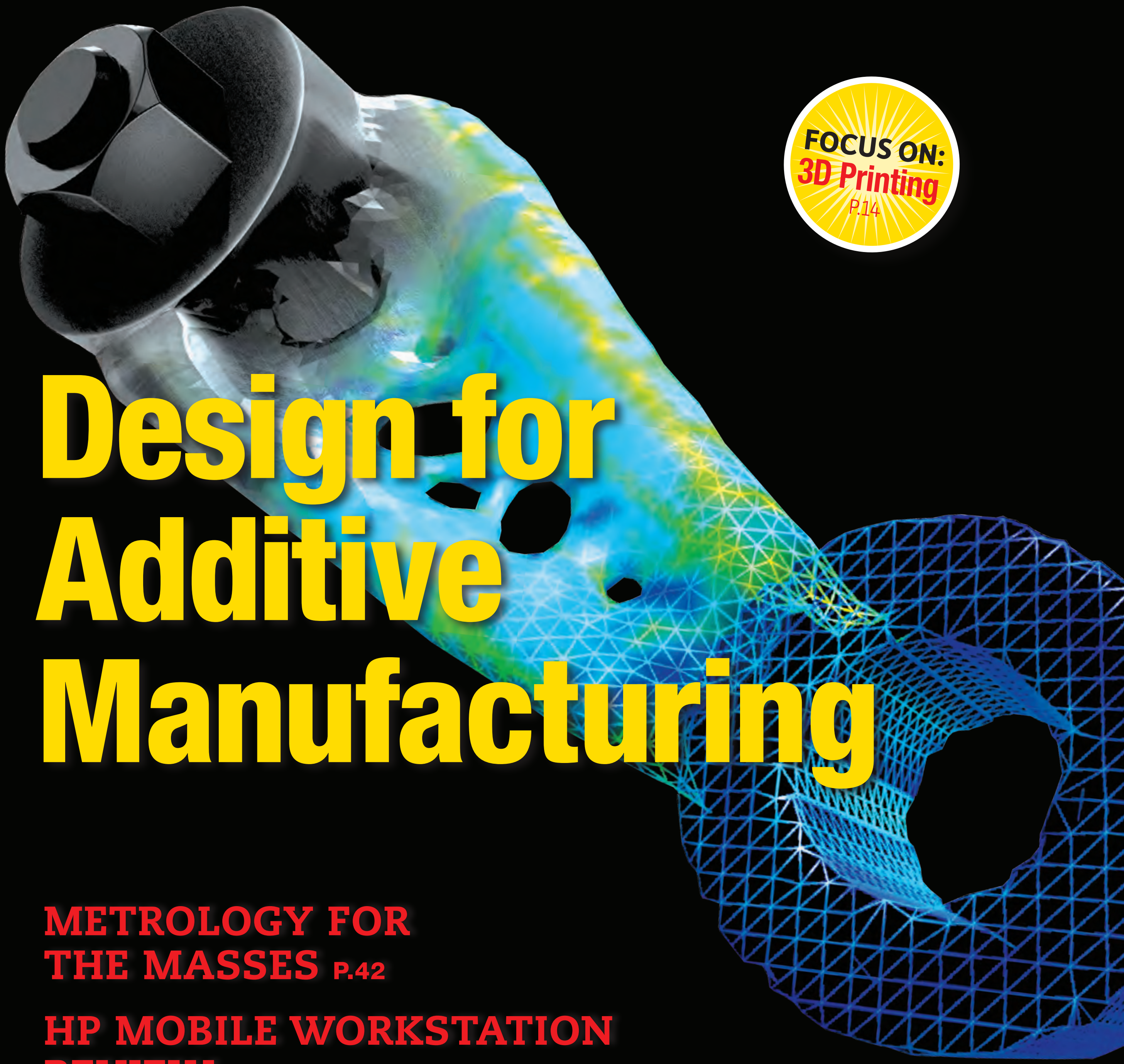
digitaleng.news //////

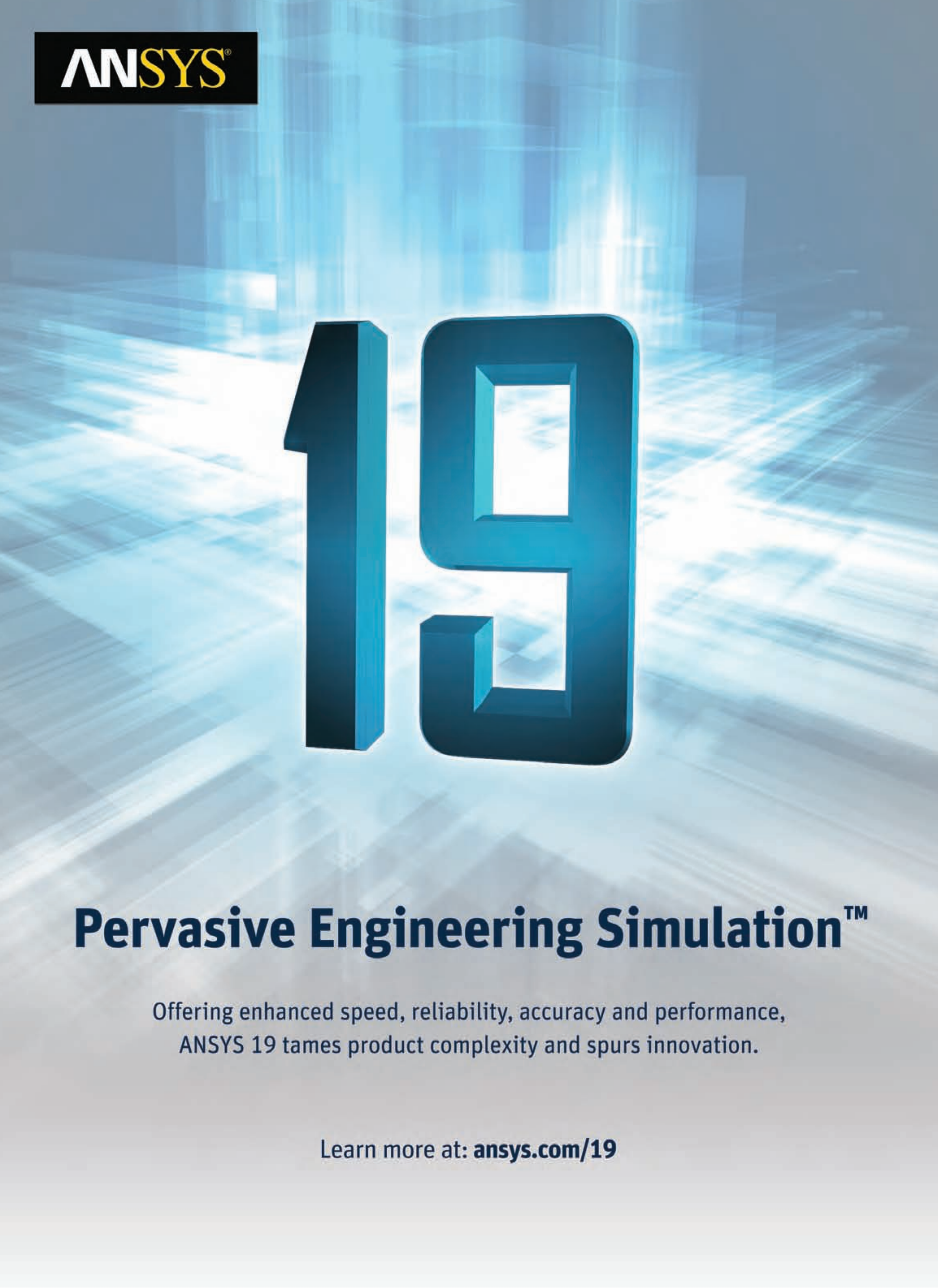
DE Digital Engineering

April 2018



FOCUS ON: 3D Printing P.14

Design for Additive Manufacturing


ANSYS
Pervasive Engineering Simulation™
Offering enhanced speed, reliability, accuracy and performance, ANSYS 19 tames product complexity and spurs innovation.
Learn more at: ansys.com/19


ADDITIVE MANUFAC
CNC
EOS M 400-4

by Jamie J. Gooch

3D Printing a Piece of the Puzzle

A COMMON SENSE APPROACH to solving big problems is to divide them into smaller, more manageable components. For instance, I remember my daughters intuitively dividing puzzle pieces by color, like engineers building subassemblies, to finish the bigger task. Of course, when the problem is especially large, the subassemblies can become their own puzzles. As complexity grows, it becomes increasingly difficult to put everything together.

Still, we've become pretty good at creating solutions when we can see the finished product—whether it's putting 1,000 jigsaw puzzle pieces together to match the picture on the box or putting 30,000 parts together to form an automobile. When we know the final outcome and can all work toward the same goal, the divide-and-conquer method of problem solving works well.

But when it comes to implementing a new technology, the old "solution in search of a problem" maxim has a ring of truth. In many cases, it's not that there is no problem to be solved, it's that there are a mind-boggling number of problems that could potentially be solved.

The Value of Vision

Take 3D printing, for example. The decades-old invention had advanced enough five years ago that it was being hailed as a technology that would change the world. Changing the world certainly qualifies as a big puzzle to solve, so big that it was broken up into a myriad of smaller problems—but there was no agreement on what the big picture on the "Change the World" puzzle box looked like.

Many entrepreneurs had visions of a 3D printer in every home, and set off to solve that problem. Some discrete manufacturers saw mass customization driving the factories of the future. Supply chain experts focused on replacing costly inventories and centralized manufacturing with an on-demand, distributed model. Economists worried over the effects of freely downloadable or 3D-scanned products becoming real. Mechanical engineers saw organic, lightweight parts that couldn't be made before. Electronics engineers imagined 3D-printing their own circuit boards. Medical professionals envisioned more affordable, custom prosthetics and implants. Architects saw 3D-printed buildings, chefs saw 3D-printed foods, fashion designers saw 3D-printed clothes, and on and on.

What we now look back on as the height of hype surrounding 3D printing were not flights of fancy that had no chance of becoming reality. Some of the puzzles were just missing pieces—important pieces like technical know-how, material choices, more advanced hardware, better design tools and government approvals. There weren't enough educators, material scientists, equipment and software makers, or government regulators to fill in those missing pieces for every puzzle. The near-endless possibilities of 3D printing/additive manufacturing diffused implementation efforts, slowing progress.

Bringing the Pictures into Focus

Now those pieces are being assembled, thanks to 3D printing hardware and software vendors working together (see page 14), a focus on industrial use cases (see page 18), increased training on how to design for additive manufacturing (page 24) and more material options (page 28). However, if the impressive market predictions for the near future of 3D printing (see page 8) are to come true, there is much more work still to be done. Other technologies are emerging that need to be incorporated into the big picture of 3D printing.

In just the past few years, we've seen how important robotics and vision systems will be to the future of 3D printing. Automating the loading and application of materials, part removal, post-processing and inspection will all continue to advance mass customization in industrial additive manufacturing. Already, generative design software has resulted in lighter weight, organic-like 3D-printed parts in the field, while artificial intelligence promises to suggest even more innovative designs. It no longer seems far-fetched to imagine connected machines monitoring part wear and predictively ordering their own 3D-printed replacement parts.

There is a lot to learn from the rise and fall and rise of 3D printing. One technology won't change the world, but it's a growing part of the puzzle for people with the right vision. **DE**

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

DE
Digital Engineering

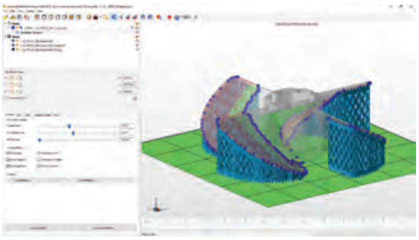
TECHNOLOGY FOR OPTIMAL ENGINEERING DESIGN

INSIDE

digitaleng.news

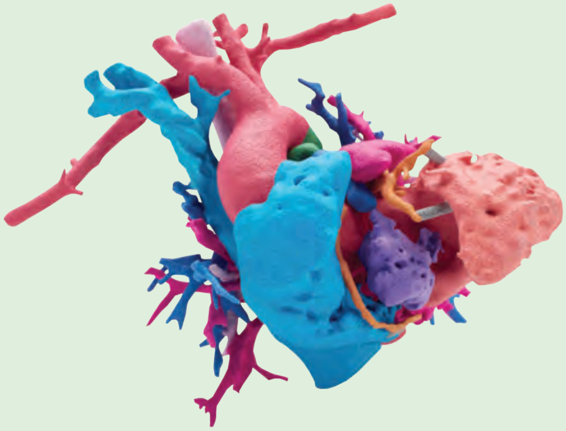
April 2018
Vol.23 • No.8

FEATURES



ON THE COVER:
Image courtesy of Dassault Systèmes.

FOCUS ON 3D PRINTING



DEPARTMENTS

PUBLISHER
Tom Cooney

EDITORIAL
Jamie J. Gooch | Editorial Director
Kenneth Wong | Senior Editor
Anthony J. Lockwood | Editor at Large
Stephanie Skernivitz | Associate Editor
Sarah Petrie | Copy Editor

CONTRIBUTING EDITORS
Tony Abbey, Brian Albright, Mark Clarkson, David S. Cohn, Tom Kevan, Randall Newton, Beth Stackpole, Pamela Waterman

ADVERTISING SALES
Tim Kasperovich | Eastern and Midwest Regional Sales Manager
Phone: 440-434-2629
tkasperovich@digitaleng.news

Tom Cooney | Western U.S. and International Sales Manager
Phone: 973-214-6798
tcooney@digitaleng.news

ART & PRODUCTION
Darlene Sweeney | Director
darlene@digitaleng.news

A PEERLESS MEDIA, LLC PUBLICATION
Brian Ceraolo | President and Group Publisher

ADVERTISING, BUSINESS, & EDITORIAL OFFICES
Digital Engineering® Magazine

Peerless Media, LLC
111 Speen St., Suite 200,
Framingham, MA 01701
Phone: 508-663-1500
de-editors@digitaleng.news
www.digitaleng.news

Kenneth Moyes | President and CEO, EH Media

SUBSCRIBER CUSTOMER SERVICE
Digital Engineering® magazine
PO Box 677
Northbrook, IL 60065-0677
Phone: 847-559-7581
Fax: 847-564-9453
E-mail: den@omeda.com

Digital Engineering® (ISSN 1085-0422) is published monthly by Peerless Media, LLC, a division of EH Media 111 Speen St., Suite 200 Framingham, MA 01701. Periodicals postage paid at Framingham, MA and additional mailing offices. *Digital Engineering®* is distributed free to qualified U.S. subscribers. **SUBSCRIPTION RATES:** for non-qualified; U.S. $108 one year; Canada and Mexico $126 one year; all other countries $195 one year. Send all subscription inquiries to MeritDirect, *Digital Engineering®*, PO Box 677, Northbrook, IL 60065-0677. ***Postmaster:*** Send all address changes to MeritDirect, *Digital Engineering*, PO Box 677, Northbrook, IL 60065-0677.

CAASE 18 Preview: Cars Will Have Souls, Personalities, Preferences

Piero Aversa, Ford's chief engineer for Global Powertrain NVH & CAE

BY KENNETH WONG

CARS OF THE FUTURE will behave a lot more like humans, according to Piero Aversa, Ford's chief engineer for Global Powertrain NVH & CAE.

"The car as we know it today will totally change. It will have a so-called soul and will be an extension of your personality," he writes in the preview of his upcoming talk at the Conference on Advancing Simulation and Analysis in Engineering (CAASE, June 5-7, Cleveland, Ohio), cohosted by NAFEMS and *DE*. It would become something that "you can talk to, can read your face and lips, and would know your mood and feelings as it transports you from point A to point B," he predicts.

Eco-boost Technologies Are Key

Aversa oversees a team of more than 200 engineers, responsible for simulating and testing the noise, vibration, and harshness (NVH) of the carmaker's powertrains. As the automotive landscape evolves, from an industry driven by combustion engines to one that embraces the hybrid model, the NVH & CAE team's work also changes.

"The trend we're seeing now is the move toward downsized engines with eco-boost technology—that means smaller, lightweight engines that produce a lot of performance in an efficient manner," he says.

By comparison, electric and hybrid cars tend to be much quieter; therefore, other ambience noises previously deemed not noticeable could become much more prominent.

CAE Goes Mainstream, Upfront

Aversa and his team use a mix of CFD, FEA and topology optimization technologies in their powertrain design workflow.

MORE → digitaleng.news/virtual_desktop/?p=13651

CAASE 18 Preview: We Trust You, But You Still Need to Prove It

Patrick Safarian, fatigue and damage tolerance senior technical specialist for the FAA.

It generally takes five years to certify a brand new part, but it can take as long as 10 to 15 years if it involves unproven, composite materials, reveals Dr. Patrick Safarian, fatigue and damage tolerance senior technical specialist for the FAA.

The rigorous testing and validation may be at odds with some manufacturers' desires to bring new designs to the market as fast as possible, but there's a reason to be methodical.

"Once we certify something, whether it's a component or an airplane, it's very difficult for us to decertify it," says Safarian.

As a regulatory body, the FAA is responsible for certifying airlines, aircrafts, airmen and even airports. But there are some misconceptions about how certification works, specifically as it relates to the analysis tools. Safarian plans to shed some light on it in his upcoming keynote talk at CAASE, cohosted by NAFEMS and *DE*.

We Certify Parts, Not Tools

If the FAA's stance toward new technologies like composites and digital simulation seems conservative, it's because the organization has to prioritize safety over speed and industry trends.

"We tend to be skeptical. We sometimes lag behind the industry in embracing new technologies," says Safarian. "For us to embrace something, it has to be tried and true."

Safarian also recognizes that digital simulation and analysis tools are the workhorses of the aerospace industry, and they are indispensable in the design validation process.

"The regulations are written for parts, not tools. So we don't certify software; we don't certify the analytical tools," clarifies Safarian. "We certify parts either by tests, or by analysis supported by tests."

For this reason, Safarian doesn't usually have an easy answer for those who ask: "Is such and such software an acceptable tool for certification?"

MORE → digitaleng.news/virtual_desktop/?p=13792

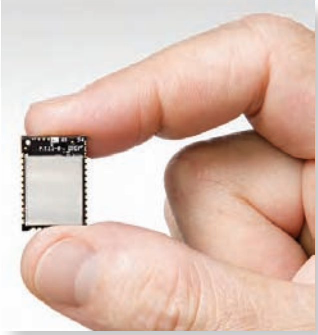
REGISTER TO ATTEND CAASE 18 → nafems.org/CAASE18

CAASE18
The Conference on Advancing Analysis & Simulation in Engineering
June 5 - 7, Cleveland, Ohio

Embedded World 2018 Explores New Frontiers

BY RANDALL S. NEWTON

AT THE ANNUAL EMBEDDED WORLD trade show and conference in Nuremberg, Germany, more than 30,000 attendees packed the aisles and visited more than 1,000 vendors. Both numbers set records for the 16-year-old show. Additionally, more than 1,700 attendees from 73 countries signed up for the added-cost conference program.



Controllers and embedded processors were in abundance at this year's Embedded World. The new Digi xBEE 3 is half the size of its predecessor, supports Python programming, offers a dual-mode radio and can be upgraded via software to support Bluetooth LE. *Image courtesy of Digi International.*

Embedded Technology and the IoT Marketplace

Embedded technology (see page 50) is a subset of the larger internet of things (IoT) market, which continues to grow at a rapid pace. Research firm IDC estimated the global IoT market grew by 16.7% in 2017 to just over $800 billion and predicts global IoT industry spending to hit $1.4 trillion in 2021 as manufacturers and service industries continue to invest in the hardware, software, services and connectivity that enable the IoT. Hardware maker Cisco estimates there will be 3.3 billion machine-to-machine (M2) connections worldwide by 2021, up from a current estimate of 1.5 billion.

"The discussion about IoT has shifted away from the number of devices connected," notes Carrie MacGillivray, vice president for IoT and Mobility at IDC. "The true value of IoT is being realized when the software and services come together to enable the capture, interpretation and action on data produced by IoT endpoints." IDC says the industry segments that attracted the largest investments for IoT development in 2017 included manufacturing operations, freight monitoring and production asset management. IDC predicts the top growth markets for IoT spending in 2018 will include airport facilities automation, electric vehicle charging and in-store contextual marketing.

Hardware spending on IoT is dominated by the modules and sensors that connect end points to networks, thus the reason 30,000 engineers crowded the aisles at Embedded World 2018 in Nuremberg, Germany, in late February.

There was the usual emphasis on making embedded devices safe and secure, as well as plenty to learn about emerging industry themes including autonomous computing applications, IoT and embedded vision.

The increased use of embedded vision applications was a key topic this year. Computer vision is the use of digital processing to interpret meaning from video; embedded vision refers to the practical use of computer vision in machines, which understand their environment through visual means.

The arrival of powerful, low-cost and energy-efficient processors has made it possible to incorporate practical computer vision capabilities into embedded systems, says Jeff Bier, president of the Embedded Vision Alliance and a panelist at a well-attended session on embedded vision applications.

Bier says there has been "huge growth in awareness that vision is practical." One key is that vendors have been assembling systems that simplify the specification of vision. "You can add visual to processing today without having to be a specialist engineer." Embedded vision is a necessity for autonomous products, not just automobiles. Plants don't need vision, but animals do, Bier noted; the difference is mobility.

IT vendors of all types have noted their world was rocked by the competitive pressure of smartphones, creating consumer expectations regarding all computer-mediated experiences. The embedded vision industry is no exception. "Our customers ask why cameras in smartphones are better and cheaper than in embedded devices," says Arndt Bake, chief marketing officer of Basler AG, a German provider of industrial cameras. "Smartphones pushed our industry."

Two primary reasons for the perceived difference between camera quality in smartphones and industrial vision devices is longer product cycles and the need for more rugged products, notes Qualcomm's Leon Farasati, who is director of embedded computing applications for Snapdragon, Qualcomm's line of smartphone system on a chip (SoC). Farasati says Qualcomm is working with manufacturers on ruggedizing Snapdragons for industrial applications and committing to extended lifecycles for selected chips. Qualcomm recently announced its Snapdragon 820 will be supported for industrial applications through 2025. "This change is required and is in response to industrial markets," says Farasati.

Edge Computing

Powerful CPUs or SoCs will be needed as part of embedded vision as industrial applications become more complex, because there is too much data being generated to ship it all off to cloud processing. Such local processing is known as edge computing, and it was another key theme at this year's conference.

AMD was present at this year's Embedded World conference to promote its new generation of computing devices as suitable for embedded use.

MORE → digitaleng.news/de/?p=42686

| CONSULTANT'S CORNER |

IoT

by Monica Schnitger

A Legacy of Connected Equipment

News articles about the internet of things (IoT) often cover personal or home devices, such as fitness trackers and refrigerators that tell us when to buy more milk. But those are just a tiny fraction of the real use cases for the IoT—the industrial sector has millions or billions of machines ready, today, to be digitally active in their own performance. What does the industrial IoT mean for these manufacturers who manage a fleet of installed equipment?

Let's first understand the opportunity. The IoT combines sensors, a way to transmit the sensor data and an analysis engine that uses this data to suggest actions. Imagine a climate control system that monitors itself. It has sensors that transmit data to both a building management system and to its manufacturer's maintenance engine. Locally, a building manager can optimize operations to meet comfort and cost targets. The centralized analytics enable the manufacturer to gather data across its installed fleet that highlight opportunities for maintenance services while also informing the next product design iteration. In addition, this connectedness creates the opportunity to sell heating or cooling degrees, charging customers for the effect of the system rather than the system itself.

Data Collection Affects Design

All of this requires a rethink of the manufacturer's design and go-to-market capabilities. The designer needs to understand what data matters and where to place sensors. He must know about power requirements and the data transmission options available for this type of equipment. (Wi-Fi doesn't exist everywhere!) Designing a product to include sensors, power and comms creates new objectives. In the past, goals may have included attributes like ease of maintenance, flawless operation for 10 years or the ability to survive an earthquake. In an IoT world we might add the ability to transmit uninterrupted and accurate data every 10 seconds, or display part numbers or other data to match up with an augmented reality platform. Someone also needs to build the apps that gather the sensor data, transmit it to the analysis engine and serve out results to the equipment operator.

From a go-to-market perspective, the IoT changes the relationship between maker and user. Some users may prefer to own their assets and are uncomfortable with a rental or performance-based scheme. They may also want to know all costs up front, which usage-based models can't readily predict at the outset. In the HVAC example I mentioned, a colder-than-average winter will lead to higher costs when heat-degree-based pricing is in effect. A cooler-than-average summer means less air conditioning, which means less revenue to the HVAC manufacturer. This scheme requires both sides to share in operating risks.

Building on a Legacy

Industrial equipment makers with a legacy fleet face many of the same problems, but they also have another market challenge: How can they compete against an IoT-ready product that may offer these new business and technical models? And do their customers even want this? The sense I'm getting is that, yes, many buyers want clearer insights into their equipment's operation, even those embarrassed by past lapses in maintenance. And the odds are that most operators already have access to a lot of data they aren't using from sensors placed years ago, feeding data historians for regulatory or after-the-fact analysis. Why not repurpose that data with software and analytics? This creates an IoT offering without requiring significant expenditure by the buyer.

Equipment manufacturers with a base of older products should start by investigating the IoT platforms on the market today and see which of them support the sensor types already installed. Do a pilot project to track data and create analyses. Let the platform build user apps, manage communication and uptime. Many buyers want to work with installed vendors but that doesn't mean they're not interested in the process and data potential of the IoT. Don't let someone take this business away from you! And be open to new ideas and business models. Expect some of them to fail. The IoT is a new world of connectedness and data flows, which means that good ideas will come from unexpected sources. DE

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

| MAKING SENSE OF SENSORS |

SENSOR DESIGN TOOLS

by Tom Kevan

What AI Can Do for EDA

FOR YEARS, analysts and developers have been saying that artificial intelligence (AI) and electronic design automation (EDA) are a perfect match. EDA problems have high dimensionality, discontinuities, nonlinearities and high-order interactions. What better way to grapple with this level of complexity than to apply a technology that takes past experiences and uses them to predict solutions for similar problems?

In fact, AI has begun to come into its own, making tremendous strides over the past few years. But for all its successes, applications of AI-like machine learning, neural networks and deep learning have been slow to find a place in EDA.

But that's changing.

Enhancing CMP Modeling

Mentor Graphics has enhanced chemical-mechanical polishing (CMP) modeling by generating accurate post-deposition profiles via machine learning and neural networks.

CMP plays a key role in chip fabrication by leveling the wafer layers. The outcome depends on the materials being polished and the density and shapes of the materials in any given location.

Because many of today's integrated circuit designs are so tightly packed and scaled down, post-CMP planarity variations can significantly affect the fabrication success. To mitigate any negative effects, chipmakers use CMP modeling to detect potential hotspots as part of their design-for-manufacturing flow.

CMP hotspot analysis looks for areas of the design likely to experience post-CMP defects. Because different materials exhibit different erosion rates in the CMP process, the fab must maintain a constant density balance across the die to prevent bumps and dishing that cause shorts and breaks in the metal interconnects.

To achieve optimal CMP modeling accuracy, the chipmakers must be able to generate high-quality, pre-CMP surface profiles. If these profiles are not accurate, the results of CMP simulations for the post-CMP profile will be compromised. The problem is that building physics-based models for different types of depositions processes—such as high-density plasma CVD and spin-on dielectric—is challenging and isn't practical for more exotic deposition flows, such as enhanced high-aspect-ratio processes.

To address this problem, the engineers at Mentor used machine-learning algorithms to perform sensitivity analysis of measurement data in the pre-CMP surface profiles. They found that the profile dependency was primarily influenced by the underlying pattern geometries. With this information, the researchers used neural network regression calculations to model the pre-CMP surface profile, using the geometric characteristics of the underlying patterns as input. The neural network would then estimate the pre-CMP profile, which would be used as input for the CMP modeling, improving the accuracy of the overall process.

Making the Right Connections

Tackling a related design issue, NetSpeed Systems introduced Turing, a design product that aims to help chip architects optimize SoC (system-on-chip) interconnects. NetSpeed's approach marks a break with the past, recognizing that architects can no longer rely solely on their experience and intuition to make interconnect topology and routing decisions.

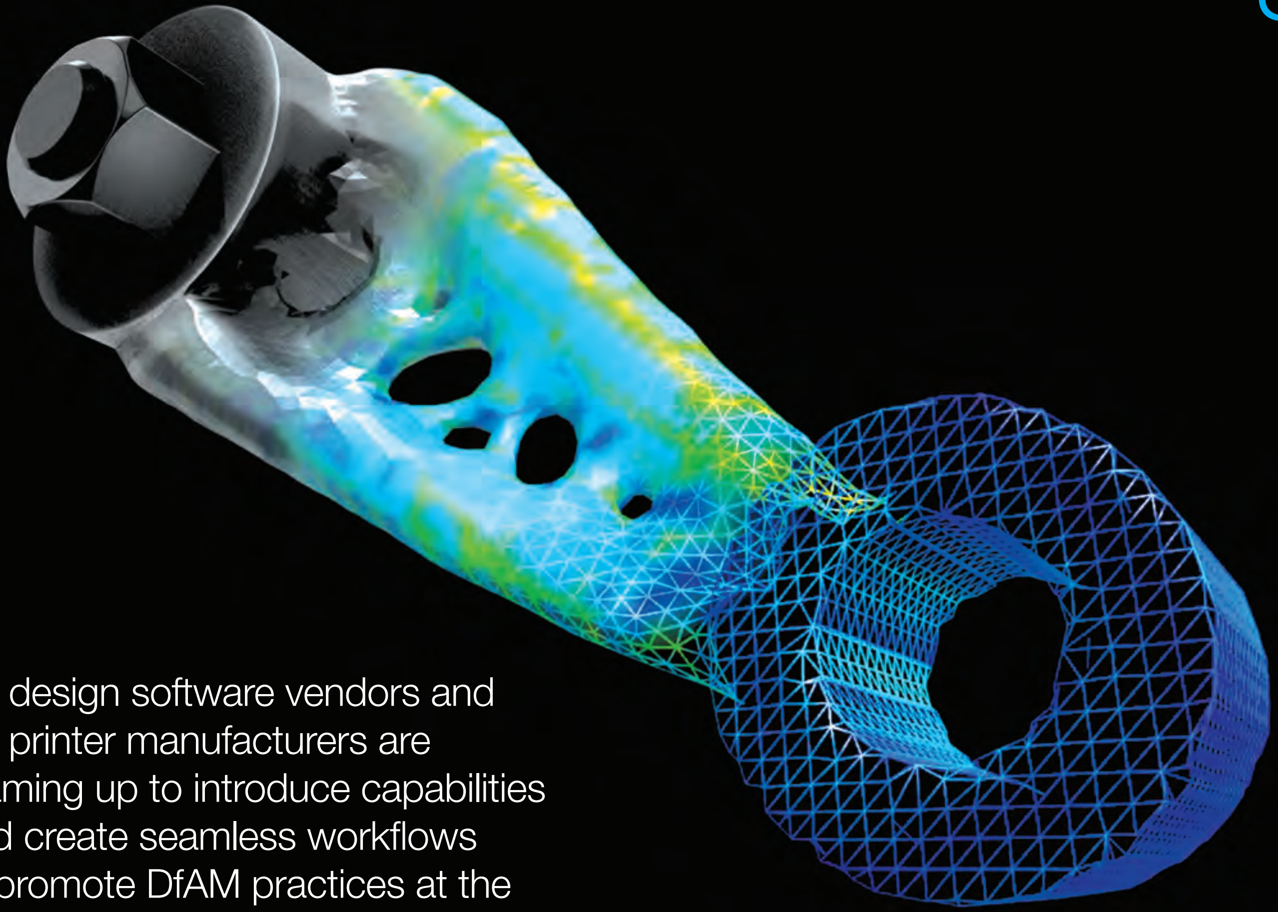
The rise of heterogeneous systems like SoC requires architectures that must accommodate a daunting degree of complexity. To come up with a sound interconnect strategy, a designer must consider a large array of parameters, including routing constraints, connectivity requirements, protocol dependency, clock characteristics and process characteristics, such as wire delay, bandwidth and latency constraints. The number of dimensions in the design space can easily grow to several hundreds.

To address these issues, NetSpeed has adopted a requirements-driven design flow, where the architect specifies IP blocks, connectivity and performance requirements, and system-centric use cases. Turing then uses supervised learning algorithms to search for patterns in interconnect design data to identify promising strategies, evaluating each approach for performance, power and functional safety. The algorithms then suggest an interconnect implementation, allowing the architect to review automatically generated results and fine-tune the implementations accordingly.

These two examples demonstrate how AI has begun to carve out a place in the chip design process, in some cases promising a tenfold improvement in productivity. AI's ability to complement EDA is no longer in question, the working relationship between the two technologies is a long way from being defined. DE

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

Partnering on Design for Additive Manufacturing



3D design software vendors and 3D printer manufacturers are teaming up to introduce capabilities and create seamless workflows to promote DfAM practices at the earliest stages of design.

Desktop Metal partnered with Dassault Systèmes on Live Parts, a generative design tool that aims to simplify design for additive manufacturing (DfAM). ***Image courtesy of Dassault Systèmes.***

BY BETH STACKPOLE

EVALUATING DESIGNS WITH AN EYE toward organic shapes and lightweighting components; consolidating parts into streamlined assemblies; applying multimaterials at the voxel level to achieve optimal structural performance—these are some of the emerging principles defining a new age of design for additive manufacturing (DfAM). This new age is driven by less expensive and more accessible 3D printers and buffeted by new partnerships between 3D design software companies and 3D printing system manufacturers.

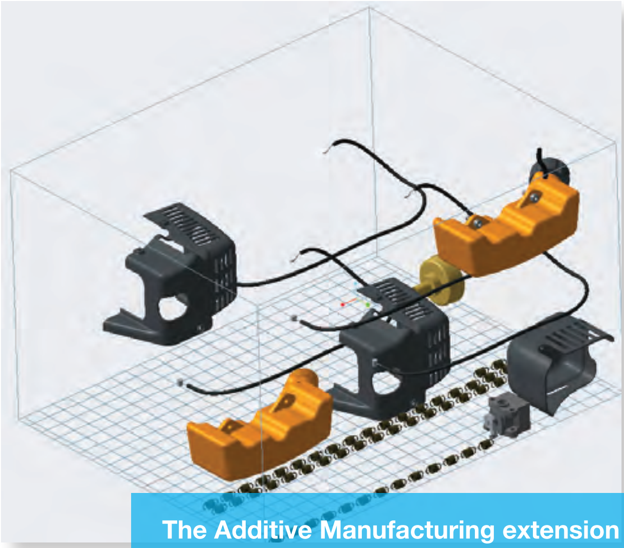
Digitalization, as part of the shift to smart factories or Industry 4.0, is escalating the use of 3D printing not just as a means for rapid prototyping but as an alternative for full-scale production. Companies are expanding use of additive manufacturing to garner cost efficiencies, promote mass customization strategies and to effectively produce organic shapes and lightweight structures that were simply not possible with traditional manufacturing methods like injection molding or CNC machining.

Yet for companies to fully reap the benefits of 3D printing, they need to do more than swap out traditional production processes as a means to output existing designs. Instead, experts say engineers need to take into account the unique properties and material options offered by additive manufacturing from the onset of the development process, in some cases changing the way they approach specific design challenges and following an emerging set of DfAM best practices.

"The frameworks and guidelines for what makes a successful design for injection molding or CNC machining are well established, but with 3D printing, you're often using a design [conceived] for another process," explains Mark Rushton, product portfolio manager for SOLIDWORKS at Dassault Systèmes. "People have operated with tribal knowledge, building up their own expertise on what works based on the materials and printers they have. It's still very disjointed and based on so many variables that it's difficult to establish a finite set of rules like you have with traditional manufacturing processes."

A 3D Printing Backbone

To codify some of the practices and fuel momentum around 3D printing, 3D design software companies and 3D printer manufacturers are teaming up to empower new DfAM principles. Through partnerships and collaborative development initiatives, these players are extending their platforms with new capabilities and creating seamless workflows between 3D design and 3D printing software to promote DfAM practices early in the development effort as opposed to at the end of the cycle when it is more expensive to make adjustments, and when there is a greater risk of build failures.



The Additive Manufacturing extension to Creo 4.0 allows for auto positioning and nesting of components in a "print tray" container, which can be reused and leveraged to save time and money. *Image courtesy of PTC.*

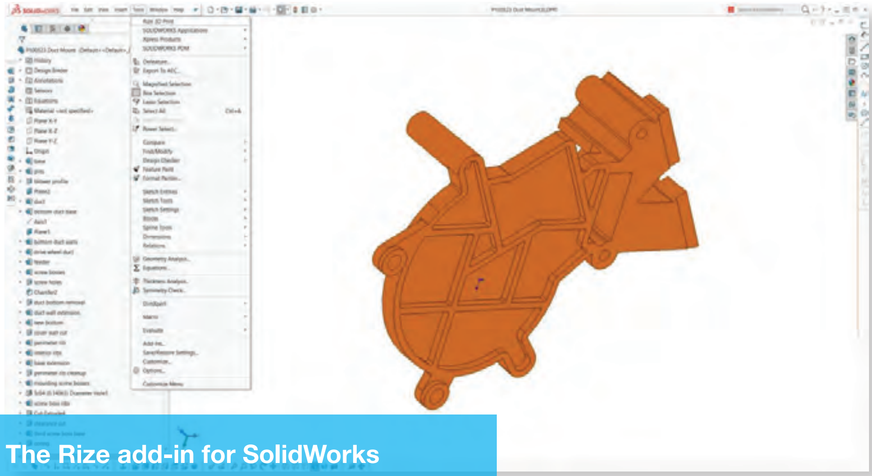
"We want to let engineers take design considerations for AM into account inside of CAD," explains Bryan Crutchfield, vice president and general manager for Materialise North America, which offers a range of 3D printing software and services, including Magics, a data preparation package and STL editor. "We are aiming to help design engineers understand that they can unlock all of this value with 3D printing and determine if a design is 3D printable before it goes to a printer."

Materialise sees its role as a middleman of sorts, building out a backbone for 3D printing by forging partnerships with 3D software companies like PTC and Siemens PLM Software as well as with the leading 3D printer manufacturers, Crutchfield says. On the hardware side, the company has created build processor packages for most of the leading 3D printer OEMs, including for HP's Jet Fusion 3200 and 4200 printers. These packages function as high-tech printer drivers allowing Materialise Magics—which aids in data preparation, production planning and machine control, along with other third-party applications—to take advantage of the highly advanced capabilities of individual machines (for example, zone-based slicing and hatching capabilities or specific material-based printing profiles).

"What this does is bring together a workflow from content creation all the way through manufacturing linked very tightly together," Crutchfield says. "In this way, you can archive workflows, which prove you printed a product correctly," a critical step, he explains, for highly regulated industries such as medical and dental applications.

On the software front, Materialise and Siemens PLM Software created a partnership last year to integrate Materialise Magics 3D Print Suite software directly into Siemens NX to streamline the design to manufacturing process. The solution seamlessly and associatively links NX with Materialise capabilities such as lattice generation, support structure design, 3D nesting and build tray preparation, eliminating the need for data translation and conversion. It also creates a single, smart model in NX 12 that can be output directly to a 3D printer such as HP's Multi Jet Fusion offering. The company more recently joined hands with PTC to create a seamless connection between PTC's Creo CAD software and 3D printing machines equipped with a Materialise Build Processor specifically in the area of metal 3D printing, enabling better control over the design and creation of metal support structures. These capabilities will be introduced with Creo 5.0 this spring.

Dassault Systèmes has a variety of partnerships with 3D printer manufacturers, including Stratasys, Desktop Metal, 3D Systems, Formlabs and Ultimaker, to create direct integrations be-



The Rize add-in for SolidWorks automatically transfers files to the Rize slicing software for output on the printer without the need for file import or export. *Image courtesy of Rize.*

tween the hardware and its 3DEXPERIENCE platform, specifically CATIA and SOLIDWORKS. "The main challenge for design engineers is software integration," says Rani Richardson, CATIA business experience consultant at Dassault Systèmes, explaining the firm's strategy around collaboration. "Typically, multiple software tools are used to design, optimize and reconstruct surfaces, which makes for an error-prone and lengthy process for reconstructing the geometry after the model or assembly is optimized."

Empowering DfAM Workflows

Siemens PLM Software is also pursuing a variety of partnerships and capabilities to streamline historically disconnected processes surrounding design and 3D printing to help avoid critical data loss and to capture knowledge of DfAM practices as they are learned, according to Aaron Frankel, the company's senior director of product marketing. "If you have a lot of disconnected apps, you have to do a lot of rework, manage lots of different files and you can't control processes—that's not what you need in an industrial additive manufacturing system," he explains.

One way Siemens PLM Software is streamlining DfAM processes is via its convergent modeling technology integrated in the NX product stack that melds traditional modeling capabilities with new generative design capabilities. The Parasolid-based convergent modeling functionality means users can leverage a seamless and unified set of modeling functions for classic detailed B-rep geometry or facet models, which are synonymous with additive manufacturing. This eliminates the need for data conversion and allows engineers to easily iterate and combine traditional models with the organic shapes being created through generative design and topology optimization tools, Frankel explains.

As part of that convergent modeling functionality, NX is now stacked with topology optimization capabilities that let an engineer establish constraints for weight, strength or cost, for example, and unleash the software to automatically calculate the optimal geometries for potential designs. In addition, NX 12's convergent modeling technology, combined with its lattice structure functionality, enables engineers to create integrated structures that reduce component weight from within the familiar CAD environment, eliminating the need to employ a separate lattice design application. The NX environment has also been enhanced with new feature checking and validation capabilities to support the new DfAM tools and workflows, ensuring that resulting designs are viable prior to sending to a 3D printer for output.

"Making sure everything is linked together and that we provide a smooth end-to-end process is where we are focusing our development efforts," says Jim Rusk, senior vice president and CTO for Siemens PLM Software.

Rize, a hybrid 3D printer manufacturer, says that its ability to meld fused filament fabrication (FFF) and piezo jetting technologies in a single print advances DfAM principles in the area of materials science to evolve designs, according to Andy Kalambi, the company's CEO and president. Although traditional subtractive manufacturing processes like CNC machining limits its designs by the materials used, AM eliminates some of those constraints. The Rize One hybrid 3D printer uses an augmented polymer deposition (APD) process that can simultaneously extrude a compound of engineering- and medical-grade thermoplastic and jet Release One inks to change material properties of the thermoplastic at a voxel level, producing both lightweight and high isotropic strength parts, Kalambi says. The Release One ink can also be used between the support structures and 3D printed part to ensure quick and easy removal, he explains.

In addition to introducing DfAM capabilities in SOLIDWORKS 2017 and 2018 (among them, generative design capabilities and check tools for flagging faces requiring supports or validating the viability of wall thicknesses), Dassault Systèmes has forged a number of partnerships aimed at seamlessly integrating 3D printing into the design workflow. At the SOLIDWORKS World 2018 conference in February, the company announced an alliance with HP to ensure its CAD and related design tools can take advantage of HP's Multi Jet Fusion 3D printers' voxel-level capabilities for lightweighting and optimizing designs using both color and DfAM principles around materials science. Both HP and Dassault Systèmes support the 3MF (3D Manufacturing Format) file format, a challenger to STL that can handle a richer data set, including color and materials. Nano Dimension, a solution for 3D printing electronics, also advanced DfAM practices in the area of materials science with its add-in for SOLIDWORKS that lets users combine conductive and insulating materials in a single 3D print on its

DragonFly 2020 Pro unit.

At the same time, Dassault Systèmes also expanded its long-standing partnership with 3D Systems. Now, all SOLIDWORKS CAD subscription customers get free access to an integrated version of 3DXpert, 3D Systems' tool for designing lattice and support structures and arranging the build platform. By integrating 3DXpert directly into the SOLIDWORKS workflow, Dassault Systèmes can offer designers an all-in-one solution as opposed to moving between multiple applications, Rushton explains. "Accessibility is key to everyone adopting AM," he adds. "This gives our users the ability to try out the technology without having to make a big investment."

At PTC, Creo 4.0 and the forthcoming Creo 5.0 are ushering in a host of new DfAM capabilities in the areas of creating lightweight structures, including parametrically controlled lattice parts; creating tray assemblies as a repository for storing AM information such as positions, materials and colors in the PLM systems; and improved integration between the CAD systems and 3D printers. Creo's integrated finite element analysis simulation capabilities provide a single environment to analyze and optimize lattice structures and its print tray capabilities allow for the automatic positioning and nesting of models on a tray volume to optimize the build cycle, according to Jose Coronado, product manager, Creo Manufacturing and Simulation Applications, at PTC.

Although much has evolved on the DfAM front over the last few years, Coronado acknowledges there is more to be done and that's why partnerships like the one with Materialise and 3D printer manufacturers are crucial. "The printers do more than we can model at this point," Coronado says. "We need to be very close to the printer manufacturers in order to evolve our systems and close those gaps." **DE**

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

INFO → 3D Systems: 3DSystems.com

→ **Dassault Systèmes:** 3DS.com

→ **Desktop Metal:** DesktopMetal.com

→ **Formlabs:** Formlabs.com

→ **Materialise North America:** Materialise.com

→ **Nano Dimension:** Nano-di.com

→ **Rize:** Rize3D.com

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

→ **Stratasys:** Stratasys.com

→ **Ultimaker:** Ultimaker.com

For more information on this topic, visit digitaleng.news

The **Rise of Design** Software for 3D Printing

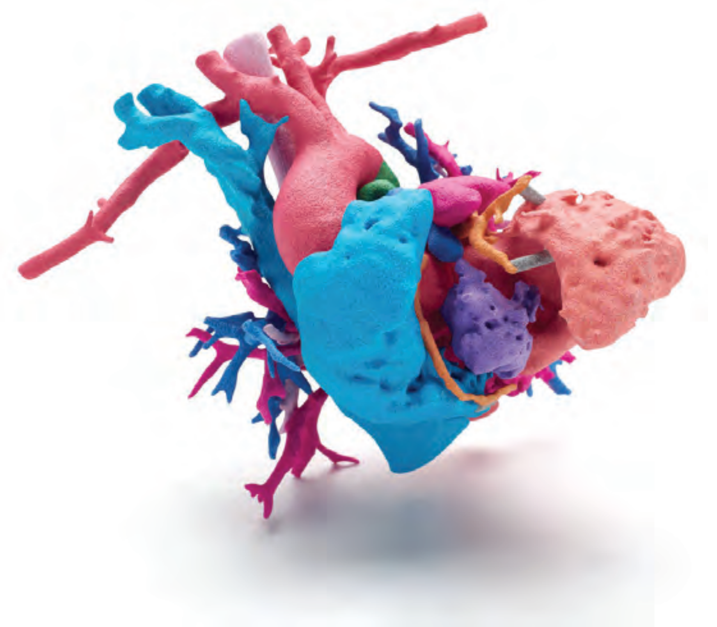
Manufacturers' embrace of additive manufacturing pressures software providers.

BY KENNETH WONG

TEN YEARS AGO, design software users lamented that some of their designs might never see the light of day because the complex surfaces, structures and beams they could depict in pixels via their CAD software, could not be machined, molded or manufactured in the real world. Now, the tables have turned. Some delicate features and structures that could be produced with 3D printers may prove impossible to model in a standard CAD software package.

The 3D printing market is at $6.063 billion, according to the analyst firm Wohlers Associates (*Wohlers Report 2017*). The firm noted: "Ninety-seven manufacturers produced and sold industrial additive manufacturing (AM) systems in 2016. This is up from 62 companies in 2015 and 49 in 2014." The swelling number of industrial systems suppliers suggest AM has evolved from a prototyping technology into a viable means for mass production.

For the design software industry, the proliferation of AM hardware is a boon and a test. The software developers and suppliers stand to benefit from more people turning to 3D modeling software to create printable designs. But the AM pie may be out of reach for those who are not nimble and adaptable enough to cook up modeling techniques compatible with 3D printing.



A full-color, 3d-printed model of a human heart used to enhance presurgical planning. *Image courtesy of HP; data courtesy of Phoenix Children's Hospital; Heart of Jemma.*

Blending Parametric CAD with AM

Parametric CAD was developed as a modeling solution for the subtractive age, for the era of machine tools. Consequently, from the way you create holes to the way you round out sharp corners, parametric CAD mimics the subtractive manufacturing methods. The geometry permissible in the software also reflects the range and limitations of what's best for mass production in subtractive manufacturing.

The finite element analysis (FEA), simulation and computer-aided manufacturing (CAM) software programs in the current market also reflect the historical dominance of subtractive manufacturing. The well-known FEA programs employ solvers and setups that let you evaluate the various types of geometry sculpted in subtractive-centric CAD software. CAM software use time-tested machine-tooling principles to identify failures imminent in machining operations.

"There have been attempts by existing CAD vendors to address the need for AM," observes Arjun Aggarwal, AM startup Desktop Metal's VP of business development. "Some augment their existing tools with new ones. Others make plugins that can be shoehorned into the current products. Topology optimization software is a good example of that kind. But the problem is, to optimize something, you need design input [in the form of 3D geometry]. Usually, that shape is made with traditional modeling software that reflects traditional methods."

Using AM-centric simulation and optimization methods on geometry sculpted in subtractive-centric CAD programs is, at best, a compromise. Parametric CAD software developers are gradually adding AM-centric geometry-sculpting features to their flagship products, but it will take some time before CAD programs can fully exploit AM hardware's capabilities.

"No doubt, existing CAD tools lack some key capabilities to fit design for additive manufacturing," says Roy Sterenthal, VP of software products at 3D Systems. "However, we do not expect the design world to adopt new CAD and FEA solutions just for additive. Instead, we do see a need for complementary solutions to existing CAD and FEA solutions to fill the gap."

Hardware Makers' Software

The software gap is filled, for the time being, by AM hardware makers. At the SOLIDWORKS World 2018 user conference (SWW18), 3D Systems CEO Vyomesh Joshi joined SOLIDWORKS CEO Gian Paolo Bassi in a press conference to announce 3DXpert for SOLIDWORKS, developed to let SOLIDWORKS CAD users prepare and optimize their design for AM projects. "I believe [3DXpert for SW] is the tool to democratize 3D printing," says Joshi.

The original 3DXpert is described as "an all-in-one solution for metal additive manufacturing." By contrast, 3DXpert for SOLIDWORKS is designed to tackle both metal and plastic design for additive. Whereas the standalone version of 3DXpert operates independently, 3Dxpert for SOLIDWORKS is nested inside the design software, allowing SOLIDWORKS users to design 3D printable parts from the familiar interface.

"Additive manufacturing's promise is for more shapes, more ways and ultimately to provide design freedom: If you can design it, you'll be able to print it. However, getting additive manufacturing right is not easy to achieve and new software tools are required to facilitate it. Software solutions are required to provide both analysis tools as well as geometrical tools," says Sterenthal.

Voxel-based 3D printing with NVIDIA GVDB (GPU voxel database), where the inside structure is optimized based on stress and automatically generated. *Image courtesy of NVIDIA*.

Growing vs. Cutting

Also in attendance at SWW18 was Desktop Metal. Founded in 2015, the company is a relative newcomer to the scene, but its team is a roundup of CAD veterans. The firm brought its production system to SWW18 to join the AM Symposium. The company describes its technology as "a new approach to metal 3D printing—single pass jetting (SPJ). Created by the inventors of the binder jetting and the single pass inkjet processes, SPJ builds metal parts in a matter of minutes instead of hours."

The company also gave sneak peeks of some code brewing in its lab—including a software program called Live Parts. It's described as "an experimental technology that applies morphogenetic principles and advanced simulation to auto generate part designs in minutes."

"Basically, you identify the areas in your parts that you want to connect," says Andy Roberts, Desktop Metal's software engineer for Live Parts. "The user can identify forces, but they're different [from typical FEA loads]. They're shape-affecting forces that guide how the structure grows. The software grows the part without any preconceived notions of what the result is supposed to look like. The process is much simpler, much more organic."

In many topology optimization programs, the user provides a generic block of geometry as the starting point. The software uses load calculation, stress analysis and other means to remove as much materials as possible to arrive at the optimal—or the lightest possible—geometry. To start from a blank space and grow materials where needed, as Live Parts does, is the opposite. It's a radically different approach.

The parts are subjected to not only the forces specified by the engineer, but also to the unanticipated ones, according to Roberts. "Your design is subjected to what we call transitional forces, similar to the random, fluctuating forces you see when the wind is blowing on a tree," he said. "We found that parts grown this way distribute the stress loads evenly and it reduces hot spots for strains."

"Live Parts as it is right now is a general shape-finding tool. It doesn't inherently consider the manufacturing method you would use [for example, injection molding, machining or 3D printing]. But because the parts are geometrically complex, most often, you might find that the part modeled in Live Parts can only be manufactured in 3D printing," says Aggarwal. "Eventually, as we build more functionalities into it, Live Parts will have direct ties to the Desktop Metal ecosystem."

HP Enters

SWW18 also marked HP's introduction of its HP Jet Fusion 300 and 500 series printers. The company writes, "HP Multi Jet Fusion (MJF) Technology has the unique ability to produce parts with controllable physical and functional properties at each point in a part"—something HP describes as "voxel-based printing." While developing the MJF hardware, HP had also been quietly developing a software program to control print properties of parts at the voxel level.

"There are currently a few experimental software tools in the market, but most professional CAD and simulation software isn't yet ready to support HP's voxel-level 3D printing," explains Luis Baldez, HP's 3D printing software business leader. "However, HP has started establishing strong partnerships with some of the world's leading CAD and simulation companies to align our roadmaps and ensure that MJF's advanced capabilities are fully supported. Siemens, Autodesk, Materialise and SOLIDWORKS are among the leaders who have already taken the first step and are releasing products to specifically support HP's advanced 3D technology in the marketplace."

Last year, at the GPU Technology Conference hosted by NVIDIA (GTC 2017), HP Labs and NVIDIA showcased an experimental software program, dubbed GVDB. To break down the name, G stands for the GPU; VDB stands for voxel database. GVDB's ray-tracing rendering and GPU-driven performance acceleration is GPU maker NVIDIA's contribution; the software's voxel-based simulation and optimization come from HP Labs, according to Andrew Page, NVIDIA's product manager for GVDB.

> **"In the past, we were able to design parts we couldn't produce; now, we have parts that we could make, but cannot design in the CAD system."**
>
> – Andreas Vlahinos, principal, Advanced Engineering Solutions, *DE's* online roundtable, January 2016

But moving forward, AM hardware makers and AM-targeted software developers may seek better alternatives to match what the printers can do.

One rival to STL that has emerged is the open, nonproprietary 3MF, championed by the 3MF Consortium comprising Microsoft, HP, PTC, Siemens and other tech leaders. "Our goal is to provide a specification that eliminates the issues with currently available file formats, and allows companies to focus on innovation, rather than on basic interoperability issues," announces the 3MF Consortium on its homepage.

"3MF recently approved a variation of our [nTopology's] LTCX beam & shell representation," says Rothenberg. "Other representations of 3D volumes are also now used in [nTopology's software] Element. For example, when you want to transition from lattice to solid, we use a function that represents the signed dis-

New Ways to Draw

Whereas complex microstructures like lattices and honeycombs cannot be machined, they can now be produced using 3D printers. Lattice-filled metal parts can weigh significantly less than their solid counterparts, yet carry equal or almost the same strength and durability. Therefore, aerospace and automotive engineers seeking to reduce weight in their products often explore such geometric patterns. Currently, however, they're not easy to model or simulate in CAD.

"Geometric representation is the most important new issue that's come along with this new wave of generative design tools," says Bradley Rothenberg, cofounder and CEO of nTopology. "For example, today, the primary way we represent parts output from generative design was once alien to CAD, yet standard in simulation: the mesh. The two major CAD kernels, Parasolid and ACIS, are just now starting to support modeling operations on meshes. Lighter weight representations are also now being used for lattices like beams and shells."

"Current CAD packages represent lattice and honeycomb structures as meshes, detailing every single element individually. This requires an incredible amount of processing and memory to create, edit and render for the 3D model. And the output file can take hundreds of gigabytes, essentially limiting the designs that the hardware can produce," notes Baldez.

The de facto standard for 3D printing is currently STL (stereolithography), a format supported by most CAD programs.

Subtractive, Additive and Hybrid Manufacturing

Subtractive manufacturing, as the name suggests, creates parts by cutting away unnecessary materials from a stock to create the desired geometry. Machining, the long-established standard for mass production and manufacturing, falls into the subtractive category.

By contrast, additive manufacturing creates parts by depositing layers of materials. 3D printers belong to this category.

Some newer machines such as Matsuura's LUMEX and DMG Mori's LASERTEC 65 3D are capable of both additive and subtractive operations. In other words, they can remove materials and also add new materials. The technology could be a prelude to the era of hybrid manufacturing—the convergence of subtractive and additive hardware.

tance to the surface—signed meaning that inside the surface, the distance is negative and outside it's positive. From this volumetric representation you can then also go directly to simulation or to manufacturing without meshing ... All of these new representations are starting to gain popularity for tasks that would be impossible with classic NURBS b-reps."

"Traditional CAD packages are based on 3D modeling kernels that only represent the surface of the object, also called Boundary Representation or B-Rep," explains Baldez. "They assume each part is of a single color, texture and material. The voxel-based parts need to be designed outside the existing CAD packages with lots of workarounds and hacks ... The 3MF team is already working on lattice structures and voxel representations."

Integrated FEA

Mainstream CAD programs now incorporate basic stress analysis and simulation tools, but for the most part, design and FEA environments are separate, allowing the user to design and analyze sequentially. Software targeting AM tends to use FEA or simulation in the background as part of its form-seeking and shape-optimization algorithm.

This is the case with nTopology, which describes its technology as a "combination of generative, manual and simulation-based design tools ..." nTopology's product Element is available both as a free version and a fee-based professional version. "With Element, you can optimize lattice structures with respect to user-defined inputs, imported data or our integrated FEA. You input what you know and what you need, and then we generate designs with the user's guidance," says Rothenberg.

"Design for additive manufacturing needs to use FEA tools as part of the design process and not only for final simulation and functional approval. This must be done as a continuous process with immediate feedback to the design decisions," says Sterenthal. He adds, "[In 3DXpert,] extensive analysis tools, including FEA analysis, are incorporated into the design and preparation for additive manufacturing with immediate feedback to apply modifications to the model."

The Convergence of Design and Manufacturing

In March 2017, startup Frustum announced a partnership with Siemens. The company wrote: "We are excited to enable Siemens NX customers to design fully optimized parts, ready for 3D printing, as well as empower them to move beyond the boundaries of traditional CAD geometry." Jesse Blankenship, CEO of Frustum, describes the company's technology as "functional generative design," pointing out that their proprietary geometry kernel TrueSOLID "allows for blending indeterminate generative geometry to traditional surface based CAD with engineering precision, pushing additive manufacturing to its limits."

Partnerships between design software and AM hardware makers will increase, as each needs the expertise of the other to enable AM. At the most basic level, design software needs to be printer-aware to help orient the parts in the print tray for optimal part strength and printing efficiency.

Parametric CAD has a significant learning curve, especially for those with limited engineering background. Adding new tabs and commands to accommodate AM design, while necessary, also carries the risk of added complexity—creating a difficult balance for established parametric CAD vendors.

The new breed of standalone AM-specific programs look and operate more like topology optimization programs, less like CAD modelers. Therefore, standalone design-for-AM software may emerge as a separate class of its own, or a subsection of the simulation software market.

The innovation made possible by AM cannot be realized unless it's supported by the design software. By the same token, existing design software makers realize they must find ways to facilitate AM to remain relevant. Thus with their fates intertwined, the two disciplines are learning to dance to a new beat. 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 → **3D Systems:** 3DSystems.com

→ **3MF Corsortium:** 3MF.io

→ **Desktop Metal:** DesktopMetal.com

→ **Frustum:** Frustum.com

→ **nTopology:** nTopology.com

→ **Wohlers Associates:** WohlersAssociates.com

For more information on this topic, visit digitaleng.news.

A Campaign to Train Tomorrow's Workforce

The ACADEMI curriculum is designed to boost additive manufacturing training—and industry savvy.

BY STEPHANIE SKERNIVITZ

AS ADDITIVE MANUFACTURING (AM) gains traction across diverse industries in both public and private sectors, its rapid growth has generated a not-so-minor deficiency: There's an absence of skilled professionals to meet the demand.

Anthony Hughes leads a course on Design for Additive Manufacturing at the America Makes facility. ***Image courtesy of Autodesk.***

That's why organizations such as The Lanterman Group (a 3D printing innovation strategy and design firm) and America Makes (a collaborative partner in AM/3D printing technology and workforce development) have stepped up to the plate with a training program to try to offset any future shortage.

Together, they are offering what's called ACADEMI (the Advanced Curriculum in Additive Design, Engineering and Manufacturing Innovation), which was created to encourage the transfer of business and technical know-how to industry.

It's about "creating [a] national additive manufacturing educational program to train the next generation of workforce," according to America Makes' ACADEMI-devoted page on its website.

ACADEMI represents a partnership of The Lanterman Group, founded by Anthony Hughes to help manufacturing executives and organizations grow through the adoption of manufacturing technologies; and America Makes, a public-private partnership with members representing industry, academia, government, non-government agencies and workforce, along with others in the industry that are providing equipment, software and support.

"ACADEMI is an innovative and multidisciplinary training program focused on engineering and manufacturing innovation in additive manufacturing (AM) technologies, applications and processes," explains Hughes, president of the Chagrin, Falls, OH-based The Lanterman Group. "ACADEMI has been shaped by input from over 100 companies and over 30 subject matter experts from across industry and academia."

Its primary focus is design for additive manufacturing (DfAM). Courses within the ACADEMI portfolio will address taking an industry application through all or parts of the DfAM workflow (e.g., value identification, part selection, material selection, lattice structure design and post-processing). Additionally, coursework includes hands-on opportunities with software and equipment during lab periods.

The targeted audience for ACADEMI training, according to The Lanterman Group, includes design engineers, manufacturing engineers and material science engineers who wish to develop skills from a holistic, integrated set of AM disciplines.

Those who stand to benefit: "Companies that desire a workforce who can cross disciplinary boundaries, such as materials science, mechanical engineering and manufacturing engineering. These learners will be key enablers for a stronger AM design community," Hughes adds.

3D Systems says the ProX DMP 320 direct metal printer combined with LaserForm metal materials offer reduced waste, greater production speeds, short setup times and dense, pure metal parts. *Image courtesy of 3D Systems.*

How and Why it Got Rolling

The ACADEMI program initially emerged as the result of insights from an America Makes additive manufacturing and 3D printing workforce and education roadmap. For background and context, three separate studies were done between 2015 and 2016. (TLG and Bush Consulting Group did the work.)

"While training in the industry exists, training aligned toward specific requirements (or needs) in the member-driven, public-private roadmap was lacking," says Rob Gorham, executive director of America Makes.

Hughes adds: "While companies and government organizations are beginning to utilize the new technology and manufacturing processes, there is not a skilled workforce of trained professionals to support the industry."

Coinciding with the needs that the roadmap uncovered, the industry has been vocal in seeking deeper training and acknowledging a lack in workforce skills tied to production of commercially ready additive manufacturing products, Hughes notes. He highlights specific weaknesses in current AM-specific training:

- tends to be superficial when linking AM process, materials, machines and part quality;
- lacks integration of diverse disciplines, including advanced concepts such as materials, process, design simulation, biomimicry and reverse engineering;
- often fails to connect the AM processes to the economic/business case; and
- leans toward training environments that can be more theoretical and lecture-based than hands-on and application-based.

Nuts and Bolts of ACADEMI

ACADEMI is designed to create what Hughes calls an "immersive, hands-on training environment" by fusing skills from different disciplines into a design-for-additive manufacturing (DfAM) portfolio of classes.

"The ACADEMI does cover general knowledge of AM, but mainly focuses on design for additive manufacturing workflow, which is one of the major obstacles to widespread adoption of the technology. 3D Systems sees significant value in sharing our experiences in designing for additive manufacturing," says Jared Blecher, Aerospace & Defense engineer, 3D Systems. 3D Systems is one of the industry leaders actively involved in the ACADEMI program.

Autodesk's Aaron Magnin further describes the ACADEMI program as a weeklong immersive "bootcamp"-style training course that covers all aspects of the additive manufacturing process.

"Starting with the design, attendees are presented with a wide array of considerations required to address DfAM. To properly understand this, deep dives in different additive processes and technologies will be presented—and used—by the multidisciplinary attendees," Magnin adds.

A key differentiator, says Hughes, is that "we develop the content and curriculum, and coordinate its delivery in conjunction with membership, including equipment providers, training content providers and other industry partners."

Suppliers Already Plugged In

A couple equipment and software providers for ACADEMI weighed in on their companies' involvement.

Blecher of 3D Systems, says his com-

Fundamentals in Additive Manufacturing Certification Program Announced

Just as acceptance of AM technologies can only move forward with the establishment of independent production standards, so the development of the full workforce—designers, technicians, operators, engineers, inspectors—also needs standards by which to measure competency and progress.

Two major groups with long histories in manufacturing, SME and UL, recently joined forces to create just such a new "gold standard," with America Makes as the lead sponsor. Building on their previous successes, they've developed a three-tiered program that combines UL's multi-tiered training program and Tooling U-SME's professional certification. The first tier is the AM Fundamentals Certification, with a review course and exam to be offered in April at both AMUG and RAPID + TCT conferences.

This SME website description shows the depth of thought, collaboration and planning that produced and will support this effort:

"The Fundamentals in Additive Manufacturing Certification aligns to the Additive Manufacturing Body of Knowledge compiled by Tooling U-SME, America Makes, the Milwaukee School of Engineering (MSOE), the National Coalition of Advanced Technology Centers (NCATC) and Technician Education in Additive Manufacturing & Materials (TEAMM), with input from more than 500 additive manufacturing professionals."

Who would benefit from this certification? Individuals working in or seeking to work in AM roles in automotive, aerospace, medical, consumer goods and energy industries, as well as architecture, the arts and more. The program could also serve as a capstone or standalone achievement for high schools and colleges, to increase workforce readiness in additive manufacturing.

For more information, visit rapidreadytech.com/?p=12255.

— Pam Waterman

pany has worked with ACADEMI from the get-go.

The first ACADEMI class, according to Blecher, was funded through America Makes by the Air Force Research Laboratory (AFRL) as a part of an effort to contribute to the development of a workforce capable of accelerating advanced engine and material transition development.

"As a subcontractor in the project, 3D Systems assisted The Lanterman Group in developing content for the weeklong class in October 2017," Blecher says.

Currently, for its role, 3D Systems works with students by covering the ProX DMP 320, 3DXpert, design of parts for powder bed fusion additive manufacturing and operation of metal 3D printers.

3D Systems is also supporting the ACADEMI program by sending a Ph.D.-level scientist to provide instruction on the operation of the ProX DMP 320, according to Blecher. The company is sending a ProX DMP 320 and 3DXpert super-user for hands-on instruction of 3DXpert and as a resource for designing for additive manufacturing including support, lattice and feature design. In addition to personnel, 3D Systems has provided temporary software licenses so that students can learn in 3DXpert.

Autodesk's Magnin says Autodesk's collaboration with ACADEMI has been an ongoing effort since December of 2016.

"We've been involved since its inception by providing both software and the technical expertise to accompany it in the development of curriculum," Magnin says.

Autodesk offered ACADEMI instructors its catalog of software offerings. "After careful consideration they opted to use Fusion 360 for most all of the design portions and some simulation, and of course Netfabb Ultimate to cover additive processes," Magnin says. In addition to the software, he says Autodesk has assisted with curriculum development and delivery at RAPID and the inaugural run of ACADEMI.

"We are committed to providing new software as it matures, such as Autodesk Generative Design, and will help keep the ACADEMI curriculum up-to-date with Netfabb enhancements, as it rapidly adapts to industry requirements," he says.

How ACADEMI Complements University Curriculum

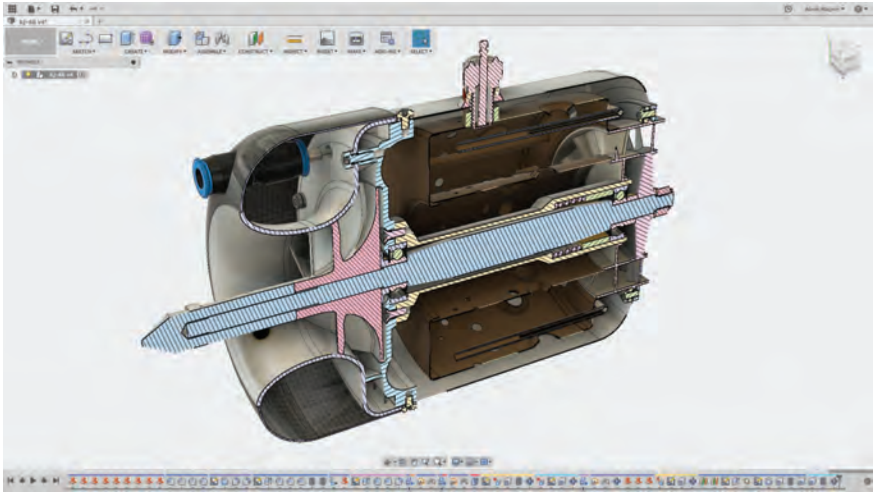
Some of ACADEMI's collaborators are from universities, so ACADEMI leadership is working to help "speed information from their existing longer-term efforts into ours," Hughes says.

Additionally, there is discussion of integrating ACADEMI into existing university facilities focused on continuing education, though specifics were not available at press time.

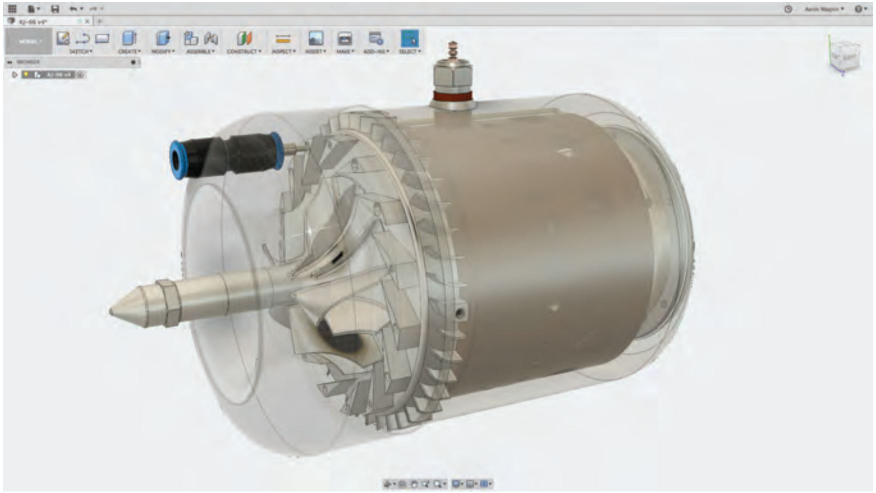
2018 Goals and Expansion Plans

Though the goal list is lengthy, following are some larger initiatives for this year, according to Hughes:

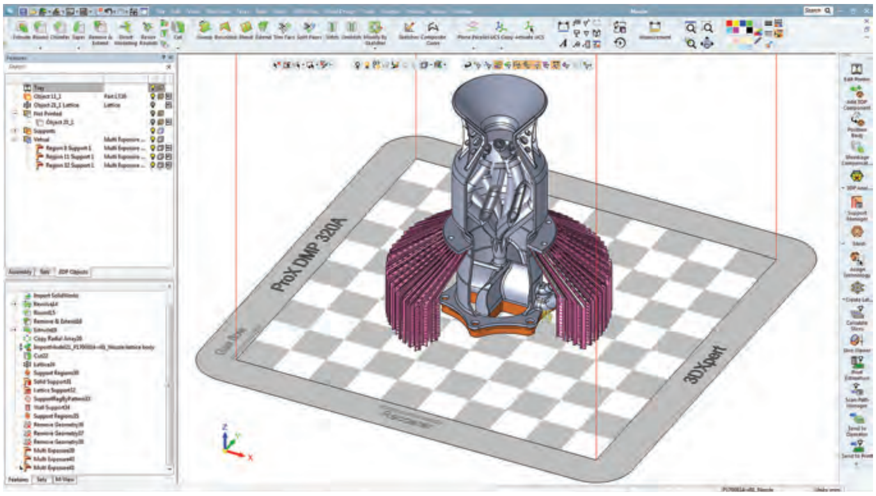
- leverage the existing ACADEMI operating model, course offerings, content, sustainability model and cost share contributions already developed for America Makes membership;
- deliver a metal DfAM class for general registration, starting in early spring;
- develop a new course offering to meet the gaps/needs defined in the America Makes-led DoD roadmap work by working with DoD stakeholders to identify training needs affecting greater AM adoption within acquisition, requirements and sustainability programs; and
- deliver the new course offering to



A cross-section of the microturbine that students rebuilt using additive manufacturing techniques throughout the course. *Image courtesy of Autodesk.*



Fusion 360 was used in the design and validation of the microturbine used in many of the lessons. *Image courtesy of Autodesk.*



3DXpert design for metal additive software delivers a range of tools to prepare 3D design data for metal additive production including optimization of supports, zoning, addition of lattice work, build simulation and more. *Image courtesy of 3D Systems.*

two DoD partners, e.g., The U.S. Army, Department of the Navy, U.S. Air Force, and Defense Logistics Agency, Air Force Research Laboratory, Systems Engineering and Special Operations Command.

In 2018, ACADEMI's course offerings will be expanded by working with other industry partners, Manufacturing USA Institutes and Department of Defense partners, according to Hughes.

"We plan to add to the existing manufacturing curriculum around identified gaps within the advanced manufacturing education portfolio that America Makes partners have identified. Expanded course offerings are intended to be offered as continuing education and on-the-job training for industry and DoD partners," Hughes says.

Regarding the future, Hughes says ACADEMI serves as a foundational platform that will "enable us to plan more directed hands-on training efforts inside and outside of its membership (i.e., satellite centers, universities, community colleges, vocational/technical schools, etc.)."

Autodesk's Magnin adds the ACADEMI initiative is a must-have for the industry.

"We see this initiative as being crucial to help prepare industry leaders for the looming paradigm shift in manufacturing. Additive manufacturing has the potential to transform the way we make things, but designers' approaches need to be retooled to leverage these processes, and new constraints need to be factored in as well." **DE**

Stephanie Skernivitz *is associate editor of* DE. *Send e-mail about this article to sskernivitz@digitaleng.news.*

INFO ➜ America Makes: AmericaMakes.us/academi

➜ **The Lanterman Group:** TheLantermanGroup.com/academi

➜ **SME:** SME.org

➜ **Tooling-U:** ToolingU.com

➜ **UL:** UL.com

Advancing AM Materials

BY JAMIE J. GOOCH

FOR THE THIRD YEAR, *DE* has worked with Senvol to share material providers of industrial additive manufacturing (AM) materials from the Senvol Database. Just between this time in 2016 and now, the number of material providers has grown by 186% and the number of materials in their database has grown by 204%. That rate of growth has left many design engineering teams racing to keep up with the best materials for their applications.

Nylon and stainless steel (shown here) are two of the most popular 3D printing materials. *Image courtesy of Proto Labs.*

Some applications, such as those in medical and aerospace, require specialized materials, not only to meet exacting specifications but to satisfy regulatory requirements and certifications. To those ends, some manufacturers are working on their own proprietary 3D printing/AM materials or working directly with material providers.

"Materials don't stand alone," says Chuck Alexander, director of Product Management at Stratasys Direct Manufacturing. "Materials go with process and application. All aspects need to work together to deliver a reliable repeatable result."

Alexander says part of Stratasys Direct Manufacturing's 3D printing and advanced manufacturing services includes engaging with customers to develop processes for specific high-value applications—such as sensor housings for "down the hole" oil & gas industry drilling that have to resist corrosion or rocket nozzles with good thermal conductivity.

However, the majority of design engineering teams aren't as specialized. They value familiarity and versatility when choosing a material. "Probably unsurprisingly, the most in-demand materials are the general purpose ones," says Eric Utley, applications engineer, Proto Labs. "Specifically, metals and plastics that are well-rounded in mechanical properties and can fill a wide range of uses. PA 12 nylon in plastic printing and 316L stainless steel in metal printing are extremely versatile and are among our most popular materials. Both are moderately stiff and flexible and fit the bill for a wide range of applications."

The Possibilities are Not Endless

The right materials, married to the right AM process, can yield impressive 3D printing results that aren't viable for traditional manufacturing. However, after years of being touted as enabling design complexity with very little trade-offs, industrial users of 3D printing now understand there are limits to what AM can efficiently and economically do.

"For example, if a part has fine channels snaking through the interior and needs to be clear, the only real option to 3D print the part is via stereolithography," Utley says. "Usually the biggest factor is if the geometry requires supports or is at risk of warping during the build. An organic shape like an oak tree would be virtually impossible in a 3D printing technology that requires supports and would be better suited to be built in a support-less tech like SLS (selective laser sintering) or HP's Multi Jet. Typically, stiffer materials fare better against material warping, so if a part has thin walls or is otherwise at high risk for warp we may recommend going with a stiffer material to compensate."

When working with a material and/or part provider, design engineering teams need to communicate their application requirements, Alexander says. For early prototypes, the material choice may be less important than cost and speed factors. When creating parts for testing, certain functional requirements will come to the fore. For production AM, quality certifications and controls help determine the material and process.

"The devil is always in the details," he says. "It all starts with the application."

Getting Real

Addressing the realities of AM design constraints, processes and materials is helping to advance industrial additive manufacturing. More engineers are becoming accustomed to designing for 3D printing and AM design software is becoming more robust.

"It's an exciting time out there," Alexander says. "New processes and materials are becoming available all the time. It's been a great thing for the market—all that competition." DE

Jamie Gooch *is* DE*'s editorial director. Contact him via jgooch@digitaleng.news*

INFO → Proto Labs: ProtoLabs.com

→ Senvol: Senvol.com

→ Stratasys Direct Manufacturing: StratasysDirect.com

For more information on this topic, visit digitaleng.news.

Material Supplier	Specific Material Types	Selected Examples
3D Platform	ABS, HIPS, PETG, PLA, Rubber-like	3DP ABS, 3DP-ABS-X, 3DP-HIPS
3D Systems	ABS/PP, ABS/PP-like, ABS-like, Acrylic, Aluminum, Cobalt, Gypsum, Nickel, PA, PA-Glass, PA-metal, PC, PP-like, Rubber-like, Steel, Titanium, TPU, Wax-like	Accura ClearVue, DuraForm EX, VisiJet M5-Black
3DCeram	Alumina, Zirconia	Alumina (3DCeram), Zirconia (ZrO2/MgOPSZ)
3DXTech	ABS, ABS-Carbon, ASA, HIPS, PA, PA-Carbon, PC, PC/ABS, PC/ASA, PEI, PETG, PETG-Carbon, PETG-Glass, PLA, PLA-Carbon	3DXMax ASA 3D Filament, Firewire Carbon Reinforced PEEK Filament, iOn Nylon Filament
A. Schulman	PA-Glass	PA612-GB 3800
Ackuretta	Wax-like	QuraCLEAR, QuraDENT, QuraGP
Additive Elements	PMMA	AE12 Polymethacrylate
ADVANC3D Materials	ABS, PA, PA-Carbon, PA-Glass, PA-Glass-Metal, PC/ABS, PP-like, TPU	AdSint PA11, AdSint PP flex, AdWire PRO ABS FDA
Allied Photopolymers	ABS-like	KZ-1860-CL, KZ-1862-ICE, KZ-1870-WH
ALM	PA, PA-Carbon, PA-Glass, PA-Metal, PA-Mineral, PS	FR 106, PA 650, PS 200
AP&C	Titanium	Cp-Ti, Ti-6Al-4V
Apium	PEEK, POM-C	PEEK 450 Natural, POM-C ESD White
APWORKS	Aluminum, Nickel, Steel, Titanium	ALSi10Mg, Scalmalloy, Ti6Al4V
Arcam	Cobalt, Titanium	Arcam ASTM F75 CoCr Alloy, Arcam Grade 2 Titanium, Arcam Ti6Al4V
Arevo Labs	PAEK, PAEK-Carbon, PARA-Glass, PEEK, PEEK-Carbon	Katevo, PEEK F1, Quantevo
Argyle / Bolson Materials	ABS, ABS/PC, PEI	ABS (P400), ABS B31 (M-TYPE), ABSmax
Arkema	PA	Orgasol Invent Smooth, Rilsan Invent Black, Rilsan Invent Natural
Asiga	ABS/PP-like, Rubber-like, Wax-like	Plas, PlasCLEAR, SuperCAST
Aspect	PA, PA-Glass, PS, Rubber-like	ASPEX-EL, ASPEX-GB, ASPEX-PA
Aubert & Duval	Nickel	Pearl Micro HX, Pearl Micro Ni625, Pearl Micro Ni718
BASF	PA	Ultrafuse 316LX, ULTRASINT PA6 - X028
BigRep	PETG, PLA, PVA	PETG Filament, PLA Filament, PRO HT
BOHLER Edelstahl	Nickel, Steel	BOHLER AMPO L718, BOHLER AMPO N700, BOHLER AMPO W722
Carbon	Resin	CE220, EPU 40, RPU 80
Carpenter	Cobalt, Copper, Nickel, Steel, Titanium, Zirconium	CarTech 15-5 PH, CarTech BioDur 108, CarTech CCM
Cerhum	HA, TCP	PRINT3D Hydroxyapatite, PRINT3D Tricalcium Phosphate
CMET	Epoxy, Silicone-like	HS-680, TSR-510, TSR-884B
Concept Laser	Aluminum, Bronze, Cobalt, Gold, Nickel, Silver, Steel, Titanium	CL 100NB (Inconel 718), CL 42TI (Commercially Pure Titanium), Remanium star CL
Coobx	ABS-like, PP-like, TPU-like	No IND0002 SR, No MED0002 Splint, No MED0003 Coobx Tray
Cookson Gold	Gold, Platinum, Silver	18K 3N Yellow Gold, 950 Pt/Ru (Platinum), Brillante Sterling Silver
CRP Technology	PA, PA-Carbon, PA-Glass, Rubber-like	Windform EL, Windform GT, Windform XT 2.0
Diamond Plastics	—	Laser HDPE HX 17, Laser PP CP 22
D-MEC	Epoxy, Oxycetane Resin	SCR11120, SCR751, SCR950
Dow Corning	Rubber-like	Silastic LC 3335 Liquid Silicone Rubber
Dreve	—	FotoDent cast, PLASTCure Cast 100, PLASTCure Clear 100
DSM	PA, PET, TPC	Arnitel ID 2045, Arnite 3040, Novamid ID 1070
DSM Somos	ABS-like, ABS/PBT-like, PP-like	Somos 14120, Somos NanoTool, Somos ProtoTherm 12110
DuPont	PA	Hytrel 3D4000FL NC010, Surlyn 3D7000FL NC010, Zytel 3D1000FL NC010

Material Supplier	Specific Material Types	Selected Examples
DWS Systems	ABS-like, Gypsum-like, PP-like, Rubber-like, Wax-like	AB 001 (White), GM08B (Black), TEMPORIS
Eastman	—	Eastman Amphora 3D Polymer AM1800, Eastman Amphora 3D Polymer HT5300, Eastman Amphora Flex 3D Polymer FL6000
EnvisionTEC	ABS-like, Gypsum-like, PA, PBT, PC, PE, PEEK, PEI, PEKK, PET, PP, PP-like, PPS, Rubber-like, Silicone-like, Wax-like	ABS Flex M Series, Ortho Tough M, PolyPro MAX 3SP
EOS	Aluminum, Cobalt, Nickel, PA, PA-Carbon, PA-Glass, PA-Metal, PEEK, PS, Steel, Titanium, TPE	Alumide, EOS Titanium Ti64ELI, PA 1102 Black
Essentium Materials	PA, PC-Carbon, PCTG, PLA, TPU	Essentium PA, Essentium Copolyester PCTG, Essentium PLA
Evonik	PA, PEEK	VESTAKEEP AM 9000, VESTOSINT 3D Z2773, VestoSint Z2611
Exceltec	PA, TPU	Innov'PA 1350_Etx, Innov'PA 1550_Xs, Innov'PA 3450_GBx
ExOne	Carbon-Metal Composite, Chromite, Cobalt, Glass, Iron, Nickel, Refractory Metal, Steel, Zircon	316 Stainless Steel, FS 001 ExOne silica sand, Tungsten Carbide
Fabrisonic	Aluminum, Copper, Gold, Refractory Metal, Silver, Steel, Titanium	Aluminum 1100-H18, Pure Copper (99.9), Stainless Steel 316
GKN Sinter Metals	Steel	Additive Manufacturing 20MnCr5
H.C. Starck	Cobalt, Nickel, Refractory Metal, Steel	AMPERSINT 0032 CoCrMo, AMPERSINT 0168 Ni-SA, AMPERSINT 1556 FeNiCoMo (18Ni300)
Heraeus	Aluminum, Amorphous Metal, Copper, Iridium, Platinum, Titanium	Ir Metal Powder, Ptlr50 Metal Powder, Ti6Al4V Metal Powder
Hoeganaes Corporation	Nickel, Steel, Titanium	AncorTi Ti6Al4V Grade 23, AncorTi Ti6Al4V Grade 5
HP	PA, PA-Glass	HP 3D High Reusability PA 12, HP 3D High Reusability PA 12 Glass Beads
Hunan Farsoon	Aluminum, Bronze, Cobalt, Nickel, PA, PA-Carbon, PA-Glass, PA-Mineral, Steel, Titanium, TPU	AlSi10Mg Aluminum, FS3250MF, FS3400CF
Kevvox	ABS-like, PP-like	Beige (LC 120), Dental Stone, Castable
Lehmann&Voss&Co.	PP, TPU	LUVOSINT 65-8824, LUVOSINT X92A-1, LUVOSINT X92A-2
Lithoz	Alumina, Silicon Nitride, TCP, Zirconia	LithaCon 3Y 610 Purple (ZrO2), LithaLox HP 500 (Al2O3)
LPW	Aluminum, Cermet, Cobalt, Copper, Nickel, Refractory Metal, Steel, Titanium	LPW 316 (316L), LPW AlSi12, LPW WC CoCr
Magnesium Elektron Powders	Magnesium	LPW 1V, LPW 64, LPW 7075
MarkForged	PA, PA-Aramid, PA-Carbon, PA-Glass	Carbon CFF, Kevlar CFF, Tough Nylon
MASSIVit3D	—	Dimengel 100 Base Material
Material Technology Innovations (Mti)	Cobalt, Nickel, Steel, Titanium	MTI C01 (CoCr), MTI S01, MTI S10
Mcor	Paper	Letter, A4
Molecule Digital	ABS-like, CE-like, PC-like, Silicone-like	Jf - Flexible, Pr - Rigid, Ss - Super Stretch
NanoAl	Aluminum	Addalloy
NanoSteel	Steel	BLDRmetal J-10, BLDRmetal J-11, BLDRmetal L-40
NextDent	—	NextDent C&B, NextDent Model Ortho, NextDent SG
NinjaTek	TPU	Armadillo 3D Printing Filament, NinjaFlex 3D Printing Filament
Oerlikon Metco	Cobalt, Nickel, Steel, Titanium	MetcoAdd 718A, MetcoAdd 75A, MetcoAdd 78A
Optomec	Aluminum, Carbon-Metal Composite, Cobalt, Copper, Nickel, Refractory Metal, Steel, Titanium	Composite CrC, Aluminum 4047, Stainless Steel 420
OSAKA Titanium Technologies	Titanium	TILOP64-150, TILOP64-45

Material Supplier	Specific Material Types	Selected Examples
Owens Corning	PP-Glass	GF30-PP
Oxford Performance Materials	PEEK, PEKK	OXFAB ESD 15% Carbon Filled, OXFAB N Unfilled, OXPEKK OXFAB
Powder Alloy Corporation (PAC)	Cobalt, Nickel, Steel	15-5AM, 625AM, K500AM
Praxair	Cobalt, Nickel, Steel, Titanium	Fe-271 (316 Stainless Steel), Ni-914 (Pure Nickel), Ti-201 (Ti Aluminide)
Prodways	Alumina, PA, PA-Carbon, PA-Glass, PA-Mineral, TPU, Zirconia	PA11-GF 3450, PA12-GFX 2550, PLASTCure Model 200
Push Plastic	ABS, ABS-Carbon, PC/PBT, PETG, PLA	Push Plastic PC/PBT, Push Plastic PLA, Push Plastic Premium ABS
Renishaw	Aluminum, Cobalt, Nickel, Steel, Titanium	CoCr-0404, Renishaw Inconel 718, Ti6Al4V ELI-0406
RICOH	PA, PA-Glass, PP	PA11 S5500P, PA12G S5500P, PPS5500P
Rize	—	Rizium One
SABIC	ABS, ABS-Carbon, ABS-Glass, PC, PC-Carbon, PC-Glass, PEI, PEI-Carbon, PPE-Carbon, PPE-Glass	CYCOLAC AMMG94F Filament, LEXAN AM1110F Filament, LNP THERMOCOMP AM COMPOUND AC004XXAR1
Sandvik	Bronze, Cobalt, Copper, Nickel, Steel	430L (Sandvik), F75 (Sandvik), IN625 (Sandvik)
Sartomer (Arkema Group)	HDPE-like	N3xtDimension N3D-F130, N3xtDimension PRO21904
Shanghai Union Technology	ABS-like	UTR6180, UTR9100
Sino-Euro Materials Technologies	Nickel, Titanium	Superalloy EP741NP (0-45 microns), Superalloy Inconel 718 (45-105 microns), Ti6Al-4V (45-105 microns)
Sinterit	PA, TPU	Sinterit Flexa Black, Sinterit PA12
Sintratec	PA	Polyamide 12
SLM Solutions	Aluminum, Bronze, Cobalt, Nickel, Steel, Titanium	SLM Solutions Inconel 625, SLM Solutions CuSn10, SLM Solutions Reintitan
Solidscape	—	3Z LabCAST, 3Z Model
Solvay	PA, PEEK, PEEK-Glass, PPSU	TECHNYL XP 1501/F, TECHNYL XP 1537/A, Radel PPSU
Stratasys	ABS, ABS/PP, ABS-like, Acrylic, ASA, PA, PA-Carbon, PC, PEI, PP-like, PPS, Rubber-like	Tango Plus, VeroClear RGD810, ULTEM
Structo	—	Structomer META, Structomer OrthoPro, Structomer PROTO+
Taulman 3D	PA, PA/TPE, PE, PETG	Alloy 910, BluPrint, T-Lyne
TechmerPM	ABS-Carbon, ABS-Glass, PA Carbon, PC-Carbon, PEEK, Carbon, PEI-Carbon, PPS-Carbon, PPSU-Carbon	Electrafil ABS CF5 3DP, Electrafil TPX PA 16009 3DP, HiFill J-1200/20 3DP
Tekna	Refractory metal, Titanium	TEKMAT Mo-45, TEKMAT Ta-75, TEKMAT W-25
TORAY	PPS, PPS-Carbon, PPS-Glass	TORAY PPS 30%wt CF Reinforced, TORAY PPS Unreinforced
TPM3D (A Stratasys Company)	PA, PA-Glass, PA-Metal	Precimid1170, Precimid1170RL, Precimid1172
United States Metal Powders	Aluminum	AM 2024, AM AlSi12, AM F357
Valimet	Aluminum	AM-103, AM-205, AM-7075
Verbatim	ABS, PET, PLA, PP, TPE	Verbatim ABS Filament, Verbatim PP Filament, Verbatim PRIMALLOY
voxeljet	PMMA, Silicate, Zircon	Cerabeads, PMMA - Polypor C, Silica Sand - Inorganic Binder
Xi'an Bright Laser Technologies	Aluminum, Nickel, Steel, Titanium	BLT-G09 (17-4PH), BLT-S22 (HX), BLT-T08 (TA15)
ZRapid Tech	ABS-like, Aluminum, Cobalt, Copper, PA, Steel, Titanium	PA-RP12S, Titanium Alloy (TC4), ZR90

The information in the table above is courtesy of Senvol, a provider of data for additive manufacturing. One data product Senvol provides is the Senvol Database, which is a comprehensive database for industrial additive manufacturing machines and materials. For more information on any of the above materials, visit the Senvol Database – which is online and free to use – at senvol.com.

SENVOL®

Optimization Overview: solidThinking Inspire

BY TONY ABBEY

THIS MONTH'S walkthrough looks at solidThinking Inspire 2018 from Altair. This is a structural optimization program designed to provide a complete workflow from geometry creation and or manipulation, through FE analysis to topology optimization and geometry shape fitting of the resultant configuration.

Editor's Note

This is one of a new series of overview articles looking at simulation and optimization software products. Each review takes the format of a walkthrough using a simple structural example. The full capabilities of each product cannot be covered in a few pages, but we hope to give you a feel for the basic workflow required for each product.

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

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

You can view the complete model build in an online video at digitaleng.news/de/inspire.

Fig. 1 shows the Inspire layout, partway through a topology optimization exercise. The main graphics area shows the geometry being reviewed. The very top-level menu controls the major activities such as Geometry (building and manipulating), Structure (setting up FEA and Optimization), View (controlling the User Interface) and File (normal file operations).

Below this is the toolbar ribbon that contains icons to drive the various tasks. The toolbar changes, dependent on the main menu action chosen. Fig. 2 shows the toolbar under the Geometry menu selection (upper) and under the Structure menu selection (lower).

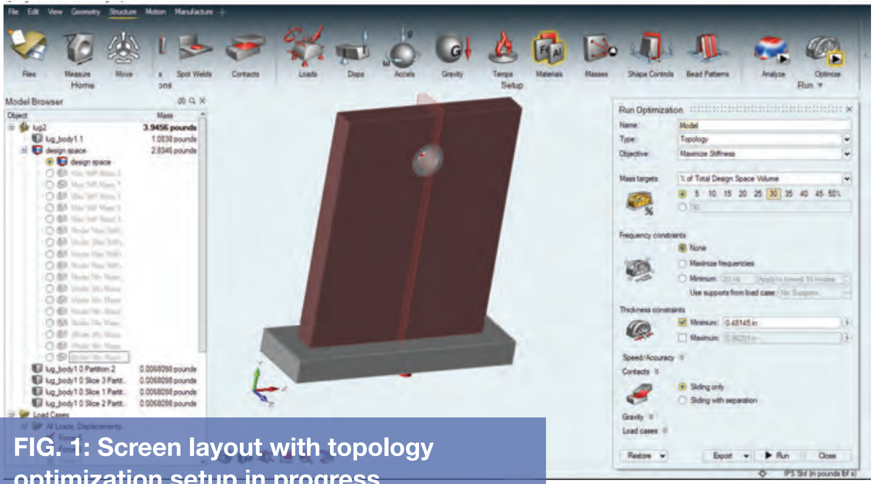


FIG. 1: Screen layout with topology optimization setup in progress.

FIG. 2: Toolbars under Geometry menu (top) and Structure menu (below).

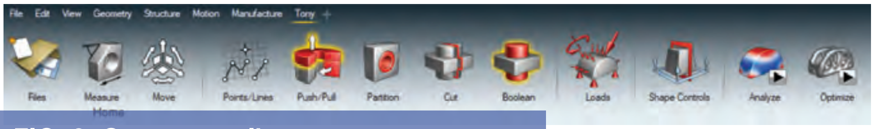


FIG. 3: Custom toolbar.

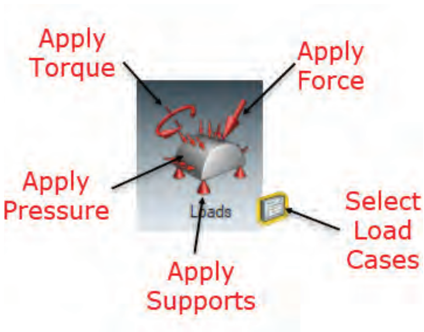


FIG. 4: Loads icon with list of actions.

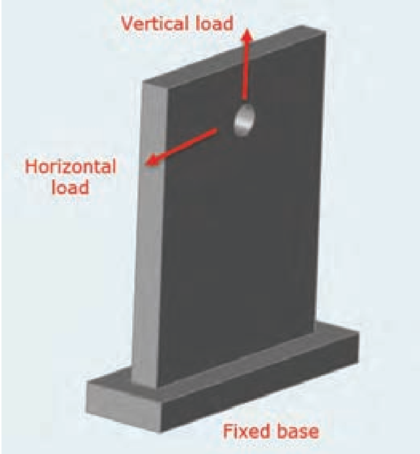


FIG. 5: Initial design space, loading and constraint.

A small toolbar is positioned in the lower left of the screen area to control screen views, orientation, entity visibility etc. A unit selector is positioned in the lower right area of the screen.

A feature that may be useful for first-time users is the ability to create a custom toolbar, composed of icons drawn from any of the menu areas. In Fig. 3 I have created a simplified workflow (called Tony) that allows some geometry manipulation, basic loads and boundary condition setup and the ability to analyze and optimize.

The home icons are always present. Separators can be inserted to further clarify the icon context in the workflow, and icons can be dragged left and right. Here, I have split up geometry, loads and boundary conditions, shape controls, and analysis/optimize as distinct stages.

As you explore outside this initial range of features, the corresponding icons can be added to your custom toolbar. This provides a comfortable platform for self-training—or instructor-led training as I show in the accompanying video.

Minimalist Approach

The Inspire house-style is minimalist. Only a relatively small number of icons are present, but their versatility allows a wide range of functionality to be supported. This versatility is shown in the number of options associated with each.

Fig. 4 shows the "Loads" icon. The title is a bit of a misnomer as the icon supports all of the actions shown in the exploded labeling that I have added.

Hovering over each region highlights the required action. This was a bit bewildering at first, and I recommend exploring and practicing with each icon until you are comfortable with its usage. Once each icon is understood, the workflow is visual and very efficient. Notice that Inspire uses the term "support" instead of the usual "constraint"—presumably to avoid confusion with optimization constraints. The little object I have highlighted looks like a suitcase. It is a nice visual clue that unpacks to allow allocation of loads and boundary conditions across a range of load cases. This underpins how important multiple loading conditions are for practical optimization studies.

The Optimization Task

My objective was to create a lug-like configuration starting from the geometry shown in Fig. 5. The vertical part is the design space; the base is a non-design space.

The lug will carry axial loads and side loads. From engineering basics, a lot of the material is not needed above the hole. A tighter initial design space can be defined and has the advantage of reducing the element count in the underlying FEA and making the target Volume Fraction reduction more focused on critical material.

A 50% Volume Fraction used on 20 cubic inches, with 10 cubic inches is redundant and is not effective in driving toward a useful configuration. If the redundancy is removed, then 50% Volume Fraction is literally attacking the meat of the problem in the 10 cubic inches of design space left. Conversely, if too much material is clipped from the initial design space, then the final configuration can be skewed away from a more "natural" result. In this lug, the width is a control-

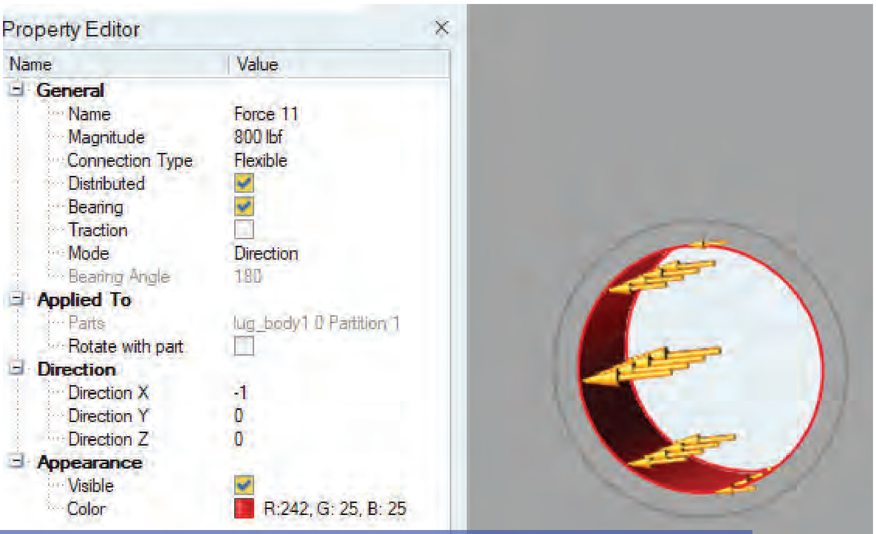


FIG. 6: Load screen picking and Property Editor window.

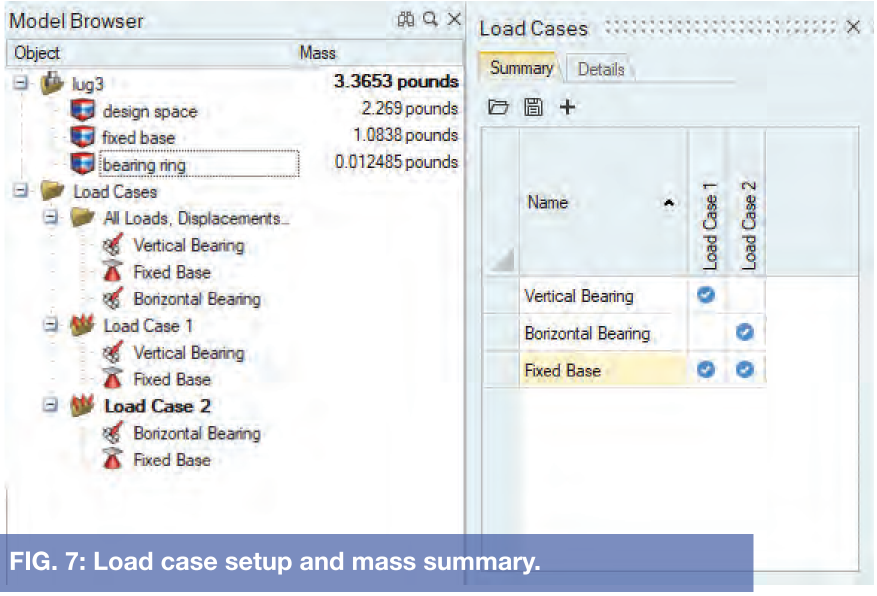


FIG. 7: Load case setup and mass summary.

ling factor. The bending load case would naturally want a wide base to provide the biggest reacting couple. So, my width limit skews the resulting configuration.

It is a good idea to make this kind of assessment of design space, maybe even to try a set of exploratory FEA studies on broad design space options to understand useful limits.

The Model Setup

I want to slice the corners off of my initial design space to make the topology search more efficient as described. Inspire has some neat tools to do this within a versatile geometry creation and manipulation set. By clicking on the line feature in the Points/Lines icon, a sketching toolbar appears. Two lines are snapped to the corners of the surface. The new faces created by the line intersections are then pulled through the body using the Push/Pull icon, creating an extruded cut.

I am loading the inside of the hole, so the material immediately abutting the load must remain intact by designating it a non-design space. The Partition Icon is used to achieve this. An annular ring is partitioned as a separate body by offsetting the hole surface. The thickness of the ring is important. Too thin and the element size will be prohibitively small, too large and the non-design region will dominate the topology configurations.

Now I add the loading. Inspire supports a bearing distribution, which is im-

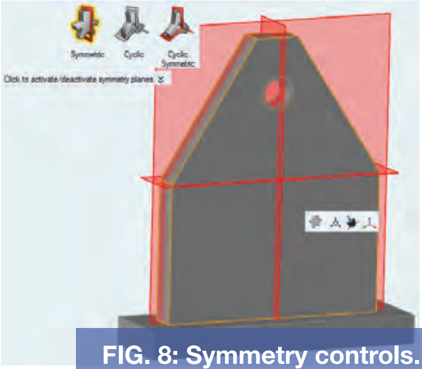


FIG. 8: Symmetry controls.

portant for realistic loading. I found the load setup quite tricky, and the best routine for me was to select the force action, select the correct surface area and direction and then convert to a bearing distribution. The Property Editor dialog box can also be opened from the View menu. This means that you can screen pick and correct with a conventional dialog box as shown in Fig. 6. I must admit, however, that millennials may be far more at home with direct icon action than me.

I created two bearing forces: one laterally and vertically. The non-design partitioned region can also be seen in Fig. 7.

The support (structural constraint) is straightforward in this case, as the complete base is fixed. I created a second load case and then allocated the forces and constraint to each as shown in Fig. 8.

The model setup is shown by using the Model Browser, called from the top menu. I have renamed the forces and support for clarity. Fig. 7 also shows the mass breakdown by part —I have renamed these to clearly identify the mass totals. There is 2.269 lbs. weight available in the design space out of 3.365 lbs. total. The fixed base and bearing ring parts are set as non-design space.

The final step prior to analysis and optimization is to set the shape controls. I required the design to be symmetric about the vertical centerline to cater for reversed lateral loading. I also wanted a design that was symmetric through thickness. I used planar symmetry, but cyclic; cyclic symmetric can also be used. Control of draw direction is also available, which includes single draw, split draw and overhang. These are critical controls when attempting to generate manufacturable topology configurations.

Fig. 8 shows the symmetry control in action.

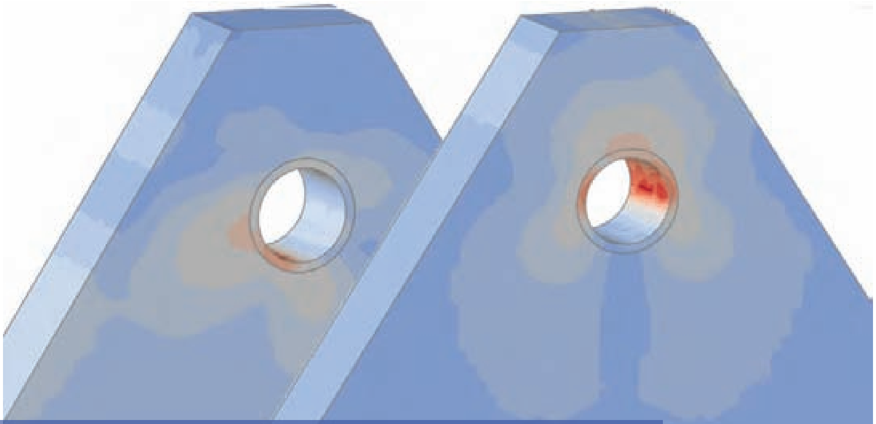


FIG. 9: von Mises stress plot for both load cases.

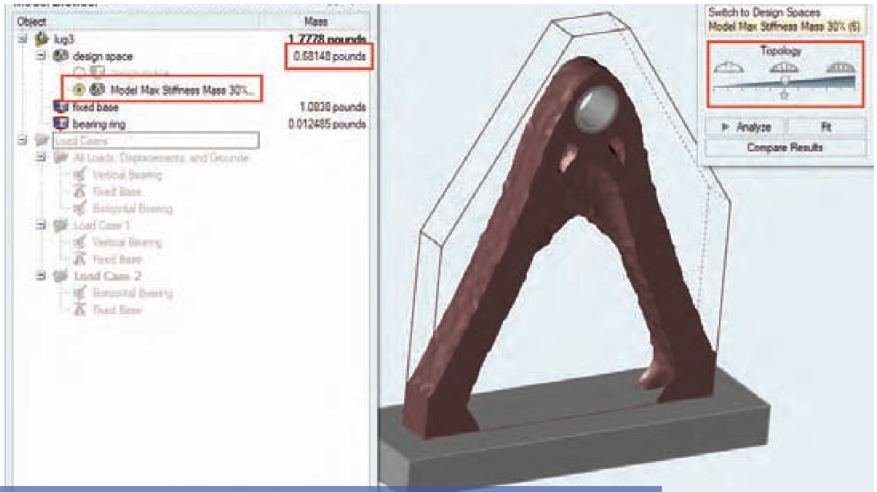


FIG. 10: Topology at 30% Volume Fraction.

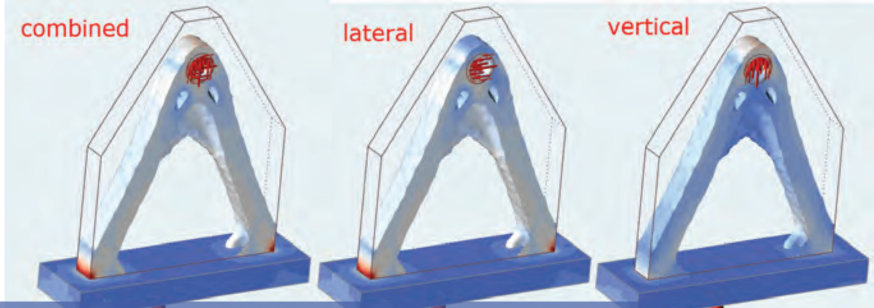


FIG. 11: FE Analysis of the optimized configuration.

The available symmetry planes are shown and can be set relative to any part or to the basic coordinate system. The plane also can be manually shifted. The symmetry plane (or any shape control) can be switched on and off during successive optimization runs to see its influence.

Before running the optimization, it is worth doing a check FE analysis to make sure the loads and boundary conditions are set up properly. Fig. 9 shows the results from the two load cases run separately.

The stress values and distributions make sense—which is important as the topology optimization is totally dependent an accurate analysis setup. One trick here is to set the lower stress value on the legend scale to be about -1 times the maximum stress value. This will ensure the contours are clustered more tightly around the maximum value and the stress distribution can be seen more clearly.

The Optimization

Finally, it's time to go and optimize! I set the optimization Type to Topology. Other options are Topography, Gauge and Lattice. Lattice is one of the new features in 2018. The optimization objective is to maximize stiffness, in other words, to find an efficient design. The target design space volume (Volume Fraction) is 30%. The direct input option below the fixed radio button percentages allows for custom percentages, and also, by stringing values together, a batch of runs. I found this useful once I had explored some of the configurations produced by various Volume Fractions. I could then quickly sweep through a full range. There is no constraint on stress or specific deflection values.

I also did a parallel study that used the minimize mass option as an objective with stress as a constraint. Stress is expressed as a Factor of Safety and is a global measure.

The minimum feature thickness is set at 0.25 in. There are two considerations here; from a design point of view, there will be a minimum practical feature size. If this is set very small, then we allow "filigree" strands of material. This could be a goal—to seek a more organic type of shape. If this is set very large, then the structure becomes chunky and the volume fraction target may not be achievable. The most efficient designs have more distributed material.

The other consideration is the number of elements. If we demand a very small minimum feature size, then the mesh must be able to represent the resultant configuration—which could mean a large number of elements.

Fig. 10 shows the topology optimization result.

The brown object is a surface fit through the remaining material in the topology optimization mesh. The Model Browser reports the new design space mass, as highlighted in the figure.

Investigating the Results

A slider bar (highlighted in Fig. 10) can be moved to adjust the amount of material displayed. This is essentially juggling with the interpolation of the "solid" material in design space. Inspire uses the SIMP method of topology optimiza-

Compare Results

Run	Mass design space		Compliance	
Model Max Stiffness Mass 10% (15)	1.906e-001 pounds	55.31%	6.198e-001	288.92%
Model Max Stiffness Mass 15% (13)	2.568e-001 pounds	74.54%	3.323e-001	154.89%
Model Min Mass SF 1.5 (20)	2.797e-001 pounds	81.18%	5.140e-001	239.58%
Model Max Stiffness Mass 20% (11)	3.446e-001 pounds	100.00%	2.145e-001	100.00%
Model Min Mass SF 2.34 (19)	4.222e-001 pounds	122.52%	2.539e-001	118.35%
Model Max Stiffness Mass 25% (8)	4.326e-001 pounds	125.55%	1.526e-001	71.14%
Model Max Stiffness Mass 30% (6)	6.815e-001 pounds	197.79%	1.183e-001	55.15%

FIG. 12: The Compare spreadsheet.

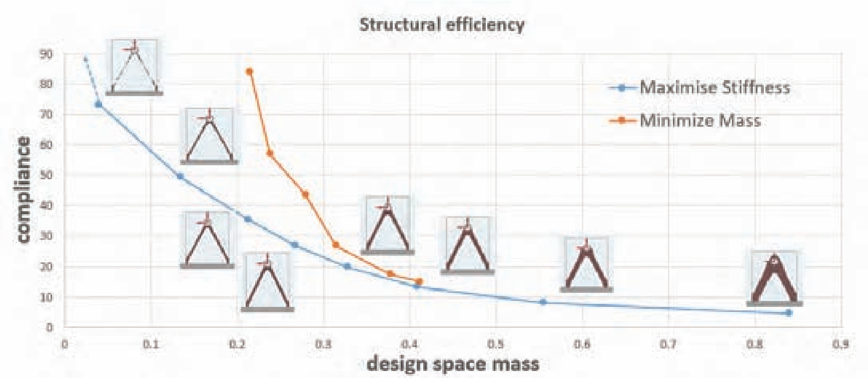


FIG. 13: Two parallel optimization studies.

tion (see digitaleng.news/de/topology-optimization). This means the relative material density is varying from close to zero (material not present) to 1.0 (material present). The "gray" area in between is very much subject to interpretation, particularly in a coarse mesh.

The central position is the baseline topology optimization result. If the configuration changes a lot with a small slider bar movement, then the configuration is not very representative of a "real" structural configuration. The mesh may be too coarse, or the Volume Fraction may just not be feasible with design space and loading provided. The configuration is a very rough suggestion at that point. Bear in mind that aggressive Volume Fraction targets will often produce disconnected configurations. The slider bar also can be used to see if disconnected regions will join up, with a small increase in mass. The changing mass is updated in the Model Browser window. If, however, there is little change in the configuration as the slider bar is moved, then the candidate configuration is much more promising.

Under the slider bar is an Analyze button. This carries out an FE analysis on the configuration and interpolates the stress distribution Fig. 11 shows the result of the analysis, with the two load cases shown.

The combined stress plot is an envelope of the highest stresses seen in the load cases. In this case the lateral (i.e., bending) case dominates. For complex loading scenarios, it is useful to see the design drivers among the load cases.

The next button available is Fit; this fits a set of smoothed surfaces to the optimized configuration. If the surfaces are continuous, then a "smooth" label is appended to a new part name generated. This can be exported as a set of surfaces, as opposed to an STL format. This should help in further geometry manipulation required to turn the configuration into a manufacturable part.

Finally, the Compare button allows the comparison of metrics across a set of optimization runs. Fig. 12 shows the resulting spreadsheet format.

In this case I have tabulated the Mass against Compliance for a set of optimization runs. The columns and parameters can be arranged, ordered and filtered to suit your investigation. Double clicking on a row will pop the configuration open in the graphics window. Here, I set the Mass to ascend and show the corresponding Compliances. I have run a large batch of topology configurations. Several of the low mass configurations have very large compliances as they become very spindly. I have clipped them out of the review table so that they don't distort the trend.

By clicking in the corner of the spreadsheet all the cells are highlighted and can be copied to the clipboard, and then into Excel. I mentioned I had carried out a parallel study using mass minimization subject to a stress constraint. I was able to export all the data and produce the Excel graph shown in Fig. 13 to see trends.

The first curve shows configurations achieved by maximizing stiffness for a given target Volume Fraction (30% down to 8%). Each point is an efficient structure. Below 0.3 lbs. mass the structures are not realizable due to high stresses, deflections or badly connected structure. The compliance (1/stiffness) shoots up as the configurations get more absurd.

The second curve shows the effect of minimizing mass with a stress constraint. The stress constraint has been relaxed progressively to allow lighter mass configurations.

There is an interesting crossover where the two curves meet at around 0.3 lbs. mass. The configurations are quite similar here, and this could represent an overall efficient solution. The curves do provide useful design information on which to make decisions about what configuration to select to work up into a manufacturable component. Inspire has allowed a rapid investigation across a range of efficient candidate configurations.

More Features to Explore

I mentioned the surface fit option that can export smoothed geometry for design workup. Another very powerful alternative is to use the Inspire PolyNURBS tool. This interactively fits and manipulates surfaces to the topology configuration via a host of methods. It is fun to use and can produce very useful geometry. It deserves its own review, so watch this space. **DE**

Tony Abbey *partners with NAFEMS, and is 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.*

INFO → solidThinking: solidThinking.com

For more information on this topic, visit digitaleng.news.

Netfabb: Prepared for Additive Manufacturing

The latest release of Autodesk Netfabb includes multiple enhancements.

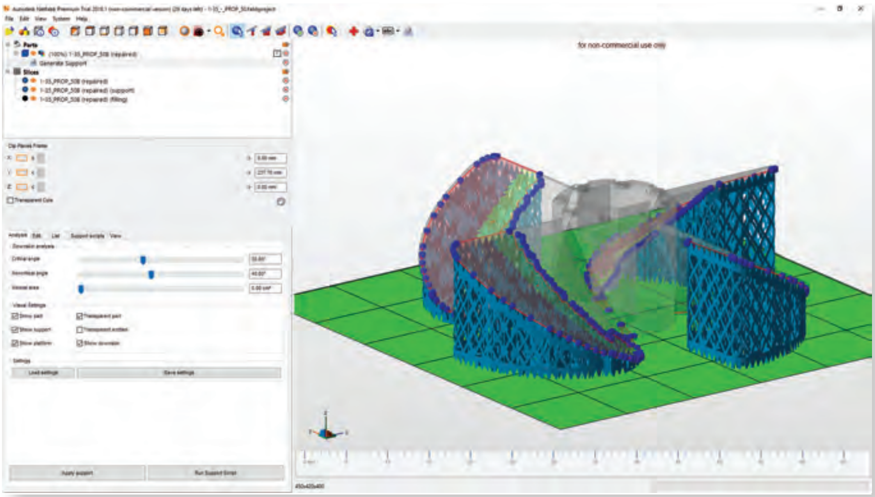
BY DAVID COHN

IN NOVEMBER 2015, Autodesk acquired the German company netfabb GmbH, developer of netfabb software solutions for additive design and manufacturing. Netfabb was already considered by many to be one of the most important 3D print prep tools in the industry. Less than a year later, the software giant released its first Autodesk-branded versions of Netfabb. Now, the company has followed up with Netfabb 2018.

Netfabb is a comprehensive toolkit for additive manufacturing professionals. It integrates design enhancement, manufacturing preparation and build simulation tools in a single software environment that shares a common installer, common file formats and process definitions. Since acquiring the software, Autodesk has added powerful new capabilities—including enhanced simulation, optimization and advanced toolpath capabilities—that provide engineers and designers with a broad collection of additive design and manufacturing tools.

Netfabb prepares three-dimensional files for printing and converts them into 2.5-dimensional slice files, consisting of a list of two-dimensional slice layers. The software includes tools for viewing, editing, repairing and analyzing three-dimensional or slice-based files in various formats. To perform the print preparation operations, Netfabb uses a STL (stereolithography) file format to create a mesh of the part.

STL files contain lists of three-dimensional corner point coordinates and flat triangles (faces). Adjacent triangles typically use common corner points and share edges, resulting in a continuous triangle mesh. But since STL files do not contain any topological information about the mesh, errors can occur when CAD files with different formats are converted to STL. Netfabb can be used to detect and repair these errors to create a faultless mesh without holes, deformations or intersections. These meshes can then be converted into slice files ready for additive manufacturing.



Tools within Netfabb 2018 let you analyze and repair models and add supports to hold parts in place and mitigate thermal effects during printing.

Updated UI and Toolsets

The Netfabb interface consists of a menu and toolbar across the top of the screen with panels containing the project tree, cut plane and content frames on the left and a large display area on the right. The display area allows you to view your model on the build platform while the project tree lists all parts, slices and structures contained in the model. The layout of the interface can be adjusted by resizing, repositioning and even detaching frames and moving them around. The UI has changed since the acquisition, but should remain familiar to anyone who has used Netfabb in the past.

Tools within the interface enable you to reorient the display area and reorient parts that have been placed in the display area. You can also easily adjust the size of the build platform to match that of the hardware on which you will print the part. Netfabb 2018 includes an extensive library of machines; you can also specify your own custom build platforms.

Many of the main functional capabilities of Netfabb are presented in modules. For example, there are modules for creating supports, repairing models, mesh manipulation, part analysis, labeling, part orientation and so on. Each module loads its own components into the Netfabb interface, changes the tools available in the menu and toolbar and modifies the graphical representation of the part in the display area. A new branch is also created in the project tree for each loaded instance of a module.

Although you could model parts entirely in Netfabb—and the software comes with a collection of basic parts—most projects begin by importing parts that have already been modeled using a 3D CAD program. Netfabb can import files created in nearly any CAD program, including CATIA, Creo, Inventor, NX, ProE, Rhino, Solid Edge and SolidWorks, as well as neutral formats such as IGES, JT, STEP and VRML, files created using SketchUp and files saved in native ACIS and Parasolid formats. The software converts the imported CAD data into an STL file.

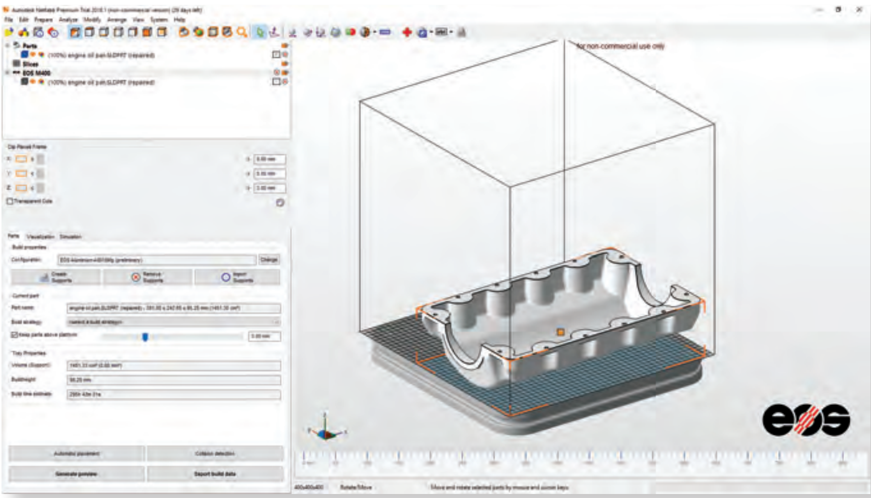
You can control how finely the resulting mesh is triangulated and thus control the resolution of the printed part. Netfabb can speed up workflow by importing files in batches. The software also clearly indicates when it detects errors in the model that would prevent it from being printed correctly.

Preparing Parts for Manufacture

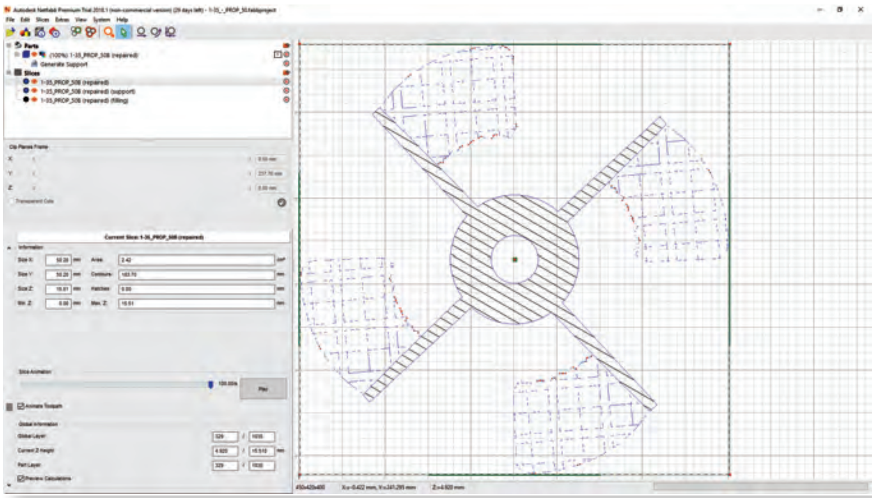
Once the geometry has been read into Netfabb, you can quickly fix errors in a triangular mesh that would otherwise make the part unsuitable for further printing preparation steps. The program can automatically repair parts to stitch triangles, close holes, fix flipped triangles, eliminate self-intersections and so on. Netfabb comes preloaded with recipes of common repair sequences. For special cases, you can create your own recipes using a simple dialog. You can also use manual repair tools to enhance the manufacturability of models, manually cut out errors, edit meshes and compare repaired parts with the original model to determine deviations and verify build geometry. The program also includes measuring tools you can use to examine specific details of a model.

After repairing parts, you can simply save them in the STL format for 3D printing, or use tools in Netfabb to analyze parts to make more informed estimates of the effort necessary to prepare parts. For example, parts can be compared, with differences displayed as heat maps. This is an effective way to compare an initial design with simulation data to see where and how much distortion will happen due to thermal effects during printing. Analysis tools include the ability to generate and export reports that can be used to collect information about the current state of the build platform, the parts and their quality and other properties that can be used for estimates and quotations.

You can also analyze up- and downskins to determine areas of the model that need to be supported, determine the center of gravity of parts and so on. You can then use other tools to generate supports to hold parts in place and mitigate thermal effects during print-



Netfabb 2018 provides a well-organized interface, with tools arranged around a display area in which you can view your model on a build platform matching the machine on which you will output your 3D part.



After slicing parts, you can view an animated simulation of the toolpath as each layer is created.

ing. Netfabb provides three main types of supports—bar, polyline and volume supports—and the program handles supports parametrically. Supports can be created with few or no manual steps and can be recreated whenever the arrangement of the parts changes.

Although you can place parts manually, Netfabb can also automatically arrange individual parts within the build platform so that multiple parts can be built at one time. You can then analyze the project to ensure that individual parts can be unloaded by only moving parts vertically, one part at a time.

You can also use tools in Netfabb to offset, hollow or smooth parts, adjust wall thicknesses, add machining stock and reduce sharp edges to adhere to the capabilities of the machine on which the parts will be produced. Boolean operations allow you to merge several parts into one, separate parts, extract new features, drill holes or add fixtures. You can also add text, emboss logos and transform pictures and textures into reliefs. An automatic mass labeling tool enables you to apply unique identification codes to any number of identical parts.

You can then use the slicing module to dissect the three-dimensional parts on the build platform into 2.5-dimensional information, a collection of two-dimensional layers with a defined thickness (slice stacks). Netfabb also processes the slice information to generate toolpaths, or exposure patterns, for the actual printers. You can then view an animated simulation of the toolpath as each layer is created. The slicing module handles the slice stacks loaded or created by slicing a mesh part, and the slices can be exported in various slice formats. Depending on the complexity of the model, performing some modifications at the slice level, rather than at the mesh level, can be significantly faster due to the simpler nature of the dataset.

Updates and Multiple Flavors

The first Autodesk release of Netfabb included customized workspaces for machines from Sinterit, Prodways, Rapidshape, Carbon, ZYYX and others, as well as collaborative multihead 3D printing capabilities that distribute toolpaths between multiple print heads working in unison in a single printer.

Netfabb 2018 adds the ability to create custom scripts to automate tasks that are repetitive or common across projects, the ability to preview supports and optimize orientation, automatic support update after any changes are made and the ability to output stress results from process simulations to identify potential cracking issues and support structure failures. The software can also compensate geometries based on simulation results to achieve the desired shape when printed.

The latest release also includes several technology previews, and new functionality still in a conceptual stage. These include parametric model support (which imports parametric CAD models and retains associations to the original geometry) and generative design (that enables the software to synthesize forms in a wide range of viable alternatives.

When Autodesk acquired Netfabb, existing customers were able to update to the latest version for free. Since the acquisition, new customers can purchase subscriptions to the Standard, Premium and Ultimate editions through quarterly, annual and multiyear plans.

Netfabb Standard includes the ability to import files, prepare and modify parts, and automate file analysis and repair. But the Standard version lacks more advanced features such as automatic packing and simulation tools.

The Premium edition adds configurable build supports, solid modeling tools and simulation. It also includes several utilities, including PowerShape, a separate program that provides quick and easy methods to prepare CAD models for production, including checking the quality of the CAD model and repairing problems; positioning the part in the optimum orientation for layer-by-layer manufacture; the addition of fixtures, supports and other geometry required to ensure reliable manufacture and easier post processing; exporting the data in a suitable file format for manufacture; and integration with subtractive manufacturing applications.

The Ultimate version incorporates all of these features and adds an optimization utility that enhances 3D parts using lattice optimization and topology optimization, and a lattice topology utility that enables you to define your own unit topologies.

You can download Netfabb free from the Autodesk website, which gives you access to all the Netfabb Premium features. After 30 days, the software converts into a free, non-commercial use version of Netfabb. You can also choose to opt out of the trial and use the limited capabilities contained in the free version. Since its acquisition, the new capabilities and features added by Autodesk ensure that Netfabb remains one of the most important 3D prep tools available today. **DE**

David Cohn *has been using AutoCAD for more than 34 years and is the author of over a dozen books on AutoCAD. As senior content manager at 4D Technologies, he creates the CADLearning courses for AutoCAD and AutoCAD LT (cadlearning.com). He is a contributing editor to* Digital Engineering, *and also does consulting and technical writing from his home in Bellingham, WA. You can contact him at david@dscohn.com or visit dscohn.com.*

New Netfabb 2018 Features At-A-Glance

Autodesk continues to enhance Netfabb for subscribers. Below are the some of the enhancements the company lists for Autodesk Netfabb 2018.

- **Generative design tech preview.** Synthesize forms in a wide range of viable alternatives and explore your complete design space.
- **Lattice Commander tech preview.** Optimize designs for additive with a simplified approach to generating lattices and skins.
- **Build prep automation.** Create custom scripts to automate tasks that are repetitive or common across projects.
- **Part orientation and support preview.** Preview supports and optimizes orientation based on supported area, outbox volume and height.
- **Support enhancements.** Automatically update supports after any change and create angled supports to ease finishing.
- **Simulation interoperability.** Make more informed decisions by overlaying simulation results when placing or editing supports.
- **Produce compensated pre-forms.** Automatically compensate geometries based on simulation results to achieve the desired shape when printed.
- **Dynamic editing in PowerShape Utility.** Precisely control and edit the placement and sizing of additional stock or support structures.
- **Display stress results.** Output stress results from process simulation to identify potential cracking issues or support structure failures.

INFO ➜ Autodesk: Autodesk.com

Autodesk Netfabb is only available by subscription.

PRICES:

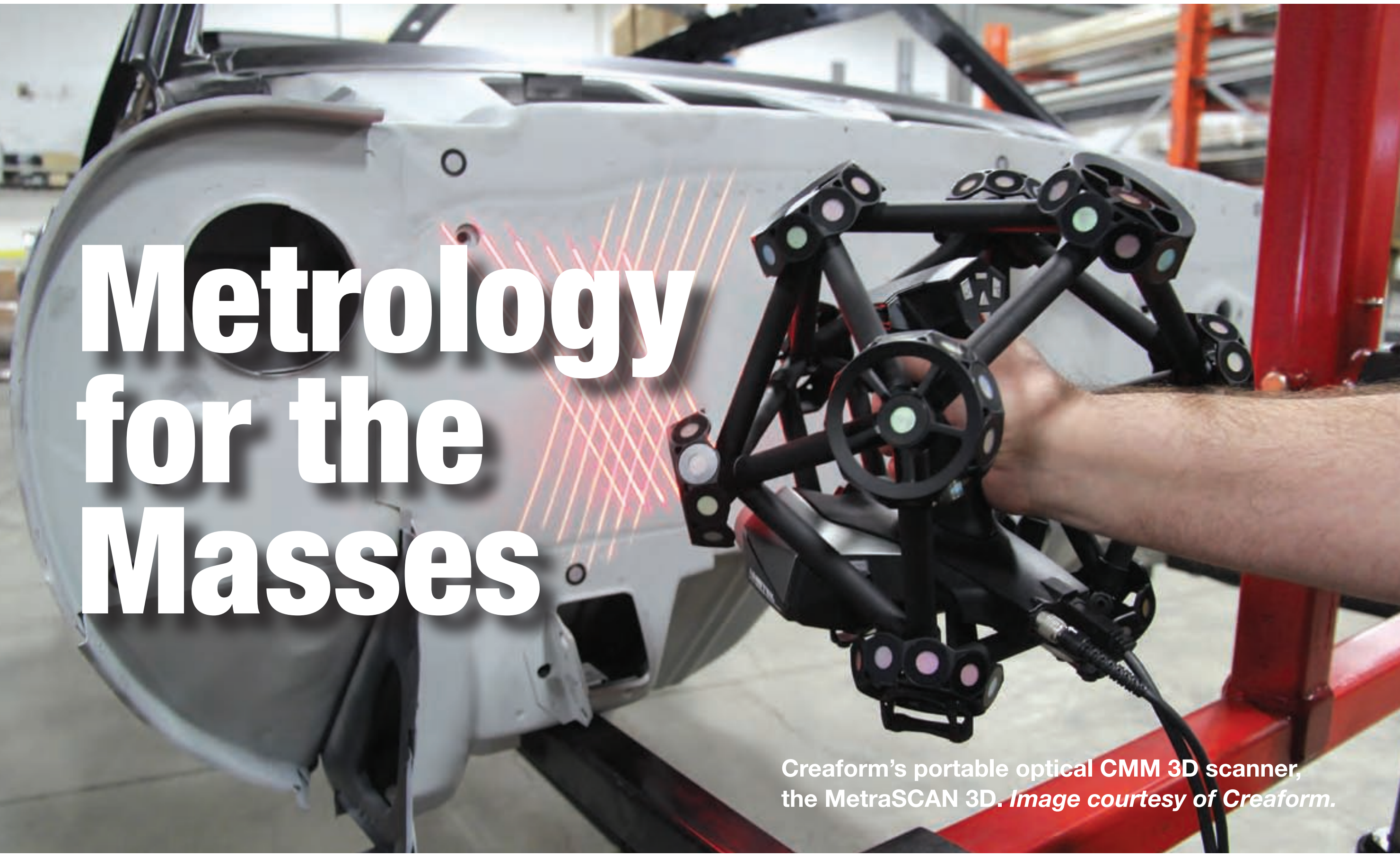
Netfabb Standard
- Monthly $30
- 1 Year $220
- 2 Years $440
- 3 Years $660

Netfabb Premium
- Monthly $500
- 1 Year $4,000
- 2 Years $8,000
- 3 Years $12,000

Netfabb Ultimate with support*
- Monthly $4,690
- 1 Year $12,500
- 2 Years $25,000
- 3 Years $37,500

** Approximated based on reseller data*

SYSTEM REQUIREMENTS
- **Operating System:** Windows 10, 8.1 or 7; 64-bit
- **CPU:** 2GHz or faster
- **Memory:** 8GB
- **Disk Space:** up to 3GB
- **Display Resolution:** 1280x1024 minimum
- **Display Card:** discrete GPU with 2GB of dedicated memory (OpenGL 3.3 recommended)



Metrology for the Masses

Creaform's portable optical CMM 3D scanner, the MetraSCAN 3D. *Image courtesy of Creaform.*

Can smaller companies benefit from advanced metrology?

BY BRIAN ALBRIGHT

FOR LARGE MANUFACTURERS, metrology has long played a key role in part and product quality. Now, these same manufacturers in the automotive, aerospace and other sectors are asking their suppliers to provide parts that meet increasingly tight tolerances, which has further expanded demand for metrology solutions.

The global metrology market will experience a compound annual growth rate of 6.82% through 2027, growing from $607.9 million in 2016 to $1.25 billion in 2027, according to a report by Market Research Future. That includes traditional coordinate measuring machines (CMMs) as well as portable CMMs, laser scanners and optical digitizers.

"As part of their quality initiatives, larger manufacturers will push measurement upstream to their suppliers," says Jim Cassady, factory metrology product marketing manager at FARO. "Those that need greater quality from their suppliers or subsuppliers are encouraging the use of metrology and measuring equipment, without a doubt."

Other small- and medium-sized companies are launching their own quality initiatives in order to reduce the amount of back-and-forth that occurs during the first article inspection process. "They have this iterative process that may, in some cases, take 15 iterations and days and weeks," Cassady says. "They are now doing their own inspections and not waiting for the customer to tell them it's not right."

For their customers, this measuring capability also eliminates the need for multiple trips to the CMM machine that can create bottlenecks.

"These mom-and-pop shops are trying to find ways to distinguish themselves as customers try to drive down the piece price they are wiling to pay," says Les Baker, senior applications engineer and global ScanArm specialist at FARO. "These smaller establishments need to find a way of increasing the value they supply, and a great way to do that is to ensure product quality before it leaves their facility."

"By having a precise color map inspection report comparing the actual to the nominal, companies are able to quickly see the areas of deviation of the entire object to have a better

Portable metrology offers an affordable alternative to CMMs for many use cases. *Image courtesy of Creaform.*

understanding of what is occurring," says Rick White, director of business development, at Capture 3D. "This dramatically reduces the number of iterations [and] rework and helps avoid unforeseen costs for a leaner and faster time to market."

Cost, Staffing Challenges

However, small- and medium-sized businesses (SMBs) may be reluctant to invest in metrology solutions. One of the biggest obstacles for smaller companies trying to implement metrology is the cost of the equipment. Large CMMs are expensive and complicated to operate. The company may also have to hire new staff to operate the measuring equipment or manage the quality program.

However, there are now smaller and more portable laser scanners and other equipment that can provide measurement accuracy at a lower cost and with less training.

Many engineers don't understand how laser scanning or other forms of metrology can help them, according to Frank Thomas, metrology and additive manufacturing solution specialist at Adaptive Corp. "It would surprise you how many engineers—when we show them the ability to 3D scan a part in a minute or two and in three mouse clicks, tell them if it matches their tolerance requirements or not—have never seen that," Thomas says. "It was not nearly as fast and simple in the past as it is today."

Advancements in metrology solutions are making it easier to use and less costly to deploy. For instance, Hexagon Manufacturing Intelligence launched a new version of its PC-DMIS 2018 R1 software that makes it easier to convert AutoFeatures to points, and can reduce measuring time while making it easier to analyze data.

Manufacturers are also making CMMs and other measuring equipment more adaptable. Hexagon, for example, has also released a new version of its GLOBAL S CMM series that can be configured with different software and probe options to meet a customer's specific application needs.

"We're taking away some of the technical implementation issues associated with using the machine," says Jonathan O'Hare, user experience strategist at Hexagon. "This can make it a more useful tool by eliminating some of the technical steps in the workflows that are now unnecessary because of the technology available."

Smaller companies with tighter budgets may look into buying a used CMM system, but other options are emerging. There are also challenges to using a traditional CMM that may make them unappealing to these manufacturers.

"In a lot of organizations, CMM becomes the slowest link in the process," Thomas says. "You have to custom fixture the CMM, and there is a lot of turnover among programmers."

Thomas says Adaptive often encourages customers to adopt portable metrology, which may not be quite as accurate as a CMM but is much easier to use.

Portable metrology equipment is more flexible, costs less and makes it easier for smaller companies to get started without as much programming or training. "You can inspect products on the plant floor or on the CNC machine," Thomas says.

3D scanning equipment can be used to inspect parts with complex contours and surfaces, whereas portable arm-style metrology devices can be used for simpler designs. There are also optical digitizers that use cameras and sensors.

For customers that may require highly accurate measurements (say, within 7/10ths or 9/10ths) for some aspects of a product, a hybrid approach might be more useful. "In many cases, they may only have two or three measurements that require very high tolerances," Thomas says. "Why are we using the CMM on everything? Let's use a portable device to get the first-pass review of the part, and if it passes then you take it to the second stage for CMM. If I scan something and it does not pass, I can find that out faster and rework the part sooner than having to stand in line for the CMM."

Capture 3D provides both laser scanner and optical digitizer solutions using ATOS equipment from GOM. "The ATOS Core Essential Line was created to address the needs of companies that may not have the budget to invest in a larger system, but don't want to compromise on quality," says White. "ATOS software is intelligent and intuitive, so it does not require any specialized programming skills like a CMM. We have training classes year-round at our facilities, which help make learning the systems easy for those who are concerned about staffing challenges."

At Hexagon, O'Hare says the company has altered its PC-DMIS software to meet the needs of different classes of manufacturers. For smaller job shops, the INSPECT application in PC-DMIS can help visualize in CAD what the shop is measuring as they are measuring it, and that can help facilitate manual alignments.

The GLOBAL S coordinate measuring machine (CMM) is available in three performance levels: Green, Blue (shown here) and Chrome. ***Image courtesy of Hexagon Manufacturing Intelligence.***

Another utility in the software helps larger batch manufacturers create a playlist-style setting to select different routines that run in series as a single program, without the need to reset the program.

"Software is everything," O'Hare says.

Metrology Improves Efficiency, Lowers Costs

Even with these advancements, smaller companies still need to cost-justify an investment in metrology solutions. In most cases, this can be quickly accomplished through reducing the cost of creating and measuring multiple test pieces and improving efficiency.

Des Moines, IA-based Auto-jet, which provides mandrel tube bending and stainless steel tubing for automotive exhaust and other applications, has deployed FARO's Edge ScanArm HD portable CMM and Advanced Tubular's V-Tube LASER software to replace manual measurements.

The laser scanning system and software have saved operators

INSPECT software, first introduced with PC-DMIS 2017 R1, can help visualize measurements in CAD. ***Image courtesy of Hexagon Manufacturing Intelligence.***

10 to 15 hours per week in programming time. They can also quickly reverse engineer customer-supplied pipes, reducing the time needed for measurement and engineering by half.

These systems also reduce scraps and improve part quality by ensuring that parts are in-spec before they are shipped to a customer.

This saves time by reducing the number of iterations needed to get to the final product. Another FARO customer, sheet- and stamped sheet metal fabrication shop, Laser Specialists, is using the FAROBlu Laser Line Probe to eliminate delays associated with part inspections. In the past, customers would send math data and stamping to the company. After cutting the stamping, Laser Specialists would send the part back to the customer for inspection, then make any edits and cut new samples for additional inspection. The process could take several weeks and multiple inspection phases.

In addition to eliminating those multiple iterations, the company is able to identify any anomalies between the customer-provided parts and associated CAD files. The solution also reduces equipment downtime. "They need all of their shifts running constantly, so you not only shorten time to revenue, but you also make the whole process easier so you don't have any extra downtime," Cassady says.

With greater accuracy, smaller manufacturers are able to meet the requirements of more advanced customers, which can potentially win them new business.

Metrology is also playing an increasing role as more companies turn to 3D printing and additive manufacturing to create both prototypes and finished parts. Metrology equipment can be used to both reverse engineer existing parts that can be printed, as well as inspecting printed parts—which can show high degrees of variance, depending on the print process and material.

"The shapes are more complex, and you can't measure these items with the same point surface sampling strategies we would with traditional manufacturing," O'Hare says. "It lends itself to more optical and non-contact scanning to measure surfaces and get into tight cavities where internal shapes can't be visualized or accessed by probes."

This also allows companies to measure the entire surface. "In traditional machining, if you measure a drilled hole at one level, you can assume the same thing is happening further down the hole," O'Hare says. "With AM, depending on the build layer, the shape could vary. It's a greater benefit to measure the entire surface."

Thomas adds that laser scanning and inspection can be used for model-based definition processes in 3D printing. "If you are doing traditional manufacturing and there is no 2D drawing, how do you inspect and validate and qualify the part?" Thomas asks. "The metrology solutions we provide have the ability to read the model-based definition incorporated in a 3D model without creating drawings."

The types of portable metrology devices that are most appealing to smaller companies can also enable additional applications that can help accelerate the return on investment. "We have customers who justify the purchase on one or two applications, but once they have the technology and understand what it brings them, they are able to implement it throughout their processes and get additional cost savings they didn't envision," says FARO's Baker. **DE**

Brian Albright *is a freelance journalist based in Cleveland, OH. He is the former managing editor of* Frontline Solutions *magazine, and has been writing about technology topics since the mid-1990s. Send e-mail about this article to de-editors@digitaleng.news.*

INFO ➜ **Adaptive Corp.:** AdaptiveCorp.com

➜ **Advanced Tubular:** AdvancedTubular.net

➜ **Capture 3D:** Capture3D.com

➜ **Creaform:** Creaform.com

➜ **FARO:** Faro.com

➜ **GOM:** GOM.com

➜ **Hexagon Manufacturing Intelligence:** HexagonMI.com

For more information on this topic, visit digitaleng.news.

Out of This World: HP ZBook 15 G4

There's a good reason why this is the best-selling mobile workstation.

BY DAVID COHN

The HP ZBook 15 G4 is a stylish and powerful 15.6-in. mobile workstation. *Image courtesy of HP.*

BECAUSE IT HAS BEEN QUITE A WHILE since we last reviewed an HP mobile workstation (*see DE September 2016*), we were very excited when the new HP ZBook 15 G4 arrived at our testing lab.

Part of the latest refresh of HP's award-winning mobile workstations, the fourth-generation ZBook 15 G4 includes HP Sure Start Gen3, the industry's first self-healing PC BIOS. A separate chip on the motherboard unrelated to other circuitry detects if malware was installed at the BIOS level and refreshes the original BIOS. HP Sure Start was first introduced in the company's third-generation workstations, but only checked the BIOS at bootup and shutdown. HP Sure Start now runs all the time.

The HP ZBook 15 has become the No. 1 workstation in the world (in terms of units shipped). It is even used by NASA on the International Space Station. The new fourth-generation systems include Intel Xeon or seventh-

Price vs. Performance of Recent Workstations

generation Core processors, and can be equipped with up to 3TB of storage, 64GB of RAM and NVIDIA Quadro or AMD Radeon Pro graphics.

Great Design

This 15.6-in. mobile workstation comes housed in a sleek aluminum and magnesium alloy chassis measuring 15.2x10.4x1.0-in. The evaluation unit we received weighed 5.89 lbs., plus another 0.92 lbs. for the external 150-watt power supply, which, at 6x2.6x0.7-in., is even thinner than the laptop. An HP logo is centered in the lid, while a recess surrounded by a band of rubber on the base makes the system easy to hold and helps keep it from sliding around on your desk or in your lap.

Raising the lid reveals a spill-resistant 100-key backlit keyboard that includes a separate numeric keypad. The keyboard proved quite comfortable to use despite its relatively shallow key travel.

Most of the keys are full size, with the exception of a row of half-height function keys above the number row and small up and down arrow keys on the bottom row. A black point stick input device is nestled between the G, H and B keys and has its own set of three buttons, while a 4x2.25-in. touchpad is centered below the spacebar. The touchpad has its own set of three buttons, supports multi-touch and includes a dedicated scroll zone. You can also double-tap the upper-left corner of the touchpad to toggle it on and off. When off, a small LED in the upper-left corner of the touchpad glows amber. A fingerprint reader sits to the lower right of the keyboard.

A rectangular power button, located in the upper-left, above the keyboard, glows white when the system is powered up. A pair of smaller buttons in the upper right toggle the wireless capabilities and mute the volume of the superb Bang & Olufsen sound system. These, too, glow white when enabled, turning amber when toggled off. The caps lock and number lock keys have their own LEDs to indicate when they are selected. Tiny LEDs along the left-front edge of the system indicate wireless, power, battery and hard drive status.

Our evaluation unit came with a FHD UWVA 1920x1080 anti-glare display. A 720p HD webcam is centered above the display, flanked by a pair of microphones as well as an LED that glows white when the webcam is active.

HP includes ample ports. Along the right side is a Smart Card reader, a microphone/headphone combo jack, a pair of USB 3.0 ports, an HDMI port, a pair of Thunderbolt 3 ports, the connection for the external A/C power supply and an LED that glows white when the battery charge is greater than 90%, amber when the battery charge is between 0 and 90%, and is off when the battery is not charging. When A/C power is disconnected, this LED blinks amber when the battery reaches a low battery level and blinks more rapidly when the charge reaches a critical level.

On the left are an SD UHS-II flash media card slot, a USB 3.0 charging port, a VGA port, an RJ-45 ethernet port and a security cable slot. The underside of the case includes a removable panel for accessing the hard drive bay, LAN module slots and memory sockets.

Well Equipped

Prices for the HP ZBook 15 G4 start at $1,329, although to configure a system like what we received, the base price jumps to $1,977 for a system that starts out with a 2.8GHz Core i5-7440HQ CPU, a 1920x1080 SVA display, an NVIDIA Quadro M620 GPU, 8GB of memory and a 500GB 7200rpm SATA-3 hard drive.

The Intel Xeon E3-1505M v6 “Kaby Lake” CPU in the system we received immediately adds $200 to that

Mobile Workstations Compared	HP Zbook 15 G4 15.6-in. 3.0GHz Intel Xeon E3-1505M v6 quad-core CPU, NVIDIA Quadro M2200, 32GB RAM, 512GB NVMe PCIe SSD	PNY PREVAIL PRO P4000 15.6-in. 2.8GHz Intel Core i7-7700HQ quad-core CPU, NVIDIA Quadro P4000, 32GB RAM, 512GB NVMe PCIe SSD and 2TB 5400rpm SATA HD	Dell Precision 5520 15.6-in. 3.0GHz Intel Xeon E3-1505M quad-core CPU, NVIDIA Quadro M1200M, 32GB RAM and 512GB NVMe PCIe SSD	MSI WT73VR 17.3-in. 2.9GHz Intel Core i7-7820HK quad-core CPU, NVIDIA Quadro P5000, 64GB RAM, 512GB PCIe SSD and 1TB 7200rpm SATA HD	MSI WS63 15.6-in. 2.8GHz Intel Core i7-7700HQ quad-core CPU, NVIDIA Quadro P3000M, 32GB RAM, 512GB PCIe SSD and 2TB 5200rpm SATA HD	Eurocom Tornado F5 15.6-in. 3.6GHz Intel Xeon E3-1270 quad-core CPU, NVIDIA Quadro M4000M, 32GB RAM, 2TB PCIe SSD
Price as tested	$3,095	$4,499	$2,759	$4,699	$2,599	$5.450
Date tested	12/1/17	3/5/18*	11/27/17	6/28/17	4/3/17	2/13/17
Operating System	Windows 10	Windows 10	Windows 10	Windows 10	Windows 10	Windows 10
SPECviewperf 12 (higher is better)						
catia-04	71.62	110.72	44.56	157.84	96.83	85.32
creo-01	69.15	94.21	45.88	129.89	87.28	80.21
energy-01	5.29	12.40	3.66	12.56	11.59	6.36
maya-04	50.99	73.75	34.47	100.99	66.22	60.58
medical-01	25.62	50.11	16.48	59.31	39.09	27.39
showcase-01	32.19	60.28	23.29	67.53	54.80	48.46
snx-02	58.62	111.05	34.93	185.13	71.52	78.14
sw-03	97.14	121.45	72.15	160.26	103.08	100.19
SPECapc SOLIDWORKS 2015 (higher is better)						
Graphics Composite	6.60	3.44	3.44	4.95	4.38	7.60
Shaded Graphics Sub-Composite	3.33	2.00	2.25	3.06	2.71	4.14
Shaded w/Edges Graphics Sub-Composite	4.65	2.66	3.27	3.89	3.50	5.46
Shaded using RealView Sub-Composite	4.73	2.42	2.70	3.54	3.14	5.64
Shaded w/Edges using RealView Sub-Composite	7.85	2.98	4.51	4.27	3.81	9.20
Shaded using RealView and Shadows Sub-Composite	5.40	2.79	2.31	4.07	3.61	6.44
Shaded with Edges using RealView and Shadows Graphics Sub-Composite	8.34	3.17	3.69	4.51	4.03	9.56
Shaded using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	15.31	9.00	4.55	13.46	11.77	16.22
Shaded with Edges using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	21.43	9.12	6.69	13.17	11.53	23.22
Wireframe Graphics Sub-Composite	3.41	3.11	2.96	3.91	3.33	3.65
CPU Composite	4.07	2.21	2.22	4.28	3.97	4.23
SPECwpc v2.0 (higher is better)						
Media and Entertainment	2.63	2.53	2.51	3.12	2.80	2.96
Product Development	2.57	2.53	2.52	3.13	2.78	2.49
Life Sciences	3.01	3.03	2.86	3.60	3.27	3.05
Financial Services	2.87	2.47	2.88	2.90	2.81	3.10
Energy	2.11	2.67	2.58	2.94	2.74	2.60
General Operations	1.62	1.11	1.64	1.45	1.37	1.37
Time						
Autodesk Render Test (in seconds, lower is better)	72.70	58.90	87.10	67.00	52.90	78.30
Battery Life (in hours:minutes, higher is better)	13:30	4:00	9:24	2:55	4:20	3:20

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

* Represents retesting after updating the graphics driver, which affected the original results published in the February issue of *DE*.

base price. That 3.0GHz processor (4.0GHz max turbo) includes an 8MB cache and has a 45-watt thermal design power (TDP) rating. Other available CPUs range from a 2.5GHz Intel Core i5-7300HQ to a 3.1GHz Xeon E3-1535M v6 processor. All are quad-core with embedded Intel graphics.

Other display options include a 1920x1080 panel with touch capabilities ($150) and a UHD UWVA DreamColor 3840x2160 display ($350). The display in our evaluation unit was powered by an NVIDIA Quadro M2200 discrete GPU with 4GB of GDDR5 memory and 1024 CUDA cores, adding $225. Other GPU options include an AMD Radeon Pro WX 4150 and an NVIDIA Quadro M1200.

Although the base configuration comes with 8GB of RAM, our system came with 32GB of DDR4 2400MHz ECC memory, installed as two 16GB DIMMs, adding $960. Or, you could max the system out with 64GB of memory for $1,920.

HP offers lots of internal storage options, including mechanical and solid-state drives ranging from 256GB to 1TB. Our system came with a 512GB PCIe NVMe SSD, which added just $185 to the system price (after eliminating the 500GB SATA drive). The ZBook 15 G4 can be equipped with up to three drives, including a pair of SSDs that can also be configured in a RAID array. All ZBook 15 G4 units include Intel 8265 ac 2x2 wireless LAN plus Bluetooth 4.2 and mobile broadband is also available on some systems.

HP also sells several accessories for the ZBook 15 G4, including a Thunderbolt 3 dock that adds four USB 3.0 ports, an RJ-45 network port, a VGA port, two DisplayPorts, an audio jack and a Thunderbolt port. Although HP sells this accessory for $279, we found the same item online for $207.

Excellent Performance

We always expect great performance from HP workstations, but the results we recorded for the ZBook 15 G4 surpassed these expectations. The nine-cell 90Whr Li-ion battery kept the system running for an incredible 13.5 hours, the longest battery life we have ever recorded. In addition, the system supports HP Fast Charge that charges the battery from 0 to 50% in just 30 minutes, after which charging slows down to preserve the life of the battery.

On the SPEC Viewperf test, which focuses on graphics, the ZBook 15 performed very well, only lagging systems equipped with more powerful NVIDIA Pascal-based GPUs. On the SOLIDWORKS 2015 benchmark, the ZBook 15 outperformed all other mobile workstations except those equipped with much faster CPUs not really aimed at mobile systems.

The ZBook 15 G4 also turned in great results on the SPECwpc benchmark with scores that again fell only a bit behind those portable systems based on decidedly non-mobile CPUs. And with an average time of 72.7 seconds to complete our AutoCAD rendering test, the HP ZBook 15 G4 outperformed most of the other 15.6-in. mobile workstations we have tested to date.

Throughout our tests, the HP ZBook 15 was practically silent, averaging 29dB at rest and peaking at 45dB under heavy compute loads. HP preinstalled Windows 10 Pro 64-bit. Windows 10 Home and FreeDOS 2.0 are also available. Like all its other workstations, the ZBook 15 G4 is ISV certified and backed by a three-year warranty that covers parts, labor and onsite service, including replacement of the battery.

Once again, HP has delivered a mobile workstation with the power, portability and features to meet the needs of most *DE* readers. As tested, our evaluation unit had a total cost of $3,095. At that price, it's no wonder that the HP ZBook 15 G4 is the bestselling mobile workstation in the world—or the universe if you include the space station. **DE**

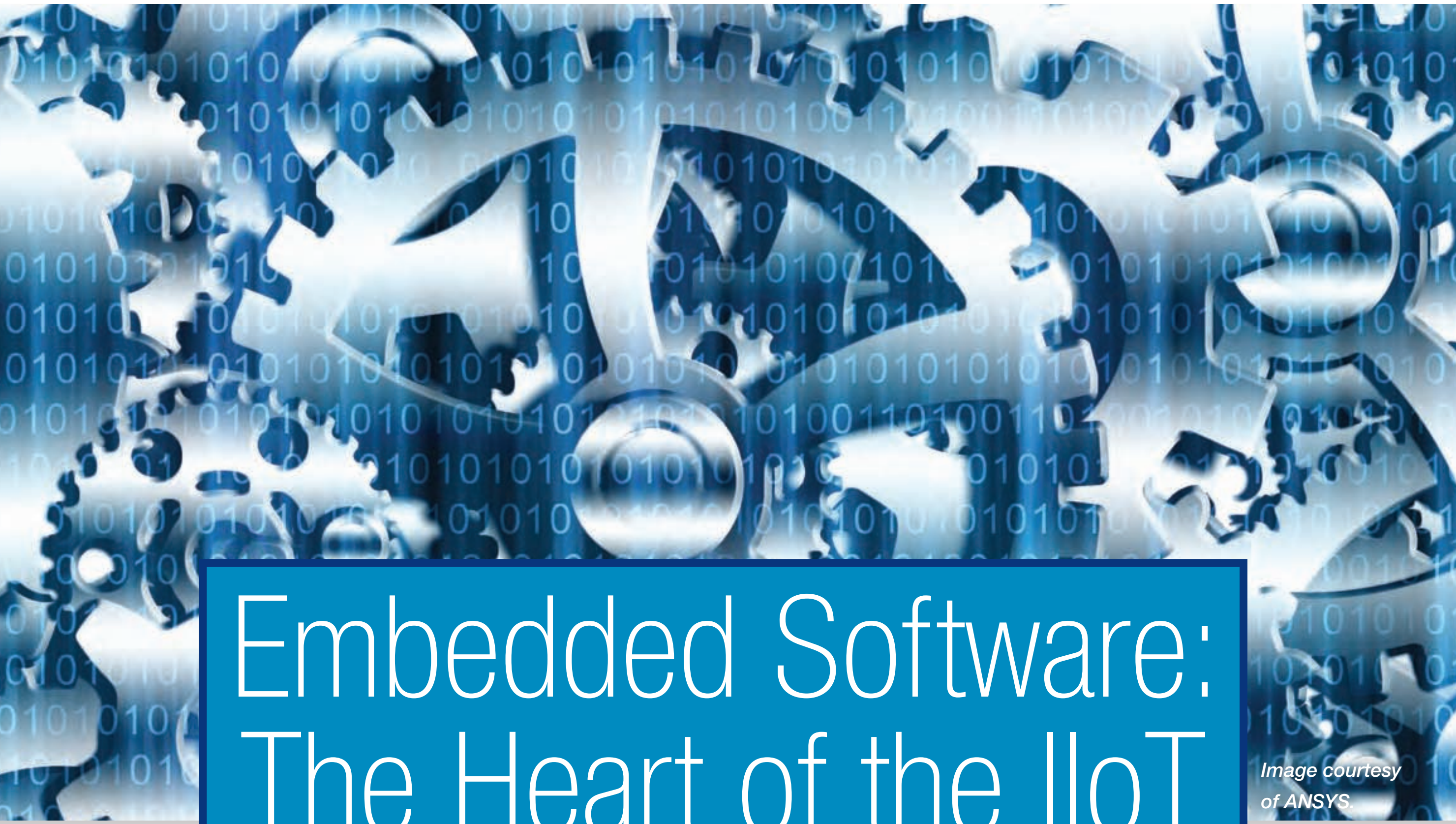
David Cohn *is the technical publishing manager at 4D Technologies. He also does consulting and technical writing from his home in Bellingham, WA and has been benchmarking PCs since 1984. He's a contributing editor to* Digital Engineering *and the author of more than a dozen books. You can contact him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

INFO → **HP:** HP.com

→ **Bang & Olufsen:** bang-olufsen.com

HP ZBook 15 G4 mobile workstation

- **Price:** $3,095 as tested ($1,329 base price)
- **Size:** 15.2x10.4x1.0-in. (WxHxD) notebook
- **Weight:** 5.89 lbs. (plus 0.92-lb. external power supply)
- **CPU:** Intel Xeon E3-1505M v6 quad-core w/ 8MB cache
- **Memory:** 32GB DDR4 2400MHz ECC
- **Graphics:** NVIDIA Quadro M2200 w/4GB GDDR5 and Intel HD Graphics P630
- **LCD:** 15.6-in. FHD UWVA anti-glare 1920x1080
- **Video:** 720p webcam
- **Hard Disk:** 512GB PCIe M.2 SSD
- **Floppy:** none
- **Optical:** none
- **Audio:** Bang & Olufsen HD audio with integrated stereo speakers and microphone
- **Network:** integrated Intel 8265 ac 2x2 LAN plus Bluetooth 4.2
- **Modem:** none
- **Other:** three USB 3.0 (one with charging), HDMI, two USB Type-C (Thunderbolt 3/DisplayPort 1.2/USB 3.1) ports, RJ-45 (Ethernet) port, VGA port, microphone-in/headphone-out combo, A/C power, smart card reader, SD flash media slot
- **Keyboard:** integrated 100-key backlit keyboard with separate numeric keypad
- **Pointing device:** integrated three-button touchpad with multi-touch and three-button pointing stick



Embedded Software: The Heart of the IIoT

Image courtesy of ANSYS.

The increasing momentum of the IIoT and the growing footprint of open-source software promise to foster the proliferation of embedded software-empowered intelligent devices and smart sensors.

BY TOM KEVAN

EVERY NOW AND THEN, a technology rises to prominence that plays a fundamental role in a transformative event. Embedded software is one such technology.

Long a part of the industrial automation infrastructure, this specialized programming, along with other key enablers, has opened the door for the next industrial revolution—the industrial internet of things (IIoT). Under this regime, manufacturers operate in a digital ecosystem, populated by intelligent, connected machines that capture, aggregate and analyze data as part of the production process. Armed with actionable information and unprecedented visibility, engineers and plant managers can optimize design, operational and maintenance processes in near real time.

"Embedded software is one of the key components in 'smart products'—IoT connectivity is another," says Nesrin Kecik, associate director and Industry X.0 smart products & embedded solution capability lead at Accenture Digital. "You simply can't build IIoT solutions without embedded systems, and you cannot build embedded systems without embedded software. You also cannot leverage more recent methods like edge computing and edge analytics, which are already becoming more and more important in a number of scenarios."

The fact is embedded software sets smart devices and systems apart from their predecessors. "Today, it's the [embedded] software that decides about the quality of a device and the functionality it delivers to customers," says Jeff Luszcz, vice president of product management at Flexera.

A close look at this specialized programming gives you a clearer understanding of where its power comes from. It also helps you understand why it is a springboard for the IIoT.

Setting the Stage

Basically, embedded software is a "system" that resides within a mechanical or electrical system, consisting of a sensor-based input system, an output actuator, a microcontroller and limited local

> **"You simply can't build IIoT solutions without embedded systems, and you cannot build embedded systems without embedded software."**
> – Nesrin Kecik, Accenture Digital

memory. This type of programming performs predefined tasks—usually with very specific requirements—and varies in complexity, according to the functions it performs. Typically, users do not interact with embedded software. Instead, external controls activate its functions. Increasingly, devices containing the software communicate with other devices for calibration, diagnostics and data sharing.

Embedded software is sometimes erroneously referred to as *firmware*. Embedded software differs from firmware in that it is often the only code running on the hardware, while firmware passes control to an operating system, which then launches and controls programs.

Embedded code pervades factory production equipment and systems. These include smart sensors, industrial gateways, security systems and industrial controls like power line communications systems, picture archiving and communication system, computer numerical control systems, robotic systems, drives, actuators and motors.

Although manufacturers have found many uses for embedded software on the shop floor, deployment of the code has been constrained by the traditionally proprietary nature of automation equipment, devices and software. Proprietary systems can be expensive to purchase and maintain, and they usually are not designed for interoperability with other vendors' products, limiting the buyer to one vendor and restricting choices of components. But perhaps more important is that adding features and upgrading systems is costly and difficult, often preventing the operator from taking advantage of the latest technological innovations.

Developers of embedded systems, however, hope that the trend toward open automation systems and the emergence of the IIoT will change this situation, opening new use cases in the process.

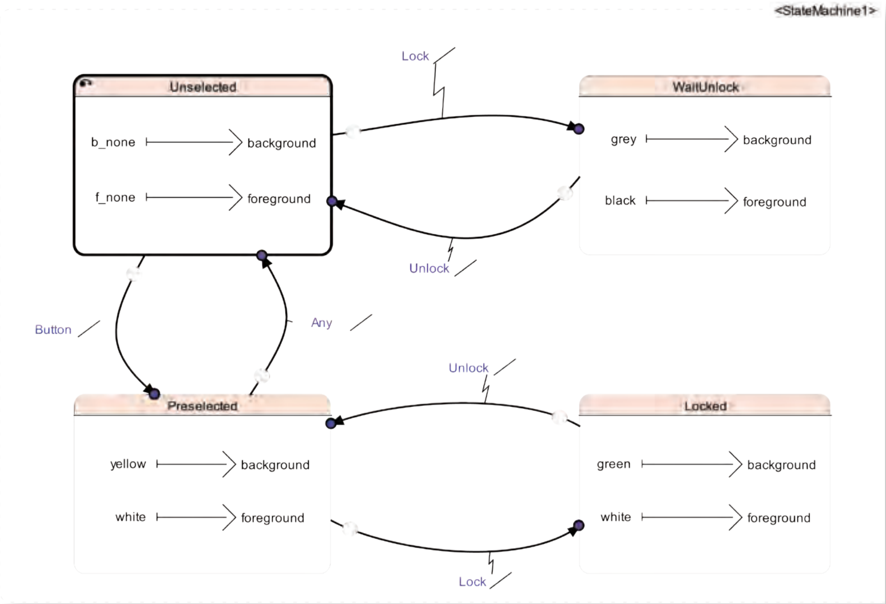
"Automation equipment usually falls into the 'hard, real-time embedded systems' category, a category that used to be dominated by proprietary software solutions," says Omer Budak, associate manager and digital technology developer at Accenture Digital. "But now, open source software is making its way into the field, with more and more equipment using open source components, which have been validated or 'battle tested' for use with critical systems."

The increasing momentum of the IIoT and the growing footprint of open source software promise to foster the proliferation of embedded software-empowered intelligent devices and smart sensors. This, in turn, will facilitate the creation of a robust digital environment at the network's edge, opening the door for enhanced asset monitoring, data analytics, process alarming and process control on the shop floor, as well as the leveraging of artificial intelligence (AI) to enable machines to make sense of and act on complex data patterns.

For embedded software to take on more complex tasks, the systems encapsulating it have had to leverage a number of recent technological developments. Chief among these are advances in processor technology.

Flexibility and Complexity

Although processor developers continue to pursue performance levels dictated by Moore's law, embedded system architects place a higher value on cost, power efficiency, integration and flexibility. This perspective stems from the unique demands placed on embedded systems, requiring more and more agility while relying on very limited resources. Reacting to these demands and the emergence of the IIoT, embedded processor vendors now increasingly tailor their products with a complex mix of computing technologies.



Automatic code generators aim to streamline the embedded software development process. ANSYS' SCADE Suite KCG C code generator, shown here, reduces the time it takes to perform such tasks as code reviews and low-level testing. With this suite of tools, you can model the embedded software controls and then use the automatic code generator to produce C code that is a one-to-one replica of the model. *Image courtesy of ANSYS.*

One way they've achieved this has been through the leveraging of multicore processors. Using this technology, chipmakers can construct a highly integrated system, dedicating individual processor cores to support multiple, separate operating environments, serving real-time and general-purpose operating systems with one computing unit. This reduces manufacturing and maintenance costs, eliminates redundant hardware and delivers greater processing agility.

These processors excel at applications involving repetitive tasks. For example, when reading a sensor in a manufacturing control application, the efficiency of a multicore processor enables a plant to tailor the frequency of sensor reads to increase its assembly line's production speed. The same system could enable finer control of parts placement, opening the door for greater levels of miniaturization.

In addition to seeking greater agility, embedded system designers gravitate toward multicore processors because they allow the engineers to better harness AI. To meet this demand, companies like NVIDIA offer manycore processors that enable embedded designs to process AI-based software for image-recognition and real-time data acquisition and control applications.

Although multicore architectures offer considerable benefits to embedded system developers, these processors also place new demands on designers. To adapt their software, programmers must apply methods that ensure the efficient distribution of software functionality across the computing resources.

This means using a threading model, where the work can be broken down to separate execution units that run on different processors in parallel. If the threads are completely independent of one another, their design does not have to consider how they will interact. If the opposite is the case, the development process becomes more complicated. Overall, the incorporation of multicore processors requires more extensive testing and validation.

The Cost of Deterministic Behavior

Paralleling the rise of multicore processors, real-time operating systems (RTOSes) provide designers with the ability to take full advantage of the processors' multitasking abilities. RTOSes differ from their predecessors in that they introduce a new level of abstraction, which enables more complex applications.

RTOSes also bring speed and deterministic behavior to embedded systems. These operating systems often have small footprints and support multithreading, which allows separation of software functionality into multiple, parallel tasks. This, in turn, gives the designer the ability to implement deterministic behavior by ensuring the availability of compute resources when required.

Using an RTOS can make it easier to design complex applications. The price for this simplification, however, is greater difficulty validating and debugging the code. In addition, designers often find that seemingly simple RTOS tasks result in surprisingly complex runtime behavior when executing as a system.

The fundamental challenge encountered in RTOS-based design stems from the fact that embedded applications have become increasingly complex, connected and event-driven, using peripherals that must be managed in parallel. RTOS tasks are not isolated. As a result, the designer must determine how the tasks are going to interact and share data using the RTOS services.

Code Writing Code

To help embedded software developers deal with increasingly complicated projects within an acceptable timeframe, software development tool vendors offer automatic code generators, which significantly reduce the time required to complete embedded system design projects. Code generation tools allow developers to concentrate on specifying the problem, letting the generator deal with the implementation.

These tools are particularly adept at solving problems involving some kind of model or cases that cannot be elegantly solved by using a traditional library. Examples of these applications include providing code for parsers, finite-state machines, digital filters and I/O routing on modern microcontrollers.

Automatic code generators use model specifications as input. With this technique, the tool often computes a more efficient solution that contains less defects than a hand-coded solution. The model specification also doubles as documentation for the problem being solved.

"Cybersecurity requires a holistic approach—starting at the system level with threat and risk analysis—to understand cybersecurity requirements to be considered at the architectural design phase."

– Eric Bantegnie, ANSYS

Design for Security

The shift from isolated systems to connected "things" has increased cyber threats exponentially. Recognizing the scale of the safety and security risks confronting them, software developers have begun to rethink their methodologies.

Traditionally, safety and security have been seen as separated areas, but many industries now realize that embedded systems that are not cybersecure are not safe either. To address this, software developers need to have well-designed security gateways and architecture between safety "islands" and open systems.

"Cybersecurity requires a holistic approach—starting at the system level with threat and risk analysis—to understand cybersecurity requirements to be considered at the architectural design phase," says Eric Bantegnie, vice president and general manager, systems business unit, at ANSYS. "This is why we have started to integrate cybersecurity risk analysis capabilities into our ANSYS

Embedded software has played a role in opening the door for the next industrial revolution—the industrial internet of things. Specialized programming enables intelligent, connected machines to capture, aggregate and analyze data.

medini tool suite, which covers systems safety analysis and system architecture design."

This holistic approach means designers must go beyond the basics. "Clearly, we've understood that the 'basics'—secure protocols, firewalls, data encryption, data source verification, authentication of both users and machines and so forth—aren't enough," says Kecik. "This is why design-for-security strategies have become part of software development, and rightfully so. 'Distrustful' subsystems, transparent interprocess comms, privilege separation and clearing resources upon free-up are becoming more important. Developers really can't afford to ignore these principles and approaches."

Software developers must also take steps to counter risks arising from the use of open-source resources. This means more governance around development processes to ensure suppliers apply as many layers of security as possible. For example, they need to make sure they ship a secure product and manage all vulnerabilities that come from open-source and third-party components.

"Tools for software composition analysis are specialized for this need and provide deep insight into what is being used, from open-source packages to copy and paste code that comes in during the development process," says Luszcz. "Developers should scan for open-source components frequently as they build their projects. By managing open-source software and third-party components diligently throughout the whole software lifecycle, suppliers can maintain an accurate bill of materials and react quickly if vulnerabilities come up and need to be patched."

The Edge and the Cloud

In addition to struggling to find ways of securing embedded systems, designers must also define embedded systems' relationship with the cloud and the edge. Torn between demands for applications on the network's edge and the power of the cloud, embedded software finds itself in the midst of an identity crisis.

Edge computing and edge analytics capabilities promise to play a critical role wherever robustness and low latency are required—just think about self-optimizing machinery. Here, the role of embedded software is certainly becoming more important.

As these edge devices evolve, however, they begin to morph into something more than a traditional embedded system. "Most edge solutions become more powerful and lean towards high-end systems, which are somewhat different than classical embedded software principles," says Kecik. "It is not uncommon that we see general-purpose operating systems, Java, Python and .NET technologies on these edge devices. Also, multicore and GPU hardware acceleration units are becoming popular on devices where edge analytics use cases are required. Embedded software is already 'reacting' to these changes. Secure connectivity, messaging protocols and device management, data collection or provisioning features are being utilized to support these capabilities, as are tools and frameworks."

The bottom line? Embedded software has begun a transformation in which both the edge and the cloud play a part. What it will look like after its metamorphosis has yet to be decided.

"Embedded software was natively designed to be executed on the edge, but we now see new architectures, where several software functions—like diagnostics and monitoring for preventive maintenance of industrial assets—can also be executed on the cloud or within gateways in three-tier architectures," says Bantegnie. "The industry is evolving into a richer paradigm, where modeling of IIoT systems has to encompass the various strategies of distribution—where actual embedded software functions are going to be executed." **DE**

....

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

INFO ➜ **Accenture Digital:** Accenture.com

➜ **ANSYS:** ANSYS.com

➜ **Flexera:** Flexera.com

➜ **NVIDIA:** NVIDIA.com

For more information on this topic, visit digitaleng.news.

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.*

HP Revs Up Engineering Workstations

Company also unveils virtual reality headset; extends support products.

HP has tricked out the Z4 workstation to handle more action. You'll be able to leverage dual extreme graphics processing units. Also, you can choose the CPU that fits your needs: A workstation-class Intel Xeon W family processor or one of the new Intel Core X-series processors.

Part of the package is the new HP Windows Mixed Reality Headset—Professional Edition. This baby offers 1440×1440 resolution per eye and a snappy refresh rate up to 90Hz.

MORE ➔ digitaleng.news/de/?p=42821

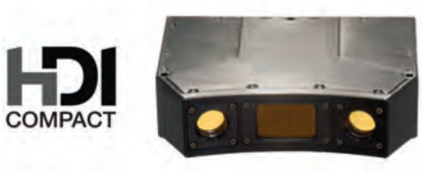
HDI Compact 3D Scanners Unveiled

Portable turnkey systems use blue LED technology for fast scanning.

Polyga rolled out its new generation of compact 3D scanners for industrial applications. This trio of lightweight units features dual 1.3-, 2.8- or 5.2-megapixel monochrome cameras.

All units use post-processing software called FlexScan3D. All are plug-and-play—load the software, connect and start scanning. Basically, the units flash light patterns on your target object. The target's surface distorts the light patterns, and the cameras capture the event.

MORE ➔ digitaleng.news/de/?p=42646



MachineWorks v8.0 Released

Multiple new tools for machining simulation and verification highlight release.

Version 8.0 of the MachineWorks computer numerical control simulation and verification software development toolkit introduces tools with optimized collision checking and customized performance for sheet metal bending. Also, MachineWorks v8.0 automatically deals with troublesome simulation and collision detection of highly complex objects.

V8.0 debuts a handy sounding feature called Simulation Snapshots. It's sort of a time-traveling Undo button.

MORE ➔ digitaleng.news/de/?p=42398

3D Scanning Solution for Designers

FARO says Design ScanArm 2.0 enables efficiency across design processes.

The Design ScanArm 2.0 is a turnkey system. It's a 3D scan-to-CAD solution for designers. You can get it bundled with third-party 3D scanning applications tailored for designers. That includes one of 3D Systems' Geomagic series toolsets—Geomagic Wrap, Geomagic Design X and Geomagic for SOLIDWORKS. These are dedicated tools for scanning, meshing and surfacing your objects of interest or even going further and creating feature-based, editable solid models.

MORE ➔ digitaleng.news/de/?p=42261

Next-Gen Engineers

Student Design Competition Profile: SME's 2018 Digital Manufacturing Challenge

Playing with Design in Today's Digital Sandbox

BY JIM ROMEO

In the age of "lean," digital manufacturing is a harbinger of innovation and productivity. Nurturing this innovation requires healthy competition and SME seeks to promote just that with their competition.

This is particularly true as manufacturing could be getting a second wind with tax incentives, possible raw materials tariffs and a full court press to bring more and better technology inside the factory floor to compete in a whole new way.

Peter P. Ried, Jr. is the chief engineer of Ried and Associates, LLC, and chair and secretary of the SME Direct Digital Manufacturing group, which runs the SME competition. We spoke to him to gain insight into this event.

Digital Engineering: Can you provide an overview of the 2018 Digital Manufacturing Challenge?

Peter Ried: Thanks to an ad hoc group of volunteer technical experts and business leaders, SME's Digital Manufacturing Challenge was inaugurated more than 10 years ago as the Design for DDM (Direct Digital Manufacturing) Competition. At the time, it was a unique response to the maturing of 3D printing and the growing potential of additive manufacturing, recognizing the need for skilled engineers and technicians to facilitate implementation and widespread adoption. Students representing high schools and colleges/universities compete in their own respective categories. High school students in the United States have participated, as have college/university students from the United States and around the world. We're pleased that the challenge has been growing from year to year and we hope to have as many as 20 teams compete this year. The demographics of our Digital Manufacturing Challenge student participants are quite diverse by a variety of measures, including the service academies and even a community college program serving those returning to the workforce following incarceration.

DE: Can you tell us about some of the designs that are part of the event?

Ried: Different themes contributed by our distinguished panel of judges attempt to focus each year's challenge, providing a minimum of design direction. The specific judging criteria imposed, however, helps ensure that the resultant entries embody a holistic approach from concept to realization. It is the imagination and creativity of the student teams with the oversight of their advisers that translate those themes into the resultant objects, subsystems or systems submitted for judging. Hence, the theme represents the "sandbox" in which digital tools enable students to "play" as they give life, i.e., form, fit and function to their ideas and concepts.

DE: What is SME's stance on adopting innovation that is linked to the program?

Ried: SME exists as a community to enhance progress and prosperity by advancing manufacturing. Therefore, innovation (both its creation and adoption) is integral to its vision, mission and purpose. SME sponsors and coordinates the Digital Manufacturing Challenge because it inspires, attracts, prepares and educates future generations in close alignment with its vision, mission and purpose.

DE: Anything else you'd like to tell us about the event?

Ried: The Challenge offers students an introduction to the industry beyond the classroom, providing a showcase for their creativity, leadership and entrepreneurship. Their teachers and professors who make this annual challenge part of their academic curriculum are vital to growing and developing students equipped with the skills sought by, and opportunities available within, our burgeoning industry. **DE**

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

Entries in the SME Digital Manufacturing Challenge center around a different theme each year.

FAST APPS

Engineering Case Studies

TuPOD CubeSat Built by CRP USA: Mission Accomplished

CubeSat, a TubeSats deployer, was developed via additive manufacturing using Windform XT 2.0 composite material.

Small satellites provide a responsive alternative to larger, more expensive ones. As demand grows, engineers must adapt these CubeSats to provide new achievements and goals.

Last phase of the TubeSats integration. *Image courtesy of GAUSS Srl.*

One of these achievements is deploying TubeSats from the International Space Station (ISS). TubeSats are cylindrical in shape and are not compatible with the normal CubeSats deployer platform (P-POD) on ISS; thus, an innovative nanosatellite, TuPOD (Tubesat-POD), was developed to address the challenge.

TuPOD inaugurated a new era for scientists wanting to use small, highly reliable satellites. It reportedly is the first complete 3D printed satellite launched from the ISS. It is made by CRP USA from CRP Technology's proprietary material Windform XT 2.0, a carbon fiber reinforced composite 3D printing material known for its mechanical properties, developed with CRP USA.

Overview

The story of TuPOD began when a group of Brazilian students needed to launch their TubeSat, TANCREDO-1, from ISS. They approached G.A.U.S.S. Srl (Group of Astrodynamics for the Use of Space Systems), an Italian company with ties to the University of Rome, to help them overcome the challenge of launching their TubeSat from ISS.

GAUSS was challenged with designing an innovative system to deploy the first TubeSats into orbit that could act as a satellite and release platform. GAUSS began the process of evaluating technologies that could produce a system with the capability to board and release two TubeSats that could meet the rigid mechanical properties for space applications while avoiding traditional tooling challenges. In that regard, GAUSS teamed up with Teton Aerospace, LLC (Tetonsys) in California, of which Bob Twiggs, founder of CubeSat, is co-founder.

MORE ➜ digitaleng.news/de/?p=42869

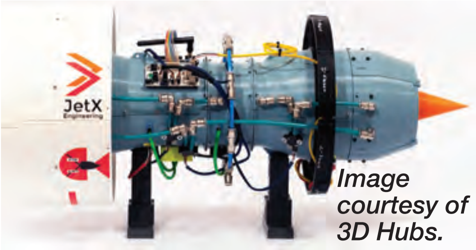


Image courtesy of 3D Hubs.

Rolls Royce and Students Create 3D Printed Jet Engine Model

BY GEORGE FISHER-WILSON

There's a shortage of engineering students and in STEM (science, technology, engineering and mathematics) subjects in general. A team of students is looking to fix this shortage by getting more potential engineers involved. 3D Hubs Student Grant finalist JetX represents a team of aerospace engineering students working with Rolls Royce to create the first functional 3D printed jet engine model. It will show that studying engineering doesn't mean you're glued to a textbook.

The project started in 2013 at the University of Glasgow when Chris Triantafyllou, the president and founder of JetX, spotted the need for more hands-on learning. He saw two important skills for future engineers to master but with no outlet to gain direct experience:

1. Design for assembly.
2. Simulation analysis.

MORE ➜ digitaleng.news/de/?p=42888

➜ For the full application stories, visit digitaleng.news/de/fastapps

AD INDEX

LS-DYNA® Advanced CFD Analysis

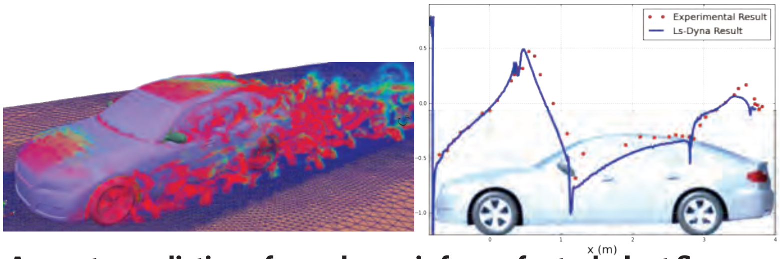
The LS-DYNA® Incompressible CFD (ICFD) tool combines state-of-the-art numerical techniques that allow robust, scalable, and accurate simulations of fluid flows. Its ability to couple with the structural, thermal, and Discrete Element Method solvers make it an excellent option for multi-physics problems.

Applications:

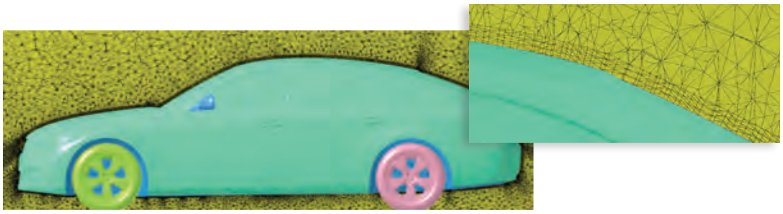
- Ground vehicle aerodynamics
- Cooling analysis
- Resin Transfer Molding for manufacturing of composites
- Turbomachinery
- Fluid-Structure interaction in the biomedical field

Features:

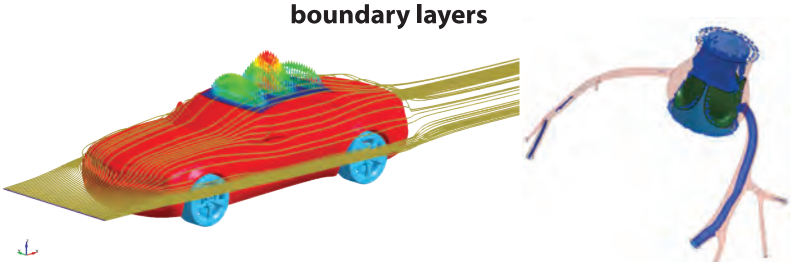
- FEM based
- Large library of RANS and LES turbulence models
- Automatic meshing and re-meshing
- Free surface flow
- Non-Newtonian flows
- Non-inertial reference frames
- Porous media models



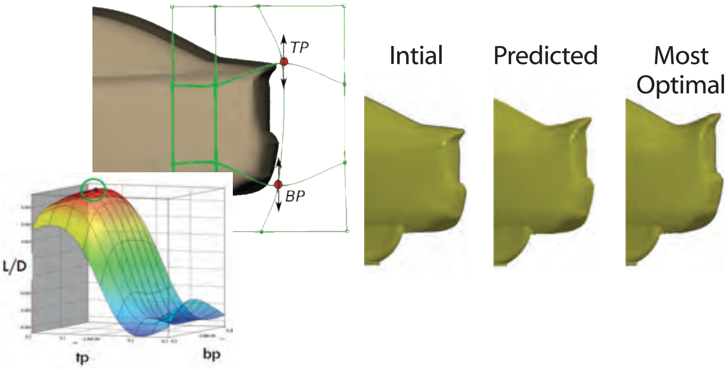
Accurate prediction of aerodynamic forces for turbulent flows



Fast mesh generation and automatic re-meshing with boundary layers



Fluid-Structure Interaction analysis for a large number of applications including automotive and bio-medical industries



Shape optimization using ANSA® and LS-Opt®

15th LS-DYNA®
International Conference & Users Meeting

June 10-12

www.ls-dynaconferences.com

For demo version, pricing, and learning version contact: sales@lstc.com

LSTC
Livermore Software Technology Corp.

www.lstc.com/applications/icfd

Youtube Channel: www.youtube.com/user/980LsDyna