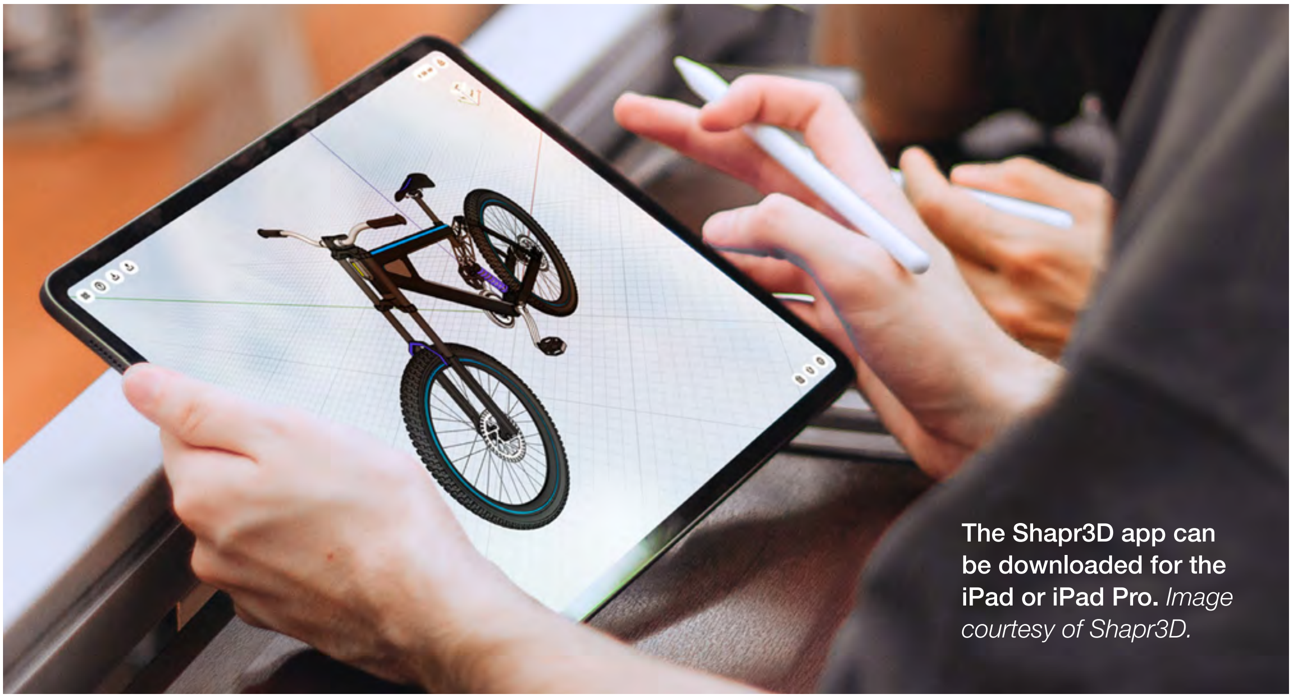
Shapr3D Unites **Modeling Rigor** with **Sketching Simplicity**

iPad modeling tool leverages the Apple Pencil for a smooth UX.

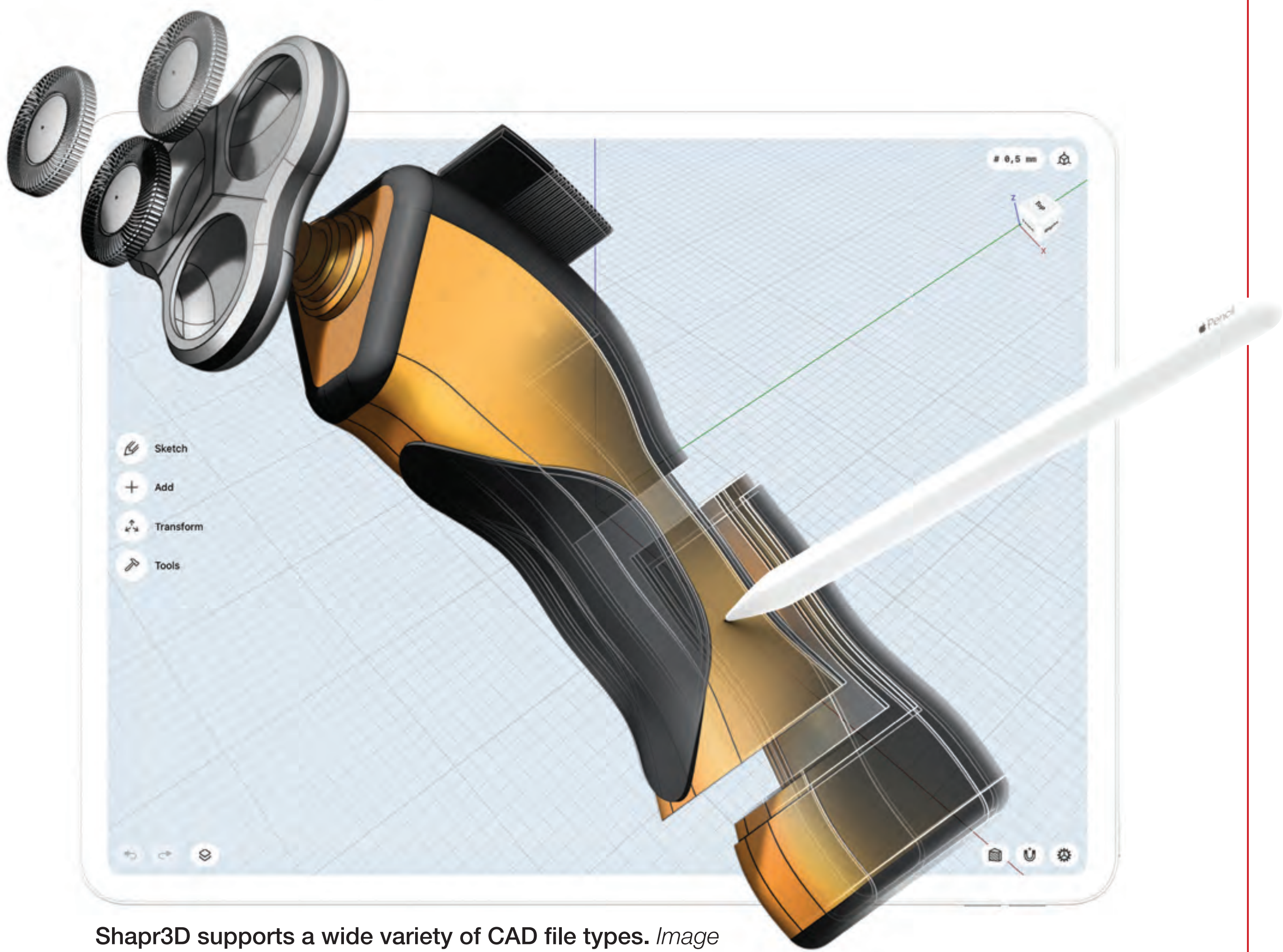
BY RANDALL S. NEWTON

Shapr3D offers a unique value position, something every vendor wants to proclaim but few really deliver. This 3D modeling app for iPad and MacOS offers quick, precise solid model sketching. These models can then be exported into a standard MCAD tool for a full engineering workup.

This review focuses on the iPad version. *Digital Engineering* considers the MacOS version adequate and useful, but once you've experienced Shapr3D with Apple Pencil on the iPad Pro, it is less likely someone would also want the Mac version, with the possible exception of using Mac-based Shapr3D to touch up a model created on the



The Shapr3D app can be downloaded for the iPad or iPad Pro. *Image courtesy of Shapr3D.*



Shapr3D supports a wide variety of CAD file types. *Image courtesy of Shapr3D.*

iPad or in another CAD product. Shapr3D waited until the release of the first MacBook running Apple's new M1 CPU.

Pairing the simple Apple Pencil with Shapr3D's intuitive approach to solid modeling offers a singularly unique mechanical design experience. Yes, you can draw in any MCAD, but only Shapr3D makes it feel pencil-and-paper natural to do it in 3D.

To get started takes only a little longer than installing a social media app. Start with the free version. Follow the guided, industry-specific tutorials and sketch an idea or two for yourself. Once you are hooked, you can upgrade in the app to the full version ($239 per year).

Under the Hood

Shapr3D creates solids but uses direct modeling instead of parametrics to create and display geometry. Constraints are available, but they are used to aid modeling, not control the geometry.

To start from scratch, use either a 3D primitive or create a 2D outline shape, then sweep, revolve or pull to create the 3D shape. There is a clever bit of artificial intelligence behind the scenes to make Shapr3D adaptive and predictive, so it always displaying the next logical step.

Under the hood, Shapr3D uses industry-leading components including Siemens D-Cubed for constraint management; Siemens Parasolid for 3D modeling; and TechSoft 3D HOOPS Exchange for file interoperability.

Siemens commented when Shapr3D was released that "working closely with Shapr3D accelerated our release of Parasolid on iOS."

Thanks to HOOPS Exchange, the list of supported file types is long. The application supports a wide variety of CAD file types, vendor-specific and neutral. Other file types include various raster and vector 2D; STL and OBJ for 3D printing; and USDZ for virtual reality. An augmented reality preview can be created from within the app. Shapr3D also allows importing photos and taking a snapshot with the iPad's camera. Shapr3D supports Apple AirDrop for fast import from other apps on the device or from other Apple devices.

Shapr3D is not the first mobile CAD app, but it is the

Supported Formats

FORMAT	IMPORT	EXPORT
X_T (Parasolid)	✓	✓
STEP	✓	✓
IGES	✓	✓
SLDPRT	✓	✗
SLDASM	✓	✗
STL	(reference only) ✓	✓
SHAPR	✓	✓
OBJ	✗	✓
DWG	✓	✓
DXF	✓	✓
PNG	✓	✓
JPG	✓	✗
PDF (single or first page only)	✓	✓
TIFF	✓	✗
BMP	✓	✗
ICO	✓	✗
RAW	✓	✗
GIF (not animated)	✓	✗
USDZ	✗	✓

Shapr3D uses HOOPS Exchange from TechSoft 3D for file import/export, allowing for a long list of supported formats. *Image courtesy of Shapr3D.*

first one to make everything local to the iPad (or Mac). There is no mandatory connection to a cloud server to load a model or render your designs. The app works off-line just fine.

"While most of our users have been professionals such as product designers, engineers, architects, jewelry designers and 3D printing hobbyists, we also have users from MIT, Harvard, Stanford, Berkeley, Duke, Columbia, Cambridge, University of Tokyo, Singapore Polytechnic and many other schools worldwide," says István Csanády, Shapr3D CTO. Shapr3D offers the pro version at no cost to educational users. The company knows of more than one user who has gone from art to part, Shapr3D to 3D printer, without using any other app.

Initial development was slow, Csanády notes, because they discovered what others before them already knew.

"After years of research, we found that touch screens are not optimal for precise engineering." The game changer was Apple Pencil 1.0. "The key to success was to integrate the Apple Pencil's pixel-perfect precision and the touch-based user interface," he adds.

The $239 (USD) for a year's subscription makes this an easy purchase decision. Needing an iPad Pro with Apple Pencil raises the stakes a bit. The loaner unit we used for the review is the 11-in. model with 512 GB storage and Apple Pencil, which lists on Apple's web-site for $1,228. A 12.2-in. model is also available.

The free version of Shapr3D is available on the Apple App Store; you can upgrade to the professional version to unlock extra features. **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.*

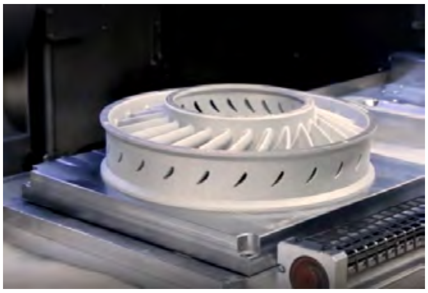
→ MORE INFO

- **Shaper3D:** Shaper3D.com

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.



Decrease Supports in Metal Additive Manufacturing

Delve into 3D Systems' NoSupports design methodology.

3D Systems' NoSupports™ is an innovative way to design for metal additive manufacturing that removes the need for supporting material to be printed with parts. 3D Systems says new printing strategies, when used in the company's 3DXpert© software, provide advanced capabilities to "expand the design envelope" and make it more likely AM can be used for metal part manufacturing. Two key concepts provide the foundations for NoSupports: multi-exposure and thermal blades.

MORE ➜ digitalengineering247.com/r/25363

Explore new multi-material 3D printing capabilities

J35 Pro and J55 Prime are compatible with Stratasys GrabCAD Print utility.

Stratasys unveils two multi-material PolyJet printers. J35 Pro is the first Stratasys multi-material printer designed for desktop use. J55 Prime extends capabilities of the 2020 Stratasys J55 to enable use of new materials. The company also debuts two software utilities that work with multiple Stratasys printers. One assists in making high-fidelity packaging prototypes, the other "unlocks" the capabilities of the printer to allow for advanced printing abilities.

MORE ➜ digitalengineering247.com/r/25347

GPU Redesign Lowers Power Consumption

AMD's RDNA 2 Architecture has enhanced compute units with Ray Accelerators.

AMD unveils the W6000 line of advanced workstation GPUs for engineering and design applications. The line has RDNA 2 Architecture, which offers speed and lowers power consumption. AMD says the three GPUs debuted can power demanding engineering workloads and create high-resolution renderings. Units are: Radeon PRO W6800; the Radeon PRO W6600 GPU for mainstream CAD applications; and Radeon PRO W6600M, for mobile workstations.

MORE ➜ digitalengineering247.com/r/25321

Creation of Digital Twins for Virtual Commissioning

MapleSim Insight features offer enhanced simulation-based 3D visualization.

The new Maplesoft solution is based on upgrades to MapleSim Insight and MapleSim, the company's simulation family of products. The company says it now offers an approach to virtual simulation that is "highly accessible even to organizations that have no experience with modeling and simulation using digital twins."

The simulation engine runs faster than in previous versions, and there are new options for creating 2D plotting and 3D visualizations.

MORE ➜ digitalengineering247.com/r/25293

Explore Components for Custom HPC Workstations

PSSC Labs says it builds technology for visionaries seeking handcrafted solutions.

PSSC Labs offers the latest Intel and AMD CPUs for its line of Axceleron HPC/AI workstations.

The newest AMD Epyc CPU is the "Milan" generation. It offers scaling from eight to 128 cores, and up to 16 double-precision FLOPS per cycle per core. These come with up to 32 MB of L3 cache per core, and up to 256 MB L3 cache per CPU. Most models in the Milan line offer at least 1 TFLOPS. PSSC Labs says it matches the right Milan Epyc to customer applications.

MORE ➜ digitalengineering247.com/r/25268

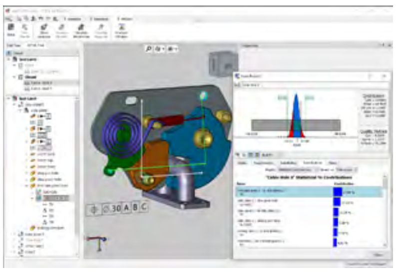
Empower MCAD/ECAD Use With Altium CoDesigner

MCAD/ECAD capability keeps electronic and mechanical designs in sync.

With Altium's CoDesigner capability, electrical and mechanical engineers can communicate directly while working in their own design environments, pushing and reviewing changes bi-directionally in real time. To access CoDesigner, mechanical engineers download a free plug-in for their MCAD tool and keep working with native assemblies without leaving their MCAD environment.

Once ready to share, designers can push/pull changes from MCAD tools into the Altium ECAD space.

MORE ➜ digitalengineering247.com/r/25242



Increased Utility for Tolerance Analysis

Designers and engineers monitor what tolerance changes will have on assembly.

Sigmetrix released *CETOL 6σ*, its solution for tolerance analysis. The company says with *CETOL 6σ* there is faster time to market by reducing the need for more design and prototype cycles.

Sigmetrix says engineering and manufacturing teams use the solution to help maximize return on work in model-based design and model-based engineering; enable more innovative product design; and facilitate the capture, transfer and retention of critical product and process knowledge.

MORE ➜ digitalengineering247.com/r/25218

New Additive Manufacturing Process for Wood

Forust wood additive manufacturing re-materializes functional wood products.

Desktop Metal launches Forust, a process to sustainably produce functional end-use wood parts using existing additive manufacturing technology. The company says the Forust process "upcycles" waste byproducts from wood manufacturing (cellulose dust) and the paper industry (lignin), re-materializing functional wood products. Wood parts and products can be made with geometries and structural characteristics unavailable using traditional subtractive wood manufacturing processes.

MORE ➜ digitalengineering247.com/r/25190

Next-Gen Engineers

Student Competition Profile: Base 11 Space Challenge

Eyes on the Sky

BY JIM ROMEO

The Base 11 Space Challenge is a competition that motivates universities to bolster their rocketry programs and empower students to learn far more than liquid propulsion system theory by providing access to resources and to world-class experts.

The team designed and fabricated components for an industrial-scale rocket. *Image courtesy of TREL.*

Students acquire expertise in rocket safety and learn how to navigate flight regulations. Teams are encouraged to conduct outreach and provide mentorship to an array of community college and high school students to better develop the STEM (science, technology, engineering and mathematics) talent pipeline.

Members of the Texas Rocket Engineering Lab (TREL) at the University of Texas Cockrell School of Engineering designed and fabricated components for an industrial-scale rocket for their entry in the race to be the first team to design, build, launch and recover a liquid-fueled, single-stage rocket to an altitude of 100 km.

We spoke to Chase Holder of the University of Texas to learn more about their design. Holder is an aerospace engineering major and propulsion engineer for the TREL.

***Digital Engineering:* Can you provide an overview of the Base 11 Challenge?**

Chase Holder: The Base 11 Space Challenge is an international engineering competition to be the first college organization to design, manufacture and launch the first liquid bipropellant rocket past the edge of space by the end of 2021. The Karman Line, the official 100 km high boundary of space, is over 30 times higher than the previous record for collegiate liquid rocketry.

For TREL, this will require over three years of work by more than 300 engineers, artists, communicators and business professionals to complete.

***DE:* Can you tell us about your rocket design and how it came to be?**

Holder: The rocket was designed first and foremost with the mission of delivering a payload past the Karman line. The design of every subsystem has always ultimately been guided by this need. The size and mass of the rocket, the choice of fuels and the thrust of the engine all come from our desired payload mass.

At 30 feet tall and 2,600 pounds, this is one of the largest bipropellant collegiate rockets ever created and the engine, Havoc, delivers 3,500 pounds of thrust. The design of the engine was aided in large part by EOS because, historically, manufacturing rocket engine thrust chambers has been one of the most difficult and unreliable parts of the process. The EOS Additive Minds team provided us with 3D design and production support so we could create the engine with fewer pieces and more reliable hardware. We're also working with EOS to produce the aerodynamic fins that will control the rocket in flight as they present more complex design options.

***DE:* How is adopting technological innovation linked to the program?**

Holder: The use of additive manufacturing in rocket engines is a recent development that allows us, even as a small entity within the space of rocket propulsion, to participate and even add to this very exciting field. New materials, manufacturing processes and design techniques are being developed daily for engines now thanks to direct metal laser sintering. We have been able to take full advantage of this in our chamber and cooling channel design by using the EOS M400 to manufacture the components of the engine.

By using additive manufacturing techniques, we can have faster design iterations with testing coupons and full-scale designs, ensure quality control at the most stringent aerospace standards and make use of cutting-edge copper alloys that are less expensive and can handle the heat of our engine. Through additive manufacturing, we will be able to design the most advanced collegiate rocket ever built and break down barriers to space for people of all backgrounds. DE

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

MORE INFO →

- **Rocket Test Video:** bit.ly/2TSmF7q