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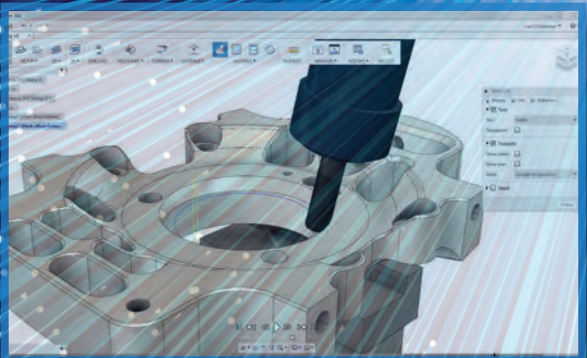
Digital Engineering

March 2018

- SOLIDWORKS 2018 Review
- Simulation Data Management
- Industrial IoT Analytics

FOCUS ON: Data Management

CAD-CAM Convergence



SIEMENS FEMAP WITH NX NASTRAN OVERVIEW, PART 2

BOXX WORKSTATION REVIEW

MASS CUSTOMIZATION & 3D PRINTING

by Jamie J. Gooch

Tackling Blockchain

IT'S BEEN CALLED the new internet, the trust protocol and the most disruptive technology in decades—and those decades include technologies like the internet of things (IoT), smartphones and the widespread adoption of cloud computing. So what is blockchain, why is it being so highly lauded and how could it be applied to engineering?

Most of us first heard about blockchain in association with cryptocurrencies like Bitcoin (which was invented in 2008) that rely on blockchain's "incorruptible digital ledger," as Don and Alex Tapscott, authors of "Blockchain Revolution," describe it. That ledger of validated transactions is duplicated thousands of times in blocks of information that also contain other transactions and are chained together. The transactions are continuously reconciled so that a decentralized database that doesn't exist in any one location is always up to date, accessible only via permission, transparent and therefore "incorruptible." That is a grossly simplified explanation of blockchain, but hopefully whets your appetite enough to research it further if you're not familiar with it.

One reason technology pundits are so excited about the possibilities blockchain offers is because its decentralized structure shores up weaknesses in the current client-server-driven internet. The very nature of blockchain offers speed and security benefits. Couple those benefits with the fact that such a digital ledger can record much more than just the financial transactions that enable cryptocurrency, and it's easy to see why blockchain is being ballyhooed.

As it turns out, many industries would benefit from a trusted, automated way of sharing continuously updated information. Virtually any transaction is a potential blockchain use case.

The Single Source of Truth?

That brings us to engineering. There are a number of day-to-day tasks and enterprise-wide initiatives that would, theoretically, be ripe for blockchain disruption.

Perhaps the most obvious use case is file sharing. While design engineers may not think of opening a file or collaborating with partners as "transactions," they fit the definition as far as blockchain is concerned. It's easy to imagine private blockchains being harnessed to handle version control. The ledger could be queried to allow only validated users to access the files while simultaneously keeping track of who opened what when—all without need for administration.

From there, it's a natural leap to extend blockchain beyond file management to upend current product lifecycle management (PLM) and supply chain practices. It's not all a thought experiment. Some companies are already taking the first steps toward implementing blockchain to assist with supply chain management.

Earlier this year, shipping giant Maersk and IBM announced a joint venture for conducting global trade using blockchain technology. "By applying the technology to digitize global trade processes, a new form of command and consent can be introduced into the flow of information, empowering multiple trading partners to collaborate and establishing a single shared view of a transaction without compromising details, privacy or confidentiality," according to the press release announcing the venture.

Replace those shipping containers with connected devices and the goods in those containers with sensor-collected data, and you have a pretty convincing use case for blockchain support of more secure IoT transactions. The mind boggles.

Developing a Digital Identity

Microsoft is thinking even bigger. Over the past year, the company has been incubating ideas on using distributed ledgers to provide digital identities. "Each of us needs a digital identity we own, one which securely and privately stores all elements of our digital identity. This self-owned identity must be easy to use and give us complete control over how our identity data is accessed and used," writes Ankur Patel, principal program manager, Microsoft Identity Division, in a February 12 post titled "Decentralized Digital Identities and Blockchain–The Future as We See It."

That type of scale puts blockchain's decentralization benefits at risk, so additional technologies—not to mention consumer acceptance—will be needed. To the company's credit, it seems to be taking this moonshot with eyes wide open: "New systems and big ideas often make sense on a whiteboard. All the lines connect, and assumptions seem solid. However, product and engineering teams learn the most by shipping," Patel writes.

Truer words were never spoken, and engineering teams have a lot to learn about distributed ledger technologies. But if blockchain lives up to half the hype, it'll allow many potentially disruptive digital technologies to reach their full potential. DE

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

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TECHNOLOGY FOR OPTIMAL ENGINEERING DESIGN

INSIDE

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ON THE COVER: Images courtesy of Autodesk, Dassault Systèmes and Thinkstock/Zoonar RF

FOCUS ON DATA MANAGEMENT

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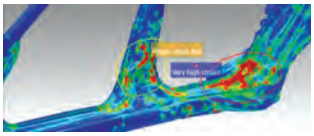

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Data's Disruptive Impact

HELP WANTED

47%

Executives ranked A.I. / machine learning as the disruptive technology with the single-greatest potential impact to their businesses over the next decade — beating out the internet of things, fintech solutions, cloud computing and blockchain.

— "Big Data Executive Survey 2017," New Vantage Partners, January 2017

28%

Demand for data scientists and advanced analysts is projected to spike 28% by 2020. Data science and analyst jobs take five days longer to find qualified candidates than the market average. IBM projects by 2020 the number of jobs for all data professionals in the United States will increase by 364,000 openings to 2,720,000.

— "The Quant Crunch: How The Demand For Data Science Skills Is Disrupting The Job Market," IBM, Burning Glass Technologies, and BHEF, 2017

85% have data-driven programs **37%** have been successful so far

More than 85% of respondents report that their firms have started programs to create data-driven cultures, but only 37% report success thus far. Only 1.6% of respondents deemed their big data initiatives failures.

— "Big Data Executive Survey 2017," New Vantage Partners, January 2017

Data: The Current Currency

$76B 2020

$57B 2017

In 2017, big data vendors will make more than $57 billion from hardware, software and professional services.

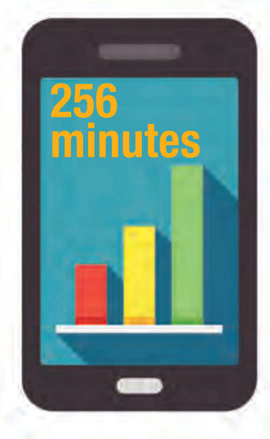
10% CAGR These investments are further expected to grow at a compound annual growth rate of approximately 10% over the next four years, eventually accounting for over $76 billion by the end of 2020.

— "Big Data Market: 2017–2030—Opportunities, Challenges, Strategies, Industry Verticals & Forecasts," SNS Research, April 2017

Mobile Data

People around the world will spend an average of 122 minutes a day accessing the mobile internet via browsers and apps, an amount that has grown from 10 minutes a day since 2010. The average person spent 456 minutes consuming media in 2016, up from 411 minutes in 2010.

— "Media Consumption Forecasts," Zenith, May 30 2017.



44% Mobile internet consumption increased at an average rate of 44% a year between 2010 and 2016 and accounted for 19% of all global media consumption in 2016. Zenith expects mobile to be 26% of all media consumption by 2019.

— "Media Consumption Forecasts," Zenith, May 30, 2017.

IoT Data Growth

$3.9 to $11.1 Trillion

The IoT could have an annual economic impact of $3.9 trillion to $11.1 trillion by 2025, with factory IoT use contributing the most ($1.4 to $3.7 billion) to that impact.

— McKinsey Global Institute analysis, McKinsey & Company, May 2017

40% IoT edge data

By 2019, at least 40% of IoT-created data will be stored, processed, analyzed and acted upon close to or at the edge of the network.

— IDC FutureScape: Worldwide Internet of Things 2017 Predictions, November 2016

CAASE18 Preview: AI Bounty Hunters & Change Management

BY KENNETH WONG

JERRY OVERTON, a data scientist in DXC Technology's Analytics Group, thinks it's time to teach the machines to think for themselves, in a manner of speaking.

In his upcoming talk at the Conference on Advancing Analysis and Simulation in Engineering (CAASE, June 5-7, Cleveland, OH), Overton plans to give real-life examples of how artificial intelligence makes an innovative difference in manufacturing. He is one of six keynoters at CAASE, which is being co-hosted by NAFEMS and *DE*.

"The biggest problem with AI application to manufacturing is, there are so many options," explains Overton. "You can use it in different areas, ranging from part manufacturing and part configuration to supply chain management."

Overton suggests looking at AI as a supercharged search engine, where you can find the best answer to specific issues. For example, you might look for the best solution to predictive maintenance, equipment reliability or safety risk minimization.

But getting that search engine into your current operations and offerings may take some outside help.

For the complete preview of Overton's CAASE18 keynote, visit digitaleng.news/virtual_desktop/?p=13608.

Jerry Overton and Caralynn Nowinski Collens

Collaboration Challenges

Caralynn Nowinski Collens, CEO of UI LABS, will also make a keynote presentation at CAASE. She says now is the right time to tackle the communication hurdles in manufacturing. "The companies in manufacturing face both technology and people problems," she observes. "Sometimes, what they need are digital tools. Sometimes, they need change management tools."

Neither digital tools nor process management methodologies are new. CAD and PLM programs have existed for more than two decades. Change management has been part of manufacturing for much longer. But Collens believes the present time offers new opportunities.

"There's now more appetite to look beyond one's own company's four walls for collaborators," she points out.

The UI in UI Labs stands for university and industry. UI Labs describes itself as "an innovation accelerator that leverages a network of hundreds of partners from university + industry."

In May 2015, UI Labs opened the Digital Manufacturing and Design Innovation Institute (DMDII). Based in Chicago, it is one of two applied R&D programs run by UI Labs and part of the Manufacturing USA network of institutes, all sharing the common aim to accelerate U.S. manufacturing as a whole.

Collens believes the communication and integration hurdles she has observed, if resolved, can dramatically speed up manufacturing.

For the complete preview of Collens' CAASE18 keynote, visit digitaleng.news/virtual_desktop/?p=13692.

CAASE18

The Conference on Advancing Analysis & Simulation in Engineering

June 5 - 7, Cleveland, Ohio

CAASE Preliminary Agenda Announced

The Conference on Advancing Analysis & Simulation in Engineering (CAASE) will take place June 5-7 in Cleveland, OH, but you can get a sneak peek at the agenda and abstracts now. CAASE18 will bring together the leading visionaries, developers and practitioners of CAE-related technologies in an open forum to share experiences, discuss relevant trends, discover common themes and explore future issues.

The 190 CAASE18 presentations, 15 training courses and 13 workshops will be centered around four key themes:

1. Driving the Design of Physical & Biological Systems, Components & Products
2. Implementing Simulation Governance & Democratization
3. Advancing Manufacturing Processes & Additive Manufacturing, and
4. Addressing Business Strategies & Challenges.

Visit NAFEMS.org/2018/americas/agenda to download the preliminary agenda and abstracts. Register for CAASE18 at NAFEMS.org/2018/americas/conference_registration, and don't miss the opportunity to visit the world's foremost museum devoted to the celebration and preservation of rock & roll music, the Rock & Roll Hall of Fame.

Dassault Systèmes Wants to be the Amazon of Manufacturing

BY KENNETH WONG

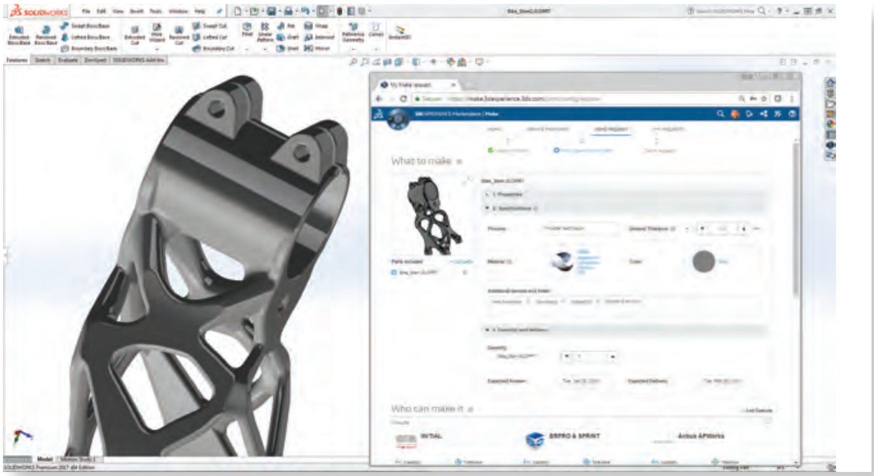
SOLIDWORKS CEO Gian Paolo Bassi and Dassault Systèmes CEO Bernard Charles entered the SOLIDWORKS World 2018 (SWW18) convention in a whimsical fashion—riding a steampunk carriage dubbed "A Moveable Feast," the creation of Two Bit Circus.

Two Bit Circus is, to use the creators' own words, "a band of mad scientists, roboticists, visual artists and storytellers … [who mix their] multiple disciplines into a breathtaking fusion of science, technology and creativity."

For the mad scientists, roboticists, engineers and designers assembled inside the LA Convention Center last month, SOLIDWORKS had ample announcements. A robust mix of new offerings and partnerships punctuated the keynotes and customer showcases.

Dassault Systèmes, the Paris-headquartered parent company of SOLIDWORKS, is steadily building up capacities in its 3DEXPERIENCE Marketplace, to do in manufacturing what Amazon has done with the books and consumer goods industry. The products and services from SOLIDWORKS are interwoven into Dassault Systèmes' vision.

That means SOLIDWORKS, which sprung into existence as a design software developer in the mid-'90s, is swiftly moving toward the manufacturing floor, into the real world of making things.



3DEXPERIENCE Marketplace Make is populated with a network of qualified on-demand manufacturing service providers. ***Image courtesy of SOLIDWORKS.***

Community and Services

SOLIDWORKS World's Day One announcements included the launch of 3DEXPERIENCE Social Collaborative Services and 3DEXPERIENCE Marketplace Make. The former is, as the name suggests, social media-style collaboration tools. The latter brings on-demand manufacturing, to connect designers with a variety of manufacturing services providers (both subtractive and additive).

The two are part of 3DEXPERIENCE Marketplace, a larger portal that also includes 3DEXPERIENCE Marketplace Parts Supply. Users will be able to search, both by shape and by meta data, the desired 3D components from part suppliers who are part of the network. The Marketplace Parts Supply library also incorporates 3D Content Central, an established part library associated with the SOLIDWORKS user community.

"With a few clicks, you'd be able to submit your part and have it made by one of the providers from around the world that we have selected and qualified," said Bassi. "In your browser, just like on Amazon, you can specify what you want."

3DEXPERIENCE Marketplace Make is now online, available to take orders. On-demand service providers such as Xometry and Plethora, and designer-vendor matchmaking sites like Fictiv could become part of Marketplace Make, explained Suchit Jain, VP of Community and Strategy for SOLIDWORKS.

"The goal of Marketplace Make is to have certified suppliers, including small shops, big shops and service bureaus," Jain added. "The platform will be integrated with both SOLIDWORKS and CATIA." It is, however, not exclusive to parts created in Dassault Systèmes products. Make vendors will service all parts created in the supported CAD and neutral 3D file formats.

The ambition of 3DEXPERIENCE Marketplace, stated a number of SOLIDWORKS executives at SWW18, is to become "the Amazon of manufacturing," with the same broad appeal and scope of services offered.

For more on SOLIDWORKS World, including the announcement of SOLIDWORKS Product Designer and partnerships with HP, 3D Systems and Desktop Metal, visit digitaleng.news/virtual_desktop/?p=13670.

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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.*

CODING

by Tony Abbey

Engineering Hacks

Editor's Note: *Tony Abbey teaches live NAFEMS FEA classes in the United States, Europe and Asia. He also teaches NAFEMS e-learning classes globally. Contact him at tony.abbey@nafems.org for details.*

BEFORE THE TERM "HACKING" was used to describe antisocial and probably illegal activities on the internet, it was used to describe patching together a computer program to do a specific, usually limited, task. Today, of course, this is called an app. Examples of hacking usage included calculating beam section properties, deriving von Mises stresses, etc.

At the time, this was a big leap forward compared with writing down hand calculations on a piece of paper. Simple mathematical errors could be eliminated and no handwriting deciphering was required.

The tools available to create these programs were invariably based around the original BASIC language. This was often a spaghetti-like sequence of GOTO statements. More sophisticated users adopted FORTRAN.

Lean Approach to Hacking

A typical program written in the '70s and '80s would have less than 50 lines of code and would run in a strictly stand-alone mode. The attraction of coding in this way was that it was quick and simple. It was a very linear approach to programming: The code was not reusable and not encapsulated in any form of object-oriented paradigm. Many would consider it a disgrace to modern programming ethos! The same functionality created today could run to thousands of lines of code when fully compiled into a graphical user environment with many supporting libraries and functions.

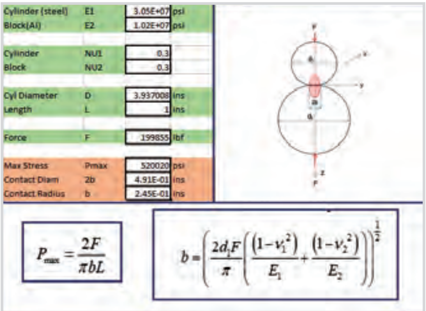

Fig. 1: Excel spreadsheet example.

One of the limitations of this approach was that it required a computer. In those days that meant a walk to the computer center, or to an early, centralized workstation such as the Wang or the PDP-10. The initial wave of programmable calculators such as the TI-59 and the TI-66 gave an alternative, but they were rather tedious with arcane programming languages and the requirement to keep a library of magnetic strips.

For me, the revolution in hacking came with introduction of the early personal computers. In the UK, the Apricot personal computer became widespread, with a good BASIC interpreter. I believe the TRS-80 played a similar role in the U.S.

Hacking with Spreadsheets

The simple and quickly coded BASIC or FORTRAN program predated the use of spreadsheets. When the first spreadsheets appeared, such as Lotus 1-2-3 and Symphony, they were very primitive and awkward in syntax. They did not generally supplant the one-off computer program. Creating applications was much more difficult than with today's Excel. Excel arrived in 1990 and was an instant hit, certainly with me. It was a quick and simple solution to programming those engineering hacks.

Almost all of the FEA work I do today is supported in some way by calculations or data manipulation within Excel. A lot of the work is very ephemeral; it is a scratchpad replacing the back of the envelope, used today and deleted tomorrow.

Going Beyond Hacking

If I want to write a more sophisticated program, rather than the immediate hack, then I use MATLAB or Visual Basic. Python seems to have a big following as well. I am reluctant to get too deep into Excel to do more complex programming. It is almost impossible to check the flow of calculation, and the accuracy of cell referencing, in anything other than the most basic spreadsheet calculations. I know my limitations and it takes a tremendous amount of discipline to make sure that the spreadsheet is correct. This may be endemic across all of Excel usage.

You could argue that the same issue would apply to my simple hacks. However, my defense is that it is no different in that sense from hand calculations. Big errors can be made in hand calculations, but the scope is so simple that there is a natural checking process based on common sense.

A Recent Hack

An example of a recent engineering hack is shown in Fig. 1. The task here is to calculate the contact radius and maximum stress due to Hertzian contact of two rollers. This is an example I use in my non-linear e-Learning course. It is fast to set up the spreadsheet and easy to play around and check the sense of the numbers. I have tidied this up for the course and for the presentation here. Normally I wouldn't spend any time on the color coding and insertion of the parent equations.

An interesting alternative to creating my own spreadsheet here is to use any of the many calculators that do exactly the same task online. There are a tremendous variety of engineering calculators out there. The only problem is that you are not always lucky in finding exactly the right application that suits you. There is also always the concern that the app might not be accurate.

How Do I Hack in the Future?

Taking this idea one step further, I have recently been exploring the possibility of an online programming language that will allow me to quickly create this type of hack. I got excited when I saw there was actually a program called Hack! However, a quick look revealed a rich set of object-oriented constructs to create extremely sophisticated applications.

I also looked at the fascinating cloud-based program called Ruby. At least part of this effort is aimed at teaching young children to code. So, I thought it was probably worth a look! It is a very pleasant and engaging interface; amazingly, it quickly gets too sophisticated for my needs.

Going back to my roots, there are numerous virtual implementations of programmable calculators online. However, these are not quite sophisticated enough.

Somewhere in the middle must be a straightforward pragmatic coding language, suited to aging hackers such as myself. If anybody has any recommendations, please let me know. **DE**

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Tony Abbey *works as training manager for NAFEMS, responsible for developing and implementing training classes, including a wide range of e-learning classes. Check out the range of courses available: nafems.org/e-learning.*

The Convergence of Design & Manufacturing

Tighter integration of CAD and CAM can eliminate problematic geometry.

BY KENNETH WONG

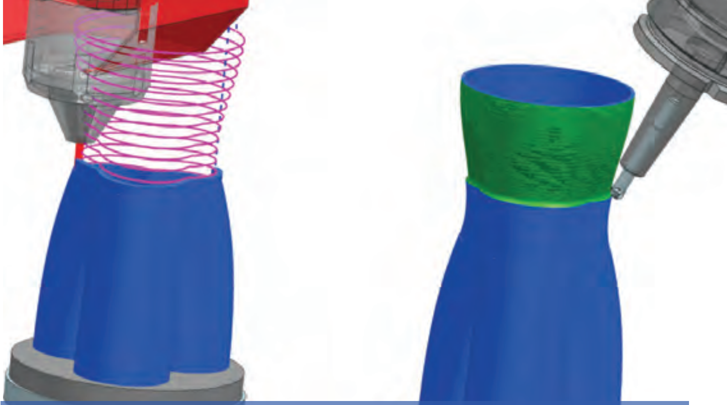
A FAMILY FRIEND OF AL WHATMOUGH possesses what many might describe as a highly specialized skill: sculpting bears out of trees using a chainsaw. Seeing him in action, Whatmough once asked: "How do you know where to cut?" The chainsaw artist replied: "It's easy. I just cut away everything that's not the bear."

In this pithy answer Whatmough found a good analogy for the way 3D CAM (computer-aided manufacturing) software works. "The software knows the stock; [it] knows the tool. So it creates toolpaths to cut away the stock until it ends up with your model [the part you've designed in CAD]," says Whatmough, Autodesk CAM product manager for the Autodesk Fusion product line.

The description may be simple, but the toolpath programming is not. A novice programmer might not be able to distinguish the areas that require precision and delicacy from those that can be liberally hacked away, thus creating a toolpath strategy that takes much longer. In CAM, longer machine runtime equates to higher cost. Therefore, one of the goals should be to produce the model in the shortest time possible. That skill is outside the realm of some CAD users.

Furthermore, designers who are unfamiliar with manufacturing methods may not be able to recognize features that are costly or impossible to produce. CAD products with built-in manufacturing intelligence, many believe, can prevent the hiccups that tend to occur in the transition from design to manufacturing—from concept to reality.

The integrated NX CAD-CAM software lets engineers program robots to perform CNC machining and machine tending using one system. *Image courtesy of Siemens PLM Software.*



Hybrid additive manufacturing incorporates 3D printing with CNC machining methods in a single machine. Shown here is how NX CAM software enables users to design parts that leverage both methods. *Image courtesy of Siemens PLM Software.*

The Call for Upfront CAM

The need to merge the two independent disciplines (design and manufacturing) and the digital tools that serve them (CAD and CAM) sprung partly from the recognition that many CAD users unfamiliar with manufacturing processes were creating CAD models with characteristics that were impractical or impossible to manufacture.

The logic seems irrefutable. A full set of CAM tools might be overwhelming to the average CAD user; however, a limited set of CAM tools nested within the familiar design software might stop a slew of problematic and unmanufacturable CAD parts from ever being conceived.

"CAD is for creating geometry. CAM is for creating digital manufacturing instructions. In that sense, every CAM tool needs some geometry creation tools. After all, the users need to be able to create toolpaths on the model. And a standalone CAM system is a system with fewer geometry creation features," Whatmough says.

In 2012, Autodesk acquired HSMWorks, which develops well-known CAM plug-ins compatible with mainstream CAD packages. HSMWorks continues to develop and market the stand-alone products for Dassault Systèmes SOLIDWORKS, a rival product to Autodesk Inventor. But much of HSMWorks' features have also become part of Autodesk Fusion 360, the cloud-straddling CAD-CAM-CAE package from Autodesk. Autodesk Fusion 360's CAM functions include 2.5-, 3-, 4- and 5-axis milling, turning with live tooling as well as cutting operations to drive laser, waterjets and plasma cutters.

In 2017, SOLIDWORKS debuted SOLIDWORKS CAM (SW CAM), powered by the technology from HCL. A long-time SOLIDWORKS Gold Partner, HCL is better known for its CAMWorks software, available for integration with SOLIDWORKS and Solid Edge (from Siemens PLM Software).

SWCAM Standard, accessible to those with SOLIDWORKS subscription licenses, supports a 2.5-axis machine. SW CAM Pro, available as an add-on to all desktop versions of SOLIDWORKS, supports 3+2 programming to drive four- or five-axis machines. Whereas SW CAM Standard supports single-part machining, SW CAM Pro supports part and assembly machining.

Common Mistakes

A good CAD program gives the users a comprehensive set of parametric modeling tools to create any geometry imaginable. But in manufacturing, where the digital CAD models must be made into tangible parts destined for installation in planes, cars and other consumer goods, not all geometry is greeted with the same enthusiasm. Some increase the production cost unnecessarily; others are simply impossible to be machined, cut or molded.

"The milling machine uses a cutter that spins, so it leaves radiuses in pockets and corners," Whatmough says. Without realizing it, some CAD users might "create sharp corners arbitrarily where they're not needed. Or they may put a radius that's far too small."

For some CAD users, the choice between a chamfer and a fillet may simply be the preference for sharp edges or rounded edges. But on the shop floor, these choices have financial consequences. "To machine a fillet, you need a specific type of cutter. But if you put a chamfer instead, one tool could be used for a wide variety of chamfers," Whatmough says.

Different Types of CAM

It's good to think of CAM software's simulation capacity in three distinct levels:

1. back plotting, which simulates the tool's movement along the toolpath;
2. stock removal, which simulates how and where the materials are removed during machining; and
3. kinematic machining, which simulates the machine's operation.

CAD-integrated CAM products generally target the first two. That is, they let users simulate and visualize the back plotting and stock removal processes. For most parts, these features prove sufficient to catch and fix problematic geometry in the conceptual design phase. Kinematic machine simulation is usually found in dedicated and higher end CAM programs used by manufacturing engineers.

It may also be helpful to divide mainstream and higher end CAM programs into the type of milling operations they support. Mainstream CAM and CAD-integrated CAM programs tend to support 2-, 2.5- or 3-axis operations, which address a majority of the parts made. Higher end CAM programs offer the more complex four- or five-axis machining operations that allow the part to be machined from a greater number of angles and directions.

"It's easy to simulate where the tool goes, or when it goes where it shouldn't and crashes. That's a standard functionality in most CAM software," says Whatmough. "But simulating to find out whether your fixtures and supports will hold up or not during machining—that's much more difficult. It's currently not done."

The Integration Advantages

SOLIDWORKS CAM uses automatic feature recognition, a strategy much more suitable for those with limited CAM ex-

Fusion 360 combines industrial and mechanical design, simulation, collaboration and machining in an integrated concept-to-production toolset. *Image courtesy of Autodesk.*

pertise. Mike Buchli, senior product and portfolio manager for SOLIDWORKS CAM, describes it as rule-based machining.

"SW CAM recognizes machine-able features, like pockets, bosses, cuts, holes and contours," explains Buchli. "Once these features are identified, the software automatically applies suitable tooling strategies based on the size and shape of each feature. The rules come from a database, but they're also customizable."

Detailing the features of SOLIDWORKS CAM in a blog post, Buchli writes: "The biggest advantage of Rules-Based Machining for designers and programmers is the ability to read MBD data [manufacturing data] within the SOLIDWORKS part file. SOLIDWORKS CAM will understand the tolerances within a given part file and change machining strategies accordingly ... The process also reduces the chance for error and the possibility of missing a dimension on a traditional drawing."

Developed by a company with deep roots in manufacturing, Siemens PLM Software's NX software includes different types of manufacturing checks that you can perform in various phases of your design, according to Vynce Paradise, senior director, advanced part manufacturing, Siemens PLM Software.

"In part design, you can check draft angles, maximum radiuses and use the Synchronous Technology to make geometry adjustments. If you're the machine programmer, it's also important for you to visualize the toolpath to see if there could be any clearance problems. At the machine level, you check the G-code [instructions for the machine]. NX includes G-code simulation in the programmer's environment," Paradise says. "With NX, you can use templates to predefine the machine or programming methods and apply them to your model. This is important, especially for novice users."

Vero Software, owned by Hexagon Manufacturing Intelligence, offers PC-based CAD-CAM package VISI, targeting the mold and die industries. "If you have vertical walls in a mold, it's much more difficult to get the part out of the mold, so you need to add draft angles," says Steve Sivitter, CEO of Vero Software. "And in sheet metal bending, if you want a 90° bend, you need to bend a bit more to account for the spring-back effect."

VISI includes automatic draft angle analysis and spring-back remedies in the software, Sivitter says. The software can correctly predict such manufacturing idiosyncrasies and recommend fixes because CAD and CAM are tightly interwoven in the same program. In a CAD package developed for design creation exclusively, "the software may not care or have any concern about whether you can actually make your part, or how you could redesign it to make it manufacturable," he adds.

VISI remains a standalone CAD-CAM product for its niche. The software can work with CAD files produced in other mainstream CAD programs, but it's not available as a plug-in, for good reasons. If VISI were to become a plug-in, "it [would] diminish our software's features and there may also be an additional cost associated with the CAD licenses," explains Sivitter.

Convergent Modeling on the Horizon

At the present, subtractive manufacturing that uses machine tools and additive manufacturing that uses 3D printers are regarded as two distinct options. The hardware and the software that serve the two are also in their own distinct categories: milling machines and CAM software for subtractive; 3D printers and additive design simulation software (an emerging category) for additive. But the birth of hybrid hardware—machines capable of additive and subtractive operations—suggests the two are converging.

Four years ago, DMG Mori unveiled its first hybrid system, the LASERTEC 65 3D. The company announced it had integrated, "for the first time, additive manufacturing into a high-tech five-axis milling machine. This innovative hybrid-solution combines the flexibility of the laser metal deposition process with the precision of the cutting process and therewith allows additive manufacturing in milling quality."

Last December at the Additive Manufacturing Americas Conference (Pasadena, CA), CNC machine maker Matsuura's LUMEX made its U.S. debut. The product line is classified as additive manufacturing CNC milling. The company wrote: "The ability to 'grow' a metal component in layers with complex internal features and mill those internal features as the layers are added ... [make] the LUMEX Series machines such a distinctive and remarkable production machine tool."

"My belief is, convergence is inevitable," says Whatmough. Buchli agrees. "As technologies advance, there may be cases where you want to print a part in metal and then put it through CNC machine to cut specific areas to a tighter tolerance," he says.

For CAD and CAM software developers, it's an opportunity and a challenge. "As we get into 3D printing, we have to create new ways to check geometry, new ways to decompose the part to figure out the build sequence," says Paradise. "That's an area that's still in development."

With topology optimization paving the way for more complex shapes, machine tool operations with hybrid hardware could also become much more complex. "For a long time, we automate things like feature-based machining—recognizing specific geometric features and being able to suggest specific machining strategies. Now, we're looking at AI as a way to augment that. We could, for example, use machine learning to study the way NX users program their parts. We could use AI to program for more complex shapes," adds Paradise.

No Replacement for Communication

Digital manufacturing erases time zones and physical boundaries. Parts designed in the U.S. and Europe can be securely transmitted to be molded and machined in Taiwan, Malaysia or Singapore. The data management systems allow contractors and clients to monitor the project phases. Software lets both design and manufacturing to occur virtually in the same environment. These give the illusion of communication. Yet, there's no substitute for the old-fashioned people-to-people communication.

"With an integrated tool [CAD-CAM], the line between design and manufacturing becomes blurred," notes Whatmough. "So, if the users are not careful, they could end up with a messy environment where the design files and the manufacturing files are not clearly distinguished." 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 → **Dassault Systèmes:** 3DS.com

→ **HCL Technologies:** HCLtech.com

→ **Autodesk:** Autodesk.com

→ **DMG Mori:** DMGMori.com

→ **Matsuura:** Matsuura.co.uk

→ **Vero Software:** Verosoftware.com

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

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Something for Everyone

SOLIDWORKS 2018 delivers features to support a complete design-to-manufacturing process.

BY DAVID COHN

DASSAULT SYSTÈMES RECENTLY began shipping SOLIDWORKS 2018, the 26th release of the company's parametric, feature-based solid modeling software. The new version delivers more than 200 new features and improvements across all aspects of the software, most created in direct response to customer requests.

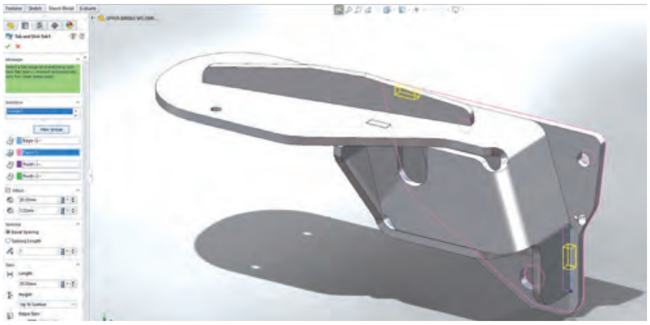
The changes in SOLIDWORKS 2018 are evident as soon as the program starts. A new Welcome dialog provides a convenient way to open documents, view folders and access resources. The dialog has four tabs—Home, Recent, Learn and Alerts—and can be accessed at any time by clicking the Home button on the standard toolbar.

Changes to the interface don't end there, however. Mouse gestures, first introduced in SOLIDWORKS 2010, enable users to execute a command or macro by right-clicking and dragging the mouse in the graphics area to display a wheel-like menu. In previous releases, the number of possible gestures was limited to four or eight, and customizing gestures was often cumbersome. Now, SOLIDWORKS 2018 users can set the number of mouse gestures to two, three, four, eight or 12, and assigning commands to mouse gestures is quite easy with a drag-and-drop user interface. You can drag tools from a list of commands onto one of four mouse gesture guides, enabling users to quickly configure different mouse gestures when working on a part, assembly, sketch or drawing. Drag-and-drop also can be used to reposition tools or remove tools from the wheels.

Touch-based interactions represent a third major user

A new Welcome screen provides a convenient way to open documents, view folders and access resources.

Changes to the Customize dialog make it extremely easy to customize mouse gestures.



The new Tab and Slot feature lets users create self-fixturing parts.

Create misaligned concentric mates and choose how to resolve imperfect conditions.

interface enhancement. With the latest Windows 10 Creators Update, more users can take advantage of touch. When touch is turned on, a toolbar of commonly used tools appears and the program optimizes the size of on-screen manipulators and other tools. Sketch with your finger (or a stylus), and when used in conjunction with Auto Sketch Entities, the software analyzes the rough sketch and automatically converts it into sketch entities without having to preselect the type of entity to draw.

Native Files and Model Display

3D Interconnect, first introduced in SOLIDWORKS 2017, replaced the software's previous translation capabilities with new technology and workflows for working with third-party native CAD data. It enabled users to insert files saved using other programs directly into assemblies as they would any SOLIDWORKS file. Then, they are treated like native components, and designs can be easily updated when those CAD files change. That first iteration supported files created in CATIA, Inventor, Pro/Engineer, Creo, Solid Edge and NX. With SOLIDWORKS 2018, 3D Interconnect now supports STEP, IGES, ACIS and JT files as well. In addition, the software can read additional information from native third-party files, such as assembly cut features, custom properties, material properties and unconsumed sketches and curves.

SOLIDWORKS 2018 also introduces ways to use data from other sources, including mesh data in a variety of formats, such as STL and OBJ. The new Surface from Mesh feature lets users quickly select faces from mesh data and turn them into surfaces. Users also can turn mesh data into a new mesh body type and then add SOLIDWORKS features and geometry.

When opening an assembly, the program now shows a progress indicator that provides information about what is happening while the assembly is opening, including how long it is taking, the number of parts and how many have opened. In addition, the Assembly Visualization tool helps troubleshoot assembly performance. For example, you can view the open and rebuild times for components, and the total number of graphics triangles for all instances of components.

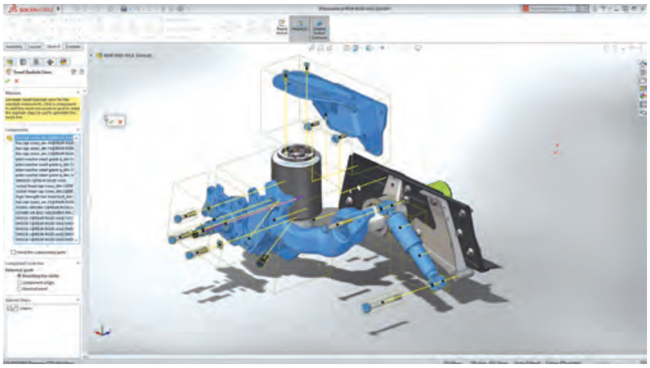
If SOLIDWORKS 2018 encounters a corrupted file that it is unable to repair, the software now prompts with an option to extract geometry if the body data of the file is still intact. After the software imports the geometry from the corrupted file into a new file, the geometry can be used to add features to create a new model, although the new file will not contain any feature history.

Parts, Features, Sheet Metal and Drawings

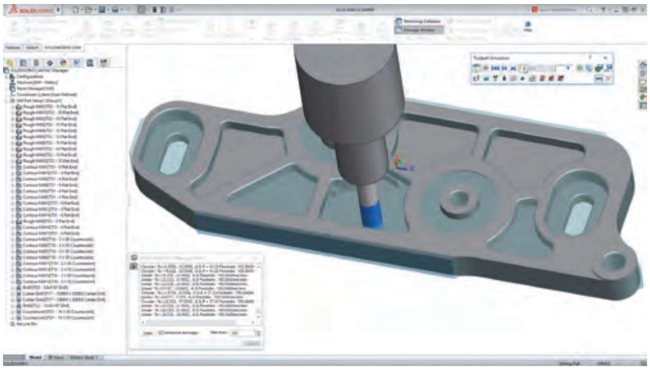
The Bounding Box tool in SOLIDWORKS was previously limited to cut list items in weldments. In the new release, users can now also create a bounding box around a single body or multi-body part or a sheet metal part. The resulting bounding box encloses the model with a minimum volume. For irregularly shaped objects, align the bounding box with a reference plane or reference surface. When the part updates, the bounding box automatically resizes. Users can include hidden bodies and surfaces in the bounding box as well as hide, show, suppress and unsuppress a bounding box from a shortcut menu.

Bounding box properties are available in the Configuration Specific tab of the Summary Information dialog. The dimensions of these properties can help determine the space required to ship and package a product.

Sheet metal improvements include a new Tab and Slot feature that creates tabs on one body and slots on another to interlock the two bodies. Tabs and slots make it easier to weld parts together and minimize the requirement to build complicated fixtures because users can interlock several parts. But tabs and slots are not limited to just sheet metal; use this feature in single bodies, multibodies and parts in the context of an assembly. Edges and faces must correspond to each other—when selecting an edge for the tabs, select a matching face for the slots. The edges and faces must be planar or cylindrical, but they do not have to touch.



Smart Explode Lines in SOLIDWORKS 2018 saves manual work by creating automatic explode lines.



SOLIDWORKS 2018 includes SOLIDWORKS CAM Standard, providing rules-based 2.5-axis milling and turning to generate NC code and preview cutter paths.

Other sheet metal enhancements include a new Normal Cut feature, which ensures that proper clearances are maintained for manufacturing, and improvements to three bend corner reliefs. If a corner relief is smaller than the required corner cutout, it is now visible in the folded state. And, now there is the ability to create a suitcase corner—a closed spherical corner without any cutouts.

Drawing enhancements include the ability to insert 3D model views, automatic advanced hole callouts, layer support for cross hatching, new trailing zero display options, broken-out section view support for section views and alternate position views and an All Upper-Case switch capability for text in tables.

Sketching and Assembly Features

When sketching, now there's a capability to mirror a 3D sketch about a plane or a planar face. In addition, 2D sketches can now be mirrored using a plane or a planar surface, and this capability is not limited to just linear entities such as lines or edges. When creating a linear component pattern, now there's an option to add rotation. It is also now much easier to add mates between hidden surfaces: press the ALT key to temporarily hide obstructing faces when selecting mates, so that faces behind them can be seen and selected.

If you encounter a situation where pins and holes are not perfectly aligned, you can define misaligned mates, which allows the option to specify which of the two concentric mates is maintained, or the part can float symmetrically between the two.

SOLIDWORKS 2018 also includes Smart Explode Lines, which lets users create automatic explode lines, eliminating manual steps. And those who have customized SOLIDWORKS will benefit from a new Login option that enables users to synchronize settings between any SOLIDWORKS 2018 installation with a copy of the settings stored in their online account. Online licensing is available regardless of whether users are on subscription; they can switch between online and standard activation if they wish.

Improvements in Other Modules

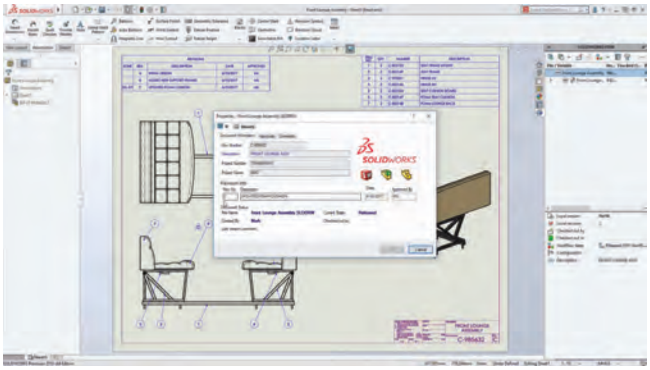
Although these enhancements are available to all users, other new features apply only to specific bundles and some add-ons are only included in those bundles for customers on an annual maintenance subscription. Otherwise, they cost extra. In addition, although Dassault Systèmes continues to sell SOLIDWORKS as a perpetual license, the company also now offers term licensing.

As was true for previous releases, SOLIDWORKS is available in three flavors: Standard, Professional and Premium. SOLIDWORKS Standard ($3,995) provides tools for part and assembly modeling (including sheet metal, weldments, plastic parts and mold design), creating 2D drawings, sharing CAD data (including 3D Interconnect), the ability to perform static and stress analysis on parts and so on.

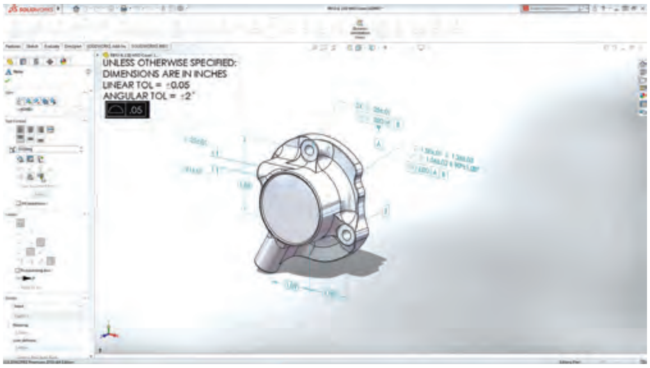
New to SOLIDWORKS 2018 Standard is SOLIDWORKS CAM Standard. Powered by CAMWorks, SOLIDWORKS CAM Standard provides 2.5-axis rules-based machining and automatic feature recognition to streamline NC programming. Cutter paths can be previewed and compared against the original model, helping users identify potential problems long before the physical part is machined. Those not on subscription can purchase CAM Standard for $1,000. The Pro version, which provides additional capabilities beyond 2.5-axis milling and turning, costs $2,400.

SOLIDWORKS Professional ($5,490) adds modules such as photorealistic rendering, parts libraries, task scheduling, reverse engineering, cost estimating and ECAD collaboration (CircuitWorks). It also includes eDrawings Professional, which allows users to send SOLIDWORKS files to people who do not have SOLIDWORKS, giving them the ability to open, measure and markup files.

The Professional edition also includes SOLIDWORKS PDM Standard, which offers data management capabili-



SOLIDWORKS PDM Standard enables management of design alternatives and manages revision updates.



Model Based Definition can eliminate the need for 2D drawings.

ties for small numbers of users. For 2018, new branch and merge capabilities enable users to explore design ideas. Parts, assemblies or drawings can be branched and individual files then included or excluded as one studies alternatives. When deciding on the preferred design, it can be merged back. Revision tables are integrated so that as a new revision is added, the revision number is controlled by the software. When a drawing is checked in, all information is extracted from the drawing, including information from the revision table. When approved, the revision table, revision callouts and title block are all updated. Again, SOLIDWORKS PDM Professional, which provides more full-featured data management capabilities for larger design teams, is sold separately.

SOLIDWORKS Premium ($7,995) includes everything in the Standard and Professional editions and adds motion analysis; structural part and assembly analysis; and routing for pipes, tubes, cabling and wire harnesses. One component in particular—SOLIDWORKS Simulation—sports a host of new features, including Topology studies (the ability to set a design goal to find the best strength to weight ratio, minimize the mass or reduce the maximum displacement of a component) and automatic email notification when an analysis is complete.

The company has also improved various add-ons not included in bundles. For example, Offloaded Rendering (part of Visualize Professional or available separately for $995), enables users to send a rendering to another machine running the PhotoView 360 Net Render Client, freeing up the computer while the rendering is performed on another machine. The second system does not require a SOLIDWORKS license. One can perform a single offloaded rendering or schedule offloaded renderings to run later, such as after business hours.

Model Based Definition ($1,995)—which lets users communicate product and manufacturing information directly in 3D, eliminating the need for 2D drawings—has gained new capabilities, such as applying datum features to patterns. It can also now import parts with 3D annotation from other CAD systems such as Creo, NX and CATIA as well as STEP AP242. Exporting to STEP AP242 is also now fully supported, enabling third-party applications to reuse the intelligent annotations generated in SOLIDWORKS MBD.

All told, SOLIDWORKS 2018 marks one of the most significant releases in years. It continues to stack up well against competing products in what is perpetually a very competitive market segment. **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. Contact him via email at david@dscohn.com or visit his website at dscohn.com.*

INFO ➜ Dassault Systèmes: 3DS.com

SOLIDWORKS 2018

Pricing:

- **SOLIDWORKS Standard:** $3,995 (annual maintenance: $1,295)
  - or term license: $810/three months or $2,700/year
- **SOLIDWORKS Professional:** $5,490 (annual maintenance: $1,495)
  - or term license: $1,080/three months or $4,600/year
- **SOLIDWORKS Premium:** $7,995 (annual maintenance: $1,995)
  - or term license: $1,450/three months or $4,825/year

SYSTEM REQUIREMENTS

Windows:

- **OS:** Windows 10 (64-bit), Windows 8.1 (64-bit) or Windows 7 SP1 (64-bit)
- **CPU:** Current generation of Intel or AMD with SSE2 support
- **Memory:** 8GB minimum (more recommended for large assemblies and simulation)
- **Disk Space:** 5GB or more
- **GPU:** A SolidWorks certified OpenGL graphics accelerator 1GB of RAM (2GB recommended)

Part 2

Siemens FEMAP with NX NASTRAN Overview

Part two of this overview of FEMAP with NX NASTRAN from Siemens focuses on meshing and FE analysis.

BY TONY ABBEY

***Editor's Note:** Tony Abbey teaches both live and e-Learning classes for NAFEMS. He also provides FEA consulting and mentoring. Contact tony@fetraining.com for details.*

WE PREVIOUSLY CARRIED OUT trial meshing on the geometry in part 1 of this article (digitaleng.news/de/siemens-femap-nx-nastran-overview). Now it's time to set up the production mesh. I split the geometry into two bodies to force nodes to be created on the centerline datum plane. I set the FEMAP mesh control option to merge nodes on common geometric faces. Otherwise, the FEA model would have a split between the two meshed bodies.

I am using tetrahedral elements because the geometry is an arbitrary shape. FEMAP supports hexahedral elements, but it would take a lot of work to prepare the geometry for a hexahedral mesh. I have used the default global element size, and the resulting mesh is shown in Fig. 1.

The mesh looks smooth in the figure, but it is inadequate around the blend region between the shaft and the end fitting and through the radial depth of the end fitting-bearing surface.

Fig. 2 shows the blend region in more detail. We are anticipating high stress concentrations around here, and there are not enough elements to produce a good result.

This is a typical starting point in any meshing task, and I use the FEMAP tools to improve the situation. There are a hierarchy of meshing controls within FEMAP.

The top level is the default element size, which is based on overall geometry dimensions. The next level controls the size of elements within a solid body using the body edge curves. The number of elements along each edge curve is used as a guide. There is a default number of

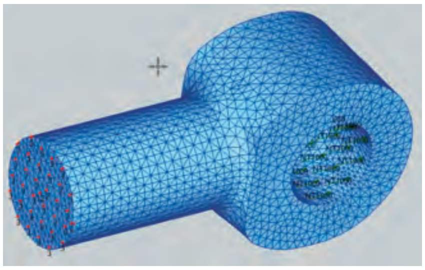


FIG. 1: Initial mesh.

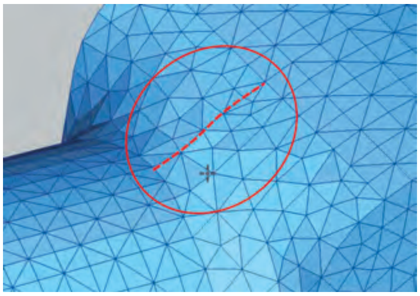


FIG. 2: Poor initial mesh.

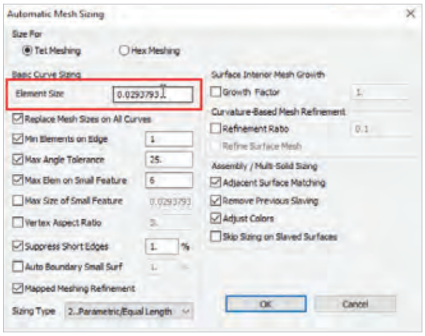


FIG. 3: Meshing controls.

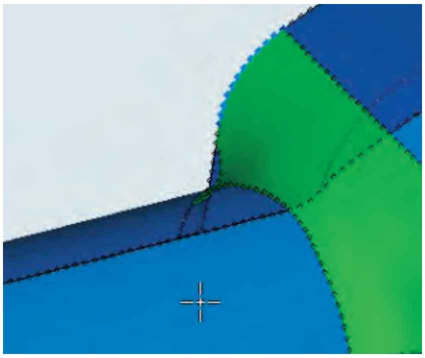


FIG. 4: Preview of mesh.

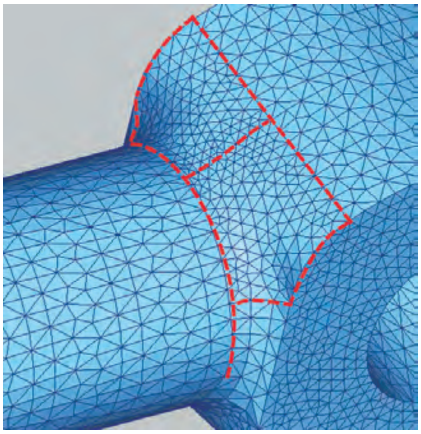


FIG. 5: Improved mesh.

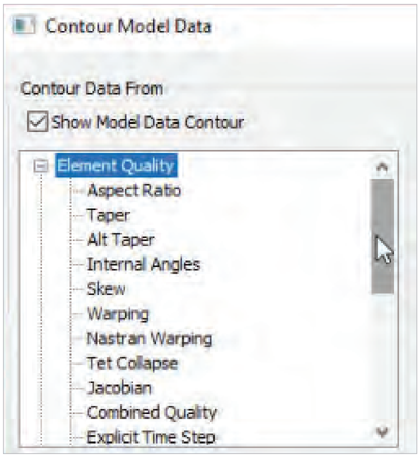


FIG. 6: Mesh quality controls.

elements applied to each edge curve. Using this default results in a similar mesh to that created with the default element size. The default sizes tend to be very conservative and result in a coarse mesh that can be viewed as being adequate for a Normal Modes analysis but usually unacceptable for a strength analysis. The objective is to selectively increase the number of elements along key edge curves to improve the mesh within the body.

There are a rich set of mesh controls, as shown in Fig. 3. These include the rate at which element size grows away from the smallest elements (finest mesh) and curvature-based meshing. It is a good idea to practice on a variety of simple CAD geometry models to get the feel for how these tools interact. Meshing is an art, not a science, and it takes practice.

To attempt to heal poor geometry, it is possible to suppress short edges and eliminate small features. By default, adjacent surfaces, such as in the split bodies in the tie-rod geometry, will have matching meshes, ready for merging.

The emphasis with any preprocessor is to set up a meshing strategy and then experiment. I typically try at least a dozen or more meshing variations before I am satisfied. FEMAP greatly assists here by providing a meshing preview. Fig. 4 shows the edge mesh size visualization as a series of dots. The preview can be easily switched on and off from the toolbar.

I have set this to a very fine value, as a demonstrator. This ability to preview without committing the meshing process speeds up the meshing development. In this case the mesh is so fine that the mesh would take a long time to complete and the element count would be way too high.

It is a good idea to get a feel for a "safe" lower limit on element size. If the mesh is too fine it may take a long time to complete, or even stall the preprocessor.

The strategy I adopted for the blend region between the tie rod shaft and end fitting is to control the mesh size along the key edges, as shown in Fig. 5. I had an initial idea of the number of elements needed on each of these edges. By experimenting with the numbers, I am able to get a reasonable looking mesh.

Progressively increasing the number of elements on edge curves to produce a series of meshes can be a frustrating experience. Mesh quality can jump up and down with no apparent reason. The meshing process is essentially a pattern generator and is very unpredictable, which is why experimentation is key.

I normally recommend approaching each meshing task with a time limit in mind. Allow 30 minutes to produce the best-looking mesh in each critical region. Fig. 5 shows such an effort after about 30 minutes of work.

I have talked about "good-looking" meshes, but we need a more objective assessment of element quality. FEMAP has a range of mesh quality plot options, as shown in Fig. 6. The two I use most from this list are the

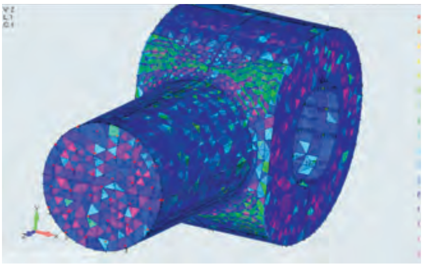


FIG. 7: Tet collapse check.

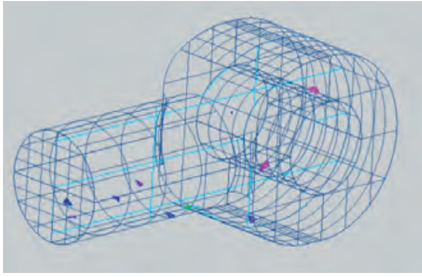


FIG. 8: Rogue elements.

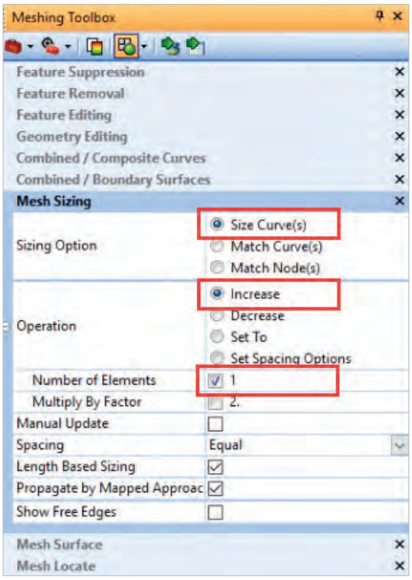


FIG. 9: Mesh toolbox controls.

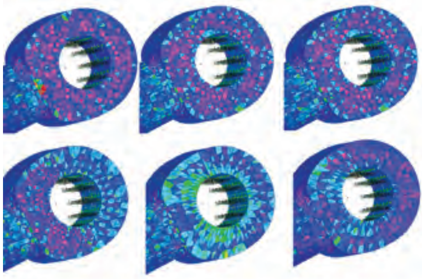


FIG. 10: Montage of mesh quality results.

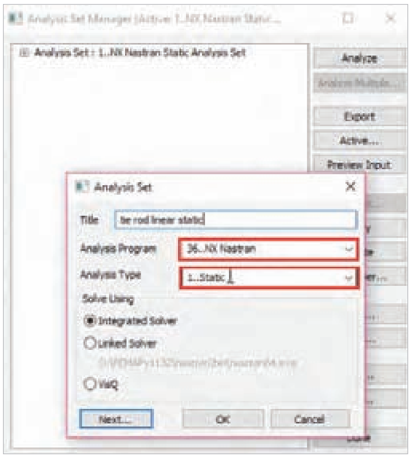


FIG. 11: Analysis setup.

Jacobian and the Tet collapse. Other analysts may have their own favorite metrics.

It is difficult to give advice on what values to use for these two parameters, as each one is solver and element type dependent. I recommend setting up a series of simple geometric benchmarks, such as a solid plate with a hole in it. These can then be meshed and analyzed to correlate stress results with mesh quality. Fig. 7 shows the Tet collapse element quality plot. In my case I used a value of 4.0 as the upper bound on Tet collapse, from inspection.

It is difficult to see the distribution of "rogue" elements that exceed the limit, within the element fill plot for 3D solid structures. One of the control options within the quality contour plotting is to set up a group containing all elements that have exceeded a certain level. In Fig. 8, I have plotted this group. I have also included a wireframe plot of the tie rod geometry.

As an aside, groups are a useful FEMAP functionality. Groups can consist of sets of entities of any mixture. In my case I had a group with rogue elements and solid geometry. Groups can be used to focus on specific model regions, for example, one of the solid bodies and its elements and nodes. They also can be used

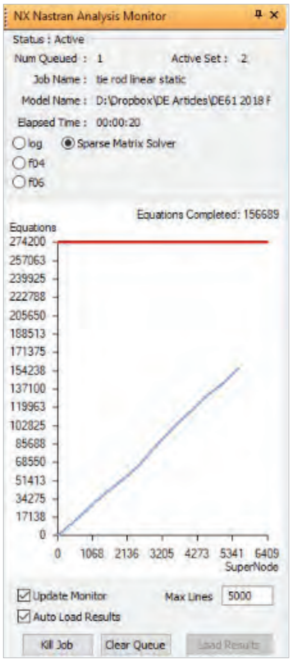


FIG. 12: Analysis Monitor.

as selection tools. I set up the key meshing curves shown in Fig. 5 as a group to allow easy picking. I would recommend that any newcomer to FEMAP practice using groups, as they will underpin many other operations.

An alternative to the manual mesh updating strategy shown so far is to use the FEMAP meshing toolbox. This collection of meshing methods has been developed over the last few years and includes an interactive meshing capability. The controls are shown in Fig. 9. I have set up interactive meshing action using edge control, adding one element to each edge when I run the tool. I can then cycle through and increment that element count automatically.

When using the toolbox, as the mesh is updated, the element quality also updates. Fig. 10 shows a montage of mesh quality plots as I step through a range of meshes with increasing fidelity. The increasing number of elements runs from top left to bottom right in the figure. The plots show the mesh on the in-

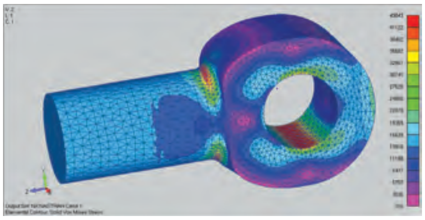


FIG. 13: von Mises stress.

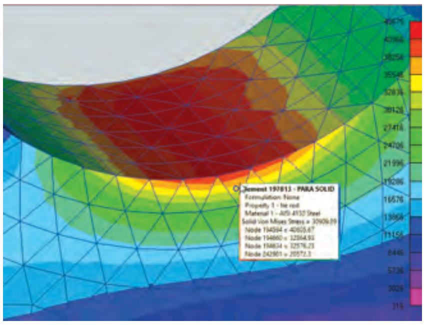


FIG. 14: Tool tips on half model.

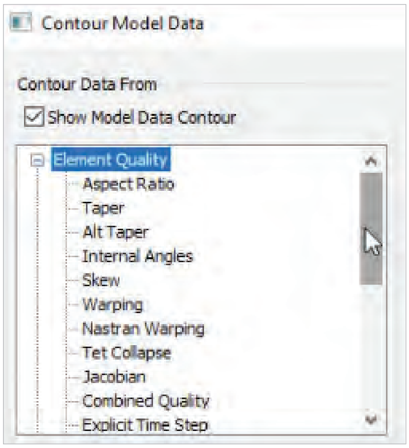


FIG. 15: Deformation.

side face of the fitting, another critical region. The random nature of the meshing operation is clearly shown. One or two configurations are rejected because of "rogue" elements appearing. The ability to experiment and quantify the mesh quality helps greatly in the search for the "perfect mesh." FEMAP allows for a large number of undo and redo operations, so it is easy to step backward and forward to make your pick of the best mesh.

Once meshing is complete, it's time to set up the NX NASTRAN analysis. Fig. 11 shows the analysis control panel. I'm using a static analysis here, but FEMAP supports a full range of analysis available within NASTRAN, including dynamics and non-linear. I've picked the NX NASTRAN solver bundled with FEMAP in my installation. There are many solvers to select, including MSC/MD Nastran, ANSYS, ABAQUS, LS-DYNA etc. This is a reminder that FEMAP started life as a solver neutral pre- and post-processor. If you are using multiple solvers on an FEA project, this can be a useful attribute.

On launching the analysis, an Analysis Monitor pane pops open, as shown in Fig. 12. This allows users to inspect the output text files that contain runtime diagnostics and output data summary. It also tracks the progress of the solver. This is particularly useful in long-running analyses. It also allows monitoring of convergence in non-linear analyses.

Once the analysis is complete, the results are loaded into the FEMAP database and the post-processing toolbar becomes live. The default output quantities are deformation and von Mises stresses. The stress contour plot is shown in Fig. 13.

The default settings for stress plots in the post-processor show a continuous color rendering and use nodal averaging of stresses. I recommend these are changed to, respectively, level colors, to give hard edges to the contours and switching nodal stress averaging off. Stress averaging can hide poor stress distributions and artificially lower the peak stress values.

The highest stresses in the tie rod are along the center line at the end fitting bearing face. This is where the geometric split in the model is useful, as it allows for plotting of the stresses accurately on the cut plane. This is shown in Fig. 14. FEMAP does have section slice controls that allow visualization of stresses in an arbitrary plane. However, these will always be interpolated by the post-processor, whereas geometry slicing guarantees better accuracy on the plane.

Figure 14 also shows the use of tooltips. Any element can be selected, and a text box produced on the plot showing the values of the contour quantity selected. Probing in specific regions is then easily achieved.

Finally, Fig. 15 shows the deformation of the tie rod. This can be scaled to help visualization. Too small a scale, and it's difficult to see the sense of the deformation. Too large a scale can be equally confusing. Here, I have augmented the deformation plot by also plotting a translucent image of the geometry. Other techniques in FEMAP include a wireframe outline of the undeformed mesh.

Deep, but Daunting

FEMAP with NX Nastran is a mature product, providing a rich set of features to carry out mainstream FEA. For a new user, the breadth and depth of functionality can be daunting. However, once an initial subset is mastered, aided by the use of customized toolbars, the "toolbox" can be logically expanded to achieve a high level of productivity.

Key aspects of FEMAP to focus on initially include picking methods, adaptive dialog boxes, adaptive Method menus and groups.

A set of five supporting videos are available for view at digitaleng.news/de/femapnx2. The geometry files for the part are located at digitaleng.news/de/nxgeometry. **DE**

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A New Age of Industrial Analytics

The emergence of the industrial internet of things and a growing appreciation of the impact of big data in this arena have sparked a revitalization of industrial analytics.

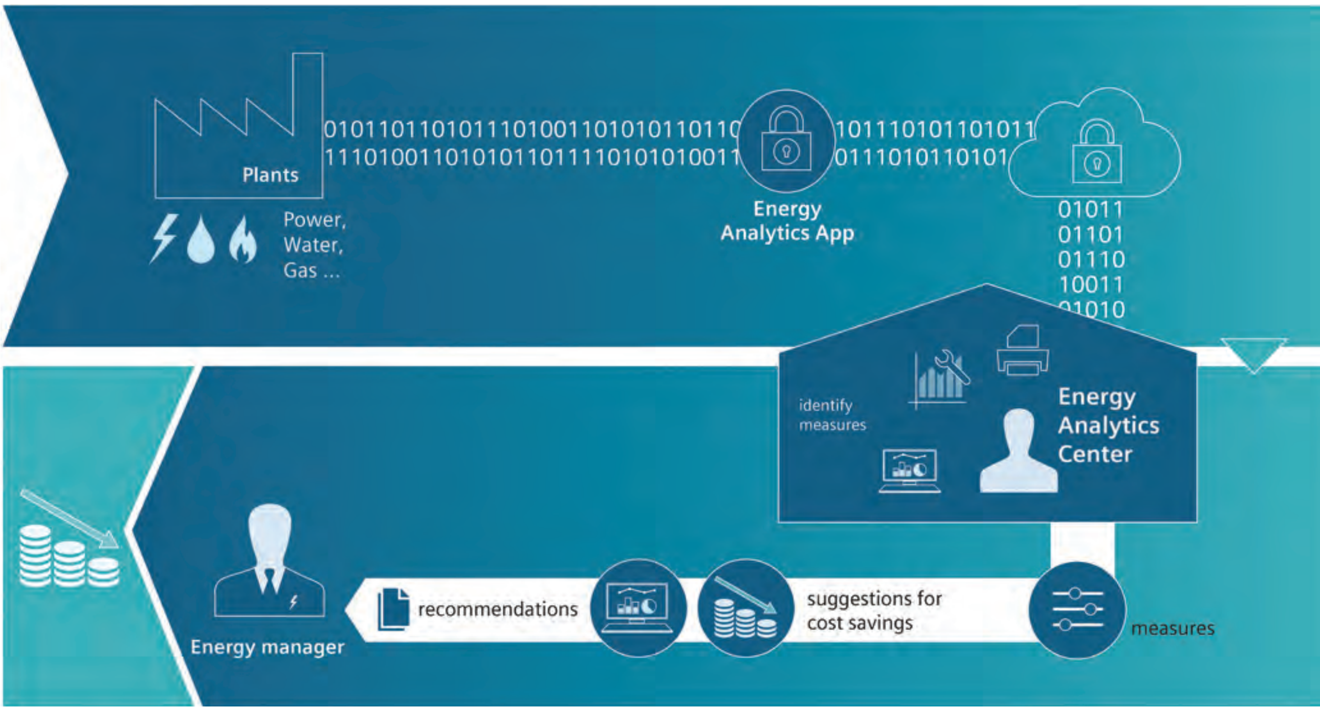
BY TOM KEVAN

THE PRIZE? UNPRECEDENTED VISIBILITY into the production processes, equipment performance and support services at the heart of the industrial sector. The means? Mountains of data from shop floor control and sensing systems. The missing ingredient? Analytics to convert raw plant floor data into insights that will support business and operational decision-making.

To be clear, the problem isn't that the analytics are unavailable. It's more complicated than that. For one, many manufacturers simply are not cultivating an analytics capability. A 2016 Forrester Consulting study (goo.gl/sg6CM1) found that only 33% of the companies collecting data actually leverage this resource to glean actionable insight. The other problem is that finding the right tools to create the analytics your company needs isn't easy.

Shifting Priorities, Expanding Resources

Until recently, analytics has played a limited role in the indus-



Analytics tailored for the IIoT hold the key to unprecedented visibility into industrial operations, promising greater efficiency in areas ranging from manufacturing processes and energy consumption to oil and gas well performance. *Image courtesy of Siemens.*

trial sector, focusing largely on condition monitoring. But the emergence of the industrial internet of things (IIoT) and a growing appreciation of the impact of big data in this arena have sparked a revitalization of industrial analytics.

Businesses have begun to realize that their internal data often provides incomplete answers to key questions confronting them. They have found that they do better by combining internal data sets with those from external sources (for example, another plant). To address this issue, IIoT analytics development platforms and applications increasingly offer technologies like advanced programming interfaces to facilitate the integration of different types of input.

The falling costs of sensors, connectivity and cloud computing have made it much more feasible for automation engineers to capture and move data from physical assets on the plant floor to back-end analytics. This has made deployment of analytics less daunting, and it has enabled a wider cross-section of companies to take advantage of IIoT data.

A more recent development has attracted great attention. Machine learning has begun to enter the mainstream, with engineers using it in a growing number of applications and industries. In the industrial sector, machine learning promises to enable factory managers to glean more insight from their data. Adopting the technology, however, isn't without its challenges. Implementing the technology often requires the expertise of data scientists. Unfortunately, there is a shortage in this area, and the data scientists who are available are expensive. In response to this hurdle, some vendors offer tools that aim to make machine learning more accessible, sweeping aside obstacles that have delayed adoption.

Although these developments have accelerated the spread of industrial analytics, some key hurdles remain. Aside from gaining broader acceptance, the most pressing issue centers on storing and processing data. Organizations that rely on database technologies built on Hadoop often experience difficulty with IIoT use

Modern analytics packages allow users to identify and investigate a variety of data types through visual interfaces ranging from dashboards to interactive graphics. Some tools also provide predictive analytics, looking at past events and forecasting future trends. ***Image courtesy of Seeq*****.**

cases. Data from sensors and machines typically take the form of time-series data, which can come in high volumes.

Unfortunately, systems based on Hadoop tend to be slow at feeding data into the analytic process. In the industrial arena, this becomes problematic if the analyses must be performed in real time. On the flip side, in-memory databases support fast processing, but they often fall short with large-volume data flows. The bottom line is that plant managers and automation engineers have limited technology options in this area.

Edge vs. Cloud-based Analytics

The next hurdle is deciding whether to use an edge- or cloud-based system. Industrial environments encompass a broad spectrum of applications. Some require edge analytics, others, cloud-based systems. Although the number of variables that must be considered before deciding on the type of system to deploy is enough to give anyone pause, engineers and plant managers do have rules of thumb that help their development and implementation efforts.

These guidelines, linked to operational constraints, are listed as follows.

- **Scale**. Derived information, not raw data, and how it can be acted upon determine the type of analytics required for the application. For example, if the goal is to maximize machine uptime at one plant, then local, or edge, analytics are sufficient. If the scale of the application involves machine uptime across multiple sites—requiring comparisons of the various factories—then analytics should be performed in a higher tier in the system architecture, possibly in the cloud.
- **Storage volume**. All data must be stored, at least temporarily, and the capacity required depends on the application. As a rule of thumb, more data storage is available in the cloud at a lower cost than on the edge.
- **Velocity**. High-frequency data, such as vibration or acoustics data, often increase the speed required for data processing. Also, transient event data must include accurate time recording to determine order of occurrence, causality and root cause. With low-latency requirements like these, analytics using high-velocity data should be performed on the edge.
- **Response time**. Applications that require deterministic analysis, processing and response demand local analytics.
- **Timing**. IIoT systems typically must correlate data from multiple sensors and process control states, including the timing at which the data is generated. Processing the data in upper tiers of the architecture—without any edge analysis—can overload the system and create bottlenecks. Applying analytics at the edge streamlines timing correlation.

Getting Started

Once you have decided whether an edge- or cloud-based system best suits your application you can begin work on the rest of the system. To obtain the full value of IIoT data, analytics must combine a variety of internal and external data sources. "Real-world decision-making is almost never made based on a single source or type of data," says Jeff Erhardt, vice president of intelligent systems for GE Digital. "To augment and automate this process with analytics, the systems need to contemplate those diverse sources of data upon which real decisions are made."

The diversity of the sources covers the full spectrum, including sensors, documents, the web and conventional databases. This variety, however, is compounded by the assortment of the data types that they provide. This data is structured and unstructured, and it comes in formats ranging from data streams and cloud data to NoSQL databases and sensor data. Additionally, the data often has missing values and contains inaccuracies and inconsistencies.

"Within industrial environments, data generation has always been in silos," says Jagannath Rao, head of the data-driven services unit at Siemens. "Production data, maintenance data, supply chain data and ERP-related data have all been managed by different operations in these environments. In addition, knowledge resides in these data sources both as structured and unstructured data—such as manuals, emails, notes, pictures and videos. To apply analytics and find meaningful and important outcomes, we want to be using all these data sources, correlating various data points to make step changes in productivity, reliability and cost reductions."

But the data variety that enables IIoT analytics to create such value for industrial organizations comes at a price. You simply cannot apply algorithms to raw data and expect them to provide insights. Before a software algorithm can begin to look for answers, you have to verify the data's relevance, clean the data, fill in missing values, format and convert the data into a unified form that the algorithm can understand and finally consolidate the data.

Therein lies the rub. This preparation process often takes 60% to 80% of the whole analytical pipeline. Developers of analytics platforms try to provide the means to automate as many steps in the process as possible. But the sheer volume of the data and the extent of its diversity almost guarantee that you will have to spend time on this process before you can begin to apply flashy technology like artificial intelligence.

"Algorithms help, but they are only part of the solution," says Michael Risse, vice president of emerging markets for Seeq. "The rest relates to the data. If you don't solve for the realities of working with data—connecting, cleansing, organizing etc.—the algorithms can't help you."

Putting Data in Context

Preparing raw data for analysis is just the first step in the process before analytics can be brought to bear to deliver optimum value. After the data is cleaned, consolidated and formatted, it has to be set within its operational context so that engineers and plant managers can gain a clear understanding of risks, options and ramifications.

The analytics software creates context by feeding the processed data through an artificial intelligence pipeline, using machine-learning tools to associate data from the various data streams to create a holistic view of plant operations. Using this structure, analytics models the production processes, operational relationships and interactions. This machine learning-driven contextualization builds a rich repository of events by surfacing like events across a broad spectrum of time, encompassing the full array of plant assets.

The strength of this process comes from the broad array of data types and data sources, such as from DCS (distributed control system), SCADA (supervisory control and data acquisition) and HMI (human machine interface) systems, as well as plant historians and asset management and pricing systems. And this requires a special set of tools. "Running supervised learning on large datasets, of disparate and diverse data types, needs analytical tools tailored for the application," says Rao. "This is where advanced analytical tools from the machine learning world become an important aspect of IIoT platforms.

Different Analytics, Different Insights

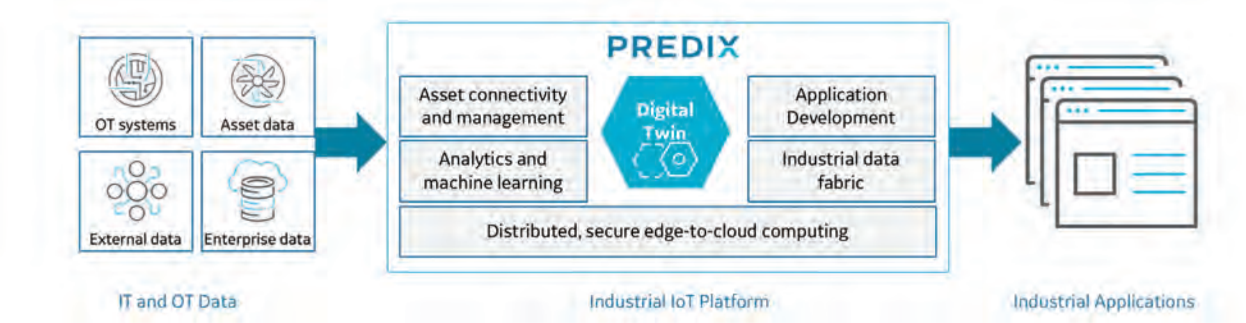
After you have completed the data preparation and contextualization, you are ready to extract insights. Analytics generally fall into three major categories: descriptive, predictive and prescriptive. Each has a different focus, applies different tools and offers different insight. No one type of analytic is better than another, and there is no one-size-fits-all strategy. In fact, these three types of analytics are interrelated and complement one another.

One way of looking at analytics is to view them as a continuum, with each type of analytic serving as a piece of the puzzle. "The time sequence is history, present and predictive," says Risse. "Figure out what happened, what mattered and why. Then be able to monitor for that scenario, and then extend to predicting outcomes. It's all one thought—but don't skip or underestimate the historian analytics. Build a model and backcast it to check for accuracy. Then tune and improve and tweak."

Perhaps the simplest form of analytics is descriptive analytics. Here, you are analyzing historical data to understand trends and evaluate metrics over time. This form of analysis summarizes raw data and presents it in a form that is interpretable by users, represented either in tabular or graphical form. This technique requires little to no coding, and there are many tools that can handle this analysis, such as QlikView, Tableau and Google Analytics.

Once the analysis process has been completed, it's up to the user to draw insights. Descriptive analytics are useful to show things like average dollars spent per unit, year-over-year changes in expenditures and total stock in inventory.

The next type of analysis is predictive analytics, which goes a step beyond descriptive analytics by predicting future



Some providers offer horizontal analytics platforms in which they provide generic analytics development tools and access to a broad collection of building blocks that bring specific vertical or domain analytics to the table. The idea is that the generic tools enable developers to build sophisticated analytics apps, and if a specific building block is needed, it can easily be integrated into the application. *Image courtesy of GE Digital*.

trends. It accomplishes this by identifying expected behaviors or outcomes, based on predictive modeling using statistical and machine learning techniques. This form of analytics takes the data that an organization has and fills in the missing elements with best guesses. It combines historical data found in MES (manufacturing execution system), ERP (enterprise resource planning) and other plant systems to identify patterns in the data, applying statistical models and algorithms to capture relationships among various data sets.

It's important to remember that predictive analytics is based on probabilities; the actionable insights it provides take the form of estimates about the likelihood of a future outcome. In the end, they are forecasts and likely will not be 100% accurate. In addition to forecasting future trends, this form of analytics can also predict values of missing fields in a data set and probable impact of data changes on future trends.

A relatively new field in data science, prescriptive analytics takes industrial analysis one step beyond predictive analytics. This form of analytics tries to find the optimal solution by determining what is likely to happen, based on empirical models, first principles and predictive analytics. This approach offers viable solutions to a problem and sketches their impact on future trends.

Prescriptive analytics is still evolving, and the range of use cases to which it can be applied has yet to be defined. But one example of an industrial application would be on-demand production from a geometric assembly model to find the optimal set of manufacturing processes. These results can then be applied automatically to machines and systems, streamlining the production process.

Analytics Options

Recently, the market has enjoyed an infusion of IIoT analytics development packages, some in the form of platforms, others billed as applications. Startups account for some of these, whereas industry giants like Siemens and GE have moved into this area as a natural progression of their portfolio. The variety of options may be enough to spur reticent companies into developing an analytics capability. But this option-rich environment isn't without challenges. Choosing the right toolset isn't easy, but a look at the various design philosophies may help.

Many of the startups offer specialized toolsets, leveraging domain expertise. Here, companies like Ambyint target the issues facing specific verticals. In this case, it's the oil and gas industry, with the focus on optimizing performance.

Other startups specialize in certain aspects of the analytics pipeline. For example, Seeq emphasizes its simplification of data aggregation, cleansing, visualization, search and modeling processes.

Established industry vendors take a more horizontal approach. They offer platforms that provide basic tools and access to a broad collection of building blocks that bring vertical- or domain-specific analytics to the table.

"Manufacturers implementing IIoT should look for platforms that incorporate generic analytics development tools," says Rao. "These analytics tools have to provide the basis for developing more dedicated apps on the platform. I would classify such tools as machine learning APIs or visual analytics tools. The idea is that these generic analytics tools provided on the platform can enable engineers and developers to build sophisticated analytics apps, and if a specific, not-so-generic building block is needed, it can [be] integrated into the application instead."

Keep in mind that IIoT analytics are a work in progress, so their final form has yet to be defined. "One thing that's unclear to me is either the horizontal platforms will begin to develop vertical-centric suites or apps on top of themselves, or they will partner with companies doing that," says Ryan Smith, vice president of engineering at Sight Machine. "I think it's too early to tell." DE

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Mass Customization's DATA CHALLENGE

adidas is leveraging Carbon's Digital Light Synthesis 3D printing technology to mass produce custom, high-performance sneakers. *Image courtesy of Carbon.*

3D printing has evolved to make mass customization a reality, but capturing and integrating the relevant data to drive designs still requires some heavy lifting.

BY BETH STACKPOLE

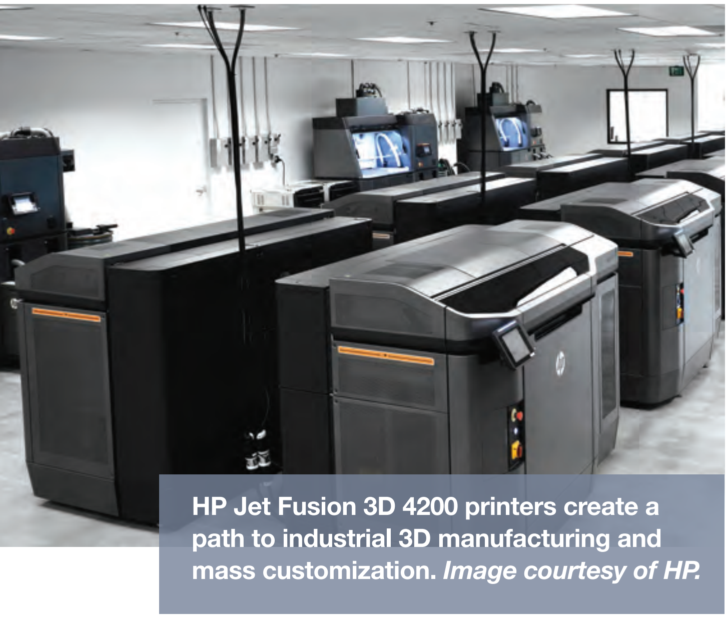
HAVING A PAIR OF CUSTOM-DESIGNED ski boots and inserts is a dream come true for an avid skier. Ill-fitting gear detracts from comfort and performance, yet the industry has struggled to come up with a mass customization method that is affordable and practical for the ski boot manufacturer as well as for retailers and consumers.

Thanks to additive manufacturing and advanced 3D scanning, Tailored Fits, a Swiss manufacturer, is making fast tracks toward a solution. The company partnered with Materialise to create a digital customization platform for wearables that can turn around orders for custom inserts along with fully customized ski boots in just 10 days. Although advances in 3D printing and 3D scanning have made the new gear possible, it was the pair's collaboration around digital workflow and design automation software and processes that allowed Tailored Fits to cost effectively offer a mass customized product, says Reto Rindlisbacher, CEO of the firm.

"A total digital workflow is important because when you're working with 3D data, you create a significant amount of work that you want to avoid," Rindlisbacher explains. "We want to be able to get product to market fast and we don't want to spend a lot of money setting up a large crew to prepare data for 3D printing. It's important from the beginning to have a smooth process."

Degrees of Design Freedom

Mass customization, a holy grail for manufacturers across many industries, has had a difficult run given a range of



HP Jet Fusion 3D 4200 printers create a path to industrial 3D manufacturing and mass customization. *Image courtesy of HP.*

obstacles, from inadequate materials and still immature 3D printing practices to challenges related to integrating all the critical data sources to drive production of a customized product. Advances in 3D printing materials and technology have launched the practice from a small segment of companies in specific industries like medical instruments and dental fixtures to a growing number of pilot deployments in mainstream retail and consumer sectors, including customized footwear, eyeglasses and even a new generation of personalized vehicles.

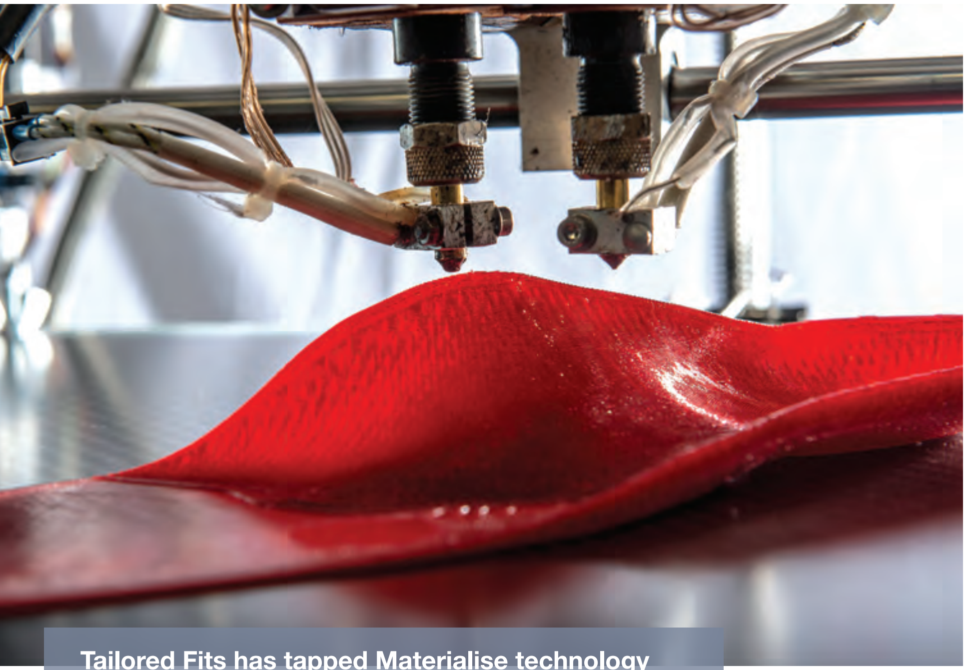
"There's increased interest in mass customization because the desire and pull from designers at product companies has always been there, but now 3D manufacturing practices have matured to where there's the right push from advances like speed and surface finish resolution," says Gurjeev Chadha, technical product marketing expert at Carbon. Carbon's 3D printers are based on an additive manufacturing process called CLIP (Continuous Liquid Interface Production), which harnesses light and oxygen to produce products from resin while addressing some of the resolution and surface finishing shortcomings of conventional 3D printing technologies.

Key to making mass customization a reality for manufacturers is creating the digital platforms and accompanying processes that establish a digital thread connecting relevant data about an individual consumer with different product variations and ultimately serving it up in a format that can drive the 3D printing process. Currently, most of these early digital platforms are built around custom software and company-specific data transformation, integration and automated workflow processes designed collaboratively by the manufacturer and its 3D printing partners as opposed to implementation of off-the-shelf software and solutions.

Also essential to the mix are new data acquisition tools and data sources that can drive the mass customization, regardless of product type. "To get there, it's all about data sources," explains David Tucker, market development manager, 3D printing at HP, which is touting its Jet Fusion 3D 4200 printers as a path to industrial 3D manufacturing and mass customization. "We need to figure out the sources of data we can exploit—whether they exist or whether we need to invest in them. We also need to incorporate additional data acquisition tools, otherwise you are simply presenting customized products with limited options."

As part of its vision, Carbon is touting a full portfolio of specialized software that facilitates on-demand 3D manufacturing, including algorithmic design tools to help designers easily create internal lattice structures, and its SpeedCell platform that supports fleet management of multiple printers so manufacturers can produce customized products at scale.

In one of its most prominent customer examples, Carbon is working with footwear giant adidas, initially on Futurecraft 4D, a mass production process that can churn out previously impossible midsole designs with 3D printed materials and will eventually pave the way for custom, high-performance shoes that meet the unique needs of custom-



Tailored Fits has tapped Materialise technology and expertise to create a customization platform and digital supply chain for 3D printed ski boots and inserts. *Image courtesy of Materialise.*

ers. Key to the adidas effort is lattice simulation and FEA automated support tools, which allow for design freedom to produce shoes with variable properties throughout the midsole, cutting back on trial and error. The software was a collaborative design effort between Carbon and adidas, and is now offered as a commercial product for customers working with Carbon technical partners.

"With mass customization, you want efficiencies—you need the first sole out of the printer to be accurate otherwise, there are serious doubts that the business model can work," Chadha explains. "These tools unlock the ability to design and manufacture midsoles right the first time, but also to create lattice structures or materials where the simulation behavior matches the mechanical behavior."

Collaborative Design

As the Carbon/adidas partnership illustrates, much of the software driving mass customization and data integration workflows is currently highly customized itself, born from collaborative efforts between the individual manufacturers and their key 3D printing partners. There is a lot of activity in the footwear sector. In addition to the Carbon/adidas collaboration, Under Armour last November announced a strategic partnership with EOS to leverage its advanced laser sintering technology for printing powder-based parts and evolving polymer powder development, and Nike's NIKEiD, available on its website and in select stores, lets customers tailor the more aesthetic parts of design like color, text, collar and lacing. Even the automotive industry is getting in on the act: European car company Opel offers an almost unheard of level of customization (4 billion combinations) on its ADAM and ADAM ROCKS models, thanks to a manufacturing concept that adapts material and production flow based on customer requirements.

The medical industry has been way out in front on mass customization practices, particularly for surgical cutting guides, which are well established for producing far better outcomes for patients, reducing costs and making much better use of surgeons' time, according to Laura Gilmour, global medical business development manager of EOS North America. EOS works with a variety of customers in this space on customized software and workflows that enable them to quickly churn out patient-specific instruments—in the case of Smith & Nephew, 650 unique cutting guides per week. An MRI or CT scan is used to create a virtual model of a patient's anatomy that engineers and surgeons use to preplan the surgery along with the sizing and placement of implants and a subsequent design for a disposable surgical instrument matched specifically to the patient's anatomy.

Although the medical industry has a lot of the mass customization processes down, there are remaining challenges, many related to data. Specifically, ensuring that the patient data tracked with digital design data all the way through the process is kept in compliance with patient privacy regulations like HIPAA (Health Insurance Portability and Accountability Act). The data also is used to ensure product quality, certification and qualification.

"Generally speaking, most product customizations to date are variations on base designs, allowing for a range of flexibility while still maintaining the integrity of the product," notes Dr. Greg Hayes, director of applications and consulting for EOS North America. "Software design programs together with trained users can identify design for manufacturing improvements and help ensure quality."

HOYA Vision Care set out to shake up the eyewear industry with a mass customization strategy co-developed with its partner, Materialise. It starts with the Yuniku 3D scanning system and kiosk designed for use in optician shops to take high-resolution scans (they register within 1/10 mm accuracy) of a customer's facial anatomy. Unlike conventional eyewear design, which restricts lens perfor-

HOYA has launched Yuniku, a 3D scanning system that aids in the production of custom eyewear. ***Image courtesy of HOYA Vision Care.***

EOS technology lets Exactech create medical instruments in small production runs with reduced lead times and costs. ***Image courtesy of Exactech.***

mance because opticians must match lens placement to the chosen frame, the Yuniku platform leverages tools like 3D scanning, parametric design automation and 3D printing, to design the frame around the ideal position of the optical lens on an individual's face.

HOYA-designed software parses facial and visual data to determine the ideal placement of the lenses in relation to the eyes, while Materialise's software is used to modify the frame appropriately based on those parameters and the individual's unique characteristics. Consumers can also select color and finish, and once the design is complete, it is sent off to the HOYA factory for 3D printing and some additional manual finishing work, according to Felix Espana, HOYA's global new media manager. Currently, HOYA has about 200 Yuniku operational platforms, mostly in Europe.

Hearing aid manufacturer Sonova USA transformed its technology and workflow processes more than 15 years ago to support the mass customization model. "By definition, what we do is mass customization—every ear is different, every hearing loss is different, the complexity is widespread and we have to customize for individual patients," explains Mujo Bogaljevic, the company's vice president of operations.

With its partners, including 3D printer maker EnvisionTEC, Sonova custom-designed software and brought in hardware specifically mapped to support its data-driven processes. There are 3D scanners, which capture 30,000 data points in 30 seconds and scan silicone impressions of patient ears to create digital files. There is a custom-built design program, the Rapid Shell Manufacturing Design software, which marries the 3D image with patient and order data stored in SAP or other business systems, including key information such as preferences for size, color and options along with more clinical information about the patient's hearing loss. The software, which was designed for use by operators who are non-CAD users, also directs placement of all the electronics and other components required for the hearing aid.

"The software performs the collision detection and knows what can be produced and what can't," Bogaljevic explains. "It's a combination of automated CAD design software with the ability to modify as necessary by the operator using their experience."

Also developed in-house by Sonova, is its Digital Work Order Management (DWOM) application, which is the connective tissue that integrates the relevant data from the different databases and helps automate the workflow, including pushing orders to the EnvisionTEC 3D printers, without requiring operator intervention.

This piece of the puzzle is critical if manufacturers are serious about making the leap from 3D printing for rapid prototyping to a full-scale mass customization process. Says Bogaljevic: "This is a fully integrated, mass customization environment so we had to tie everything together; if we were passing data off manually, it would be very inefficient." **DE**

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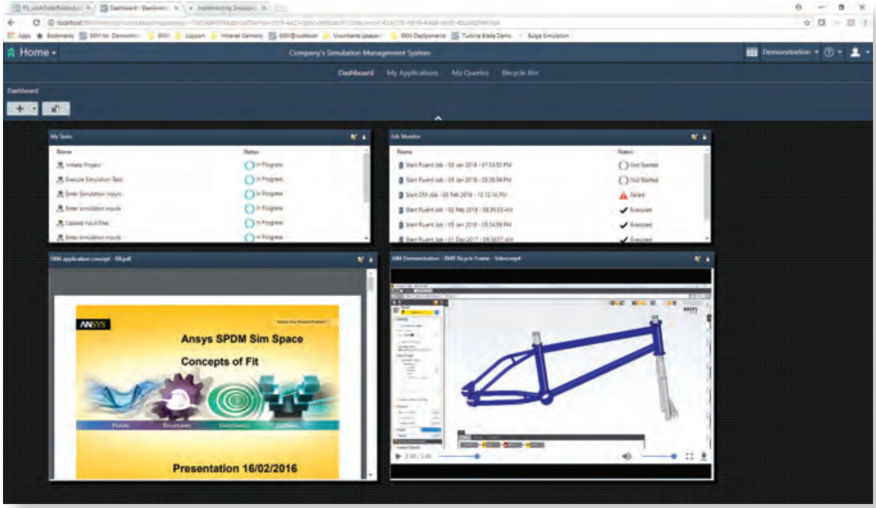
Simulation Management Evolves

Simulation data management solutions can help formally manage data, make it searchable and traceable, and provide insight.

BY BRIAN ALBRIGHT

SIMULATION IS A standard practice at many design engineering firms, but many of those organizations still struggle to efficiently manage and reuse simulation data.



A dashboard that is customizable by users to track simulation projects, activities and jobs. *Image courtesy of ANSYS.*

In some industries, companies may find themselves recreating simulations using data or versions of software that are several years old for compliance purposes. More commonly, companies want to revisit existing simulations to improve an iteration without having to rerun the simulation, or to create new derivative designs based on existing products and data.

In either case, they often struggle to use existing data to inform the next design or assembly without asking their analysts to spend valuable time reproducing simulations that have already been completed.

To overcome this issue, companies need tools that go beyond standard product data management (PDM) systems. "A design may have multiple configurations and changes, and just one variant may have hundreds of simulations applied to it," says Matteo Nicolich, enterprise solutions product manager at ESTECO. "A PDM system cannot handle those simulations. That is why companies need a specific solution for managing simulation data."

But many companies aren't even trying to wrangle their simulation data at all. "Simulation is managed in silos that are not only related to the analysts themselves, but also to the different physics that are addressed by them," says Dominique Lefebvre, product director at ESI Group. "There is a relatively weak link between PLM/PDM at large and simulation."

Once a solution for a design has been validated, it is considered finished and everyone moves on, which is not necessarily optimal when it comes to leveraging all of the data generated to get to that point. The data is not optimally stored for reuse or searchability. "Most engineering groups don't do much to formally manage data," says Bruce Hart, business development director for Dassault Systèmes SIMULIA. "Often that data may be managed by an individual analyst, or even stored on a local disk or thumb drive. That not only isolates the data; it also isolates the simulation function in the company."

More companies are turning to simulation data management (SDM) because they recognize the value of intellectual property reflected in those simulation models. That has led them to seek out solutions to help store the data, make it searchable and apply version control to it.

FMI (Future Market Insights) forecasts that the simulation and test data management market will reach $480.6 million in revenue by the end of 2026, with a compound annual growth rate of 12.5%.

"Model-based systems and digital twins and other use cases require a strong foundation for simulation data and process management," says Sanjay Angadi, director of product management at ANSYS. "It's really a foundational block for enabling the use cases that customers will get into in the future."

SDM Challenges

As more non-analysts are asked to take part in simulation, having a better handle on searching for and accessing existing simulations can help make running basic tests easier for engineers and other stakeholders—the data can be used to create templates and best practices, as well as automate some of those functions so it is easier for non-experts.

However, simulations generate large amounts of data that rely on a variety of tools and different analysts' interpretations. "It's an iterative process, and simulation may produce many models, with one that is useful for real results," Hart says. "The inputs into that model can vary considerably, and analyst assumptions vary considerably. How do you store that?"

The simulation data is also underused, because only a fraction of the results are ultimately used to optimize a design.

Not being able to locate simulation data after the fact can result in wasted time looking for data, or time spent recreating models. "We were working with a medical equipment supplier that had to resurrect old content, and they literally had to go on a year-long review to pore through that data and cobble together the information that led to that design and those decisions," Hart says. "This is frustrating for analysts as well as engineers."

Another challenge is that simulation models may have been generated by various software tools from different vendors over lengthy periods of time. "It's not only the digital information that needs stored, but you may also need specific hardware and software that were used for that specific simulation," Nicolich says.

"As soon as there is an engineering or design change, you have to redo the first model, redo the second model and retest the physics," Lefebvre says. "Keeping track of engineering changes is often not automated or a single process."

Analysts also have a unique role in the organization, so there are cultural and organizational challenges as well. "There is also the sheer complexity of the simulation data and tools that you have to deal with," Angadi says.

Emerging SDM Solutions

Companies tend to go through an evolution when it comes to simulation management. Storing and organizing the data is usually just the first step. "These environments are just holding tanks for data, but don't do much to help you get your hands on the models you want to look for," Hart says. "What's missing is the analyst input into the data. You have to build analyst confidence that the model has been built with certain assumptions and techniques to developing the physics, so they can trust the data that is available."

Simulation management solutions can help formally manage that data, make it searchable and traceable, and provide insight into every aspect of simulation—geometries, meshes/models, input/output parameters, test conditions, supporting material, the tools used and the results.

According to Lefebvre, better leveraging simulation data can help improve data analytics and design space exploration activities as well, but only if the entire process of creating, storing and managing the simulation data has been automated.

"You have to manage not just the data, but the process," Lefebvre says. "You check a given model against different physics, and it is difficult to keep track of all of these simulations related to the same product."

In the case of ESI Group, its Visual DSS tool helps manage processes and models, including assigning tasks and better managing how design changes are communicated to different stakeholders. The company's Vdot project management tool also provides SDM.

A variety of other types of tools are also available that can help companies get a better handle on simulation results. ANSYS Enterprise Knowledge Manager is a web-enabled solution for sharing and managing simulation data and creating workflows.

"When simulations are uploaded, the data is checked into our data management system," Angadi says. "We extract metadata from those files, which then becomes searchable anywhere in the organization."

Analysts can also create simulation workflows to establish standard processes that help improve management of the data and collaboration.

MSC Software's SimManager manages large volumes of complex simulation data by automatically capturing information and allowing engineers to manage collaborations based on that data. PDTec's SimData Manager tracks CAD geometries and simulation models to make it easier to find the correct analysis results, while also updating analysts about CAD model changes. Altair offers the Simulation Manager web-based portal that allows access to simulation data and provides traceability.

ESTECO's VOLTA simulation data management offering is a browser-based system that organizes and accesses analysis models and results.

"They can keep the definition for the model and simulation, and the key results information," Nicolich says. "They can quickly use the key results for retrieving information about how the results were obtained."

The ESTECO tool can work with simulation tools from multiple vendors. "We manage and store the information about these processes, and they can be reproduced as many times as you want very quickly," Nicolich says. "That provides a direct benefit in democratizing simulation. The system can recognize a complex simulation chain without having the analyst regenerate the model from the past. You can store the properties and then reproduce the results."

Dassault's SIMULIA Simulation Lifecycle Management is integrated with the company's design platform. "In the 3DEXPERIENCE platform we capture that data automatically, so we have information about codes being run, what data was run, etc.," Hart says. "The next layer is to capture some information about how the model was created, so the next person downstream can make sense of the data and reuse it."

An analysis by CIMdata (sponsored by Dassault) found that companies could reduce costs by up to 90% by reducing the effort required for data acquisition, model creation, solving, reporting and other tasks. Analysis model reuse could potentially reduce costs by as much as 60%, and companies could further cut costs through reducing the need for prototypes and tests and reducing rework.

As simulation becomes more democratized and is used earlier in the design process, SDM will be even more critical. **DE**

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INFO → **Altair:** Altair.com

→ **ANSYS:** ANSYS.com

→ **CIMdata:** CIMdata.com

→ **Dassault Systèmes:** 3DS.com

→ **ESI Group:** ESI-Group.com

→ **ESTECO:** ESTECO.com

→ **FMI:** FutureMarketInsights.com

→ **MSC Software:** MSCsoftware.com

→ **PDTec:** PDTec.de

Tracking Parametric CAD's Odyssey Into FEA and AM

Developers look for alternative treatments of CAD data in simulation and additive manufacturing.

BY KENNETH WONG

INTEROPERABILITY DISCUSSIONS tend to revolve around formats: *Can your CAD program read native AutoCAD files? Does it support DWG? Does it support OBJ, STEP or IGES?* And the list goes on.

In some ways, the focus on formats is understandable. For a long time, AutoCAD was—and some would say still is—the *de facto* standard in engineering drawing; therefore, the ability to read and edit AutoCAD and DWG files is crucial to those working with old construction documents and shop drawings. Because the majority of 3D printing hardware and the associated print preparation software work with STL, those who want to explore additive manufacturing for mass production are inclined to favor modeling programs that can export STL files.

But perhaps it's time to take a closer look at what happens to the original CAD file's precision geometry when it's converted to mesh models for simulation or 3D printing. Finding new and more efficient ways to address the transitions in modeling, simulation and manufacturing may be the key to unlock more sophisticated operations, such as meshless simulation, topology optimization and lattice-driven lightweighting.

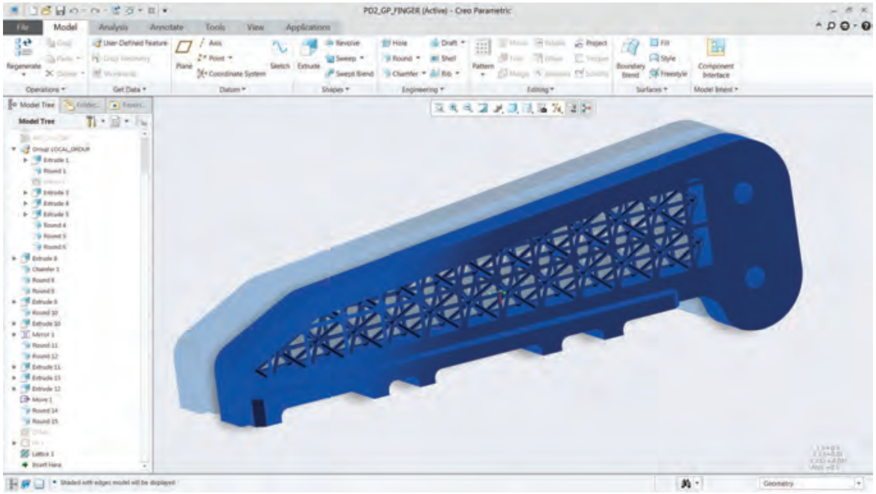
Assemble Your FE Model for Machines

About five years ago, with support from Germany's Federal Ministry of Economics and Technology, a group of researchers from The Institute for Control Engineering of Machine Tools (ISW, Stuttgart, Germany) decided to spin off their efforts into a startup, dubbed Meshparts.

"In the future, all FE simulation models of machines, just like real machines, should be assembled from individual finished simulation models of individual components," says Meshparts Founder Alexandru Dadalau, an alumni of the Mechatronics Faculty of the University of Stuttgart and a former research assistant and Ph.D. at the ISW. "The component-oriented and fully parametric FE modeling is a fully new approach in the machine simulation."

The centerpiece of the company's product is the FE Model Kit, a library with a "wide variety of typical machine components" delivered "as fully parametric ANSYS FE models." The kit's content includes standard and manufacturer-specific components.

This means Meshparts software users could assemble a FE model with standard machine parts from the kit, instead of importing a CAD assembly and converting it into a mesh model. Meshparts can also read-in non-standard machine parts and convert them to ANSYS or Abaqus format to be consistent with the rest, according to Dadalau. Furthermore: "Meshparts can read a complete assembly structure from CAD and mirror this structure into its own FE assembly structure. Then you can add predefined parametric assemblies or parts from the model kit to this FE as-

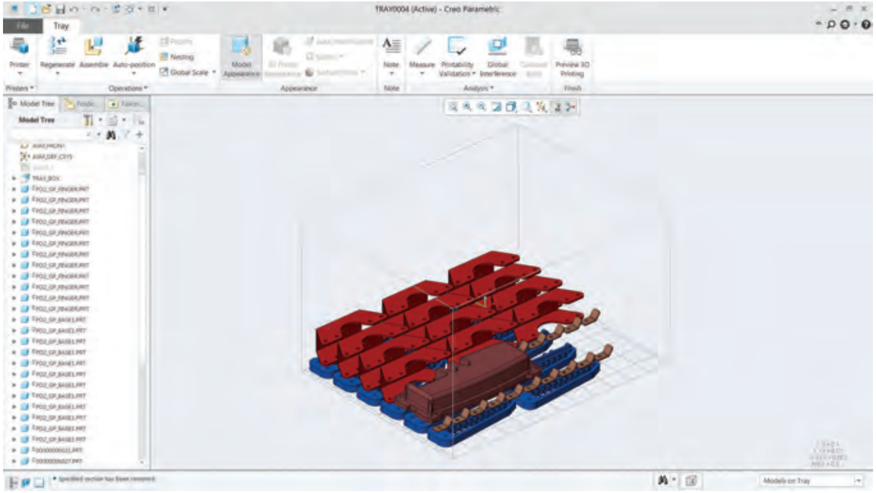


Mainstream CAD packages look for ways to faithfully model and represent complex lattice-filled parts. Shown here is a PTC Creo Parametric part with lattice structures. *Image courtesy of PTC.*

sembly," Dadalau explains.

Support for the ANSYS format makes sense, as ANSYS is recognized as an industry leader. However, the appeal of Meshparts' component-oriented method will likely increase when the assembly kit's content is available in a much wider variety of FE formats.

"We will soon release new library parts based on GMSH scripting and meshing technology," Dadalau adds. "But Meshparts is, from the architectural point of view, not limited to ANSYS or GMSH when it comes to developing new model libraries. It's just that we currently focus on ANSYS and newly on GMSH. We do hope that in the near future we will have a community of people developing new libraries for common use."



Automatic orientation and positioning of parts to be printed in the printer chamber for efficiency is a desired feature for designers exploring additive manufacturing. Shown here is PTC Creo's deployment of this feature. *Image courtesy of PTC.*

Don't Mesh Your CAD

To put a detailed CAD model through simulation, you have to simplify it and mesh it. The two-pronged approach—removing unnecessary details and subdividing the model into hundreds, thousands or even millions of tiny geometric elements for force, stress and load calculation—is fairly standard in preprocessing software. But the method is also compute- and memory-intensive.

One new simulation program, SIMSOLID, uses what's known as meshless simulation, allowing users to bypass arguably the most burdensome parts of preprocessing. According to SIMSOLID, its technology "eliminates geometry simplification and meshing, the two most time-consuming, expertise-extensive and error-prone tasks done in traditional FEA."

As the new year began, SIMSOLID announced the launch of SIMSOLID Professional. "The Professional edition extends the SIMSOLID feature set to include more CAD connectivity to applications such as CATIA, NX, PTC/Creo and Inventor, transient dynamic analysis and weld connection automation," the company writes.

Ken Welch, founder and CEO of SIMSOLID, used to complain about the "dirty CAD geometry" that makes simulation difficult—the misaligned geometry, gaps that need to be closed and so on. But not anymore. He's come to accept that, as part of the exploratory conceptual phase, CAD users are bound to move parts around, reorient them and deform geometry many times through different design iterations. Thus, the so-called dirty geometry may be the inevitable outcome of conceptual design; it may be unfair to ask design engineers to put in additional time to clean up or simplify the data before submitting it to simulation.

"SIMSOLID reads in the native CAD data as faceted topology," Welch says. "Others talk about tools to simplify CAD, create mid-planes and defeature. Our approach is, just use your CAD geometry as is for the best simulation results. With this approach, we can solve large assemblies with hundreds to thousands of parts in minutes instead of hours or days."

Task-Specific Extensions

Jose Coronado, PTC's product manager for Creo manufacturing and simulation, finds it difficult to talk about file formats because the different Creo applications (such as simulations and additive manufacturing extensions) access a single Creo file to execute their operations. "We keep all the data needed (for modeling, simulation, additive etc.) in Creo. This removes the need to constantly recreate models in CAD or to do any file transfer between applications," he says.

Most CAD programs employ one of a handful of geometry modeling kernels as the foundation for their modeling techniques. Dig into one of the mainstream mechanical CAD modelers and you'll likely come across the Parasolid kernel, owned by Siemens, or the ACIS kernel, owned by Dassault Systèmes.

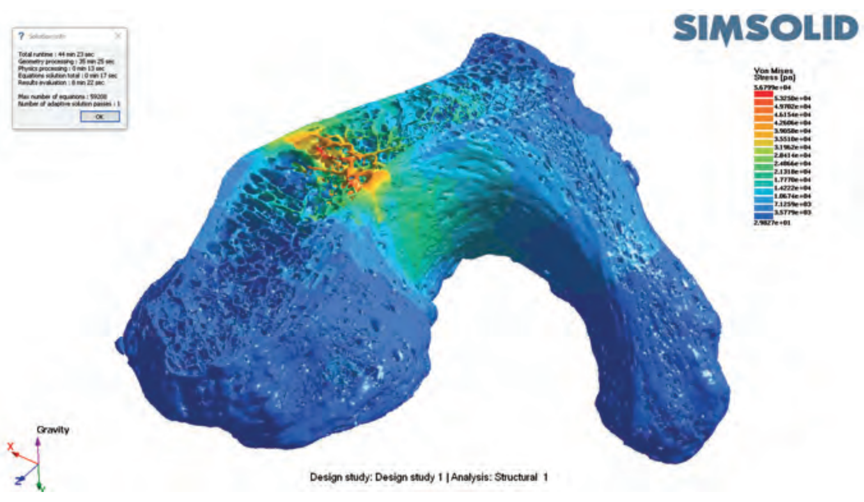
Some CAD vendors developed and used their own proprietary kernels, which appear in their own products and their development partners' offerings. For instance, Autodesk once licensed its kernel, but now uses its proprietary ShapeManager kernel in Autodesk Inventor and AutoCAD software. PTC uses its proprietary Creo kernel for the PTC Creo product line.

"Most FEA programs use the H-element meshing technology. Creo Simulate uses the P-element technology and auto-meshing. This eliminates the need to understand element types. [The software] automatically creates the mesh model and accurately captures geometry contours. Additionally, the mesh is automatically refined during the solving process," says Coronado. "It's one of the distinctive characteristics and advantages of Creo Simulate."

The close integration between Creo Parametric and Creo Simulate allows the adaptive mesh refinement and automatic convergence. Therefore, users with limited expertise in complex simulation can, for example, bypass the need to manually define the type of mesh to apply to certain zones in the geometry—a skill that's common among simulation experts but rare among novices and design engineers.

The Burden of Lightweighting

In many manufacturing firms, lattice structures have become the ideal solution for lightweighting parts. Because



SIMSOLID, which champions meshless simulation, says its approach is well-suited for analyzing complex structures such as bones and lattice structures. ***Images courtesy of SIMSOLID.***

they use much less materials than solid parts, such structures are attractive to those seeking to reduce weight in automotive and aerospace components. But due to their structural and geometric complexity, they can also put a heavy burden on simulation.

With Creo, users can use the simulation results and the embedded solver to drive automatic lattice creation, with control on the part's stiffness to achieve the desired performance.

"With Creo, the time savings comes from the usage of idealizations by the solver. We tell the solver to use idealizations, like beams, shells and masses. That's much faster than solving full, detailed mesh geometry—in some cases, it can be in minutes instead of hours," explains Coronado. "What we propose to our customer is: They should run their initial simulations with simplified geometry, then when they get close to the final design, run with detailed geometry in H-elements."

Most of the time, lattice structures also prove challenging or impossible to manufacture in traditional methods due to geometry complexity. Metal-based 3D printers offer one alternative to make lattice-filled parts. For additive manufacturing applications, "the level of implementation is such that, when you hit *print* in Creo, the STL conversion happens automatically. And you don't have to worry about support structures. The printer driver automatically takes care of that," says Coronado. "This automatic creation of support structures is not for all printers, but only for the printers that support this integration."

Printer-Aware CAD

Joe Dunne, developer relations manager for the cloud-hosted CAD program Onshape, believes being part of the cloud software ecosystem makes direct integration possible with other cloud services. "With a cloud app, you can quickly see how a change in CAD might affect the 3D printing process—in the support structures it needs, for instance," he says.

The company's strategy is to concentrate on browser-based parametric CAD modeling. It relies on partners such as SIMSOLID (meshless simulation), Simwise 4D (rigid body dynamics and assembly simulation) and SimScale (cloud-hosted simulation) to augment its CAD program with simulation applications. Similarly, it relies on Kiri:Moto, x3D-Print and others to supply additive manufacturing functions to Onshape users.

In his view, it makes more sense to leave the 3D print preparation software in the hands of the hardware makers, because they possess the intimate knowledge about their own machines' eccentricities and capabilities. "The overhangs, the support structures—they are so unique to each printer or printing platform that printer companies are much better at solving these issues with their own software," he notes. "Where we could get involved is, for instance, taking an assembly and arranging it in an optimized volume so you can print them efficiently. That's something a CAD system should do."

In PTC Creo's AM extension, once the CAD program is connected to the printer, the CAD program becomes aware (so to speak) of the printer's capability—color options, material options, build envelope size, recommended orientation for best printing and others. "Then, Creo can use the printer's own algorithm—not PTC's generic method—to suggest the optimal way to stack up the parts for best printing," says Coronado.

Where exactly should the CAD program intervene, and where should it cede control to the printer's firmware? The issue may be up for debate as more and more CAD vendors add AM-friendly features.

Lattice Can Fill Up Your Memory

An area where Onshape's Dunne feels CAD developers should start looking for alternatives is lattice modeling. "We'll have to figure out a way that's different from how we currently represent lattice structures," he says. "Even if you just have a simple bracket, if you were to add lattice structures inside it to optimize it for weight, you could easily get to a gigabyte file to represent that model, because there [are] so much details in it. So even if the CAD system can create it, the printer software might not be able to slice the file—it might run out of memory. In my view, we need to find a way to represent the lattices without modeling all the details in triangles."

SIMSOLID is a partner of nTopology, makers of the nTopology Element and Element Pro software for generative design. nTopology offers, among other things, detailed lattice structure modeling. "Lattice analysis with traditional finite element analysis methods is difficult," SIMSOLID's Welch says. "We're orders of magnitude more efficient in analyzing lattices, both in memory use and in time required. When we once worked with an nTopology assembly with lattice-filled parts, we finished it in about four and a half minutes."

Interoperability used to mean the ability to read a comprehensive list of neutral and proprietary 3D formats—the longer the list, the better. Support at the file format level worked well when CAD, simulation and manufacturing were treated as separate parts of the product design workflow. Now that many CAD users are looking to conduct simulation upfront in the conceptual phase and identify potential manufacturing issues in their geometry, that means that interoperability discussion, too, must evolve to address the metamorphosis of the data itself.

For the new generation of engineering teams that believe in collaborative workflows, the ability to easily reuse the rich CAD data in simulation apps without too much preparatory works, and the ability to visualize and simulate how their parts might be manufactured or printed, may be much more important than the length of the file formats supported by a certain program. **DE**

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INFO → **ANSYS:** ANSYS.com

→ **Autodesk:** Autodesk.com

→ **Dassault Systèmes:** 3DS.com

→ **Onshape:** Onshape.com

→ **PTC:** PTC.com/en/products/cad/creo

→ **SIMSOLID:** SIMSOLID.com

→ **Meshparts:** Meshparts.de

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

→ **nTopology:** nTopology.com

→ **X3D Group:** X3D-print.com

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Data Acquisition: A Primer for the IoT Age

Data acquisition hardware and software enable smarter decisions in engineering design environments.

BY JIM ROMEO

JAGUAR LAND ROVER (JLR) is the parent company of two iconic British car brands known for rugged design and luxury. Their more than 400 engineers who work in the powertrain calibration and controls department have access to huge volumes of raw test data to make smarter decisions before a vehicle goes to market.

Using data acquisition (DAQ) devices and software, they created a fully automated analysis routine that helps design engineers make smart decisions and improve the time it takes to arrive at those decisions by 20-fold.

"Within one year of developing and implementing this solution, we estimate that we now analyze up to 95% of our data and have reduced our test cost and number of annual tests because we do not have to rerun tests," says Simon Foster, powertrain manager of Jaguar Land Rover.

A DAQ is typically an electronic device that records data within a specified time frame relative to some variable such as location. It achieves this with an integrated sensor or external instrumentation of sensors and is usually linked to a digital processor.

DATA ACQUISITION DEVICES enable real-time visualization dashboards. *Image courtesy of XAir Corp.*

50 Billion Devices by 2020

The market research firm Technavio forecasts the global data logger market to grow at a compounded annual growth rate of almost 12% between 2017 and 2021, according to its latest report.

"The function of data loggers in automated systems can be summarized into test, measurement and control functions," says Chetan Mohan, a computing devices research analyst at Technavio. "For example, a specific temperature needs to be maintained in a cold storage warehouse; hence, data loggers are connected to automated systems that increase or decrease the effect of cooling to maintain the specific temperature."

National Instruments, which designs and fabricates data acquisition devices and licenses software to use in conjunction with them—including that of Jaguar Land Rover, believes the market for data acquisition devices is robust. The company cites Cisco, who predicts there will be 50 billion connected devices by 2020.

National Instruments cites processing industries that use data to monitor their operations to prevent downtime and boost efficiency. They note that data gathered ranges from basic information such as temperature and pressure to more complex data that can be challenging—such as waveform vibration data. For example, to identify higher orders of vibration faults on rotating machinery you often need a sampling frequency of 50kHz or more. These specifications require conditioned measurement systems with enough processing power to perform analysis at the edge of the network.

"Operational data in the last few years has moved from a want to an expectation," says Graham Green, group manager of Product Marketing for National Instruments in Austin,

NATIONAL INSTRUMENT'S CompaqDAQ is a portable DAQ platform that integrates connectivity and signal conditioning into modular I/O. *Image courtesy of NI.*

TX. "There is a divergent trend in the devices used to gather this data. On the one side, the maker market is driving down the cost of small, cheap computational platforms such as Raspberry Pi. These can be combined with a measurement 'hat' available from multiple vendors to allow distributed data logging at a very accessible price.

"The challenge here is that the measurement quality is low, and sometimes even unspecified, which threatens the trust that engineers can have in the data they acquire," Green continues. "On the other side, the need for 'edge ready' measurement devices that have the capability to acquire accurate waveform data, perform some analysis at the edge and be deployed in harsh environments is also on the rise. These often come at a higher price point, but wide adoption is still being seen, especially in industries where either the core infrastructure is expensive such as power generation, or the cost of downtime is high such as manufacturing."

Understanding DAQ

Seshu Kiran GS is a consulting engineer and the founder and CEO of XAir in Los Angeles, CA. He explains that DAQ, from an industrial perspective, refers to process control and automation, thus the term SCADA systems is frequently used (supervisory control and data acquisition). So, DAQ is meant for visualizing the process data and controlling the process variables.

He adds that DAQ related to design testing purposes could have different meanings or purposes. It could refer to validation, for example, testing electronic circuitry parameters, and it may also refer to other applications like automotive noise and vibration analysis or aircraft non-destructive testing (NDT).

Kiran explains that DAQ system functions are three-pronged: acquire, analyze and present. More specifically: acquire—digitize and acquire the data; analyze—compute digital signal processing, or math or logical functions on the DAQ board itself, or in a post-analysis software; and present—in an intuitive and interactive user interface with recording and storage functions.

Fully Standalone Versus PC-Integrated

"There are some companies that are midway between fully standalone vs. PC-based and highly configurable and programmable," Kiran says. "The reason to have a midway is this: In PC-based or highly configurable DAQ systems, there is a considerable load on software. Generally, software is not fully deterministic in the timeline of millisecond to microsecond. There is certain function that needs to purely perform in the hardware itself. For example, performing FFT (fast Fourier transform) or any other mathematical operations on a huge data set takes a lot of time on PCs. If it is implemented on the hardware, it can crunch much quickly. Also, there is certain high frequency RF equipment, where a strict dependency on the hardware is needed."

Data-Driven Future

Data acquisition enables data gathering, which may be used to deliver reports and fill dashboards with useful information.

As for Jaguar Land Rover, thanks to data acquisition hardware and software, engineers may now query and order data to perform an analysis routine on all test results that meet the specified parameters. They may now run a batch process, sometimes on thousands of files, using a predefined analysis routine or can create an ad hoc analysis routine on data that requires closer inspection. The result of any analysis routine is a templated report to help make data-driven decisions more quickly.

Green of National Instruments says the expectations of data move far beyond just the instantaneous operation of any individual asset toward a system-wide view where data can be aggregated and analyzed from multiple connected devices and the opportunity to use a single software product diminishes.

"No one vendor has a product that can span the technology stack of an industrial IoT application nor [does] any one engineer [have] the expertise to code every element from the ground up," Green says. "Therefore, the key is for vendors to work together and provide software that both abstracts the complexity for their element of the technology stack while ensuring openness and interoperability within an ecosystem of software tools." **DE**

Jim Romeo (*JimRomeo.net*) *is a freelance writer with a focus on business and technology topics.*

INFO ➜ **Cisco:** Cisco.com

➜ **Jaguar Land Rover:** Jaguarlandrover.com

➜ **National Instruments:** NI.com

➜ **Technavio:** Technavio.com

➜ **XAir:** XAirsky.com

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Portable Engineering POWER

New use cases push mobile workstation advances in 2018.

BY RANDALL S. NEWTON

LEFT: The new HP ZBook 14u G5 mobile workstation offers AMD Radeon Pro graphics. *Image courtesy of HP.*

TOP: The Lenovo ThinkPad P52 is the first Lenovo thin-and-light mobile workstation to run a quad-core Intel CPU. *Image courtesy of Lenovo.*

ABOVE: The Dell Precision 7720 mobile workstation offers a 17-in. viewing screen and seemingly unlimited configuration options. *Image courtesy of Dell.*

THE MARKETPLACE FOR MOBILE workstations hit an inflection point in 2017, as sales of mobile workstations increased in relative and absolute terms compared to the larger workstation class market. The results of that change mean new opportunities for engineers in 2018.

When buying computers, the price/performance curve is an ocean wave and the marketplace is divided into beachcombers, swimmers and surfers. Beachcombers are consumers; swimmers are enterprise users. They have low expectations of the ocean and won't pay much extra for a "premium" wave experience. Engineers are surfers. They want the big wave of power.

As a result, workstation-class computers continue to gain in sales, while consumer and enterprise PC markets continue to shrink. Market watchers like Alex Herrera at Jon Peddie Research (JPR) report that workstation sales continue to grow at a faster rate than the rest of the market, and in 2017 mobile workstation sales grew even faster than desktops. In the third quarter of 2017 alone workstation sales revenue was $2.36 billion, according to JPR, on sales of 1.25 million workstations (desktop and mobile).

"Professionals are more mobile than ever," notes Scott Hamilton, a Dell workstation market specialist. "They need powerful systems they can take on the go. Engineers specifically are spending more time in the field, whether working from a home office or at different job sites."

The desire for increased mobility by itself would not drive increased demand for mobile workstations if performance was compromised. "Performance limited the growth in mobile workstation sales in years past," says Sean Young, HP's workstation global lead for product development and AEC. "There was an inflection point last year, where workstation users started replacing desktop units with mobile workstations."

Customers want both portability and power, but what has changed is the performance specs of mobile units. "Thin and light are constants" for most mobile users, Young says; only a thin segment of the market will consider a heavy mobile workstation that offers no performance compromises. "But the definition of 'power' varies with the customer and the workflow."

Another factor driving increased use of mobile workstations is the greater willingness to work collaboratively. Chris Russo, Lenovo's industry expert for AEC and product development, says mechanical engineering is one of several engineering disciplines where he sees an increase in collaborative work. One large Lenovo customer recently moved its entire design and engineering staff from desktop to mobile workstations. "They saw it was easier to work with vendors or from remote job sites," he says.

Breaking Moore's Law

There is talk in the computer industry that using Moore's law to describe computer performance growth is an outdated notion. Raw growth in number of transistors is not a valid measurement, the thinking goes. Instead, the argument goes, look to other improvements such as the Intel Xeon class of CPUs, which are designed as server CPUs but are now finding their way into workstations with their support for error-correcting code memory, higher core counts and support for greater amounts of RAM.

The response from graphics processing unit (GPU) vendors could be characterized as "hold my beer." Both NVIDIA and AMD are packing more transistors and more performance power into smaller footprints with every product update. HP's Young notes the current high-end NVIDIA mobile GPU, the P5000, is powerful enough to run such demanding applications as CATIA or NX.

Professional rendering software is now embedded into most MCAD products, notes NVIDIA's Andrew Rink. "Designers have been exposed to easy rendering; its use is accelerating," he says. The P5000 will be available from various mobile workstation vendors as they refresh their product lines in the first half of 2018; models from Dell and HP are already available.

AMD has increased its R&D in the mobile workstation space in the last two years, yet holds a very small market share. HP and Dell offer AMD products as options in some of their mobile workstations for customers who have standardized on specific GPU technology and who have mainstream uses (AutoCAD, SOLIDWORKS) for mobile workstations. AMD counters the NVIDIA advantage of its CUDA graphics programming language by embracing open standards.

Real-Time Simulation Pushes the Envelope

Engineering graphics are moving beyond the flat screen with an explosion of new use cases. Virtual reality and augmented reality have become a necessary extension of product development. Robotics engineering is using VR as a prototyping environment, to test fully functional—albeit virtual—robots before they are built. Internet of things applications, parts created with 3D printing and autonomous vehicles all benefit from real-time visualization as part of the engineering process.

These new domains are computationally intensive. Consider design review of an automobile in virtual reality. The workstation must deliver 90 frames per second (fps) of high-quality graphics in real-time response to the observation and movement of the VR user; the field of view can change unpredictably at any time. That is four times as much graphics throughput than required to put a 3D CAD model on a flat display. The amount of data required exceeds the memory and bandwidth specs on most computers.

Not every GPU board on the market is powerful enough to run such new engineering use cases. The latest versions of both the AMD Radeon Pro and the NVIDIA Quadro P5000 can support this level of graphics intensity.

"There is an expectation of visual data use," says HP's Young, for product visualization and for upfront simulation. "Looking at airflow, a static image doesn't cut it; you need an animation."

Every vendor interviewed for this article pointed to the new ANSYS Discovery Live as a "killer app" for next-generation engineering graphics. It is designed to work with the CUDA graphics programming environment, so it requires NVIDIA GPUs. Rink says it "works fine" on a single Quadro P5000 mobile GPU and is easy to use. Rink sees early stage product development collaboration as an ideal use for Discovery Live on a mobile workstation. "An engineer can make little adjustments to a product sitting with the customer, quickly testing and making incremental changes."

Other Workstation Trends

We all use a finger or a stylus to navigate our smartphones and tablets. But within product development, that sort of input has been limited to early-stage industrial design. But things are changing. SOLIDWORKS 2018 supports pen-based workflow, for example; so do various apps in the CATIA ensemble. Siemens Solid Edge and NX units work closely with Microsoft on its Surface technology. In 2018 all the leading mobile workstation vendors will offer more options for pen and touch user interaction, starting with various thin-and-light ultrabook models where touch interaction is a market expectation.

Other market trends that will affect mobile workstations in 2018 include the following:

More RAM: "CAD models aren't getting smaller," notes Lenovo's Russo. 64GB of RAM has been standard for the higher-end mobile workstations but is now moving into the mainstream and ultrabook segments of the market.

Storage without moving parts: The transition away from optical drives is nearly complete—and mechanical hard drives are not far behind. The new technology standard for solid-state drives (SSD) is non-volatile memory express (NVMe). Like SCSI and SATA for mechanical drives, NVMe takes better advantage of the data pipeline. NVMe improves on previous data storage specifications by only requiring a single message for a 4KB data transfer (instead of two messages). Older standards processed one data queue at a time; NVMe can process 65,536 at a time. The bigger the engineering model, the more back and forth takes place between RAM and storage. Engineers who upgrade to a mobile workstation using NVMe will notice a substantial performance improvement.

Thunderbolt connectivity: Shop carefully if you have a preference for device connections beyond Thunderbolt. Older standards including HDMI or USB are on the wane in mobile workstations as Thunderbolt becomes an industry standard. DE

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INFO → AMD: AMD.com

→ **Autodesk:** Autodesk.com

→ **Dassault Systèmes:** 3DS.com

→ **Dell:** Dell.com

→ **HP:** HP.com

→ **Intel:** Intel.com

→ **Jon Peddie Research:** JonPeddie.com

→ **Lenovo:** Lenovo.com

→ **NVIDIA:** NVIDIA.com

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

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BOXX APEXX S3: Overclocked and Under Budget

This new workstation delivers the best price/performance of any system *Digital Engineering* magazine has ever tested.

BY DAVID COHN

WE GOT OUR FIRST LOOK at the new BOXX APEXX S-class workstations during Autodesk University this past November (see "digitaleng.news/de/?p=41103"), and the first impression was impressive. That's no surprise. The Austin-based company has been building high-performance workstations for more than 21 years and *DE* has reviewed many of them. When a new BOXX APEXX S3 workstation arrived at our offices a few weeks later, we were more than ready to put it through its paces.

Based on an overclocked eighth-generation Intel Core i7 processor, the APEXX S3 replaces the previous BOXX flagship workstation, the APEXX 2 2403 (*DE* reviewed its predecessor, the APEXX 2 2402, in June 2016: digitaleng.news/de/?p=30802). The new S3 system comes housed in a new aluminum chassis measuring 6.85x17.75x15.25-in. (WxDxH) and weighing 24 pounds. The case is all black except for a small, brushed aluminum BOXX logo at the bottom of the removable front panel. As in previous BOXX workstations, that front grille conceals an air filter that is easily removable for cleaning. Behind it is a pair of 4-in. diameter cooling fans and a large radiator, part of the CPU liquid cooling system.

A sloping panel along the top front of the case contains four USB 3.0 ports, audio jacks for headphone and microphone, a round power button with a bright white LED power indicator, a blue hard drive activity light and a small reset button. A third cooling fan is concealed behind this front panel and blows air through the interior of the case. Like many other manufacturers, BOXX no longer includes an optical drive—the new case offers no front panel drive bays.

The rear panel provides four additional USB 3.0 ports, a USB 3.1 Type-A port, a USB 3.1 Type-C port, two RJ45 network jacks, HDMI and DisplayPort connections for the CPU's integrated graphics, a PS/2 mouse/keyboard jack, an S/PDIF out port and five audio connectors (microphone, line-in, line-out/front speaker, center/subwoofer and rear speaker). There is also a pair of antennas for the built-in Wi-Fi and a button to clear the CMOS.

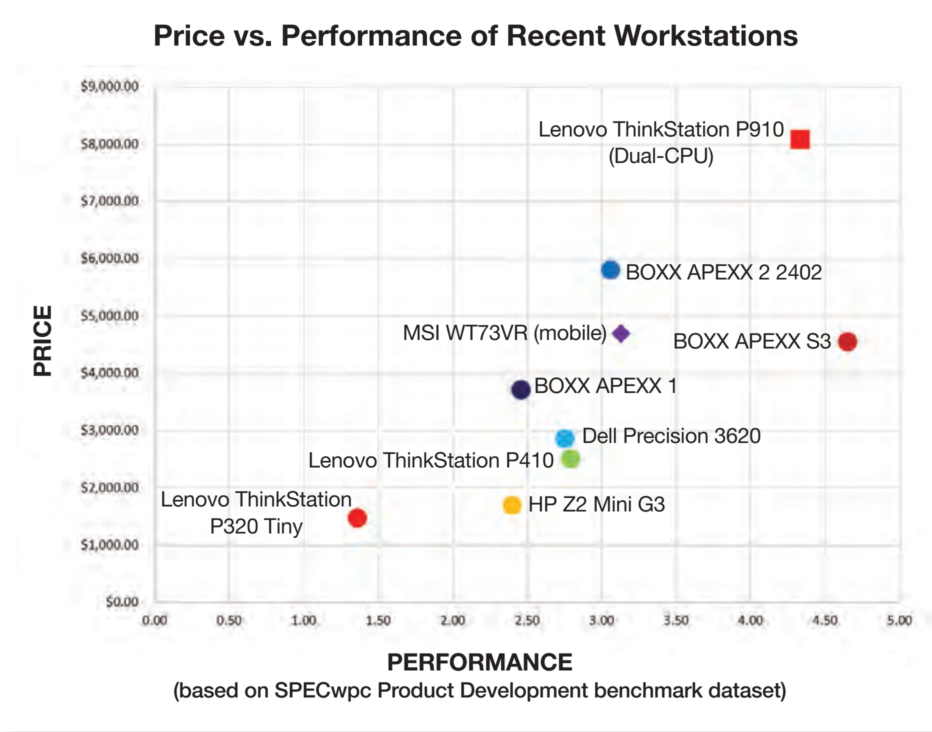
The new BOXX APEXX S3 workstation from BOXX Technologies features a new aluminum chassis with no front-panel drive bays. *Image courtesy of BOXX Technologies.*

New CPU and Motherboard

Loosening a pair of captive screws and removing the right-side panel reveals a spacious, well-designed interior. A pair of 3.5-in. drive bays with quick-release drive mounts hangs from the top of the case. Each of these can be split to accommodate a pair of 2.5-in. drives, but since the new APEXX S3 accommodates up to three M.2-based solid-state drives, both of these bays were empty in our evaluation unit.

The new APEXX S3 uses an ASRock Z370 Taichi motherboard, with the CPU hidden beneath the liquid cooler, which is then tucked below the 650-watt power supply that occupies the bottom-rear corner of the case.

The only CPU BOXX offers in the APEXX S3 is the new Intel Core i7-8700K, which was just released in the fourth quarter of 2017, making this the first system we've received based on the new "Coffee Lake" six-core CPU. The processor includes a 12MB cache (4MB more than in the previous generation "Kaby Lake" CPU, to accommodate the additional cores) and integrated Intel UHD Graphics 630 (the same as in "Kaby Lake"). At its base frequency of 3.7GHz (4.7GHz max turbo), the 8700K has a Thermal Design Power (TDP) of 95 watts. But the "K" designation indicates an unlocked CPU multiplier, meaning that it can be overclocked. In the new APEXX S3, BOXX overclocks the CPU to 4.8GHz and then keeps things running smoothly thanks to the liquid cooling.



In addition to a new motherboard, the "Coffee Lake" architecture also requires a new chipset, the Intel Z370, which also supports overclocking as well as multiple M.2 slots and lots of I/O. The motherboard provides five expansion slots—three PCIe 3.0 x16 slots and two PCIe 3.0 x1 slots—and supports both NVIDIA SLI and AMD Crossfire X technologies. The ASRock motherboard also includes integrated Realtek 7.1 HD audio, gigabit LAN, an Intel 802.11ac dual-band Wi-Fi module and Bluetooth 4.2.

Memory, GPU and Drive Choices

At $3,644, the base configuration of the BOXX APEXX S3 comes with 16GB of RAM, an NVIDIA Quadro P2000 GPU with 5GB of GDDR5 memory and 1024 CUDA cores, and a 512GB SSD M.2 PCIe drive, making even the entry point excellent. But for our review, BOXX upped the ante.

The system we received came with 32GB of DDR4 2666MHz memory, installed as a pair of 16GB DIMMS. The additional memory added $425. Because the motherboard provides four memory sockets, this left two more sockets for future expansion. If 32GB is all you will ever need, you could save $103 by going with four 8GB DIMMS. Opting for 64GB of RAM at purchase would add $1,173 to the starting price.

BOXX also offers a wide range of discrete GPU choices. Our evaluation unit included an NVIDIA Quadro P4000 graphics card, with 8GB of GDDR5 memory and 1792 CUDA parallel processing cores, contributing an additional $400 to the system cost. That board provides a 256-bit interface and a bandwidth of 243 GB/second, while its 105-watt power consumption requires an auxiliary power connection. Other options include NVIDIA GPUs ranging from the Quadro P600 to the P6000 as well as several AMD Radeon graphics boards. With its three PCIe x16 slots, the APEXX S3 can support up to three full-size GPUs and the spacing of the slots ensures that no adjacent expansion slots will ever be blocked.

Although our evaluation unit included only the 512GB SSD M.2 PCIe drive provided as part of the base configuration, BOXX also offers M.2 drives of 1TB and 2TB capacities, so you could have as much as 6TB of solid state M.2 storage once you get past the sticker shock. And that still leaves the two 3.5-in. drive bays at the top of the case. Here, BOXX offers SATA drives, with solid-state options ranging from 240GB to 4TB and 7200rpm drives with capacities of 2TB to 8TB.

Incredible Performance

With a high-end GPU and six CPU cores running at 4.8GHz, we expected the BOXX APEXX S3 to perform well, but the results we recorded on our suite of benchmark tests exceeded our expectations. On the SPECviewperf tests of graphics per-

Workstations Compared

Workstations Compared	BOXX APEXX S3 one 3.70GHz Intel Core i7-8700K 6-core CPU over-clocked to 4.8GHz, NVIDIA Quadro P4000, 32GB RAM, 512GB SSD	Lenovo ThinkStation P320 Tiny one 2.90GHz Intel Core i7-7700T quad-core CPU, NVIDIA Quadro P600, 16GB RAM, 512GB SSD	HP Z2 Mini G3 one 3.2GHz Intel Core i7-6700 quad-core CPU, NVIDIA Quadro M620, 32GB RAM, 250GB SSD and 1TB SATA HD	Lenovo ThinkStation P410 one 3.6GHz Intel Xeon E5-1650 v4 6-core CPU, NVIDIA Quadro M4000, 16GB RAM, 1TB SATA SSD HD	Dell Precision 3620 one 4.0GHz Intel Core i7-6700K quad-core CPU, NVIDIA Quadro M4000, 32GB RAM, 5126GB PCIe SSD and two 1TB SATA drives in RAID 0 array	BOXX APEXX 2 2402 one 4.0GHz Intel Core i7-6700K quad-core CPU cover-clocked to 4.4GHz, NVIDIA Quadro M5000, 16GB RAM, 800GB PCIe SSD
Price as tested	$4,498	$1,479	$1,698	$2,515	$2,860	$5,806
Date tested	11/30/17	9/8/17	1/20/17	10/26/16	8/5/16	1/30/16
Operating System	Windows 10	Windows 10	Windows 10	Windows 10	Windows 10	Windows 10
SPECviewperf 12 (higher is better)						
3dsmax-05	140.20	30.87	33.19	n/a	n/a	n/a
catia-04	170.48	40.37	33.97	89.66	86.07	133.05
creo-01	148.65	41.63	36.68	76.93	72.47	108.03
energy-01	12.62	0.41	0.63	6.34	6.33	11.44
maya-04	120.80	37.07	29.95	63.31	69.94	101.53
medical-01	56.17	12.24	10.74	26.62	26.54	45.12
showcase-01	82.78	16.32	19.63	46.58	45.77	60.37
snx-02	159.37	36.04	28.29	125.39	72.93	121.01
sw-03	196.79	63.53	57.90	106.37	108.73	158.22
SPECapc SOLIDWORKS 2015 (higher is better)						
Graphics Composite	6.25	2.59	2.51	8.08	8.23	7.65
Shaded Graphics Sub-Composite	4.53	1.99	2.04	4.87	4.95	4.19
Shaded w/Edges Graphics Sub-Composite	5.55	2.46	2.58	5.97	6.36	5.57
Shaded using RealView Sub-Composite	5.51	2.17	1.94	6.43	6.35	5.45
Shaded w/Edges using RealView Sub-Composite	5.93	2.60	3.33	9.99	10.19	9.01
Shaded using RealView and Shadows Sub-Composite	5.82	2.25	1.73	7.23	7.07	6.77
Shaded with Edges using RealView and Shadows Graphics Sub-Composite	6.22	2.55	2.84	10.47	10.57	10.29
Shaded using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	10.77	3.97	2.21	16.01	15.04	14.87
Shaded with Edges using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	11.93	4.49	3.37	22.75	21.89	21.17
Wireframe Graphics Sub-Composite	4.67	2.05	3.46	3.26	3.88	4.19
CPU Composite	4.27	1.67	2.78	5.08	4.96	6.09
SPECwpc v2.0 (higher is better)						
Media and Entertainment	4.91	1.44	2.53	2.84	3.22	3.52
Product Development	4.65	1.36	2.40	2.79	2.75	3.06
Life Sciences	5.24	1.39	2.59	3.03	3.25	3.65
Financial Services	6.07	1.70	3.11	4.60	1.40	1.54
Energy	4.91	1.10	1.97	3.11	2.77	3.17
General Operations	2.33	0.86	1.47	1.14	1.58	1.99
Time						
Autodesk Render Test (in seconds, lower is better)	33.40	109.90	62.40	50.10	58.20	41.70

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

The APEXX S3 workstation features an eighth-generation Intel Corei7-8700K six-core CPU overclocked to 4.8GHz and supports up to three high-end GPUs. *Image courtesy of BOXX Technologies.*

formance, the BOXX APEXX S3 achieved the highest scores we've ever recorded on all but two of the nine datasets.

Although the system did not reach the same lofty heights on the SPECapc SOLIDWORKS benchmark, it still performed very well, setting marks among the fastest systems we've tested and turning in the top score on one of the 11 test components.

But perhaps the most telling results were those we obtained on the SPECwpc workstation performance benchmark and our own AutoCAD rendering test. On the SPECwpc benchmark, which includes six test suites representing vertical markets that often have very different computing demands, the BOXX APEXX S3 turned in the top scores on many individual tests (21 of 33). Those results place it at the top among single-CPU tower workstations in all six test suites, a position it retained in the Media and Entertainment, Product Development and General Operations categories, even when compared to the top-rated dual-CPU workstation.

On the AutoCAD rendering test, which clearly shows the advantages of fast CPUs with multiple cores, the new BOXX APEXX S3 surpassed every system we have ever tested, averaging just 33.4 seconds to complete the rendering.

BOXX rounds out the APEXX S3 with a Logitech K120 104-key USB keyboard and a Logitech M100 USB mouse, although our evaluation unit included a Logitech M500 USB laser mouse, a $29 add-on. BOXX also offers other input device options. Windows 10 Professional 64-bit comes preloaded and is the only operating system offered. Like its predecessors, the APEXX S3 is backed by a three-year warranty that includes premium next-business-day on-site service with 24/7 phone support during the first year and depot repair service and weekday daytime phone support during the second and third years. Premium support during years 2 and 3 is available in the U.S. and Canada for an additional charge.

As equipped, the new BOXX APEXX S3 we reviewed priced out at $4,498, considerably less than its predecessor, while delivering performance that surpassed workstations costing nearly twice as much. Even the $3,644 base configuration would likely beat much of the competition. Simply put, the new BOXX APEXX S3 represents the best price/performance of any system we have ever tested at *DE*, making it a great choice for anyone doing CAD or 3D modeling. **DE**

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

INFO → BOXX Technologies: boxx.com

BOXX APEXX S3

- **Price:** $4,498 as tested ($3,644 base price)
- **Size:** 6.85x17.75x15.25-in. (WxDxH) tower
- **Weight:** 24 pounds
- **CPU:** one Intel Core i7-8700K (6-core) 3.7GHz (overclocked to 4.8GHz)
- **Memory:** 32GB DDR4 at 2666MHz (up to 64GB supported)
- **Graphics:** NVIDIA Quadro P4000
- **Storage:** Samsung 512GB SSD M.2 PCIe drive (support for up to 3 M.2 drives plus two 3.5-in. internal SATA drive bays)
- **Floppy:** none
- **Optical:** none
- **Audio:** onboard integrated 7.1 high-definition audio (microphone and headphone on front panel; microphone, line-in, line-out/front, rear, and center/subwoofer and S/PDIF out on rear panel)
- **Network:** integrated 10/100/1000 LAN with two RJ45 jacks; Intel 802.11ac dual-band Wi-Fi and Bluetooth 4.2
- **Modem:** none
- **Other:** Four USB 3.0 on front panel; four USB 3.0, one USB 3.1 Type-A, one USB 3.1 Type-C on rear panel; integrated DVI and HDMI video ports
- **Keyboard:** 104-key Logitech K120 USB keyboard
- **Pointing device:** Logitech USB Laser Mouse

EDITOR'S PICKS

*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.*

Inspired for Simulation-Driven Design

Design topology optimization and simulation solution sees range of enhancements.

Altair's Inspire can help you create strong, lightweight parts with minimal ado. You can use Inspire from a design project's "digital napkin" stage, to take a new look at a trusty old design or in-between.

You can make and simulate dynamic systems to resolve loads. You can simulate competing ideas for, say, static loads and buckling. To meet lightweighting targets, you can optimize designs that consider both the intended machine and materials.

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Industrial 3D Printing Lands on the Desktop

New desktop system said to rise to a new class of industrial equipment.

Airwolf 3D introduced its fifth-generation additive manufacturing system. The EVO Additive Manufacturing Center comes out of the box with a roomy 12x12x11-in. build volume and a snappy 250 mm-per-second print speed.

The EVO sports dual printheads. It auto levels and calibrates. It has linear precision guides and an LED-lit machine vision system. A full-color touchscreen provides controls and status reports. EVO also has a HEPA and carbon filter air-purifying system.

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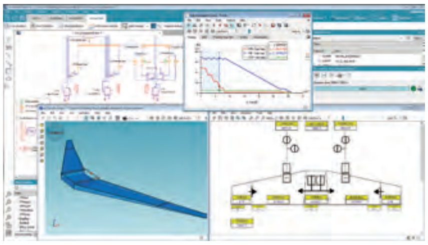

Mechatronic System Simulation Platform Updated

Two Simcenter applications and two system simulation solution updates debut.

Siemens offers the v16 edition of Simcenter Amesim, its 1D mechatronic system simulation platform formerly branded as LMS Imagine.Lab Amesim. This release has a new user interface, tighter coupling with CAE, CAD, controls software, Excel, other Simcenter solutions and Siemens' Teamcenter suite of product lifecycle management applications.

There's more support for automotive, transportation, aerospace, defense and industrial machinery applications.

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Simulation Software Suite Updated

BETA CAE Systems releases new edition of its simulation tool sets.

In this release, version 18.1.0, the ANSA preprocessor sees a lot of action as does the META post-processor. The big show-me improvement is a new Sketch tool. This collaboration tool lets you highlight something in a model and add in some notes.

ANSA offers a new approach to synthesize modular assemblies that have interdependent subsystems. Also new is an Octree tree data structure entity for creating and previewing the results of Octree-based algorithms.

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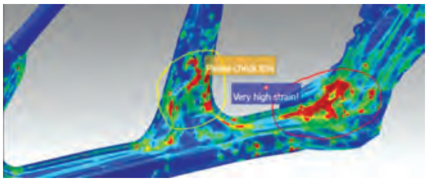

Next-Gen Engineers

Student Design Competition Profile: Autodesk's Design for Industry

Meeting Industry Challenges with Software Tools

BY JIM ROMEO

WE SPOKE TO TORIE ANDERSON, senior manager, Strategic Partners and Initiatives, at Autodesk to learn more about this competition.

Digital Engineering: Please provide an overview of the Design for Industry competition?

Torie Anderson: In 2016, Autodesk launched Design for Industry to offer the next generation an opportunity to show off their design skills in thematic challenges, judged by industry professionals who are experts in fields related to the theme and soliciting designs that solve real-world challenges. The program helps participants better understand key skills and challenges faced by the industry and is supported through access to learning content and software resources to build proficiency with professional tools, including Autodesk Fusion 360.

Designs are then made public, which not only showcases the work of the next generation, but also allows companies to view designs while assessing candidate pools for potential projects, new hires or internships. Participants may vote for their favorite entries. The judges use these votes as the basis for picking finalists, and the winners (8 to 12 per competition) are decided by the industry partners that defined the challenge criteria. Once the winners are announced, the 1:1 mentoring sessions commence.

The competition is open to students who are 13 to 25 years old; participants must be enrolled at secondary or postsecondary educational institutions. Autodesk has received more than 15,000 entries from more than 100 countries, proving the next generation is motivated to design for industry.

DE: Can you elaborate on the designs that are part of the event and how they originated?

Anderson: To participate, submission of a render of a 3D model and a brief description of their design is required. Some participants choose to also submit annotated drawings, marketing materials or videos to support their designs in an effort to clearly convey their design intent. Entries for each Design for Industry challenge are publicly viewable on the Design for Industry gallery. Winners receive mentoring sessions with the judges where they can receive feedback on their design and mentoring in support of their career aspirations.

DE: Anything else you can add about the event?

Anderson: To encourage the next generation to pursue STEM (science, technology, engineering and mathematics) fields, we must reframe what careers in these areas really look like. Today's current education system often positions the manufacturing industry as 19th and 20th century notions of the industrial age, the welding and metalworking field of the past, not the smart, connected product manufacturing, advanced material development and digital design integration we're seeing in today's field.

It's imperative to connect the next generation with the industry to help shape their perception of engineering and manufacturing and train them with the skills needed in the workplace of the future. From challenges that directly connect the next generation with industry leaders as mentors and judges, to working directly with local universities and companies to help create solutions in support of today's global challenges, Autodesk aims to inspire and empower the next generation to imagine, design and make a better world. **DE**


One student entry: A microscope designed for dermatologists.

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MORE → academy.autodesk.com/design-for-industry

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| COMMENTARY |

By John Kawola

3D Printing's Role in Manufacturing's Resurgence

ALTHOUGH THE MANUFACTURING SECTOR has undergone a lack of growth in recent decades, the industry has taken a positive turn over the past year. According to the Bureau of Labor Statistics, the U.S. has added 70,000 manufacturing jobs since November 2017. Many factors, including the political landscape and improving economy, have contributed to this newfound revival—but we cannot discount technology's positive impact on the industry, particularly 3D printing.

Although many experts believe that 3D printing is still in its infancy, its impact can already be felt throughout the manufacturing sector. 3D printers are poised to become a mainstay of factories, with the World Economic Forum asserting that they have helped bring about a "Fourth Industrial Revolution," especially in combination with technology such as robotics, software and other digital solutions that are making processes more automated.

As 3D printing technology becomes more entrenched within the manufacturing industry, it has the potential to encourage the creation of new jobs for higher skilled workers, positively impact design and production efficiency, and completely disrupt the basis of traditional manufacturing.

Opening Doors for Highly Skilled Workers

Research from HP and A.T. Kearney asserts that it is crucial for government agencies, industry leaders and academia to form a strategic partnership to navigate new technologies within manufacturing. If these technologies are fully embraced, they have the potential to create "$600 billion to $900 billion in new revenue and 3 million to 5 million new jobs in the next 10 years."

Leaders within the manufacturing sector, as well as educational institutions, should prioritize programs that focus on 3D design and engineering to create a tech-savvy workforce capable of meeting the challenges of Industry 4.0. According to the World Economic Forum's 2018 report (http://reports.weforum.org/future-of-jobs-2016), the U.S. is "globally renowned for its ability to innovate and is currently at the forefront of major developments surrounding the emerging technologies of the Fourth Industrial Revolution." The U.S. clearly has an advantage—a large and eager workforce, with the potential to learn the skills that will be paramount to remaining a global manufacturing leader.

Introducing New Levels of Efficiency

3D printing is already used by many factories for prototyping and to create production tools with the added benefit of real-time customization. Factories can speed up their delivery time for parts by printing them in house, rather than waiting for an order fulfillment, increasing production volumes and lowering costs as well as time.

Take the automotive industry as an example. Manufacturers have already embraced 3D technologies and their benefits, with the U.S. Department of Energy's Oak Ridge National Laboratory predicting that "3D printers have the potential to reduce the price tag of developing an entirely new vehicle from $600 million today to just $60 million." Volkswagen Autoeuropa has used 3D printers to produce tools in-house, leading to a 91% reduction in tool development costs and reduced development time by 95%.

Many of these cost-saving benefits are coming from more accessible and reliable desktop 3D printers, rather than a large centralized 3D printer. The smaller desktop models allow for specialized groups of engineers to print prototypes near where their design process occurs. With the ability to create a quicker and cheaper prototype of a product using 3D printing, manufacturers can quickly identify design flaws and redesign, shortening time to market. As products are delivered to the market quicker, companies are nimbler in responding to customer feedback and trends.

Distributed Manufacturing Opportunity

Past business models determined that centralized manufacturing was most cost-efficient for enterprises, locating one large factory or warehouse where labor and land was cheapest. But distributed manufacturing is starting to become a reality—and 3D printers are set to shine in this environment. We've seen companies like Amazon shifting to this business model by building several smaller regional factories and distribution centers to reduce shipping costs and expedite products to customers. The ability for 3D printing to create customized replacement parts, coupled with a smaller supply chain network, can lead to large savings for the manufacturer—and get products into the hands of customers faster.

3D printing continues to evolve and advance, slowly making its mark on the manufacturing sector. Although factories are beginning to see the benefits, not only to their bottom line, but in productivity and job creation, more widespread implementation of this technology will continue. The scalability and efficiency of 3D printing make it ripe to further disrupt the manufacturing status quo, and it is inevitable that its impact will be felt outside of factories in the future. DE

Kawola *is the president of Ultimaker North America (Ultimaker.com).*

DE
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