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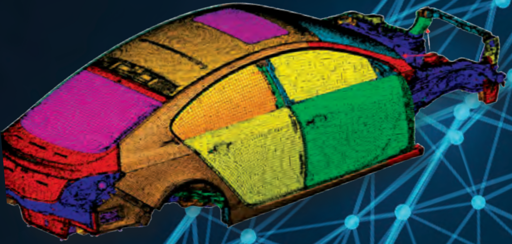
Digital Engineering

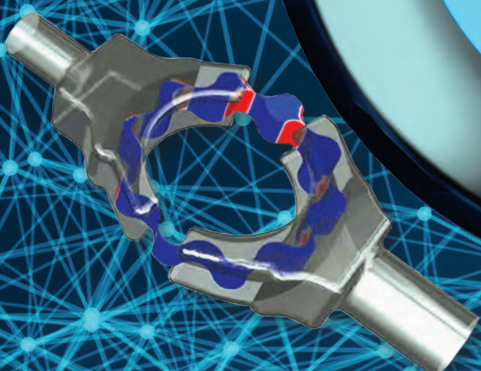
June 2018

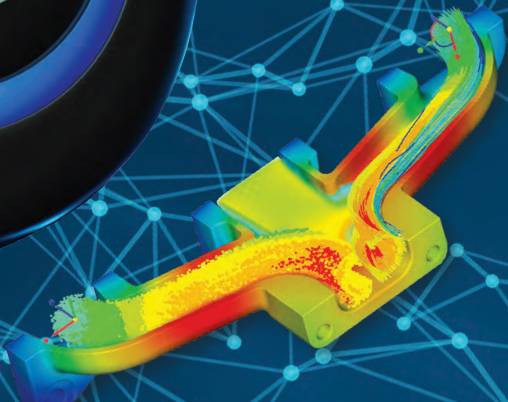
- Engineering for 5G
- Interactive Simulation
- SOLIDWORKS Simulation Overview

FOCUS ON: Democratization



UNLOCK Engineering Innovation





ONSHAPE REVIEW

AGILE VERSION CONTROL

ADDITIVE MANUFACTURING SERVICES

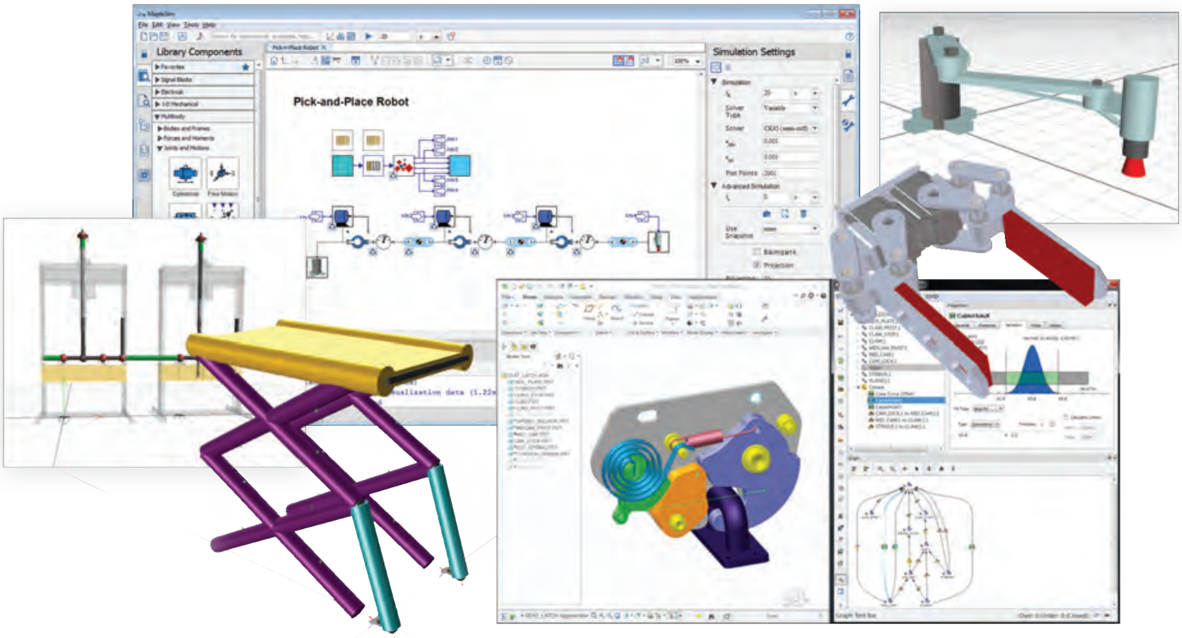
High-Performance Products without High-Performance Costs

From Design to Build: Model-Based Tools for Reliable Development

Even simple systems can have unforeseen issues. From revolutionary new products to evolutionary improvements, engineers are always at risk of missing some detail of their projects. These issues often come to light only once physical prototypes are constructed, while some are discovered well into production. The costs to fix these issues can have a serious impact on a company's bottom line.

The best time to fix performance issues is before they occur. Using model-based techniques helps engineers address concerns before building a physical prototype. At this stage, solving a problem amounts to the click of a mouse, whether it be adjusting for a complicated tolerance issue, or choosing the right motor to handle fast-moving payloads.

Together, Maplesoft™ and Sigmetrix offer tools that help you quickly expose issues in product performance and production tolerance.



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| **DEGREES OF FREEDOM** |

by Jamie J. Gooch

Different Paths Toward Democratization

THE LORE OF MY FAMILY includes the story of my father taking apart a car's engine with a hammer, a screwdriver and a pair of pliers to replace a gasket with one he had cut from a cardboard box.

The car was an early Ford, really early. My dad was born in 1922, so the beater of his youth had a hand crank. Automotive technology was different then. Still, he kept up with it, working as a mechanic for awhile and then maintaining the family cars. Oil, filters, tires, brakes, radiators, batteries, exhaust systems and more were repaired or replaced in our garage, no mechanic required.

From Cars to Computers

Now, I look under the hood when buying a car only as a force of habit. If anything more serious than an oil and filter change or battery replacement comes up, I know I'd be dropping it off at the mechanic. The complexity of automotive technology today, combined with a fairly low incidence of catastrophic failure and convenient access to specialists has won out over the auto repair democratization ideals my father prescribed to. As my dad would eventually say when he ran across an auto repair he couldn't do: "Too many computers in cars today."

I saw that as a good thing then. The car of his youth was the personal computer of mine: a revolutionary technology that was changing the world. While playing the role of mechanic's assistant as a tween, I would have rather been tinkering with my computer. I could upgrade RAM, hard drives, and power supplies, overclock processors, install graphics cards and replace motherboards. I knew every jumper setting.

The last computer upgrade I undertook was a simple solid-state drive installation in my laptop. My daughter assisted, glancing up from her phone occasionally as I pointed out what the various components were and what they did. She would have rather been Snapchatting.

When it comes to cars and personal computers, their widespread use didn't come in the form of "simpler" technology, but via shifts in reliability, affordability and ease of use—backed up by convenient access to specialists—which continue to take place over generations. I don't need to know how to change a tie rod to steer my car. My daughter doesn't need to know the difference between integrated and discrete graphics to watch a video on a computer. If something catastrophic goes wrong, we have options when it comes to hiring specialists to make it right.

From Computers to Software

You can take your pick of revolutionary technologies changing the world today. In the field of design engineering, technologies like simulation, cloud computing, artificial intelligence, augmented reality, additive manufacturing and sensor-laden, connected products are just a few with society-altering promise.

I would argue that most of those will eventually follow the usual democratization rules. Proving themselves useful, they "just" need to be easy to interact with their underlying complexity, decrease in cost and increase in reliability. And with the current rate of technological innovation, I don't think democratization will take generations to happen.

But simulation is different. The fact that simulation software (and the AI that it will increasingly employ) is used by engineering teams to help create and validate complex technological products puts it on a different democratization bell curve. We want someone on the engineering team to be able to "look under the hood" and understand what the software is doing and why. For many teams, that mechanic equivalent—the simulation analyst—is not available in-house or is only available from the software vendor's network.

You could also argue that simulation is actually on multiple paths because different products in different industries with different physics require their own cycles of simplicity, reliability and affordability to become democratized. And can a specialized use case for one type of product in one industry ever truly be considered to be "democratized"?

When we talk about the democratization of simulation, we can't expect it to meet the same definition of the ubiquitous technologies in PCs or cars. We *can* expect easy-to-use, modern interfaces that hide the complexity when it's not needed and help explain what's happening when it is, affordable options for different engineering team sizes and use frequencies, and increasing reliability when applied to more and more types of product design and development scenarios. As you'll see in this issue and our upcoming coverage of the Conference on Advancing Analysis & Simulation in Engineering (CAASE, June 5-7), software vendors, academia and end users have made great strides in the democratization of simulation. What more needs to be done? Tell us here: digitaleng.news/de/simsurvey. **DE**

Jamie Gooch *is editorial director of* Digital Engineering. *Contact him via jgooch@digitaleng.news.*


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Digital Engineering
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INSIDE

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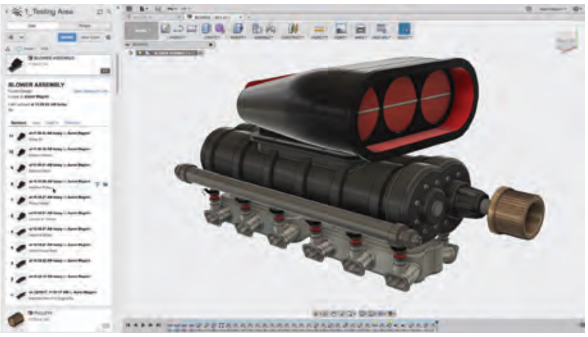

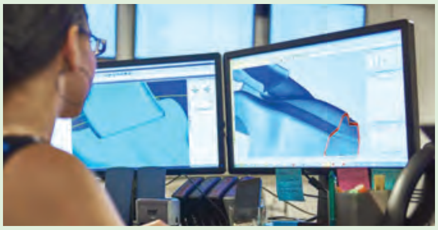

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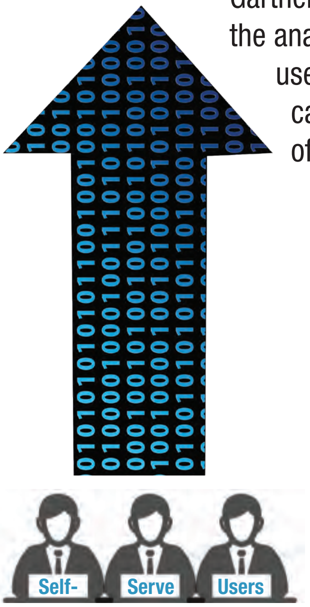
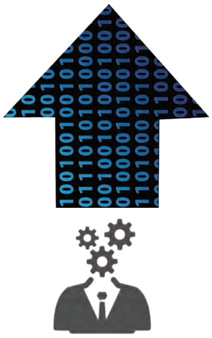
Do it Yourself Data Analysis?

2019

Gartner, Inc. predicts that by 2019, the analytics output of business users with self-service capabilities will surpass that of professional data scientists.

— Gartner, 2018 Gartner CIO Agenda Survey, January 2018





4,524 job openings

Data scientist was named the best job in America for three years running, with a median base salary of $110,000 and 4,524 job openings.

— Glassdoor's 50 Best Jobs In America For 2018, January 2018

10% Have AI Expertise

Only 10% of internet users worldwide say they know and understand artificial intelligence technology, while about half (53%) say they know what AI is, and 30% have heard of it, but don't know much about it.

— Qualtrics survey, March 2017

Technology Growth Rates

CAD: 6.9%

The size of the CAD software market is expected to reach $11.097 billion in 2023, growing at a compound annual growth rate (CAGR) of 6.9% from 2017 to 2023.

— P&S Market Research, "CAD Software Market by Technology, by Level, by Application – Global Market Size, Share, Development, Growth and Demand Forecast, 2013-2023," July 2017

PLM: 8.1%

The global product lifecycle management (PLM) market was worth $40.26 billion in 2014, while expected to expand at a CAGR of 8.1% from 2015 to 2022, to reach $75.87 billion by the end of 2022.

— Transparency Market Research, "Product Lifecycle Management (PLM) Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast 2015 - 2022," September 2017

Cloud Computing: 13.38%

The total global public cloud computing market is expected to hit $411.4 billion in 2020, a CAGR of 13.38%. Infrastructure-as-a-Service (IaaS) is growing at a 23.31% CAGR. Software-as-a-Service (SaaS) revenue is growing at a 15.65% CAGR.

— Gartner, "Forecast: Public Cloud Services, Worldwide, 2015-2021, 2Q17 Update," October 2017

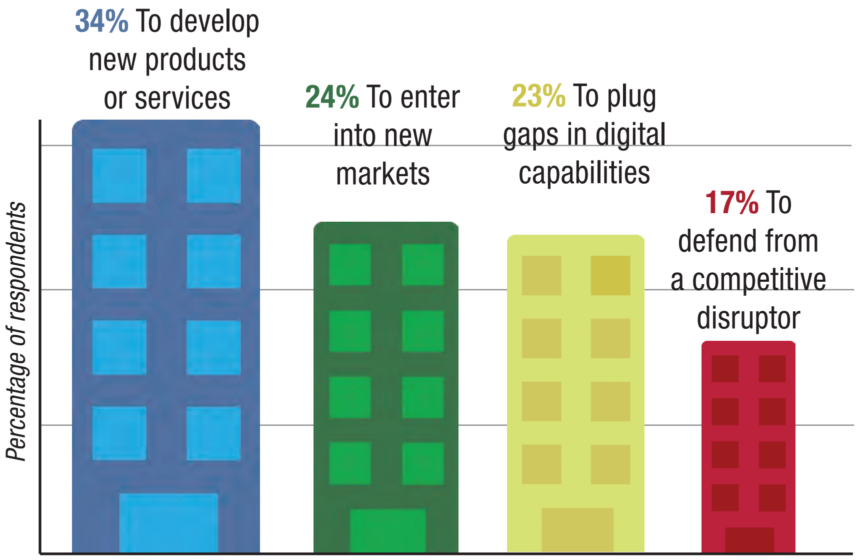
Simulation: 16.5%

The global simulation software market is expected to grow from $6.26 billion in 2017 to $13.45 billion by 2022, at a CAGR of 16.5%.

— Research and Markets, "Simulation Software Market by Component, Application, Vertical, Deployment Mode, and Region - Global Forecast to 2022," December 2017

Building a Digital Ecosystem

48% of companies are significantly investing in a digital ecosystem.



Why respondents are investing in digital transformation

Their top challenge, cited by 33% of respondents, is finding digital expertise to drive their approach.

— EY, "Digital Deal Economy Study," January 2018

Simulation on the Cloud: 11.4%

The cloud-based simulation market reached $3.3 billion in 2016, and is expected to have a CAGR of 11.4% through 2025, reaching $8.5 billion.

— Transparency Market Research, "Cloud Based Simulation Application Market – Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2017 – 2025.

SMB IT Spending

Total IT spending by small and medium-size businesses (SMBs) was expected to approach $568 billion in 2017 and increase by more than $100 billion to exceed $676 billion in 2021. In 2019 software and IT services spending are expected to both surpass hardware spending for the first time.

— IDC, "Worldwide Semiannual Small and Medium Business Spending Guide," July 2017

An April Additive Manufacturing Odyssey: **AMUG and RAPID 2018**

BY JAMIE J. GOOCH

REALITY HAS SET IN about 3D printing/additive manufacturing, and that's a good thing.

"I feel we are reaching an age where all [additive manufacturing] expectations and conversations are much more balanced, much more practical, much more pragmatic," said Consultant and AMUG Advisor Todd Grimm in his Additive Manufacturing Users Group (AMUG) keynote on April 9. "I firmly believe that that is a powerful thing for us. Make it real instead of this big lofty dream, this goal that is just hanging out there. Instead of making these bold promises of revolution and disruption—driving people by pure emotion, out of fear or out of hope and desire, asking them to take a leap of faith—we are providing paths ..."

At this year's AMUG Conference April 8-12 in St. Louis, MO, those paths took the form of product demonstrations, presentations and networking opportunities. AMUG celebrated its 30th anniversary this year, with a nod to its origins as the 3D Systems North American Stereolithography Users Group. Its members now include owners and operators of all types of additive manufacturing technology. A look at AMUG's recent growth—from 262 attendees in 2012 to 1,700+ attendees this year—provides a snapshot of the kind of growth the 3D printing/additive manufacturing industry has experienced.

The Missing Middle

One of the most obvious examples of additive manufacturing getting down to business was the number of products and announcements aimed at mid-sized businesses. For years, there were a mind-boggling number of 3D printers aimed at consumers, hobbyists and small business owners and plenty of choices on the high end, albeit with price tags that put them out of reach for many mid-sized businesses. In the middle, the options were more limited, especially if you wanted to venture outside the realm of polymers.

At AMUG, in addition to the fused-filament printers that had been filling the medium-sized business void, a number of vendors showcased machines and materials aimed at bringing medium-sized additive manufacturing along for the ride.

FULL AMUG 2018 COVERAGE →
rapidreadytech.com/?p=12457

The Rapid + TCT 2018 conference and trade show, produced by SME, took place April 23-26 in Ft. Worth, TX, with a focus on closing the 3D printing knowledge gap and accelerating the adoption of additive manufacturing.

Before the April 24 keynote, Michael Grieves, the executive director of the Center for Advanced Manufacturing and Innovative Design and a professor at the Florida Institute of Technology, introduced one effort to close that gap: the ITEAM (Independent Technical Evaluation of Additive Manufacturing) Consortium.

The XJet Carmel 1400 AM System uses the company's NanoParticle Jetting technology. *Image courtesy of XJet.*

The new HP Jet Fusion 300 / 500 series. *Image courtesy of HP.*

"The ITEAM mission is the creation and operation of an analysis platform—a dynamic repository of equipment and material capabilities to evaluate the 'can I make it, should I make it' questions ... the technical and business issues that are going to drive additive manufacturing," he said. "We want to engage feedback from actual user experience to close the gap between theoretical—what people think is going to happen—and actual performance."

On the people side of the knowledge gap, Stratasys and a consortium of colleges and universities announced a new industry certification program in North America just before RAPID that is intended to enable students to prove their additive manufacturing workforce readiness.

Behind the stage curtain where Grieves presented his RAPID address, more than 300 exhibiting companies were ready to explain how their products and services would advance the additive manufacturing efforts of the 6,000+ attendees.

FULL RAPID 2018 COVERAGE →
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Data Takes **Center Stage** at 2018 Hannover Messe Industrial Trade Show

RANDALL NEWTON

Fujitsu showed how the cryptocurrency technology IOTA could create a hands-off system to tag and track a product from assembly to deployment. ***Image courtesy of Randall Newton.***

THE ANNUAL HANNOVER Messe is one of the world's largest engineering and manufacturing industrial trade shows. This year more than 220,000 visitors—one-third from outside Germany—swarmed the 23 halls in late April to see the casting and injection samples, rows and rows of standard parts, and a variety of race cars on display. But this year's Hannover Messe was also a trade show about the role of data in manufacturing: how to make it, how to store it, how to transmit it.

The emphasis was more on IIoT—the industrial internet of things—than the consumer-oriented IoT. Much of the discussion was about convergence of IT into mechanical engineering, including new IT platforms such as blockchain and the rise of artificial intelligence in both the creation and use of products.

Every year Hannover Messe selects a partner nation; this year it was Mexico. Attendees who paid attention—after all, there are plenty of distractions—learned Mexico has 94 R&D centers devoted to IoT, advanced manufacturing and Industry 4.0; ranks third in the global Digital Transformation Index and eighth in the global Renewable Energies Investment Index.

IOTA's Low-Key Reveal

Blockchain technology was at the show, but with one exception—it was not given prominence by vendors. Fujitsu devoted one section of its very large booth to a "use case" of IOTA distributed ledger technology. Fujitsu representatives were quick to point out that there was no formal relationship between the company and the IOTA Foundation, which develops the open-source cryptocurrency project.

In the demonstration, which took up nine connected screens and a miniature assembly line in the booth, Fujitsu demonstrated an end-to-end use case for tracking manufactured products as they roll off the assembly line.

Strictly speaking, IOTA is not a blockchain; instead it builds a distributed ledger using a technology it calls the "tangle." The cryptographic proof of work cycle in IOTA requires each transaction to validate two previous transactions. It is a "feeless" approach, which IOTA enthusiasts say make it an ideal cryptographic solution for industrial applications, where microtransactions could happen by the millions.

Digital Thread Enters the Conversation

Ten years ago aeronautics engineers were the only ones talking about a digital thread, envisioning a model-based technology to drive fuselage assembly using composites. Today "digital thread" and "digital twin" are becoming IIoT's Castor and Pollux, twins with features both earthy and ethereal. Examples on display in Hannover included the following:

- Bosch demonstrated the concept of a modular automated factory, where changes in the model drive machine reconfiguration. Communications will be using 5G wireless; energy comes from the ground via an inductive charging system.
- SAP demonstrated a "collective platform" in which both manufacturing equipment and the product being built are monitored.
- Festo showed a digital twin scenario where both model and the product are physical—a robot training platform called BionicWorkplace. The lightweight robot, named BionicCobot, moves using hydraulics and is designed to be used in a human-robot mixed environment.

The next generation of wireless cellular technology, 5G, also was a major theme at Hannover Messe. A new industry consortium, The 5G Alliance for Connected Industries and Automation (5G-ACIA), made its formal debut in Hannover. 5G-ACIA is meant to become a global collaboration and standards forum.

MORE → digitaleng.news/de/?p=43889

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

| CONSULTANT'S CORNER |

SIMULATION

by Monica Schnitger

So, You've Started Simulating—Now What?

THIS COLUMN IS SUPPOSED to be about using simulation data management (SDM) and product lifecycle management (PLM) technologies to cover CAE data and processes. We will get there, but first we need to talk about simulation in the overall context of your design process.

Recently, I've spoken to a lot of CAD users who are excited about the latest shiny toys and seem to have lost interest in the oldie but goodies. Attention has shifted from CAE to additive manufacturing, IoT and virtual and augmented reality, with simulation losing its cool-kid status. That's too bad.

If you currently over-design to avoid CAE, you probably spend more than you should on materials and shipping. If you rely on your parts suppliers to certify fit-for-purpose, you may not be as innovative you could be. People come up with all sorts of reasons to not use simulation but none are, today, defensible. CAE products are more affordable than ever—heck, structural and motion finite element analysis (FEA) is bundled into many CAD products. It's far easier to use than it used to be and is much more intuitive. It likely runs on the hardware you already have access to and quickly produces results. With these advantages, it's rarely going to disrupt your design process by adding significant cost or time.

Learn it, try it, then explore and understand everything you can about your designs.

Getting Results and Promoting Consistency

Once you've committed to a simulation program, you need to consider how you're going to track the models and results, ensure repeatability and automate what you can. That's where PLM and SDM come into the picture. Both began as repositories, places to put files and track access and changes. That's tricky for a lot of simulation-related files, simply because of their size. So rather than tracking the exact files, SDMs track model references, inputs, outputs and the path from one to the other. This means that an SDM can also be used to automate simulation processes—creating process automations that ensure consistency as well as traceability.

As products get more complex and release schedules accelerate, we have less time in each design cycle to experiment with new concepts. But what if we could jump-start that next cycle with data from a prior iteration?

If we already knew that using material X would create a lighter part, but one that's not strong enough under design criteria Y and Z, rather than running that simulation again, we could refer to prior results and move right into something new. But that presumes we can find those old runs—enter SDM.

If you can develop a consistent set of tags and other reference mechanisms to organize your simulation models and results, you can set up this data store as a valuable resource for collaboration today and for future work, too. Factor in the types of queries they might make: model parameters, material types, load conditions, solver versions, outputs—all will have relevance in upcoming projects. Your objective is to save time later by anticipating now what might be needed then.

Expanding on Previous Design Generations

Consider legacy projects, too. If, for example, you're working on the second generation of your product, gather the simulation models and results for gen one. Start building up a repository of "tried that, worked" and "tried that, didn't work" concepts and results. New designers can explore this treasure trove to learn how your products work. You can teach your marketing team to question the repository, as they work through priorities for the next-generation product. If they can see that a potential design feature might not be workable, they can front load their market discovery processes to find something else that could be a true differentiator. And you can use it to inform all of the simulations you do now, avoiding pitfalls unique to your designs.

SDM and PLM can be so much more than data warehouses, if you implement them with these end-use cases in mind. If you have many designers and engineers doing simulations, SDM enables you to define and deploy simulation methods across the team, automate processes as well as manage both simulation and test data. The first step is doing the simulations and storing as much about them as you can; automation and consistency are add-on benefits that you shouldn't overlook. DE

Monica Schnitger *is president of Schnitger Corporation (schnitgercorp.com). Send email about this commentary to de-editors@digitaleng.news.*

| MAKING SENSE OF SENSORS |

ULTRASONIC 3D PRINTING

by Tom Kevan

Hybrid System Builds Sensors into Metal

OHIO-BASED MANUFACTURING technology company Fabrisonic has developed a hybrid production process that promises to help equipment makers build sensors directly into 3D-printed metal parts. In one of the first applications of the technique, which combines ultrasonic additive manufacturing (UAM) with a computer numerical control (CNC) framework (youtu.be/M7EOGPzyNrY), the company built an embedded fiber-optic strain sensor.

Creating the sensor represents a step in the instrumentation of the "things" populating the internet of things (IoT). Embedded sensors promise to provide the means to effectively capture in-situ data from industrial equipment, opening the door for advanced setup, maintenance and diagnostics. This, in turn, clears the way for a smart infrastructure of real-time contextual data.

One factor that makes Fabrisonic's hybrid manufacturing technique stand out from other technologies on the market is that it overcomes a key hurdle that has limited sensor deployment. Whether the application involves monitoring the structural integrity of an airframe or appraising the operational health of a manufacturing system, engineers have conventionally attached sensors to the external surface of the component or system. Unfortunately, harsh operating conditions—such as high temperatures, moisture, electromagnetic interference and vibration—can compromise data collection, limiting the amount of usable data.

Embedding sensors mitigates these effects and provides a robust system for in-situ data collection.

How the Hybrid Process Works

The manufacturing process distinguishes itself largely via the solid-state nature (the materials do not melt) of its ultrasonic welding technology. The UAM process builds solid metal objects using a rotating sonotrode, driven by piezoelectric transducers, to apply ultrasonic vibrations (>20 kHz) to metal foils. This creates a scrubbing action between the foil and the material to which it is bonding, often a metallic baseplate, part or other foils. The scrubbing action displaces surface oxides and contaminants that interfere with the bonding process. With this physical impediment eliminated, the system bonds successive layers of metal foils together to build a solid 3D component.

CNC milling helps create the desired shape, with the required tolerances and surface finish. The subtractive process can deliver higher accuracy of complex internal shapes.

Examining how the fiber-optic strain sensor is manufactured offers a clear view of how the UAM and CNC technologies work together. First, CNC machining cuts a channel into which the sensor is placed. The metal flow in the UAM process then creates a strong mechanical joint between the metal baseplate and the sensor material. This structure enables excellent strain transfer for stress and temperature measurements.

The UAM process delivers many advantages over some other technologies on the market. Most of these stem from the fact that Fabrisonic's technology does not require a directed energy heat source (e.g., laser and e-beam).

By staying below transformation temperatures of most metals, the UAM process avoids altering the inherent mechanical properties of the feedstock, avoiding significant changes in material properties, such as grain size, precipitation reactions and state. And because of the low process temperature, the system can embed complex electronic components—such as microprocessors, sensors and telemetry—without risking damage to delicate circuitry caused by overheating.

UAM also provides flexibility. Low-temperature operation allows it to safely function in a shop environment without special shielding. Plus, it can use commercially available foil feedstock.

A Work in Progress

Fiber-optic strain sensors embedded in metal components are still in the fundamental stages of development. However, mechanical testing and analysis of the strength of the bond between the sensor and the metal structure of the component show promise.

Collaborative efforts of Fabrisonic, EWI and the NASA Langley Research Center indicate that the strength of the bond is stronger than the yield stress of the metal and that the bond shows no sign of fatigue loading.

As part of these ongoing research efforts, Fabrisonic and EWI are exploring other metal matrix alloys and applications of the manufacturing technology. **DE**

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

INFO ➜ **EWI:** EWI.org

➜ **Fabrisonic:** Fabrisonic.com

➜ **NASA Langley Research Center:** NASA.gov/centers/langley

Simulation in the Cloud

Cloud-based solutions allow engineers to access a wider variety of hardware instances than would be possible to support on-premise.

BY BRIAN ALBRIGHT

DEMAND FOR SIMULATION RESOURCES has expanded as engineering firms increase their use of simulation in the design process and throughout product development. That has taxed the IT infrastructure at many firms and left smaller companies struggling to find ways to run more complex simulations absent their own high-performance computing (HPC) resources.

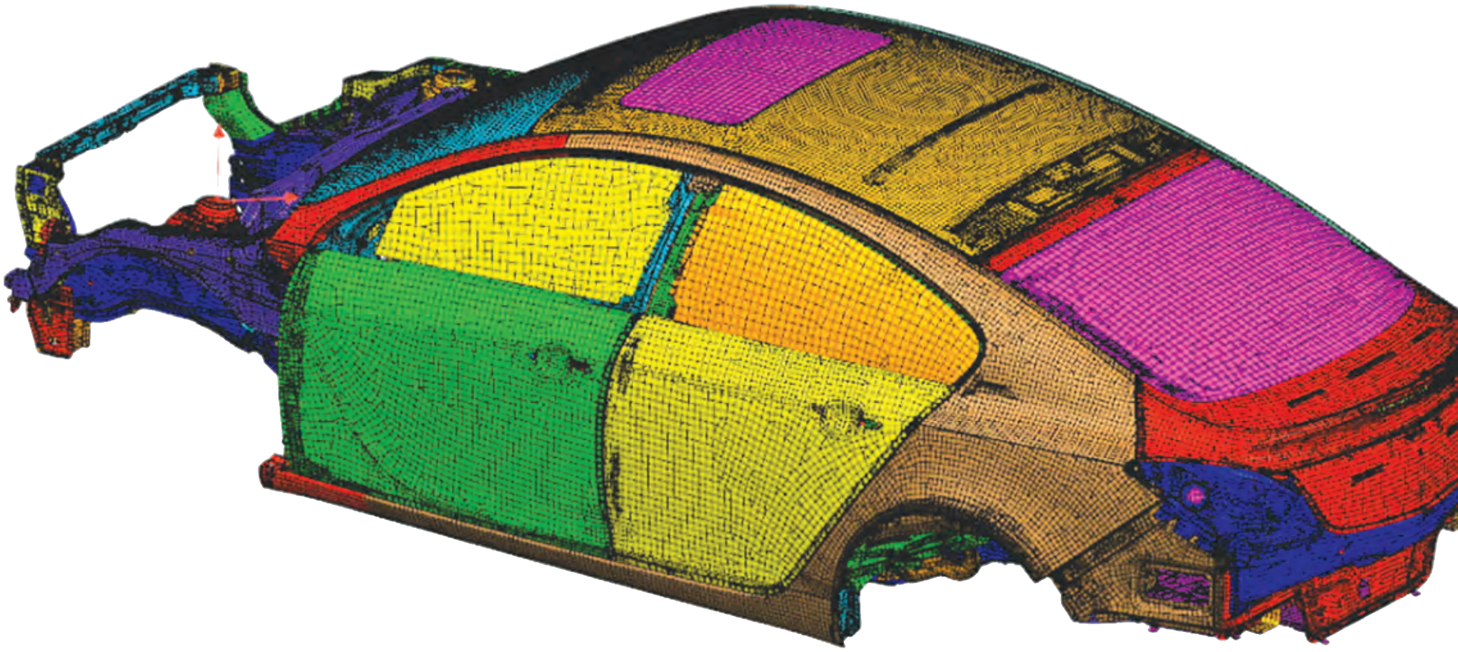
Cloud-based simulation is slowly emerging as a solution to both problems. Transparency Market Research says the cloud-based simulation market reached $3.3 billion in 2016, and is expected to have a compound annual growth rate of 11.4% through 2025, reaching $8.5 billion—a faster rate of growth than the simulation market overall, according to the company's data.

The need for cloud-based simulation is growing, particularly within the past year, because companies are searching for more elasticity when it comes to simulation, according to Todd McDevitt, director of product management at ANSYS. Companies are also looking for burst capabilities during peak demand periods without having to invest in additional hardware or software licenses.

"Customers may have some form of on-premise HPC infrastructure, but they want to reduce queue times, or they are going through a refresh cycle on their hardware and want to move workloads off of those resources," McDevitt says. "But it usually begins with a bursting need."

As a result, traditional simulation providers are branching out into the cloud, and new cloud-only startups are gaining traction in the market.

"There is an educated market around cloud engineering software now," says



Cloud computing allows this NX Nastran automotive body model to be simulated efficiently using parallel processing on a large number of cores. *Image courtesy of Siemens PLM Software.*

Moving streamlines show airflow around a Chevy Traverse rendered using photorealistic ray tracing. Visualized using ANSYS Ensight. *Image courtesy of ANSYS and General Motors.*

David Heiny, CEO at SimScale. "The large vendors have made steps toward offering cloud solutions, so the industry is more familiar with the approach."

The appeal of cloud-based simulation varies based on an individual company's existing investments. "If they have already invested in existing hardware, then the impetus to go to the cloud is not as great," says Ravi Shankar, director of simulation product marketing for Siemens PLM Software. "Cloud options get more interesting when [companies] are purchasing new hardware. They may have larger models and want to take advantage of better processing."

That bottleneck of queuing up for access to on-site HPC resources was the impetus behind the founding of OnScale, according to CEO Ian Campbell. "Legacy CAE is too costly, too risky and too slow," he explains. "Every engineering firm goes through cycles of engineering workloads, but the way existing CAE models work [is] you have variable workloads and a fixed computer infrastructure that can't scale to meet those workloads. If demand exceeds supply, you are wasting time waiting for access. If supply exceeds demand, you are wasting budget and resources."

"The simulation load is never stable," Heiny says. "You have peak demands. On the cloud, if you want to run 20 simulations on 100 cores, it's just there. You just run it. You don't have to talk the vendor about getting a burst license. With a cloud-based solution like SimScale, it's there out of the box."

Different Approaches

Simulation providers have taken slightly different approaches to their cloud products. SimScale was created to provide structural, mechanical, flow and thermal simulation in the cloud, as well as some multiphysics simulations. The company's platform can be integrated with other design tools and fundamentally supports most general exchange formats. "Everything produced in SimScale can be downloaded and used in another solver," Heiny says.

SimScale also offers a community plan for free that can be used for open source and hobby projects. A professional pricing level is targeted at proprietary projects and includes unlimited data storage, encryption and real-time support. The enterprise level is for multi-user and more computationally demanding simulations.

The community plans make projects public to other members. "Sharing this know-how in simulation becomes more intense and effective within the same software and with the community," Heiny says. "There is collaboration built into the product."

The company is targeting customers that are new to simulation. "Our approach is to make simulation more widely accessible," Heiny says. Cloud-based simulation not only lowers the cost of entry, but also enables a greater degree of collaboration. "You can collaborate in real time with other stakeholders, who can all view the same simulation projects in real time," Heiny says. "We have also leveraged data science to automate some of the work, and these things were not possible in the desktop realm."

ANSYS has worked closely with its own network of cloud hosting partners to optimize its products to run on their infrastructure to ensure reliable availability via their data centers. "We make sure that our solvers and our products are robust and scalable enough to take advantage of cloud resources, that we are parallelizing on the new GPU instances and other HPC architectures," McDevitt says. "We also don't force our customers into a particular business model. Our customers can take their paid licenses to the cloud and use them there, and we've introduced a usage-based licensing system."

Siemens offers cloud-based simulation primarily through its partnership with Rescale, providing access to NX Nastran, Simcenter 3D and Star CCM+. Customers can either purchase a fully software-as-a-service (SaaS) based license through Rescale, or they can purchase a traditional license from Siemens and use Rescale to host the software.

"Our philosophy and strategy is to offer as much flexibility as possible in terms of the way customers can interact with the software solutions we offer," Shankar says. "The cloud model adds another layer of that flexibility."

Moving forward, he says the company plans to eventually offer solutions that were built natively for the cloud.

"Demand for cloud has varied," Shankar says. "It's not a major part [of] our business today, but we are making sure we have everything in place for customers who do need it today, and we anticipate future growth."

OnScale offers its software for free (for 10 core hours per month) and leverages Amazon Web Services (AWS) for its compute platform. "Users don't have to pay all of that money per seat. The service is sold on a subscription basis," Campbell says.

OnScale is targeting markets that Campbell notes are overlooked by other simulation companies, like internet of things (IoT) organizations that don't necessarily have access to tools that meet their requirements. OnScale claims it can outperform traditional simulation tools thanks to its access to nearly unlimited compute resources on AWS, as well as perform tasks that would be difficult or impossible using traditional infrastructure, like 3D versions of surface acoustic wave filters.

Some experts believe that a full SaaS model is the future of engineering. "Engineers are enthusiastic about the removal of the licensing and computational bottlenecks," says Gerry Harvey, vice president of engineering at OnScale.

Other new tools are emerging, and traditional players are partnering with cloud-based firms as well. Earlier this year, SimScale announced it was integrating Siemens Parasolid software and HOOPS Exchange to provide a more seamless simulation workflow and improved accuracy.

Autodesk offers cloud simulation for Autodesk CFD, Moldflow and Fusion360. Plastic simulation provider Moldex3D has also released a cloud extension of its software on AWS, allowing users to offload larger simulations without the expense of investing in new hardware or software licenses.

Rescale provides cloud-based access to a wide variety of applications, different cloud providers and hybrid on-premise data centers. In addition to working with ANSYS and Siemens, Rescale also offers X2 Firebird CAE software from Xplicit Computing, charging a flat, hourly rate. Other partners include Autodesk, CAE Solutions, COMSOL and Dassault Systèmes.

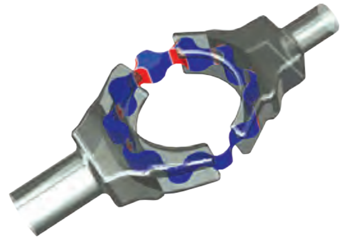
Greater Flexibility

Customers take different approaches to cloud deployments, based on the size of their models and their own existing infrastructure. Often they want burst access or are looking for other ways to augment their own computing infrastructure. Smaller firms may rely entirely on cloud solutions for their simulation needs.

The cloud also provides hardware elasticity. Different solvers and physics are usually optimized to run on different types of hardware. Cloud-based solutions allow engineers to access a much wider variety of hardware instances than would be possible to support on premise (at least without significant costs). How much memory per core a user needs is different for computational fluid dynamics (CFD) than for high-frequency electromagnetic or mechanical simulations—the cloud provides access to all of these configurations.

Companies with existing on-premise infrastructure may take a hybrid approach, running some simulations on their own equipment and others in the cloud, based on demand. Data is a factor as well, since simulation creates large amounts of data that users don't necessarily want to move back and forth between systems.

Whether a simulation is run on premise or on a cloud-based infrastructure should be invisible to the engineer. "The platform should send the job to the appropriate resources, so the process looks the same to the engineer," McDevitt says. Those decisions about resources can be made at the application layer rather than the platform level.



ANSYS Fluent simulation of oil volume in a gerotor pump showing the extent of cavitation (red) on the gear wall. Visualized using ANSYS Ensight. *Image courtesy of ANSYS.*

At ANSYS, McDevitt says that for CFD customers, many users do some pre-processing locally and then push out the solve portion to the cloud so that they can achieve faster turnaround times. That has been driven, in part, by model size and complexity.

"On the mechanical side, we see customers want[ing] to be more interactive and do more pre- and post-processing on the cloud," McDevitt says. In the electronic space, customers may solve for a particular frequency on their workstation, but move to the cloud to repeat the same test across multiple other frequencies.

"That's similar to a design point scenario, where customers want to look at different geometry parameters or different material configurations to optimize design points," McDevitt says. "They'll solve one design point and then go back for a hundred or a thousand different variations."

Shankar explains that the Siemens customers most interested in cloud-based offerings have been those with larger models that want to take advantage of parallel processing or burst simulations. "They are able to use the extra capacity that the cloud provides almost instantaneously, without the need for IT to set up new hardware," Shankar says.

That doesn't mean that the cloud will work for every company. Users looking for steady-state usage won't find an economic benefit to cloud platforms. "It's like selling your car, and then paying for an Uber driver to sit outside your house 24/7," McDevitt says. "The economics are not going to work out."

Going Off-Cloud

Some aerospace and defense customers cannot utilize certain types of cloud services because of certification requirements or security issues. Companies that primarily are working with smaller models that can compute quickly, or those that already have unused compute capacity in house, are not likely to benefit from a move to the cloud. “If the models are not taking advantage of parallel processing, then those would be situations where the cloud doesn’t offer an advantage,” Shankar says.

“And if you just invested in a new HPC architecture, you first want to make sure you can leverage that hardware,” Heiny adds.

He says that the biggest challenge for cloud simulation customers is one shared by their on-premise counterparts—users must trust the simulation results.

“If they aren’t ready to take advantage of those insights, then there’s no point in doing it, and that’s true of both on-promise and cloud solutions,” he says. “That’s where collaboration and support come in handy. We have a dedicated onboarding program to work with customers to get them to the point that they can trust in what they are doing. That’s mission critical. The cloud doesn’t remove that obstacle, but the tools that make the user successful allow us to get there faster than in the desktop realm.” **DE**

INFO ➜ **Amazon Web Services:** AWS.Amazon.com

➜ **ANSYS:** ANSYS.com

➜ **Autodesk:** Autodesk.com

➜ **CAE Solutions:** CAEsolutions.com

➜ **COMSOL:** COMSOL.com

➜ **Dassault Systèmes:** 3DS.com

➜ **OnScale:** OnScale.com

➜ **Rescale:** Rescale.com

➜ **Siemens PLM Software:** Siemens.com/PLM

➜ **SimScale:** SimScale.com

➜ **Transparency Market Research:** TransparencyMarketResearch.com

➜ **Xplicit:** XplicitComputing.com

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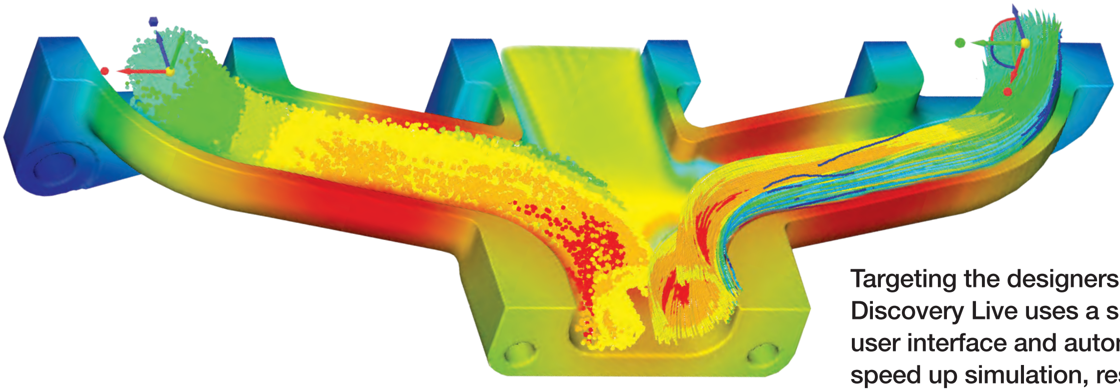
Instant Feedback in Simulation



Targeting the designers, ANSYS Discovery Live uses a simplified user interface and automation to speed up simulation, resulting in near-instant feedback. *Image courtesy of ANSYS.*

In designer-friendly simulation products, real-time visuals may become a standard feature.

BY KENNETH WONG

WAITING IS AN ESSENTIAL PART OF SIMULATION—or so it seems. The typical workflow with simulation is: you set up your job, press run, then go make a cup of coffee or grab lunch while your workstation does the number crunching. Depending on the complexity of the job, the wait could be a few minutes, hours or days. Many engineering firms and design shops that rely heavily on simulation develop workarounds to avoid the wait. Scheduling simulation jobs to kick off after hours or over the weekend is one way.

But the launch of ANSYS Discovery Live and a few other simulation programs suggests, for products targeting the non-expert crowd, near-instant feedback can be delivered using simpler calculation, parallel processing and mesh automation. The trade-off—speed over accuracy—is the subject of discussion among many engineers.

Instant Design Exploration

The simulation software industry's overtures to the designer community usually come in one of three forms: CAD-integrated simulation (simulation tools nested inside a CAD package); simplified simulation (simulation with a simpler interface and fewer choices); and app-style simulation (template-driven simulation apps that address specific scenarios).

ANSYS' latest offering, ANSYS Discovery Live (ADL), falls into the second category, but with a twist. The emphasis is not only on simplicity, but also speed.

"This instant, interactive simulation environment allows engineers—at all levels and in every discipline—to explore their concepts and designs," the company claims.

"There's no preprocessing, no postprocessing. Results are real time. You can change direction or the size of your forces, edit your geometry or change materials, and interactively get updated results," says Mark Hindsbo, VP and GM of ANSYS.

Part of the speed comes from the incorporation of direct editing—a technology ANSYS acquired from SpaceClaim in 2014. Different from parametric editing, direct editing (or push-pull editing, as some call it) allows designers to make geometric changes quickly without concerns for the part's parametric history or the feature. Incorporating it into ADL allows the simulation user to edit the targeted geometry inside the simulation environment, avoiding the round trip back to CAD that's usually required. For instance, if you have just completed stress analysis for a bar stool with three legs, but now wonder how the design might perform with longer legs or a wider seating area, you can edit the geometry inside ADL without going back to the CAD program you used to create the stool.

The other part of the speed comes from graphics processing unit (GPU) acceleration, the use of the GPU's parallel processing power to speed up computation. "We wrote solvers from the ground up on (NVIDIA) GPUs. Where others might augment compute power on GPUs, we did it natively, embracing its massively parallel nature. Modern PCs have thousands of cores on their GPUs versus a handful of CPU cores. In the process, we had to invent new numerical and computational algorithms," says Hindsbo.

Simpler Choices, Hidden Meshes

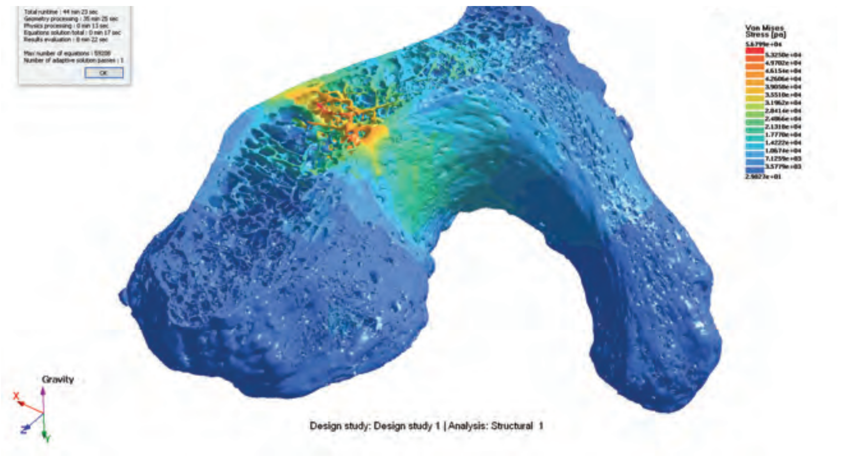
The simplicity in ADL's user interface (UI) is a departure from other products by ANSYS, which offer users a lot more menus and choices to allow complex simulation scenarios.

"We designed ADL for rapid concept exploration, not high-accuracy design validation," Hindsbo explains. "As a result, we do not expose anything in the software unless we can do it in a simple, easy-to-use way that our casual simulation users will love. For example, complex physics decisions such as time-step size and convergence criteria do not appear in the software and are instead decided dynamically by the technology based on the model, boundary conditions and current simulation results. We believe this dynamic and adaptive approach to be key to making simulation accessible for every engineer."

The conspicuous absence of certain simulation steps—such as meshing—may surprise some ADL users. That is intentional, according to Hindsbo. "The people who want to tweak meshing parameters are usually experts," he points out.

Automating and delegating these functions to the background contributes to the simplicity of the UI, where the user doesn't need to decide the type of mesh to use or the appropriate density. In higher-end ANSYS products, this tool is open to the users, as experts generally understand the correlation between such choices, and like to control the accuracy as desired.

Fully automating the meshing process or skipping it altogether might have been an unthinkable proposition five or six years ago, but a few simulation software titles now promote it as part



SIMSOLID speeds up the simulation process by skipping the meshing process altogether, resulting in faster solving time. ***Image courtesy of SIMSOLID.***

of its strength, especially in its appeal to the designers. CAE software industry veteran Ken Welch describes its product SIMSOLID as meshless simulation.

"The bottom line is that these CAD-to-Mesh steps require many judgment calls, are labor-intensive, error prone and require experts in both simulation and CAD," Welch says. "We are pioneering new methods that work directly on fully featured CAD assemblies and do not create a mesh. With this, you can work lockstep within your design process to quickly and efficiently analyze the original CAD geometry without modification or simplification."

With SIMSOLID, typical run times only take seconds to minutes, even for large assemblies, according to Welch. It works on standard computers and does not require additional high-performance computing (HPC) or GPU hardware. The program also provides a broad set of analysis capabilities including unique real-time transient dynamics, he says.

The company csimsoft, which specializes in geometry preparation and mesh generation software, offers what it describes as push-button mesh generation in Bolt. "Bolt is a push-button solution for generating all-hex meshes from complex geometries with little or no user interaction," notes csimsoft. Bolt also offers tools to isolate mesh elements beyond the desired value, make adjustments to the cell-generation setup, and remesh the geometry for better accuracy.

The degree of mesh controls to expose or hide remains a difficult balance for simulation vendors hoping to attract non-experts. Whereas experts possess the necessary skills to decide on the right mesh type, the level of resolution and the regions of the geometry that need special attention for a particular job, most designers may not be equipped to make these judgments.

Interactive Moldflow

Computational fluid dynamics (CFD)—the solver technology for simulation and analysis of airflow, heat flow, liquid flow and other types—is considered a compute-intensive process, due to the amount of calculation involved in predicting the complex flow patterns. The technology has proven to be a staple among plastic product designers, who need to study the injection molding process to ensure manufacturing success.

"We began looking at interactive response in this area because we want to give people who study plastic design real-time feedback," says Brian Frank, senior product line manager for Simulation and Analysis Solutions, Autodesk.

Ten years ago, Autodesk forked over approximately $297 million to purchase Moldflow, which develops special software to simulate how plastic parts are manufactured. Today, Autodesk Moldflow is a leading plastic mold design simulation package.

"One way to compute as quickly as possible is to rely on the GPU to break the problem down so it can be computed in parallel," says Frank. "The other is to limit the input the software asks from the engineer or the designer. Mesh sizes and voxel types are also automated so the user doesn't need to understand it. The software uses rules and assumptions to account for what's not asked, in order to reduce the complexity of the problem."

Moldflow users can reposition the mold inlets and outlets in their design or make alterations to the geometry and obtain the updated flow patterns with near-instant feedback, Frank points out.

The same interactive response was also in a product formerly called Autodesk Flow Design, for virtual wind tunnel testing. The product is no longer sold individually, but its components are now found in the company's core mechanical design package Autodesk Inventor and architectural wind-load analysis products.

Generative Design with Real-Time Response

The same interactive response can be a far more powerful tool when implemented in one of Autodesk's pursuits, generative design software, according to Frank. "We're looking at the next step, where we want the software to inform your design decisions. It's the aided part of the computer-aided design," he says.

Generative design, some argue, is the next step in simulation. Standard simulation programs can verify the performance of a design submitted by the user. By contrast, generative design software can propose various design alternatives based on user-provided parameters, such as loads, stress and pressure.

Currently, much like typical simulation, generative design requires the user to set up the job, then wait for the computation to complete. The so-called generative response is not instantaneous or in real time. But Frank believes this will soon change.

"We're getting close to it. We're doing some really complex things mathematically. If we continue to push the boundaries, apply the same techniques as simulation and partner with the hardware vendors to eke out performance in memory management and parallel processing, we'll get to near-real-time feedback," he says.

Growing Parts in Real Time

3D printing system maker Desktop Metal's software Live Parts is among the growing number of simulation programs that cater specifically to the additive manufacturing space. Whereas most topology optimization software focuses on removing materials (to create a lighter product), Desktop Metal's Live Parts takes the opposite approach. It begins with a blank space, then grows materials only where necessary to create the optimal design.

"It's not using traditional FEA [finite element analysis] or CFD. Rather, it's based on modeling a cellular organism that grows from seed cells into an embryo and finally a mature structure that meets the requirements of the part. It uses the GPU to dramatically speed up the growth and physics processing so that it operates in real time," explains Andy Roberts, the creator of Live Parts.

In its demonstration videos, Roberts is able to change forces and loads in the middle of a simulation session (or, to be more precise, a cell-generation session) to obtain near-instant feedback from the software. Live Parts is currently in beta, part of Desktop Metal Labs.

"Live Parts is hosted in the cloud on a pool of GPU-accelerated virtual machines (VMs)," says Roberts. "The application leverages 2,500-3,000 core GPUs running in parallel on each VM to perform thousands of cell-level calculations and multiphysics simulations in real time, enabling support for rigid and elastic bodies, fluids, cloth and more. Users can access Live Parts by connecting to a VM from most internet-enabled devices through the browser or through a downloadable client that runs locally. The software sends a graphical representation as a video stream in real time to the users' local device, ensuring a consistent and high-quality experience regardless of local device specifications."

Cool Visuals or Practical Use?

The real-time feedback in simulation and some generative design software unquestionably makes for impressive presentations, as a way to help ordinary folks understand the engineering and design issues on display. But does the interactivity serve any practical purpose?

"[In Autodesk simulation products] it's a useful tool to understand at the high level how things behave and react to one another," says Frank. "What we often hear from users is, 'this is a very good way to understand how we may want to set up a higher-level simulation problem.'"

"In [Desktop Metal's] Live Parts, we wanted to enable parts to grow in a life-like environment in which forces change dynamically and the part is able to react to these changes as it grows," says Roberts. "This interactivity also makes it possible for users to modify physics inputs and see how their designs react immediately. This allows users to better understand cause-and-effect relationships between constraints and designs more easily, enabling faster design iteration and shortening the cycle from design to manufacture."

To a large extent, the instant or near-instant feedback is possible on the current generation of hardware only in simplified simulation runs, the type that caters to designers working at the front end of the process, or the conceptual phase. For more sophisticated simulation, instant feedback requires parallel processing on a cluster or in the cloud.

Approximate Answers

In the early design phase, users tend to seek general design guidance; therefore, approximations can be employed with little or no detriment. "The Discovery Live applications makes smart assumptions and defaults so you can get started immediately. The user can then subsequently make refinements or override defaults, but they don't have to specify every single parameter before getting results," says Hindsbo.

One of ADL's early users was Travis Jacobs, principal engineer of Jacobs Analytics. "The power of Discovery Live is that it communicates very powerfully the idea and the concept to a non-technical audience. These concepts can be created very quickly, 15 minutes or so, and changed on the fly [...] The design concept can be iterated upon many, many times and changed in 30 seconds with a click of a mouse," says Jacobs. "Discovery Live is perfect for solving problems very fast and exploring new concepts and solutions. The concept can then be validated using ANSYS flagship tools. There is no other suite of tools that I would rather use than ANSYS."

In the subsequent phases, the detailed design stage, where experts scrutinize the design to refine it to shave off the last millimeters or ounces from the design without jeopardizing its structural strength, has less-forgiving calculations. In these phases, interactive visuals may be less important than the accuracy, and a different specimen of software is required.

"It is about innovation. Later in the process you absolutely want to validate with high accuracy, but if the upfront cost of failure is days or weeks of lost work, you are not going to explore much. We have seen that when the insight from simulation becomes intuitive and real time, behavior changes and engineers try more design options," adds Hindsbo. **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.*

INFO → **ANSYS:** ANSYS.com

→ **Autodesk:** Autodesk.com

→ **csimsoft:** csimsoft.com

→ **Desktop Metal, Live Parts:** labs.DesktopMetal.com/liveparts

→ **NVIDIA:** NVIDIA.com

→ **SIMSOLID:** SIMSOLID.com

From Perpetual to **On-Demand** Licensing

A look at the design software industry's movement toward usage-based, time-based sales models.

BY KENNETH WONG

IN MARCH 2017, as he got ready to step down from his post as CEO of Autodesk, Carl Bass discussed his legacy with *DE* ("Carl Bass' Parting Shots," March 8, 2017). Asked to identify some of the biggest risks he had taken in his reign, he said without hesitation, "The move to pure subscription."

In mid-2015, Autodesk began issuing advance warnings to the media and customers about the shift that was coming. February 2016—that was the point of no return. After this date, Autodesk would only sell products on subscription licenses—no more perpetual licenses.

Autodesk isn't the only design software firm that made the move to subscription. Its three biggest CAD rivals—SOLIDWORKS, PTC and Siemens PLM Software—now all offer various types of subscription licensing options for some of their products. But what made Autodesk's move particularly bold was its decision to eliminate the long-established perpetual model altogether, leaving future buyers with subscription as the only option.

It's been two years since Autodesk and its customers crossed the deadline. It's time to check in, to see if subscription is gaining momentum or losing steam.

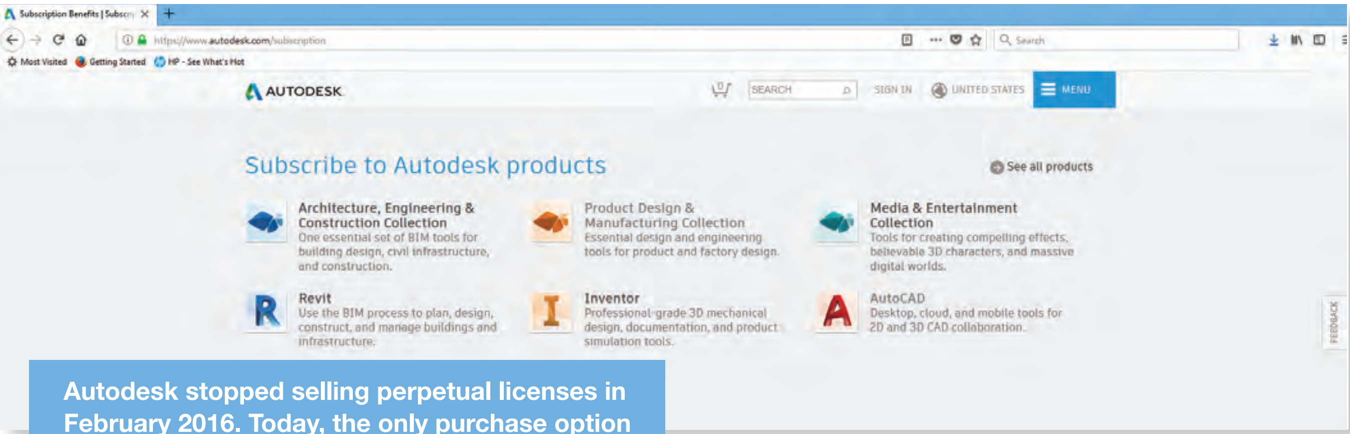
Natural Fit, Retrofit

Coming online as public beta in 2015, the software-as-a-service (SaaS) CAD software Onshape was architected from the ground up to run in the cloud. "In the future, a few years from now, we'll see engineers and designers expecting naturally to go to any computer—their phone, their web browser—and have access to a powerful CAD system and all their CAD data," says Cofounder and CEO Jon Hirschtick. "I don't think people will still be asking whether CAD can be done on a browser, a phone or from the cloud."

For cloud-hosted CAD startups like Onshape, subscription licensing seems like a natural fit. The company has never had a pool of perpetual license owners, therefore no one could cry foul at the sales model.

On the other hand, for vendors who have historically sold their products in perpetual licenses, the subscription model is more a retrofit, something they—and their customers—have to adapt to. Most of them now offer both options: subscription as well as perpetual.

Even with that industry standard, Autodesk still decided to cut the cord. "While we knew we would face some resistance because we were introducing something new, we built the program based on requests from many of our maintenance customers. They wanted a path to subscription that gave them value for their



Autodesk stopped selling perpetual licenses in February 2016. Today, the only purchase option is subscription. *Image courtesy of Autodesk.*

previous investment and kept them current," says Teresa Anania, senior director of Subscriber Success at Autodesk.

The success of Autodesk's transition depends on two factors: The ability to convince perpetual license holders to switch to subscription and simultaneously attracting new subscribers. "We are encouraging enterprise customers to move to one of our subscription offerings," says Anania. "Our preferred offering for large customers is an enterprise business agreement (EBA)."

Autodesk's EBA, Anania explains, provides flexible access to an expansive portfolio of Autodesk products through Token Flex, a usage-based subscription model; and a Customer Success Program that includes a range of consulting and/or support services based on the customer's business needs.

"The conversion from perpetual to subscription exceeded our expectations—in fact, it more than doubled our estimates. In Q4 of 2017 alone, we had 168,000 maintenance customers convert to subscription," says Anania.

In Case of Power Outage

Long-time SOLIDWORKS user Richard Williams, nicknamed "Corporal Willy" by his peers in the user community, is originally from Brooklyn, NY. The former marine went to work for the Grumman Aircraft Engineering Corporation after his honorable discharge. He currently lives in Las Vegas, NV, spending his retirement promoting STEM (science, technology, engineering and mathematics) education in the local school district.

"The only things that should be in the cloud are the angels," he quips, revealing his reservations for SaaS CAD. "I do prefer having a licensed perpetual copy of my programs loaded onto my own computers."

His dreaded scenario is a long stretch of internet outage, leaving him with no access to browser-based CAD. The fate of the Puerto Ricans left without power following Hurricane Marina, he says, "should have been a wakeup call" for the SaaS CAD advocates.

In the unlikely scenario of a long power outage, the workstation itself will become inoperable; therefore, the software, whether in the cloud or on the machine, will be inaccessible. In case of an extended internet outage, thick-client subscription CAD programs like SOLIDWORKS and Autodesk Inventor will still be operable, so long as the subscriber has a way to check in and validate the subscription at least once within 30 days.

"If you already know a program very well but cannot afford to buy an outright number of perpetual licenses for your workers, [subscription] might be the way to go on a temporary basis," adds Corporal Willy. "[But] I still believe that over a period of time it might be more expensive for a young business."

Perpetual Licenses with Maintenance Plans

The math for perpetual software vs. on-demand subscription is similar to buying a car vs. renting one, or using ridesharing in times of need. To someone who regularly commutes and uses the vehicle heavily, paying a one-time fee for perpetual ownership makes more sense. To those who need to use the vehicle infrequently, semifrequently or only for a set period, renting or paying a usage-based fee makes more sense.

In the case of subscription software, tallying up the incremental usage fees paid over a long period of time—say, 15 to 20 years—will definitely add up to more than the one-time cost of a perpetual license. But many subscribers may see the chance to skip the steep upfront acquisition fee as an offsetting benefit in itself.

The truth is, most perpetual CAD licenses come with a subscription-like maintenance plan—the fee you must pay to keep receiving updates, new features, bug fixes and support. Two years ago, when Autodesk still sold perpetual licenses, AutoCAD was available through the company's resellers for roughly $4,200. But in addition to this one-time cost, you would also need to pay roughly $1,300 for yearly maintenance. Currently you can get an AutoCAD subscription for $1,575 a year or $195 a month.

A perpetual license of SOLIDWORKS Standard is usually $3,995. But you would also need to pay the annual maintenance fee, roughly $1,300, to receive upgrades and support. SOLIDWORKS is now also available under term licensing, for three months or a year. The exact SOLIDWORKS term license prices are difficult to find, since neither SOLIDWORKS nor its resellers publish them. The quote is given upon contact.

The Battle in the 2D Front

Some Autodesk rivals see a chance to undercut the CAD giant in the uncharted waters of subscription pricing. Graebert, which develops the 2D drafting and drawing program ARES, believes AutoCAD perpetual licensees who are not too keen to move to subscription may look favorably at ARES as a candidate for replacement. The company offers ARES both as subscription and perpetual licenses.

"Our strategy is to keep offering both perpetual and subscription licenses," says Cédric Desbordes, sales and marketing executive, Graebert. "The customers can decide." This March, Autodesk launched AutoCAD 2019. Soon afterward, Graebert published a video clip on LinkedIn, highlighting the price comparison between AutoCAD and ARES Commander.

"It has not been easy for us to keep offering choices," says Desbordes. "Combining mobile and cloud with desktop [what Graebert describes as the Trinity of CAD] is a challenge when it comes to perpetual licenses. Indeed, mobile apps are frequently updated, and the app store and mobile apps in general are not adapted to perpetual licenses."

Simulation by Subscription

In March, when simulation software maker ANSYS launched its new product ANSYS Discovery Live (ADL), it also did something unprecedented with its licensing: offering it only under subscription. ADL is, in fact, the only product ANSYS currently offers under the subscription model, but if it proves to be a hit, the company might be tempted to apply the subscription model to other products.

"This really is a matter of the right licensing for the right solution," explains Mark Hindsbo, VP and GM of ANSYS. "ADL is an end-user tool that hopefully becomes as pervasive as Excel for engineers. As such, subscription is a very appropriate mechanism." GPU-accelerated and powered by direct editing, ADL is developed for the design-centric user pool, different from the expert simulation user pool that ANSYS targets with its higher end products.

"We believe in choice, and for most products we offer both license models. Some customers prefer to buy an asset when they buy software—these customers chose perpetual. In general, however, we are seeing a slow increase in the share of customers who prefer lease," says Hindsbo. ADL comes in three different editions: Essential, Standard and Ultimate. Annual subscription prices are from $1,195 per year to $5,995 per year.

Consumption-Based Pricing

Also on the rise is the type of simulation that caters to the digital twin market, for manufacturers who wish to manage real products through digital replicas. "Here, the product could be more consumption-based licensing, device-based licensing or even revenue sharing models that would be more appropriate," Hindsbo says.

Newer topology optimization software vendors seem to favor the subscription model, with a usage component

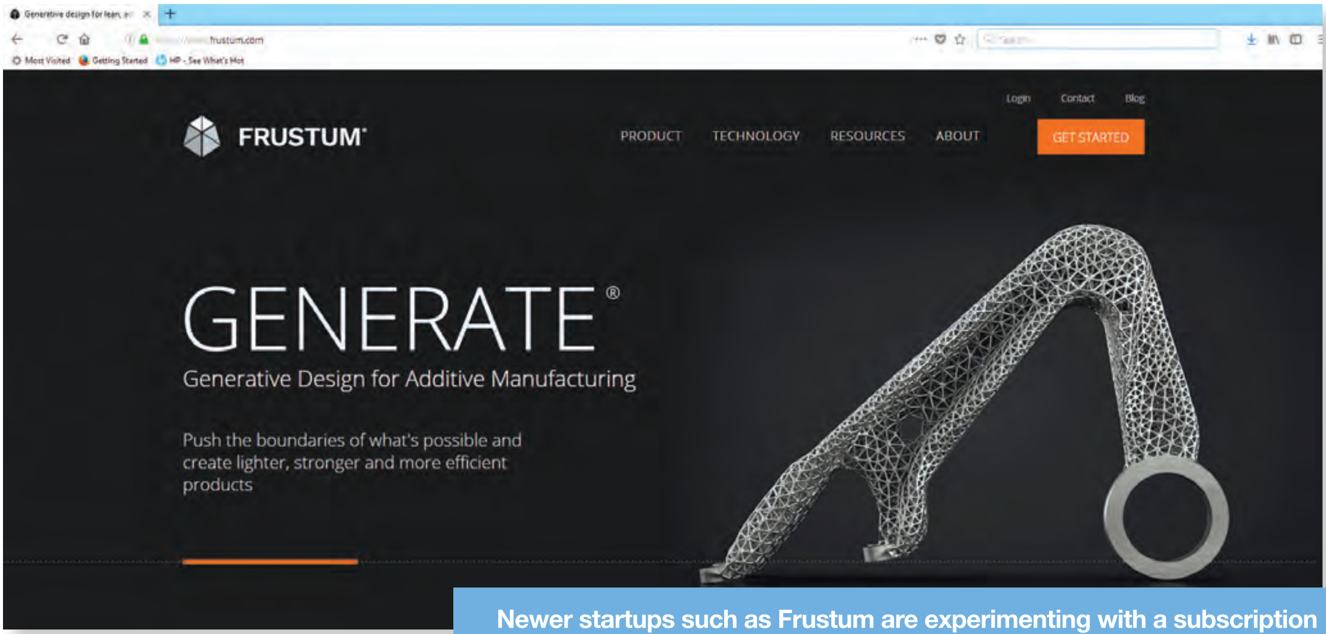
SaaS vs. Subscription

Nearly all software-as-a-service (SaaS) products are subscription products, but not all subscription software titles are SaaS.

SaaS products, such as Salesforce.com or Quickbooks, are delivered from the cloud, accessible from a standard browser. The user seldom needs to install something to run the SaaS product. In general, local installation goes against the principles of SaaS.

By contrast, some subscription software may still require a local installation. For example, AutoCAD, Autodesk Inventor and SOLIDWORKS are now available as subscription software. But the user still needs to install a substantial portion of the product on his or her workstation or local machine to run the software.

Subscription software may require the user to periodically go online to validate that the subscription is still active. But it may or may not require an internet connection to use the product.



Newer startups such as Frustum are experimenting with a subscription plus usage model, combining a mix of job processing credits and subscription fees in its licensing. *Image courtesy of Frustum.*

added to it. Frustum Generate, for example, offers its software Generate Professional for $100 per month, augmented by a usage credit plan.

The Generate software is accessible from the supported browser (Google Chrome); no installation is required. Under Frustum's Pay-as-You-Grow plan, you get 100 monthly credits with the subscription setup. The credit consumption depends on the optimization jobs you run and the number of jobs you execute.

The subscription plus usage model makes sense for optimization software because it requires both access to the software and access to computing power. The more complex the optimization, the more computation it demands. Because the software runs in the cloud SaaS-style, the required computation can conveniently be delivered from the cloud as well. The same pricing model may work well for simulation software vendors who make the cloud an integral part of the offerings.

nTopology, another startup, released the first commercial version of optimization software called Element in early 2017. The software is offered under an annual subscription plan.

"As a CAD user myself, I really appreciate when my tools get better over time. Sure, it's nice to think of a software purchase as a one-time capital expense, but if I can trade the one-time purchase for something that improves as I use it, I definitely will," says Spencer Wright, who oversees nTopology's product roadmap. "As a CAD vendor, I can honestly say that the incentive structure of the subscription model is real. It pushes us to continuously improve our core functionality and provides a built-in rhythm for soliciting and integrating our users' feedback."

Bellwether or Short-lived Fad?

In the era of Netflix streaming and Google Drive, perpetual licensing seems quaint. Yet, in the design software business, subscription is not the norm—not yet, at any rate. It's more of an exception to the rule, an emerging trend.

In enterprise and consumer software markets, Salesforce.com, Adobe Creative Cloud, Quickbooks and Microsoft Office have paved the way. They exemplify the shift from desktop to the cloud, from perpetual license to usage-based subscription models. But some of the transitions have not been silky smooth.

In 2013, when Adobe switched from perpetual off-the-shelf software to subscription-only with the launch of Adobe Creative Cloud, the move was met with backlash. History suggests turbulences and upheavals may be unavoidable for any established design software vendors that make a notable change like Autodesk.

However, Autodesk gave its customers plenty of advance notices, with programs designed to ease the transition. Currently, most of Autodesk's rivals offer both types of licenses. In the future, if subscription becomes more widespread and acceptable, perpetual licenses may fade away, becoming a legacy of the past.

One of the key components to Autodesk's switch may be its resellers—those who provide sales and support at the frontline. Their ability to adapt to the new model or the failure to do so could accelerate or jeopardize the momentum.

"Last quarter, 70% of revenue was generated through our channel partners," says Anania. "Channel partners are also playing a pivotal role helping maintenance customers move to product subscription." **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.*

INFO → **Autodesk:** Autodesk.com

→ **ANSYS:** ANSYS.com

→ **Graebert:** Graebert.com

→ **Frustum Generate:** Frustum.com

→ **nTopology:** nTopology.com

→ **Onshape:** Onshape.com

A NEW WAY to Manufacture

Online portals are quickly becoming the industry standard for parts. Here's a look at the benefits and when to bring in specialists.

BY JESS LULKA

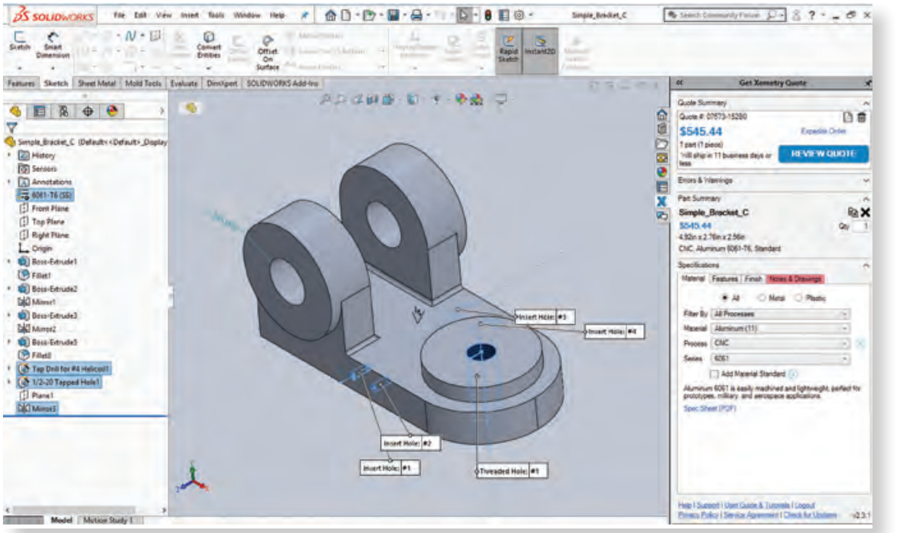
TODAY, CONSUMERS CAN do almost anything through an online interface: order food, buy home products, set items for in-store pickup and hail an Uber. This type of convenience is making its way into design engineering and manufacturing with the emergence of rapid prototyping service portals that allow users to get instant price quotes and manufacturing feedback.

"Designing parts using an online interface typically connects you to a community of designers who can provide valuable feedback to improve your project," says Chuck Alexander, director of product management at Stratasys Direct Manufacturing.

Aside from the expedited workflow these portals provide, their capabilities are bringing in more benefits for users.

"We find that with an online interface, a customer of ours can rapidly iterate and compare options just by a click of the mouse," says Greg Paulsen, director of applications engineering at Xometry. "We like to think of ourselves as a one-stop manufacturing service." With this ability and setup, he adds, companies can produce parts that can fit price, lead time and quality requirements.

De-risking is another big part of these portals. Traditionally, there's a lot of upfront risk with creating parts, and prototyping is very expensive. However, with online portals' quoting systems, users can instantly see what sections might cause manufacturing troubles and how much modifications will add to the overall cost.



In addition to an online portal, Xometry offers a plug-in for SOLIDWORKS, letting users get a price while they design. *Image courtesy of Xometry.*

With this design feedback and reduced risk, engineers have greater transparency into the overall process, instead of waiting for design input through multiple rounds of paper drafts. They also collectively enable more effective file version control, file-specific mark-up and comments, advanced search features, project libraries and often accommodate your preferred 3D CAD software, notes Ben Bradley, SmartQuote specialist at FATHOM.

"It's all about the digital thread," says Mark Flannery, global product manager, at Protolabs. "If the online quoting system isn't connected to the manufacturing software, you're constantly having iterations, and you risk getting parts you didn't think you were going to get. The digital thread lets you iterate quickly."

This notion of the digital thread also makes it much easier for teams to collaborate across time zones, countries and offices. Multiple teams within the same company can work together without having to leave their desks, which is especially important for designers and engineers who are working in different parts of a building with varying degrees of access. Plus, they can generate email notifications when changes have been made and integrate approval checkpoints, Bradley explains.

Just as the quoting and manufacturing process has seen upgrades over the years, so has design and simulation software. With these interfaces, users can access some of the technology all at once, instead of needing to purchase different software for optimization, simulation and design for manufacturing, because a lot of these principles are already integrated into the portal.

The access to design for manufacturing knowledge allows users to make the most of additive manufacturing, says Filemon Schöffer, chief marketing officer at 3D Hubs. "Traditionally, in aerospace, you wouldn't be able to take advantage of design for manufacturing and optimization so quickly," he says, for example.

What to Know Beyond CAD

Even with the benefits that these interfaces bring, a certain amount of engineering design knowledge is still needed. Because certain types of manufacturing automatically work with 3D models, users need to be able to produce a CAD model for feedback and pricing. Depending on the portal, customization options may change, since most offer feedback but require the actual changes to be done to the CAD model.

Beyond the model itself, it's helpful to know project specifics when placing an order. This way, users can ensure their design will meet any production requirements, such as timing, costs, specific materials and project scale. This can be particularly important, because different manufacturers will generate quotes depending on certain factors.

"Every portal is different. If [users] have the basics of 3D CAD and [an] idea of what they want to design, then they can use it for a range of technique[s] of manufacturing and materials, which the portals provide," says Sarah-Jane Bayliss, global marketing, On-Demand Manufacturing at 3D Systems.

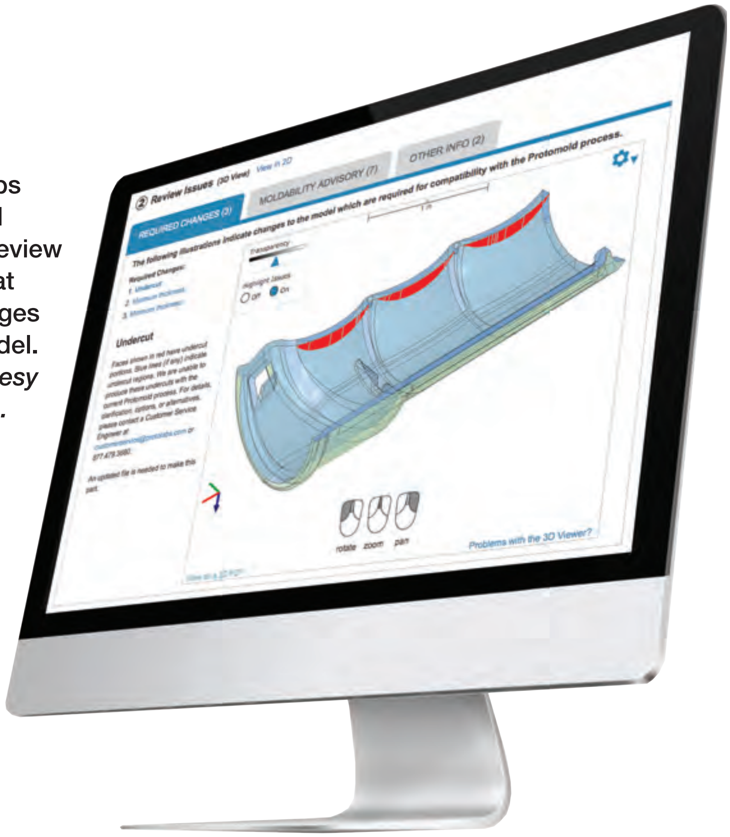
Beyond the CAD model and project specifications, users should look into the repeatability and reliability of a service partner, and be cognizant of quality of intellectual property protection, notes Greg Thompson, global product manager, at Protolabs. One way that engineers will be able to tell quality is from a provider's published tolerances, minimum features and design guidelines.

Bringing in the Specialists

Still, there are instances when bringing in outside help is advised, especially with parts that require specific paperwork or certifications. This is relevant in industries such as aerospace, automotive, or medical device design, which require extensive compliance.

Product complexity is another factor. For projects that have multiple CAD models, materials and parts that need to be manufactured, working with a specialist or team can help coordinate the entire process and provide advice so that parts are truly optimized for the right applications.

On a more basic level, Thompson notes, engineers should reach out if they aren't sure about a certain manufacturing method or material. "Each 3D printing [method] offers a lot of benefits but will also have some limitations," he says. "If there's a degree of uncertainty, that's an indicator that they should reach out."



The Protolabs online portal provides a review of issues that shows changes via a 3D model. ***Image courtesy of Protolabs.***

Picking a Portal

With all of the different prototyping services available online, how should engineers figure out which one is right for their needs? This can be narrowed down to three main factors: machine access, availability of materials and support services.

For a majority of service providers, they either have their own manufacturing facilities, or are supported by a network of machines or shops. Depending on the number of machines that they have, this can affect the type of services they offer, such as 3D printing, CNC machining or injection molding. It also will determine time to manufacture depending on machine capacity and application needs.

Users will also run into different material options depending on the service provider, which might be a requirement, depending on what is being manufactured.

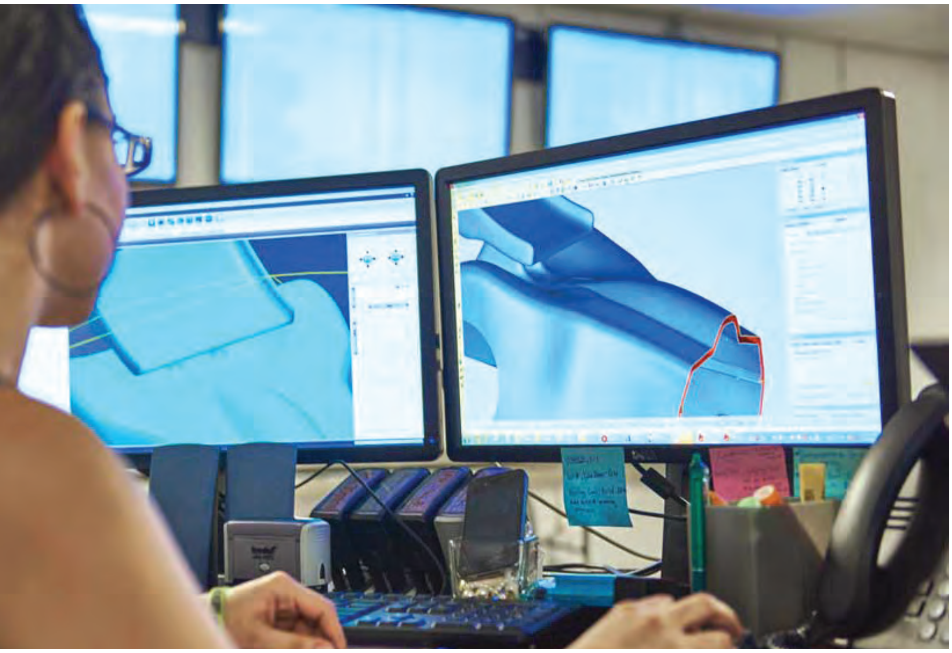
Portal Offers Access to Industrial 3D Printing

Recently, logistics company PostNord Strålfors launched a new portal for additive manufacturing in conjunction with 3YOURMIND.

3YOURMIND provides platforms intended to streamline industrial 3D printing for companies and 3D print services. The digital 3D workflows connect teams and production locations, optimize resource utilization and enable smart AM production decisions, the company's website notes.

"We appreciate 3YOURMIND's agile approach and rapid development to adapt the platform to our needs and business model," says Tomas Lundström, 3D business development project manager at PostNord Strålfors. "3YOURMIND's platform enables automate pricing, order management and customer fulfillment, which makes them a partner we can develop with as the 3D business is growing,"

With this partnership, the two companies aim to connect data and create truly agile manufacturing processes that will fuel the Industry 4.0 growth cycle.



To accelerate digital manufacturing, online portals are based off of CAD models, which users can update according to instant feedback. *Image courtesy of Stratasys Direct Manufacturing.*

This can be especially important for end-use production parts, which might require specialty or metal materials that aren't necessarily supported by all online portals.

Furthermore, delving into the various support materials and online guides can also be helpful throughout the process. "Online 3D printing platforms such as Sculpteo can easily provide useful resources to increase knowledge around these techniques," says Clement Moreau, CEO and co-founder of Sculpteo. "We notice every day that our tutorials, blog posts and other kinds of content are really appreciated by our customers, and that it brings them a true value to build the best products."

For advanced design, FATHOM says it has developed a complete Design for Additive Manufacturing program, which can help users understand the basics and promote adoption.

Advancing Design for Manufacture Capabilities

In industry, online access to manufacturing is becoming standard for both engineers and manufacturers. Online portals and quoting mechanisms have already established themselves as a way to expedite the production process and advance design-for-manufacturing capabilities.

Specifically, for additive manufacturing, "it increases accessibility; it's telling the user how their design requirements may vary across the different methods and how different features may affect their pricing," Thompson says. "All of this helps engineers become a lot more familiar with the process; it also helps engineers consider 3D printing [and other manufacturing methods] earlier."

By being able to work with design feedback and also get a large variety of machining and material options, engineers can better understand how to optimize their parts and learn exactly how to design for specific manufacturing methods and how these systems can work as a whole.

Ultimately, these portals provide a way to start the digital thread and connect part designs to different machines, optimization technologies and materials so engineers can produce prototypes and end-use parts in an efficient and effective way.

Their connection to the digital thread may explain why engineering software vendors like Dassault Systèmes and Siemens are getting into the mix.

At SOLIDWORKS World 2018, Dassault Systèmes launched 3DEXPERIENCE Marketplace Make, which connects designers with a variety of manufacturing services providers (both subtractive and additive). It is part of 3DEXPERIENCE Marketplace, a larger portal that also includes Social Collaborative Services and Marketplace Parts Supply. Users will be able to search, both by shape and by meta data, the desired 3D components from part suppliers that are part of the network.

At Hannover Messe 2018, Siemens launched its Additive Manufacturing Network, an online collaborative platform designed to bring on-demand design and engineering expertise, knowledge, digital tools, and production capacity for industrial 3D printing to manufacturers. It is expected to roll out in mid-2018, the company says.

"The availability of online portals worldwide gets many more people creating, building and sharing their knowledge," FATHOM's Bradley says. "It is incredibly inspiring to see how much the global community specific to our industry has helped grow the adoption of additive technologies for prototyping and manufacturing." DE

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INFO ➜ **3DHubs:** 3DHubs.com

➜ **3D Systems:** 3DSystems.com

➜ **3YOURMIND:** 3yourmind.com

➜ **Dassault Systèmes:** 3DS.com

➜ **FATHOM Studios:** StudioFATHOM.com

➜ **Protolabs:** Protolabs.com

➜ **Siemens:** Siemens.com

➜ **Stratasys Direct Manufacturing:** StratasysDirect.com

➜ **Sculpteo:** Sculpteo.com

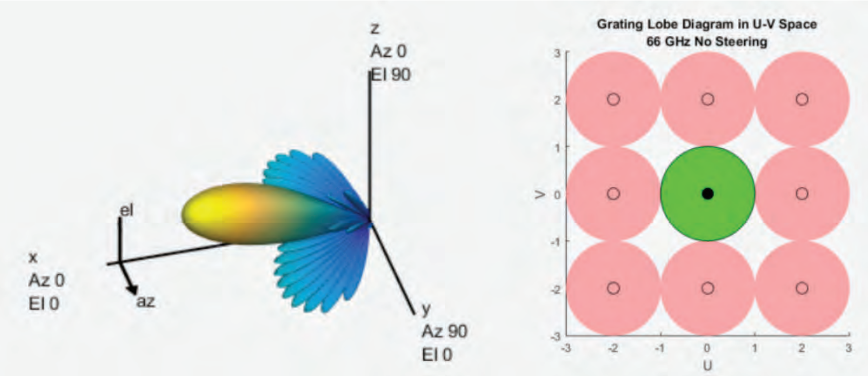
➜ **Xometry:** Xometry.com

5G-Based Product Development

The possibilities available with 5G adoption will force many companies to rethink their businesses—and provide opportunity for smart startups.

BY RANDALL S. NEWTON

THE TERM "5G" may not exactly be a household name yet, but those working on the next-generation wireless cellular network standard say it won't be long before its massive upgrade in bandwidth and throughput technology will radically change how we use wireless cellular networking for both consumer and industrial applications. By using millimeter-wave bands and MIMO (multiple-input multiple-output) antenna arrays, 5G will provide speeds up to 20 gigabits per second—that's up to 10 times faster than the current wireless cellular standard 4G.



A beam pattern and grating lobe diagram for 66 GHz 64x64 element design, designed with MathWorks Antenna Toolbox. *Image courtesy of MathWorks.*

The speed and data throughput 5G offers is being touted as a solution for many technologies that promise much but are hamstrung by data throughput and latency issues. Virtual reality (VR) will be able to work without a wired connection, and motion sickness caused by its latency should be eliminated. Researchers in autonomous vehicles say the ultra-low (1 ms) latency of 5G offers the possibility of cars communicating with each other in traffic, synchronizing their movements through city streets or highways as smoothly as a hive of bees or synchronized flock of birds.

One distinctive aspect of 5G ,when compared to preceding wireless standards, is not obvious at first: 5G is the first standard to be optimized for computers, not for humans. Voice calls are rarely mentioned in any technical discussion of 5G features and capabilities.

All of this hype and promise means big engineering challenges, not just for those deploying the actual hardware required to distribute 5G, but all the billions of new devices that will take advantage of the 5G tsunami. The industrial internet of things (IIoT) will be a prime beneficiary of 5G, enabling many new applications and integration of existing products.

Thought leaders are already describing scenarios of how 5G will improve existing processes and augment current infrastructure, then go on to empower new services like teleoperation of machines and other situations that rely on interface and control of real objects using digital technology. Writing new business models might not be on the R&D agenda, but the possibilities available with 5G adoption will force many companies to rethink their businesses—and provide opportunities for smart startups.

Edge or Fog?

New research into localized computing and connectivity for industrial environments—known as edge or fog computing—will extend current notions of cloud computing by allowing direct machine-to-machine computation and storage, with 5G connectivity replacing existing Wi-Fi or 4G connections. Network hardware vendor Cisco forecasts 50 billion connected devices by 2020 "chattering to one another in the background over 5G, dealing with small, low-data applications."

Ginny Nichols, from Cisco, coined the term "fog computing" in 2014 to describe the extension of cloud computing to the edge of an enterprise's network. Although "fog" and "edge" are often used interchangeably in describing newly distributed and decentralized computing IIoT environments, there are differences. In a fog environment, intelligence is at the level of the local area network. Data moves from endpoints to a gateway, and from there to processing sources. In an edge environment, processing is more decentralized as the devices are capable of higher-level computation and direct machine-to-machine data use.

The IIoT will use either fog or edge

KEY 5G PARAMETERS	
Latency in the air link	<1 ms
Latency end-to-end (device to core)	<10 ms
Connection density	100x vs. current 4G LTE
Area capacity density	1 (Tbit/s)/km^2
System spectral efficiency	10 (bit/s)Hz/cell
Peak throughput (downlink) per connection	10 Gbit/s
Energy efficiency	>90% improvement over LTE

Key elements of 5G technology. *Image courtesy of MathWorks.*

computing—most likely both—to deliver integration between operational technology and information technology. The goal is to deploy IT-enabled (smart) machines, networked sensors and data analytic systems that serve the device, its owner and the vendor. If the IIoT were an organism, 5G would be its nervous system.

Model-Based Engineering for 5G Deployment

Product engineering teams will need software tools that provide test bed utility as well as reference architecture for adding 5G capabilities to smart products. One engineering software company tackling the move to 5G is MathWorks, working closely with standards agency 5GPP. MathWorks is already providing software tools for engineers who need to create 5G compatible products, with an emphasis on making 5G accessible to engineers who have no prior background.

"5G is proving to be revolutionary," says Arun Mulpur, industry marketing manager for Communications, Semiconductors and Networks at MathWorks. "The when and how of coming to market" is how MathWorks sees its role in preparing product engineers for working in 5G. "Our experience shows you don't find 5G experts in [product] engineering organizations," he adds. So, MathWorks is adding tools and knowledge specific to 5G development into the products engineers already know.

Manufacturers like Ericsson have documented how the use of test beds accelerated time-to-market in developing 4G and LTE products. MathWorks is bringing the notion of software models as virtual testbeds to 5G development. In particular, they are extending the use of model-based design for development and testing of 5G algorithms and related system architectures. Because of this approach, MathWorks products MATLAB and Simulink can be used to iterate and simulate new design concepts. When the algorithm runs correctly in simulation, engineers can then generate synthesizable Verilog or VHDL (VHSIC hardware description language) code for deployment to a field-programmable gate array-based hardware testbed.

Mulpur says model-based design for 5G-compatible products is like the digital thread notion used in aeronautics. "There is the notion of Golden Reference, one truth in one model," he says. "Changes are propagated from the model."

While 5G standards are not finalized, there is a standard draft to work from. Mulpur recommends R&D teams act now, in advance of 5G standards finalization. "It is not a good idea to wait for full ratification. Tool vendors will provide what is needed to do the work now, allowing manufacturers to be ready to deploy when 5G comes online," he says.

Big companies like Ericsson may be the known leaders in the field, but Mulpur says small companies should not feel left out in the cold. Products like MATLAB and Simulink give startups "a common toolset conducive to doing executable specifications, with standards-compliant models and libraries. These are the building blocks for small teams to build a compliant system model in a test bench," Mulpur says.

Cyberphysical Manufacturing System Demands

University researchers from National Chung Hsing University and Beihang University (goo.gl/HCuFLh) note that current wireless network standards cannot meet the contemporary demands of cyberphysical manufacturing systems (CPMS), which generate "massive amounts of data." 5G, they say, has the "significant potential to promote IIoT and CPMS." The research team has proposed the development of 5G-based IIoT devices for three "typical application modes" of enhanced mobile broadband, massive machine type communication and ultra-reliable and low-latency communications (URLLC).

Among the many industrial benefits, the researchers foresee the widespread use of augmented reality and VR, due to the increased throughput of data and low latency 5G offers. "It will improve production efficiency, reduce production cost and enhance product quality though applying virtual reality and augmented reality in product design, manufacturing, maintenance and production equipment overhaul," they state. They cite the existing example of oil and gas vendor Total using Siemens VR software to train staff for offshore installation work.

The abstract is quite enthusiastic about the long term. "IIoT aims to realize ambient ubiquity networks in industrial environments based on the technologies of reliable sensing, computer networks, real-time communications, and big data," the researchers write. "IIoT can acquire the important manufacturing process parameters with lower cost, more convenience and higher applicability, which cannot be acquired in the traditional industrial production line." **DE**

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INFO ➜ **5GPPP:** 5g-ppp.eu

➜ **Cisco:** Cisco.com

➜ **Ericsson:** Ericsson.com

➜ **MathWorks:** MathWorks.com

The IoT Reshapes Wi-Fi Design

As more devices become connected to the IoT, how will engineers design for bandwidth considerations?

BY TOM KEVAN

THE RISE OF THE INTERNET OF THINGS (IoT) has forced engineers to rethink how they design wireless networks. The sheer number of mobile, wearable and other IoT devices joining the internet has caused developers to shift their focus to metrics like capacity and airtime utilization. Add this influx of client devices to the rich assortment of communication modes expected by businesses and consumers alike, and you have a Rubik's Cube with which network planners must wrestle to keep up with the overwhelming demand of the IoT.

The fact is that capacity planning involves more than sustaining the highest data rate between wireless devices and access points (APs). Today's networks must be able to accommodate a broad spectrum of data transfer requirements, ranging from the small, intermittent payloads of smart home appliances to the large, continuous data transmissions of real-time video surveillance systems.

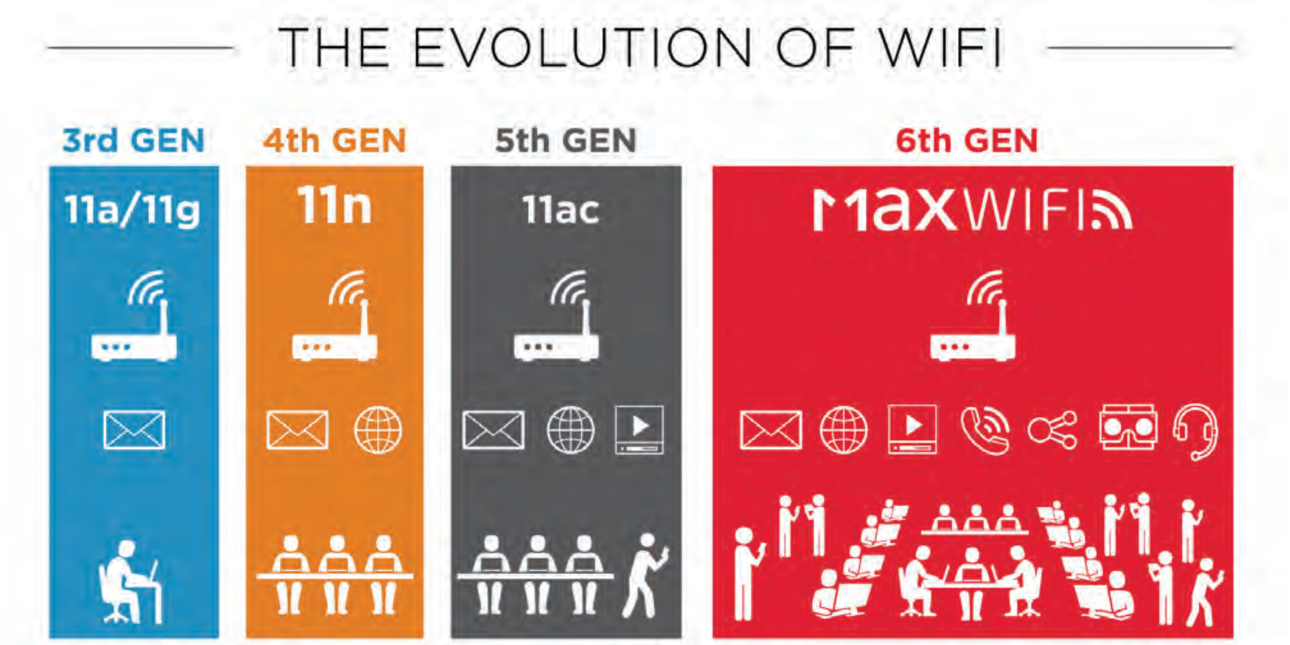
At the same time, the designs must also support operational ranges that vary from feet for wearables to kilometers for automation monitoring and control. And networks have to be able to include devices sustained by energy sources ranging from button cells to mainline power supplies.

This inevitably raises the question: Is there a single wireless technology that can support all these variations in a capacity-based network design?

The materialization of the internet of things has caused network planners to gravitate toward capacity-based design approaches to accommodate the rapid proliferation of wireless devices. Within this context, network capacity encompasses diverse throughput, range and energy requirements, as well as packet-transmission and channel-use efficiency. *Image courtesy of MaxWiFi.org.*

Wi-Fi's Role

In the near term, most network technology providers believe the answer to that question is yes—sort of. They see Wi-Fi as the primary wireless technology for IoT devices. But as endpoint density increases and more precise location data is needed, other technologies will begin to assume greater roles.



In the evolution of Wi-Fi, the standard's authors have tried to add features that will enable the technology to meet emerging networking demands. The latest generation of Wi-Fi—802.11ax, or Max WiFi—attempts to accommodate transmission speed, stream efficiency and energy requirements of the internet of things. *Image courtesy of MaxWiFi.org.*

"Wi-Fi will continue to be a dominant near-term wireless technology for IoT in IT," says Dennis Huang, director of enterprise wireless product marketing for Ruckus Networks. "But as IoT usage reaches further into environments that are difficult to connect and power, other wireless technologies—like BLE, Zigbee and other 802.15.4-based standards—will become more important. Wi-Fi continues to be the preferred option when a wireless device has access to the power grid, but when tethered power is unavailable or expensive, alternative wireless technologies will be essential."

Wi-Fi's strength arises from its established place in the wireless infrastructure. The 802.11ac and 802.11n standards already provide near ubiquitous in-building coverage. It also offers speed, ease of implementation, cross-vendor interoperability, low cost, reliability and the ability to handle large data transfers

Another factor in Wi-Fi's favor lies in the fact that it will play an integral part in 5G cellular networks. "A lot of the 5G cellular traffic demand will likely be offloaded via Max WiFi or other 802.11ax installations using Wi-Fi's existing dense and ubiquitous installed base to reduce the telecom carrier's overall capital expenditure," says Nitin Madan, marketing manager for Broadcom. "Wi-Fi is already the most heavily used internet connection technology, moving more than half of all internet traffic and 80% of all wireless traffic. Already, it's critical to many cellular networks, which rely on Wi-Fi's existence in end-user devices."

That said, standard Wi-Fi does have shortcomings that inhibit its use in certain IoT applications.

Designing for Capacity

Early Wi-Fi networks were built for basic connectivity and low-data applications. But with the emergence of the IoT, the market has experienced a sea change in usage patterns. The Institute of Electrical and Electronics Engineers (IEEE) anticipates that there will be 50 billion connected wireless devices by 2022. With so many devices populating the network, designers have had to adopt a capacity-based network design approach, a technique tailored to manage densely populated environments, increased data traffic and a diverse mix of applications.

Deploying for capacity rather than just coverage requires changes in the network's basic structure and adoption of specialized management technologies. One option involves increasing the number of deployed APs and their proximity to each other.

Client throughput is but one facet of capacity-based networks. "Capacity planning is not only about sustaining the highest MCS [modulation schemes and coding] rate connection between a device and the AP for all the devices on the network," says Huang. "It is also about how the network moves that packet over the air."

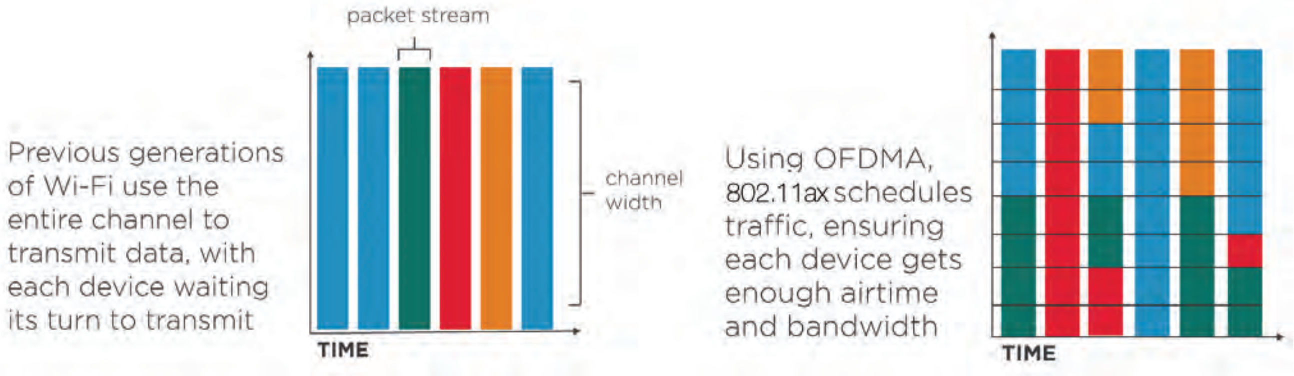
Making changes to the network's architecture opens the door for improved performance, but it also brings its own brand of challenges; this is where specialized management technologies come into play.

Mitigating Interference

One of the biggest challenges encountered by network designers is co-channel interference (CCI). Adding access points to improve network capacity can exacerbate CCI. To counter this problem, designers can benefit from a number of wireless technologies and techniques.

A key component to reduce CCI is the move to 5 GHz with 802.11ac, which alleviates traffic congestion in the 2.4 GHz band and helps reduce interference issues. As valuable as this approach is, it still is not enough.

"Mitigating co-channel interference will require a good channel-reuse plan, including defining appropriate channel widths on 5 GHz," says Bryan Harkins, training and enablement manager for Ekahau. "Capacity-based designs in general will require increas-



Orthogonal frequency-division multiple access (OFDMA) allows 802.11ax to more efficiently handle data traffic. It achieves this by separating individual channels into subchannels, each with a different frequency. Rather than have devices wait until the entire channel is free before they transmit data, the devices can use the subchannels to simultaneously transmit data using the same channel. *Image courtesy of MaxWiFi.org.*

ing the density of APs, compared with coverage-based designs. Because of this, AP placement will be key for breaking up collision domains into smaller pieces while providing more airtime."

In addition to channel-reuse planning, designers must load-balance clients between APs, bands and radios. Traffic must be load-balanced by media type to prioritize latency-sensitive voice and video. Load balancing allows the network to distribute client demands across all APs, maximizing the available spectrum within the coverage area and enhancing spectral efficiency.

Another technique is band steering, which leverages the capacity to communicate over both the 2.4 GHz and 5 GHz bands. If the client is dual-band capable, band steering directs the client to connect with the less congested 5 GHz network by actively blocking the client's attempts to associate with the 2.4 GHz network. This provides greater capacity and reduces co-channel interference.

Making Wi-Fi IoT-Friendly

Although contemporary Wi-Fi standards—802.11 ac and 802.11n—have supported wireless network designers well in the past, the technologies struggle to meet the capacity demands of the IoT. But the latest version—802.11ax, or high-efficiency wireless—aims to eliminate the shortfalls, improving performance, expanding coverage and extending client battery life.

The authors of 802.11ax have tailored the technology to meet the specific demands of the IoT. Thanks to a complete redesign of the standard, 802.11ax promises to provide as much as six times faster speeds, four times greater range and seven times longer battery life.

One of the technologies enabling this, orthogonal frequency-division multiple access (OFDMA), allows 802.11ax to handle data traffic much more efficiently. Instead of using an entire channel to transmit one client's data while another client's data waits for "their turn," 802.11ax schedules traffic so that each device's data gets enough airtime and concurrently transmitted bandwidth.

OFDMA achieves this by separating individual channels of the spectrum into many smaller subchannels, each with a slightly different frequency. So rather than queuing to transmit data using the entire frequency band, multiple devices can simultaneously share a channel. OFDMA further enhances capacity by allocating devices only enough of the spectrum to meet their needs.

In addition to OFDMA, 802.11ax incorporates BSS Coloring, a feature that increases capacity in dense environments. In situations where you have multiple, overlapping Wi-Fi networks, average network throughput degrades due to the "historical politeness" of Wi-Fi protocol—technically called CSMA/CA. This feature prevents collisions by waiting until the channel is completely clear before transferring a packet. As a result, only one packet can be sent at a time. With BSS Coloring, you can have multiple conversations at the same time, increasing the average data rate.

The 802.11ax standard also addresses concerns about Wi-Fi energy consumption with a technology called target wake time (TWT). This feature enables phones and other devices to turn off their radios when they are not exchanging data, improving efficiency and battery life.

All these features represent significant advances in network performance and energy efficiency, but the standard will not have an immediate impact on the IoT. The Wi-Fi Alliance doesn't expect to see mass adoption of 802.11ax until 2019, when product certification begins. The certification process ensures that all Wi-Fi products work together as they're supposed to. In the meantime, companies can and will introduce Wi-Fi products before certification, but most will wait for the standard to be finalized.

In addition to the delay caused by the standard-making process, basic market forces may push availability back even further. "The rollout of newer technologies, such as 802.11ax, will be delayed," says Harkins. "Replacing existing client devices that are working is going to be a slow go. Companies do not replace all the clients as soon as the standard adds amendments and APs start shipping. APs are replaced every five years or so. Client devices will take longer to be developed and longer to be adopted in the enterprise. It is not like flipping on a switch when new ideas arise."

Design Tools and Automation

It's one thing to talk about how the IoT has triggered changes in design concepts, techniques and strategies. But how has the change affected the basic tools of network design?

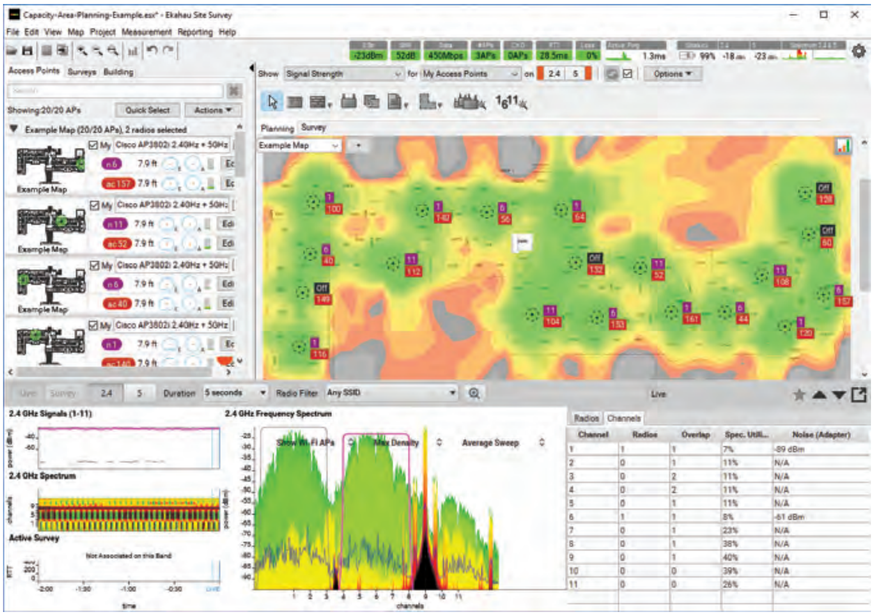
The answer is that as designers build more complex networks, they need the clearest possible picture of the environment in which the network will function. As a result, tools that used to be luxuries have become essential.

"The need for well done, complete surveys has been increasing since the early 2000s," says Harkins. "As the volume of wireless client devices grows, this will only become more important. Being able to control the size of your contention domains, channel use and coverage shape will all rely upon solid designs. This is achievable only when analyzing both layer one and layer two in pre-deployment physical surveys is done professionally."

This requires spectrum analysis in all frequencies used by Wi-Fi to identify noise sources that must be avoided in your design. It includes heat maps that allow the user to visualize different aspects of the RF environment. And it means being able to see where troubles reside to better design the network to work in that space.

Another factor designers must keep in mind is that the one constant in a network is change. As a result of this and the growing complexity of networks, technology providers have been increasing the amount of automation enabled in their systems.

"A thorough understanding of the deployment environment is essential for planning Wi-Fi access point placement and settings, but you have to assume that no deployment will be static," says Mike Tennefoss, vice president of strategic partnerships for Aruba Networks. "So it's equally important that the Wi-Fi network dynamically adapt to a changing environment without manual intervention except in extraordinary circumstances—such as a wall was moved or an access point was damaged."



The growing complexity of Wi-Fi networks requires that site survey tools provide designers with a thorough understanding of the deployment environment. Shown at the top of the screen, Ekahau's Site Survey Pro depicts a map, with simulated access points and their predicted signal strength. At the bottom, the troubleshooting tool visualizes narrowband interference impacting multiple Wi-Fi channels. *Image courtesy of Ekahau.*

Stopgap Measures

As a result of the delayed impact of 802.11ax, legacy devices will populate the network for years. These devices will not support OFDMA or TWT. How can designers make the most of advances with a mixture of old and new systems?

The answer is a hybrid approach that buys time until 802.1ax achieves broad adoption. "We recommend that one must segregate legacy devices on a separate channel than the newer 802.11ax devices to obtain the full benefit of the new technology, such as higher battery life and reduced airtime consumption," says Madan. "Additionally, it is important to consider complementary technologies, such as MBO [multi-band operations] and OCE [optimized connectivity experience], in deployment scenarios to optimize the user experience."

The MBO and OCE initiatives aim to provide a robust, interoperable client-steering mechanism that allows a client to share information with the AP about its capabilities, connection choices and migration options. This enables better AP steering decisions that consider the client's perspective.

Embracing Diversity

Wi-Fi already plays a key role in cellular network connectivity. Companies like Cisco, Samsung and Mojo Networks offer Wi-Fi APs that serve as gateways for the IoT, supporting combinations of already established technologies.

Wi-Fi will play a major role in the IoT, as the network grows and technology changes. But as the web of connectivity evolves, technologies like BLE, ZigBee and 5G will take on specialized functions, playing to their unique strengths. **DE**

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

INFO → Aruba Networks: ArubaNetworks.com

→ **Broadcom:** Broadcom.com

→ **Cisco:** Cisco.com

→ **Ekahau:** Ekahau.com

→ **Mojo Networks:** MojoNetworks.com

→ **Ruckus Networks:** Ruckuswireless.com

→ **Samsung:** Samsung.com

CAD Gets IN SHAPE

Onshape is a 3D CAD system that runs entirely in a browser.

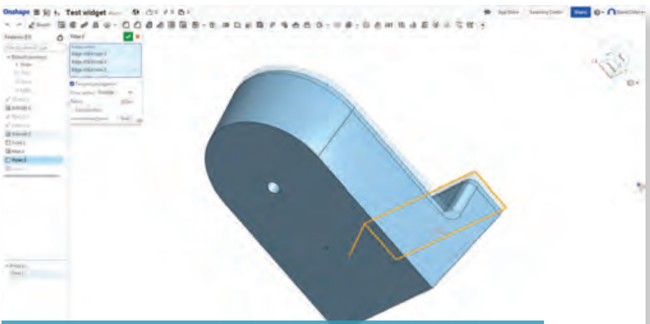
BY DAVID COHN

IMAGINE A CAD SYSTEM where it's not necessary to install any software, deal with license codes, think about upgrades and incompatible versions, or worry about crashes, data loss or where files were saved. Such a CAD system exists, and it's called Onshape.

The brainchild of many of the same people who created SOLIDWORKS, Onshape is a complete reimagining of CAD in the era of the cloud. It is a full parametric platform that incorporates 3D part and assembly modeling, associative 2D drawings and data management combined with sharing and collaboration, version control, release management and powerful tools that enable users to create custom features. With Onshape, both the data and the CAD system itself are in one place: the cloud. Anyone anywhere in the world accesses the same system at any time using any device. On a computer, Onshape runs in a web browser. There is no software to install. Users simply go to the Onshape website, log in and go to work. Any projects users already started or that have been shared are immediately available. Windows? Mac? Chromebook? It doesn't matter.

On phones and tablets, users can install an Android (18MB) or iOS (34.1MB) app. Then users have access to virtually the same features and functions and can work on any of the projects, in an environment specifically tailored for mobile users.

Because the software itself runs in the cloud, there are no downloads, installs, license keys, service packs or compatibility issues. Everyone always has the latest version of the software. Because projects are stored in the cloud, there are no files to download and none of the checkout/check-in hassles and IT overhead of some traditional product data management (PDM) systems. All files are stored in and shared from a secure cloud workspace. Anyone on the design team can access projects anywhere, anytime. As an administrator, users can adjust access privileges at any time as needed, so that users retain complete control over their work. And since everyone accesses the same data, control and monitoring of that data is baked into Onshape. Users can immediately see who changed what and when it was changed.



When logging into Onshape, the Documents page lists all the documents users have permission to at least view.

Familiar Interface

I got my first look at Onshape when I bumped into co-founder John Hirschtick in a restaurant. He gave me a quick demo by opening a model of a car engine on his iPhone. More recently, I sat down with Hirschtick at the Congress on the Future of Engineering Software (COFES) for a formal demo. When I finally decided to try it for myself, I was traveling. So, using my iPhone as a Wi-Fi hotspot, I opened my laptop and signed up for an Onshape account. In less than a minute, I was using Onshape to create simple parts.

Onshape will likely feel quite familiar to anyone who has ever used a modern CAD program like Inventor or SOLIDWORKS. When first signing in, users will see the Documents page, which lists all documents with access permissions. Use tools on this page to view information about each document. Also use filters to aid in finding folders and documents and a search bar at the top of the page to search for documents within the active filter.

Once a user has created or opened a document, the program initially provides two tabs: Part Studio and Assembly. Part Studio is used to define parts, while the Assembly tab is used to define the structure and behavior of an assembly. In Part Studio, users will notice the Document and Feature toolbars across the top of the screen and a Feature list along the left, with most of the screen given over to the canvas. As the user sketches or adds features, the toolbar changes to provide pertinent tools. The Feature list and its Rollback bar can be used to view work at different points in the history and reorder features. Onshape has unlimited undo that is persistent across work sessions, numerous right-click context menus, and lots of keyboard shortcuts to accelerate work.

The Assembly tab is where users can outline a hierarchical structure of part and subassembly instances, as well as set degrees of freedom and relations. It's possible to have more than one Assembly tab in a document. For example, one assembly can instance another assembly as a subassembly, or instance a part directly. Parts can be instanced from the same document or any other document with permissions. Also users can create multiple parts in a single Part Studio.

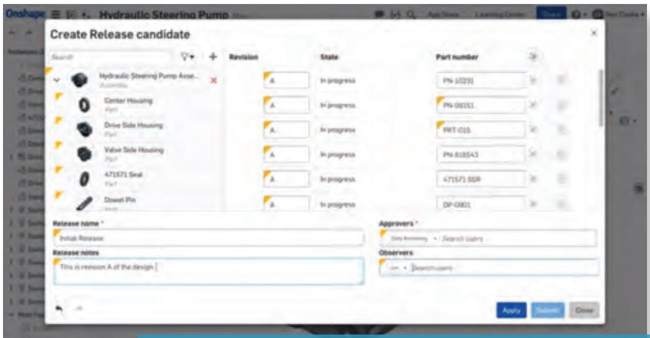
To create a drawing, a user can select the part or assembly, right-click and choose Create Drawing. After selecting the drawing template to use, the drawing is created within a new Drawing tab in the document.

A fourth type of tab—Feature Studio—is where users can employ the FeatureScript programming language to define custom features. This language, which is built into Onshape, is used to define Onshape standard features (like Extrude, Fillet and Shell). FeatureScript can be added to any Onshape document, and the company provides a tutorial, documentation and source code.

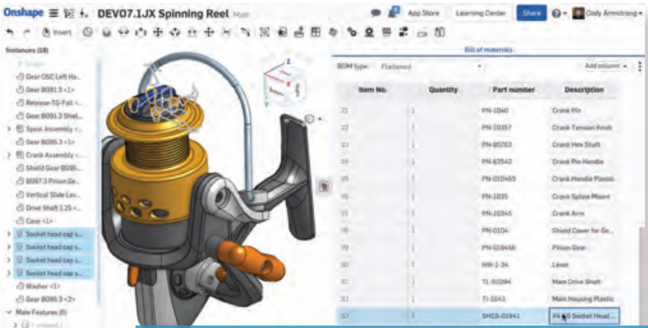
Users can also import existing CAD files to load those designs into Onshape. Onshape supports most CAD formats, including Parasolid, ACIS, STEP, IGES, CATIA, SOLIDWORKS, Inventor, Pro/E, Creo, JT, Rhino, NX and Solid Edge.

My restricted internet connection made very little impact, because all the heavy lifting is done in the cloud. When rotating a part or making a change, such as adding an extrusion, Onshape sends instructions to the cloud, the geometry server updates the model and the program sends a small packet of information back so that the display of the model updates. As a result, the software works very well regardless of bandwidth. Although a persistent internet connection is needed, if the connection is lost momentarily, the software continues working. And if the connection is lost entirely (or the program closes), there's no need to worry. Because the data is in the cloud, the project will be there again when re-establishing the connection.

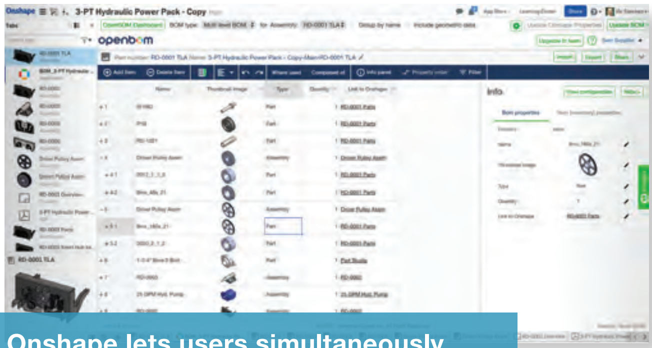
Select fasteners from a standard library and quickly add them to every hole in a selected face.



Release management and approval workflows give users a product release process integrated directly within Onshape.



Generate a bill of materials directly within an assembly and then interact with it.



Onshape lets users simultaneously view sheet metal parts as folded, flat and table views.

Onshape in the Enterprise

Onshape just announced its plan to launch Onshape Enterprise, a new version that includes analytics. Exclusive to the Enterprise edition are tools that offer insights into productivity, access history, release status, and more. The subscription price for Onshape Enterprise is $20,000 per year minimum. Customers can configure their Enterprise subscriptions with a mix of full user and light user licenses ($3,000 per year and $300 per year, respectively).

Onshape Enterprise API is compatible with PLM systems from other providers, including those offered by Onshape's CAD rivals, according to Dave Corcoran, Onshape cofounder and VP or product. "But each PLM system is different, so there's no single data bridge," he pointed out. Therefore, Siemens Teamcenter, Dassault Systèmes ENOVIVIA, and PTC Windchill, for example, may use different methods to transact with Onshape Enterprise.

Notable is Onshape Enterprise's strict enforcement of centralized data sharing in the cloud, with roadblocks to prevent unauthorized duplication and download of CAD data to local machines. The approach is consistent with the company's mission, to offer a cloud-hosted CAD experience. Currently, Onshape is working toward ITAR compliance, which will make its software much more appealing to government, military, and security-conscious clients.

— Kenneth Wong

Frequent Seamless Updates

Onshape was founded in November 2012; the company released the first public beta of its CAD software in March 2015. This was followed by the release of an Android app in August 2015 and the launch of its first full commercial release in December 2015. Since then, the company has issued numerous updates—six already in 2018 (as of this writing). But, as the software itself resides in the cloud, every user immediately has the latest release. There's nothing to install and there are never any file incompatibilities because there are no files.

So far this year, users have gained many new capabilities. For example, users can now build multiple variations of parts using parameter-driven configurations. Instead of saving every conceivable permutation in a single table, Onshape lets users build complex families of parts by creating separate small tables for each set of independent configuration options. Onshape also added a library of standard fasteners for use in assemblies. Each fastener includes a mate connector, making inserting a fastener a one-click process. Automated assembly tools make stacks of fasteners (such as bolt-washer-washer-nut) easy to build. An auto-size feature enables the software to automatically select the proper fastener based on hole size. After selecting the fastener size, if selecting a face, Onshape can place fasteners in every hole at once.

An update in March added release management and approval workflows, giving users a complete product release process integrated directly within Onshape. Administrators or owners will find the new release management tools within the account management functions. Once configured, to release a design, right-click whatever is necessary to create a release candidate that includes configurations, parts, assemblies, drawings and so on. It's possible to select an individual configuration of a part and release that, either independently or as part of a larger release candidate, is something product data management systems cannot do because they manage data at the file level. Onshape automatically notifies the necessary people. Once approved, released designs are indicated in the history, and when inserting designs, a new filter shows only what has been released, ensuring someone doesn't mistakenly insert something before it's ready.

A new simultaneous bill of materials (BOM) feature lets users generate a BOM directly within an assembly and then interact with it. For example, when selecting a part in the BOM, it is highlighted in the graphics and in the instance list of the assembly. Add and remove columns and even edit the assembly from within the BOM, which updates in real time as users make changes to the assembly. Then insert the BOM into the drawing and quickly add associative BOM balloons.

Onshape also added a new approach to sheet metal that allows users to simultaneously visualize sheet metal parts as folded, flat and table views, eliminating the trial and error of having to move back and forth between the folded and flat state of the model. By combining the sheet metal design tools, multi-part Part Studios and in-context assembly design workflows, users can build complex sheet metal parts, solid parts and assemblies together and streamline the entire design process from start to finish.

Purchase Options

There are four different ways to use Onshape. A free version enables anyone willing to freely share their designs to sign up for an account and immediately begin using the software. For students and educators, Onshape's free Education Plan lets students log in from home or school and collaborate together in real time. Professionals who only need Onshape's design tools can sign up for Onshape Standard.

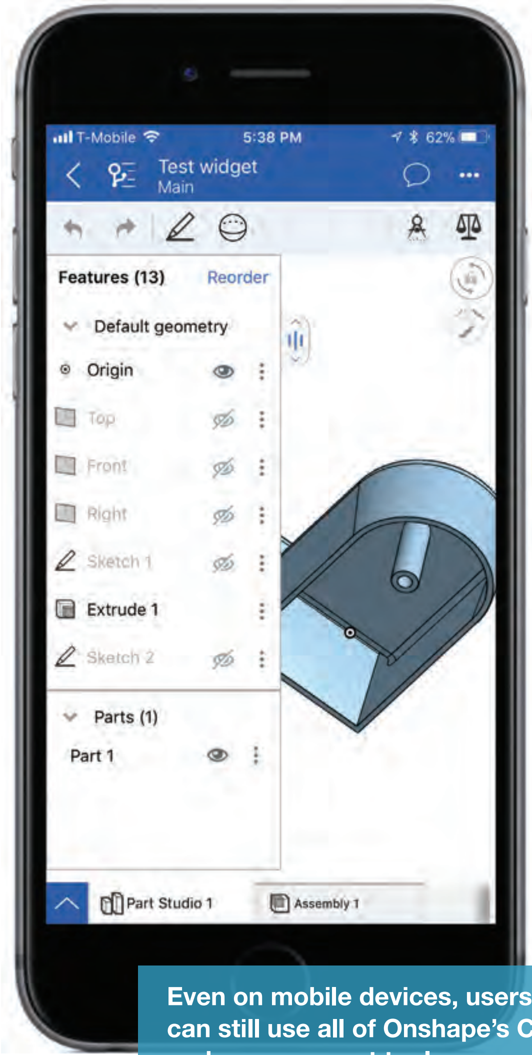
At $125 per user per month, the standard plan provides all the power of Onshape, including part and assembly modeling, drawings and direct technical support. Those who also want complete data management, formal release management, approval workflows and notifications, and company-level administration tools can purchase Onshape Professional ($175/month per user). Users can collaborate with any other Onshape user, regardless of their plan (assuming they have access permission), but free plan users cannot edit private documents (even if the sharer has given them editing permission). The Standard and Professional plans require an annual subscription.

Onshape also provides its own app store where users will find add-on programs in categories including simulation, rendering, CAM, ECAD and data management. Many of these are integrated apps, meaning they are accessible from within an Onshape document, appearing as an additional tab within the document.

Onshape currently supports Google Chrome, Mozilla Firefox, Safari (Mac OS only) and Opera. Microsoft Edge and Internet Explorer are currently not supported. Onshape also requires WebGL. Although Onshape does not require a discrete graphics card, it will perform better on systems equipped with a separate graphics processing unit (GPU)—just make sure that the computer uses its GPU when running a web browser.

With its many updates, Onshape has become a robust alternative to expensive software running on expensive hardware. It can be used by a single user working at home, small teams and large manufacturers. Its cloud-based nature allows Onshape to be used whenever inspiration strikes or it's time to get something done. DE

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



Even on mobile devices, users can still use all of Onshape's CAD and management tools.

INFO ➜ Onshape: onshape.com

Pricing:

- **Onshape Free:** Free to anyone, designs shared
- **Onshape Education:** Free for students and educators
- **Onshape Standard:** $125/month per user (billed annually)
- **Onshape Professional:** $175/month per user (billed annually)

System Requirements:

- **Onshape runs on any computer with a compatible web browser:**
  Google Chrome, Mozilla Firefox, Safari (Mac OS only) and Opera. Microsoft Edge and Internet Explorer are currently not supported.
- **Onshape is also available as an Android app (from Google Play) or an iOS app (from the Apple App Store):**
  - Android: requires Android 4.4 or higher
  - iOS: requires iOS 10.0 or later

Part 1

SOLIDWORKS Simulation Overview

Walk through a static analysis study of an aircraft keel section in SOLIDWORKS.

BY TONY ABBEY

SOLIDWORKS Simulation is an add-in to the SOLIDWORKS program from Dassault Systèmes. It provides a finite element analysis (FEA) capability within the traditional CAD environment. This is attractive to design engineers and others who are familiar with the SOLIDWORKS user interface.

A wide range of FEA solutions are available, from linear static to non-linear dynamic analysis. However, a potential purchaser needs to work closely with their SOLIDWORKS reseller to define the precise range of solution capabilities needed. The segmentation of the CAD functionality interleaved with the FEA functionality can be very confusing.

The origins of the FEA solution within SOLIDWORKS stem from the COSMOS FEA solver, a different solver from the advanced nonlinear Abaqus solver found within the Dassault Systèmes SIMULIA product family.

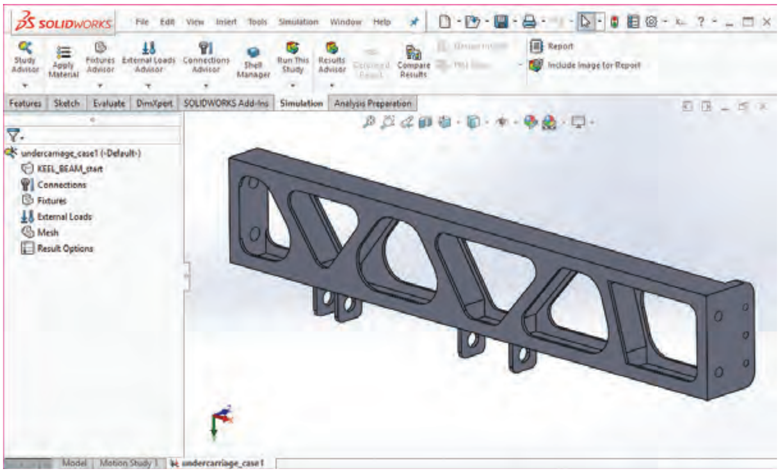


FIG. 1: The aircraft keel section geometry.

The Aircraft Keel Project

The FEA task in this review is to carry out a static analysis study of the aircraft keel section shown in Fig. 1. In part one of this overview, I focus on the initial setup and the solid meshing controls.

The keel section is on the lower centerline of a combat aircraft fuselage. It transmits undercarriage loads into the fuselage. It also provides a load path through the lower fuselage section in overall bending and torsion loading due to maneuvers. The geometry has been created in SOLIDWORKS. Many of the smaller fillet radii have been defeatured in preparation.

The Simulation add-in has been invoked in Fig. 1. Two new tabs appear in the CommandManager area; the Simulation tab and the Analysis Preparation tab. The Simulation tools are shown. The Study Advisor icon is selected, and a new Simulation Study is set up. This is a static analysis study; undercarriage_case1.

Multiple studies can be created in a SOLIDWORKS file and each will have a tab on the bottom of the screen. To switch between the simulation study and the geometry model, click on the Study or the Model tab. The Analysis Preparation tab contains a useful subset of geometry tools to manipulate the geometry ready for analysis.

The feature tree in the left-side panel contains icons that give access to required FEA entities. Right mouse-clicking on the top Study icon provides a menu that includes the analysis Properties selection. Fig. 2 shows the resultant dialog box.

Within the highlighted Solver Selection drop-down are

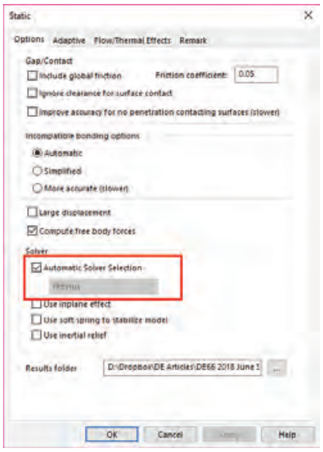


FIG. 2: **Static analysis properties dialog box.**

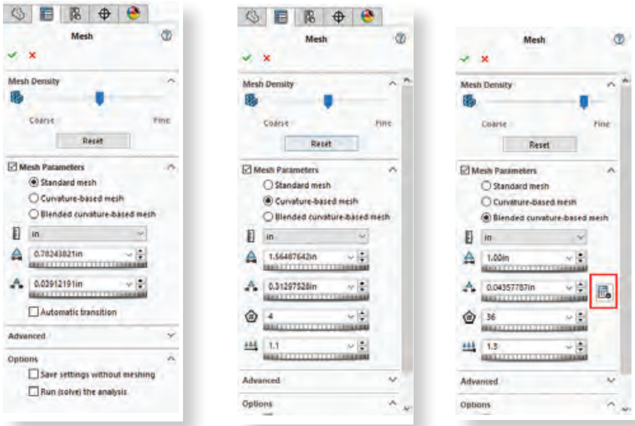


FIG. 3: **Standard (left), curvature (center) and blended-curvature based options in the Meshing menu.**

a range of FEA solver options, including Direct and Iterative solvers. The optimum choice of solvers is complex, dependent on solution type, model size and available system memory. I checked the Automatic Solver Selection option. This adopts the best method based on the characteristics noted. I recommend reviewing the documentation carefully and carrying out benchmarks to decide which solver setting is most applicable. There can be big differences in runtime, so time spent tuning will be worthwhile.

Standard Mesh Control

The mesh icon in Fig. 1 pops up a dialog box, as shown in Fig. 3 on the left, from which I selected the Standard mesh method. The mesh density is controlled with a slider bar, or by inputting two parameters: maximum and minimum element size. The default, specific to my model, is a medium density setting with maximum and minimum element sizes set to 0.782 in. and 0.039 in. The 20:1 ratio is the default. It is important to know your critical geometry dimensions and the implications within the settings. Fig. 4 shows the overall mesh and the local mesh around the critical stress area.

I ran an exploratory analysis (not shown) to confirm the high stress areas. These are the fillet radii seen in the inset of Fig. 4, which need a fine mesh. The adjacent bolt hole needs a coarser mesh and is typical of the rest of the structure.

The bolt hole periphery is 3.14 in. (0.5-in. radius). The fillet periphery is 1.57 in. (1.0-in. radius). The default maximum element size forces two elements around the fillet radius, nine around the bolt hole. The mesh shown in Fig. 4 is generally too coarse, and far too coarse at the fillet. The model has 61,701 degrees of freedom (DOF).

The "Fine" setting gives maximum and minimum element sizes of 0.39 in. and 0.019 in. Now four elements are forced around the fillet and nine around the bolt hole. This mesh is shown at top right in Fig. 4. The general mesh size is acceptable now, but the fillet is still far too coarse. The model has 210,501 DOF.

I have progressively halved maximum element size by manually setting to 0.195 and 0.0975 in., as shown in Fig. 5, bottom left and right. The model sizes are 1,234,647 DOF and 7,687,593 DOF. For a converged stress at the fillet, the local mesh size needs to be around 0.0975 in., as shown in the last model, but this is clearly not an acceptable solution. My desktop with 64GB RAM hit a wall here and took 23 minutes to mesh!

This academic exercise shows the need for alternative meshing strategies, and SOLIDWORKS offers three approaches: curvature-based meshing, local mesh control and adaptive meshing. The first two methods are based on user-defined controls. Adaptive meshing uses a series of automatically created analyses that update the mesh to

Editor's Note

This is one of a series of overview articles looking at simulation and optimization software products. A set of videos documenting and expanding on the steps taken can be found at: digitaleng.news/de/SWsimulation1.

Each overview represents Tony Abbey's independent assessment and is not sponsored in any way by the companies developing the products. However, in many cases, he is indebted to the companies for supplying temporary licenses to allow the reviews to be carried out.

Abbey teaches both live and e-Learning classes for NAFEMS. He also provides FEA consulting and mentoring. Contact tony@fetraining.com for details.

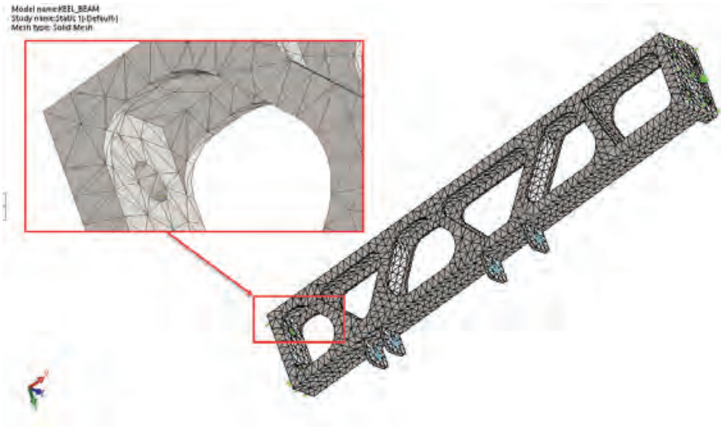


FIG. 4: **Default mesh using Standard method, with detail inset.**

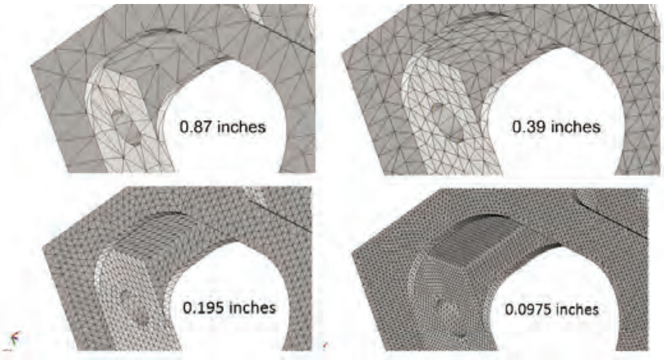


FIG. 5: **Standard mesh control with decreasing element size as shown.**

minimize stress jumps between adjacent elements. The program seeks out stress concentrations and refines the local mesh.

Curvature-Based Meshing

In the curvature-based option of the mesh dialog box (Fig 3, center), the slider bar controls maximum and minimum element size, as before. The default element size is coarser. The key parameter is the minimum number of elements around a circle (curvature control), shown by the pentagon-shaped icon. The range is between 4 (default) and 36 (maximum).

The default curvature setting of 4 gives a very coarse mesh of 56,097 DOF, as shown in Fig. 6.

Successive curvature controls of 8:18:36 are also shown in Fig. 3, center. The model sizes are 106,563 DOF, 195,252 DOF, and 252,768 DOF. There is little difference in the meshes beyond curvature control 18. The fillet and bolt hole element numbers are stuck, because the minimum element size has not been changed. The fillet periphery is 1.57 in., the minimum element size is 0.312 in., hence five elements are allowed. Similar math shows the limit around the bolt hole of 10 elements. Without this insight, use of the curvature-based meshing can be frustrating, as it appears to stall.

If we back-calculate, nine elements around the 90° fillet give a minimum element size of 1.57/9 = 0.174 in. This is the maximum in curvature-based meshing control (36 around a full circle). Using a smaller element size does not allow for a higher number.

Using these settings, a reasonable mesh is created, shown in Fig. 7, labeled Growth Rate 1.1. The model has 732,612 DOF. The maximum element size of 1.56 in. is the default, but the largest elements in the figure are much smaller than that. It would be useful to be able to further coarsen the mesh away from the fillet. The clue is the Growth Rate parameter, shown as a series of triangles in the menu. The value of 1.1 is the size multiplier on each successive element layer. A value of 1.1 gives a very slow growth rate from the fillet. The effect of growth rate is

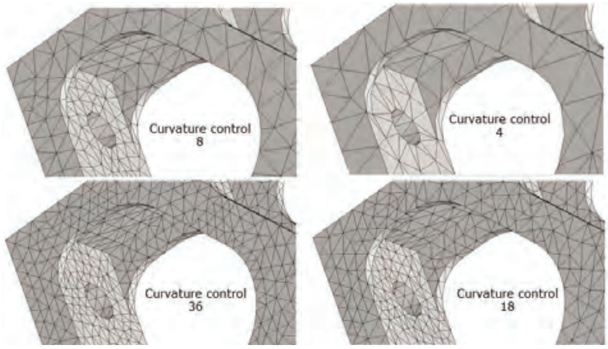


FIG. 6: Effect of curvature-based controls.

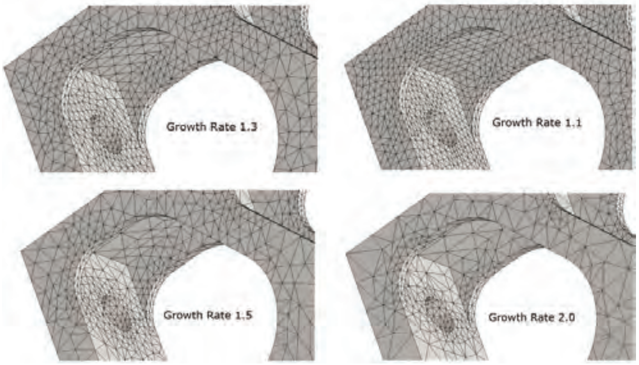


FIG. 7: Effect of growth rate on curvature-based meshing.

shown in Fig. 7.

Setting the value to 1.3 gives a useful gradation from the fillet to the edge and a model with 411,282 DOF. Over 300,000 DOF are saved. The next mesh at Growth Rate of 1.5 shows how sensitive this parameter is, since the model size has dropped to 287,964 DOF. Finally, a setting of 2.0 on Growth Rate gives 173,685 DOF. The fillet local mesh size has remained constant during these meshing runs.

The keel structure is relatively "narrow" in all places, so the Growth Rate does not have enough element rows to achieve the maximum element size of 1.56 in. The maximum element size is redundant here, but in a "wide" structure where many element rows exist, away from controlling curvature-based features, the mesh can coarsen to the target value.

To sum up the Curvature-based mesh strategy:

1. Select critical curved features and calculate the element size for 36 elements in a 360° circle.
2. Set this as minimum element size.
3. Set growth rate to 1.5.
4. Set the largest target element size in the coarse mesh region.
5. Adjust the Growth Rate until you find a gradation you like.

Blended Curvature-Based Meshing

This is an automated version of the curvature-based meshing. The dialog box is shown in Fig. 3, right.

The highlighted button in the dialog box activates a calculator that finds the smallest curvature-based feature in the model. The blended curvature-based smallest element size is 0.0435 in., because of 0.25-in. radius bolt holes that are present. The other parameters remain the same, using settings from the previous exercise. Fig. 8 shows the resultant mesh.

Interestingly, the blended mesh overrides the limit of 36 elements around a circle, using the new smaller minimum for all curved surfaces! This produces a good mesh around the fillet—but is overkill in other non-critical curved regions. The model has 674,685 DOF.

This method could be used as an additional "step 6," after normal curvature-based meshing settings are established. The blended mesh minimum element size, entered manually, would "nudge" up the number of elements around key features.

Local Mesh Controls

After curvature-based meshing, the fillet has reached its limiting size. This is frustrating as we need a finer mesh at the fillet. Local mesh control now plays a key role.

Right mouse-clicking on the mesh icon allows Apply Mesh Control to be selected. Fig. 9 shows the menu and the fillet surfaces chosen.

I have halved the "stalled" fillet mesh size. The resultant mesh is shown in Fig. 10.

The local mesh control is highly selective. It allows good mesh refinement at the fillet region, while keeping the model size to 385,899 DOF.

Individual mesh controls can be set. Using these as fine control adjustments on a sound baseline mesh provides a powerful technique.

Conclusion

The solid meshing controls in SOLIDWORKS Simulation allow very good mesh control. However, there is a great deal of interaction between parameter settings. To avoid frustration, I recommend exploring the options with simple geometry to develop a consistent workflow.

In part two of this SOLIDWORKS Simulation walkthrough, I will review loads and boundary conditions and then focus on the post-processing options. DE

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INFO → Dassault Systèmes SOLIDWORKS: 3DS.com

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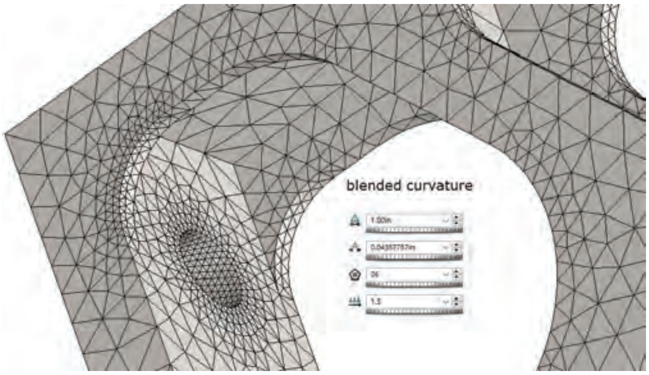


FIG. 8: Blended curvature-based meshing.

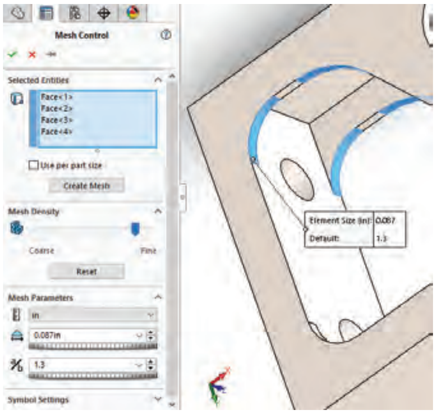


FIG. 9: Local mesh control menu and selected fillet surfaces.

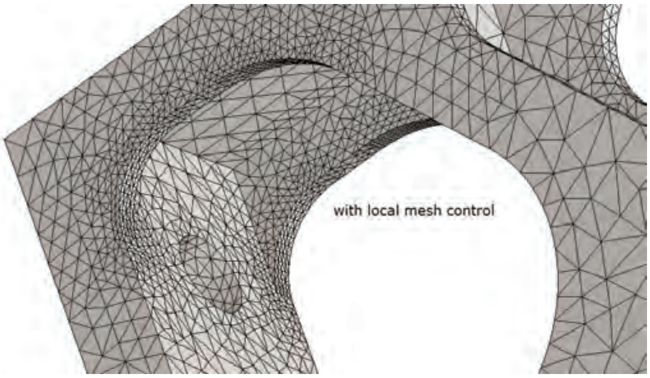


FIG. 10: Local mesh control.

Tony Abbey *is a consultant analyst with his own company, FETraining. He also works as training manager for NAFEMS, responsible for developing and implementing training classes, including a wide range of e-learning classes. Check out the SOLIDWORKS Simulation courses Abbey has created at: linkedin.com/learning/instructors/tony-abbey?trk=insiders_17432580_learning. Send e-mail about this article to de-editors@digitaleng.news.*

Additional Simulation Options for SOLIDWORKS

DASSAULT SYSTÈMES offers a portfolio of simulation tools designed to help SOLIDWORKS users solve specific physics.

- **SOLIDWORKS Simulation** is a portfolio of structural analysis tools that use the finite element analysis (FEA) method to predict a product's real-world physical behavior by virtually testing CAD models. The portfolio provides linear, non-linear static and dynamic analysis capabilities. It is available in Standard, Professional and Premium packages.
- **SOLIDWORKS Flow Simulation** is a computational fluid dynamics (CFD) solution embedded within SOLIDWORKS 3D CAD that enables the simulation of liquid and gas flows through and around designs to calculate product performance and capabilities. Modules are available for HVAC and electronics cooling.
- **SOLIDWORKS Sustainability** facilitates the measurement of environmental impacts of designs across the product life cycle—including the effects of materials, manufacturing, assembly, transportation, product use and disposal. Assessment results are saved for each design configuration to compare versions.
- **SIMULIA Simulation Foundation** is designed to access and maintain an organization's library of deployed simulation processes to make more informed decisions and design better products. It can act as a dashboard for finding, monitoring or resuming previous simulations.
- **SIMULIA Structural Engineer** uses ABAQUS on the 3DEXPERIENCE platform for conducting structural static, frequency, buckling, modal dynamic response and structural thermal analysis of parts and assemblies. It can leverage design and simulation data in SOLIDWORKS models.
- **SIMULIA Stress Engineer** enables users to assess product performance and quality under static, thermal and buckling conditions with ABAQUS on the 3DEXPERIENCE platform. It is designed to automatically present options for fast product integration in engineering.

— DE editors

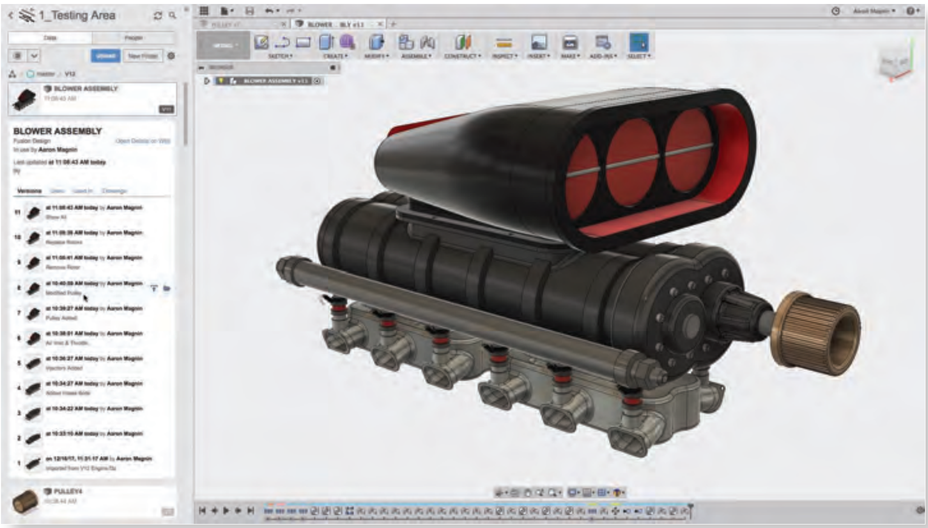
Version Control Systems Borrow from Software Playbook

Traditional PDM and PLM platforms are embracing software version control concepts in an effort to increase collaboration and promote design agility.

BY BETH STACKPOLE

FAST AND FURIOUS IS THE *MODUS OPERANDI* for most software engineering teams, which rely on open, web-based version control platforms to easily share code and empower innovation. Compare this freewheeling approach to traditional engineering, where design teams are constrained by rigorous processes that lock down work in progress and set limits on agile iteration.

With complexity on the rise and embedded software monopolizing product real estate, the question becomes whether distributed version control concepts popularized in the software world could now influence traditional engineering. As it turns out, the answer is yes. In a show of what's possible, new cloud-based tools and traditional product data management (PDM) and product lifecycle management (PLM) platforms are starting to borrow concepts from distributed version control systems (DVCS) and establish a middle ground.



Cloud-powered version management is built into Fusion 360, giving engineers an easy way to track the evolution of designs. *Image courtesy of Autodesk.*

"The connection between agile engineering paradigms and more traditional staged-gate processes has to align somehow," says Christoph Braeuchle, senior director of product management, for PTC's Integrity Lifecycle Manager and ThingWorx Connected Requirements and Validation applications.

Although there is opportunity for alignment, Braeuchle acknowledges the inherent differences between the engineering disciplines and the version control workflows required to support them. Software engineers, for example, need a local work environment with the ability to debug code and understand the flow of software, he explains. Also, most software code is easily compressed, which makes it less onerous to store and distribute compared to detailed 3D models.

This is a different scenario from mechanical engineering, where prototyping is expensive and time-consuming, involving more than sending files across the transom or running automated software builds. "Nevertheless, at some point, embedded software and mechanical hardware designs have to fit together and make for a well-connected product," he says. "That means the agile DevOps paradigm and the sequential V model have to fit together."

Design Iteration on Steroids

The danger in sticking with the status quo is an inability to iterate designs and respond quickly to changing market conditions, experts say. Adopting software-inspired distribution and modern version control tools gets traditional engineering closer to the agile development mindset, with the potential for getting a jump on the competition, notes Cody Armstrong, technical services manager for Onshape, a CAD system designed as a cloud-based platform.

"Ultimately, it's all about how quickly you can iterate and get product to market faster," he explains. "Inevitably, if the competition is getting prototypes out the door faster or products into market before you, that's the motivation to try something new."

Onshape, started by a team of CAD veterans and SOLIDWORKS founders, is lauded by industry players as taking the biggest leap to bridge the version control worlds of software and traditional engineering (see *DE's* review on page 34). Take the concept of branching and merging, popularized by Git and other DVCS used extensively in software development. Branching is a mechanism for isolating work so individuals can iterate on their own in parallel, then merge their changes in a way that preserves the integrity of the design. Traditional CAD and PDM have had no such mechanisms in place for managing divergent design paths as part of a centralized repository and version control system.

Onshape, on the other hand, lets engineers build variations and experiment with new ideas using branches that will not impact other design collaborators or the original design; when officially "merged," the various iterations are represented in the final result, essentially combining many ideas into one. Onshape's approach is possible, Armstrong says, because it is built on a modern database-driven architecture, unlike traditional file-based CAD tools, which handle the practice by overwriting or replacing one file with another.

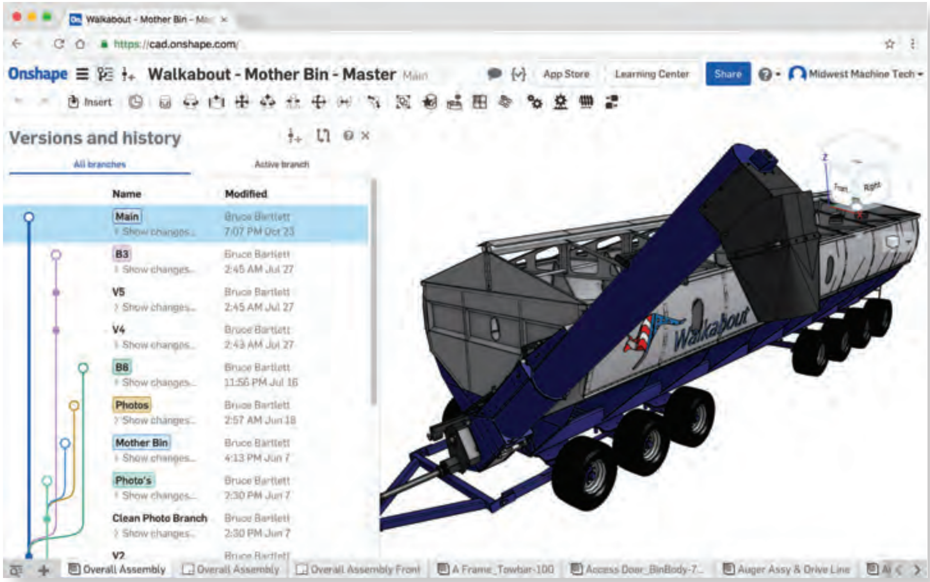
The latest Onshape release further connects the hardware/software version control workflow gap by fully integrating its Release Management and Approval Workflows feature into the base platform as opposed to being a separate application that has to be configured independently, Armstrong says. As part of this capability, traditional check-in and checkout processes standard in older PDM platforms no longer apply. This allows collaborators to have instant access to a design without having to check out or update a version. Additionally, the new Onshape lets released designs be referenced anywhere, using the Insert dialog filter to track history while ensuring that a change isn't mistakenly inserted before formal release.

"We want users to be able to release designs and manage approvals, but we never want to block them from creating something that is inspiring," Armstrong says.

Autodesk, which came late to the PLM market with a built-from-the-ground-up cloud-based platform, also specified version control as a core capability of its Fusion Lifecycle platform unlike competitors, many of which deliver the functionality as an optional bolt-on, according to Bankim Charegaonkar, senior product manager for Fusion.

He explains Autodesk made that decision early on after discovering many potential PLM customers weren't using formal version control, but rather relying on manual processes or simple network file server management. In addition, Fusion Lifecycle's cloud-based architecture allows for easy extended collaboration—one of the core benefits of distributed version control, he says.

With a core version control foundation in place, Autodesk began exploring more sophisticated capabilities, including whether it made sense to incorporate elements of software-inspired DVCS, he says. The company launched a preview, which showcased a form of branching and merging to allow engineers to isolate work so they could riff on a design without impacting collaborators; however, the team found it



Branch and merge capabilities, popularized by DVCS in the software world, have been a staple of Onshape since its first release. ***Image courtesy of Onshape.***

didn't go far enough and created additional problems when trying to merge changes. Today, Autodesk is looking at intelligent automation as a possible solution to the challenge.

"The real problem is continuous integration and delivery—you need a way to have all the changes be integrated all the time while validating that the changes are not breaking something else," Charegaonkar says. "The longer someone is in a space of isolation, the more divergence we get. Automation can provide feedback if someone made a change that will result in a clash."

PTC also sees merits in merging the two development disciplines, but doing so through integration and orchestration—not by building new DVCS features into the core Windchill PLM platform, Braeuchle says. PTC offers a software configuration management capability through its Integrity Lifecycle Management platform, and that system interfaces with Windchill along with popular software development tools like the Jenkins continuous integration build server and Git-based solutions, Braeuchle says.

As part of its efforts in this space, PTC is working on a workflow orchestration platform, previewed this month at its LiveWorx conference, which will facilitate information exchanges between different platforms in real time while sending notifications on updates and changes. "This idea of orchestration of a heterogeneous work environment is important because a monolithic, centralized repository is not fit for the agile engineering world," he says. Using the orchestration capabilities, PLM will serve as the curator of all of the information, presenting it in a system and in a manner that makes sense for a particular role doing the work, he explains.

For Aras, maker of the Innovator open PLM platform, there is nothing about PLM data that counts it out from being handled using distributed version control principles, yet the company has to see a demand among its user base and believes the need will vary depending upon industry, according to Rob McAveney, the firm's chief architect. "PLM manages a much more heterogeneous set of data than source code control systems, with different data types having different configuration management rules," he explains.

"PLM also doesn't generally organize data in bite-size chunks like repositories—rather, it's a large interconnected network of data with no clear delineation of project and product boundaries."

Formal change management and the large-size of CAD file content would be additional obstacles to making a clean break with traditional version control practices in favor of software-focused DVCS, he says.

It's not only inevitable, but it's actually essential that we see more DVCS capabilities make their way into traditional engineering tools, contends Michael Tiller, president of Xogeny, which specializes in web-based engineering analysis tools. Although such capabilities are crucial for collaboration and effective content management, he acknowledges the difficulty blending the two version control worlds and says it will take time getting established engineers comfortable with a new paradigm until there's a proven track record.

"The problem is not everyone has the luxury to start with a clean slate," he says. "People aren't willing to give up the proven aspect of their tools without some really serious benchmarking, and that can make it difficult to move things forward in a big way." **DE**

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

INFO → **Aras:** Aras.com

→ **Autodesk:** Autodesk.com

→ **Onshape:** Onshape.com

→ **PTC:** PTC.com

→ **Xogeny:** Xogeny.com

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*Each week, **Tony Lockwood** combs through dozens of new products to bring you the ones he thinks will help you do your job better, smarter and faster. Here are Lockwood's most recent musings about the products that have really grabbed his attention.*

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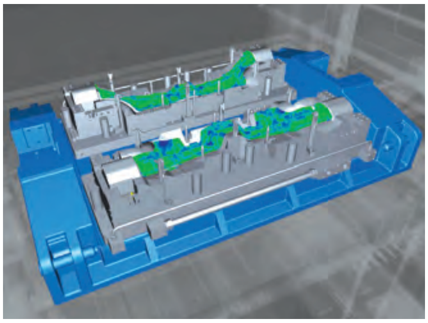

PAM-STAMP 2018 Debuts

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Multi-CAD Interoperability Solutions Updated

Offers enhanced geometry simplification in fully automated process.

Elysium debuts the EX8.0 editions of ASFALIS and CADdoctor, its data translation system for digital enterprises and its multi-CAD data translator for engineering desktops, respectively.

ASFALIS is a smart communications and collaboration infrastructure. It features the ability to automatically simplify files to remove unwanted details for analysts. For smaller workloads, CADdoctor is an interactive desktop application for 3D CAD translation and geometry simplification for CAE.

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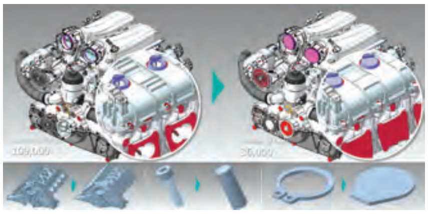

Deskside Deep Learning, GPU-Accelerated Rendering

BOXX also debuts deep learning server.

BOXX Technologies has announced the APEXX W3 compact, deskside workstation for high-performance computing applications.

All BOXX workstations are highly customizable "basic" platforms. Basic means a recommended configuration with power supply, internal cooling, external ports, storage and networking to build off to fit your needs. For the APEXX W3 workstation, the building site starts with an Intel Xeon W series processor with up to 18 cores.

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Graphics Power to Change Engineering Workflows

Can deliver real-time ray tracing and deep learning to the engineering workstation.

NVIDIA has begun shipping its new Quadro GV100 GPU. View it as engineered to handle next generation, extreme design, simulation and engineering workflows that are beyond the ability of this generation's desktop workstations to execute practically.

That means real-time ray tracing, artificial intelligence, simulation and virtual reality enhanced workflows on your workstation with the speed and the 3D visual acuity that previously could only inspire techno-dreaming.

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Next-Gen Engineers

Student Design Competition Profile: The Collegiate Inventors Competition

Students Walk the Innovation Talk

BY JIM ROMEO

FOR TODAY'S TECHNOLOGY THINKERS, innovation begins early in their career, often, at the collegiate level. That's the premise that the National Inventors Hall of Fame sought to capitalize on in developing the Collegiate Inventors Competition.

Rini Paiva is the vice president, Recognition and Selection, for the National Inventors Hall of Fame. We spoke to him to learn more about the Collegiate Inventors Competition.

Digital Engineering: Can you provide an overview of the competition?

Rini Paiva: The Collegiate Inventors Competition was founded in 1990 to encourage and drive innovation and entrepreneurship. The competition brings together the nation's brightest undergraduate and graduate students to showcase, recognize and award their cutting-edge research and discoveries. With the help of our sponsors, we have awarded more than $1 million to the country's most innovative collegiate students.

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

Paiva: Entries include outstanding inventions in disciplines as varied as medical devices, biotechnology, nanotechnology, renewable energy, robotics and systems engineering. Entries must be the original idea and work product of a student, or team of students, and an academic advisor. The invention must be a reduced-to-practice idea—or working model—and be capable of reproduction. Many of the entries that we receive are the result of a research assignment or senior capstone project.

DE: Can you provide some examples of past winners?

Paiva: This past year, team members Matthew Rooda and Abraham Espinoza (SwineTech) from the University of Iowa were awarded the undergraduate gold medal for their invention SmartGuard, which prevents piglet-crushing deaths by their mothers by monitoring the pitch, loudness and duration of squeals, and determining whether a piglet is in distress.

When a piglet is in distress, the device sends a vibration to a wearable patch on the mother, prompting her to stand and free her piglet. The SwineTech team also won the Arrow Innovation Prize from Arrow Electronics. This exclusive prize advanced the team to the final round of judging—all expenses paid—at the competition, and it included a private networking opportunity with a group of innovators from Arrow Electronics.

The graduate gold medal winner was Ning Mao from Boston University for her invention Engineered Probiotics, an engineered safe bacterium that inhibits the progression of a cholera infection. This bacterium provides early detection of cholera and helps contain the spread of the disease. In addition, the technology could be adapted to fight other types of bacterial infections.

DE: What drove the National Inventors Hall of Fame to sponsor the event and coordinate it?

Paiva: The National Inventors Hall of Fame, in partnership with the U.S. Patent and Trademark Office (USPTO), is the driving force behind lifelong innovation, paying forward America's bright history of invention and securing our country's competitive advantage for the future. We believe our role is to honor the individuals whose inventions have made the world a better place, and to ensure American ingenuity continues to thrive. This belief drives our mission: to recognize inventors and invention; celebrate our country's rich, innovative history; inspire creativity and advance the spirit of innovation and entrepreneurship. **DE**

Jim Romeo *is a freelance writer based in Chesapeake, VA. Contact him via JimRomeo.net.*

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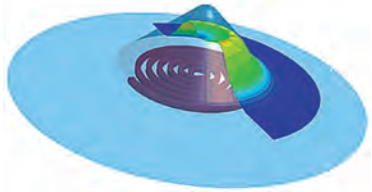
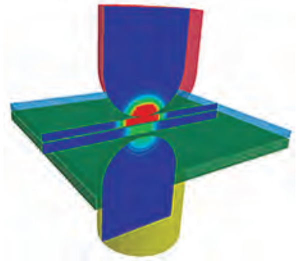
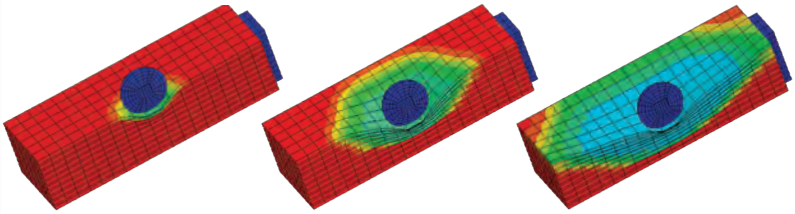


Magnetic forming of a metallic plate against a conical die.



Resistive spot welding simulation, where the Joule heating due to the material and contact resistances gives the temperature needed for the weld.



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