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Digital Engineering

September 2020

Self-Driving Design

- NEXT-GEN AUTO SIMULATION
- CONNECTED CARS AND THE DIGITAL THREAD
- AV DESIGN CHALLENGES

Peerless MEDIA, LLC

| **DEGREES OF FREEDOM** |

By Brian Albright

Dog Days, Indeed

THE SUMMER is winding down as I write this, and we have experienced roughly our third significant heat wave in Ohio. Reminded that we were in the "dog days" of summer, I did a quick search to remind myself why we call them the "dog days" in the first place. It's because of the position of the dog star, Sirius, marking the hottest days of the year, which the ancient Greeks and Romans believed could portend fevers and catastrophes.

Not exactly what I needed to hear in 2020. Uncertainty is still clouding most industries, but there are some silver linings here and there.

In addition to higher temperatures, August also brought the latest round of 2nd quarter financial reporting. In the vendor community, the news has been mixed. While a few CAD and simulation software providers have taken a hit, most are weathering the pandemic as well as could be expected, and a few are seeing increased interest in their cloud or software-as-as-service solutions. Mobile workstation vendors have seen an uptick in demand in some markets. The 3D printer space has probably been affected most significantly, with many vendors reporting year-over-year revenue drops of 20% or more. Two of the biggest names in the space, 3D Systems and Stratasys, announced major restructuring (see page 8). There have been a few mergers. I expect we'll see more announcements as we head into the fall.

For engineering firms, the outlook has also been mixed. Organizations that specialize in sectors like hospitality, retail, aerospace, automotive or construction have seen demand contraction and, in some cases, chaotic market conditions. Most companies have successfully transitioned to remote work, but are bracing for a drop in demand.

What does this mean for engineers moving forward? The current pandemic is expected to increase adoption of automation technologies and digitalization. In some cases, that is because manufacturers have had to rethink how their facilities are arranged to accommodate worker distancing. In others, companies are trying to address vulnerabilities in their supply chains that were exposed by current events. Some companies have found that being forced into digital collaboration has helped accelerate some product development processes.

Designers and engineers who have both embraced these technology solutions internally to enhance and accelerate their own development cycles, and those who are designing products that will help their customers do the same, will have an edge in both the near term and the long haul.

This issue is focused on the design and development of autonomous and electric vehicles. The automotive industry was already at a crossroads prior to COVID-19. OEMs are facing a future in which people buy fewer cars and use them in new ways (i.e., ride sharing, or short-term rentals in urban environments). Despite economic conditions, automakers have continued to push forward on creating viable self-driving cars to help meet the evolving needs of their customers.

Our team of writers has taken a look at the design challenges involved, and how simulation will play an even larger role in vehicle development. We also examine how connected cars will tie into the digital thread, and how virtual reality is being leveraged. Senior Editor Kenneth Wong even takes a look at a unique problem for electric vehicles: without engine noise masking other sounds, what new acoustic design challenges will automakers face?

We hope you enjoy the issue. As always, feel free to reach out via email or on our website to share your thoughts and feedback. In the meantime, try to stay cool, stay positive and stay safe. **DE**

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INSIDE

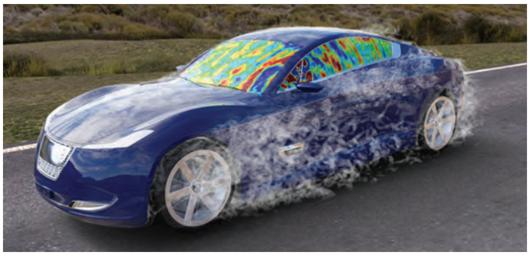
COVER STORY

FOCUS ON AUTONOMOUS VEHICLES

DESIGN

AUTONOMOUS VEHICLES

SIMULATION



DIGITAL THREAD

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ON THE COVER: Designed with image courtesy of Ansys.

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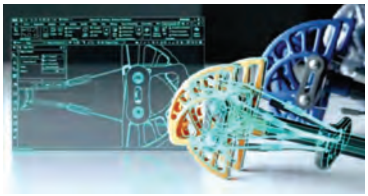

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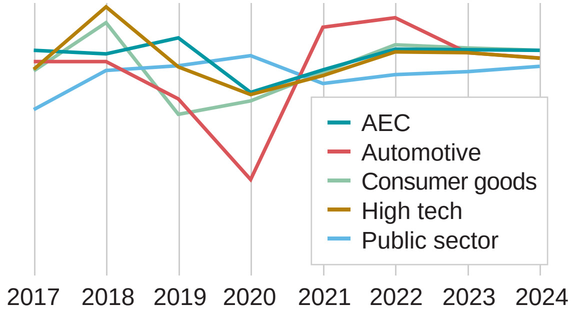
CAE Data and Forecasts

CAE Software Market Growth for Selected Industries



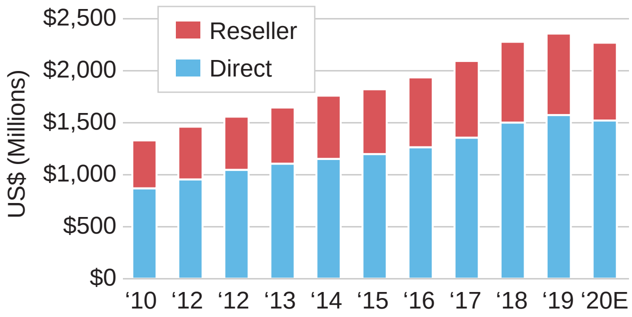
Source: Cambashi Ltd., 2020

Cambashi and intrinSIM have released COVID-19-adjusted CAE and simulation market data and forecasts. The adjusted figures indicate the CAE market has been **growing by double digits** and will continue to do so, excluding 2020.

> *"While **2020** will present lower growth rates, and Cambashi expects negative growth from, e.g., the automotive industry, growth overall is still expected to be positive."*
>
> ***–PETRA GARTZEN, senior consultant, Cambashi***

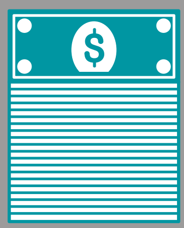
CAM Software and Services Growth

The worldwide market for CAM software and services grew **3.9%** in **2019**, according to the 2020 CIMdata CAM Market Analysis Report (MAR). The estimated end-user payments grew from just under **$2.3 billion** in **2018** to nearly **$2.4 billion** in **2019**. However, CIMdata projects that in 2020 the CAM market will be strongly impacted by the COVID-19 pandemic. End-user payments for CAM software could decrease by **3.7%** to just under **$2.3 billion**.



> *"The CAM results at the end-user level were lower in **2019** than their historical range of **5%** to **7%** growth. There has been weaker growth in machine tools for two consecutive years, which could be inhibiting new investments in new CAM software."*
>
> ***– STAN PRZYBYLINSKI, CIMdata's vice president***

$30 BILLION

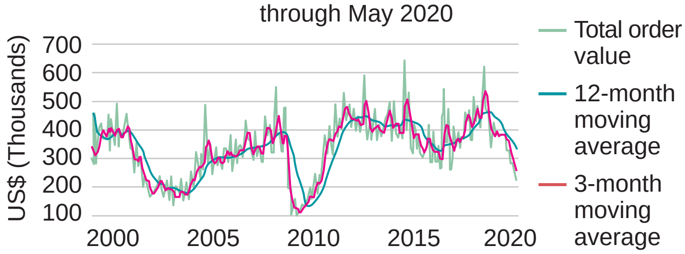


Value of the augmented and virtual reality (AR/VR) market by **2030**, according to IDTechEx. According to "*Augmented, Mixed and Virtual Reality 2020-2030: Forecasts, Markets and Technologies*," the use of virtual communication and interaction will be even more important in the wake of the COVID-19 pandemic.

U.S. manufacturing technology orders decreased **5%** in May from the previous month to **$219.4 million**, according to the latest U.S. Manufacturing Technology Orders report published by the Association for Manufacturing Technology. New orders were **45%** lower than in **May 2019**, and total orders through **May 2020** were **$1.3 billion, 31%** lower than year-to-date **2019** orders.

Total U.S. Manufacturing Technology Orders

through May 2020



NEWS

3D PRINTING

Restoring Vintage Cars with 3D Printing

Polish firm uses Zortrax 3D printers to make hard-to-find car parts

BY KENNETH WONG

If you own a vintage car from before World War II, chances are, you don't have the option to go online and order a replacement part you need to repair or restore your classic beauty.

This is a specialty of ABcar Oldtimers, a Polish firm that restores cars from the bygone eras. With 15 years under their belt, its engineers have fully restored a Corvette C1 and a Mercedes 190SL; they have also transformed a Porsche 911 into a 911 RS, and a Ford Mustang 1966 into a GT350H.

To solve some of the toughest challenges posed by the clients, ABcar Oldtimers employs a very modern technique—3D printing, powered by printers from Zortrax.

For example, "the thin needles in the display of tachometers and speedometers mounted in the vehicles provided by Mercedes Benz were beautifully crafted with a crescent moon at their tips. These are no longer produced. It is possible to order similar ones cut with a diamond blade. However, they would be shaped in a standard pattern, losing the unique spirit provided by the crescent moon. Thanks to Zortrax Inkspire printer, we can recreate such elements in a few minutes. In addition, we can customize their thickness and length to specific meters. The needles that come out of the printer are the ultimate elements of the equipment in cars we produce," according to Bartłomiej Błaszczak, director of design and engineering, ABcar Oldtimers.

ABcar Oldtimers relies on 3D printers from Zortrax to restore vintage cars with discontinued spare parts.

To restore a Ferrari 599's steering wheel with embedded diodes, ABcar Oldtimers used Zortrax's resin-based 3D printer Inkspire. *Images courtesy of Zortrax.*

One satisfied customer of ABcar Oldtimers is Patryk Mikiciuk, a Polish journalist covering the automotive industry. He asked the firm to restore a damaged Ferrari 599 in time for a TV show. A particularly pesky part of the repair job was the steering wheel.

"In a 599, there is a system of diodes on top of the steering wheel that light up whenever the engine revs are high enough to shift gears," explained Błaszczak.

To reproduce this feature, ABcar Oldtimers relied on a Zortrax printer capable of printing in resin. "It was quite hard to find the material with similar properties, which at the same time would give you the look and feel of the original Ferrari part. So, we just 3D printed it on the [Zortrax] Inkspire," says Błaszczak.

The Inkspire printer is described as capable of surgical precision—50x50 microns with minimal layer height of only 25 microns.

"The black resin, when applied in relatively thin parts, exhibits limited light-transmitting properties. Basically, the part designed and 3D printed to mimic the geometry of the original Ferrari cover looked the same when the diodes on the wheel were lighting up," wrote Zortrax in a blog post about the project. DE

3D PRINTING

3D Systems Reorganizes, Retrenches

Company to cut workforce by 20%, seeks to reduce costs by $100 million.

3D Systems has announced significant budget and staffing cuts as part of a wide-reaching effort to reorganize and restructure. The company made the announcement on Wednesday as it released disappointing Q2 financial results.

The company's revenue for the second quarter of 2020 was down 28.7% compared to the same period in 2019, and fell 16.8% compared to the first quarter of this year. According to the announcement: "The lower demand was across all products and services due primarily to the COVID-19 pandemic, as many customers were shut down or on a significantly reduced level of activity. Revenue from Healthcare decreased 11.4% to $50 million, compared to the same period last year, driven by the decrease in the dental market. Industrial sales decreased 38.5% to $62.1 million, compared to the same period last year, as decreases were in all products, materials and services across all geographies."


Jeffrey Graves, 3D Systems president and CEO. *Image courtesy of 3D Systems.*

"Our results in the second quarter reflect continued impact from the COVID-19 pandemic; however, the pandemic has also demonstrated a clear role for flexible supply chain enabled by additive manufacturing, particularly in the medical field, which speaks to our unique capabilities as a provider of hardware, software, materials and services to drive application-specific solutions," said Jeffrey Graves, president and CEO. Graves joined the company in May.

The company plans to focus its sales efforts on the health care and industrial markets.

"We will focus on markets and applications where a premium is placed upon performance and reliability; with engineering/technology cultures that seek product innovation as a means of delivering value to their customers; and with processes that tend to be highly controlled," Graves said. "Thanks to our unique offering of hardware, software, materials and services, combined with our leadership in application knowledge, we believe we are best-positioned to provide additive manufacturing solutions for specific, high-value applications in growing markets like health care, aerospace and defense. We have a demonstrated capability to be successful in these markets, with our technologies and process knowledge today enabling up to half-million production parts to be made through additive manufacturing each day."

As part of the resizing effort, the company plans to reduce annualized costs by approximately $100 million by the end of next year. That includes a 20% workforce reduction that will be completed by the end of 2020.

Other cost reduction efforts include reducing the number of facilities and "examining every aspect of the company's manufacturing and operating costs." The company is also evaluating the divestiture of parts of the business that do not align with its strategic focus.

In order to increase the company's liquidity and flexibility, the Board of Directors has also approved an at-the-market equity program ("ATM Program") that allows 3D Systems to issue up to a total of $150 million of shares of the company's common stock to the public, at the company's discretion.

As of June 30, 2020, the company had cash on hand of $63.9 million, total debt of $21.5 million and a $100 million unused revolving credit facility with approximately $24 million of availability based on the terms of the agreement. Cash on hand decreased $69.7 million since December 31, 2019.

In June, competitor Stratasys announced a similar restructuring, including a 10% workforce reduction and a $30 million reduction in operating expenses. DE

Riding the Virtual Road

Autonomous vehicle simulation shortens development cycles, reduces costs and makes cars and trucks safer.

BY KIP HANSON

Hats off to those riding shotgun in the self-driving test vehicles operated by Lyft, Uber, Argo AI and other autonomous vehicle (AV) adoption pioneers. With their eyes on the road and hands at the ready, these brave souls are paving the way toward a more efficient future—one where commuters can avoid wasting time behind the wheel each day, where accidents and traffic jams are ancient history and where individual car ownership will likely become obsolete.

Unfortunately, these manual testing efforts are doomed to failure, according to Sandeep Sovani, director of advanced driver assistance systems (ADAS) and autonomy at Ansys.

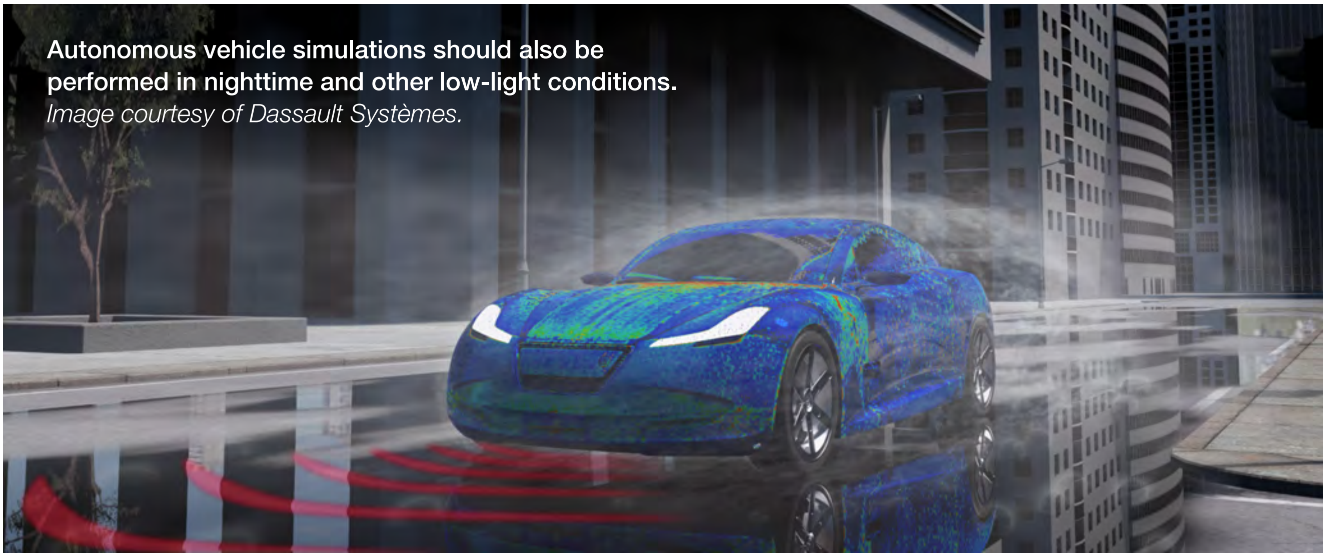
Sovani suggests that without comprehensive simulation tools like those found in Ansys Autonomy, this glorious future is 26,400 years away.

"That's how long it will take for traditional road testing to log the 8.8 billion miles needed to make self-driving cars a reality," he says. "Simulation offers tremendous advantages over the current testing methods and can reduce that by a factor of a hundred or maybe a thousand, which would mean two and a half years to get where we need to be."

Another and perhaps more important advantage is simulation's ability to test the scenarios that drivers most want to avoid, such as icy road conditions or collisions with pedestrians and other vehicles. These are dangerous, potentially life-threatening events in the real world; in the virtual one, they're no big deal. Sovani refers to this as one of simulation software's superpowers, in that it can go places and do things that no human driver would dare attempt, as well as see things invisible to the human eye.

"Simulation allows an engineer to visualize temperature, vibration and mechanical forces, or virtually cut an internal combustion engine in half while it's operating for a peek inside the combustion chamber," Sovani says. "None of this is possible in the real world, but in the simulated one, you can go deep inside any object and look at what's happening. With those insights, it becomes much faster and easier to improve product designs."

AVs, he explains, must be able to sense, think and act. Somewhat surprisingly, the Ubers and Lyfts described earlier



Autonomous vehicle simulations should also be performed in nighttime and other low-light conditions. *Image courtesy of Dassault Systèmes.*

Autonomous emergency braking system development, using a digital twin of the vehicle, its controls algorithms and virtual environment. *Image courtesy of Siemens Digital Industries Software.*

are already doing a reasonably good job on each of these counts, but nowhere near as effectively and intelligently as required for automakers to avoid the legal and possibly moral responsibility, should their inventions fail. Hence the need for simulation software.

"Some AV manufacturers are targeting hundreds of millions of kilometers of driving simulation every two weeks," says Sovani. "That's what's needed to subject these systems to the universe of scenarios they are likely to encounter."

Running Interference

Automakers face several challenges with the first of Sovani's AV requirements: sensing, notes Rachel Fu, technical director for R&D strategy for SIMULIA at Dassault Systèmes. She says the sensors used in autonomous driving systems must be electromagnetically high-performing; compatible with the available installation space; either invisible or capable of aesthetically improving the vehicle design; and compliant with electromagnetic compatibility and interference (EMC/EMI) requirements.

"When radar sensors are placed behind bumpers, for instance, the beam can become distorted, resulting in ambiguous object detection," Fu says. "Electromagnetic simulation helps predict these effects, providing additional optimization opportunities or recommendations for system tuning. Such simulation can also predict sensor behavior in a realistic virtual environment that includes car geometry, roads and highways, accounting for the detection of so-called ghost targets that sometimes occur due to reflections."

In addition to electromagnetic performance, so-called "soiling" and wind or road noise are other factors that should be considered when determining optimal sensor location. Designers can either replicate these conditions via extensive road testing or use software with advanced fluid simulation capabilities. Regardless of the method, the number of sensors and their placement must be optimized to minimize both conditions, a task that the company's SIMULIA simulation software is quite capable of performing, Fu adds.

"Another factor affecting the adoption of self-driving vehicles is the ability of passengers to perform activities such as reading or socializing without experiencing motion sickness," she says. "Because they're no longer focused on the road, drivers are more sensitive to the quality of the vehicle dynamics and overall riding experience. SIMULIA's simulation capabilities provide fast, accurate and stable solutions, including flexible chassis and real-time tire modeling, all of which are critical for passenger comfort."

Simulation Necessity

But is all this simulation really necessary? Waymo recently announced that its self-driving vehicles have driven 20 million miles of driving on public roads in 25 cities. Most new cars offer automated steering, braking and other "super cruise" technology. Does this mean the industry is getting close to AV nirvana without investment in these advanced software systems?

We're not even close, according to Matthieu Worm, director of autonomous vehicles at Siemens Digital Industries Software. Where the adaptive cruise control systems just mentioned are required to pass roughly 150 proving ground tests before approval, AVs must adapt to a seemingly endless list of scenarios before they are considered better drivers than their flesh-and-blood counterparts.

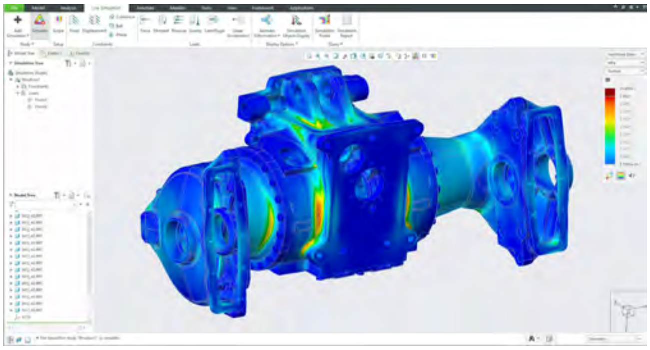
"Unlike computers, humans are very capable of making decisions in unexpected, unseen situations," he says. "Consider an AV in Australia. It's certainly possible to teach it to brake when a kangaroo jumps in front of the car, but what happens when you take that same car to the United States and it encounters a cow? Humans have no problem differentiating between the two, but it's still quite easy to fool the relatively crude neural network found in today's self-driving cars."

Further, you might get the car to react appropriately under each of these situations, at least until it starts to rain, or a human is walking alongside the cow, or it's late afternoon and the sunlight is hits the camera at the right angle. An AV must learn to behave properly regardless of the circumstances, and do so perfectly—or at least, more perfectly than humans.

"Simply put, there's no practical way to develop fully autonomous vehicles without advanced simulation, such as what we offer with Simcenter Prescan, part of our Simcenter portfolio for simulation and testing," Worm explains.

Smart Cars, Smart Roads

AV development extends well beyond the bumpers. Worm points to Cooperative Vehicle Infrastructure System (CVIS), a European project that "was funded a couple of years ago with many initial players and academia partners working together on determining the role of infrastructure sensing and vehicle-to-vehicle communication."



Finite element analysis continues to be an integral part of the design process, for autonomous and human-operated vehicles alike. *Image courtesy of PTC.*

The role of infrastructure has thus far been underestimated, Worm adds, but the automotive design community continues to gain awareness about the added value of infrastructure simulation.

"Simcenter Prescan therefore not only brings on-board sensor simulation capabilities for radar, camera and lidar, but also for 4G and 5G communication and [global navigation satellite system] positioning, to virtually test vehicle to infrastructure communication in challenging conditions," Worm says.

This screenshot illustrates the nearly infinite variety of lighting and road conditions with which a fully autonomous vehicle must grapple. *Image courtesy of Ansys.*

Snow, salt and road dirt can all have an adverse effect on sensor performance, and must be considered in any accurate vehicle simulation. *Image courtesy of Dassault Systèmes.*

Bernhard Mueller-Bessler is the managing director of VIRES Virtual Test Drive (VTD) at MSC Software, a part of Hexagon Manufacturing Intelligence. He concurs with the need for a realistic-yet-comprehensive testing environment, noting that VIRES Virtual Test Drive (VTD) is a "toolkit for the creation, configuration, presentation and evaluation of virtual environments in the scope of road and rail-based simulation."

"Think of it as a virtual proving grounds, one that includes not just the streets but any number of infrastructure components, other vehicles, traffic conditions and so on," Mueller-Bessler says. When used in conjunction with tools like MSC Software's Adams Real Time, which he described as a hardware-in-the-loop solution, and SimManager for process and data management, the software suite is [made] to give automakers the ability to simulate and test "thousands of vehicles simultaneously."

What About the Hardware?

Such broad-scale testing requires an immense amount of computing power, however, which is why MSC Software works closely with the likes of Amazon and Microsoft, leveraging their cloud-based systems to provide the necessary hardware.

Despite these capabilities, Mueller-Bessler warns that there's a delicate balance between acceptable simulation performance and what's actually needed to make the correct decisions.

"You can throw a lot of details into the car and the surrounding area and therefore visualize things better, but this might not make sense from a cost perspective," he says.

NVIDIA is a well-known hardware and software pioneer, although its participation in automobile development—autonomous or otherwise—might surprise you. "We've been an innovator in the transportation industry for several decades and have numerous partners who are building applications on our [graphics processing units (GPUs)], including all types of simulation," says Danny Shapiro, senior director of automotive at NVIDIA. "Examples include crash test and wind tunnel simulations, where you're essentially modeling physics directly on the GPU. Doing so allows designers to iterate faster, make better products and reduce costs by not having to physically build models and place them in a wind tunnel or crash test facility."

The company is also active in developing the artificial intelligence needed to safely operate AVs. It does this through a platform called NVIDIA DRIVE AGX, which Shapiro described as an end-to-end platform able to efficiently process all of the sensor data the car needs to make split-second decisions. These vision systems once required tedious programming and endless lines of static computer code to recognize something as simple as a stop sign; now modern systems like DRIVE AGX use deep learning technology.

"For instance, we feed the system pictures of stop signs taken from different distances, different angles [and] different weather conditions, and we then repeat this exercise with all kinds of objects," Shapiro points out. "Over time, the system's neural nets learn to recognize cars and trucks and pedestrians and bikes and motorcycles—everything that it might encounter in the real world. We then incorporate this same intelligence into DRIVE Constellation, our hardware-in-the-loop simulator, and use it to validate the actual hardware and software used by AV manufacturers. The DRIVE AGX process the data, plans a safe route and sends acceleration, braking and steering commands,

NVIDIA is enabling the industry to drive billions of qualified miles in virtual reality with powerful NVIDIA DRIVE Constellation. *Image courtesy of NVIDIA.*

Siemens solutions for ADAS and AV system development, using a digital twin of the vehicle, its controls algorithms and virtual environment. *Image courtesy of Siemens Digital Industries Software.*

not to an actual vehicle, but back to the simulator. The system thinks it's on the road even though it's actually in a data center. This is a much more efficient and safer way to augment on-road testing."

Time to Market

Jesse Blankenship, senior vice president for advanced development at PTC, views it differently. He says the tools needed for AV design—and even the hardware and software within the vehicles—are nothing new. Companies have designed and manufactured increasingly smart, sensor-equipped, self-driving airplanes, mining equipment, spacecraft, machinery and more for decades; the call for Level 5 (full driving automation) is just forcing automakers to up their game.

Aside from the simulation tools, competing in the AV automation game will require the next generation in design and manufacturing software systems.

"Setting aside the role of a sensor and the data it will collect, think for a minute about the mechanics behind that sensor's placement, and how it's attached to the vehicle," he says. "If you mount it in a zone of plastic deformation, it's quite likely that the data you receive from that sensor will never be accurate. You need to be able to simulate conditions like these in your products before you manufacture 10,000 of them."

Mark Fisher, senior director in PTC's CAD product management group, also notes the need for more automated software tools, ones with generative design capabilities that serve to accelerate the design process, and topology optimization to help reduce vehicle weight and streamline manufacturing. Both will be required in this age of continuous product development, where the traditional years-long design cycles are compressed into months or even weeks.

"Whoever gets to market first wins, something that's true for autonomous and traditional cars alike," Fisher says. "We [at PTC have] introduced a number of different technologies to support this need, real-time simulation among them. This allows designers to speed up and improve the iterative process, and also reduces some of the downstream costs, such as sending a model out for design analysis and evaluation. This is typically an expensive [process] using very expensive software, so you don't want to learn a few days into it that you put the wrong screw somewhere. That's just one small example, but the point is that advanced CAD capabilities like those in Creo save time, whatever it is you're working on." DE

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

MORE INFO

- **Ansys:** Ansys.com
- **Dassault Systèmes:** 3DS.com
- **MSC Software:** MSCSoftware.com
- **NVIDIA:** NVIDIA.com
- **PTC:** PTC.com
- **Siemens Digital Industries Software:** SW.Siemens.com

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

Autonomous Vehicle Design: An Exercise in Complexity

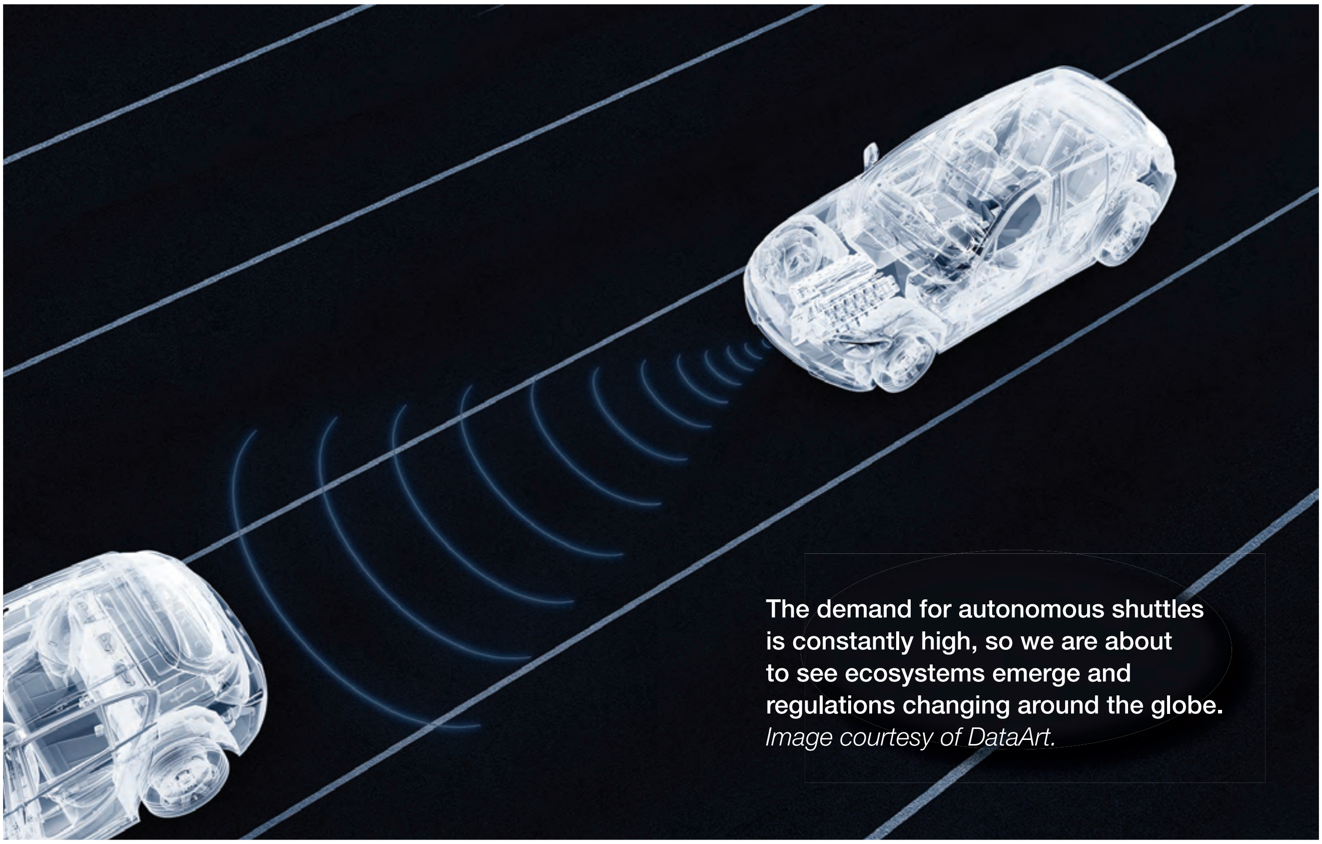
Vendors find new ways to build up toolkits for AV construction and simulation.

BY JIM ROMEO

Autonomous vehicles (AVs) are moving out—slowly, it seems. They've been talked about for decades, as far back as the 1930s at the New York World's Fair. In 2020, there's been more talk about their use, potential, application and the transformation they offer to the world.

But design engineers creating autonomous vehicles must consider many factors. Operational accuracy and safety are among many critical considerations. Add to this a growing number of design tools, technologies and approaches—what's a designer to do?

Proceed carefully while considering the tools and approaches available. But be sure to factor in all the ramifications of safety and performance as the autonomous revolution



The demand for autonomous shuttles is constantly high, so we are about to see ecosystems emerge and regulations changing around the globe. *Image courtesy of DataArt.*

Above: **Vehicle data and monetization have attracted interest from analysts and OEMs, nudging their imagination. Left: The industry is experimenting with different displays, panels, devices and accessories. The drivers and time will decide which of them will become a future standard.** *Images courtesy of DataArt.*

takes grip and vehicles begin to roll soon.

DataArt is a technology consultancy that designs, develops and supports unique software solutions. The company's autonomous driving technologies are progressing, and the next autonomous driving level shift will be significant, according to Max Ivannikov, a solutions consultant at DataArt.

"It's hard to name the exact date when it will happen, but the technology is changing our world already," says Ivannikov. "Driverless shuttles are being tested in medical facilities, on huge campuses, at airports, for last-mile deliveries and for other purposes and places. The demand for the autonomous shuttles is constantly high, so we are about to see ecosystems emerge and regulations change around the globe. New human-machine interfaces are expected to emerge as well. There are voice assistants on the market already, and they'll become more sophisticated. The industry is experimenting with all kinds of displays, sensor panels, rearview mirrors, cameras [and] heads-up systems. The drivers and time will decide which of them become a future standard."

"Intelligent transportation networks are highly interconnected due to emerging communication, computing and artificial intelligence algorithms," notes M. Hadi Amini, assistant professor in the School of Computing and Information Sciences within the College of Engineering and Computing at Florida International University in Miami. They integrate a wide range of technologies to provide affordable, equitable and reliable mobility services to the community. These technologies, however, lead to new challenges for society.

Ivannikov says vehicle data and monetization have attracted interest from analysts and original equipment manu-

Autonomous vehicles perform well. But, like so many other modern inventions, they face the problem of getting over the final hurdle of scaling. *Image courtesy of Nanotronics.*

facturers (OEMs), nudging their imagination.

"If we speak from the technological side, the industry is ready for it, the technology exists," he explains. "But there are still a lot of talks on how to implement it best from the business point of view, and how to build a healthy ecosystem around it. So, once it happens, we will see the dramatic impact on all areas: smart parking, smart cities, insurers, gas and electric stations [and] body shops. Safety issues of the sort will always be affecting innovative projects. It's more about us, about our lifestyles and feeling safe. We are all aware that a lot of people die in car crashes every day, yet we don't really consider stopping using cars. Speaking of self-driving cars for enterprises as an emerging trend, I immediately think of self-driving trucks like the ones on the roads in Sweden, or Elon Musk implementing his autonomous tanker ships' plan."

Product Line Engineering

Whether it's Musk or someone else rising to the top, autonomous vehicles are complex, requiring integration of many features. It is important to ensure that a ready portfolio of design tools is available to design engineers.

BigLever Software is an Austin, TX-based provider of product line engineering (PLE) tools. PLE approaches design with a portfolio of related technology tools and products and shares such assets to organize and build efficiency in how a product is created; AVs are ideal candidates for PLE due to their complexity.

BigLever uses PLE for its work with manufacturers, including leading automotive companies, to help them address the complexity, product variation and design challenges of manufacturing advanced automobiles.

"Reducing the risk of automotive defects is one of the most critical issues facing automotive manufacturers today, to protect the well-being of consumers, as well as their own reputations and financial health," says Cathy Martin, vice president of BigLever Software. "This is especially challenging when you consider the extreme degree to which the hardware, software, systems and subsystems contained in an AV must work together, seamlessly, to replicate the actions of a human driver. Most new models on the road today have self-driving features to autonomously accelerate, brake or steer, such as adaptive cruise control, lane-centering or hands-free steering. Imagine how this complexity grows when you consider the entire automotive product family."

Martin emphasizes feature-based PLE, stating that auto manufacturers are turning to it to influence how their product lines are engineered, produced, maintained and evolved. "PLE allows an organization to create a 'superset' of digital assets that are shared across the product line," she says. "These assets are equipped with all the feature options offered in the product line. Product line features are contained in a feature catalog, which becomes the 'single source of feature truth' for the entire organization. The features chosen for each product are specified in a bill-of-features, which is used by the PLE product configurator to assemble and configure the digital assets to create a product instance."

Integration of Functionalities

Incorporating all necessary features into AV design means integrating the many functionalities that apply. This is a design challenge that must not be overlooked.

"Advanced AV technology requires component innovation and integration of functionalities," says Andreas Minatti, head of business development, automotive, at Datwyler in Germany.

"At any level, these systems require a high degree of sensor functionality, whether it be in the form of cameras, radars, lidars or lasers; how these components are secured, housed and sealed is a critical element to ensure their optimal performance. This is extremely important, as given the roles of these technologies, their reliability is directly connected to the safety of the vehicles they are embedded within, and ultimately the safety of the global road-using public," he says.

Minatti says simulation is a key design tool for AVs and can help support the development of these essential and complex component systems.

"Consider housings for control electronics as an example," he explains. "Such housings are often manufactured using a thermoplastic material that forms a stable shell to protect the sensitive interior from environmental influences. Another key component of the housing is the elastomeric seal. In addition to ensuring the static seal between the housing base and cover and protecting the interior, the seal or the sealing material's elastic structure keeps electronic components in place via buffer elements."

AV design will require a multidisciplinary approach that encompasses everything from simulation to virtual reality. *Image courtesy of Ansys.*

Advance Driver Assistance Systems

To be sure, integrating functionality is at the core of aiding an AV to safely operate with assistance. Jordi Soler Castany is vice president, global business development, electromagnetic simulation, and electronic solutions at Altair.

Castany emphasizes the importance of assistance systems in designing AVs. Assistance systems are key to the safe operation of autonomous vehicles as they are deployed for actual use.

Specifically, he cites advanced driver assistance systems (ADAS) as being key to AV design. In fact, the global ADAS market size is projected to grow from $27 billion in 2020 to $83 billion by 2030, according to a report available from MarketsandMarkets.

"One of the challenges for AVs is the design and integration of the different types of required ADAS sensors, including radars, ultrasonic, cameras and lidar," says Castany. "These sensors are required, considering the different levels of vehicle autonomy, while we move forward to the high and full automation levels. As AVs are integrating more and different types of sensors, electrification is a key and challenging topic. Electrification comes with an increased presence of electronics, with higher voltages systems, which without a proper design can generate electromagnetic interferences [EMI]. This can cause big issues for the safe operation of the vehicle, which test car manufacturers' and suppliers' need to pass before being able to sell their products."

Going Electric, Carefully

ADAS is key, and so is the drivetrain of the planned vehicle. For AVs, this means focusing on using tools, technologies and design principles for robust electric power. Electric drives enable maneuverability and the agility that AVs require to operate with diverse functional demands. There are numerous concerns in designing electrical drive systems.

"The electric powertrain consists of three main components: battery (energy storage), power electronics (conversion of electrical energy) and the electric drive (conversion of electrical energy into mechanical energy)," says Rachel Fu, technical director, R&D Strategy, SIMULIA, for Dassault Systèmes. "These three components have strong interdependencies and therefore need to be developed together; a model-based systems engineering approach is used to manage the dependencies and complexities."

Castany adds that electromagnetic interference is another challenge for electric vehicles (EVs) and AVs that Altair's high-frequency (HF) electromagnetic simulation (EM) solutions can address. "Testing with simulation before hardware prototypes are available, at both the component and vehicle level, helps to improve designs and to create new design guidelines and processes," he notes.

"In an EV, range is one of the most important owner concerns," says Ed Tate, industry process senior director, SIMULIA, for Dassault Systèmes. "Achieving high range requires both expensive batteries and an efficient vehicle. Higher vehicle efficiency allows a reduction in battery cost for the same range. Efficiency is achieved through the powertrain, reduced aerodynamic drag, more efficient tires, a lighter structure and an efficient cabin comfort system. Finding the right solution requires trade-offs between multiple teams. Engineers will need a broad understanding of multiple disciplines to effectively collaborate on these complex development programs. With access to the right tools these renaissance engineers can handle the complexity and move much faster than ever before."

Companies like Ansys also emphasize the importance of system-level simluation in AV development via platforms like Ansys Autonomy. This level of simluation not only helps test the interaction of the various systems and disciplines involved, but also enables the simulation of millions of miles of road testing required to ensure vehilce safety. (See page 10.)

Advancing Autonomous Collaboration

Matthew Putman is the co-founder and CEO of Nanotronics. He notes that AVs perform well. But, like so many other modern inventions, they face scaling issues.

"It is possible that this was a design problem from the start, where production and costs should have been considered from the onset," Putman says. "But it is not too late to take the engineering advances we have seen and rethink how products are built."

Altair's Castany emphasizes the need for smart collaboration from many stakeholders. Different stakeholders are part of the team that gets design results. Pulling together various disciplines and using different and emergent design principles, concepts and tools is key.

"Engineers will need more expertise and teams will need to become more multidisciplinary to successfully design these vehicles," says Castany. "No longer will engineers work in silos. Rather, they will need to pull insights from all aspects and apply them to the design of these complex vehicles." DE

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→ MORE INFO

- **Altair:** Altair.com
- **Ansys:** Ansys.com
- **BigLever Software:** BigLever.com
- **Datwyler:** Datwyler.com
- **Dassault Systèmes:** 3DS.com
- **DataArt:** DataArt.com
- **Florida International University:** FIU.edu
- **Nanotronics:** Nanotronics.co

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Autonomous Vehicles Take VR Test Drive

Automakers explore augmented and virtual reality in vehicle development and to enhance the driving experience.

BY KENNETH WONG

At CES 2020 in Las Vegas (one of the last big in-person tech shows before the COVID-19 shutdowns began), BMW Group tickled the automotive enthusiasts' fancy with a demo of the BMW i Interaction EASE, a concept car for the future. Part of the "wow" factor was its use of the panoramic windshield as an augmented reality (AR) display.

"It can show additional information on the windscreen that is tailored to the situation at hand and the vehicle's surroundings. Thanks to 5G connectivity the vehicle knows exactly where it is and can offer the user information on the surrounding buildings, businesses and other objects as and when required," according to BMW's CES announcement.

Public records of U.S. patent application 20180089899 from Apple, published in March 2018, describes "an AR system that leverages a pre-generated 3D model of the world to improve rendering of 3D graphics content for AR views of a scene, for example an AR view of the world in front of a moving vehicle." It further explains the system may "augment local data (e.g., a point cloud of data collected by vehicle sensors) to determine much more information about a scene, including information about occluded or distant regions of the scene, than is available from the local data."

"AR is not only useful for developing autonomous cars; it will likely be part of the vehicle itself," notes Sandeep Sovani, director of Global Automotive Industry, Ansys.

For autonomous car developers, the current shutdown is a quandary. With fewer cars on the road, it seems to offer an ideal situation to test their car's self-navigation system. But the current low traffic flow doesn't reflect how the car is expected to perform, making the test results less reliable. In this article, we explore how some developers are continuing to make progress, aided by AR/VR technologies.

Autodesk's automotive-focused software like Alias Create and VRED offer a way to remotely collaborate during the shutdown. *Image courtesy of Autodesk.*

Simulation is Unavoidable

Conducting road testing to satisfy the safety requirements of autonomous vehicles (AV) is a daunting task, in terms of the sheer number of hours and miles involved. Research and analysis firm Rand Corporation decided to find out how many miles of driving it would take to demonstrate autonomous vehicle reliability.

The conclusions vary depending on the desired degree of reliability, but the most cited statistics from the Rand report reveals that "to demonstrate with 95% confidence, [it would take] 8.8 billion miles (400 years)."

For this reason, Ansys and other leading simulation software makers are betting that AV developers will inevitably be relying on simulation for the lion's share of the testing.

"In the development process, engineers might use Ansys SPEOS," says Sovani. Ansys SPEOS "predicts the illumination and optical performance of

Some of Varjo's customers use its AR/VR headsets (shown here, Varjo XR-1) to drive real cars. The goal is to experience the interior of cars still in development and not yet built. *Image courtesy of Varjo.*

systems," according to the product homepage.

"You need to project bright light onto the head-up display through various optics. The image shouldn't be distorted, and perfectly tuned for the cabin's ambient lighting," says Sovani. "Ansys SPEOS can do the optical calculation required."

For designing the display itself, Sovani suggests the use of Ansys SCADE Display, part of the Ansys SCADE collection. The software lets you prototype head-up displays commonly used in the aerospace, rail transportation and automotive industries, among others.

The entire cabin environment may be prototyped and simulated in Ansys VRXPERIENCE, Sovani suggests. "You could use VRXPERIENCE to simulate thermal camera images or radar feed, for example," says Sovani. (For more on VRXPERIENCE's role in acoustic simulation, read the article on page 26.)

Both Ansys SPEOS and VRXPERIENCE are the upshots of Ansys's 2018 acquisition of OPTIS, an optical simulation software firm. Ansys SCADE was the outcome of the company's 2012 acquisition of Esterel.

Sovani also envisions engineers using immersive VR caves to simulate the vehicle's autonomous reaction to different weather and traffic conditions (nighttime, rainy weather, encounter with an animal, heavy traffic, for examples). "You can run the software on your desktop, but the more effective use is to put on VR googles and view the results," says Sovani.

"AR/VR technologies may also be helpful to give reluctant consumers a way to experience autonomy, to see what it's like to ride in an autonomous car in virtual reality," notes Sovani.

Meeting in Pixels During the Shutdown

To test-drive cars not yet physically built or mocked up, Volvo has been using Varjo's XR-1 hardware. The driver drives a real car wearing the XR-1 headset to experience the inside of a car that only exists in pixels. XR, which stands for extended reality, is AR hardware that can combine digital and physical realities. (For more, read "Are you ready for extended reality?" August 2019).

"The driver is really relying on the real-time video signals from the headset to drive the car," notes Urho Konttori, chief product officer and founder of Varjo. "The high-quality graphics and 5G connection in Varjo headsets make this feasible."

Some of Varjo's automotive customers are now using VRED from Autodesk to digitally prototype, review and validate their work. The software offers several application programming interfaces to connect to VR hardware and software. Multiuser collaboration support was added in VRED 2019.2 release. This allows, for example, the chief designer to review and improve on weekly design iterations during the shutdown via VR.

"The XR (AR and VR) workflows in products like Alias and VRED help our customers to better create forms and shapes, understand proportions in the context of their design ideas, and empower collaborations and digital decision-making," says Thomas Heermann, associate VP of Design and Creation Products, Autodesk.

The use of AR/VR in automotive is about more than visualization. It's also seeping into design creation and editing tasks. "Autodesk Alias Create VR allows conceptual designers to use VR to create mobility products in 3D in VR, while VRED empowers designers, engineers and decision makers to visualize design ideas, and put them in a real-world context," adds Heermann.

The ease of use with VRED, as Konttori sees it, comes from its handling of imported STEP files and material assignment. "You just need to assign the materials once," he says. "After that, whenever you open the model again, the same material properties show up."

The collaborative real-time use of VRED requires powerful workstations as the rendering takes place on local machines, not in the VR headset. In such usages, the GPU plays a critical role to constantly pump out and refresh the graphics as users move around and their perspectives shift.

"But this is not new. The software is basically sending the participants' XYZ positions and head orientations in the virtual world, just like you do in multiplayer games in the virtual world," points out Konttori. "With NVIDIA RTX GPUs, the application really benefits a lot from the real-time raytracing possible."

BMW's presentation at CES 2020 hinted at the use of windshield and other surfaces as augmented reality displays. *Image courtesy of BWM.*

Collaborative use of VR is not confined to Varjo's customers themselves. "We keep a minimum number of people in the office. These are people who must put together new PCBs, for example. Out of the 130 R&D engineers we have, about 100 are working from home now," says Konttori.

Part of Konttori's weekly routine is to review new designs of Varjo headsets. He does so by viewing the design in his VR-1 headset from home, using the Keyshot rendering program's KeyVR function for visualization. "COVID has made remote work a common practice," notes Konttori.

Varjo currently offers XR-1 Developer Edition (mixed reality or augmented reality), along with its VR-2 and VR-2 Pro headsets. The hardware offerings are augmented with its software with support for Unity and Unreal game engine data.

During the shutdown, VR products seem to be in greater demand than AR, Konttori notices. To use mixed reality properly, you would need to overlay a variety of digital data on top of a life-size product—a car, in the case of automotive design. "Let's face it. People's living rooms are not meant to house a car," Konttori quips.

But Konttori says he had seen significant increase in the customers' desire to explore VR-based collaboration during the shutdown. As a result, the company recently entered into a partnership with MeetinVR in May to offer their products as a bundle.

"No doubt companies are sensitive to expenditure during tough times, but allowing engineers to work remotely with peak performance is also important," observes Konttori. DE

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Pros and Cons of the Shutdown

In March, when the outbreak began, Venture Beat reported, "Waymo, Uber, GM's Cruise, Aurora, Argo AI and Pony.ai are among the companies that have suspended driverless vehicle programs in the hopes of limiting contact between drivers and riders" ("Coronavirus fears halt autonomous vehicle testing").

In theory, the significantly lighter traffic during the shutdown seems to offer an opportunity to ramp up road testing, but in practice, the 6-feet-apart social-distancing requirements make it difficult to run tests even with the smallest possible team—two people.

"Near-empty roads create an abnormal condition," notes Sovani. "This is not ideal for testing, because you don't want to train an autonomous car that can only drive on sparsely crowded roads. You want them to learn to navigate through thick crowds and heavy highway traffic."

It may sound counterintuitive, but for autonomous car developers, virtual reality offers a better option to mimic reality. Because COVID era traffic don't represent normal traffic flow, the virtual traffic flow and driving conditions simulated and visualized in AR/VR might be a better training environment than the real highways.

→ MORE INFO

- **Ansys:** Ansys.com
- **Autodesk:** Autodesk.com
- **Keyshot:** Keyshot.com/keyvr
- **Varjo:** Varjo.com

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Is Your Car a Good Listener?

Breaking down the role of acoustics analysis in electric and autonomous vehicle development.

BY KENNETH WONG

Human drivers are trained to rely on "visibles" and "audibles" to make split-second decisions. An emergency vehicle's siren, unusual mechanical noises from the engine and the loud bells from railroad crossings are just a few of the auditory alerts that might prompt a sudden change in driving strategy. So, when the human driver is removed from much of the decision-making process in autonomous vehicles, who is listening?

Your car is, as it turns out. There's a specific discipline that studies the noise, vibration and harshness (NVH) of the vehicle. In classic automotive design, the noise-refinement goal is primarily to reduce the level of undesirable noises in the car's interior. If your engine noise is too loud, you won't be able to enjoy the latest Taylor Swift single streaming from your smartphone, for example. But with the emergence of self-driving cars, the discipline takes on new burdens: one is teaching the car to listen.

A Multiphysics Approach

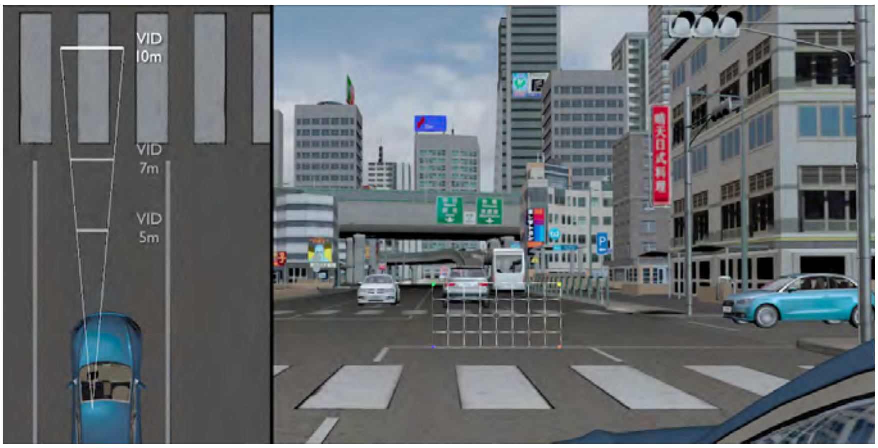
Mads Jensen, technical product manager for Acoustics at COMSOL, is someone who listens to your future car's hums and whispers. He points out the reversal of acoustic engineering—the shift from noise cancellation to noise amplification—with the emergence of electric vehicles.

"In different countries and regions, the car is required to make a certain level of sound so the pedestrians can hear it approaching. So, with electric cars [which do not have a noisy combustion engine], you now have to actually emit sound with loudspeakers to meet that requirement," explains Jensen.

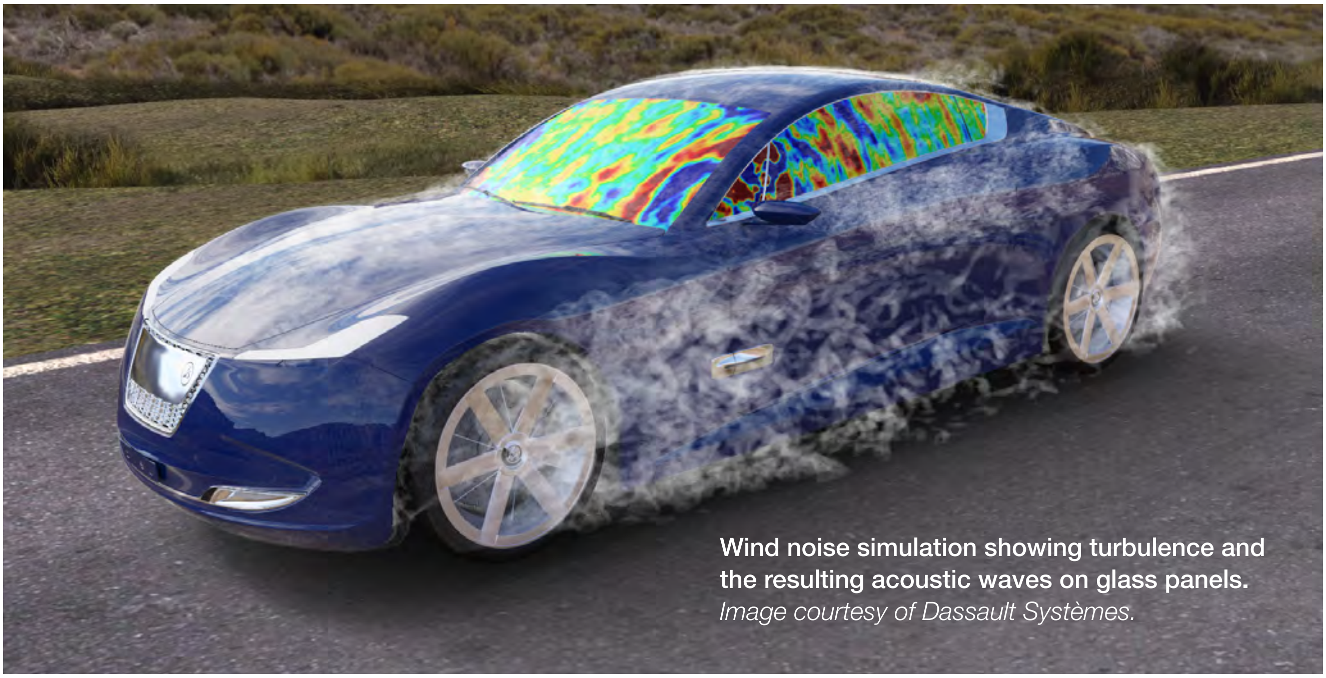
Modeling the outbound acoustics of the car, such as sound emitted from the car's speakers, can be done with the Acoustic Module in the COMSOL Multiphysics software suite. "Acoustics can be coupled with other physical effects, including structural mechanics, piezoelectricity [accumulated electric charge] and fluid flow," according to COMSOL's product details page.

"A lot of the car makers are modeling the acoustics inside the car as well. It's a relatively small acoustic space, but a complex environment. You have people and objects, so you have to use multiple speakers to create sound zones inside the space," Jensen says.

Imagine a fully autonomous van in which the driver has the option to turn around for chitchat with the passengers sitting in the back. The optimal speaker



In 2018, Ansys acquired OPTIS, an optical simulation software maker. The technology is now incorporated into Ansys VRXPERIENCE Sound. *Image courtesy of Ansys.*



Wind noise simulation showing turbulence and the resulting acoustic waves on glass panels. *Image courtesy of Dassault Systèmes.*

placements for such a vehicle are significantly different from a typical family van where everyone is facing the front for the most part.

"To figure out the optimal configuration of speakers and sound zones for such a space, you really need to rely on simulation," adds Jensen.

By itself, sound propagation is not multiphysics; however, the mixture of electromagnetics, structural vibration and sound fields to account for the behavior of the speakers makes the simulation multiphysics—a specialty of COMSOL's simulation technology, Jensen points out.

Though electric cars do not have a combustion engine, they do have an electric motor, which generates certain noise and vibration. "These sounds can propagate through the vehicle's body to create unwanted sound inside the cabin," Jensen says. "When you have sound fields interacting with the car's structure, it's a multiphysics problem."

Raytracing for Sound Simulation

Engineers traditionally use finite element analysis (FEA) methods to model the wave fields inside the vehicle and solve simulation in the frequency domain or time domain, Jensen explains.

"With this approach, you need a lot of discrete points or mesh elements to resolve the wavelengths, so it's computationally expensive … With the latest development in COMSOL software, you can now run the full wave approach to a much higher frequency. Both computational methods and computational power are improving," says Jensen.

An improvement in the software is the use of time-explicit discontinuous Galerkin method. "This allows you to model wave propagation in the time domain," says Jensen. "This approach is extremely suitable for parallel computing."

The latest strategy is to employ a hybrid approach—a mix of full wave simulation and raytracing. "With raytracing, you can think of soundwaves as particles traveling like rays. When it hits a surface, it bounces back, but some energy is also absorbed by the surface, depending on the surface's porous or smooth texture," says Jensen. "That's an inexpensive way to model acoustics inside a confined space."

An important step in the acoustic simulation is the treatment of the CAD geometry, which defines the space in which soundwaves propagate.

"The better you can prepare your CAD geometry for meshing and simulation, the more accurate your simulation is," says Jensen.

Too Quiet for Safety

Ales Alajbegovic, vice president of worldwide industry process success & services at Dassault Systèmes' SIMULIA, recalled a cab ride to the Munich International Airport. The cab driver was complaining about the loud wind noise, but the wind was not particularly strong that day.

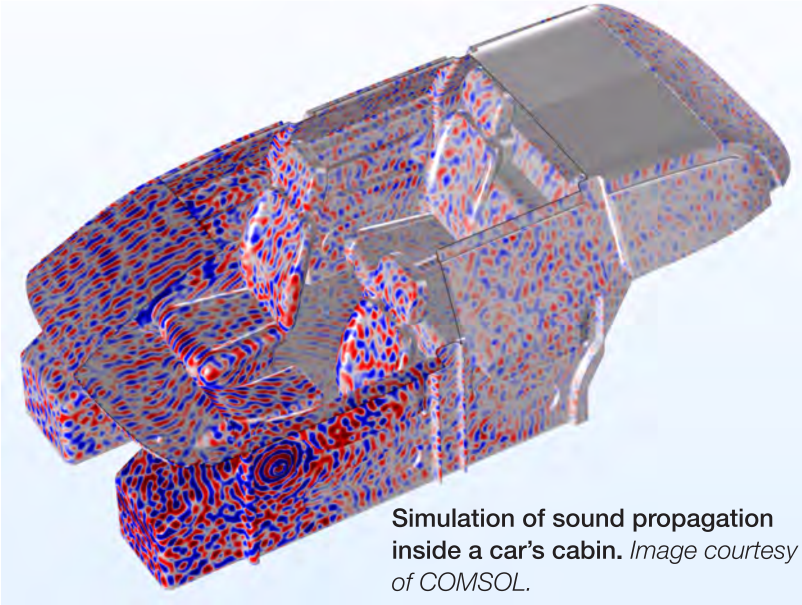
"When you remove the noise of the combustion engine, the noise inside the cabin is reduced significantly. But as a result, you start to notice other noises, like wind noises, and much more," he observes. "In many cases, they may be even more bothersome than a car with a combustion engine."

Wind noise comes from aerodynamics, or the friction between the airflow around the car and the car's chassis itself. Therefore, "the shape of the car is crucial to what you hear in the cabin," says Alajbegovic. One way to minimize it is to reduce drag by modifying the shape of the chassis—the geometry of the car.

"The autonomous car itself has to react to the environment. So, in addition to seeing [using real-time video feed and computer vision], it also has to listen to what's happening around it. That means the microphones in the car have to be placed properly to hear the environment better," says Siva Senthooran, director of technical sales at

SIMULIA Centers of Excellence.

Dassault Systèmes offers several tools for aerodynamic simulation and geometry modeling in its 3DEXPERIENCE product line. PowerFLOW software, based on transient Lattice Boltzmann-based physics, includes features for thermal, aerodynamic and aeroacoustic simulation. The company also offers Wave6 software for vibro-acoustic and aero-vibro-acoustic simulation; and Abacus, a structural analysis suite.



Simulation of sound propagation inside a car's cabin. *Image courtesy of COMSOL.*

Can You Hear Your Car?

In May 2018, Ansys acquired OPTIS, an optical simulation software developer. Subsequently, Ansys also acquired GENESIS, an acoustic simulation software developer. The new acquisition enables Ansys software to generate not only visual representation of sound fields but also the audio—in theory, what you would hear inside the vehicle.

"The electric vehicles are quiet—maybe too quiet. So secondary noises like hatchback noise and duct effects become clearly audible. Also, the electric motor has a fast rotation, which creates a whining sound," says Patrick Boussard, senior manager, product management at Ansys. Boussard is also the founder of GENESIS before its acquisition.

"Because the car is too quiet, any squeak or creak from the panels or misalignment in the windows gets noticed. There's nothing to drown out these sounds," says Siddharth Shah, principal product manager, Ansys.

Acoustic analysis gets more complex in combining autonomous driving and the quieter electric powertrains. With the need to focus less, humans in the autonomous vehicles are more likely to listen to music, watch a movie, engage in conversation or even take a nap. That means the vehicle needs to create a variety of sounds to alert the passengers to lane changes, emergency stops and the need for someone to assume manual control.

Using Ansys VRXPERIENCE Sound, users can virtually experience the cabin of a car still in development, visually and auditorily.

"It adds signal processing, so you can hear all the sounds from different audio sources in a surround environment," explains Boussard.

"What you can do with VRXPERIENCE is to assess the sound," says Shah. "With it, you can tell whether you increase the sound by a certain decibel if you make changes to the mirror, the vent or the profile of the car, for example."

In autonomous cars, the in-cabin audio experience takes on new importance as drivers and passengers may demand a better environment for entertainment (movies, music and conversation, for example). But the car must now also learn to listen and react to the sound signals the drivers may not be actively listening to. DE

Are All Autonomous Vehicles Electric?

Autonomous isn't synonymous with electric. Things get muddled in the intersection of profitability, fuel economy and innovation. According to the paper "Tradeoffs between Automation and Light Vehicle Electrification" from Nature Research (www.nature.com), the authors Mohan, Sripad and others point out, "automation will likely reduce electric vehicle range by 5%–10% for suburban driving and by 10%–15% for city driving."

The intense computing power required to process natural-language commands, lidar and video signals for image-driven decision making, and other factors adds to the battery drain in autonomous cars.

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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- **Ansys:** Ansys.com
- **Dassault Systèmes:** 3ds.com

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A Convergence of Data in the Connected Car

There's a need to adopt and adapt new development methodologies, tools and design concepts.

BY TOM KEVAN

The vehicles rolling off of today's automotive assembly lines may look like their predecessors, but delve deeper into their designs, and you will find a very different creation. This change lies in the convergence of advanced software, digital thread technologies, ubiquitous sensing and wireless communications—a perfect storm that aggregates all the ingredients required to produce the connected car.

What does this disruptive development mean for the automotive engineer? It introduces the need to adopt and adapt new development methodologies, tools and design concepts (Fig. 1).

But there's a reason why analysts call metamorphoses like this "disruptive." The market offers the engineer a raft of design tools, practices and philosophies. But at this stage, the challenge is finding the right combination. To successfully develop the connected car, design teams must reconcile an interesting clash of design cultures, problem-solving styles and ultimately visions of what a successful design looks like.

What's Different?

Buyers have traditionally compared vehicles on their driving performance, and that likely will be the top consideration until autonomous vehicles become a reality. Various new factors, however, have emerged, in many ways paralleling developments in the consumer electronics market. These market forces are redefining consumer expectations and changing automotive value propositions.

Fig. 1 (Above): The connected car provides the perfect venue for digital thread and advanced software technologies to transform automotive design, development and refinement, ushering in what just may be a new automotive era. *Image courtesy of Siemens Digital Industries Software.*

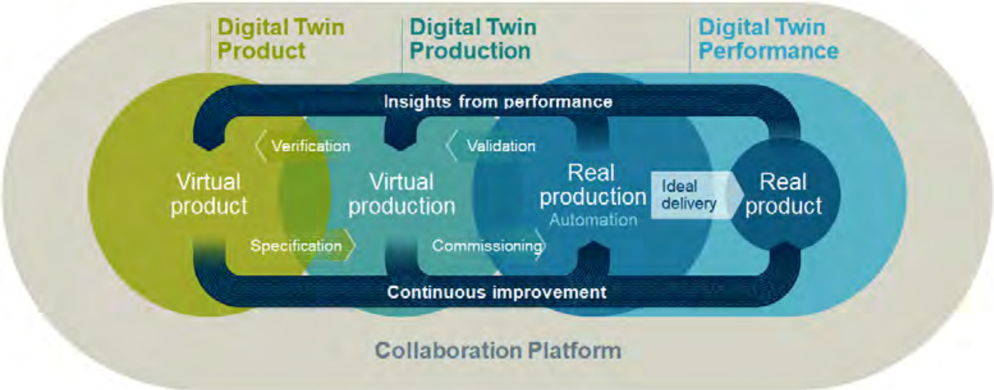

Fig. 2: The ultimate goal of digital thread is to provide the data required to create a closed-loop connection between the virtual world of product development and a physical world of product performance. This connection results in the creation of the digital twin, which enables engineers to extract actionable insight upon which they can base informed decisions throughout the product's lifecycle. *Image courtesy of Siemens Digital Industries Software.*

One of these agents of change is the increasing value attributed to software-based functionality.

"Software-based features and services are among the greatest differentiators of the connected car, and many of them will—in fact, they already are starting to—mimic those that have proven so popular on mobile devices," says Pawel Chadzynski, senior director of product marketing at Aras. "The ultimate mimicking, however, will likely not be achieved through replication of the mobile platform features within the car's software but through a much tighter integration of the mobile platform with the car's infotainment platform through initiatives like Apple CarPlay and Android [Auto]."

Software-enabled infotainment features and services, however, are just the tip of the iceberg. Software now touches almost every aspect of the vehicle's operation. In fact, most automotive functions today are software-controlled or managed, including critical subsystems like the powertrain, transmission and braking systems.

Add to the mix new connected-car safety features that interact with other vehicles and transportation infrastructures, and it becomes clear that software ultimately goes a long way toward defining tomorrow's vehicles.

To appreciate the scale of software's footprint, consider how much code goes into today's cars. As far back as 2014, a typical car contained more than 100 million lines of code, and that number has since grown. By comparison, the Boeing 787 has around 14 million lines of code.

Beyond Reinventing Transportation

The disruption ushered in by the increasing role of software promises to fundamentally change the automotive era as we know it.

"Everything about automotive transportation is changing—the way we buy vehicles, the way we drive them, the way we get them serviced and updated and the way vehicles are integrated into our daily lives," says Piyush Karkare, global director for automotive industry solutions, Siemens Digital Industries Software. "The only way for automotive [original equipment manufacturers (OEMs)] to maintain their profit margins is to reduce costs and provide rewarding customer-facing features. OEMs and suppliers alike have realized this can only be done by shifting more toward software-driven features and services and reducing or commoditizing hardware content."

In Pursuit of Traceability

To meet the challenges of a disruption at this scale, engineers need comprehensive digital threads that tightly integrate both hardware and software development data sources. Thread development platforms must provide a window on all of the hardware-software interdependencies that make up the complex designs, throughout the vehicle's lifecycle (Fig. 2).

"The platform must support explicit traceability of specific features from as-designed to the state of the car in the field," says Chadzynski. "This is because manufacturing, maintenance, wear and tear, and customization of the car result in configurations that no longer represent the as-designed configuration."

This approach provides automotive development teams with the holistic view required to see emergent properties that may cause catastrophic results. For example, the availability of a feature delivered by software as a service often depends on the presence of the appropriate hardware. There are times, however, when inclusion of the required hardware may be cost prohibitive for all product variants, and that must be considered in the overall system design.

Design engineers must realize that the ability to create differentiators and services through software directly relates to how software and hardware are designed. Thread development platforms must support coordinated co-design of the car's software and hardware as a system.

Bridging the Software-Hardware Gap

One way to integrate hardware and software development processes throughout a product's lifecycle is to blend product lifecycle management and application lifecycle management (ALM) platforms.

This approach promises to give software considerations equal footing with those of hardware, bringing the interdependencies between the two into sharper focus earlier in the design process. In addition, using this combination of tools aims to provide all members of development teams easy access to all product data throughout the lifecycle. This level of data transparency delivers a clear view of where defects are generated, where they are resolved and how to refine the development process.

Unlike standalone software developing tools, ALM platforms merge various engineering disciplines under one roof. In doing so, the platform can continuously manage the life of software from the initial concepts to its eventual retirement.

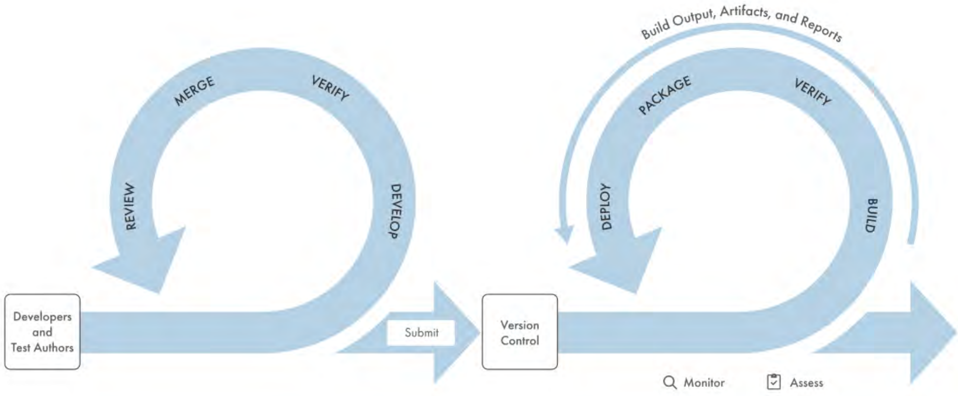

Fig. 3: Using the continuous integration (CI) Agile methodology, software developers regularly submit and merge their source code changes into a central repository. These "change sets" are then submitted to a version control system, which automatically converts source code and models to object files and executables, performs testing and bundles executables, documentation and artifacts for delivery to end users. Together, these automated steps are called the CI pipeline. *Image courtesy of MathWorks.*

These platform features cover a broad spectrum of functional areas. These include such development phases as requirements management, planning, source code management and version control, testing, deployment, traceability, collaboration and application portfolio management.

Engineering software vendors generally sell ALM platforms as software suites made up of a number of specialized modules or components. The advantage of this architecture is that the platform incorporates the modules in a standardized environment that integrates data from a variety of systems and lifecycle stages, in an assortment of data formats.

Toward Agile Software Development

ALM platforms provide a systematic way of managing software throughout its lifecycle, but in an age of increasing customization and almost continuous software upgrades, this isn't enough. The dynamic nature of the software requires development workflows capable of handling the ever-increasing speed and frequency of software delivery cycles.

An Agile workflow called continuous integration (CI)/continuous delivery (CD) aims to meet these challenges, with users combining these tools with the other modules under the ALM umbrella.

"We see organizations evolving their established model-based workflows by combining them with agile methodologies," says Jim Tung, MathWorks fellow. "There is a focus on automating tasks, including simulations, regression test execution, code generation, document generation and so on (Fig. 3)."

CI calls for developers to integrate code into a shared repository several times a day. The process occurs after a "git push," usually to a master branch. With each check-in, an automated process builds the application and runs tests to confirm that the newest code integrates with the software currently residing in the master branch. This helps the software engineers to more easily detect problems early in the development process.

CD then picks up where CI leaves off. These practices provide an automated process by which code changes are pushed to other infrastructure environments, such as development and testing.

CI/CD tools store environment-specific parameters that must be packaged with each delivery. Automation then makes the necessary service calls to databases, web servers or other services when applications are deployed.

Combined, the CI and CD processes facilitate collaboration and reduce time to market, enabling development teams to more quickly respond to customers' needs. Furthermore, the automated pipelines created by these workflows reduce manual intervention, which promotes efficient use of development team resources.

Translating Data into Improved Performance

How do all these technologies and techniques enhance the connected car's performance and drive design improvements in their engineering down the road?

For one, the increasing presence of software in the connected car provides engineers with a tremendous influx of valuable data. Properly managed via digital thread, this data gives engineers greater visibility of the vehicle's behavior as it operates and interacts with humans and surrounding infrastructure.

This transparency allows engineers to rapidly verify and validate expected system behaviors in virtualized environments, based on real-world scenarios. Engineers can repeatedly execute scenarios, testing with a multitude of factors, such as glare, rain, fog, snow and sleet.

Development teams can also use data from real-world accidents and sensor models to further refine virtual testing and virtual hardware-in-loop simulation, where engineers can mask sensor input on a physical vehicle or system test with virtual scenarios.

This setup allows for rapid verification and validation cycles of changes to system behaviors before physical vehicles must be tested, further reducing the overall engineering costs and allowing for robust data-driven evidence for process and regulatory compliances.

From another perspective, the addition of vehicle communications capabilities opens the door for automakers to make near-real-time vehicle-performance improvements.

"A digital thread helps automakers proactively release over-the-air updates to address performance issues before warranty claims start cropping up," says Greta Cutulenco, co-founder and CEO of Acerta Analytics. "They can even identify where the issue was introduced in the manufacturing process and address that in the next generation. Having visibility across the entire lifecycle of the vehicle means it won't take years to figure out where something went wrong, and that significantly shortens development cycles."

Raising the Bar on Maintenance

Another benefit of software's growing presence and the emergence of digital thread is more informed vehicle maintenance. The level of service provided to connected car owners goes well beyond the maintenance experienced by previous generations of vehicle owners.

These improvements spring from an unprecedented level of visibility and accessibility, and they take the form of predictive maintenance.

"With digital thread, you know exactly what's happening on your vehicles," says Cutulenco.

Today, automakers can collect and analyze data from simulations and fleets of operational connected cars, determining the current state of a vehicle's components and subsystems and how they have deteriorated over time. As a result, engineers can create effective predictive maintenance models based on data from different types of failures and associate those datasets with those failures.

"Connected-car data retrieval, well-designed data repositories and tools for building predictive maintenance models become the key technology combination," says Tung. "With that in place, the ability to remotely retrieve information that indicates the history and current state of the vehicle, either at regular intervals or on demand, becomes the means for applying predictive maintenance."

Although the flood of raw data stems from the extensive instrumentation of the connected car, the real powerhouse behind the increased visibility comes from off-vehicle software and this trend is only going to gain momentum.

There are already examples of this if you look closely under the hood. For instance, some drivetrains and chassis now monitor, collect and send data back to the cloud for analysis, recalibration and engineering updates, creating a feedback loop that improves the user's experience. For instance, Tesla released an over-the-air update that improved performance and range by 10%.

Engineers can also use the data to infer the performance of components that aren't instrumented. For example, you might not have sensors in your tires, but if you can detect suspension free play, you can also determine whether the tires are wearing out or need to be rotated. Combine this data with access to powerful off-vehicle analytics, and owners of connected cars can head off mechanical failures before they happen.

These maintenance enhancements, however, don't stop there. Over-the-air software updates working with digital thread provide the overall traceability of changes, upgrades and service actions down to requirements, test cases and even lines of code.

This functionality also can be extended to monitor deployed software usage, to run analytics on issues and customer satisfaction factors, and to provide a closed-loop back to the as-designed phase to perpetually improve on feature and service offerings while reducing engineering costs.

Although the increased presence of onboard and off-vehicle software brings rich benefits, they also bring unique challenges.

"Given the many combinations of software and hardware configurations, which may or may not be compatible with a potential new function, digital thread data from integration test simulations are important for determining the configurations that would be a candidate for a particular over-the-air update," says Tung.

An End of an Era?

The automotive era emerged about 120 years ago, replacing horses as the prime mode of transportation. Today, the forces shaping and leveraging the connected car may well prove to be the catalyst for the next sea change.

"We could very well be seeing that level of disruption causing the end of the automotive era as we know it," says Siemens' Karkare. "Automotive disruption in today's automobile market is not about reinventing transportation, it's about reinventing personal independence." DE

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MORE INFO

- **Acerta Analytics:** Acerta.ca
- **Aras:** Aras.com
- **MathWorks:** MathWorks.com
- **Siemens Digital Industries Software:** sw.siemens.com

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Make Way for Large-Scale Additive Manufacturing

The combination of new technologies and a maturing market has kicked off heightened interest in large-scale AM for production-grade applications.

BY BETH STACKPOLE

JAMADE's Amazea breaks the mold for water sports innovation in various ways. The vehicle is an underwater scooter, which replicates a dolphin's body ergonomics for faster movement, and it is also emissions-free with low noise operation—an attempt to minimize impact on the marine ecosystem.

Another point of disruption: 75% of the Amazea —specifically, the scooter's body and front parts—are produced with BigRep large-scale 3D printing technologies in contrast to using traditional casting or injection molding methods.

Large-scale additive manufacturing (AM), and the BigRep One printer in particular, fit the bill because they deliver cost efficiencies along with better accuracy and quality compared to the high investment associated with traditional tooling, JAMADE founders maintain. That's especially important in light of the company's expectations

Seventy-five percent of the AMAZEA underwater scooter, encompassing its body and front parts, is being produced with BigRep large-scale 3D printing technologies. *Image courtesy of Jamade.*

The BigRep Pro's build envelope of 1 cubic meter enables multiple different parts to be packed onto the same print bed for more efficient manufacturing. *Image courtesy of BigRep.*

for modest sales in Amazea's first year as marketing and distribution efforts ramp up and customer demand builds.

Just as JAMADE charts new waters with its manufacturing approach, other companies in industries like aerospace and automotive are beginning to see value in trading up traditional manufacturing practices for large-scale AM technologies.

The ability to 3D print large parts either in-house or through a specialized service bureau significantly shortens lead time compared to shipping tooling and parts overseas for production or waiting for a third-party player to create custom tooling. Plus, advances in metals 3D printing technology and slicing software along with new materials and lower-cost printer options are making large-scale AM technology more accessible for companies to deploy on a production basis, not just for intermittent prototyping.

"When you're talking about real industrial parts, customers care about the quality and there can't be a throwaway," explains Mark Douglass, business development manager, additive solutions for Lincoln Electric's Additive Division, which offers large-scale 3D printing services, including wire-arc additive manufacturing (WAAM) techniques.

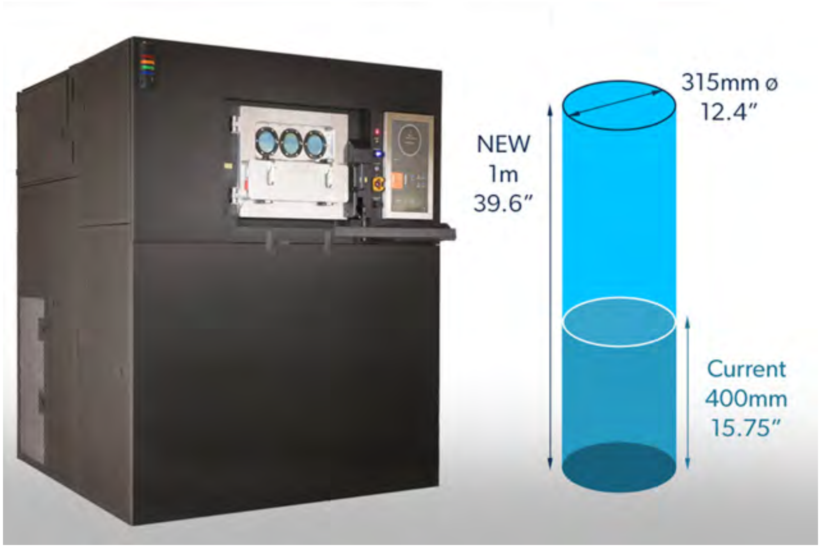
"The technology had to mature to the point where people can rely on it to produce quality parts, whether that's Fused Deposition Modeling [FDM] machines, powder-bed machines or now large-format metal additive," he says.

Large-scale AM technologies have been around for some time, but they were traditionally extremely expensive and highly specialized, requiring multiple experts to configure, run and maintain 3D printing operations. As large-scale AM technologies evolved and 3D printing, in general, gains traction, companies are more willing to consider the methods as a legitimate alternative to traditional manufacturing modes such as molding, milling and casting.

The companies designing novel products in emerging categories such as electric mobility solutions are already predisposed to thinking outside the box and therefore are more open to modifying long-standing processes, including new modes of manufacturing, says Frank Marangell, chief business officer and U.S. president for Big Rep, which specializes in industrial AM printers and services.

The abrupt disruptions to in-person work environments and to the global supply chain resulting from the sudden onset of the COVID-19 pandemic have also given many companies pause to consider large-scale AM when they might not have previously.

"People now see the challenges of buying a tool or part from a foreign country and what the supply chain risks are," Marangell says. "COVID-19 exposed why it's beneficial to have more in-house manufacturing than buying parts."



Velo3D's meter-tall system enables industrial applications that couldn't be built before, especially for flight hardware and oilfield service tools. *Image courtesy of Velo3D.*

Technologies at a Glance

BigRep's area of focus is delivering large-scale AM systems targeted at applications supporting industries like aerospace, automotive and consumer parts. Companies that have an incentive to redesign their products to be lighter and stronger are natural candidates for large-scale AM as are companies that are heavily reliant on custom forms and molds as part of their manufacturing processes, Marangell says.

The BigRep PRO was designed specifically for manufacturing applications with a build envelope of 1 cubic meter with metering extruder technology (MXT), which offers speed, precision and control over materials deposition when dealing with large-scale parts.

The BigRep PRO's print bed is outfitted with sensors and hardware to allow for semiautomatic print bed leveling—another way the printer ensures repeatable, high-quality parts. One more differentiator is the integration of a state-of-the-art Bosch computer-numerically controlled motion-control system, designed to deliver maximum responsiveness and accuracy along with closed-loop controls.

Untethered from the volume constraints of a traditional build plate, large-scale AM gives engineers the freedom to orient parts in a way that makes the most sense, whether it's to deliver specific strength properties, to ensure finer details are captured or simply for economies of scale to output multiple parts in a single build.

"Volume production is perfect for large-format AM, large part production is perfect for large-format AM, and the flexibility to put the part where the parameters suit the technology is perfect for the medium," Marangell says.

RIZE is coming at the large-scale AM market via a partnership with South Korean-based printer manufacturer Sindoh Co. Ltd. The pair collaborated on the design and release of the sub $5K RIZE 2XC professional desktop composite 3D printer and followed up with the RIZE 7XC, an industrial composite variation that just recently launched. It is designed from the ground up to support industrial manufacturing applications at scale, according to Andy Kalambi, RIZE CEO.

A key challenge with early large-scale AM technologies relates to material science—ensuring that supported materials can output a high-quality print at such large sizes, he explains. The 7XC addresses that problem via its use of composites, a material set that is not yet fully implemented by most large-scale AM systems, and specifically those that are not cost prohibitive, Kalambi says.

Having a large-scale AM printer optimized for composites is crucial for mimicking the properties of metal parts. It is also key to using the technology to manufacture parts with organic shapes and unusual geometries to achieve lightweighting goals or parts consolidation, which are common design strategies across industries such as automotive and aerospace.

"There's a tendency to warp when you lay over a large volume or surface and you need accuracy when building large parts," Kalambi says. "You need to ensure large parts are uniformly strong when 3D printing and that everything is done in a consistent and uniform way."

Like its original XRIZE printer, the 7XC has a dual-jet system, one of which releases a safe agent between the supports and parts, ensuring supports can be easily stripped away without requiring any post-processing rework. The system, which launched for under $20,000, is also affordable compared to other large-scale AM offerings that cost in the hundreds of thousands of dollars, he adds.

Velo3D has carved out a specialty area in metals, not composites, though it, too, places an emphasis on addressing challenges related to supports. The firm, which caters to the oil and gas sector, among other industries, offers SupportFree technology that enables printing at low angles and overhangs down to zero degrees as well as large diameters and inner tubes up to 100 mm without reliance on supports.

The Sapphire laser powder bed fusion metal AM system, designed for SupportFree production output, is being readied in a version that supports a 315-mm diameter by 1-meter height build envelope to enable output of large-scale components. The existing version of the Sapphire printer has a 315x400-mm build envelope.

As the need for large-scale AM output grew, Velo3D moved to evolve its printer offerings to support taller part and component output instead of the wider build envelopes embraced by many of its competitors. Although there is a need for both configurations, Velo3D thought the taller approach was a less-served opportunity and it was also easier to evolve its existing hardware without a total redesign, according to Zach Murphree, vice president of technology partnerships at Velo3D.

"When you go wider, you have to change the laser and a lot of other aspects of the machine—it requires a completely different recipe to run the system," Murphree says. "With this, the machine remains essentially identical to the standard configuration of the Sapphire just with a taller elevator. That shortens development time, lessens costs and keeps things easier for qualification."

Knust-Godwin, a precision tool and component manufacturer, has placed an order to produce with latest version of the Sapphire, slated to ship later this year. Knust-Godwin, which is leveraging the large-scale Sapphire machine to create a part for oilfield drilling, chose the newer system because of its reliability and confidence it would produce industrial-grade parts without compromise to quality, says Mike Corliss, vice president of technology at Knust-Godwin.

With many of the large-scale AM systems, there are high operating costs associated with having to source all the powder to cover the entire build volume even when the particular part heading for production is not wide, but tall.

"The operating costs are down and there is less risk with the [Sapphire] machines," Corliss says. "It's a short, tight envelope … and we're not moving lots of mechanical parts over a wide area, which could surface problems in quality and accuracy."

Challenges Along the Way

Though interest in large-scale AM as a manufacturing alternative has increased lately, challenges remain. One of the biggest obstacles is getting customers to recognize the advantages, especially those who may have worked with older generation systems and services and got burned in the process.

That's one of the biggest hurdles for Thermwood Corp., a maker of CNC routers in addition to LSAM, its proprietary large-scale AM systems for 3D printing of thermoplastic polymers. LSAM uses what Thermwood calls the "near net shape" approach to part production where the part is printed at a high speed slightly larger than what's called for and then trimmed to meet the final size and shape specifications.

Thermwood also has a patented compression wheel that, in tandem with large print beads and a patented bead board, creates solid, fully fused, void-free structures that sustain vacuum in a pressured autoclave at elevated temperatures without the need for add-on coatings, says Dennis Palmer, the company's vice president of sales. Though the technology has greatly improved the integrity and quality of large-scale AM parts, many potential customers remain skeptical.

"They are gun shy and now we have to prove that our prints work," he explains, adding that the customer tests have provided some valuable lessons. "No one gives us anything easy that they want to print—they give us their most difficult projects," Palmer says. "It's been a good learning process."

Having expert talent on staff or access to talent who understands what can be done with large-scale AM is also important to maximizing the benefits of the technology for manufacturing.

"To make the business case work, a part should be redesigned for AM and that just takes time," notes Lincoln Electric's Douglass. "A lot of the challenge is generating awareness of AM as a means to produce large parts and then designing and thinking about parts for AM." DE

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➔ MORE INFO

- **BigRep:** BigRep.com
- **Knust-Godwin:** KGsbo.com
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- **Thermwood:** Thermwood.com
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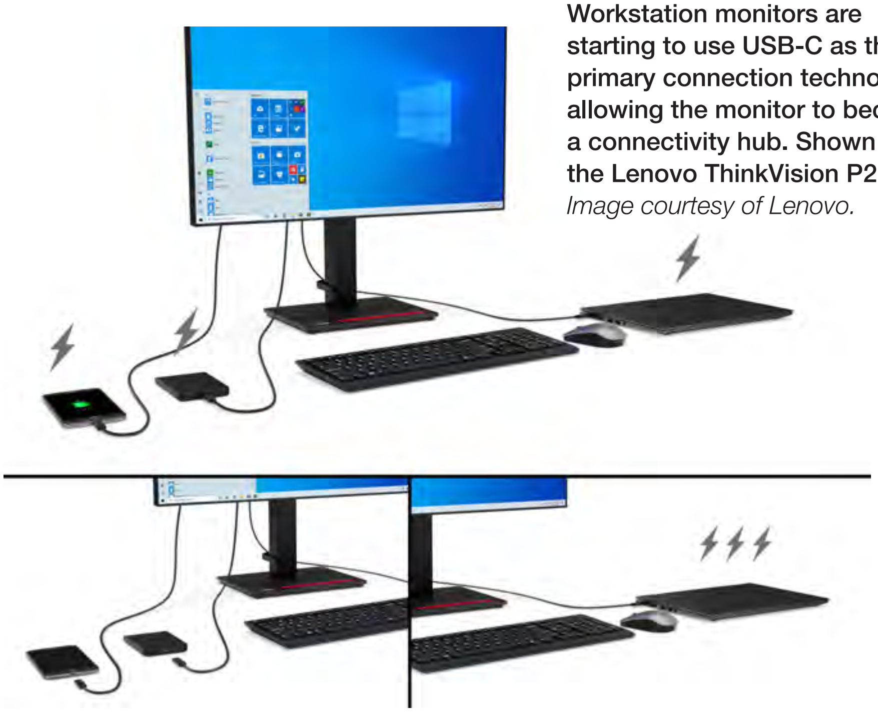
Workstation Monitors Boast Curves and Connectivity

Engineers put more consideration into monitor features as work-from-home setups emerge.

BY RANDALL S. NEWTON

As working from home is more common with product engineers, companies and employees are taking a fresh look at what constitutes a productive work-from-home workstation. This evaluation suggests that the monitor should no longer be an afterthought. The new wave of workstation-class monitors are recognized for their ability to improve ergonomics, increase user productivity and improve the connectivity dynamics of having more than one work environment.



Workstation monitors are starting to use USB-C as their primary connection technology, allowing the monitor to become a connectivity hub. Shown is the Lenovo ThinkVision P27H. *Image courtesy of Lenovo.*

Bigger Can be Better

Research has confirmed the increased productivity of using multiple task windows, whether with single- or dual-monitor configurations. In a Wichita State University study, participants were first assigned tasks to do on a dual-screen setup, then moved to a single 17-in. screen for similar tasks. By the end of the study participants "were often observed to show disappointment" when asked to use the single monitor.

A similar study at the University of Utah showed a 44% productivity increase for text tasks and a 29% increase for spreadsheet tasks, when moving from a single screen to a dual-monitor arrangement. In a Georgia Institute of Technology study, participants were able to complete tasks nearly 2.5 minutes faster using a dual-monitor setup. If one employee gains 5 minutes per hour doing such tasks, that adds up to an hour a day per employee.

Graphics industry research firm Jon Peddie Research (JPR) also has noted similar productivity boosts, measuring the impact of more screen real estate on graphical computing. In three studies in the past 10 years, companies using dual-screen displays reported higher productivity and higher usage satisfaction.

Samsung is one of several vendors with new 49-in. curved monitors designed for workstation use. One widescreen curved monitor replaces the need for two or more flat monitors. *Image courtesy of Samsung.*

"Our studies have found that in some cases productivity can be increased by 50% or more with multiple monitors," comments Jon Peddie, president of JPR. "Realism and the details revealed with more display area not only improve understanding in a visualization, but increase enjoyment. It's tiresome to have a constrained view of the world; it's like looking at the world through a tube or a pair of binoculars."

There are also vendor-hosted studies. A new study from Dell measures the productivity of attaching a second monitor to a notebook system. "Give a notebook user a flat 27-inch monitor and their productivity improves 38%," says Vinay Jayakumar, a Dell product consultant for commercial displays.

In the same study, Dell measured the use of a curved screen as the second monitor for notebook users. A 34-in. curved monitor offered a 42% increase in productivity.

"Curved monitors reduce eye movement," Jayakumar notes. "Yet, the panoramic view is different from the flat view from a distance," he adds, which suggests the decision between a flat or curved screen as a second monitor for a notebook computer depends on intended use.

Productivity Benefits

Pepperdine University researchers compared various hardware upgrades for productivity benefits. They found higher screen resolution was a more reliable predictor of user satisfaction and productivity increase than a faster CPU.

Specifically, there was increased insight into user data, decreased stress and more time spent on primary tasks. The study concluded, "The ability to see more of one's data reduces user stress as this utilizes more external memory—the monitor—and less cognitive memory. Just as writing a list down on paper can relieve the burden of remembering the information—which frees the mind up to perform the task as hand—having a larger monitor enables people to access more information at once and thus to focus more energy on solving the problem as opposed to remembering facts. In addition, increased display space can enable users to retain greater amounts of data in their long-term memories."

4K Now the Standard

Pepperdine's productivity research cited was based on HD displays. Now 4K monitors are the industry standard. 4K has four times more pixels than an HD display, and the difference is noticeable.

"Nobody will buy HD today," says Andrew Rink, a senior technology strategist at NVIDIA. "More pixels mean higher image quality, smoother lines and less need for anti-aliasing technology. Clearer views mean less need to minimize and maximize windows."

Boutique workstation vendor Orbital Computers primarily assembles workstations for engineering and media professionals. When 4K monitors first came out, CAD programs and other engineering software products were not automatically scaling to the new resolutions, leading to widespread frustration. That time lag in support has disappeared, says CEO Danny Payne.

Now all CAD vendors directly support 4K, and "the results are spectacular; once you use 4K for CAD, it is impossible to go back to HD," says Payne. "Everything looks so much sharper, diagonal lines in particular."

Two specific monitor panel technologies compete in the marketplace, in-plane switching (IPS) and twisted nematic (TN). The vendors we interviewed for this article all agreed that IPS is preferred for engineering and other technical graphics applications.

TN offers faster response times, which gamers like, but IPS offers better color accuracy, color contrast and viewing from a wide field. The speed difference between IPS and TN is approximately 5 to 6 ms. As Payne notes, "Six milliseconds is nothing in CAD use."

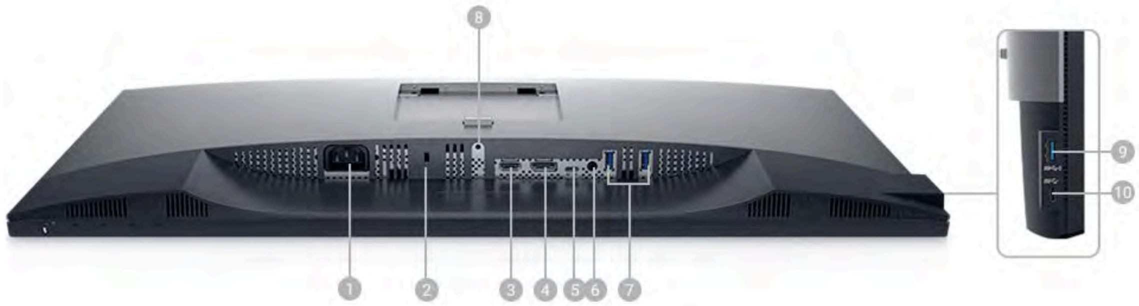
Lenovo is noticing increased interest in a third monitor technology. Vertical alignment (VA) is a type of LCD panel characterized as having improved image contrast and image depth.

"It offers the benefits of IPS, and is an improvement on TN," notes Brandon Smith, the visual experience product manager at Lenovo. Smith says Lenovo is now offering a 44-in. curved VA display for engineering workstations, meant to replace two 24-in. displays.

USB-C is a game changer

It is typical today for workstation-class monitors to come with USB-C connectivity. USB-C technology allows for one single cable to provide audio, visual, data transfer and electric power.

"Our vision is that the monitor is the hub," says Dell's



The placement of ports and slots on this Dell UltraSharp 4K USB-C model U2720Q is typical of the new generation of workstation monitors. 1. AC power port | 2. Security lock slot | 3. HDMI port | 4. DP port | 5. USB-C/DisplayPort | 6. Audio line-out port | 7. USB downstream ports (2) | 8. Stand lock | 9. USB downstream port | 10. USB-C downstream port. *Image courtesy of Dell.*

Jayakumar. This allows for the mouse, keyboard and an [external] solid-state drive to be hooked to the monitor, instead of the computer. "It makes for a clutter-free environment," he notes.

Engineers setting up a work-from-home workstation do not have the luxury of an IT specialist; "investing in USB-C enables simplified setup and easy transition between mobile and workstation computer," adds Jayakumar. Using USB-C has the added benefit of charging the notebook computer when the monitor becomes the new docking station.

"USB-C is a game changer for connectivity. Audio-video-data power is a revolution for the industry," Jayakumar says.

"Given the pandemic and working from home, USB-C connectivity is a phenomenal piece of tech added to workstations and laptops," adds Lenovo's Smith, who has a USB-C monitor as the center of his work-from-home workstation. The ability to connect devices and charge from the monitor "will not only save space on a user's desk, but will also improve productivity."

Smith warns that available wattage in USB-C connectivity in workstation monitors is an issue buyers should consider. The USB-C specification is 100W, but "many monitors support less, down to as low as 15 watts or so," says Smith.

If a notebook workstation includes a large (or dual) graphics processing unit, there might not be enough electrical power from the monitor to fully support use and charging. "We are serious about lots of wattage in our monitors," he adds.

A Return to Ethernet

To save space many workstation notebook computers have eliminated an ethernet port, allowing connectivity only using Wi-Fi. Yet workstation-class users often prefer a faster ethernet connection when available.

Smith says Lenovo, like other vendors, is starting to add an ethernet port to its workstation-class monitors. The combination of USB-C and ethernet in a monitor "is a trend that will continue, as vendors offer more supportive options for work-from-home settings."

Monitor or TV?

All the vendors we interviewed say they often receive questions comparing dedicated monitors with flat-panel TV screens. "TVs have input lag," notes Orbital Computers' Payne. "They are not built for interaction but for streaming signals." In addition, Payne says the larger TVs also cause eye fatigue. For daily work, Payne says a 24-in. HD monitor is better than a 55-in. 4K television. "The 4K TV would be OK in a conference room, but not for dedicated one-person use."

Another way monitors differentiate from TVs is their ability to control visual elements of interest to workstation users. Some vendors are adding the ability to manage the amount of blue light the screen produces.

"Blue light is a primary culprit in eye comfort," says Lenovo's Smith. Most workstation vendors offer monitors that can be calibrated for 3D or 2D CAD work. **DE**

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MORE INFO

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- **Jon Peddie Research:** JonPeddie.com
- **Lenovo:** Lenovo.com
- **NVIDIA:** NVIDIA.com
- **Orbital Computers:** OrbitalComputers.com

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Dell Precision 5550: Thin, Fast and Pricey

DE tests the world's smallest 15-in. mobile workstation.

BY DAVID COHN

Dell recently announced a couple of new mobile workstations in its Precision line—the 5550 and 5570—offering the portability of a laptop and the processing power of a desktop PC. The Precision 5550 is reportedly the world's smallest 15-in. mobile workstation, according to Dell. A few weeks later, we received one of these new systems and immediately put it to the test.

As soon as it arrived, the new Dell Precision 5550 grabbed our attention. Nestled inside an elegant hinged black box made with 100% recycled materials, unpacking the Precision 5550 was a treat. And the computer packed inside that box was indeed incredibly thin.

Like the Precision 7540 we recently reviewed (see *DE*, April 2020; digitalengineering247.com/r/24243), the Dell Precision 5550 comes housed in a silver-colored case. But while the 7540 was more than an inch thick, the Dell Precision 5550 is less than half that. Its case measures a mere 13.56×9.07×0.46-in. (WxDxH) and our evaluation unit weighed just 4.42 lbs., plus 0.94 lb. for its 130-watt power supply (5.62×2.56×0.88-in.).

Great Design, Few Ports

Lifting the lid reveals a 15.6-in. display with a 16:10 aspect ratio and one of the thinnest bezels we have seen. Dell calls this new design "Infinity Edge." Measuring just over 1/8-in. surrounding a panel surfaced with Corning Gorilla Glass, the result is a near borderless screen.

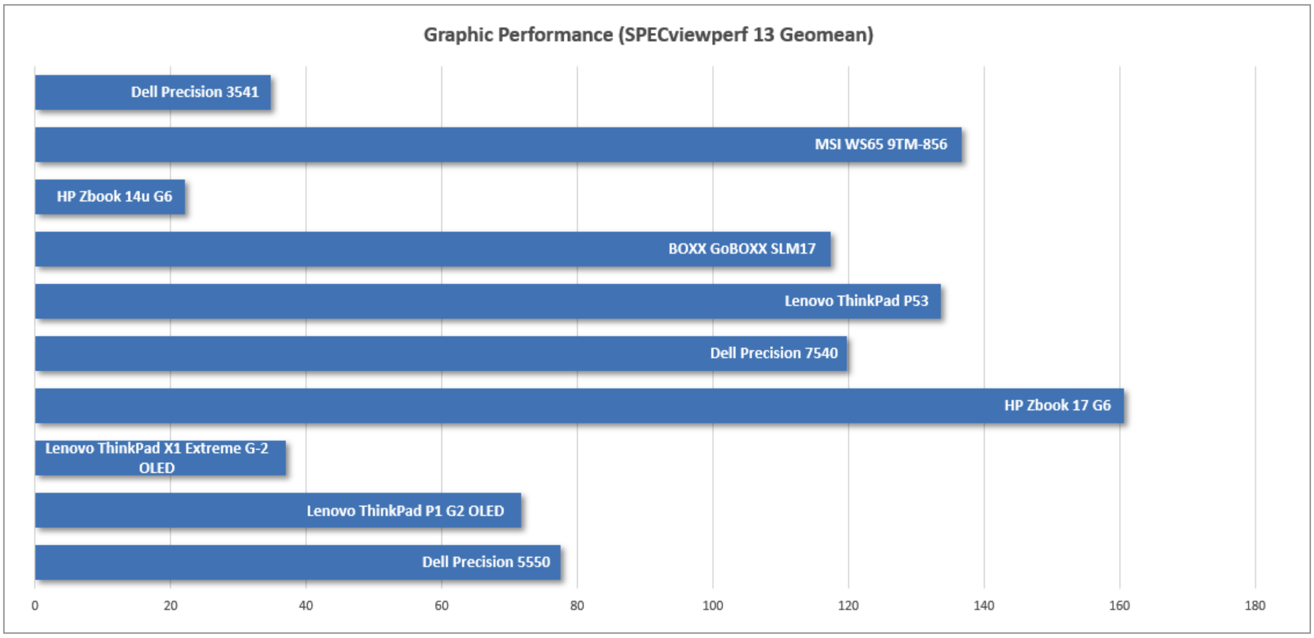
Dell still managed to place an RGB-infrared (red, green and blue-infrared) webcam centered in the top edge of the bezel, flanked by a pair of infrared emitters, an ambient-light sensor and a camera-status light, while a pair of microphones are located on the top edge of the case. The bezel is too thin to accommodate a privacy shutter.

The Dell Precision 5550 incorporates a 79-key backlit keyboard with a very good feel and ample 1.3-mm key travel. An additional key in the upper-right corner of the keyboard doubles as the power button and a fingerprint reader. The keyboard is flanked by a pair of top-firing stereo speakers that provide very good sound.

There are also a pair of slots along the bottom edge on either side of the case for left and right woofers. A large (5.94×3.56-in.) gesture-enabled touchpad, centered in the palm rest below the keyboard, lacks any dedicated buttons, but recognizes the difference between left- and right-clicks. Only the Caps Lock key includes an indicator light, while a battery status light is located on the front edge of the case, centered below the touchpad.

Though the reduced size of the Dell Precision 5550 is to be applauded (the system is 6% smaller than the previous generation), the thin chassis leaves limited space for external ports. The left side provides a wedge-shaped security lock slot and a pair of USB 3.2 Gen 2 Type-C ports with Thunderbolt 3. The right side hosts an additional USB 3.2 Gen

The Dell Precision 5550 packs power and a gorgeous display into a thin, lightweight chassis with minimal ports. *Image/charts courtesy of David Cohn.*



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

2 Type-C port, an SD-card slot and a 3.5-mm audio port. One of the Type-C ports on the left side is meant to be used to connect the external power supply, but you can plug the power supply into any of the Type-C ports.

There are no other ports—no USB Type-A ports at all—and the only air vents are located on the bottom of the case.

Our evaluation unit came with a small adapter that, when plugged into a USB Type-C port, provided a single HDMI port and a single USB Type-A port; this is simply not sufficient.

A minimum of two USB Type-A ports are often required (one for a mouse and the other for an external drive). Some users might also want an RJ-45 jack to connect to a gigabit network. Dell does sell several other adapters—including a USB-C mobile adapter ($70) that provides six ports (USB-A, USB-C, HDMI, VGA, DisplayPort and RJ-45) and a Thunderbolt Dock ($275) that houses 11 ports (three USB-A, two USB-C, HDMI, two DisplayPorts, two audio combo jacks and a power connector) plus both wedge-shaped and Kensington lock slots. There are also a number of third-party adapters that would work. Either way, you may want to include one of these as part of your purchase.

Ample Options

Although external connections are limited, Dell does offer quite a few internal options. With a starting price of $1,999, the base configuration includes an Intel Core i5-10400H 2.60GHz four core CPU with integrated Intel HD Graphics 630, a 1920×1200 display, 8GB of RAM, a 256GB M.2 PCIe NVMe Class 35 SSD, a 3-cell 56Whr lithium ion battery and a 90-watt power supply. But that is just the starting point.

Dell presents a choice of five different 10th-generation 14nm processors. In response to competition from AMD Ryzen processors, these Comet Lake CPUs offer increased core counts and faster clock speeds.

In addition to the base four-core i5 CPU, you can opt for one of two Intel Core i7 6-core variants (the 2.6GHz i7-10750H or 2.7GHz i7-10850H), the eight-core i7-10875H, or the Xeon W 10855M (a 6-core CPU running at 2.8GHz).

All offer higher turbo-boost speeds than the previous generation, but the highest numbers are only achievable "opportunistically," with what Intel calls "Thermal Velocity Boost." This means the additional speed is only available periodically when the processor is operating below its maximum temperature.

Our evaluation unit came with an Intel Core i7-10875H CPU, an eight-core processor with a 2.30GHz base frequency, 5.10GHz max turbo, 16MB of Smart Cache and a thermal design power rating of 45 watts. This CPU added $382 to the base price.

In addition to the integrated Intel graphics, Dell offers the Precision 5550 with a choice of two NVIDIA discrete graphics processing units (GPUs)—the Quadro T1000 ($140) or the Quadro T2000 ($266), which was included in the system we received. This GPU includes 4GB of GDDR5 memory and 1024 compute unified device architecture cores, while consuming 60 watts. Its 128-bit interface enables it to deliver a bandwidth of 128GB/second.

You also get a choice of two different displays. Our evaluation unit included a gorgeous 3840×2400 touch-enabled display covering 100% of the Adobe color gamut, adding $313 to the total cost.

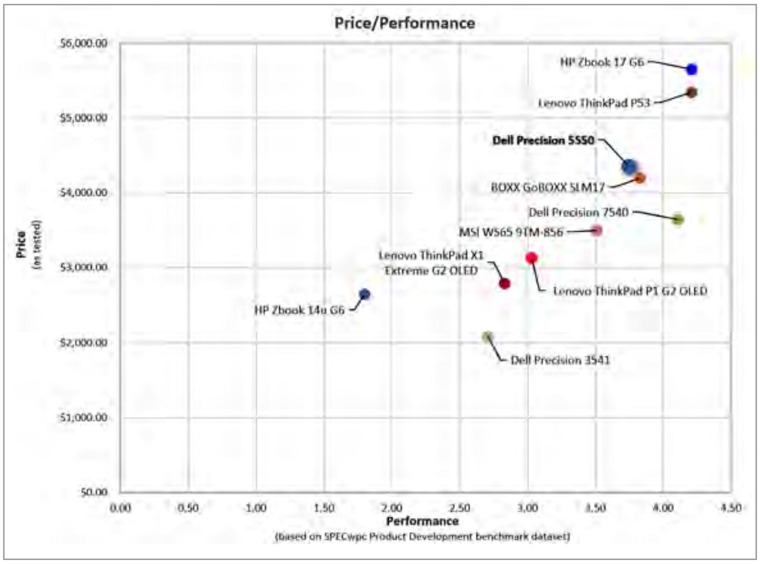
Although the new 10th-generation Intel CPUs can support up to 128GB of memory, its two memory sockets mean that the Dell Precision 5550 is capped at a maximum of 64GB. Our system came with 32GB of RAM, installed as two 16GB DDR4 2933MHz modules, adding $420. Dell also offers error-correcting code memory for those systems equipped with a Xeon CPU.

The Dell Precision 5550 also supports up to two M.2

Mobile Workstations Compared

	Dell Precision 5550 15.6-inch mobile workstation (2.30GHz Intel Core i7-10875H 8-core CPU, NVIDIA Quadro T2000, 32GB RAM, 1TB NVMe PCIe SSD)	**Lenovo ThinkPad P1 G2 OLED** 15.6.3-inch mobile workstation (2.80GHz Intel Xeon E-2276M 6-core CPU, NVIDIA Quadro T2000, 32GB RAM, 1TB NVMe PCIe SSD)	**Lenovo ThinkPad X1 Extreme G2 OLED** 15.6-inch mobile workstation (2.60GHz Intel Core i7-9850H 6-core CPU, NVIDIA GeForce GTX 1650, 32GB RAM, 1TGB NVMe PCIe SSD)	**HP Zbook 17 G6** 17.3-inch mobile workstation (2.40GHz Intel Xeon E-2286M 8-core CPU, NVIDIA Quadro RTX 5000, 32GB RAM, 512GBB NVMe PCIe SSD)	**Dell Precision 7540** 15.6-in. mobile workstation (2.40GHz Intel Core i9-9980H 8-core CPU, NVIDIA Quadro RTX 3000, 32GB RAM, 512GBB NVMe PCIe SSD)	**Lenovo ThinkPad P53** 15.6-in. mobile workstation (2.80GHz Intel Xeon E-2276M 6-core CPU, NVIDIA Quadro RTX 5000, 64GB RAM, 1TB NVMe PCIe SSD)
Price as tested	$4,355.00	$3,133.00	$2,794.00	$5,654.00	$3,646.00	$5,338.00
Date tested	6/24/20	2/16/20	2/16/20	1/24/2019	10/25/2019	10/24/2019
Operating System	Windows 10 Pro 64	Windows 10 Pro 64	Windows 10 Pro 64	Windows 10 Pro 64	Windows 10 Pro 64	Windows 10 Pro 64
SPECviewperf 13.0 (higher is better)						
3dsmax-06	91.74	76.32	85.73	185.09	155.08	181.47
catia-05	147.96	126.46	56.36	279.31	209.89	269.51
creo-02	116.59	101.20	75.12	243.95	187.29	255.96
energy-02	17.31	17.11	6.37	42.15	31.69	38.63
maya-05	112.25	102.12	100.62	272.88	183.66	261.90
medical-02	51.11	47.95	24.57	91.59	63.63	85.31
showcase-02	43.99	36.50	36.83	93.46	78.72	63.79
snx-03	144.50	191.81	11.29	361.04	217.45	223.64
sw-04	100.81	86.57	53.45	158.92	130.57	88.51
SPECapc SolidWorks 2015 (higher is better)						
Graphics Composite	3.43	2.81	n/a	5.24	4.27	5.47
Shaded Graphics Sub-Composite	1.77	1.41	n/a	3.23	2.55	3.53
Shaded w/Edges Graphics Sub-Composite	2.67	2.03	n/a	4.21	3.37	4.38
Shaded using RealView Sub-Composite	2.42	1.91	n/a	3.90	3.08	4.05
Shaded w/Edges using RealView Sub-Composite	3.28	2.60	n/a	4.54	3.83	4.73
Shaded using RealView and Shadows Sub-Composite	2.85	2.23	n/a	4.48	3.42	4.59
Shaded with Edges using RealView and Shadows Graphics Sub-Composite	3.45	2.76	n/a	4.85	3.92	4.71
Shaded using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	7.51	6.92	n/a	13.41	11.30	15.06
Shaded with Edges using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	8.64	7.79	n/a	13.20	11.13	14.58
Wireframe Graphics Sub-Composite	3.53	3.13	n/a	4.00	3.91	3.92
CPU Composite	3.09	3.19	n/a	3.06	3.76	5.32
SPEC Workstation v3 (higher is better)						
Media and Entertainment	3.53	1.63	1.70	1.87	1.88	2.07
Product Development	3.75	1.62	1.57	1.81	1.91	2.24
Life Sciences	1.59	1.54	1.31	1.94	1.67	1.77
Financial Services	1.54	1.53	1.17	1.96	1.75	1.69
Energy	1.3	0.99	0.99	1.32	1.36	1.37
General Operations	1.96	1.90	1.84	1.55	1.72	1.89
GPU Compute	1.91	1.79	1.84	3.34	3.20	3.31
Time						
AutoCAD Render Test (in seconds, lower is better)	38.9	49.00	44.10	35.40	34.80	49.20
Battery Life (in hours:minutes, higher is better)	10:22	7:14	6:45	4:45	7:51	5:30

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



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

solid-state drives (with optional RAID 0 and RAID 1 on systems equipped with two identical drives). Capacities range from 256GB to 2TB. The system we received came with a 1TB PCIe NVMe Class 50 SSD, which added $734.

While a three-cell 56Whr battery comes standard, our system included a six-cell 86Whr lithium ion battery with ExpressCharge, which enables the battery to reach 80% in 60 minutes. That battery kept our Dell Precision 5550 running for an impressive 10 hours and 22 minutes. The computer was nearly silent during even the most demanding tests, but the underside got up to 115°F at times.

Great Performance

We had a very short time in which to evaluate this Dell mobile workstation, so we started running our suite of benchmarks as soon as the system arrived. On the SPECviewperf test, which measures pure graphics performance, the Precision 5550 did quite well, easily beating the scores of similarly equipped thin, lightweight mobile systems we recently tested; SPECapc SolidWorks benchmark scores were equally impressive.

On the very demanding SPEC workstation performance benchmarks, the Dell Precision 5500 also delivered very good results. It turned in the top score for general operations and its other results rank the 5550 among the recently tested systems. The Dell Precision 5550 also completed our multi-threaded AutoCAD rendering test in less than 39 seconds, placing it among the fastest mobile workstations we have ever tested.

All Dell Precision 5550 systems are independent software vendor (ISV) certified for major CAD, DCC and scientific applications and include a copy of the Dell Precision Optimizer, which automatically tunes the system to run ISV applications. Windows 10 Pro 64-bit came pre-loaded. Systems based on a Xeon CPU require Windows 10 Pro for Workstations, which adds $154 to the price. Windows 10 Home and Ubuntu Linux are also available.

Like several other vendors, Dell's standard warranty has been reduced to just one year of basic, onsite service. Warranties of up to five years are also available as are ProSupport with next business day onsite service, accidental damage coverage and an extended battery warranty. Since we base our as-reviewed price on systems with a three-year warranty, our cost includes the extra $173 for the longer warranty.

As configured, the Dell Precision 5550 priced out at $4,355, making it one of the more expensive mobile workstations we have tested recently. There are certainly faster, less expensive laptops out there, but none are as thin or lightweight as the Precision 5550. Just remember that you are paying a premium for that portability—and may need to spend a bit more for additional connectivity. **DE**

David Cohn *is the technical publishing manager at 4D Technologies. He also does consulting and technical writing from his home in Bellingham, WA and has been benchmarking PCs since 1984. He is a Contributing Editor to Digital Engineering and the author of more than a dozen books. You can contact him via email at david@dscohn.com or visit his website at www.dscohn.com.*

→ MORE INFO

- **Dell:** Dell.com
  Dell Precision 5550

Price: $4,355 as tested ($1,999 base price)

Size: 13.56×9.07×0.46-in. (W×D×H)

Weight: 4.42 lbs. plus 0.94-lb. power supply

CPU: 2.30GHz Intel Core i7-10875H 8-core w/16MB Smart Cache

Memory: 32GB DDR4-2933MHz

Graphics: NVIDIA Quadro T2000 w/4GB GDDR5

LCD: 15.6-in. UHD+ 3840×2400 anti-glare touch-enabled

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

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

Network: Intel Wi-Fi 6 AX201 plus Bluetooth 5.1

Ports: Two USB 3.2 Gen 2 Type-C with Thunderbolt, one USB 3.2 Gen 2 Type-C DisplayPort

Other: SD-card slot

Keyboard: 79-key backlit keyboard

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

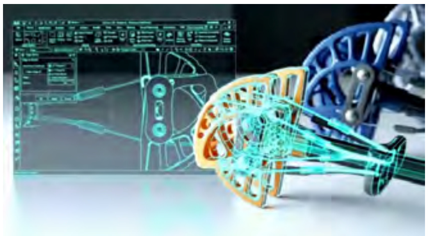
OS: Windows 10 Professional 64-bit

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

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

EDITOR'S PICKS

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



Initial 2D sketching without constraints

NX Sketch uses AI to eliminate the need for defining parameters before sketching.

Siemens Digital Industries Software offers a new solution for capturing design concepts in 2D. Siemens says changing the technology of 2D sketching allows users to sketch without pre-defining parameters, design intent and relationships. The AI technology infers relationships on the fly, offering flexibility in concept design sketching. Siemens says this new technology makes it easier to work with imported data, and allows rapid design iteration.

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Zero emissions composite 3D printing

RIZE 2XC desktop composite 3D printer is first deliverable of the RIZIUM Alliance.

RIZE debuts a professional desktop composite 3D printer designed with safety and sustainability in mind. RIZE 2XC uses a dual-extrusion 3D print unit from Sindoh, a 2D and 3D print engine manufacturer in South Korea. The print head is designed to run new RIZE engineering-grade composites that are zero emission and moisture-resistant, and require minimal post-processing. The unit can print carbon and glass fiber composites, made for industrial strength functional parts.

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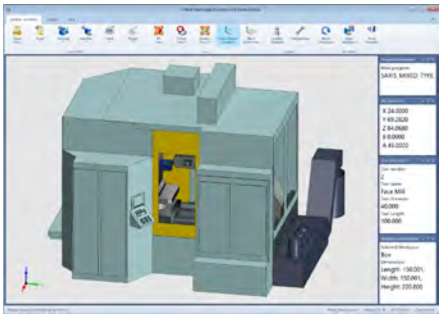


Extending training to 5-axis computerized milling

FANUC America Machining Simulation for Workforce Development is now available.

Factory automation solutions provider FANUC America announces the expansion of its CNC training to include 5-axis simulation. FANUC's Machining Simulation for Workforce Development provides training for controls operation and part programming in a virtual environment. FANUC says the Complex Milling Extension option combines FANUC's CNC Guide and simulation software, allowing the software to virtually operate one of three main 5-axis mill kinematics.

MORE ➜ digitalengineering247.com/r/24110

One license to access full rendering portfolio

Users will receive free upgrades for the life of their license.

Chaos Group now offers instant access to 15 products and services for one annual license fee. The company says its new V-Ray Collection will allow designers and artists to "connect their entire creative pipeline through a single floating license."

V-Ray Collection users can move freely between 3D applications, applying photorealistic renderings, fluid simulations and real-time scene exploration to projects. Chaos Group says it will not require a separate render node for products.

MORE ➜ digitalengineering247.com/r/24100X

Desktop 3D printer boasts rugged reliability

Made for any user who needs 3D printing in a desktop form factor for high quality.

The SynDaver Axi 3D printer features a large color touchscreen; a heated, automatic self-leveling and removable bed plate; and an E3D Hemera toolhead. It can print large volume builds to the full size of the print bed with edge-to-edge printing capability. The Axi supports various filament types, up to 290°C, including polylactic acid, acrylonitrile butadiene styrene, carbon fiber filled, fiberglass filled, metal filled, wood filled, and more.

MORE ➔ digitalengineering247.com/r/24082

Faster updates for large 3D assemblies

IronCAD 2020 update targets speed improvements and user productivity.

IronCAD says the purpose of this first update is to continue to focus on user productivity that began with the design of IronCAD 2020. The company says there is a "significant improvement" in large assembly performance, enabling users to work more efficiently. Specific changes include reduced load/save times; speed improvements in the IronCAD View Creation mode; and new functionality to help the user selectively modify camera interaction for greater efficiency.

MORE ➔ digitalengineering247.com/r/24051

Closing the gap on 3D printing expertise

Materialise Mindware is billed as an advisory service for businesses.

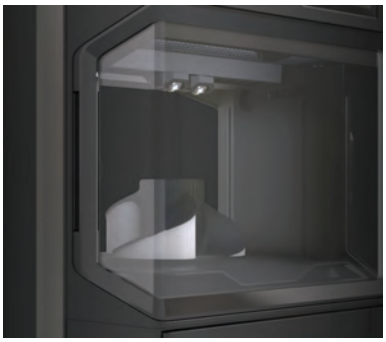
Mindware advisory service offers businesses strategic, tailored and technology-neutral insights on the use of 3D printing.

Materialise says Mindware can help companies with exploring or developing applications for 3D printing as well as collaborate on defining strategy and qualifying manufacturing processes for additive manufacturing. It will allow businesses direct access to Materialise's experts and their insights.

MORE ➔ digitalengineering247.com/r/24019

Print nylon carbon fiber parts on the desktop

MakerBot says material optimized for high strength, heat resistance and stiffness.



Stratasys subsidiary MakerBot introduces two additions to its METHOD platform of desktop 3D printers. The METHOD and METHOD X Carbon Fiber Edition 3D printers print carbon fiber reinforced nylon.

Both printers have an identical build box of 25.6-in. high, 16.3-in. wide and 17.2-in. deep. The METHOD model is suited for nylon carbon fiber; it prints nylon carbon fiber plus a wide range of engineered composites.

MORE ➔ digitalengineering247.com/r/23981

Student Competition Profile: SolidProfessor Design Challenge

Challenge Sparks Excitement in Engineering

BY JIM ROMEO

For a few years, SolidProfessor has hosted a themed quarterly design challenge primarily for post-secondary school teachers to assign to students and professionals. This past fall (2019) they challenged student designers to create a Halloween accessory that could be 3D printed. Kelly Mantick is a marketing manager with SolidProfessor. We spoke to Mantick and Tony Glockler (CEO) to learn more about this competition.

This cat mask was created for 3D printing as part of the annual design challenge. *Image courtesy of SolidProfessor.*

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

Kelly Mantick: When we created these design challenges, we had a few different goals.

First, we wanted to give teachers fun—and challenging—projects to assign to their students. As a company created by engineers, for engineers, we want to spark that love of engineering in the next generation. Solving fun design challenges and creating unique models is a great way to encourage students' excitement and curiosity. Secondly, we hoped to rekindle that love of engineering design for current engineers. This competition gives them a chance to break out of their routine and put their creativity to the test, both of which are incredibly beneficial for keeping skillsets sharp and for avoiding burnout.

SolidProfessor CEO and Co-Founder Tony Glockler: It's exciting to see students put their skills to work through real-world engineering design experiences. It gives students exposure to what it's like working in a professional setting, and it takes the application of engineering and makes it fun.

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

Mantick: The first-place winner submitted a short explanation of her design: "My mask was inspired by the cats in ancient Egyptian iconography. My file was designed in three parts because it made it easier for me to print! I have included the CAD files, renders of the mask and the physical print as proof that it is printable. The printed mask lacks some of the detail of the final file due to the sandblasting process to remove the print lines."

This was in response to our design prompt: "The country's largest 3D printing company, 3Design Wizards, is hosting its annual Halloween bash, and this year, they want to go all out by 3D printing costume accessories that guests can pose with at their photo booth.

"3Design Wizards has hired your company, Boss Engineering, to create the designs for the accessories they will 3D print. They're looking for creative, Halloween-inspired models like a magic wand, werewolf claws, Jason mask, pirate hook, witch's broom and the list goes on. The most important criteria: the accessory must be 3D printable and it must be faBOOlous!"

DE: **Does SolidProfessor have a particular stance on adopting an innovation that is linked to the program? What drove them to sponsor the event and coordinate it?**

Mantick: Our design challenges focus on inspiring creativity and challenging engineers to design something that's a little outside of their wheelhouse. This is a great time for entrants to test out new skills, features or tools that they don't normally use to expand their experience and skillsets. Whether students or professionals, engineers often have very little room for error in their jobs, so these challenges are their opportunity to explore their design software and just have some fun! We sponsor these to keep that love of engineering alive for current and future professionals. And we enjoy seeing all the fabulous entries! **DE**

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

→ MORE INFO

SolidProfessor: SolidProfessor.com

| COMMENTARY |

By Marcel Spiegler

Accelerate Automotive Design via 3D Printing

Additive manufacturing is playing a key role in revamping automotive design workflows.

Success and growth depend on constant innovation to stay ahead of the competition. Last May Harvard Business Review found that 10 times more money is spent on R&D than on advertising worldwide.

But for many traditional manufacturers, implementing digital technology into their workflows can still be seen as an insurmountable challenge, with major financial implications that are not always realistic, leaving them struggling to know how to compete.

This can be particularly true of the automotive industry, largely due to the higher number of parts required in production. Leading automotive manufacturers are relying on additive manufacturing (AM) to accelerate the product development cycle and also to reduce resources such as time and energy. AM is already transforming automotive production workflows, impacting R&D, supply chains and production.

Iterative Research and Development

AM has revolutionized R&D for vehicle manufacturers—increasingly being used to reduce development times, improve prototyping workflows and deliver innovative parts that would not be possible using traditional techniques.

In several major U.S. auto manufacturers, 80% to 90% of each initial prototype assembly has been 3D printed. Some of the most popular components are air intakes, exhaust parts and ducting. These parts are designed digitally, 3D printed and fitted on a car in short order, then tested through multiple iterations. Rapid prototyping enables a shorter development phase and reduced time to final part.

Avoid Supply Chain Disruption

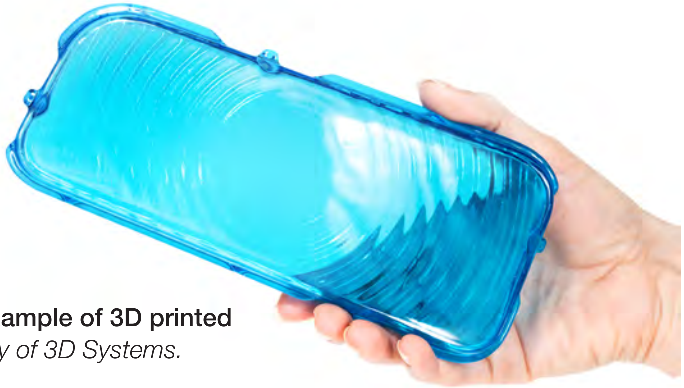
Most volume car manufacturers use just-in-time manufacturing, where large quantities of parts arrive at the production line immediately before assembly to reduce the need for costly warehouse space. AM can facilitate this process to create production parts on site, should there be disruptions to a manufacturer's supply chain.

For example, during a recent planned release of a new car, the tooling for the box that contained the engine control unit (ECU) was incorrectly manufactured. As a result, the launch of this new vehicle was set to be delayed. To avoid the costly wait time for new tooling from a third-party supplier, the makers employed AM. The first several hundred cars produced in that run included ECUs housed in boxes created using direct digital production. The CAD file was optimized for 3D printing, resulting in an end-use production part in a fraction of the time needed for retooling.

Specialty Car Industry Customization

An intriguing example of real-world part production is with specialty car manufacturers such as sports cars, luxury cars and hypercars. These manufacturers produce low volume, prestigious and exotic cars for their customers. Because of the unique vehicles they manufacture, they also look for ways to create

AM was used for both prototyping and production of this automotive bracket. *Image courtesy of 3D Systems.*



Light covers are just one example of 3D printed vehicle parts. *Image courtesy of 3D Systems.*

parts for these out-of-the-ordinary cars.

In this case, AM is being used to create custom brackets, spacers and grommets as well as complex, specialized units made specific to the individual requirements of the purchaser. One great example is the creation of personalized inscriptions for interior components such as the dashboard or doors.

AM Fuels the Rise of Electric Vehicles

Electric vehicles (EVs) are gaining popularity with consumers as an 'environmentally friendlier' mode of transportation. The incorporation of battery power versus an internal combustion engine has not removed weight reduction and engine cooling requirements from the equation.

Although recent advances have reduced the weight of the batteries that power EVs, they continue to be one of the heavier components of the vehicle. Increased vehicle weight impacts efficiency and performance. Therefore, as engineers design components for these vehicles, they are seeking ways to reduce weight in each part. Design for additive manufacturing (DfAM) causes engineers to rethink how they create components—allowing them to produce parts in ways not possible with traditional technologies. This results in parts with unique geometries—often at a reduced weight—that can be produced as a single final part versus multiple pieces requiring assembly. The result is reduced burden on the powertrain, which helps increase vehicle range.

Another innovation possible via the power of AM is a 3D-printed cooling jacket that acts as a heat exchanger. An EV's electric motor and battery can generate a great deal of heat, especially during charging. To create the part, a designer scanned the car's motor and battery, optimized the design using AM software and produced the part using a 3D printer. The bespoke design of the cooling jacket draws heat away from these vital components of the vehicle, helping reduce wear and tear—thus optimizing the parts' lifespan. As automotive manufacturers continue to embrace AM, this is one area with incredible potential for the future.

How Automakers Pioneer in the Fast Lane

The quest to out-innovate competitors and reduce costs for every aspect of product development is business as usual in the automotive industry. Thorough, innovative designs and engineering require precise, reliable technology solutions—a space where AM can play an integral role.

AM complements traditional technologies in an automotive manufacturing workflow and is transforming various applications including creating replacement parts for vintage automobiles, prototyping parts for the latest automotive releases and developing unique parts for one-of-a-kind creations. The result is improved efficiency and reduced time to final part, which is accelerating innovation and competitive advantage. Automakers worldwide are seeing the benefits AM can bring and the tremendous potential to manufacture parts—and vehicles—in ways previously not considered possible. DE

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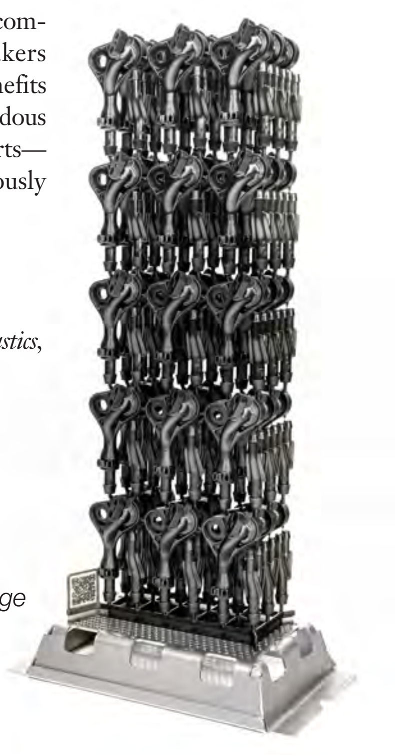
Marcel Spiegler *is director, Customer Innovation Center, Plastics, 3D Systems.*



Bimodal stacked printing of this washer fitting and y-connector increases production efficiency, reducing time to part. *Image courtesy of 3D Systems.*

| COMMENTARY |

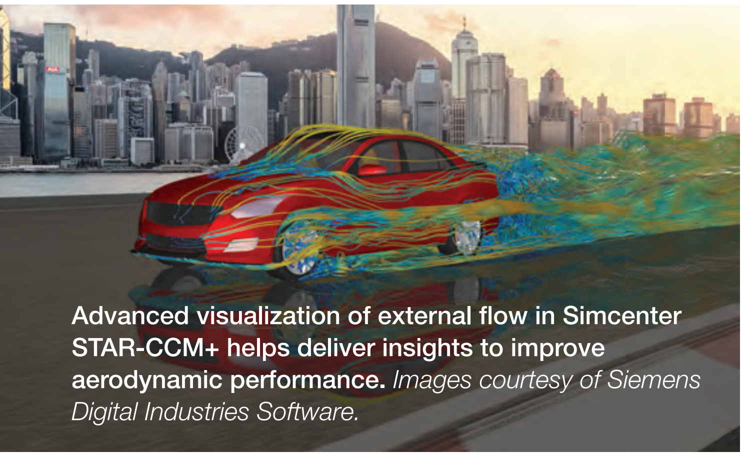
By Nand Kochhar

Holistic Digital Twin: the Backbone of Product Development

The comprehensive digital twin, built around state-of-the-art simulation and testing tools, is key to helping automotive OEMs remain competitive and embrace complexity.

The boundaries between automotive design and vehicle product life after delivery are disappearing. This trend will transform automotive development from a process that delivers discrete generations into a continuous process that tracks individual vehicles and constantly updates them until end of life. The comprehensive digital twin, built around leading-edge simulation and testing tools, is key to achieving this new reality to help automotive original equipment manufacturers (OEMs) remain competitive and embrace complexity.

Within the last few years, a convergence of technologies has transformed the automotive industry. Consider the emergence of viable electric vehicles and the potential of new materials to change the relation between form and function to provide vehicle lightweighting, helping to extend the range of the electric vehicle. Trends for mass personalization and new manufacturing processes such as additive or 3D printing make it possible to produce shapes that were never before possible. And the integration of software and electronics are improving performance, while paving the way to the ultimate goal of fully autonomous driving.



Advanced visualization of external flow in Simcenter STAR-CCM+ helps deliver insights to improve aerodynamic performance. *Images courtesy of Siemens Digital Industries Software.*

However, the result of all this is an increase in the complexity of products and processes used to engineer and manufacture vehicles. How does a company that is expert in internal combustion engines lead the way in battery technology or autonomous sensing technology?

Success in this demanding new environment requires fusing various domains of engineering to design and manufacture the product, thereby accelerating digital transformation—becoming digital enterprises that share data and collaborate in the design, manufacture and deployment of products and processes. All this requires embracing the concept of a comprehensive digital twin.

Benefits of Digital Twin Approach

The digital twin is a way to address challenges of complex vehicle system development by building a set of highly accurate models that help predict product behavior during all lifecycle phases of the vehicle. These models come in multiple scales and instances for various applications, integrate multiple physical aspects, contain the best available physical descriptions and mirror the life of the product and its production process.

When companies integrate all these models, they have access to a holistic digital twin that becomes the backbone of their product development—capable of delivering greater insight, reducing development cycle time, improving efficiency and increasing market agility.

If the comprehensive digital twin is critical to the future of automotive engineering innovation, simulation and test are the beating heart of the digital twin, providing insight into the real-world performance of the vehicle and accelerating innovation over the entire lifecycle. Simulation and test can predict every aspect of product performance, which enables the digital twin to evolve throughout every challenge a product faces in its operational lifetime.

By providing an integrated view on the vehicle's physical and behavioral aspects, the digital twin allows simultaneous balancing of all functional performance requirements throughout the development cycle.

The comprehensive digital twin helps to break down silos and blur boundaries between engineering disciplines, teams and organizations so companies achieve engineering effectiveness, scaling from components to full system and model-based systems engineering.

Investing in the Digital Twin

It is imperative for OEMs and their tier 1 and tier 2 suppliers to start their journey toward the implementation of a digital twin strategy now rather than wait for some future event to trigger investment, by which time it may be too late.

To help companies take a measured approach to adopting a digital twin in product development, companies should aim to focus on realism, continuity and exploration.

Realism: To address increasingly complex systems and technologies, it is critical that companies have a realistic representation of their product to instill confidence in their designs and ensure that design decisions are correct. More sophisticated simulation models yield results that are closer to reality by combining disciplines and physics, including, for example, a computational fluid dynamics (CFD) model of the vehicle, a structural dynamics model, a thermodynamics model, a stress analysis model and a fatigue-cracking model.

Improved confidence in simulation and test data can reduce the need for over-design, end-of-cycle physical testing and numerous field failures. All this leads to faster time to market and significant cost savings.

Continuity: To support the comprehensive digital twin, it is critical that performance engineering processes are not isolated and disconnected from the rest of the organization or the product lifecycle management (PLM) process. If companies can reduce barriers and enable collaboration across their suppliers, they not only increase their process efficiency, but they also get a more holistic view. This enables them to make the right decisions with all stakeholders in the supply chain across the organization and close the loop between requirements, design and verification over the complete engineering cycle.

Exploration: Realistic and integrated processes and models need to be deployed to yield the necessary insight for making rapid design decisions. For the most benefit from simulation tools, engineers need to intelligently explore the design space, as well as quickly understand design drivers and trade-offs to discover better designs. The comprehensive digital twin enables the frontloading of multidiscipline and multiphysics simulation earlier in the design process, giving engineers the freedom to rapidly evaluate possible alternatives and quickly innovate to find the best design.

Development of new electric and autonomous vehicles is critically dependent on leveraging a comprehensive digital twin.

Digital Twin Influence on Decision-Making

A digital twin can also deliver insights to influence decisions about service or predictive maintenance, timing of upgrades to improve performance or decisions made during development phases. Sensors on the vehicle can easily give feedback to the development team, enabling engineers to enhance their simulation to make better predictions and plan updates or maintenance. They can decide to replace parts or components. Or they can use all this information as improved starting parameters or boundary conditions when working on the next generation design.

Comprehensive Journey

When automotive companies transform their performance engineering processes based on a digital twin approach, they are able to engineer innovation. The digital twin helps accelerate complex system development by leveraging robust simulation and test capabilities for enhanced vehicle performance engineering. Once the vehicle is out in the real world, the digital twin then can be used to understand and predict performance and behavior. Ultimately automotive companies are able to bring better, more innovative products to market faster at a lower cost to keep pace with emerging capabilities such as electric and autonomous vehicles—helping transform complexity into a competitive advantage. DE

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