September 2021

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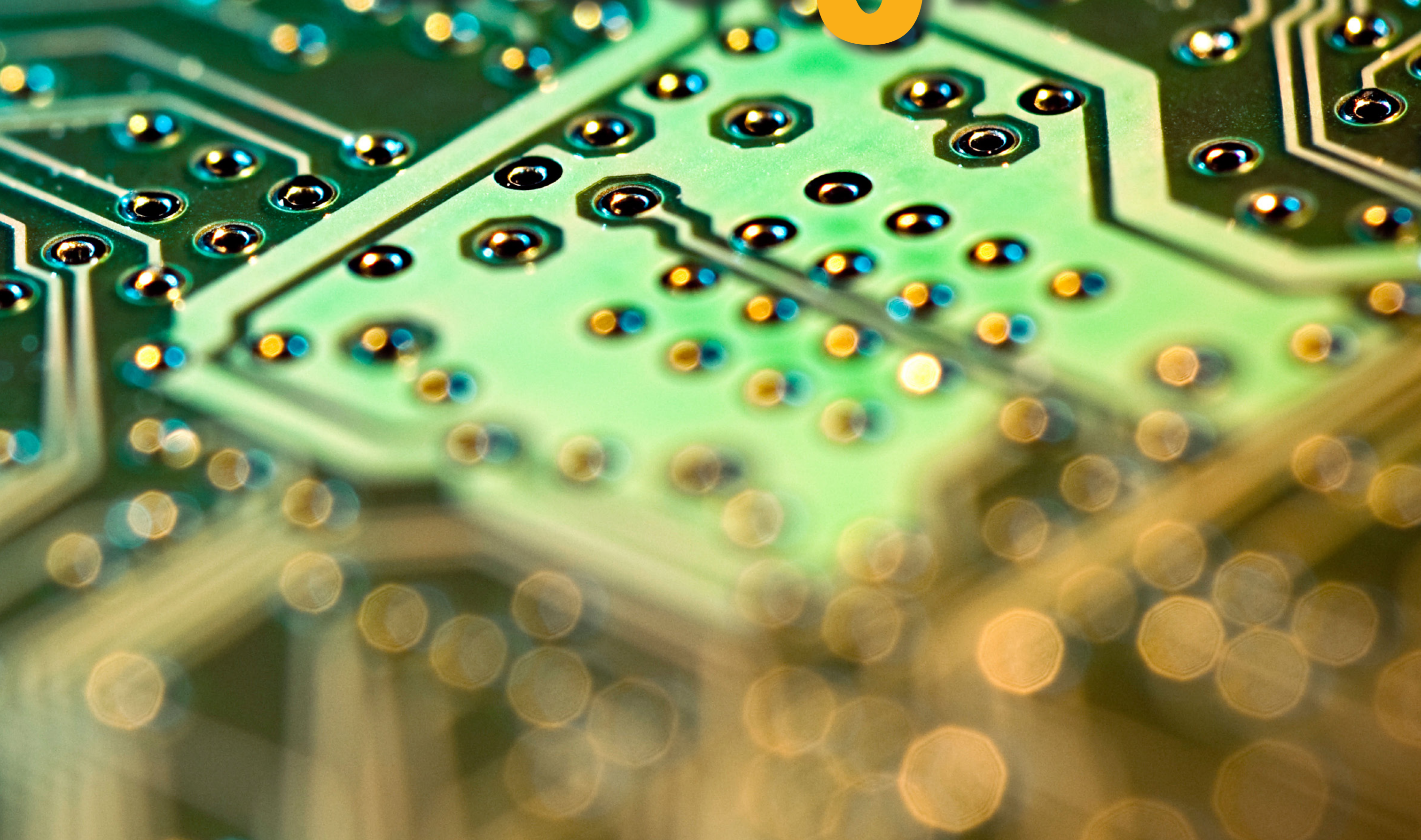
Electronics Design



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| **DEGREES OF FREEDOM** |

By Brian Albright

Engineering the Olympics

SUMMER IS WINDING DOWN AS WE PUT THIS ISSUE TOGETHER, and like many people I spent a big chunk of August watching the Summer Olympic games. Here in Ohio we were particularly thrilled to see Clevelander Katie Nageotte take gold in the pole vault, and cheered on other medalists with Ohio ties like Joe Kovacs (shot put), Duke Ragan (boxing), David Taylor and Kyle Snyder (wrestling), Oshae Jones (boxing), Hunter Armstrong (swimming), and others.

It was an unusual Olympics with no spectators and COVID protocols in place. There were the usual moments of drama and weirdness (horse punching?), but also plenty of amazing performances from Italian runners, U.S. gymnasts and many others, along with inspirational performances. How about Dutch runner Sifan Hassan, who won the women's 1,500 after she fell down? The men's high jump winners who decided to share the gold? Or 46-year-old gymnast Oksana Chusovitina putting us all to shame, competing in her eighth Olympic Games?

There was also plenty of engineering know-how on display in Tokyo as well. All 89 Olympic ceremony podiums were 3D printed this year (from 24 tons of recycled plastic waste); some of the competitors in the air pistol competition relied on a 3D-printed pistol grip.

A few British riders in the cycling events used Hope HB.T bikes that were specially engineered for performance, including a wider fork design, components customized for individual riders, and a seatstay with a noticeably wider stance. Portions of the bikers were also 3D printed with titanium. Hyundai had a hand in designing technology that aided the Korean archery team (which swept gold in those events).

Track records fell left and right at this year's games, in part because of the track surface designed by Italian company Mondo. The track included a semi-vulcanized rubber granule surface, with a honeycomb backing that could compress in all directions, returning plenty of energy back to the runners' feet.

One of the most fascinating stories about Olympic engineering feats came from China. The China Aerospace Science and Technology Corp. helped train the country's swimming team using facilities and technology normally associated with the development of ballistic missiles. Swimmers were able to take advantage of an inertial navigation system, aerospace measurement equipment, and simulated training and data analysis. Outfitted with sensors, the swimmers actually simulated swimming in a wind tunnel, which allowed scientists to calculate the precise drag of each movement.

All 89 Olympic ceremony podiums were 3D printed this year (from 24 tons of recycled plastic waste), while some of the competitors in the air pistol competition relied on a 3D-printed pistol grip.

With the games over, I am looking ahead to an autumn that will hopefully see my kids back in school, and better news on the COVID-19 front. We are also planning for the upcoming Digital Engineering Design & Simulation Summit, which will feature a keynote panel on digital twin technology, as well as contributions from our partners at the ASSESS Initiative, our own crew of contributors, and other leading technology experts. You can find out more here.

After that, it will be time to get ready for the Olympics again, with the winter games starting in just six months.

Brian Albright, Editorial Director
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DE247 Digital Engineering

TECHNOLOGY FOR OPTIMAL ENGINEERING DESIGN

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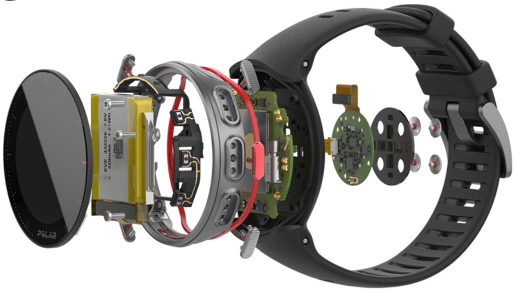
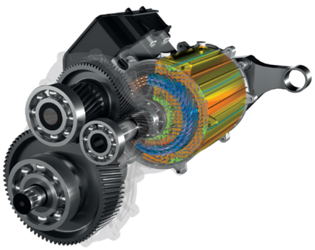
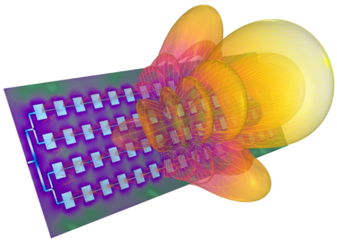
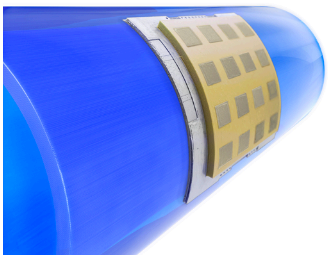
INSIDE

FOCUS ON ELECTRONICS DESIGN









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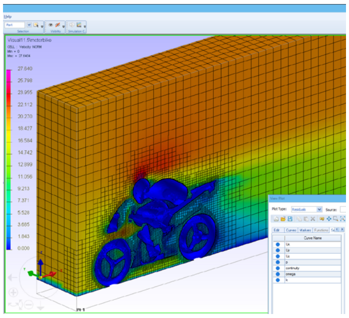
DEPARTMENTS



Editor's Pick, Page 43

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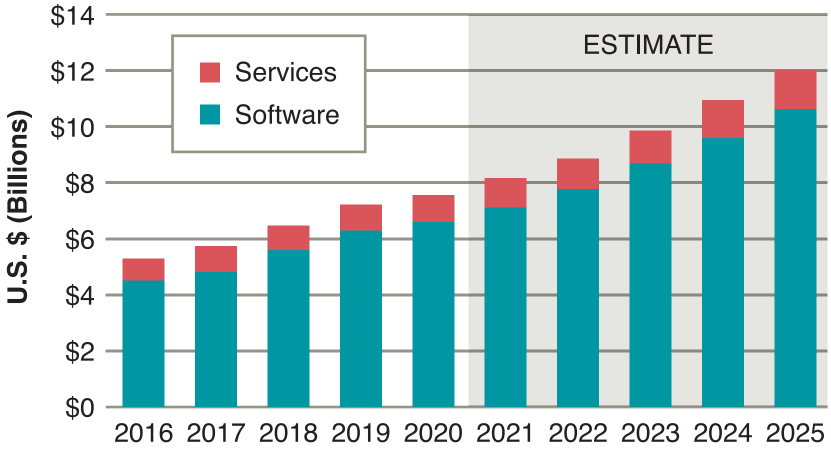
Engineering Software



The **simulation and analysis market grew** by **4.2%** to nearly **$7.5 billion** in 2020, according to the CIMdata Simulation and Analysis (S&A) Market Analysis Report.

The market will **grow 8.1%** with revenues just under **$8.1 billion** in 2021, and reach **$12 billion** by 2025 with a compound annual growth rate of **10%**.

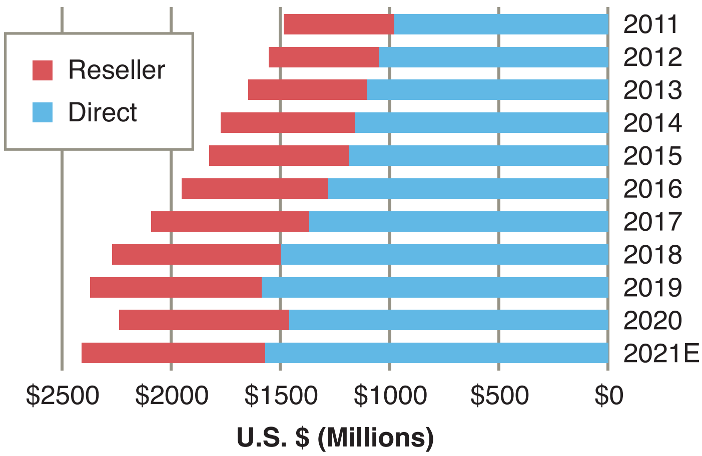
"Detailed geometric modeling, simulation, and analysis for virtual prototyping and verification/validation still makes up the majority of the S&A market segment. But to support the development and lifecycle support for smart, connected products, systems-level behavior modeling, simulation, and analysis are increasingly recognized as must-have core competencies to enable the digitalization of product development, manufacturing, and in-service lifecycle operations."

–DON TOLLE,
CIMdata's practice manager for Simulation-Driven Systems Development

The **CAM market shrank** by **5.4**% in 2020, according to the 2021 CIMdata CAM Market Analysis Report.

The estimated **end user payments** were **reduced** from nearly **$2.4 billion** in 2019 to just over **$2.2 billion** in 2020.

The pandemic-related economic downturn caused this retraction, and CIMdata expects the market to **increase** by **7.2%** to reach **$2.4 billion** in 2021.



Source: CIMData, July 2021

4.6%

The **growth rate** of the **CAE market** in 2020, according to the CAE Market Snapshots released by Cambashi and IntrinSIM. With economic activity returning to normal, the market is expected to rebound at a **rate** of **13.4%** in 2021.

Source: IntrinSIM, July 2021

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

NEWS

3D PRINTING

Rawlings Aims for Home Run With 3D Printed Performance Glove

Baseball giant Rawlings teams up with Fast Radius and Carbon to create 3D printed lattice inserts for REV1X high-performance glove.

3D printing is the newest player on deck for Rawlings as the baseball equipment giant since 1887 teams up with modern-day innovators like digital manufacturing company Fast Radius and 3D printer maker Carbon to innovate a new high-performance glove.

"We needed someone who could make our REV1X glove design a reality, and we found that in Fast Radius," says Ryan Farrar, senior director of ball gloves at Rawlings. "The glove is transformative for everyone in the baseball industry—both professionals and amateurs alike."

The REV1X glove was designed based on players' desire to have more variable stiffness in the thumb and pinky area without sacrificing protection, durability or playability, according to Rawlings engineers. There was also a goal to replace conventional padding materials like foam and plastic with more lightweight structures that will allow stiffness to be tuned while creating a design that was sleek and would reduce weight. In addition, the 3D printed inserts don't wear out as easily as more traditional materials, thus helping to improve ball handling when on the field, Rawlings officials said.

"The 3D printed lattice replacements are not just lighter and thinner, they are also calibrated with variable stiffness that conforms to the player's hand," explains John Nanry, chief manufacturing officer and co-founder of Fast Radius. "It's immediately ready for game play and lasts much longer than traditional materials." Another benefit: The lack of tooling in the AM process meant that testing, iterating and part improvement could be done more rapidly, greatly accelerating the product development process, he says.

The new REV1X glove uses an intricate lattice design in the pinky and thumb inserts. Rawlings' engineering team zeroed in on the Carbon Digital Light Synthesis (DLS) process as the optimal 3D printing technology to output the lattice structure that would help it achieve its design goals due to its high tolerances and ability to print complex geometries at rapid speeds. Moreover, Carbon's FPU 50 material provided a flexible polyurethane for producing malleable and formable parts that are capable of withstanding significant impact while maintaining their shape, Nanry says.

The REV1X glove is designed for variable stiffness in the thumb and pinky area for higher performance. *Image courtesy of Fast Radius.*

REMOTE COMPUTING

HP Acquires Remote Computing Platform Teradici

Acquisition will strengthen hybrid work offerings.

HP has signed a definitive agreement to acquire Teradici Corporation, a global provider of remote computing software that enables users to securely access high-performance computing from any PC, Chromebook or tablet. According to HP, the acquisition will enhance the company's capabilities in the Personal Systems category by delivering new compute models and services tailored for hybrid work.

As hybrid work becomes the norm, 67% of the workforce is expected to work remotely at least three days a week, according to internal research conducted by HP.

"Teradici's cutting-edge technology has long been at the forefront of secure, high-performance virtual computing," said Alex Cho, president, Personal Systems, HP Inc. "Their world-class talent, industry-leading IP, and strong integrations with all major public cloud providers will expand our addressable market, and meet growing customer needs for more mobile, flexible and secure computing solutions. We look forward to welcoming the Teradici team to HP."

"We have long admired HP as one of the world's most innovative technology companies and we are thrilled to be joining the team," said David Smith, CEO, Teradici. "HP's strong culture of innovation, customer-centricity and corporate values aligns extremely well with our mission at Teradici and this deal will significantly expand our global reach and drive new sources of innovation."

Through its ZCentral Remote Boost software, which is focused on providing remote access to physical workstations, HP already enables remote and hybrid work for professionals such as engineers, animators, editors and other users of high-performance computing.

According to HP's press office, the Teradici brand will remain, and the acquired company and its talents will join HP's Personal Systems Services division.

Teradici provides a complementary set of capabilities that are focused on cloud PCs and virtual workstations. According to HP, combining the two remote access solutions will enable HP to offer a broader remote compute platform that spans on-premise and cloud solutions from any type of device, including macOS, public clouds and iPad and Android tablets.

The transaction is expected to close in Q4 2021, pending regulatory review and other customary closing conditions. Financial terms of the transaction were not disclosed.

Teradici's products are also bundled with other PCs and workstations in partnership arrangements. These partners include some of HP's rivals, such as Dell, Lenovo and BOXX. "HP values Teradici's partnerships and will encourage their continuation," says HP's press office.

ROBOTICS

Last Mile Autonomous Delivery Robot Developed With Ultimaker S3

Final Aim used 3D printing to develop a solution that tackles Singapore's delivery issues.

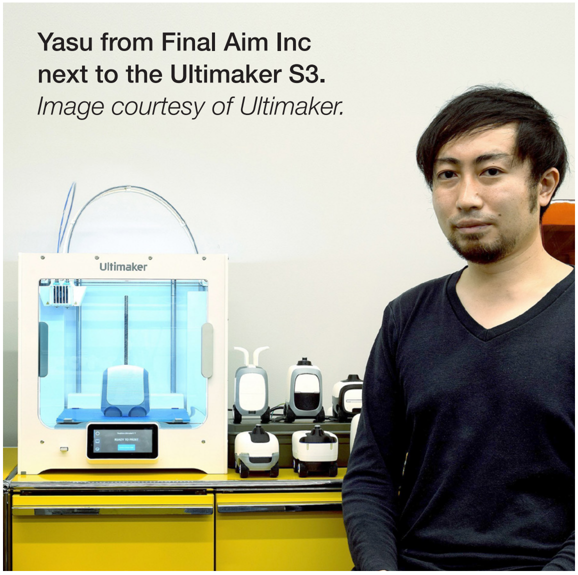
Ultimaker reports that Final Aim, a hands-on technology firm in Japan, used the Ultimaker S3 to rapidly design the first autonomous delivery robot in use for Singapore. Final Aim collaborated with the robotics start-up OTSAW Digital PTE LTD to develop the robot Camello to tackle inefficiency issues that Singapore faces in the last mile of the logistics chain. Brulé, official sales partner of Ultimaker in Japan, served as a knowledge and support partner for the teams.

In collaboration with large industrial businesses such as NTUC FairPrice and DHL, the robot is currently in service for parcel and grocery delivery. Camello is user friendly, featuring an ergonomic cargo space and sleek design—made for Singapore's urban environment.

"3D printing enabled us to bring our numerous ideas to life," says Yasuhide "Yasu" Yokoi, co-founder of design and technology firm Final Aim. "The Ultimaker S3 is very easy to handle, which gave me extra time to work on new designs while printing. Compared to other common prototyping methods, we found 3D printing to be much more efficient for prototyping."

For the Camello to be a success, its design had to be intuitive and accessible. 3D printing enabled stakeholders to see and touch a physical product, deepening their understanding of the Camello's concept and design—while streamlining and speeding up the decision-making process.

"It has been truly magical to witness the teamwork between Final Aim Inc, OTSAW and our partner Brulé to bring this robot to life," says William Lee, channel director at Ultimaker. "This solution contributes to an improved logistic ecosystem for smooth and efficient delivery to customers, while increasing profit margins for those businesses that use it."



Yasu from Final Aim Inc next to the Ultimaker S3. *Image courtesy of Ultimaker.*

SIMULATION

Ansys and IPG Automotive Accelerate Autonomous Vehicle Path to Market

New partnership integrates simulation technology from IPG Automotive with Ansys' immersive autonomous driving simulation solutions.

Ansys and IPG Automotive are teaming up to fast-track the creation, integration and validation of advanced driver-assistance systems (ADAS) features and autonomous vehicles (AVs). Combining Ansys VRXPERIENCE with IPG Automotive's CarMaker will enable joint customers to virtually verify and validate sensor design and performance.

Integrated in VRXPERIENCE, the CarMaker open test platform has a complete environment of flexible models of intelligent drivers, detailed vehicles, roads and traffic. The event and maneuver-based testing method ensures that flexibility and realistic execution of real-world test driving are part of virtual test driving.

VRXPERIENCE gives users human machine interface testing, physical sensor simulation, embedded software controls integration, headlamp simulation and links to simulation data management and systems safety analysis.

"As vehicle systems continue to become more complex, it is increasingly important that they are tested under realistic conditions," says Martin Elbs, general manager, sales and business development at IPG Automotive. "Together with Ansys, we are helping automotive OEMs improve the safety and reliability of AVs and ADAS while reducing cost and time to market."

"Our partnership with IPG Automotive will enable our mutual customers to use an industry-leading driving simulator seamlessly integrated into our VRXPERIENCE solution," says Shane Emswiler, senior vice president of products at Ansys. "Through this partnership, we are providing mutual customers with the necessary technologies to improve and expedite ADAS and AV development and delivery, also leading to reduced accidents on the road thanks to improved safety measures."

Sources: Press materials received from the company and additional information gleaned from the company's website.

Fortifying the **MCAD-ECAD** Bridge

CAD-embedded plug-ins, mergers and acquisitions, and the quest for common file formats reinforce works already in progress across the industry.

BY KENNETH WONG

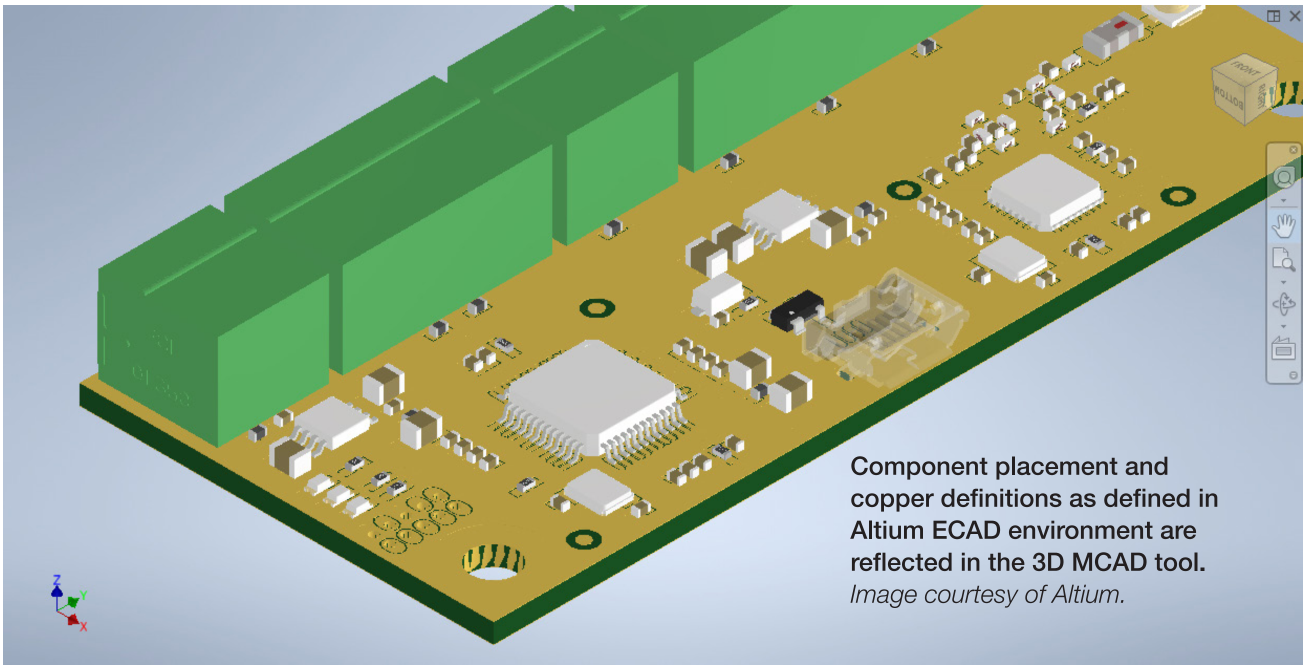
In early June, the design software giant Autodesk went after the popular electronic CAD (ECAD) software maker Altium. The company submitted a non-binding proposal to acquire all the outstanding shares of Altium Limited, stirring up excitement in the market.

The merger "would advance Autodesk's strategy to converge design and make through a unified design, engineering and manufacturing cloud platform that enables greater productivity and sustainability for its customers," wrote Autodesk in its press release.

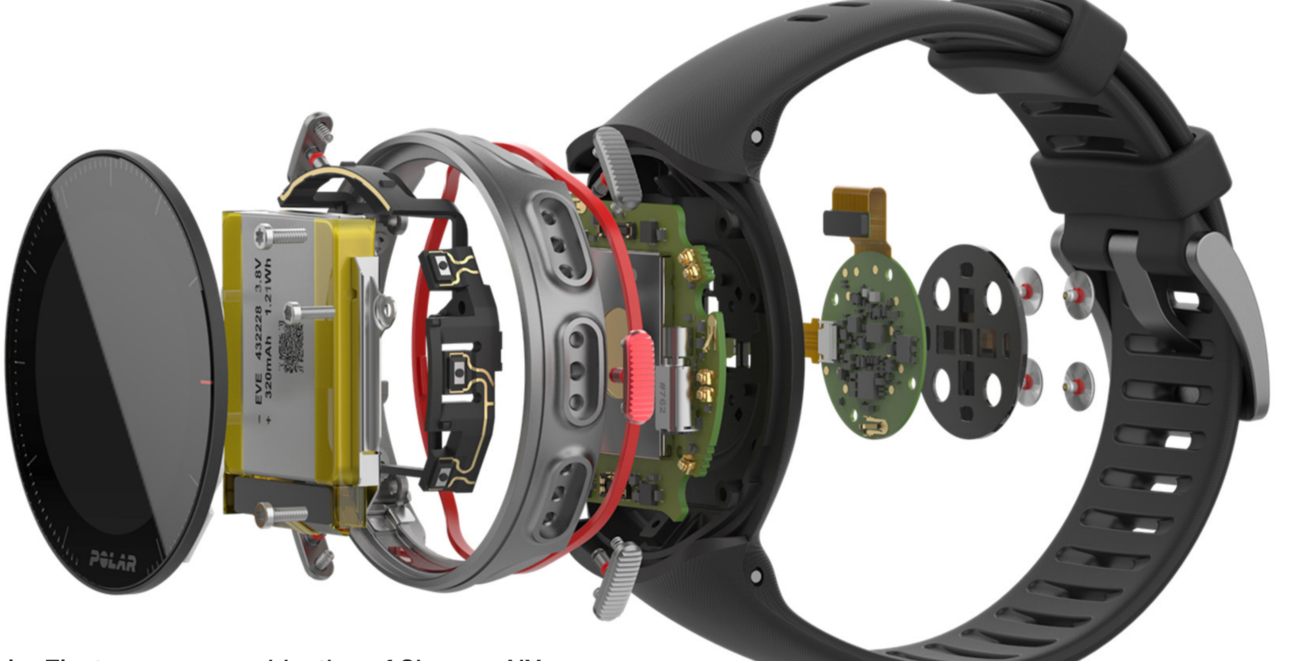
Autodesk's 2016 acquisition of CADSoft, developers of the ECAD software EAGLE, resulted in a rich set of ECAD tools nested inside Autodesk Fusion 360. With bidirectional data exchange between ECAD and MCAD objects, Fusion's shared work environment allows both sides to be aware of the edits and revisions that take place in the electronics and the overall housing.

Altium 365, marketed as the "design platform that unites [printed circuit board] design, MCAD, data management and teamwork," is well-known to the CAD users in the Autodesk Inventor, SolidWorks and PTC Creo communities. Many of them use the product to collaborate with ECAD designers. Autodesk's ownership of Altium could have huge implications. It would give Autodesk greater control of the bridge that connects MCAD and ECAD.

However, the acquisition didn't come to fruition. In July, Autodesk announced in another press release it had termi-



Component placement and copper definitions as defined in Altium ECAD environment are reflected in the 3D MCAD tool. *Image courtesy of Altium.*



Polar Electro uses a combination of Siemens NX, Teamcenter and ECAD tools from Mentor Graphics (acquired by Siemens) to design its smartwatches. *Image courtesy of Siemens.*

nated discussions to acquire Altium.

"Autodesk has a long track record of disciplined strategic acquisitions," said Andrew Anagnost, CEO of Autodesk. "While we did verbally improve our initial proposal, we were unable to agree on the basis to advance discussions. We respect the leadership team at Altium and wish them the best with their business."

The news was bound to be greeted with some relief by Autodesk's rivals. At the same time, it was sure to trigger greater discussions about the gateway between ECAD and MCAD, and the competitive advantages it brings to whoever controls the traffic through it.

What Brought MCAD and ECAD Closer

ECAD used to primarily be 2D diagrams that diagrammed out the components and connectivity in circuit boards. For a time, the ECAD and MCAD disciplines didn't have a good reason to exchange data. The ECAD designer simply worked within the space constraint allotted to them; so long as they didn't violate the space envelope, there was little or no need to communicate with the MCAD designer who worked on the overall housing and the product's assembly.

But the miniaturization of products, a trend in the Internet of Things (IoT) era, brought the two disciplines closer than before, quite literally and figuratively. With electronics sitting close to other parts in tightly packed smart objects, such as smartphones, smartwatches and Wi-Fi-enabled thermostats, conflicts arose and unintended interferences became more common.

Let Us Meet on Neutral Ground

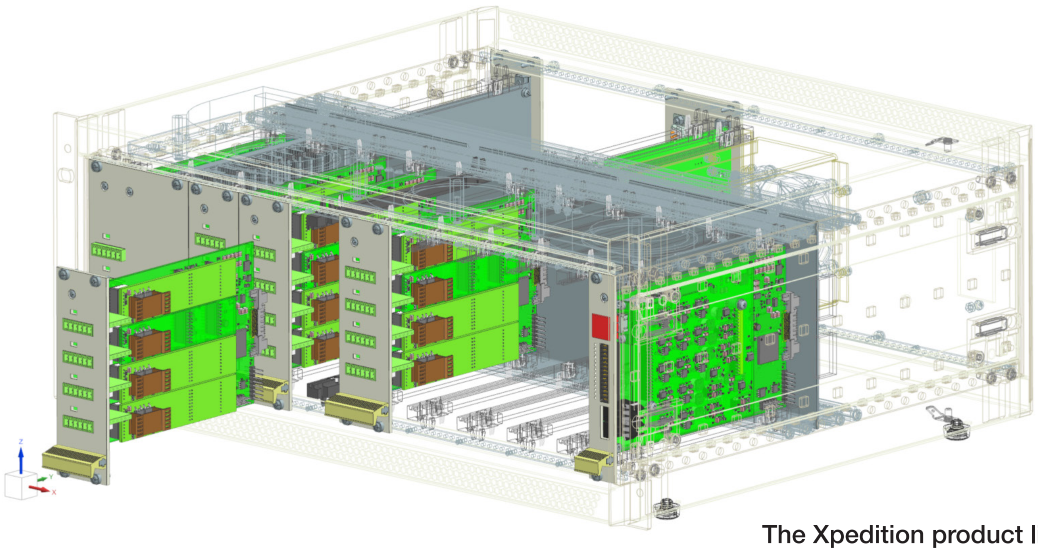
The biggest barrier to MCAD and ECAD collaboration is actually the discipline-specific software the two groups employ. The MCAD packages for mechanical designers and ECAD packages for electrical designers have standard libraries, geometry construction tools and terminologies that cater to their own sectors. Consequently, asking either side to switch to the preferred tool of the other party is an unfair demand.

CAD-embedded ECAD tools, such as those available inside Autodesk Fusion 360, PTC Creo MCAD-ECAD Collaboration Extension and Altium's MCAD plug-ins, are a common way to bridge the two disciplines.

Many ECAD tools evolved to accommodate 3D viewing, which allows printed circuit boards (PCBs) and integrated circuits (ICs) to be designed in context alongside mechanical enclosures and other PCBs that might affect their placements.

"This makes them more MCAD-aware, but definitely doesn't replace ECAD tools," says Robert Haubrock, senior VP of product engineering software, Siemens Digital Industries Software. "Similarly, some MCAD tools have looked to build in PCB design functionality by combining ECAD and MCAD tools into a single embedded system, but that is only useful for the simplest of designs."

"The real benefit of a CAD-embedded ECAD package happens when there's a need to collaborate and unite both disciplines for joint products," says Edwin Robledo, technical marketing manager of electronics at Autodesk.



The Xpedition product line from Siemens allows ECAD designers to work in collaboration with NX CAD users. *Image courtesy of Siemens.*

Autodesk Fusion 360, an integrated CAD/CAM/CAE with cloud-hosted features, comes with an electronics workspace. It includes tools for length matching, manual routing, manufacture role check and PCB schematics. The user can export the completed PCB design as Gerber files for manufacturing using Fusion 360's CAM processor. The built-in tool offers SPICE-based schematic simulation and design-rule checks before production.

Collaborative CoDesign

Altium CoDesigner is the MCAD-ECAD bridge for Quantel Laser, a division of Lumibird, a laser technology provider to the industrial, defense, scientific and medical sectors. In Quantel's products, the PCBs and high-power diode drivers, control electronics and regulator electronics sit on top of one another in multiple stacks.

"Before we began using CoDesigner, we used to receive DXF files. We should then have to take the component and ask [the ECAD designer] how tall are these? Then we had to extrude the materials. We have some very tight-fitting applications," says Laine McNeil, senior mechanical engineer at Quantel Laser.

The DXF file exported from ECAD includes the profile but not necessarily the height. The missing height is critical to MCAD users like McNeil, who designs the MCAD assembly that encompasses electronics. With CoDesigner McNeil feels he has a much better understanding of the physical geometry of the PCBs in the assembly.

In certain products, Jeremie Waller, senior electrical engineer at Quantel Laser, must work with McNeil early on to conceive a mechanical housing that can accommodate the complex electronics.

"I need to get him involved to show me where the mounting holes are," he says.

CoDesigner can be installed as an add-on to popular MCAD packages, such as SolidWorks, Autodesk Inventor, Autodesk Fusion 360 and PTC Creo. The setup allows McNeil to work with his 3D SolidWorks files in a shared environment with his ECAD counterpart Waller.

The Push and Pull functions allow either side, MCAD or ECAD, to send and request revisions. This workflow eliminates the risk of one side designing something that will be a misfit for the other.

"We're more competitive in the market because we can make our circuit boards smaller. And the space that [McNeil] is working with in his world is getting tighter and tighter," says Walker.

Different Types of ECAD

With the letter "E" representing anything electronic, ECAD could mean software for designing PCBs or ICs. The distinction is important for those working in cross-disciplinary collaboration.

"When people say ECAD to MCAD, the question is: which ECAD? In fact, for many companies we are seeing engineering teams doing E/E systems design, so they're collaborating between two ECAD design solutions and an MCAD solution, [so] talk about process complexity," says A.J. Incorvaia, senior VP of electronic board systems, Siemens Digital Industries Software. "Only Siemens addresses all three domains with NX, Xpedition and Capital."

Xpedition, Xpedition EDM and PADS Xpedition are part of Siemens' Teamcenter product lifecycle management (PLM) framework. The products were originally developed by the semiconductor and chip design software maker Mentor Graphics, which Siemens acquired in 2016. It uses the incremental data eXchange format (IDX or EDMD, also known as ECAD design and MCAD design) to allow MCAD and ECAD designers to communicate the changes and revisions, which either side can accept or reject.

One of Siemens' customers that uses the integrated approach is Polar Electro, a smartwatch maker. The IoT-enabled watches rely on software, hardware and electronics to connect to mobile phones, sensors and third-party apps.

The top-level PLM framework of the product is usually the starting point, says Hannu Hannila, senior consultant at CGI and former manager of PLM at Polar Electro. "After that, different teams can add their substructures, like mechanical design, electrical design and packaging designers … we integrated Siemens NX and Mentor Graphics tools into Teamcenter. We also manage our hardware-software compatibility in Teamcenter," he explains.

Quest for a Common Language

Haubrock predicts the intermediate data format (IDF) will likely remain the interchange solution for the two disciplines.

"Engineers do not like change and will continue with a method that just works. Exposing customers to the latest method, IDX [supported by the Siemens Xpedition products] brings them a whole new world of capability and once transitioned … all formats have limitations. What Siemens has done is to extend the capability of IDX to provide an extended range of functions that are only possible between the Siemens toolsets, NX and Xpedition," he explains.

Autodesk's Robledo points to STEP and DXF as two common formats for MCAD-MCAD data exchange, but also notes their weaknesses.

"They aren't designed to store an electronics netlist and other component information. These file formats are essentially just artwork, which limits their utility in an electronics workflow. And manually switching formats is inefficient and prone to introducing errors. That is why we designed [in] Fusion 360 to house everything under one roof, such as an electronic schematic editor, PCB layout, electronic component editor, mechanical workspace and much more," he reasons.

"Regardless of the format, any file exchange brings some problems to the engineering workflow. Mechanical engineers get frustrated with losing MCAD constraints and references. Performance can be slow as it can take quite some time to generate those files. Moreover, they are always dealing with static files, and it can be difficult for both mechanical and electrical engineers to keep track of changes made on either side and of which version of the file is the latest," says Nikolai Nyrkov, MCAD CoDesigner product manager at Altium.

Accelerating ECAD

The growing complexity in simulation is not confined to the structural and fluid analyses commonly done in the mechanical domain. It has also reached semiconductor, electronics and electrical simulation, prompting many in the ECAD software sector to look for ways to parallelize the code.

"Even without simulation, we have a lot of cases where software performs a lot of complex calculations and users expect to have them in live mode—directly during PCB design. The most popular cases are [design rules check] and polygon repouring," says Alexey Sabunin, global head of product marketing, Altium.

Tomek Brzuchacz, head of CAD software at Altium, also points to design rules check (DRC) as a good example of the type of operations that benefit from multicore processing.

"It's a simple distance calculation upon a pair of geometry primitives. During the full board DRC, there could be millions of such pairs to be checked and that task can be efficiently performed by GPU [graphics processing units] in parallel to CPU operations. CPU is only needed to preprocess and arrange data for GPU calculations and aggregate the results," he says.

In Altium Designer, the software harvests GPU processing to speed up:

- interactive 3D scene transformation for rigid/flex;
- polygon pouring (in the research phase);
- clearance boundaries visualization during interactive routing; and
- building hatched polygons.

"There are also efforts to utilize GPUs for limited simulation functions, and we see the use of GPU acceleration as important for the future to help deal with the complexity of product designs," says Siemens' Incorvaia.

The strictly 2D ECAD applications do not benefit much from the GPU, but the 3D workflow inside Fusion 360 does, according to Robledo.

"The future of consumer electronics engineering is heading toward a 3D modeling environment, meaning engineers will benefit from better hardware resources —especially graphics," he says. DE

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

MORE INFO

- **Altium:** Altium.com
- **Autodesk:** Autodesk.com
- **PTC:** PTC.com
- **Siemens:** sw.siemens.com/en-US

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Multiphysics Sparks Innovation in Electronics Design

Multidisciplinary modeling and simulation will play a larger role in solving electronics design challenges.

BY JIM ROMEO

Electronic devices are complex. They combine many different components and material including semiconductors, integrated circuit (IC) packaging, printed circuit boards (PCBs), cabling and system housings.

The engineering design challenge at present is to combine such complex subsystems and validate their performance before building prototypes or testing.

Simulation minimizes the testing costs, ensures regulatory compliance, improves reliability and drastically reduces product development time. Advanced physics-based simulation is enabling engineering designers to accomplish these goals.

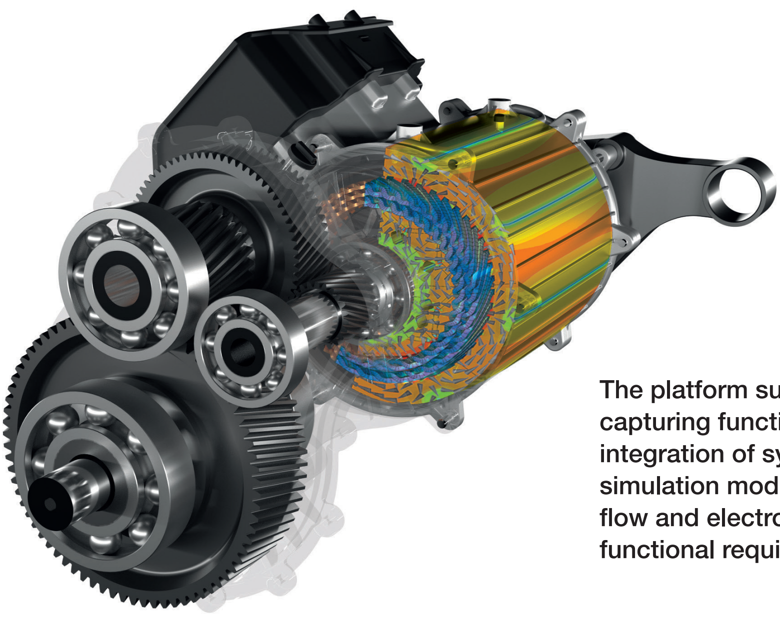
Evolution of Simulation

David Kan is the vice president of sales for COMSOL. "The evolution of simulation tools for electronics and other systems is driven by the high demands of today's engineering tasks," says Kan. "These demands vary, but at the core of every digital simulation tool, there should be two primary attributes: accuracy and usability.

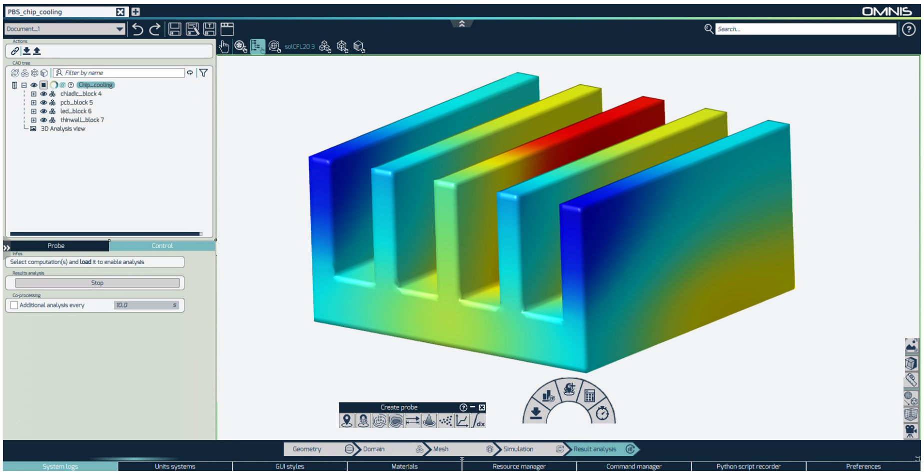
Kan says the demand for accuracy leads to the inclusion of any and, preferably, all contributing physics in your simulation systems via multiphysics modeling.

"Consider thermal management for electronics. As advances in technology demand more power being conducted through smaller and smaller components, cooling then becomes more critical," Kan says.

"Otherwise, phenomena such as thermal stresses that lead to diminished performance and even system failure become a real danger," Kan adds. "Modeling these multiphysics phenomena becomes indispensable, yet the most accurate software in the world is only as useful as it is usable. Usability can be difficult to achieve, as multiphysics modeling is inher-



The platform supports multidisciplinary workflows by capturing functional requirements and enabling the integration of system logic models with the multiphysics simulation models to include effect of structural loads, fluid flow and electromagnetics in relation to system performance functional requirements. *Image courtesy of Dassault Systèmes.*



The potential for the future is to investigate larger systems with greater accuracy in less time. *Image courtesy of Cadence.*

ently complex," he says.

Dale Berry is the senior director of SIMULIA technical marketing at Dassault Systèmes. He says Dassault's 3DEXPERIENCE platform supports multidisciplinary workflows with functional requirements by capturing and integrating system logic models with the multiphysics simulation models to include effect of structural loads, fluid flow and electromagnetics in relation to system performance functional requirements.

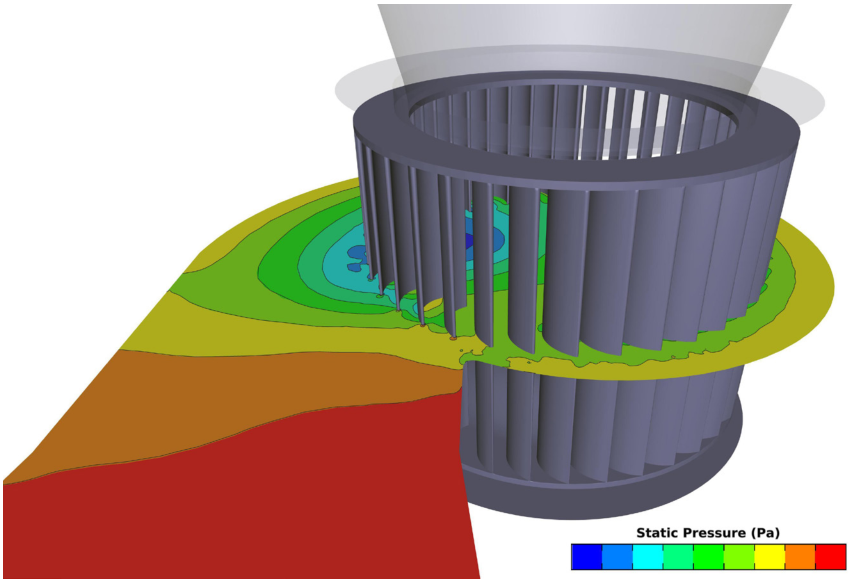
"The platform provides interconnects for high-performance computing, knowledge capture, process automation tools for multidisciplinary optimization and secure data management," says Berry. "A simulation-centric digital enterprise will place design, modeling and simulation users right at the center of a company's development processes—right where they need to be. This allows product developers to truly focus on nimble simulation-powered designs to reduce errors, increase certainty, speed time to market, reduce costs and move toward zero prototyping."

Living up to Simulation Challenges

Applying simulation to design engineering, however, has its challenges. The result of simulation can be bedazzling, however, and arriving at a simulated model that provides distinct benefits can be a challenge that requires knowledge, skill and training in software tools to accomplish it.

"The biggest challenge of using simulation today is training. Simulation is a powerful tool, but it's still only a tool," says Murad Kurwa, VP of advanced manufacturing for Flex.

The engineering design challenge is to combine such complex subsystems and validate performance before building prototypes or testing. Simulation minimizes the testing costs, ensures regulatory compliance, improves reliability and reduces product development time. *Image courtesy of Dassault Systèmes.*



Simulation helps remove barriers and allows engineers to think bigger and be ambitious with stretching the design envelope by enabling the evaluation of more configurations using efficient optimization engines. *Image courtesy of Cadence.*

"This technology is something most students do not learn in detail in academic programs. When it comes to the workforce, they require additional training and up-skilling to fully grasp the power of these tools, interpret the results and analyze the data to drive continuous improvement initiatives that improve business outcomes."

Kurwa adds that training for commercial simulation tools is widely available and accessible.

"Advances in technology have made it easier for engineers to train and receive certifications online," he adds. "However, organizations must democratize this training and make it accessible to the full factory and engineering teams. Simulation training is not only about knowledge but also about driving consistent results across engineers and sites."

Throughout the decades, stand-alone pre-processors, solvers and post-processors entered the market as commercial solutions, according to David Waltzman, product marketing group director for multiphysics system analysis at Cadence.

"After much consolidation, some firms now offer end-to-end analysis workflows, while others maintained an identity as best of breed in one particular step of the workflow or a subset of physics," says Waltzman. "There are two primary challenges: user experience and data. Disparate tools have unique user interfaces that require user training and ramp up time. Data import and export across disparate tools can also cause [a] headache from both a compatibility perspective as well as data management."

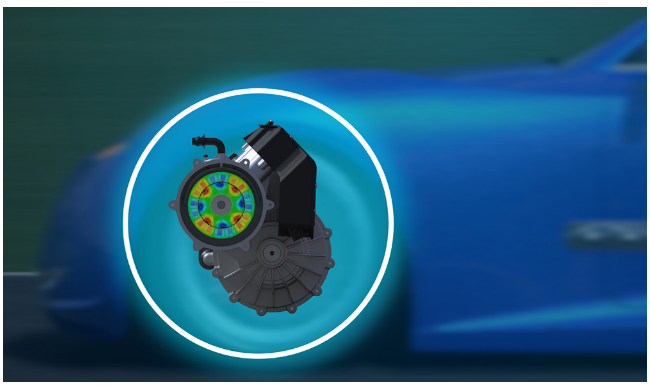
Sometimes simulation challenges are unique from industry to industry. For example, according to Aditya Pathak, business head for automotive, transportation and logistics for Cognizant Technology Solutions in the New York metropolitan area, one of the greatest challenges for automotive manufacturers is managing the flow of data throughout a product or component's lifecycle.

"In many organizations, data can be siloed functionally resulting in inaccurate and untimely information," says Pathak. "Patchy information often results in out-of-bounds issues—costing time and effort. To remedy this, Cognizant is working with a number of clients on digital thread strategy enablement for their products to create a single source of truth accessible to multiple stakeholders in the OEM [original equipment manufacturer] organization. The digital thread will not only abstract the right information from various systems; it will also enable automation of multiple manual workflows along with integration of disparate systems. This will result in improved efficiency and predictability of the systems along with the potential of reduction in time to market."

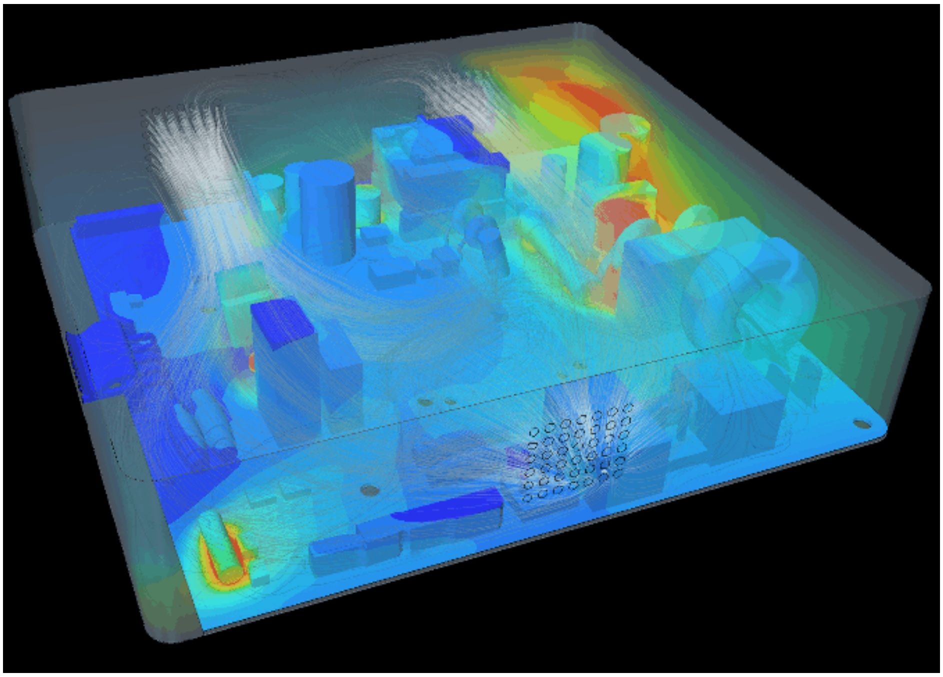
A Bright Simulated Future?

Multiphysics simulation tools, like all simulation tools, face a prosperous future with much promise.

"Although simulation is an established part of the design process for electronics systems and other physics applications, there is great potential for the use of simulation to grow exponentially," says COMSOL's Kan. "Look at the number of engineers with direct access to, and understand-



A simulation-centric digital enterprise will place design, modeling and simulation users at the center of a company's development processes. *Image courtesy of Dassault Systèmes.*



Simulation tools for electronics and other systems are highly sought by engineers as they provide tasks that were not only laborious, but beyond the routine intellectual capacity of many to find solutions to complex problems. *Image courtesy of Cadence.*

ing of, the tools used for full-scale multiphysics simulation. It is just too limited."

In the current practice of most R&D groups, only a small group of experts can use simulation software, creating a bottleneck for those that need the analyses and data from these simulations, Kan adds. COMSOL's approach could potentially remove this bottleneck via lightweight simulation apps.

For multiphysics simulation, the past is prologue for the future. "Simulation tools for electronics have been adopted since the 1970s, with SPICE tools for circuit simulation and simulation for IC design, and development is a must," says Sarmad Khemmoro, vice president, global technical business development for electronics for Altair.

"For system-level (PCB, multi-PCBs or complete system) [simulation], companies with these products started doing it sporadically in the mid-'90s. The computer and consumers electronics industry led them to adopt simulation for electronics, followed by Aerospace/Defense and Automotive. With electrification in both automotive and aerospace, the simulation for electronics will see exponential growth, especially when you bring multiphysics into the equation."

Dassault's Barry adds that a platform approach for integrated modeling and simulation is an exercise in looking beyond just solving a complex system design and engineering problem and viewing it as providing the foundation for tackling today's product development priorities around sustainability, carbon pollution, circular economy, resource management, public health and the other big challenges that face the population.

"These challenges are multidisciplinary at their core, so integrated multidiscipline modeling and simulation will clearly play a larger role in solving these problems," says Barry.

"Electrification of an automobile, for example, requires control systems logic, simulation for electromagnetics (motors, batteries), thermal (temperature control), fluids (lubrication), aerodynamics, acoustics, passenger safety, lightweighting, mechanical vibration and durability," Barry adds. "Loosely integrated stand-alone tools will not provide the power, efficiency or reliability needed to solve these problems in a production environment."

To solidify these challenges, says Barry, consider who is going to do software quality assurance for a homegrown solution that links products from multiple vendors.

"Often the answer is, 'no one,' as the only person who had the knowledge has retired," he says. "Only a data-managed, collaborative, multidisciplinary approach based on tightly integrated technologies built on a common platform will be able to address these important problems with the reliability, quality and efficiency needed to meet our challenges today and in the future." **DE**

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

MORE INFO

- **Altair:** Altair.com
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- **COMSOL:** COMSOL.com
- **Dassault Systèmes:** 3DS.com
- **Flex:** Flex.com

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Autonomy and 5G Are Inseparable

Antenna placement and network coverage analyses drive the use of simulation in 5G deployment.

BY KENNETH WONG

Writing for Forbes in March 2018, contributing editor Bijan Khosravi went so far as to title his analysis of 5G as follows: "Autonomous Cars Won't Work—Until We Have 5G."

The crux of his argument was, "The current 4G network is fast enough for us to share status updates or request rides, but it doesn't have the capability to give cars the human-like reflexes that might have prevented the Uber accident."

In telecommunications service provider Qualcomm's 5G timeline, 2019 was the year the technology became a commercial reality; 2020 was the year of proliferation; and 2021 is the year of advancement (qualcomm.com/research/5g/5g-timeline).

For average consumers, 5G means better mobile streaming of high-definition videos and interactive 3D games. For autonomous car developers, it's one more method for the car to see, hear and make navigation decisions.

Qualcomm predicts 5G connectivity "will also define a direct communication mode that will allow cars to communicate with each other directly for autonomous driving use cases. This mode of operation can operate without dependency or reliance on wide area network coverage," the company stated in its report, "How will 5G unlock the potential of autonomous driving?" in May 2018 (https://bit.ly/3xEAAvy).

As 5G adoption grows, it seems that simulation software vendors are refining their codes to allow autonomous car developers to plan and optimize 5G coverage in their offerings.

Autonomy Is Impossible Without Networks

In 2019, technicians gathered at the waterfront-facing Boston Convention Center to trade tips and learn new developments in microwave theory, techniques and applications. Ansys was a participant at this International Microwave Symposium (IMS). The company was there to showcase its software's role in "antenna synthesis, antenna placement and radio frequency interference (RFI) diagnosis," among other purposes.

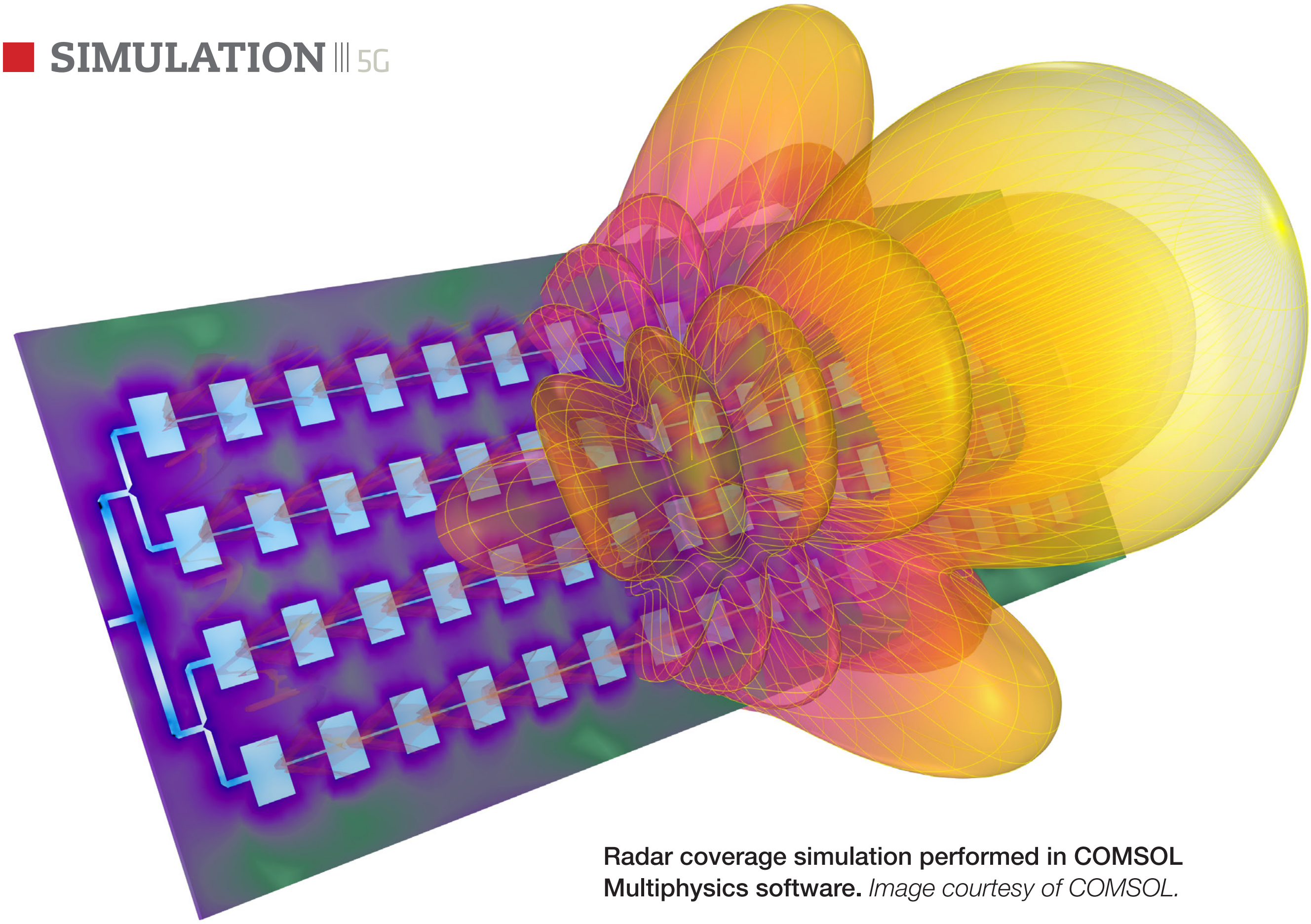
"The technology has advanced to solve fully integrated wireless systems, taking into account everything, from the 5G radios to the antennas mounted on a vehicle, even the surrounding environment," says Larry Williams, distinguished engineer, Ansys.

"Wireless connectivity to the 5G infrastructure is accomplished using wireless propagation models and system-level tools to ensure reliable connectivity. The method combines detailed physics-based models using [for example] Ansys HFSS with system modeling capabilities. Simulation also allows prediction of radio wave interference among multiple radio systems and other vehicle electronics to ensure reliability," Williams says.

COMSOL, known for its Multiphysics simulation software, also exhibited its capabilities. In the preshow press release, the company invited attendees to come see "the latest advances in its COMSOL Multiphysics software to support microwave and [radio frequency (RF)] engineers working on 5G, [Internet of Things], automotive radars and satellite communications."

Jiyoun Munn, technical product manager, COMSOL, thinks reliable 5G mobile networks and low-earth-orbit satellite networks are essential to the success of autonomous vehicle deployment.

"The demand for high-speed communication necessitates higher operating frequencies toward the mmWave range or even further up to provide more bandwidth. Devices for mmWave communication have to be much smaller than conventional RF and microwave components. To efficiently de-



Radar coverage simulation performed in COMSOL Multiphysics software. *Image courtesy of COMSOL.*

velop 5G equipment, a range of numerical analysis tasks have to be conducted: Everything from detailed component-level studies to system-level analysis," he says.

Seeing the Blind Spots

In May, Ansys expanded its partnership with Keysight Technologies to boost its wireless design capabilities. The move signals Ansys' plan to "integrate Keysight's PathWave Advanced Design System (ADS) RFPro environment with Ansys HFSS electromagnetic simulation," the announcement states.

Keysight's RFPro is an electromagnetic (EM) analysis environment for RF and microwave circuit designers. It's integrated within Keysight PathWave ADS to make EM analysis easier.

"Vehicle-to-infrastructure (V2X) applications use an extension to the wireless standards called IEEE 802.11p to provide data exchange between high-speed vehicles and between the vehicles and the roadside infrastructure in the licensed [Intelligent Transportation Systems] ITS band of 5.9 GHz (5.85–5.925 GHz)," says Williams.

This communication protocol could be the basis for toll collection, vehicle safety services and e-commerce applications for the vehicle.

"The high 5.9 GHz frequency places challenges on system designers because of the greater active multipath environment," Williams says. "Advanced simulation using high-frequency techniques like Ansys' SBR+ technology can predict that multipath environment for use in system analysis to evaluate communication reliability. This capability is also valuable for non-line-of-sight communications … to vehicles otherwise unseen by drivers."

COMSOL's Munn expects that, with 5G miniaturizations, additional physical effects have to be taken into account in simulation.

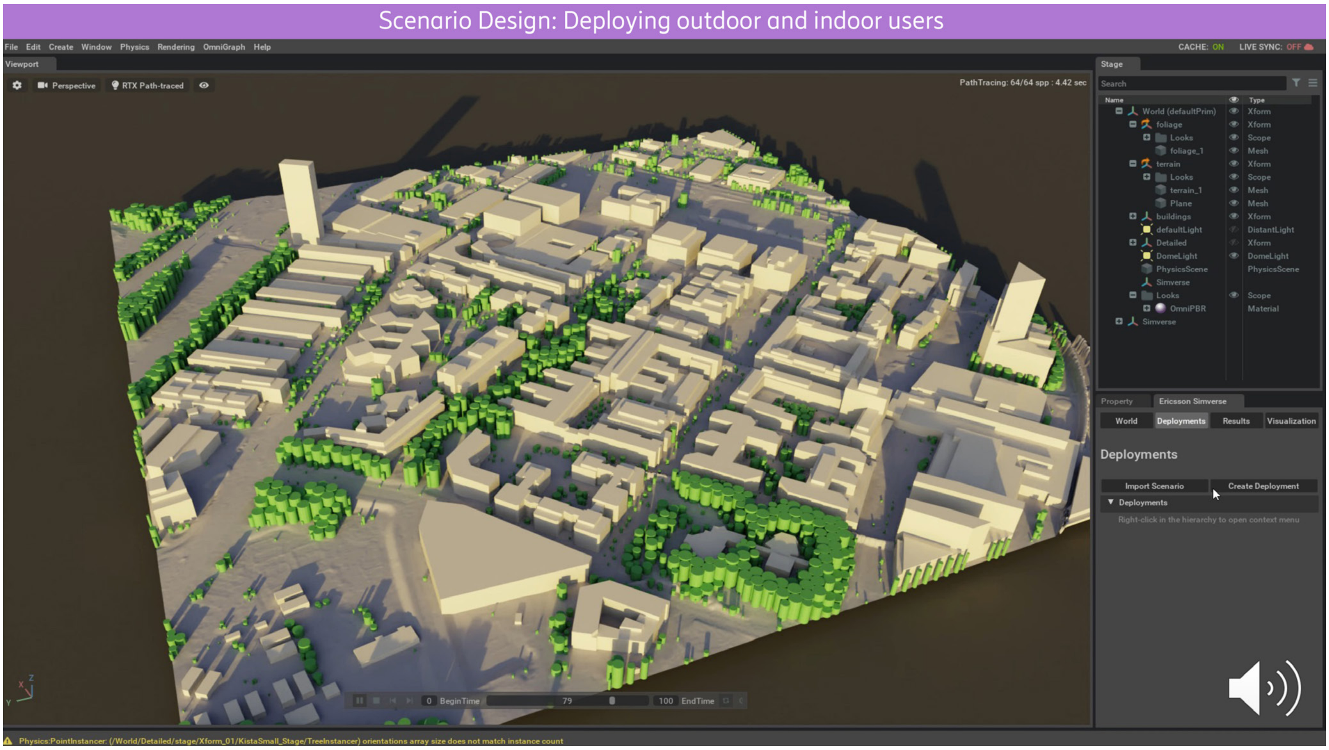
"Any mechanical distortion or material property changes, due to unexpected and unwanted phenomena such as thermal drift and structural deformation, need to be precisely analyzed before deploying such components. Because of this, multiphysics modeling typically involving the finite element method plays a key role in designing real-world devices," he says.

GPU Acceleration

The "G" in 5G (5th Generation) and graphics processing unit (GPU) may be quite different, but the fate of the two technologies is loosely connected. Phone maker Ericsson employed NVIDIA's Omniverse, a 3D simulation environment with built-in physics, to analyze its radio access network (RAN) coverages.

Ericsson says it has already launched 83 live 5G networks across five continents with many more lined up for the future.

"The NVIDIA Omniverse platform enables huge leaps in complex product modeling, simulation and visualization. Enhanced capabilities in this space drive RAN



Telecom firm Ericsson uses the NVIDIA Omniverse environment to simulate, analyze and plan 5G deployment. *Image from NVIDIA GTC 2021 presentation by Germán Ceballos, researcher, Ericsson.*

product performance, shorten time to market, [and] ease the introduction of new functionalities and solution opportunities across emerging connectivity verticals," writes Ericsson in its corporate blog (April 2021).

The two companies discussed their collaboration in this year's virtual GPU Technology Conference hosted by NVIDIA.

"In 5G, the antenna may have many direction-programmable features and must support massive [multiple input, multiple output], enabling the spatial domain to deliver signals," Williams says.

"5G antennas are generally antenna arrays and are an integral part of the radio system performance. This adaptive nature demands that full systems are tested in their operational environment using [over the air (OTA)] testing. Those testing environments can be created in simulation to speed design and make passing hardware OTA testing more likely to succeed. Working with test and measurement allows constructing virtual testing that mimics hardware tests. Engineering organizations already understand the hardware tests and hence can make the connection between virtual and hardware testing like a digital twin."

Ansys has a partnership with NVIDIA. Ansys HFSS and the SBR+ engines are fully high-performance computing ready for on-premise clusters, cloud and for CPU and GPU nodes, according to Williams.

"Hybrid electromagnetics solutions for high-fidelity modeling of installed antenna performance leverages coupling between the [finite element method] and SBR+ and it is highly valuable to speed solutions by leveraging GPUs," he said.

Williams envisions Ansys software harvesting the power of both local and cloud-hosted GPUs to compute for multiple moving reference planes for the mesh network.

"As systems evolve to leverage 5G infrastructure and the 5.9 GHz V2X standards, modeling complex systems with many moving vehicles in a dense multipath environment is imperative to deliver the reliable communications for future automotive systems," he says. DE

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

MORE INFO

- **Ansys:** Ansys.com
- **COMSOL:** COMSOL.com
- **NVIDIA:** NVIDIA.com

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Engineering On the Go

New mobile workstations from MSI provide the computing power to handle complex models and simulations, any time and any place.

Engineering workflows require increasing amounts of computing power. Designers are working with larger and more complex models, and utilize simulation software earlier and more often in the design cycle. In addition, designers have been tasked with creating photorealistic renderings for conducting design reviews, collaborating with other stakeholders, creating marketing materials, and other applications.

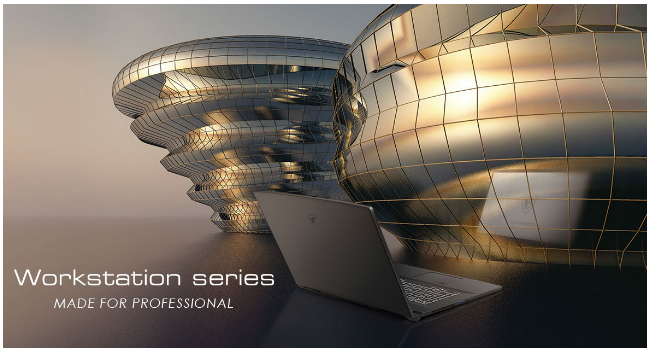
At the same time, engineers need to be able to do this work from any location—in their offices, on the road, and while working from home. They need powerful mobile workstations with enough horsepower to handle these advanced modeling, simulation, and rendering tasks.

The new MSI WS Series mobile workstation, along with the WE76 and WF Series, are powered by NVIDIA RTX graphics and 11th-Gen Intel Core processors, providing twice the performance of previous models. That means faster rendering, greater accuracy, and increased productivity to meet the challenges and demands of a modern engineering workflow. The MSI WS Series of workstations are certified for NVIDIA RTX Studio, making it possible for users to leverage real-time ray tracing, AI processing, and high-resolution video and graphics editing in a laptop form factor.

The MSI mobile workstations also support the NVIDIA Omniverse platform, enabling engineers to work across industry leading applications (like Autodesk Maya, Autodesk 3ds Max, Autodesk Revit, Epic Games Unreal Engine 4, and many more) in a shared virtual space. This removes the need for tedious export/import between applications, and transforms the traditional content creation process from a linear to a more simultaneous and dynamic experience.

A Solution for Every Engineering Workflow

The new WS Series can handle advanced engineering tasks for designers that need to regularly perform simulations and create detailed renderings and models. The WS66 15.6-in. workstation features the latest Intel Core i9 processors and supports the NVIDIA® RTX™ A5000 Laptop GPU. For engineers that require a larger digital workspace and a wider



viewing area, MSI also offers the WS76 17.3-in. model. The WS Series provides an optimal combination of performance and mobility, allowing engineers to complete their simulation and modeling work, while utilizing the laptop for on-site presentations and client reviews.

The redesigned WE76 pushes performance even further with a NVIDIA® RTX™ A5000 Laptop GPU and 11th gen Intel® Core i9 processor, making it ideal as a desktop replacement in demanding simulation and modeling environments. It also features MSI's exclusive Cooler Boost 5, which further optimizes performance. The new WE76 features a 4K resolution display, for engineering applications that require rich detail and accurate color. For engineers that need power and flexibility, the WE Series provides an ideal alternative to a tower workstation.

Basic analysis and rapid rendering have become a must-have capability across the design cycle, even for engineers that are not performing complex simulations. For these more traditional simulation and rendering workflows, the WF Series provides advanced graphics performance, but at a lower cost and in a sleek package. MSI offers both the 15.6-in. WF66 and 17.3-in. WF76, which support the NVIDIA RTX A2000 T1200 Laptop GPUs.

Engineering organizations need workstations that provide flexibility and mobility, while also meeting the diverse performance needs of their designers. With these new mobile workstations, MSI offers powerful solutions for a wide range of engineering use cases. For more information, visit the MSI Workstation website.

msi

3D Printing Inches Toward Electronics

Additive manufacturing adoption in electronics has lagged behind other sectors, but advances in materials and processes are driving experimental use cases.

BY BETH STACKPOLE

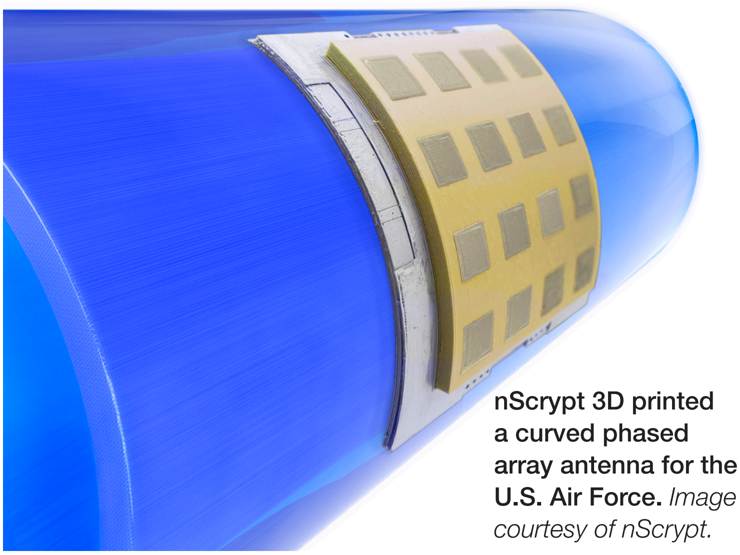
3D printing has become a transformative tool for consolidating parts in automotive and aerospace applications and for producing bespoke medical equipment, yet the technology has made far less headway in electronics innovation due to an array of challenges related to materials and performance.

That dynamic is starting to shift, albeit ever so slightly. A flurry of developments on many fronts—among them, new metal, ceramic and compound materials; conductive inks for creating traces on circuits; thin-film delaminated electronics; and high-precision, specialized hardware and processes—are empowering emerging additive manufacturing (AM) platforms to tackle the unique challenges related to electronics component and device production.

Advances in metal 3D printing technology are making it easier and more cost effective to produce the complex manifolds, wafer tables and wafer handling systems found in semiconductor lithography and wafer processing equipment.

Although most use cases are still relatively early stage—typically exploratory research and development efforts or pilot applications—there are various advantages that 3D printing technologies bring to electronics production. The primary benefits, according to experts, are simplification, accelerated time to market, ease of customization and greater design freedom. In the right scenario and for a specific type of parts, there is potential for cost reduction through elimination of expensive injection molds and tooling.

"If you can break the trade-off between price and volume with digital manufacturing, you can make the jump towards mass customization," says Matthew Dyson, senior technical analyst at market research firm IDTechX. "At present, additive manufacturing [of electronics] is not best suited for making large volumes. But for low volumes with lots of variation or some bespoke aspect, then there can be a lot of benefits to an AM approach."



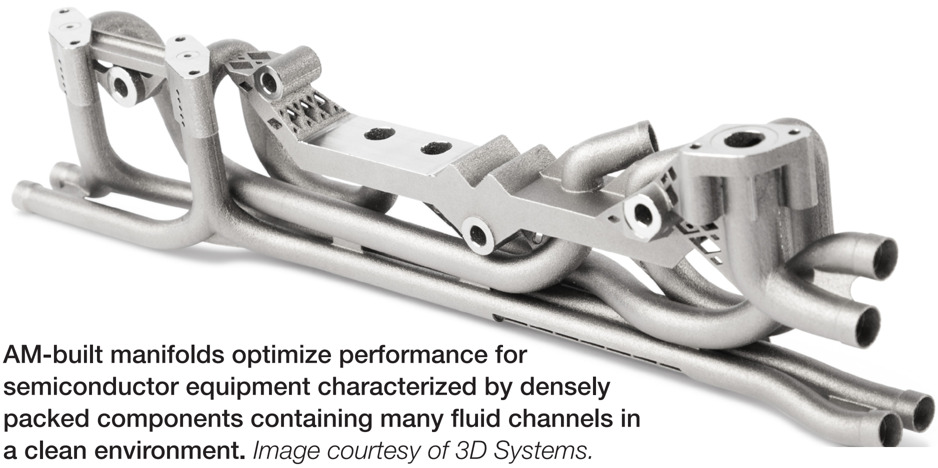
nScrypt 3D printed a curved phased array antenna for the U.S. Air Force. *Image courtesy of nScrypt.*

What's Holding Things Back?

The lack of material choice and the limited capabilities of currently available materials are among the primary inhibitors restricting widespread use of 3D printing for electronics applications.

Transducers, sensors, antennas and batteries call for highly sophisticated properties, which are difficult to replicate with the current portfolio of materials associated with most existing 3D printing platforms.

"It's much easier to define the requirements for traditional 3D-printed structural materials in terms of yield stress or whether it will meet the required performance for the application," says Karl Littau, chief technology officer at Sakuu, a company work-



AM-built manifolds optimize performance for semiconductor equipment characterized by densely packed components containing many fluid channels in a clean environment. *Image courtesy of 3D Systems.*

ing on a specialized 3D printer for producing electric vehicle (EV) batteries.

With functional devices such as batteries, multiple materials are involved, and each have specific density and structural requirements that must be met simultaneously.

"At a minimum in an electronics device, you have an insulator and a conductor and with that requirement alone, you've eliminated 99% of current 3D printers," Littau says. "It's not a common ability of AM to deposit the conductor and dielectric in the same machine in the same part, side by side. For those reasons, the AM world has focused on the more traditional elements of 3D printing."

In comparison, Sakuu offers a multiple-AM platform that blends powder bed and jetted material deposition processes and can employ different multimaterials in a single layer capability. The process combines ceramic and metal, along with Sakuu's proprietary support material, that results in an ability to quickly create high-energy density solid-state batteries (SSBs) with thin monolithic layers using an approach that encourages easier recyclability of materials compared to conventional methods, Littau says.

Sakuu is targeting players in the e-mobility space initially, but anticipates the 3D printer having applicability for a range of applications in different sectors. Sakuu also markets its own KeraCel brand of SSBs produced with the Sakuu AM Platform.

Because structural elements are commonly made out of plastic and electronics components drawn from metal materials, different thermal and mechanical properties are required; combining the two in a singular 3D printing process introduces further complexity not yet addressed by most current systems, says IDTechX's Dyson.

"Managing the close proximity of materials with different properties and how to respond to temperature cycling is a significant challenge," he says. The ability to achieve high yields before fully committing to 3D printing is another barrier that needs to be overcome before moving from prototyping to full production.

"If a problem like a dodgy connection is buried inside a part, you have to throw the whole part away," he adds. "There is no way a person or robot can make that repair."

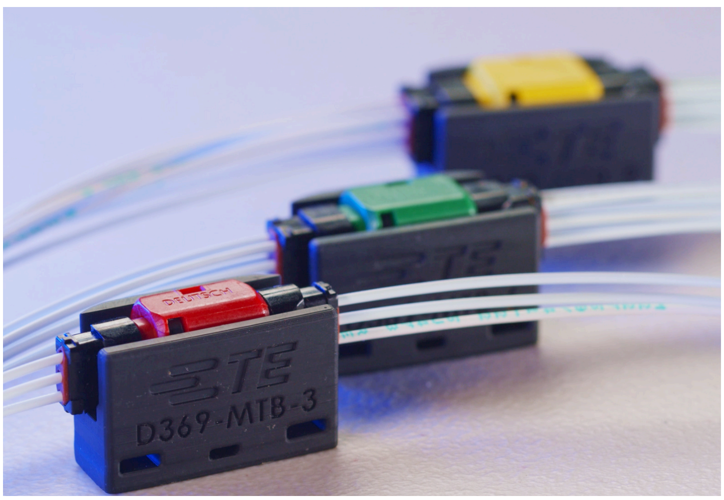
Performance characteristics and surface finish capabilities are another barrier limiting more widespread use of 3D printing in the electronics arena. Traditional Fused Deposition Modeling (FDM) printers can't produce the quality and surface finishes required for some consumer electronics applications while stereolithography (SLA) offerings can accommodate the intricate features so critical to components in this space, yet there isn't the same deep bench of materials advancements, says Chris Prucha, vice president of Origin P3 at Stratasys, and co-founder of Origin.

"Even the materials used five years ago didn't have the toughness and properties we needed out of a commercial-grade material for something like electrical connectors," says Prucha, who underscores the need for characteristics such as flame retardancy or the toughness and surface finishes associated with composites.

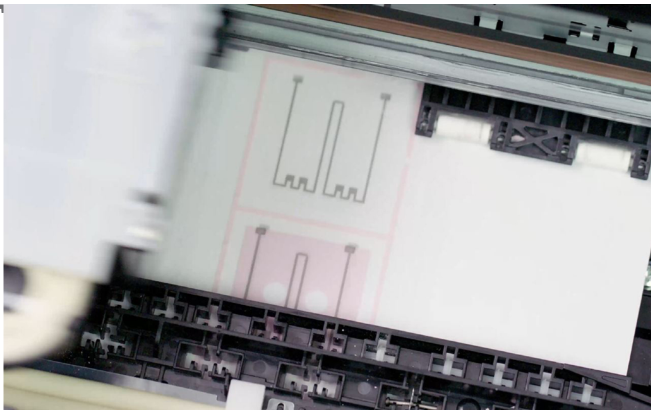
"Our technology marries the high quality and expanding materials portfolio of FDM with a high quality and high throughput print process."

Innovations on the Horizon

TE Connectivity, which produces upwards of 190 billion sensors and connector products annually, has been eying 3D printing as a more time-efficient and cost-effective way to produce portions of its product line, especially for those electrical connectors made in low volumes for aerospace applications. Rather than having to spend the time and money to build ex-



TE Connectivity taps Stratasys' Origin One to achieve double-digit micron accuracy in mass production of aerospace connector holders. *Image courtesy of Stratasys.*



Sakuu's multi-material, multi-process AM platform is taking aim at production of EV solid-state batteries. *Image courtesy of Sakuu.*

pensive tooling for parts made in the tens or maybe hundreds of thousands, TE saw promise in 3D printing as a way to get to the best possible design solution much more quickly.

Yet finding a solution that could meet TE's requirement for high-precision accuracy was a problem. "3D printing technologies were either high resolution with low material properties or offered good material properties, but had laminated or crude surface faces," says Mark Savage, research and development senior manager, additive manufacturing at TE.

Stratasys' Origin printer, with its digital light processing (DLP) technology and expanded palette of materials, provided a way to achieve components with robust material properties and high surface resolution and accuracy.

Consider one aerospace application where a single connector could have as many as 60 pins that slot into corresponding holes, which demand tolerances in the single micron range, Savage says. "We're always pushing the limits of what 3D printing can give us, whether that's tight tolerances or exotic materials," he adds.

One area where 3D printing already has a notable impact in the electronics sector is increased performance and productivity of semiconductor capital equipment. Metal AM technologies, when applied to semiconductor lithography and wafer processing equipment, can be used for liquid cooling applications, including for the design of complex metal AM parts such as manifolds and wafer tables that help optimize fluid and gas flow to reduce pressure drops and minimize mechanical disturbances and vibration.

Unlike traditional manufacturing methods, metal AM can create and output manifolds that consolidate parts, are lighter in weight and volume, and can optimize fluid flow, says Scott Green, principal solutions leader for 3D Systems.

Another potential upside of 3D printing for electronics components and devices is the possibility of increased design freedom. Similar to how the combination of 3D printing and generative design software unleashed a new generation of lightweight, organic-shaped components that weren't possible to produce with traditional manufacturing methods, new 3D printing technologies would make it possible to rethink traditional designs via an ability to integrate the electronics directly within or onto product surfaces in an approach IDTechX's Dyson calls "fully additive."

This longer-term vision applies 3D printing to the structural and electronic aspects of a device, ensuring there are no constraints on how conductive traces are distributed within a structural dielectric.

Dyson believes fully additive methods, still in the early experimental stages, could find a home for producing helical antennas and integrated capacitors as well for other bespoke parts or applications where size and weight are extremely important, such as custom implants.

"By enabling electronics to be integrated into things, designers are not forced to design products that can accommodate this rectangular [printed circuit board], but rather can make any shape they like," Dyson says, using the standard rectangular smartphone as an example.

"With an AM approach, you wouldn't have to have a circuit board that was planar—you could make something in[to] any shape," he says.

In the near term, the ability to 3D print electronics functionality onto existing injection molded components is already delivering advantages for experimental military and space station applications. The Sciperio research arm of nScrypt Inc., which makes high-precision industrial microdispensing and direct digital manufacturing equipment, is working with the U.S. Air Force Research Laboratory to print a phased antenna array on a curved surface.

This feat is possible due to the company's platform, which combines high-precision motion control, surface mapping, multi-camera machine vision, aerosol jetting as well as other milling and polishing processes into a single platform, according to Kenneth Church, nScrypt CEO.

"You can print, mill, polish and postprocess in one system and do it spot by spot, layer by layer so you can build the entire part on the system," says Church, who also touts the company's wide range of materials—over 10,000 can run in the system. DE

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MORE INFO

- **IDTechX:** IDTechex.com
- **nScrypt:** nScrypt.com
- **Sakuu:** sakuu.com
- **Stratasys:** Stratasys.com
- **3D Systems:** 3DSystems.com

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Introducing the *New* Reverse Engineering

Digitalization has created a revolution in reverse engineering. How can engineers best use these new capabilities?

BY TOM KEVAN

Gone are the days when reverse engineering lurked in the shadows of military and commercial espionage. This engineering practice must no longer be a laborious, time-consuming process that requires engineers using calipers and rulers to measure every square millimeter of a product's surface geometry.

Reverse engineering is in the midst of a radical metamorphosis. Fundamental building blocks like intent, use and technologies are moving beyond the pale of traditional concepts and toolsets.

But why now? What was the catalyst for this tectonic shift? How will it affect design engineers and manufacturers?

To answer these questions, you must recognize that the momentum driving the "new reverse engineering" springs—at least in part—from an industrial context shaped by trends such as the rise of additive manufacturing (AM) increased customization, production decentralization and manufacturing on demand.

All these factors have diminished the footprint of traditional concepts like economy of scale and mass production and replaced them with business models and engineering practices that promote shorter development cycles and greater market agility.

As for the catalyst of change, look to the dynamics created by advances in 3D scanning and scan-to-CAD technologies, as well as to the increased access to greatly enhanced computing resources (Fig. 1). These developments have recast reverse engineering in new, high-profile roles that promise to take digitization to new levels in the industrial sector, which transforms the way firms design and manufacture products and components.

Leaving Manual Data Capture Behind

Look at reverse engineering at its most basic level, and you realize that its metamorphosis began with the shift from manual data capture to digital data acquisition.

Traditionally, reverse engineering required designers to perform a large number of physical measurements, sketches and annotations to accurately translate data from the physical world to the digital domain. Designers needed to proceed one step at a time, with iterations between measuring and designing, a process that repeated itself multiple times, depending on the complexity of the project.

The very nature of this process limited the situations in which you could cost-effectively apply reverse engineering.

Fig. 1: By combining handheld scanners like Creaform's HandySCAN 3D with increasingly powerful computing resources, design engineers and manufacturers can open the door for a whole new class of reverse engineering use cases, supported by high-speed, high-resolution 3D measurements. *Image courtesy of Creaform.*

Fig. 2: 3D scanning software such as Artec ScanApp leverages advanced data capturing and processing algorithms, with an eye toward developing highly accurate 3D models. *Image courtesy of Artec 3D.*

Even in these cases, the lack of precision and accuracy greatly diminished the rewards derived from the process use. All this made reverse engineering a prime candidate for a technology revolution, a challenge that software providers have worked hard to deliver.

New Technology, Greater Efficiency

In 2021, 3D scanning systems provide engineers with highly precise data, which enable them to create complete 3D models for reverse engineering—either a point cloud or a mesh—significantly faster than traditional tools. These models can then be used as a mockup that designers can follow directly inside the CAD software.

"This allows for a much more accurate and accelerated reverse engineering process," says John Chan, software product marketing manager at FARO. "Contours can be extracted from highly dense 3D scans for the design itself. Furthermore, there is much less approximation of complex structures and surfaces that in certain cases would be near impossible to measure manually. Features on the scan can literally fit a geometrical feature on the item scanned, with micron-level approximation, as well as use constructed geometries on the point cloud to constrain the features created to the most accurate measure possible."

Essentially, with one sweep of the scanner, an engineer can now capture millions of data points across surfaces of all complexities, with submillimeter-level accuracy. The result is greater efficiency (Fig. 2).

"With 3D scanning, reverse engineering workflows are 300% to 500% faster, with repeatable precision," says Andrei Vakulenko, chief business development officer at Artec 3D. "This empowers manufacturers with a greater degree of business agility via a much faster time to market, combined with reduced labor and material costs."

Assembling the Building Blocks of Designs

To deliver these benefits, 3D scanners, with a variety of technologies, collect data that describe in detail the shape and appearance of the physical object in question. This includes defining its structure and environment.

This workflow typically begins with an assessment of the requirements, including accuracy, level of detail and scale.

"These combinations of variables can drive the hardware to be a sub-micron [computed topography] scanner all the way to a terrestrial LiDAR system capable of scanning literal landscapes of data," says Greg Groth, division manager, Brookfield, WI, operations, at Exact Metrology.

In the scanning process, the system identifies 3D points, calculated from photos and depth measurements. Once combined, the data forms a point cloud.

When the scanner creates the point cloud, it processes the data to create a polygonal mesh, which connects the dots of the point cloud to produce a complete 3D model. The mesh represents the surface of a shape with a collection of vertices and surfaces, and it includes information that describes how the vertices make up the surfaces. Mesh models don't contain any information about the object other than the position of the triangles that define the shape (Fig. 3).

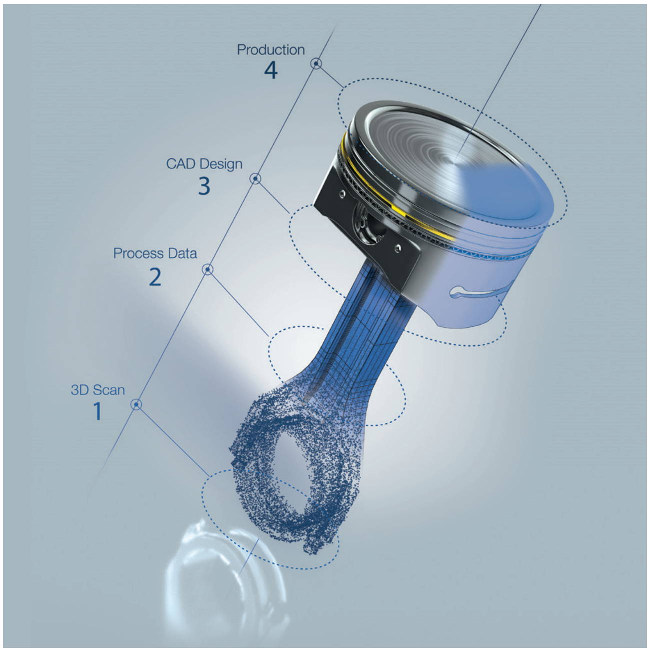

Fig. 3: This image shows the various stages of the reverse engineering of a piston. In stage 1, the 3D scanner captures measurements of the existing part. The system then processes and cleans up the point cloud or polygon mesh (stage 2). In stage 3, the engineer uses the scan data as a reference to build the CAD file. Stage 4 calls for the development of the production-ready design. *Image courtesy of FARO.*

The extrapolation process of the object's shape from points is known as reconstruction.

Bringing the Picture into Focus

Capturing measurements and defining shapes and surfaces, however, is only half the battle. As nice as it would be to have a 3D scanner that creates instant CAD models, no such technology exists. Most CAD offerings cannot work with the direct output of a 3D scanner.

The problem is that pure scanned data consists of extremely dense meshes that represent several million coordinate points or triangles. Basically, meshes are averaged point clouds interpolated into a triangle structure. This data is aggregated in mesh files, either in STL or OBJ file formats.

Before the data can be put into a ready-to-manufacture model, however, the engineer must align and optimize the mesh file (Fig. 4). This means extracting dimensional properties through geometrical entities, cross-sections and surface patches. Only then can these entities be exported to CAD software and used as reference data to create the final 3D model.

This is where scan-to-CAD toolsets come into play, but this phase of the process is not without its challenges.

Processing Challenges

For one, scanned data consists of thousands or even millions of small triangles. For a more accurate model, the engineer must measure more points. More points translate into a finer mesh, but they also mean that processing becomes more difficult.

A common approach is to convert the scan data into accurate math-based data. This requires scan-to-CAD workflows to eliminate redundancies and reduce the volume of data by culling relevant information from the larger digital representation provided by the 3D scanning.

This already difficult process is further complicated by the presence of noise.

"No matter how careful the scan is undertaken, there will always be noise—small fluctuations in data that will appear in the model that need cleaning up," says Robert Haubrock, senior vice president of product engineering software at Siemens Digital Industry Software. "The important factor here is making it easy to identify and fix these small blemishes in the data. This means being able to quickly map cylinders, planes and edges into a model to make it easier to get a clean model."

Ultimately, the scan-to-CAD workflow translates points or triangles into discrete features, surfaces and solids. The smoother and simpler the process, the more effective the toolset. Yet it can be difficult to find the right combination of tools.

"The main market challenge is getting the best tool for this translation into CAD," says Chan. "We have software that answers part of the reverse engineering need as it allows a user to translate a certain model into a CAD-digestible format, but it does not allow bringing all the information into CAD. While it basically wraps the mesh into approximated surfaces that follow the curvature of the part itself, users still need to continue the reverse engineering workflow within the CAD software environment."

The Human Factor

In its current state, 3D-scan-to-CAD technology lacks the automated processes found in more mature software platforms. The fact is that these workflows are not fully automated with the push of a button.

This means that, for now, engineers play a critical role in the process.

"Human intervention by a qualified specialist is still required to interpret the mesh data and enhance it to create the CAD 3D model," says Simon Côté, product manager at Creaform. "As such, this process requires some skills and know-how to accomplish, and depending on the quality of the scan-to-CAD solution as well as the complexity of the project, can be anywhere from easy to challenging."

A Starting Point for Reverse Engineering

Despite these challenges, the speed, agility and precision promised by 3D scanning technology is opening the door to a whole new class of reverse engineering use cases. To see what the technology can do, firms must keep in mind the basic intent of this long-standing engineering practice.

At its core, reverse engineering seeks to obtain information from, and even develop a design based on, a finished component or product. This means identifying the parts that make up the product, determining how they interact with each other, and defining how the product was manufactured.

The first step in this process is to take measurements of the existing part, using them as a guide for building a new CAD design file. This is where a 3D scanning system comes in handy, especially when reverse engineering a part with complex geometries that are difficult to measure any other way.

These scanners are proving to be well suited to make the measurements of the part in question, providing the information required to analyze its construction and create a new design file. Using the scan data as a reference, the designer can recast the part in a CAD model and add new features if necessary.

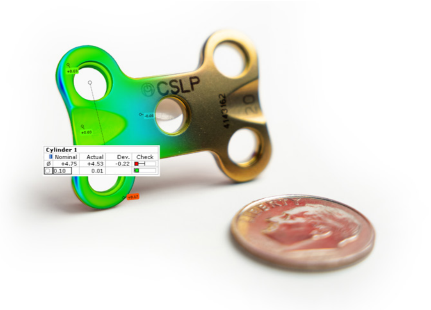

Fig. 4: A deviation color map is a color representation of a point cloud or mesh data set, compared to its intended, nominal CAD model. The software generates a measurement typically perpendicular to the CAD surface to the nearest point. The colors represent that length value and how far it deviates from the CAD surfaces in both directions. *Image courtesy of Exact Metrology.*

The Rise of New Applications

But what are these new applications that reverse engineering takes on? Overlay 3D scanners' capabilities onto prevailing

Engineering Meets Copyright Law

A fact of life in the digital age is that many technologies present ethical and legal dilemmas. In the case of 3D scanning-enabled reverse engineering, the issue is copyright infringement. The focus in this case is more on those performing reverse engineering than on the providers of the technology.

That said, the very qualities that make 3D scanning and scan-to-CAD systems so appealing exacerbate the situation.

"Working with the scan data is now easier than ever, so that is opening up new opportunities for companies to evolve design," says Robert Haubrock, senior vice president of product engineering software at Siemens Digital Industries Software. "This is especially true as we see a number of companies beginning to investigate a scan-modify-and-print approach—taking older pre-CAD data, scanning it, making some modifications to either evolve or, in the case of damaged components, repair the design and then using additive manufacture to create a new physical object."

As a result, reverse engineering copyright infringement is a hot-button issue, despite ongoing efforts around the world to sort out the issue. Evidence of this can be found in the news.

In November 2020, the Fédération Internationale de l'Automobile issued new rules for the 2021 Formula One season (https://bit.ly/3CEAAj1) to prevent teams from reverse engineering other teams' designs. The federation went so far as to implicate 3D scanning's connection in the reverse engineering process, saying that the use of the 3D cameras and reverse engineering software to create design data from images and photographs, surface scanning of parts and photogrammetry, along with software that converts generated data into 3D models, are all to be banned.

This does not, however, completely rule out the use of 3D scanning-enabled reverse engineering. "Reverse engineering is legal as long as you modify the design well beyond the boundaries where intellectual property rights cover the original," says Andrei Vakulenko, chief business development officer at Artec 3D. "But if you are in doubt, consult with an [intellectual property] lawyer."

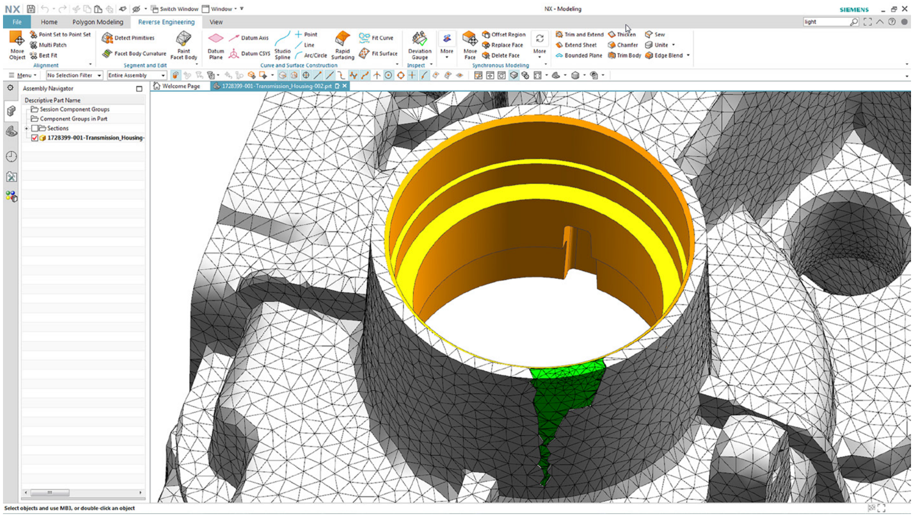

Fig. 5: This screenshot shows reverse engineering at work in a part repair. The broken old casting (light gray) that does not have a saved CAD model is scanned for recreation. The failure area is infilled (in green), and uses facet modeling to rapidly fill the gap and complete the model. The math-based geometry is shown in yellow. *Image courtesy of Siemens Digital Industries Software.*

trends such as additive manufacturing, small-batch production and manufacturing on demand, and engineers begin to see the foundations from which such use cases arise.

Consider, for example, the aftermarket parts sector. 3D scanning and scan-to-CAD systems provide the means required to translate physical legacy parts into the digital design information.

Armed with these capabilities, engineers and manufacturers can now cost-effectively support parts reverse engineering where the original manufacturer of a product no longer exists, no longer produces, and the productor is unable to supply replacement parts. The technology also proves useful in situations where the documentation of the original design is inadequate, has been lost or never existed (Fig. 5).

Scanning technologies facilitate new reverse engineering applications where there is demand to rework legacy designs to update or improve the product. Here, scanning systems can provide the necessary measurements when the original CAD model cannot support modifications, the addition of new technology, or current manufacturing methods.

Perhaps the most common area that benefits from 3D scanning-enabled reverse engineering is where design teams seek to redesign existing products. In these cases, scanning technology helps design teams analyze the good and bad features of a product. This allows the teams to address problem areas—such as determining how excessive wear might improve a product—or bolster good features, based off insights gleaned from analysis of long-term usage.

The Twin Connection

Look at the use cases that 3D scanning-enabled reverse engineering makes possible, and it becomes clear that there is a clear connection between these engineering tools and practices and the emerging digital twin technology. This is particularly true when you are talking about legacy-product twins.

Not only can 3D scanners and scan-to-CAD solutions facilitate the digital twin creation of legacy parts and equipment, but the virtual models they bring to life can be more accurate than previous representations that used manual measurements as a baseline. The ability to generate 10 times more digital twins in the same amount of time translates into digital twin deployment to a far greater degree throughout a business.

"What this means for establishing a digital thread architecture for these same parts or products is that you can have highly accurate representations to begin with, at the very outset of the product lifecycle," says Artec 3D's Vakulenko. "On top of that, 3D scanning lets you conduct precise inspections of the real-world versions of these digital twins in mere minutes, thus ensuring intelligent analyses of manufacturing variances and product performance." DE

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MORE INFO

- **Artec 3D:** Artec3D.com
- **Creaform:** Creaform3D.com
- **Exact Metrology:** Exactmetrology.com
- **FARO:** FARO.com
- **Siemens Digital Industries Software:** sw.siemens.com

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Fast Workstations Need Fast Buses: Inside PCIe Gen 4

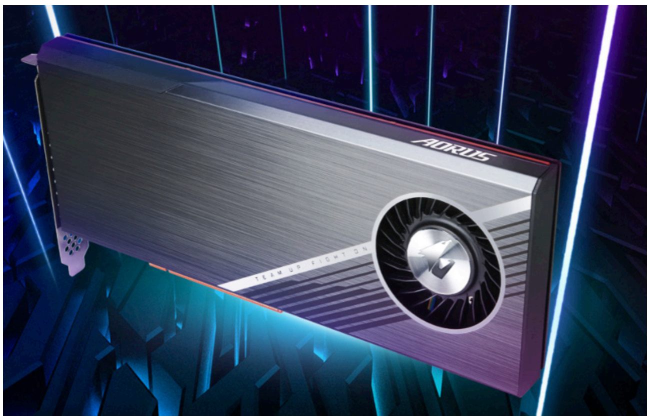
What can the latest version of this interconnect standard do for engineers?

BY RANDALL S. NEWTON

Advances in workstation performance seem to be as certain as the sunrise. The dynamic duo of faster and more powerful CPUs and GPUs always get the attention for such advances. Just as a star quarterback can't win without a team of position players, the CPU/GPU duo can't "win" without help from an overlooked component that makes all these advances possible—the PCIe interface.

Officially known as peripheral component interconnect express, PCIe is the computer expansion bus standard, the successor to generations of expansion slots that have been inside personal computers since the Apple II. The current shipping model is PCIe 4.0.

How important is PCIe? Legendary graphics expert and industry analyst Jon Peddie notes, "PCIe freed [graphics processing units] from the tyranny of buses with a scalable architecture that is still delighting and surprising us 17 years later and with no end in sight."



The Aorus 8TB SSD is one of many new high-speed storage devices that support PCIe Gen 4. *Image courtesy of Aorus.*

The fourth generation of the PCIe standard started shipping in workstations in early 2021. For years, the upgrade pace was slow as a reflection of industry demand but more recently development has been faster.

"It took us seven years to move from Gen 3 to Gen 4," says Al Yanes, the president and chairman of PCI-SIG, the standards association in charge of PCIe. "In the last couple of years we have been on steroids … "we want to double the bandwidth every three years."

PCIe Gen 4 essentially runs twice as fast as PCIe Gen 3. PCIe Gen 4 offers 16 gigatransfers per second, double that of Gen 3. The doubling extends down to the individual lanes.

Point-to-Point Connections

Originally PCI was a shared bus architecture; the PCI host (the slots) and all devices share a common set of addresses, data and control lines. PCIe advanced the standard by moving to a point-to-point topology. Separate serial links connect each device to the host, which allows for full-duplex communications not possible in the old standard.

The link between the motherboard and the peripheral or component is expressed in lanes. Some devices only need one lane; some need several. PCIe Gen 4 supports link widths of x1, x2, x4, x8, x12, x16 and x32.

This flexibility allows the standard to support low-bandwidth devices and such bandwidth devouring devices as the latest graphics processing units (GPUs) or Ethernet 10. Newer generation PCIe buses support devices built for previ-

The thin and light Dell Precision 7560 mobile workstation supports PCIe Gen 4. *Image courtesy of Dell.*

ous generations, which encourages continuity of product use.

Workstation vendors are now shipping a few models that support PCIe Gen 4. The move will take time, because not only must the motherboard support Gen 4, but all the necessary peripherals—including the CPU, memory and storage—must also support the standard.

"To get the benefit of Gen 4, all the peripherals must be compatible," says Matt Allard, director of strategic alliances at Dell Technologies.

In the increasingly competitive race between AMD and Intel, AMD was first out of the gate with workstation-class CPUs that supported PCIe Gen 4, the Ryzen 3000 line. Intel

Using PCIe Gen 4 requires multiple workstation components to be compatible with the new standard for best performance. AMD offers Gen 4 CPUs, GPU and motherboard components. *Image courtesy of AMD.*

was close behind with its Gen 11 CPUs that support the standard, making for an ample supply of CPU support.

When Gen 4 Makes Sense

There is no reason to throw out all workstations built before PCIe Gen 4, Allard says.

"We recognize that customers have budgets. Our new mobiles, like our new 17-in. thin and light, offer the choice of Gen 3 or Gen 4. Customers can make knowledgeable choices."

By assigning multiple lanes to devices as needed, devices that need the most bandwidth can get it. Mainstream workstation users may not need the extra speed boost.

Where PCIe Gen 4 makes the most sense is for large data sets, like very large CAD models or complex CAE jobs.

"3D CAD workflows using complex textures will benefit from Gen 4, as will real-time workflows for virtual reality and LiDAR point cloud scans," says Mano Gialusis, a senior product marketing manager at Dell. "People who use large datasets love [PCIe Gen 4]."

Team members creating visualizations from large models will also see a speed increase using Gen 4.

"8K video is the top end today, [so] not that uncommon in engineering," says Gialusis.

If the user must create a dissolve between scenes, it requires two high-bandwidth streams running simultaneously. In a Gen 3 workstation, the software would have to lower resolution or frame rate to get top performance. Gen 4 allows the rendering to continue at full speed and full fidelity.

By moving up to PCIe Gen 4 Gialusis says Dell can now offer a 4 TB M.2 storage device in their mobile workstations. Each Gen 4 M.2 requires three lanes, making it possible for Dell to ship a mobile with 12 TB storage. PC World ran benchmarks on early PCIe Gen 4 peripherals. A Gigabyte Aorus M.2 solid-state drive (Gen 4 compatible) hit speeds 35% higher than the magazine had seen with Gen 3 devices.

One more reason to like Gen 4 is its ability to run faster while consuming less energy than Gen 3. AMD emphasizes energy consumption as a competitive advantage over Intel, and has aligned its research and development strategy with the availability of PCIe Gen 4 to help lower system-wide energy use.

What the Future Holds

PCIe Gen 4 just started shipping in 2021, and already the next two generations are nipping at its heels. "Gen 4 is past us. The Gen 5 spec has been released for compliance review, and the spec for Gen 6 will be out by the end of the year," says PCI-SIG's Yanes.

Demand for bandwidth is rising rapidly, so the SIG is pacing its development work to match. In years past graphics seemed to drive the need for speed, but "now there are accelerators, machine language and artificial intelligence" driving the need for increased bandwidth, Yanes says.

Gen 5 and Gen 6 PCIe will offer multiple choices for hardware developers, as PCIe extends into cellphones, low-power devices and automotive. Gen 6 will be of specific interest to the automotive industry; the twin titans of automotive R&D—electric propulsion and autonomous driving —need as much bandwidth as possible.

"The need for speed, for information transfer, for calculation, all that stuff plays in our space," says Yanes. "Years ago we were not low power. Now PCIe is fast and low power." **DE**

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MORE INFO

- **Dell Technologies:** Delltechnologies.com
- **PCI-SIG:** Pcisig.com

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

Finding the Right Spot

When the pandemic struck, this midwestern manufacturer turned to the cloud to support its now remote design and engineering team. Now, there's no turning back.

BY KIP HANSON

Remote work as an option for employees was already on the table just prior to COVID-19 entering the picture, as Scott Funk, IT manager at Global Finishing Solutions (GFS), recalls. One of his colleagues had approached him in late 2019 about the possibility of allowing some of the design engineers to "work from home occasionally," and as the IT manager, it was Funk's responsibility to find a cost-effective yet powerful remote computing solution. Fortunately for everyone involved, he was well committed to the testing path for such a setup when the COVID shutdowns began. Which means they didn't miss a beat.

A Proud Legacy

GFS—originally JBI—started operations in 1975. Founder Jerry Bowe's vision was to become a leading manufacturer of spray booths and other finishing products for the aerospace, industrial and automotive markets. He was hugely successful. JBI moved to its current location in Osseo, WI, in 1990, continued to prosper and eventually gained the attention of the Curran Group, which purchased the company in 1998.

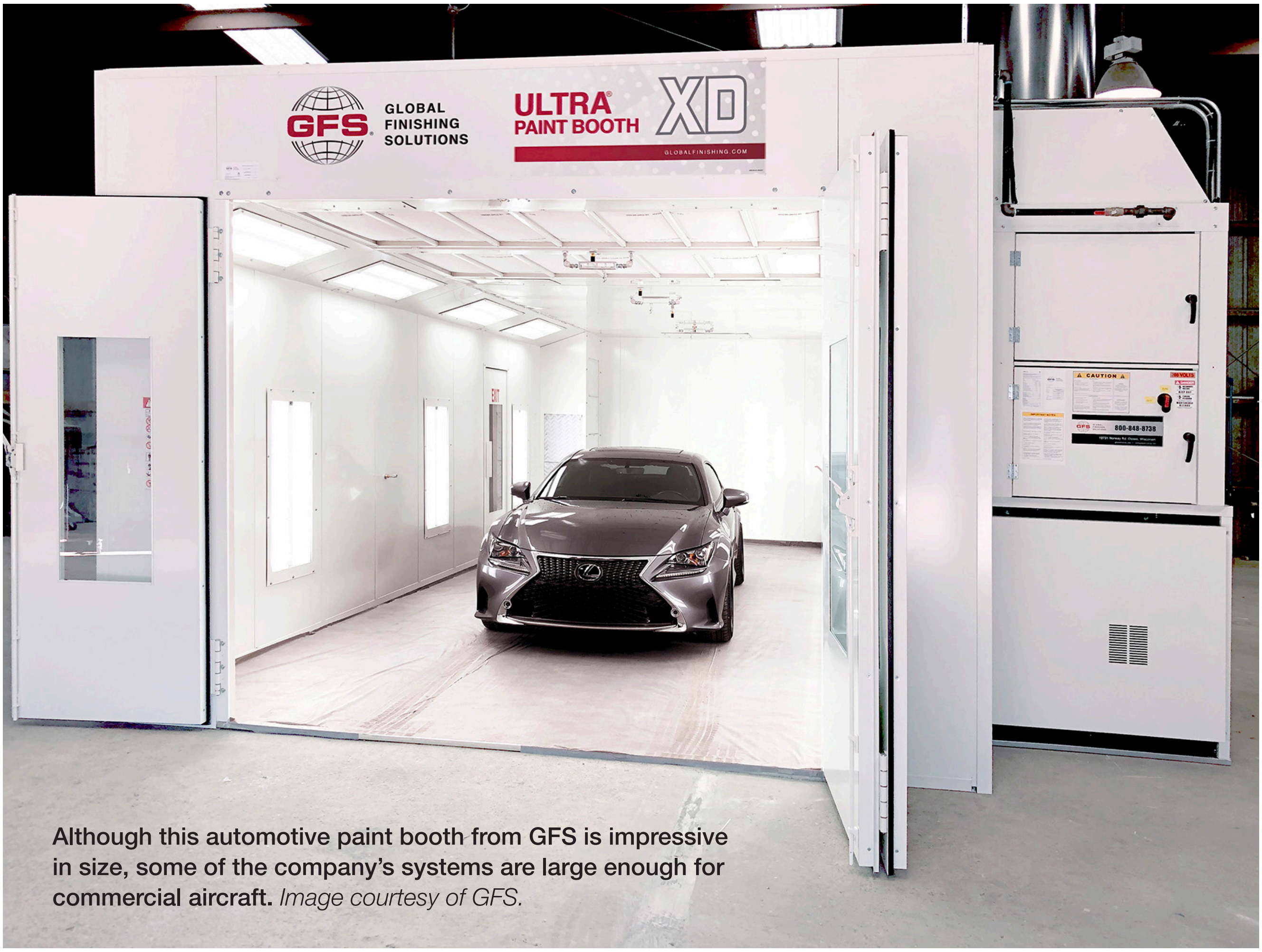
Since then, GFS has continued to expand and today boasts more than 200,000 square feet of manufacturing and office space, including a state-of-the-art Center for Excellence training, demonstration and research facility.

GFS has met and exceeded Bowe's original goal of being a premier manufacturer of high-quality paint booths. The company has expanded into powder coating, surface preparation, dust collection, clean rooms, ovens, washers and curing systems. An ISO 9001:2015 manufacturer, GFS is also vertically integrated, as it is able to address practically any finishing needs for customers worldwide.

Nights and Weekends

All of this is made possible by GFS' 300+ dedicated employees, many of them on the design team. The problem for IT leader Funk was to find a way for these compute-intensive

Global Finishing Systems enjoys more than 200,000 square feet of manufacturing and office space, including a state-of-the-art Center for Excellence training, demonstration and research facility. *Image courtesy of GFS.*



Although this automotive paint booth from GFS is impressive in size, some of the company's systems are large enough for commercial aircraft. *Image courtesy of GFS.*

employees to continue their important work in a world locked down by the pandemic.

"Even before that, we had lots of dedicated people coming in on Saturdays and staying late at night because they couldn't do their work from home," he says. "We wanted to avoid their having to do that."

It wasn't that they didn't have access—they did, but the existing virtual private network (VPN) tunnel and 400 Mbps fiber service was inadequate for heavy engineering work. Between the number and sheer size of CAD files the design team needed to access, latency was a serious problem. The line quickly became saturated for any demands greater than those of the accounting department and other users accessing the company's enterprise resource planning (ERP) system.

"This is what drove the original request back in 2019," Funk said. "Most of the engineering group use Autodesk Inventor or AutoCAD Electrical, and all of their data resides in our Vault PDM [product data management] system. And when you design paint booths the size of a 747 airliner, the files are obviously quite large, as are the GPU [graphics processing unit] requirements that come with a high-end workstation. That's why we turned to Workspot."

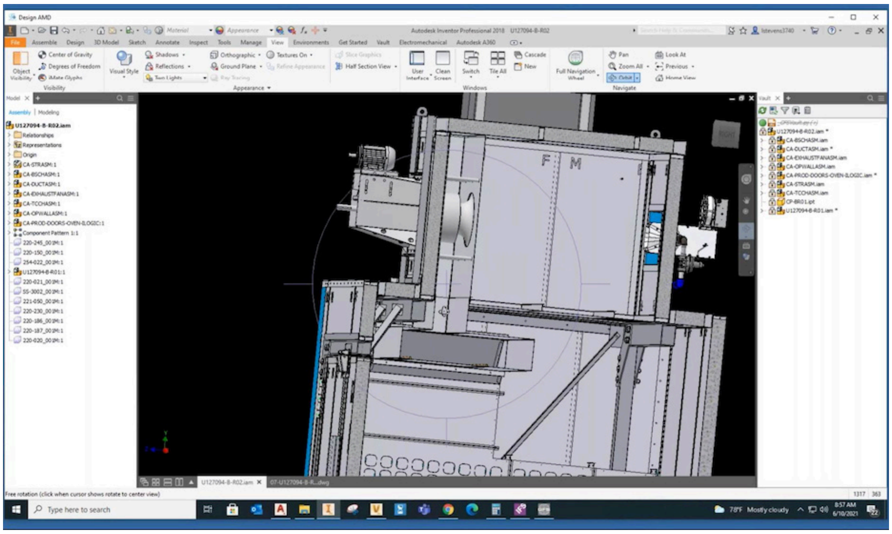
Taking to the Cloud

Based in Campbell, CA, Workspot Inc. delivers Desktops-as-a-Service, or DaaS, to customers in a range of industries: financial and legal services sectors, life sciences and healthcare, retail, education, architecture, engineering and construction (AEC), and manufacturing. Cloud desktops and workstations can be provisioned in minutes rather than months, the company claims, with "the right compute capabilities for each user, on any device, anywhere they want to work."

"Before the cloud, everything was installed on-premises," says Brad Peterson, Workspot's vice president of marketing. "That meant the IT [department] was on the hook for buying everything—the software and licenses, the desktops, servers, network infrastructure and so on—and then had to guarantee it was running around the clock, often with minimal staffing. These systems were frequently underpowered or soon would be, with the result that users were constantly complaining about performance. The cloud has allowed us to change all that."

Workspot, he explains, has developed a service that generates an abstraction layer on top of Microsoft Azure and Google cloud-based platforms. This layer allows them to launch a virtual desktop for a user anywhere in the world, and size it according to that user's needs.

"They feel like it's a local Windows 10 computer sitting right in front of them, but it's not," says Peterson. "It's up in the cloud, connected to their company's software systems through a multi-stranded fiber connection, and available at a flat monthly fee. In a nutshell, we take away the complexity of IT management."



Engineers at GFS use their Workspot cloud workstations to design products using Autodesk Inventor. *Image courtesy of Workspot.*

Headed Home

Funk had recently upgraded and then migrated GFS' Vault servers to the Azure platform and was in the process of installing a "landing zone" for the engineering department, so he was well-positioned when the request came to make design work more flexible. After consulting with his Microsoft representative, he reached out to Workspot and agreed to purchase five virtual desktops.

"That was in January. By the time the paperwork was signed and the onboarding process complete, it was mid-March," he says. "We probably had four or five days of testing under our belt when the [state's] 'Safer At Home' [COVID-19] order came down from the governor's office. My team and I had to find a way to turn the entire engineering department into remote users as quickly as possible."

Good luck is always at the crossroad of preparation and opportunity, he adds. With help from Workspot and Microsoft, GFS went from five virtual desktops to 55 within two days and sent everybody home. There were some initial hiccups with VPN connections and personal computer configurations, Funk admits, but they quickly sorted them out and have been "humming along" ever since.

From heaters to paint booths, dust collection to curing systems, GFS boasts extensive manufacturing capabilities. *Image courtesy of GFS.*

So is everyone back to work? Not quite yet, although Funk indicated that there have been some lessons learned over the past year, and that the business model may be changing to some extent.

When it's easier to work from home, for example, people will think twice about coming in when they feel sick, which leads to a healthier workplace overall. It also gives GFS greater flexibility in hiring, as they can now attract talent from anywhere in the country or perhaps the world, given their newfound compute capabilities.

And to those IT folks who might be concerned about potential downsizing of their department due to desktop outsourcing, Funk said there's no need to worry.

"Even with the cloud, there's still plenty of work to do, and I now have more time to spend with the end users and look for improvement opportunities that will help the company. There's no more calculating how much hardware to buy and whether it will be adequate in a year or two—if a user comes up short, we just upgrade them to the next service level. I'm absolutely a fan of this solution," he says. **DE**

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

MORE INFO

- **Workspot:** Workspot.com

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Beginning Your 3D Printing Journey

By Ashley Eckhoff, Siemens Digital Industries Software

Lao Tsu said, "A journey of one thousand miles starts with a single step". He could have easily been talking about additive manufacturing (AM) or 3D printing. But how do you take that first step? This is the question that faces many companies as they contemplate adding additive manufacturing to their stable of manufacturing technologies. However, there are ways that you can begin the additive manufacturing journey without risking mission-critical projects or company profits.

Ashley Eckhoff has multiple degrees in engineering and has worked at Siemens for over 20 years. His current role as a member of the Siemens Software Additive Manufacturing Program brings him into constant contact with the companies and people making additive manufacturing an indispensable production technology for the 21st century.

Gaining competence

The initial stages of the additive manufacturing journey are all about knowledge acquisition. Companies with little experience using additive manufacturing need to quickly get up-to-speed on the intricacies of the process so that they can begin understanding what it will take to capitalize upon the potential of 3D printing.

As we assist businesses moving through their additive manufacturing journey, one consistent method we see companies adopting for knowledge acquisition is the gathering of a team of experts within the organization to begin collaboration on a company-wide additive manufacturing strategy.

Businesses who execute well on AM knowledge acquisition identify appropriate stakeholders to be involved in these efforts. Individuals chosen for these groups usually tend to be designers, analysts, production engineers, and managers who are excited about technology and who are hungry to learn new skills and techniques.

Encouraging experimentation

One way we see companies rapidly acquiring additive manufacturing knowledge is by encouraging experimentation. Many companies foster an experimentation mindset by investing in multiple low-cost desktop printers to be placed in divisions or offices across their operation. Having 3D printing equipment readily at hand lowers the barriers to knowledge acquisition by allowing employees to experiment in a low-cost way with designing and printing parts.

Experimentation can be further promoted by mounting "print-a-thon" competitions where teams of designers and production engineers are given a problem to solve and are encouraged to use new design tools and methods as they collaborate to design, engineer, and print parts that solve the problem. Rewards are often given for participation, design creativity, use of new design and production tools, final part quality, and overall solution to the problem. This is, in effect, "gamifying" the acquisition of 3D printing knowledge within the organization and has been proven to be effective in many of the organizations we have worked with.

Beginning implementation

As the 3D printing experience within an organization grows, we often see the use of additive expand beyond simple experimentation. Here, we move from pure knowledge acquisition into areas where low-risk printing can be used to further the business goals of the organization.

Prototyping is, of course, the traditional use case for 3D printing. Physical prototypes allow a company to iterate quickly on the design of a part, to check fit within a wider assembly of parts, and to refine ergonomics for parts with a human interface. Thankfully, those same desktop printers that were initially used for knowledge acquisition can often be used for rapidly iterating through low-cost protypes of actual products.

Furthermore, this is the time when we often see companies begin to print manufacturing aids and even occasionally replacement parts for equipment. Manufacturing jigs and fixtures can often be produced faster and at lower cost when printed than when manufactured using traditional methods. Meanwhile, printing temporary replacement parts for equipment used in the field allows companies to maintain production volume while permanent replacement parts are acquired. Low-risk use cases like these allow companies to gain valuable printing experience without risking center-of-target production or efficiency.

Taking the first step

Regardless of how your company chooses to begin its additive manufacturing journey, the most important thing is to take that first step. At Siemens, we're ready to help you in your additive manufacturing journey, whether you are on day one, or year ten. Our comprehensive software solutions are helping companies at the very beginning of their additive journeys just as they are helping other companies to expand their printing to full-scale production. Our goal at Siemens is to help you efficiently gain the knowledge you need today to print the products of tomorrow.

Learn more…

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Between Zoom-Land and Las Vegas: **The Future of Engineering Conferences**

Tradeshows Get Ready to Welcome Back Onsite Attendees While Holding onto Virtual Viewers

BY KENNETH WONG

Before the COVID shutdown, I used to travel once every 6 weeks or so to conferences and trade shows. In Las Vegas, Los Angeles or Orlando, after the evening receptions and networking events had wrapped up, I would meet up with other editors and bloggers for one last drink in some hotel lobby or downtown bar. Here, setting aside the conference-branded backpacks, we rekindled our camaraderie, then collectively rehashed the tidbits we'd heard in the keynotes and the exhibit halls. As a pool of reporters covering a niche industry, we are by necessity a tight-knit group. We may be working for competing outlets, but our bond is solid. I miss these cerebral, energetic and (sometimes) tipsy conversations.

On the other hand, I do not miss the 4 a.m. Lyft rides to the airport, long security-screening lines and flight delays (sometimes long enough to learn to introduce myself in a new language). In many ways, the shift to virtual conferences during the shutdown allows me to continue to do my job without these hassles, so I'm thankful to Zoom.

Now, as U.S. cities begin to reopen, I realized I am actually looking forward to the salty pretzels and watery coffee the airlines begrudgingly serve as "in-flight snack," and the random conversations I might strike up with a stranger while waiting to be X-rayed by TSA.

Having learned to conduct business with greater efficiency during the crisis, is it wise to go back to the way things were? What would engineering trade shows and design conferences be like in the post-COVID world? Before I venture out to my first in-person conference, I decided to ask the people who organize and attend trade shows.

Audience Engagement: Virtual vs. Physical Events

Two of the conferences I attend regularly—Autodesk University (AU) and Dassault Systèmes' 3DEXPERIENCE World (formerly called SOLIDWORKS World)—included virtual attractions even before the pandemic. AU, for example, provided attendees with the AU Online option with a lower admission cost. 3DEXPERIENCE World offered SOLIDWORKS Live for those who couldn't be onsite. But during the pandemic, both transitioned into fully online conferences like most others.

"At its peak, the in-person 3DEXPERIENCE World (3DXW) event drew about 8,000 registrants, and 6,000 live attendees. About 3,000 of them were customers," says Suchit Jain, VP of Strategy & Business Development, Dassault Systèmes. "But when we switched to virtual in 2021, we ended up with 40,000 registrants, 21,000 attendees. Customers were about 15,000. In live events, we used to get about 500 students, but in the virtual event, we got about 9,000 students."

Steve Prahalis, chief operating officer, SME, calls virtual conferences "the rescue plan" in times when physical events were impossible. "In the early days of COVID, we were just happy to engage with our peers," says Prahalis. But as the shutdown went on, "We saw that people were getting tired of virtual conferences. They were not getting engaged the way that they wanted."

Professional in-person conferences usually require an admission cost ranging from $400 to $1,000, along with travel and airfare. Online events are usually low- or no-cost. This may explain the disproportionately larger numbers in virtual conference registrants. Audience engagement, however, is quite different.

"What we saw in virtual events is, we get a higher number of registrants, more people from more places, but the number of leads resulting from it or the level of engaged attendees was not higher. In many cases, it was the same or lower," notes Prahalis. For those planning to sell products catering to a specific region, a wider international audience doesn't necessarily provide greater value, he adds.

"In an in-person conference, once the people have flown in, they are there with you. You don't tend to lose people," observes Jain. With events held in Las Vegas, "you do lose a few people among the slot machines," he quips.

Dassault Systèmes executives in a studio during the recording of the 3DEXPERIENCE World 2021 event. *Image courtesy of Dassault Systèmes.*

Virtual event attendees are tuning in at their own convenience, in between family duties, midday meals, and ongoing work. It's nearly impossible to count on their undivided attention throughout the event. For 3DEXPERIENCE World Virtual, "present," Jain clarifies, meant the participant, on average, spent approximately an hour in total in the virtual event.

Online Events Often Not Easier to Produce

The two biggest decisions for producing an online event, Jain reveals, are choosing the right streaming platform, and deciding whether to go live in real time or prerecord the talks.

"Nobody warned us that, when you have about 300 to 400 people online in a live event, you start to test the platform's limit," he says. "It's fine if you are just presenting and they are watching. But when you open up the mics for Q&A, you could see issues."

To avoid unpredictable internet issues, 80% of the sessions in 3DEXPERIENCE World Virtual 2021 were prerecorded, with some events like the fireside chat running live. "We, for example, went to a studio during the pandemic to record the keynotes, but for some external speakers and guest customers who appeared in the event, we did a lot of rehearsals," Jain recalls. "With some breakout sessions, the presentations were prerecorded, but the Q&A was live. We made sure the talks weren't just online PowerPoint presentations."

There were 300 presenters at the 3DEXPERIENCE World Virtual 2021, Jain estimates. "So we had to check the quality of the videos. For some, we even sent them webcams," he notes.

"We do what is known as simu-live—simulating a live event," says Prahalis. "The presentation is a prerecorded presentation, but the presenter appears live for the Q&A during the event."

With physical events, producers need to work out the transportation, the venue and the ins and outs of the event itself. It seems to involve a lot more work than virtual events, "but these are well-established processes in our business, with major supplies," says Prahalis.

The undeniable advantage of virtual conferences is the digital trail, the cookie-enabled tracking of attendees' online activities. "You do get a lot more measurable data to validate or analyze, compared to a physical show, like how many clicks, how many minutes someone spent on a specific track, and so on," notes Prahalis.

Exhibit Halls in a Browser Window

The exhibit hall—one of the areas that get the most traffic at in-person events—is a challenge in virtual conferences. Without the ability to touch, feel and try out the hardware and software or mingle with other conference attendees in the same space, the virtual exhibit hall proves less attractive than its physical counterpart.

"For the same reason, the hands-on software training sessions were difficult to run in virtual events," Jain says.

Sponsors typically spend $5,000 to $20,000 for booths, banners and logo displays at in-person events to promote their products and services. But can virtual events offer the same value to justify these costs? The average exhibitor or sponsor for a virtual conference isn't willing to spend the same amount, Prahalis notes.

"Eventually we have to go back to the in-person events with known margins. Last year, most event producers were happy just to break even—just to stay connected to the audience and help exhibitors and sponsors advance their business goals," he says.

Attendee Point of View

DE publisher Tom Cooney, just like the rest of the staff, had suspended his travel routines during the pandemic, but in May, he ventured out to his first in-person event: the Additive Manufacturing Users Group (AMUG) conference in Orlando.

"The overwhelming vibe was pure excitement, from the attendees who I sat with during meals and presentation breaks to the exhibitors who were anxiously awaiting to speak with anyone who walked into their booths. It was the opportunity to engage in conversation relating to technology—something that they haven't had the chance to do one-on-one in some time," Cooney says. "The interesting comments that I had heard were that there were very few tire kickers."

Dassault personnel get ready to record the keynotes for the 3DEXPERIENCE World 2021 Virtual Conference. *Image courtesy of Dassault Systèmes.*

In the beginning of May, the cumulative number of fully vaccinated people in the U.S. reached 120M, according to

Rapid + TCT Returns to Windy City

After hosting a virtual event during the pandemic in 2020, Rapid + TCT returns as an in-person conference, augmented by Rapid Live streams. The event, organized by SME, is scheduled for September 13-15 at McCormick Place in Chicago. The show usually attracts attendees with interest in the additive manufacturing (AM) technologies, best demonstrated onsite with hands-on sessions. As one of the few shows first returning to physical venues, Rapid + TCT hopes to satisfy the conference attendees' pent-up demand for in-person exchanges.

Keynote speakers include Melissa Orme, Boeing; Terry Wohlers, Wohlers Associates; and Mark Wehde, Mayo Clinic. Orme will focus on how AM is disrupting the aerospace industry, highlighting the opportunities and challenges she foresees on the road ahead.

"The industry is currently on the steady path forward accumulating and archiving data derived from captured opportunities that increase our understanding, experience and maturity, thereby allowing additive-only solutions to their product designs. As the esteemed Nobel laureate William Faulkner intoned 'you cannot swim for new horizons until you have courage to lose sight of the shore,'" says Orme.

Wohlers, recognized for his firm's reports on the AM market, will offers a historical perspective of the AM industry, looking back at its metamorphosis over the last three decades.

"Over this time, the AM industry has grown by 26.1% per year, on average, based on research conducted by Wohlers Associates since 1989. It is difficult to name another industrial sector that has grown at this level over such a lengthy period. Even so, the company's research shows that AM represents 0.1% of the world's manufacturing economy and is only scratching the surface of what is possible," he observes.

Wehde will discuss how AM is changing the healthcare industry. Providers are shifting, he points out, from "hospital-centric care to a more virtual, distributed care that heavily leverages the latest technologies around artificial intelligence (AI), deep learning, data analytics, genomics, home-based healthcare, robotics and 3D printing of tissue and implants."

The organizers have lined up 70 presentations and 150 speakers, with an exhibit area housing 200+ exhibitors. Organizers plan to broadcast the keynotes, thought leadership panels and digital exhibits to remote attendees via the Rapid Live app, with social media-style activity feeds.

For more information visit www.rapid3devent.com.

—By Kenneth Wong

the Centers for Disease Control and Prevention's data. As July approached, the number climbed to close to 160M. Currently 68% of the U.S. adult population has received at least one dose.

Travelers still have to weigh the benefits of the trip against the risks involved. This factor serves as a screening mechanism—only the most determined business travelers venture out. "The exhibitors at AMUG were very pleased with the quality of the attendees. It had more of a feel of a festive occasion than a trade show. I'm looking forward to September," Cooney adds.

Data from SME (Society of Manufacturing Engineers)

Smart Mfg Experience 2018 (Onsite)

- 16 countries pre-registered
- 2,759 total attendance
- 35% manager level or above
- 20% have less than 50 employees
- 12% have over 2,500 employees

The Best of SMX 2020 (Virtual)

- 62 countries pre-registered
- 1,694 total attendance
- 35% manager level or above
- 23% have 25 employees or fewer
- 28% have more than 2,500 employees

The Hybrid Future

The hunger for human contact and Zoom fatigue may urge many to return to in-person conferences, but a new model is also emerging. "We learned a lot about how to keep the online audience engaged. We'll leverage the live event for content. We'll also include ways for the remote audience to participate through live cameras. We have a lot of ideas," says Jain.

"We will be launching the EventLive initiative, which will include a digital component. All our keynotes and thought-leadership panels will be live-streamed for those who cannot come in person," says Prahalis.

Prahalis compares live events to musical concerts. Since many of the musical event producers also augment their revenues producing corporate events, the analogy is quite apt. "The Pearl Jam concert at Fenway Park is the spectacle, but the community continues to talk about the event online all year round," he points out.

The next big industry event for SME is the Rapid + TCT Show, set to run onsite in Chicago from September 13-15. DE

Kenneth Wong *is Digital Engineering's resident blogger and senior editor. Email him at kennethwong@digitaleng.news or share your thoughts on this article at digitaleng.news/facebook.*

NAFEMS World Congress 2021 (NWC21) Goes Hybrid

The simulation-focused NWC21 is scheduled for October 25-29 in Salzburg, Germany. This marks the post-pandemic return of the regular congress held every two years. Described as the first hybrid event, NWC21 offers onsite attendance as well as online participation. "Our Congress team will combine with venue staff and an experienced production team to make sure your time with us in Salzburg is safe, relaxing, memorable, productive and enlightening," the organizers promise.

According to the organizers, 500 papers have been accepted this year. The keynote lineup represents automotive and aerospace industry titans. Among them are Chuck Gray, Ford Motor Company; Torben Syberg, Boeing Commercial Airplanes; and Marco Ferrogalini, Airbus Group.

Karen Wilcox, Oden Institute for Computational Engineering and Sciences, University of Texas at Austin, will discuss a topic she has touched on in the recent CAASE Virtual Conference, cohosted by NAFEMS and DE.

"Our increased ability to sense, acquire and analyze data is clearly a game-changer—from data analytics and machine learning to digital twins, engineering design is becoming increasingly data-centric. Yet in our excitement to define a new generation of data-centric engineering approaches, we must be careful not to chart our course based entirely on the successes of data science and machine learning … This talk will draw examples from digital twins and reduced-order modeling to illustrate that data-centric engineering must bring together the perspectives of data-driven learning and physics-based modeling," she writes.

Also appearing at the conference is Yewande Akinola from Innovate UK. a chartered engineer, innovator and speaker, Akinola will give a talk titled "Global Citizen: Reporting for Duty."

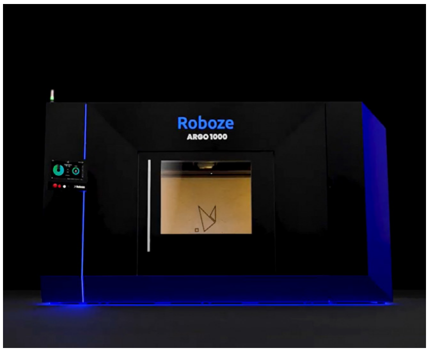
The show is sponsored by three big names in the simulation software industry: Ansys, Siemens and Dassault Systèmes.

For more information, visit www.nafems.org/congress.

—By Kenneth Wong

EDITOR'S PICKS

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



3D Printing System for Lightweight Components

ARGO 1000 has industrial system that integrates into production workflow.

Roboze debuts the flagship Production Series solution, the ARGO 1000. The ARGO 1000 can produce parts up to 1 cubic meter and transforms the way industries like aerospace, energy, transportation, medical technology and automotive can manufacture an increased number of lightweight components, the company says. The system uses more sustainable super polymers and composites such as PEEK, Carbon PEEK and more. ARGO 1000 will be available for commercial distribution in 2022.

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Improved Simulation Management

Update improves simulation workflow and management, company says.

BETA CAE Systems introduces version 22.0.0 of its comprehensive software suite for engineering simulation. The ANSA module for model pre-processing has a revamped graphical user interface (GUI), which the company says enhances the user experience through a series of features focusing on highlighting, real-time information display and a redesign of tool and option buttons. Mesh generation has been improved with new toolsets as well as a GUI update.

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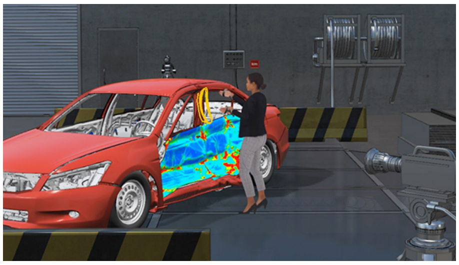

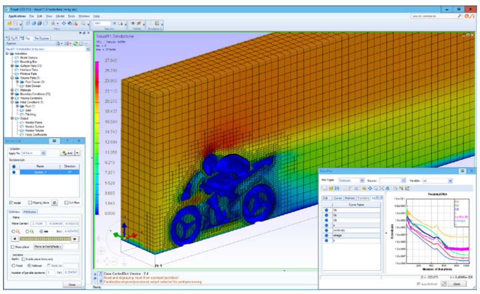

Extending Popular Open Source CFD Platform

This is a biannual update of the free, open source CFD software.

ESI Group makes available OpenFOAM v2106. OpenFOAM is managed by OpenCFD, a wholly owned subsidiary of ESI Group. The company describes the mission of OpenCFD as sustaining the future of OpenFOAM "as a highly functional, freely available and open source CFD software." The company sees OpenFOAM as a "long-term and viable complement to CFD codes, which are constrained by license costs and multi-user, multi-processor cost inflation."

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Improving Design Analysis

Multiphysics for IronCAD 2021 has fully coupled multiphysics for stress and more.

IronCAD LLC introduces Multiphysics for IronCAD (MPIC) 2021 update of the multiphysics finite element simulation application integrated into IronCAD. To use, designers add material, forces and constraints to an IronCAD model and then select "Auto Solve" to generate analysis results.

The company says MPIC provides fully coupled multiphysics for stress, thermal and electrostatic analysis. IronCAD says it also has added several technologies specific to CAD analysis.

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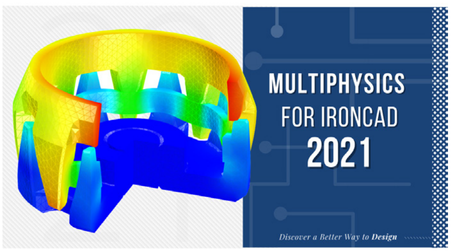

Next-Gen Engineers

Student Competition: NASA Spacesuit User Interface Technologies for Students

Tech-Driven Students Reach for the Stars

BY JIM ROMEO

NASA Spacesuit User Interface Technologies for Students (SUITS) is a student design competition that challenges students to design and create spacesuit information displays within augmented reality (AR). As NASA pursues Artemis, its international human spaceflight program to land American astronauts on the Moon, the competition is part of the agency's acceleration of investments in surface architecture and technology development.

The NASA SUITS competition challenges students to design and create spacesuit information displays with augmented reality (AR) environments. *Images courtesy of NASA.*

Each prospective on-site team member must be a full-time undergraduate or graduate student enrolled in an accredited U.S. institution of higher learning (military academy, technical college, community college or university) or faculty member at the time of proposal submission.

NASA believes that for exploration, it is essential that crew members on spacewalks are equipped with appropriate human autonomy enabling technologies necessary for the elevated demands of lunar surface exploration and extreme terrestrial access. For 2022, the SUITS Challenge targets the Artemis mission's key aspects.

Brandon Hargis is the STEM engagement manager at NASA's Johnson Space Center in Houston, TX. We spoke to Hargis to learn more about this competition.

***Digital Engineering:* Can you provide an overview of the NASA SUITS competition, how it came to be and the intent of the program?**

Brandon Hargis: NASA SUITS was first introduced in 2018 as a collaboration between the Extravehicular Activity Office and their Informatics division, designing toward the exploration Extravehicular Mobility Unit (xEMU) and the NASA Office of STEM Engagement.

The primary objective for SUITS is to develop a user interface that uses a head-mounted display (HMD) device in augmented or mixed reality to assist crew members with extravehicular activity (EVA) responsibilities and tasks during a lunar mission via procedural and EVA system state information in a non-obtrusive way. Participants in SUITS come from colleges and universities across the U.S. with about 20 teams selected each year. In the 2020-21 cycle we had 220 participants representing 28 institutions.

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

Hargis: Student designs are created in commercially available hardware like the Microsoft HoloLens 1 and 2, and Magic Leap. Design requirements include navigation, suit interaction with other devices, biometric display data, interaction with other assets and tools, the human environment and science/geology tasks.

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

Hargis: Over the last four years, the student teams representing U.S. higher education institutions have produced more than 50 user interface software design concepts and over 25 white papers for technical journals and conferences.

***DE:* What drove NASA to sponsor the event and coordinate it?**

Hargis: Engaging academic institutions and the future STEM workforce in designing future forward concepts for the xEMU creates unique opportunities for diverse groups of higher education students to contribute solutions to NASA Artemis missions, increases research and capacity to conduct research in the field of augmented reality and human computer interaction for greater astronaut EVA autonomy, and develops the STEM workforce pipeline to NASA and industry leaders. **DE**

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

MORE INFO →

- **NASA SUITS:** go.nasa.gov/3AABUl8

COMMENTARY

By Patrick Dunne

Additive Manufacturing Solutions for Silicon Wafer Tooling

Industrial additive manufacturing solutions can optimize the hardware and tools in microchip fabrication production lines.

Microchip fabrication is considered state of the art in advanced manufacturing. This industry is driven by the pursuit of faster, more efficient processors and higher capacity memory chips where we see racing vectors driving ultra-high levels of detail fidelity, resolution and precision, all wrapped within massive investments in advanced tooling systems and infrastructure. Multi-billion-dollar production lines depreciated over billion-unit production runs present staggering metrics, as well as massive continuous optimization initiatives. Regarding optimizing the hardware and tools that exist within these production lines, the emergence of industrial additive manufacturing (AM) solutions presents a significant opportunity.

Phenomena

Within silicon wafer tooling there are many complex phenomena with which to interact. Temperature, inertia, turbulence, resonance, vibrations, precision, wear-and-tear as well as ultra-high levels of pristine clean driven by zero tolerance for contamination, converge to present a significant challenge, while at the same time many opportunities for optimization.

Additive manufacturing allows for step changes in component performance and efficiency. With the traditional rules of design and manufacture that you see in conventional parts, performance is always somewhat compromised. With AM, specifically by embracing design for additive manufacturing (DfAM), the philosophy of 'design for function,' enables companies at the front line of problem-solving to innovate in ways previously never considered possible. Historically, 'design for manufacture' was constrained by the relationship between cost and design sophistication. AM breaks this equation. For example, consider cryogenic tubes and manifolds.

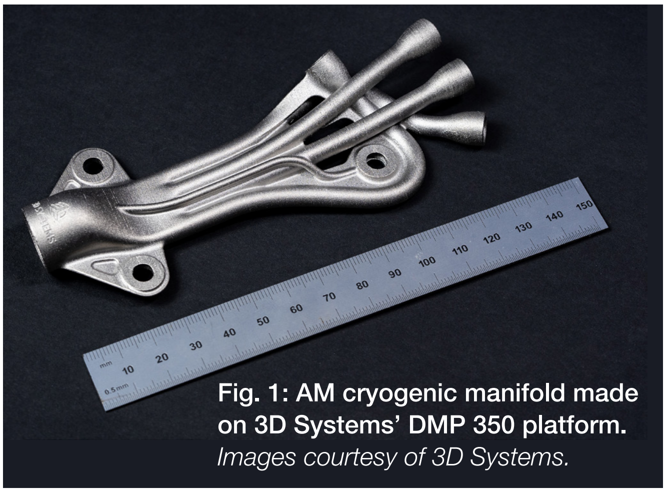

Fig. 1: AM cryogenic manifold made on 3D Systems' DMP 350 platform. *Images courtesy of 3D Systems.*

Fluid Flow

Traditionally these very complex circuitry components are time-consuming and difficult to fabricate, requiring multiple manufacturing processes from sheet metal folding to hydroforming and tube bending, all integrated with assembly steps. The net result never quite approaches the perfect solution, due to assembly processes and steps that are full of potential points of failure. The braze lines themselves present surface imperfections that can impact the smooth laminar flow. When AM is applied, designers can present the perfect tubular system using advanced fluid flow computational fluid dynamics to influence, and in some instances automate, the creation of form as well as the integration of sophisticated baffle strategies that allow for minimizing turbulence while maximizing flow efficiency. Such architectures minimize vibrations and resonance that correlate with net turbulence within systems as depicted in Fig. 1.

Turbulence and vibrations impact the precision of output, and in a world where nanometers count, this presents significant capability. Finer fluid flow within these plumbing systems equates to higher precision and better yield. Using 3D Systems' Direct Metal Printing (DMP) 350 platform engineers were able to realize a 90% reduction in liquid-induced disturbance forces to reduce system vibration and realize 1-2 nm accuracy improvement.

Part Count Reduction

An added benefit of AM is being able to grant the designers access to significant levels of component consolidation, which ultimately drives the design efficiency principle of 'part count reduction' leading to the expression of complex manifolds as monolithic components with no assembly required. This simplifies the supply chain lead time and makes the process of design easier. The time savings can be significant.

In some examples, we have seen months become hours—driven by removing the need for tooling, assembly, and the associated inspection process. We have seen up to 50x reduction in part counts under component consolidation within some of these complex systems.

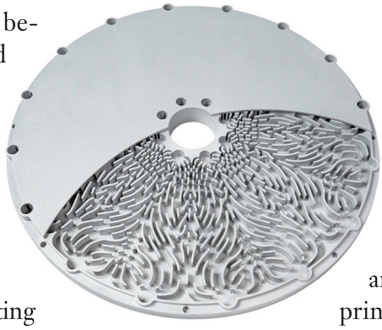

Fig. 2: Silicon wafer table with integrated advanced cooling structures (cut-away section) produced using 3D Systems' DMP 350 platform.

Thermal

Another example where we see AM presenting step changes in capability is wafer tables as shown in Fig. 2 that are used for handling and fixturing the silicon plates during the manufacturing process. Similar to cryogenic tubes and manifolds these components need to transmit and distribute super-cooled cryogenic fluids. However, in this case, the primary challenge is managing ultra-fine levels of thermal consistency. Thermal gradients and fluctuations over time can create scenarios where the position of structural elements being printed and accumulated on the surfaces of the silicon wafers can shift. To solve this, engineers are turning to AM to design, develop and manufacture next-generation silicon wafer table architectures.

For example, by using 3D Systems' additive manufacturing solutions, one silicon wafer tooling company was able to realize a 6x improvement in thermal performance and a 5x stabilization improvement. The thermal profile within the conditioning ring was able to see a ΔT improvement from 13.8 to 2.3 mK, with a thermal temperature gradient reduced from 22 to 3.7 mK, in a more responsive system presenting a time constant moving from 7 s to 1.5 s. In fact, the performance and responsiveness of the AM architecture were so high that the engineers were able to look at regressing an alloy selection from expensive copper to cheaper and lighter aluminum.

Mass

DfAM generally presents significant opportunities for more efficient design through bulk material savings. When you don't have to design for assembly and break out from under the constraints of traditional manufacturing processes, 'lighter weight' has multiple benefits. These include lower thermal mass, which results in faster thermal condition response. Lower inertia results in opportunities for faster and higher precision conveyance, more precise stop and start acceleration/deceleration profiles, while at the same time reducing wear and tear of mechanisms. Reduced mass/inertia combined with DfAM-based improvements in the stiffness of subcomponents in high-velocity reciprocating mechanisms also reduce vibration. Again, like in the high flow rate manifolds, reduced vibration improves the overall precision and resolution of the system. At a silicon wafer tooling company, engineers were able to realize 50% weight reduction for reduced inertia, with a boost in stiffness of 23%, resulting in a higher resonant frequency and reduced system vibration.

Flexures

Whereas all examples presented so far have covered static and monolithic subcomponents and parts, integrated mechanisms combine some principles of kinematics and flexures to enable dynamics. The 3D Systems DMP 350 platform has a unique capability in this space.

One, in particular, is related to the build environment within the DMP system itself. Ultra-low O2 levels of <25 ppm allow for the expression and processing of ductile cyclic fatigue-resistant titanium. With ductility, engineers are now able to explore functional leaf springs and flexures. With access to flexures VDL, for example, engineers were able to successfully manufacture advanced optical assemblies with monolithic integrated mechanisms as shown in Fig. 3. Flexures presenting full fine control adjustability with all the benefits of massive levels of part count reduction, and lead time compression ultimately allowed engineers to design and produce faster, cheaper and higher precision optical assemblies and other advanced mechanisms.

The rate of optimization in silicon wafer is not slowing down. And as we've seen, AM is playing—and will continue to play—a significant role in enabling the slope of the curve. Additive manufacturing is here to stay. We're at the beginning, yet barely scratching the surface, but the value has already proven to be significant. As more and more silicon wafer tooling engineers at the front lines of problem-solving become aware of the capability of additive manufacturing (and combine it with their creativity) they will take these advanced workflows to a whole new level. DE

Patrick Dunne *is Vice President, Application Development, at 3D Systems.*

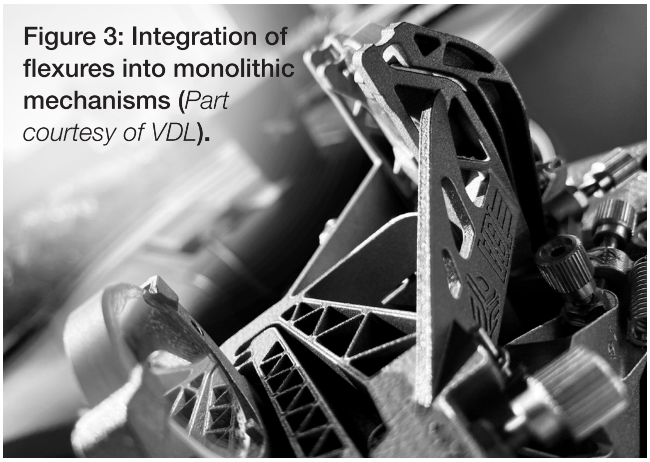

Figure 3: Integration of flexures into monolithic mechanisms (*Part courtesy of VDL*).