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by Jamie J. Gooch

Hack Your New Year's Resolution

IT'S THAT TIME of year when we reflect on the past and look ahead to the future. On one hand, this makes sense: The calendar year ends and a new year begins. What better time to make resolutions? On the other hand, it seems a bit arbitrary to make important life and work goals based on a date chosen by the pope in 1582 to be the first day of the year.

Research has shown that New Year's Resolutions don't work for most people, but just barely. According to a 2002 study by John C. Norcross and his psychology colleagues at the University of Scranton, people who made resolutions were more likely to make progress toward achieving goals than those who didn't.

For six months, the study followed 159 resolvers and 123 people who wanted to solve a problem but didn't make a New Year's resolution. By July, only 4% of the control group had made progress toward their goals, while 44% of the resolvers had kept their resolutions. Of course, that means most (46%) resolvers had not, but that's a glass half empty perspective. The study indicates that making a resolution can help you progress toward a goal 10x more than not making one.

Start Small

With all of the big changes happening in design engineering and manufacturing today, you may be tempted to set your goals accordingly. Everything from the industrial Internet of Things, to 5G connectivity, to artificial intelligence to advanced simulation seem to be here or right around the corner and require new design knowledge and skills to keep pace.

These are big disruptions to be sure, but psychology tells us that starting small is a better way to address them. To achieve change requires creating new habits. Making grand resolutions that your habits can't support leads to failure. One hack is to fool ourselves into creating small, incremental changes that become habits and then eventually lead to bigger changes.

So, instead of resolving to finally implement a full product lifecycle management solution in 2019, maybe just make it a point to collaborate more with your colleagues, add more information to your models that will help people further along the digital thread, or better manage your data. Instead of resolving to go back to school to get another degree, maybe resolve to take a course in programming, finite element analysis or design for additive manufacturing. Small successes can lead to setting loftier goals, but the trick is to build on each success to get there, rather than trying to achieve too much too soon.

Another way to engineer yourself to keep your resolutions is to share your goals. Research shows that telling people about your goals can help you stick with them. Committing to something like professional training, where you tell your supervisor your intentions, or improving your standard operating procedure on model annotation and markup, where others will notice if you slip up, can help. Just like personal trainers are more effective than a gym membership alone, having someone hold you to your resolution, or at least be in your corner, can help you keep it.

Start Often

In the Norcross study, more than a third (36%) of resolvers had broken their New Year's resolutions by the end of January, and half had given up by March. So maybe one solution is to recognize more than one New Year. In England and Colonial America (who didn't want the Catholic Church telling them when to start the year) the official first day of the year was March 25 until 1752. So, if you find your resolve waning around March, just re-up your resolution on March 25, or on April Fool's Day if that helps remind you that it would be foolish to quit.

But seriously, if you're one of the majority of people who break resolutions, then operating on the idea of continual improvement—rather than a single resolution on an arbitrary date—could be the answer. Either way, it's important to track your progress. This has proven effective in calorie-counting apps, financial planning and general to-do lists. Just like in engineering, a successful outcome depends on data.

You can't track progress until you set the goal, and the New Year is as good a time as any to start. Whatever those goals are, we wish you a happy, and productive, New Year. **DE**

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TECHNOLOGY FOR OPTIMAL ENGINEERING DESIGN

INSIDE

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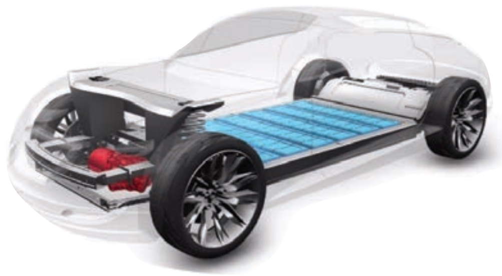

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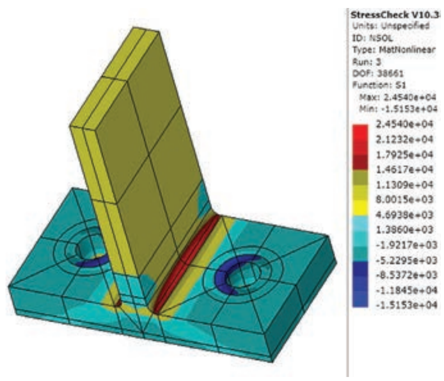

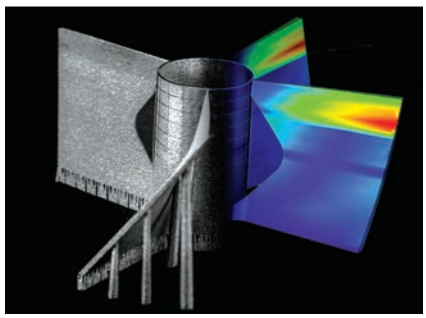

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Top 10 IoT Trends for 2019

1 Artificial Intelligence

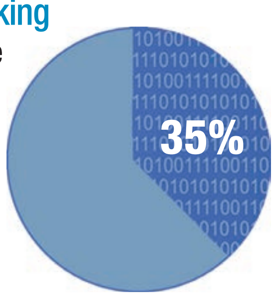
Gartner forecasts that **14.2 billion** connected things will be in use in 2019, and that the total will reach **25 billion** by 2021, producing an immense volume of data, to which A.I. will be applied.

2 Social, Legal and Ethical IoT

Ownership of data and the deductions made from it, algorithmic bias, privacy and compliance with regulations such as the General Data Protection Regulation will grow in importance as the IoT matures and becomes more widely deployed.

3 Infonomics and Data Broking

In 2017, **35%** of respondents were selling or planning to sell data collected by their products and services. By 2023, the buying and selling of IoT data will become an essential part of many IoT systems.



4 From Intelligent Edge to Intelligent Mesh

The neat set of layers associated with edge architecture will evolve to a more unstructured architecture comprising of a wide range of "things" and services connected in a dynamic mesh.

5 IoT Governance

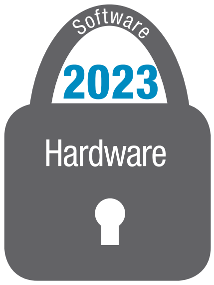
Governance ranges from simple technical tasks such as device audits and firmware updates to more complex issues such as the control of devices and the usage of the information they generate.

6 Sensor Innovation

New sensors will enable a wider range of situations and events to be detected, current sensors will fall in price to become more affordable or will be packaged in new ways to support new applications, and new algorithms will emerge to deduce more information from current sensor technologies.

7 Trusted Hardware and Operating Systems

By 2023, hardware and software combinations will be deployed that together create more trustworthy and secure IoT systems.



8 New IoT User Experiences

With an increasing number of interactions occurring with things that don't have screens and keyboards, organizations' UX designers will be required to use new technologies and adopt new perspectives.

9 Silicon Chip Innovation

By 2023, it's expected that new special-purpose chips will reduce the power consumption required to run a deep neural network (DNN), enabling new edge architectures and embedded DNN functions in low-power IoT endpoints. This will support new capabilities such as data analytics integrated with sensors and speech recognition included in low cost battery-powered devices.

10 New Wireless Networking Technologies for IoT

No single networking technology optimizes all IoT networking requirements. 5G, the forthcoming generation of low Earth orbit satellites, and backscatter networks will provide additional options.

— *"Top Strategic IoT Trends and Technologies Through 2023," Gartner, November 2018*

Automotive Automation

In terms of overall automation, while most industries have automated **20% to 30%** of their operations, the automotive industry has automated closer to **50%** of operations.

— "Smart Manufacturing in Automotive," ABI Research, Dec. 4, 2018

Big Data = Big Dough

$9.88 Billion

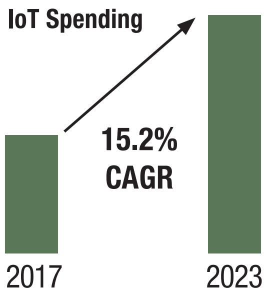
The global IoT security market size is expected to reach $9.88 billion by 2025, progressing at a compound annual growth rate (CAGR) of **29.7%** during the forecast period of 2018 to 2025.

— "Internet of Things (IoT) Security Market Analysis Report," Grand View Research, September 2018

$434.9 Billion

Companies will spend $434.9 billion to design, plan, build and run IoT solutions by 2023, up from $186.1 billion in 2017, at a **15.2%** CAGR.

— "Internet-Of-Things Spending Forecast, 2017 To 2023 (Global)," Forrester Research, Oct. 3, 2018



$197 Billion

The industrial IoT market size was valued at $115 billion in 2016, and is projected to reach $197 billion by 2023, growing at a CAGR of **7.5%** from 2017 to 2023.

— "Global Industrial Internet of Things (IIoT) Market by Component and Application," Allied Market Research, February 2018

$1.2 Trillion

IoT spending will experience a **13.6%** CAGR over the 2017-2022 forecast period and reach $1.2 trillion in 2022.

— "Worldwide Semiannual Internet of Things Spending Guide," IDC, June 18, 2018

AU 2018: Generative Design Meets Manufacturing

BY KENNETH WONG

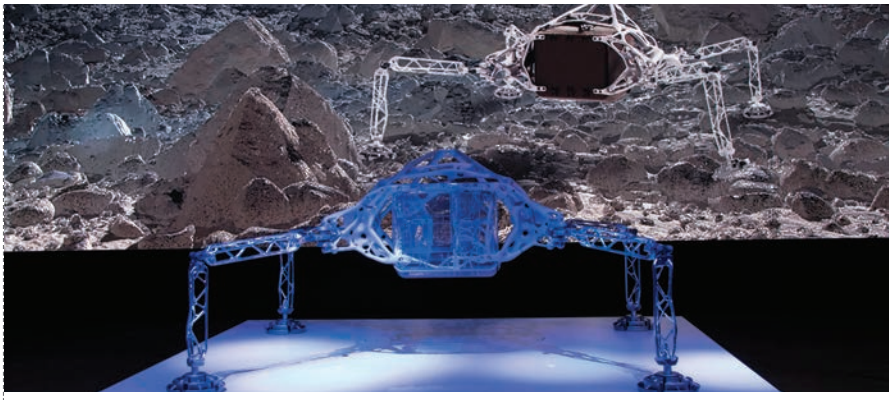
GENERATIVE DESIGN—AI-like software that can suggest the best geometry for a project—seems well on its way to reshape the design software sector. But where it is heading?

At its annual user conference Autodesk University (AU 2018, Las Vegas, Nevada, November 11-15) that attracted more than 11,000 attendees, design software giant Autodesk revealed the direction for its generative design implementation, as part of the cloud-straddling CAD-CAM-CAE software suite Autodesk Fusion 360.

During Day Two's keynote, Greg Fallon, VP of Design and Manufacturing Business Strategy, Autodesk, said, generative design "automates the ideation process, giving the user the ability to easily explore all valid geometric options for a given set of materials, manufacturing processes and operating conditions."

Adding manufacturing constraints as generative input means the software will consider, in addition to the assigned material properties and stress loads, the practical needs of certain manufacturing methods, such as milling or 3D printing.

This represents the general direction of generative design not just for Autodesk, but for the design and simulation software industry at large.



NASA JPL lunar lander concept, designed in Autodesk generative design software. *Image courtesy of Autodesk*.

Generative Design 2.0

In a blog post, Fallon describes the company's vision: "We see the convergence of design and manufacturing as the inevitable—and beneficial—future of making products. We see our customers embracing this evolution and, for our part, we're pushing to accelerate it."

One way that convergence is happening is in new manufacturing constraints added to Autodesk Fusion 360, a software suite covering design and simulation to manufacturing. Another way is via Autodesk Forge, an application development platform the company has opened to third-party developers, hoping to create an app economy centered around it.

In July, Autodesk hired Sam Ramji as VP of cloud platform. Ramji previously held the same title at Google.

"I want to turn Forge into a Manufacturing cloud," he said. "When people think of cloud for general use, they think of AWS. When they think of CRM or ERP cloud, they think of Salesforce. Just like that." **DE**

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Formnext 2018: AM Disruptions

BY RANDALL NEWTON

THE ADDITIVE manufacturing industry is built on the disruptive notion that digital processes can directly lead to physical products. At this year's Formnext conference (Frankfurt, Germany, Nov. 13-16) vendors and analysts emphasized how the latest innovations in printers and materials must be combined with workflow innovation.

The next stage of disruptive innovation must address both the processes of industrial production and the 3D printing industry itself, according to Dr. Wilderich Heising with Boston Consulting Group. By nature, so to speak, additive manufacturing technology is disruptive to both the technology of manufacturing and the supply chain. Heising says the industry has reached a point where "every player needs to redefine its strategy."

He envisions a shift among AM hardware vendors from optimization for quality to optimization for speed. The ability to "increase build rate by up to five times at the same quality" translates to

ParaMatters CogniCAD 2.0 is a generative design solution used to create lightweighted structures. ParaMatters is part of technology incubator XponentialWorks, led by former 3D Systems CEO Avi Reichental, which exhibited at Formnext 2018. *Image courtesy of ParaMatters.*

total reduction of machine cost per part by more than 50%. Heising says speed optimization will lead to the break-even point moving to higher volumes.

Open Market Materials

Heising sees new competitive pressure in AM is forming around materials.

"Established players, the machine makers, are using the razor blade business model," he says, in which the same vendor sells the machine and the consumables. More specialty players with new fit-for-purpose materials are coming, bringing with them an open market approach to materials that will lower costs. **DE**

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SIMULATION 101

By Donald Maloy

The Spectrum of FEA Analysis

AS YOU JOURNEY from the CAD world into simulation, you will quickly become familiar with an age-old saying. You don't know what you don't know. Depending on the software vendors of your choice, you will have a wide selection of analysis tools at your disposal. After attending training or learning at a self-pace, you may be asking which type of analysis you should perform. How do you know if your engineering problem requires a deeper dive into more advanced studies? There is no replacement for experience; however, developing a strategy on how you implement use of these tools will be instrumental to your success. Before considering strategy, let's explore the common swath of tools available inside the simulation toolbox.

Static Linear Analysis

Commonly referred to as static analysis, in most cases this is where you will hit the ground floor running for structural work. Static analysis operates under the principle that loads are applied slow enough to rule out the effects of dynamic behavior, the physical displacement of the problem being studied is relatively small, and the material applied is linear elastic. Materials that are linear elastic will return to their original shape with loads removed, and are operating in the linear range of the stress-strain curve. If any of these terms are new, check out your local library or used bookstore for a material science textbook that will explain physical properties of materials.

So why start with static? There are several reasons, but the most important ones are that it is less computationally demanding on the computer to establish the preprocessing phase of the analysis, as well as an initial assessment as to if any nonlinearities may exist given the initial loads and constraints applied. In short, it's easy to process a solution and get a rough estimate as to the scope and depth of the engineering problem.

Static Nonlinear Analysis

Tackling a static solution first, the results may indicate that a nonlinear analysis is required to more accurately depict the problem. With a solid understanding of the limitations of a static analysis, you may have identified concerns such as: geometric, material and boundary nonlinearities that exist, requiring further investigation. For example, if conducting a study where the part or assembly is made of steel operating in the plastic region of the stress-strain curve, and once the load is removed permanent deformation occurs—just like a paperclip being bent.

This topic could be an entire article on its own, but a nonlinear analysis will break down the solution into finite pseudo time steps to maintain a convergent path yielding a solution. Consider this in mathematical terms of solving for slope at a point on a curved line. Slope varies at every point, so we could create incremental time steps allowing us to describe the slope at every increment on the line. From careful observation, you can start concluding that every problem has some aspect of nonlinear behavior. The determination of whether it is substantial enough to make an impact on the results will come in time.

Modal Analysis

If your engineering problem requires analysis of whether your part or assembly will adversely react to specific harmonics, this will be your go to. Or maybe it's necessary to understand how an engine mount would handle vibrations coming from a motor? Commonly referred to as a frequency analysis, this tool will allow you to understand the dynamic behavior of rigid body modes, frequencies of these modes and mass participation factor where multiple bodies are present. Pay careful attention to the capabilities of this type of analysis, as they vary, vendor to vendor.

In wrapping up this month's conversation of the different types of tools available in FEA, it may be apparent that we left out a few of the simulation tools such as thermal dynamics and specialized analysis such as fatigue and topology optimization. Next month we will continue the conversation with how these other types of tools factor into the spectrum of FEA analysis. **DE**

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| MAKING SENSE OF SENSORS |

TACTILE SENSORS AND NERVE CIRCUITS

By Tom Kevan

Giving Machines the Sense of Touch

IN RECENT YEARS, design engineers have expended considerable time and resources to impart human-like senses into new products, with some notable successes. Natural language processing has helped develop intelligent virtual assistants that enable increasingly rich interaction between humans and machines. At the same time, computer vision has played an important role in bringing amazing applications to life, such as the autonomous car.

However, attempts to give devices the sense of touch have proven to be more elusive. Scientists and engineers have struggled to not only replicate our skin's ability to precisely detect tactile information—like smoothness, hardness and pain—but also to mimic its signaling and decision-making capacity.

Two new technologies point to a potential shift. These touch systems could well represent building blocks for designers to create products that interact with humans and their operating environment in an entirely new way.

A New Tactile Sensor

In the most recent development, researchers from Daegu Gyeongbuk Institute of Science and Technology, ASML Korea Co., Dongguk University-Seoul, Sungkyunkwan University and the University of Oxford have developed a tactile sensor that aims to measure surface textures with high accuracy.

The device consists of an array of piezoelectric receptors, which generate electrical responses proportional to applied stress, enabling it to identify surface characteristics of objects, such as width and pitch.

The sensor offers a number of features that differentiate it from similar existing sensors. For one, it mimics the way that humans sense surface characteristics, detecting tactile information by touch and sliding. Most competing technologies use only one of these methods.

In addition, the sensor's receptor array can calculate sliding speed, using data on the time interval between two receptor signals and their distance. Other devices use a single receptor and, as a result, require an external speedometer.

The researchers tested the sensor by pressing square, triangular and dome surface shapes against the sensor's surface. The scientists also placed soft material against the sensor to see if it could measure depth, raising the prospect of three-dimensional sensing. Although the test results were encouraging, the technology did fail to accurately distinguish between 3D shapes.

It's important to remember that the sensor is still in the early stages of development, yet the technology represents a step closer to giving robots, prosthetics and electronic devices the sense of touch. At some point in the future, this means that machines could "feel" sensations like roughness, smoothness and even pain, expanding the list of tasks and services that they could perform.

Artificial Nerves

In November 2017, researchers at Stanford University and Seoul National University announced the development of an artificial sensory nerve circuit that can be embedded in skin-like coverings for neuroprosthetic devices and soft robotics.

The circuit consists of a touch sensor that detects force and a flexible electronic neuron that relays signals to a synaptic transistor. The transistor is modeled after human synapses, and performs similar functions, such as relaying signals and storing information to make simple decisions. The developers have engineered the synaptic transistor to recognize and react to sensory inputs based on the intensity and frequency of low-power signals.

Tests evaluating the circuit indicate that the artificial nerve can detect various tactile sensations. It was able to differentiate Braille letters and accurately detect the direction of a cylinder rolled over the sensor.

Not Quite There Yet

Touch technology developers will tell you that these sensing systems are still in their infancy. The work of the two research teams discussed here, however, does represent a technological foundation upon which designers can build future touch-enabled systems.

To better impart the sense of touch in applications such as prosthetics and robotics, scientists still have challenges to overcome. To give devices access to a full range of tactile information, they will have to incorporate technologies that can detect hot and cold sensations. Serving these applications also calls for ways to embed the sensing technologies into flexible circuits and to interface them with the brain. DE

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RealWear lets you use voice control to operate its hands-free AR system. The company has a strategic agreement with Honeywell to cobrand and sell the RealWear AR systems. ***Image courtesy of RealWear.***

AR-VR: Beyond Joysticks and Touchscreens

Voice command, hand gesture, texture mimicry and other advances bring a greater touch of naturalism to AR-VR.

BY KENNETH WONG

HOW DO YOU INTERACT with 3D models of products that only exist as polygons and pixels? The current generation uses the mouse and the keyboard, a paradigm that's anything but natural.

The emergence of augmented reality (AR) and virtual reality (VR) systems represents an opportunity to redefine the human-pixel interaction, but early implementations wrestled with the less-than-ideal control systems. The joysticks and game-style controllers adopted by many AR-VR systems are well-designed for common game actions: a trigger-like button for shooting games, four directional buttons or a steering stick for game avatar movements or sturdy buttons to pound on during fight sequences. But they're poorly designed to duplicate the more delicate and complex actions involved in, say, manufacturing installation, engine disassembly or operating a tractor.

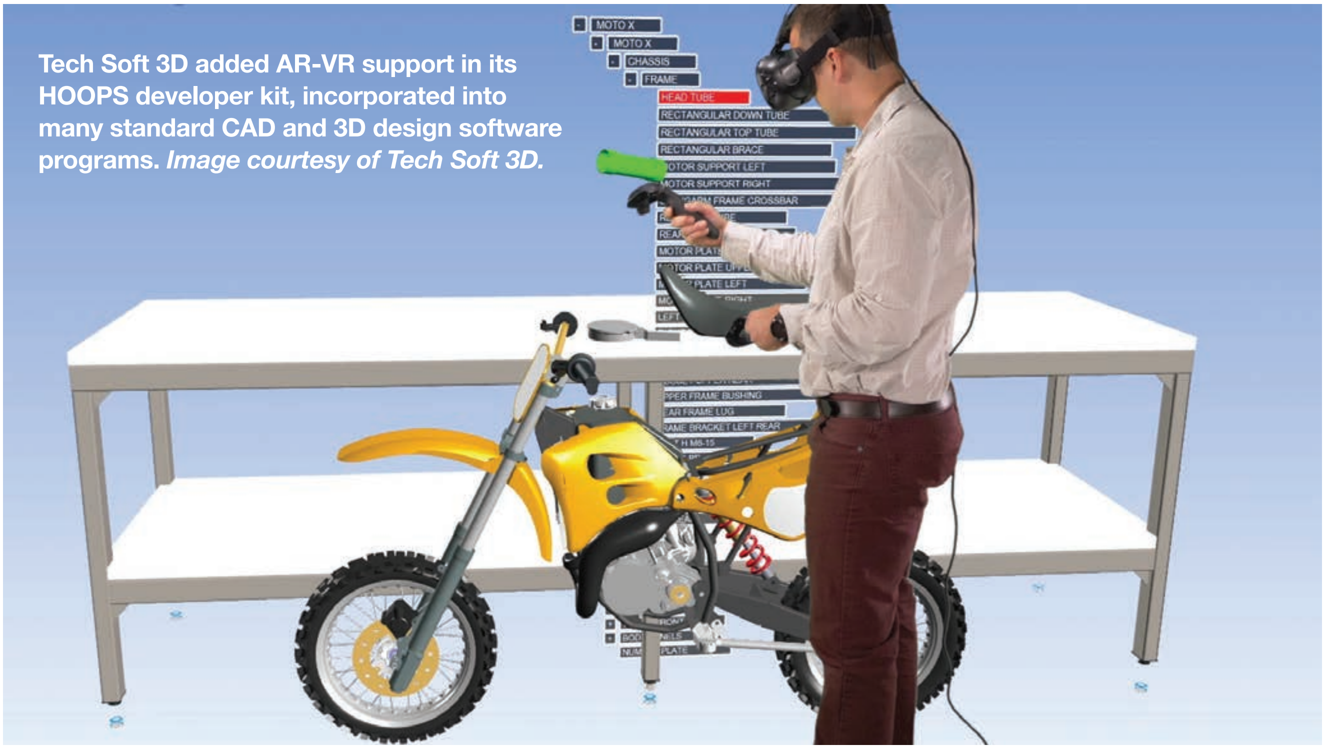
The new wave of AR-VR apps, however, comes much closer to mimicking the actions they depict, bringing the technology a few steps closer to real-world fieldwork, enterprise training and plant operations.

Is Your AR System a Good Listener?

In April 2018, Greenlight Insights, an analyst firm tracking the AR-VR market, published a report titled "XR in Enterprise Training," with "X" standing in for the unspecified variations of reality mimicry (mixed, virtual, augmented and extended reality).

"Industries as diverse as automotive manufacturing, consumer retail and healthcare delivery are using virtual and augmented reality technology to realize productivity gains and invent service models. Organizations that succeed in harnessing XR-enabled training will lead. Those that don't may be at a serious disadvantage," warns Greenlight Insights.

Last September, at the Virtual Reality Strategy (VRS) Conference hosted by Greenlight Insights, Tom Dollente, director of Product Management, RealWear, was on the panel that explores the use of AR for frontline workers. (*Editor's note: DE* Senior Editor Kenneth Wong moderated the panel.) RealWear's products—HMT-1 and HMT-1Z1—use a head-mounted camera and a small projector mounted before the right eye. Designed for hands-free use, it employs voice control for user input, command



Tech Soft 3D added AR-VR support in its HOOPS developer kit, incorporated into many standard CAD and 3D design software programs. *Image courtesy of Tech Soft 3D.*

and selection. Users may attach it to a hard helmet for deployment in construction sites and other hazardous zones.

"We learned a lot while working to perfect our voice-recognition algorithm," says Dollente. "We fine-tuned our system so it can detect the direction of the voice. If someone nearby happens to utter a command phrase (such as Home), the headset won't execute it. We also learned to use commands like 'Terminate,' which has distinct consonants, highly unlikely to be confused with other words, and is not a phrase someone might say frequently."

Such considerations are important, as the user will be wearing the RealWear system and going about their daily routines. Therefore, the system needs to be able to distinguish legitimate verbal commands from background noises, nearby conversations and the user's incidental conversations with coworkers.

At November's Autodesk University conference in Las Vegas, John SanGiovanni, CEO and cofounder of Visual Vocal, demonstrated the latest incarnation of his company's mobile VR app with voice memo feature.

"Suppose you're at a construction site, and you'd like to add a voice memo for your team, discussing the issue you have with the location of a certain door," he says. "You can launch the Visual Vocal app, then use our unique inking method to annotate and record your message."

Visual Vocal doesn't provide its own means to capture an immersive environment for playback; instead, the app works with content from other reality capture apps such as Google's Cardboard app (free; available for iOS and Android devices). The company uses Chirp, a partner technology, to link mobile devices to join the same VR collaboration session in real time, bypassing the need to email a link or transfer a file for shared viewing.

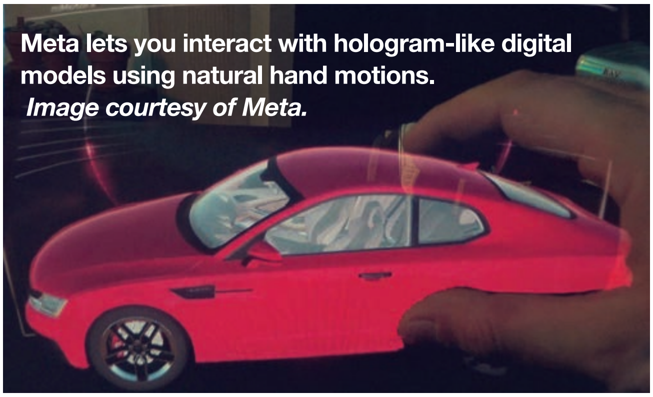
SanGiovanni refers to the cloud-hosted Visual Vocal annotations as VV, and the Visual Vocal-style multi-user collaboration sessions as Mind Merge (terms that he hopes will catch on). This approach allows users to embed floating, finger-drawn 3D markups, along with voice messages that can be played back by others you have chosen to work with. Visual Vocal's current promotional materials emphasize architecture, engineering and construction (AEC), but the app is adaptable to factory floor, manufacturing plants and other sites for the same purpose and workflow.

Jumping through HOOPS

In November, Tech Soft 3D, the firm responsible for the HOOPS 3D geometry visualization engine, announced that SolidWorks, AR-VR kit developer Meta and the VR firm Virtalis are among those using the AR-VR support features in HOOPS.

In early 2018, Tech Soft 3D revealed that the HOOPS Visualize 2018 software development toolkit would include "full 3D viewing for AR and VR applications (and) full support for Out of Core point clouds." SolidWorks is one of the early CAD programs to adopt AR in its free viewer eDrawings, allowing users to visualize how CAD models would look in the real world.

Meta is among the VR companies that let you interact with hologram-like digital objects using hand gestures. (For more, check out "Modeling for the Augmented Reality Age," August 2017, DE; digitalengineering247.com/r/16832) "Because we were re-inventing the future of AR, we needed a solution that would easily bring rich engineering and architectural data to our environment. This way we could focus on innovation and user experience," says Cecilia Abadie, director of Product Management at Meta. "HOOPS Exchange was just the toolkit we were looking for."



The Key is in Your Hand

An exhibitor at the VRS Conference, uSens, says the key to a more natural interaction in AR-VR is hand tracking. Accordingly, it uses computer vision to recognize and interpret hand gestures and movements that humans naturally use in communication (such as a raised thumb for a sign of approval) and object manipulation (for example, shaping clay with bare hands or striking nails with a hammer).

"We have two solutions for that. One uses your mobile phone's color camera and doesn't need any additional hardware," says Dr. Yue Fei, cofounder and CTO at uSens. "Another is our own hardware, called Fingo [a kit that includes stereo cameras]."

The human hand is a soft-tissue object that presents challenges for the computer to recognize. Therefore, uSens uses a technique where the system tracks the easily identifiable joints, which, in this case, are finger joints.

"Our algorithm acts like [an] X-ray; it can see through the skin and select the bone joints," says Fei.

Pure computer vision, as it turns out, is insufficient for hand tracking, especially in incidents where the angle of the hand obscures some of the fingers. By applying machine learning, uSens refines its algorithm to determine the theoretical positions of the joints, even when some of the fingers are invisible to the camera.

Feeling Surfaces

In the exhibit area of VRS, with a mix of actuator-equipped gloves and camera tracking, Miraisens Inc. demonstrated how its technology could introduce haptic feedback to the AR-VR experience. Miraisens' patented technology was developed in Japan by Norio Nakamura. Nakamura founded the company in 2014. He currently serves as chief technology officer.

The technology is designed to simulate sensations when users interact with digital objects. In a published technical paper, the company explains: "If the skin nerve is properly stimulated, the stimulation signal is sent to the brain and then generates haptics illusion [....] as a method of performing this stimulation, any kind of physical quantity such as vibration can be used."

Draw with Hand Waves

The rise of consumer and powerful professional tablets prompted many CAD developers to rethink how the sketching environment works inside their modeling programs, but now, a new challenge may be on the horizon: identifying the best way to sketch inside AR-VR environments.

Gravity Sketch says they have the answer. The company developed a drawing program that lets users draw using AR-VR controllers inside virtual 3D spaces. Using AR-VR controllers and touch technologies, Gravity Sketch lets users drag and pull on colored lines and curves to create sketches, surfaces and objects in a virtual space.

Color, brush size and brush style adjustments are facilitated via a floating virtual palette. The system offers IGES export to bring the design into CAD programs for further refinement and parametric design. The program currently works on the HTC Vive and Oculus headsets.

The Road Ahead

The demand for better human-pixel interaction has spawned many innovative, creative solutions that duplicate how people work in the real world, but limitations still remain. Voice command has gotten much better at coping with background noises, but when it comes to operating instructions (opening a file, extruding a model or adjusting the length of a line), few companies have managed to implement natural language support that mimics the way users can talk to iPhone's Siri or Amazon's Alexa.

AR-VR systems with hand-gesture recognition let users generate more natural actions, such as gripping a virtual steering wheel to navigate a car or lifting a digital object with their palm. But many lack proper haptic feedback. That means they can't feel the weight of the virtual engine they're learning to disassemble or the texture of a virtual car's interior. These may not be important for sales presentations, but in training applications that require building muscle memory and adjusting the forces and pressures based on feedback, they are indispensable. Overcoming these hurdles will lead to AR-VR becoming a much stronger rival to costly physical training facilities. 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 → **Greenlight Insights:** GreenLightInsights.com

→ **RealWear:** Realwear.com

→ **uSens:** uSens.com

→ **Visual Vocal:** VisualVocal.com

→ **Miraisens Inc.** Miraisens.com

→ **Gravity Sketch:** GravitySketch.com

→ **TechSoft:** TechSoft3D.com

→ **Meta:** Metavision.com

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Coming up ACES

Automated, connected, electric and shared (ACES) vehicles present new design challenges.

BY RANDALL S. NEWTON

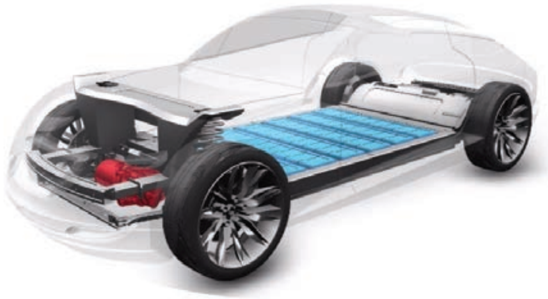
A FUTURE FILLED with electric vehicles has captured the attention of the public imagination and automotive engineers around the world. Vehicle design is entering a new era, with advancements in powertrain, electronics, software and materials, as well as all-new engineering required to add autonomy and connectivity.

The Center for Automotive Research (CAR) recently published the first in a planned series of white papers (cargroup.org/wp-content/uploads/2018/07/Impact-of-ACES.pdf) on the implications of automated, connected, electric and shared vehicles. The initial "Impact of Automated, Connected, Electric, and Shared (ACES) Vehicles on Design, Materials, Manufacturing, and Business Models" paper focuses on passenger vehicles.

The Society of Automotive Engineers (SAE) has defined five driving automation levels. Each requires specific research in multiple fields. The five levels are listed below.

CAR defines ACES vehicles as: automated vehicles with SAE Level 4 or Level 5 capabilities; connectivity capabilities for vehicle-to-everything (V2X) communication, over-the-air (OTA) updates and in-vehicles customer services; battery-electric vehicles, including gas/electric hybrids; and shared vehicles that are managed by service providers that offer short-term on-demand access to vehicles that could be driven by the customer, a third party or by a computer.

CAR interviewed experts at six of the top 10 automotive manufacturers, 12 Tier-1 suppliers and one "new mobility" company, Ridecell. All were asked to share their opinions on the potential impact of ACES on durability, safety, lightweighting, recyclability, manufacturing, business models and cost of ownership. They also organized a workshop for materials and manufacturing experts.



Future vehicle design needs to rethink most existing notions regarding the form and function of transportation. The space given to motors and powertrains is only the most obvious of many concepts challenged by new electric vehicles. *Image courtesy of Dassault Systèmes.*

Market Expectations

The study includes predictions regarding market size and product types between now and 2030. Battery electric vehicles (BEVs) are expected to be less than 30% of the global market. China and Europe will be the top markets, driven by expected regulatory requirements. Energy prices are expected to be the primary driver of lower adoption of BEVs in North America.

The study says the most aggressive estimates for Level 4 or Level 5 autonomy have the first vehicles deployed in 2020, but the majority of experts think 2030 is a more realistic expectation. The first deployments are expected to be for shared fleets, not personal ownership. All adoption estimates consider fleet turnover, which has been rising in recent years.

The Shape of Cars to Come

Although all phases of automotive engineering affect ACES development, body

1	2	3	4	5
Driver Assistance	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
The vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	The vehicle has combined automation functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	The driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

The five driving automation levels, according to the Society of Automotive Engineers.

design will attract the most attention. Function and aesthetics will be the two main body design drivers. An automobile designed for urban shared use may look like a rolling shopping cart while long-haul vehicles will probably be spacious, styled for highway-speed aerodynamics, and filled with comfort and connectivity features. Some experts believe external aesthetics will be a secondary design issue for shared vehicles: "People in general don't value the aesthetics of things they do not own," the CAR report states.

The CAR report expects powertrain components to become a commodity. "Unique brand identity could shift from powertrain performance to other components," the report notes. "Fewer opportunities for differentiation exist in an electric powertrain." Manufacturers would be better served by sharing powertrain technology and investing more in interiors, software and services, and style. "Only the control unit and software will remain a core competency of the automakers," the report explains.

Batteries provide an opportunity for structural design differentiation. Tesla talks about its "frunk," or second trunk in the front, replacing the combustion engine. Batteries are cells that can be stacked and arranged much like Lego bricks, and can be used for stability and crash protection. Battery thermal hazards will require new materials and new structural design considerations.

The most complicated new research and engineering will be in materials, the report says. First-generation ACES vehicles will likely use materials that are common today, but increased use of fatigue research and lightweighting from aeronautics will drive second-generation designs. "Aerospace fatigue standards could serve as a starting point for future automotive durability standards," according to the report. Materials research will also need to solve for protecting the wide variety of sensors (LiDAR, radar and vision/aural systems) that ACES vehicles require. "Even routine activities such as car washing can pose a threat to sensors," according to CAR.

Lightweighting will require new thinking, the study claims. Despite the use of lighter parts, automobiles have not been getting lighter in recent years. Some models are increasing in weight. Much of the increase is due to demand for comfort and entertainment features.

Serving with Software

Engineering software vendors are well aware of the CAR report and the new demands facing the automotive industry. "Twenty years ago, a model had six years to test, verify and validate," notes Michael Lalande, North America director of the Transportation Mobility Industry Group at Dassault Systèmes. "Twenty years ago a vehicle had a (bill of materials) that was 80% mechanical, 10% electronics and maybe 10% software. Today, autonomy requires a BOM that is 40% mechanical, 40% electronics and 20% software." Such a major shift in the bill of materials brings "completely different challenges," Lalande adds.

With so many new challenges, where does the engineering team begin? Lalande says start with the batteries. The industry has years of experience with batteries for hybrid vehicles; "now the trend is for full battery," he notes.

Dassault has software for analysis, simulation, verification and validation of battery chemistry, packaging and placement. A "systems of systems" approach, Lalande notes, is required to include such elements as winter vs. summer impact on battery performance, weight and performance, Restriction of Hazardous Substances (RoHS) issues, and managing content, from cradle to grave.

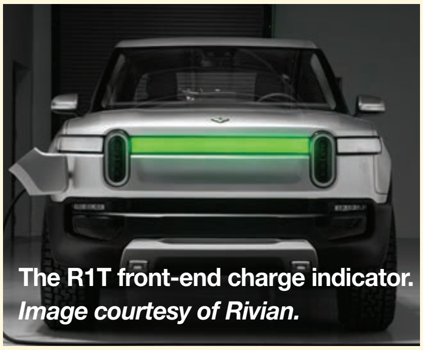
Internally, preparing for ACES engineering required Dassault Systèmes to re-evaluate its product line with the "buy or build" metric. The recent acquisitions of Exa Corporation (computational fluid dynamics) and No Magic (software systems development) occurred in preparation for ACES engineering.

Siemens PLM Software has also built up its CAE portfolio with the ACES revolution in mind. The Fibersim and Simcenter software portfolios have been assembled from a combination of existing Siemens PLM Software CAE products and acquisitions including CD-adapco and Mentor Graphics. "ACES has been a nice driver to speed the integration" of recent acquisitions, notes Dave Lauzun, VP of Automotive and Transportation Strategy at Siemens PLM Software. "(ACES vehicles) need tight integration between mechanical and electric design."

Lauzun says Siemens PLM Software is seeing companies take a two-prong strategy to automotive design, present

Electric Adventure

ELECTRIC vehicle maker Rivian was founded in 2009, but made waves when it introduced its R1T pickup and R1S SUV at the 2018 LA Auto Show in November.



The R1T front-end charge indicator. *Image courtesy of Rivian.*

The foundation of the R1T and R1S is Rivian's skateboard platform, which packages the battery pack, drive units, suspension, braking and thermal system below the height of the wheel. Three battery sizes are planned: 180 kWh, 105 kWh and 135 kWh. The truck features a range of up to 400+ miles, according to the company, which adds that about 200 miles of range can be added in 30 minutes of charging.

Built for on- and off-road driving, Rivian's vehicles feature a quad-motor system that is said to deliver 147kW with precise torque control to each wheel.

The company expects to begin delivering the R1T pickup and the R1S SUV to customers in 2020.

and future. "While developing a Level 4 fleet, companies still must pump out hundreds of thousands of profitable cars, trucks and SUVs," he says.

New Design Tools Put to Use

Such a split strategy provides the opportunity for companies to explore new software tools without disrupting existing workflows. Lauzun says Siemens has invested significantly in generative design technology, which uses a combination of brute force calculation and artificial intelligence to rapidly examine design alternatives.

"Use the laws of physics and forces of nature," Lauzun says when describing generative design. Lauzun sees generative design as particularly useful for designing new hybrid systems architectures, electrical architecture and wiring harness systems.

Significant engineering will also be required for the new manufacturing systems needed to produce ACES vehicles. "The wide range of materials and joining is a big deal," notes Lauzun. "Much more than spot welds with robots will be required." New materials and designs will require specific joining methods, while constant customizations may require a new generation of automated guided vehicles in the factory to deliver materials and tools, summoned not by a person but by the workflow software managing the assembly line.

A third line of investment for Siemens PLM Software to prepare for ACES engineering is new tools for noise, vibration and harshness (NVH) analysis. "NVH for ACES (vehicles) creates challenges from start to finish in an automotive facility," Lauzun says. "We continue to acquire companies to help address these needs."

Another company merging existing and acquired software tools to support ACES engineering is Altair. The company has customers using its FEKO and OptiStruct simulation tools to drive the design of radar integration into ACES vehicles.

"Customers are using HyperWorks to drive ADAS (advanced driver-assistance systems) and autonomous sensor designs with simulation," says Anthony Norton, VP of Americas, technical operations for Altair. "Not just for detailed antenna and radome design with Altair FEKO, but additionally multiphysics explorations and EM-mechanical simulation with other Altair solvers, for sensor integration and protection." **DE**

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INFO ➜ **Altair:** Altair.com

➜ **Dassault Systèmes:** 3DS.com

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

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Award Honors Automotive Lightweighting Innovators

Altair and the Center for Automotive Research (CAR) announced the winners of the 6th annual Altair Enlighten Award at the 2018 CAR Management Briefing Seminars (MBS) in Traverse City, MI. The Altair Enlighten Award honors achievements in vehicle weight savings each year. The awards are judged by an independent panel of automotive industry experts, academia and the engineering media who selected six winners from a field of 57 finalists this year.

The winner in the Full Vehicle category was General Motors' 2019 Chevrolet Silverado, which weighed in 450 pounds lighter than its predecessor.

BMW Group claimed the Module category with the first 3D printed metal component used in a production series vehicle, which captured a 44% component weight savings on the 2018 BMW i8 Roadster.

Asahi Kasei Corporation's Super Lightweight Pedal Bracket for the Mazda MX-5, Sika Automotive's Ultra Lightweight Constrained Layer Material System, and United States Steel Corporation's Martensitic Advanced High Strength Steel, Mart-Ten 1500, took the top honors in the Enabling Technology category.

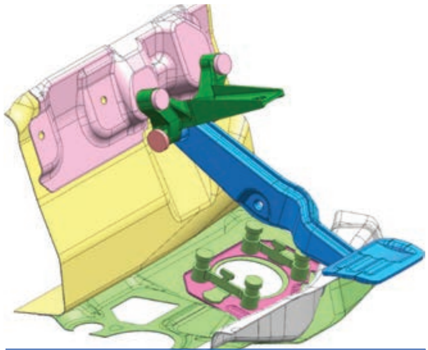
The award for the new Future of Lightweighting category, chosen by MBS attendees, went to American Axle & Manufacturing, Inc. (AAM) for its Quantum Driveline Architecture program.

"It was impressive to see the high quality of this year's Altair Enlighten Award applications. Nominations from OEMs, suppliers, materials technology companies, start-ups and academia demonstrate the tremendous and varied weight reduction effort being achieved across the global automotive industry," said judging chair Carla Bailo, president and CEO of CAR, via a press release. "Our judging panel had a very difficult task selecting this year's award winners among so many high quality entries," said Richard Yen, senior vice president of Global Automotive and Industry Verticals at Altair, via the release. "I would like to personally congratulate our award winners and thank all of our finalists and applicants for participating. It's a rewarding experience each year to witness how simulation-driven design strategies, new materials and advanced manufacturing processes are advancing automotive lightweighting by offering new opportunities to innovate weight efficient products from the start." DE

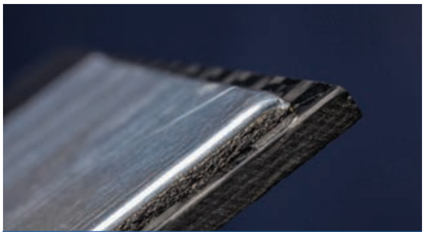
General Motors 2019 Chevrolet Silverado.

AAM Quantum Driveline Architecture.

BMW metal 3D printed convertible roof bracket.



Asahi Kasei and Mazda lightweight brake pedal bracket. *Images courtesy of Altair.*



Sika Automotive ultra lightweight constrained layer material system.

U.S. Steel Corporation Martensitic Advanced High Strength Steel (Mart-Ten 1500).

INFO → **Altair:** Altair.com

→ **Center for Automotive Research (CAR):** CARgroup.org

Meshless FEA Opportunities

Is there a future for meshless methods in mainstream analysis?

BY TONY ABBEY

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

Mainstream finite element analysis (FEA) has a long tradition of using a discrete element-based approach. The elements define the structural domain, and their combined behavior describes the response.

A range of methods described as "meshless" is emerging. This is a paradigm shift for the traditional analyst, and there is much resistance. However, for those new to FEA, or those who feel bogged down with meshing, it may be a significant breakthrough.

Let's look at what is meant by a meshless approach because a variety of methods carry that label. Is there a future for these methods in mainstream analysis?

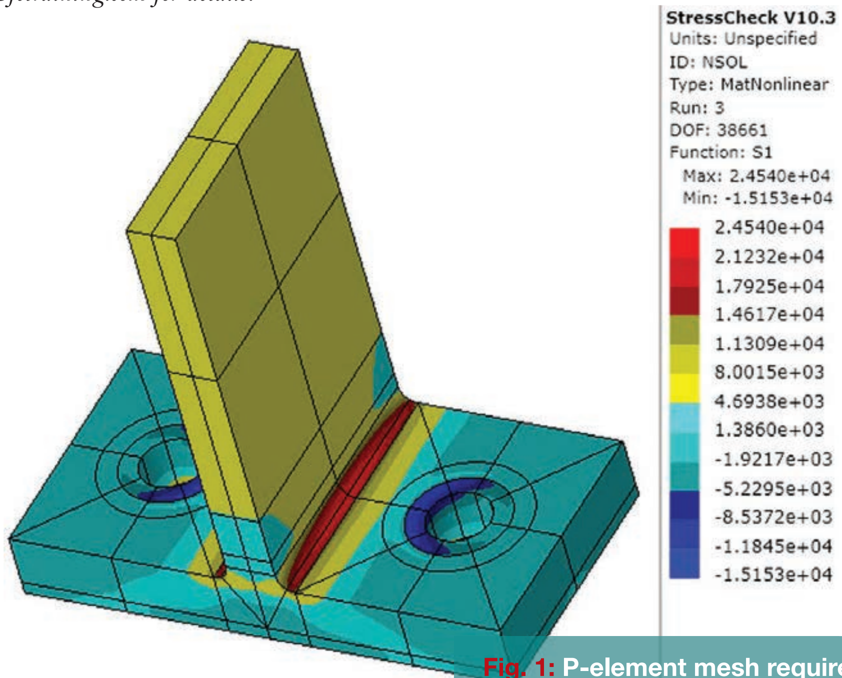


Fig. 1: P-element mesh required in ESRD StressCheck. ***Images courtesy of Tony Abbey.***

My Starting Point

I have been using traditional FEA methods since I started at British Aircraft Corporation (BAC) in Warton, Lancashire, England, in 1976. Then, FEA was new and restricted to large companies like BAC who could afford the expensive mainframe computers and software licenses. Some of my stress office colleagues seriously doubted the validity of FEA. Fortunately, FEA was considered a key technology by BAC, and they developed many pioneering techniques.

Since then, adoption of the method has been steady across many industries by a wide range of engineers and designers. It has taken a lot of development to reach the stage where, if used carefully, a reasonable structural analysis can be done.

Early element technologies and methodologies were sometimes found to be incorrect and engineers adopted more robust and reliable solutions. The NAFEMS organization, who partnered with *DE* to run the Conference on Advancing Analysis and Simulation in Engineering (CAASE) last year, played a key role in developing benchmarks to form a foundation for the FEA verification used by a range of software vendors.

Above, I included a caveat on careful use. Two essentials affecting meshing are:

1. Demonstrating a converged answer for stresses at key points within the FEA mesh. I have written about this in *DE* articles (January 2013, February 2014 and May 2017). It is one of the cornerstones of my Introduction to FEA training classes.

2. Checking element quality. I have written about this in several *DE* articles as well (see *DE* January 2014).

Traditional FEA relies on solving a complete component by breaking it down into simpler regions (i.e., elements). The displacement response of these elements is defined via internal shape functions. The shape functions are controlled by the nodal displacement responses at each degree of freedom (DOF) at the node.

The search for an overall solution for displacement throughout the component is a search for a minimum energy state. However, the strain, and hence stress, are not continuous across the component, so we can get the well-known stress "jumps" between adjacent elements. By using convergence and good shaped elements as goals, we can improve the stress response.

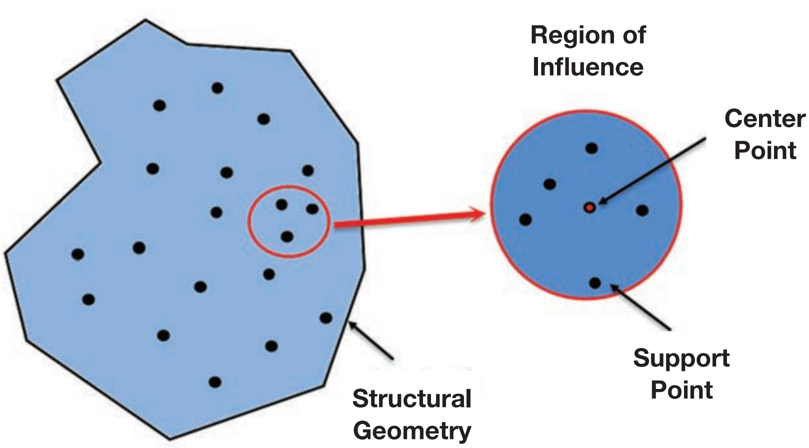


Fig. 2: Influence region within a structural domain.

The Need for Change

Now that the background and skill set of new users to FEA is much broader, the range of accessible FEA solution types is also larger. An increasing segment of users want FEA that is straightforward to use. The techniques that traditional FEA demand, particularly with respect to meshing, represent a steep learning curve.

I feel every sympathy for a designer using a CAD-embedded FEA program who wants to assess the approximate strength of a design as early as possible. In the broader context of loads, boundary conditions and modeling techniques, there really are no shortcuts. But the meshing burden is something that we have all inherited, and every analyst would be happy for it to quietly go away. An FEA mesh is just a means to an end. It shouldn't dominate the FEA process. However, sloppy meshing can give bad results, and high-quality meshing usually requires skill and experience.

Can meshless technologies ease that burden and still give acceptable results?

The term "meshless technology" can be confusing. Within this broad definition, some technologies truly do away with conventional FEA elements, some use adaptive FEA elements and some use conventional FEA elements behind the scenes. A purist would argue that doing away with conventional elements is the true definition of meshless analysis, but I think it is more useful to think of meshless technology as delivering results where the accuracy level can be quantified, and the meshing burden is removed. I have used that approach in this article.

P-element Methods

One technology that has been around for quite a while is the use of adaptive p-elements. Each element can develop its own required order (p value) of internal shape function. A single element can handle steep stress gradients. This contrasts with the more traditional h-element method, which requires an increasing number of elements to handle areas of steep stress gradient. This is the mesh convergence approach I described earlier.

In the May 2018 edition of *DE*, I reviewed CAE Handbook from ESRD, which uses the StressCheck solver. It provides automatic stress convergence by running a series of analyses. The p value of the elements adapts until a target convergence criterion is met. The convergence history is plotted by default. Fig. 1 shows the mesh required in the bracket example I ran in the review.

The mesh requirement in Fig. 1 is clearly a lot simpler then a traditional h-element FEA mesh. This mesh has been prepared by ESRD experts and is a templated example from their Handbook library. This represents the best scenario for a casual FEA user. The focus is on the engineering, rather than the meshing.

The aircraft industry is an example where this fits well: A wide range of standardized brackets and fittings are used, which can be templated for subsequent analysis by less skilled users. However, meshing an arbitrary geometry still needs some experience and care to get good answers. For those with that experience, the reduction in the meshing burden is attractive. Though this creates a paradox for CAD-based designers who do not have a strong FEA background: The template approach gives a well-controlled environment, but what happens if a radically new design is required?

This means there are two types of users, those checking strength of the component to a formal requirement and those wanting to get a feel for the strength of the component as the design is evolving. The rest of the article really focuses more on the latter area.

Designer-Oriented Technology

I wrote a previous *DE* article on preparing analysis for redesign (November 2017). I used an electronics chassis, and assessed it for preliminary strength and stiffness, subject to many design changes associated with electronics and cooling equipment positioning.

The CAD geometry can be meshed directly with solid elements. It can be made to optimize the mesh and be able to handle the loads and boundary conditions. Redesign requires remeshing, and this becomes a significant and unwanted burden.

Idealization can also be used to create a shell and beam mesh model. The motivation is that many potential design changes can be analyzed by varying wall thicknesses and beam dimensions directly. The downside is that 2D and 1D idealization is not a straightforward process within a CAD environment and some skill and experience is required.

One objective of meshless technology is to overcome these issues by allowing a tighter integration between new design concepts and their structural response assessment. The latter could be strength, stiffness or fatigue life, etc. In preparing for the article, I did background theory research. I also talked to two FEA software companies who have introduced products to address the design dilemma by using meshless technology. They present an interesting comparison in approach. As ever, my stance is completely neutral, and I very much thank the product managers and developers who have assisted me.

Element Free Galerkin Method

One approach to meshless technology is to move completely away from the normal FEA discretization. As a reminder, the FEA approach divides the geometry into the familiar elements, and then defines the displacement response within each element via shape functions. In the Element Free Galerkin (EFG) method, the geometry space is instead filled with points, which are initially randomly distributed. Each point, in turn, becomes the center of a local region of influence. Other points are found within the region of influence, and they define the basis for a set of shape functions to be created on the fly. Fig. 2 shows a simple schematic of this.

The geometry is filled with regions of influence, in some variations a simple mesh is used to map the points and for post-processing. The regions can overlap, and they can also be discontinuous, for example, to represent a crack in fracture mechanics. The overall structural energy minimization equation is created by assembling these general regions of influence. A Galerkin energy minimization is used, hence the name of the method.

The internal displacement field is the unknown to be solved, as in traditional FEA. However, the boundary conditions—zero displacements at boundary nodes—are imposed on the problem via a penalty solution. In traditional FEA these are set as a hard zero; with the EFG method, they will initially not be zero. There will be a series of solutions that iterate toward a condition where boundary displacements approach zero, and corresponding reaction forces converge.

Demonstrating reaction convergence also demonstrates convergence of the method. It is possible to map a continuous strain field throughout the structural region, which then gives rise to a corresponding continuous stress field. This is a simplistic description of the process.

For a designer, the attraction is that there is no requirement to prepare mesh for the geometry. There are wider potential advantages for the method. These include lack of element mesh bias on responses, the ability to withstand high structural distortion without corresponding element distortion, and splitting or deletion of arbitrarily regions corresponding to crack growth or damage areas.

There are a range of meshless techniques similar to the EFG method. The field is expanding and there is much literature—try researching it, but beware that the math quickly gets overwhelming!

SIMSOLID

I talked to cofounders Ken Welch and Victor Apanovitch at SIMSOLID (now acquired by Altair) and was given a demonstration of the SIMSOLID product. With it, users can analyze very large assemblies in real time. Design changes were created with the coupled Onshape CAD tool and re-analyzed with the same fast turnaround. Exploring the strength, stiffness and load path implications of an evolving design becomes intuitive.

This product has a true meshless approach, generally along the lines I've described, although the exact technology is proprietary and not necessarily the EFG method. The SIMSOLID DOF are described on their website as being functionals with geometrical support in the form of volumes areas, line clouds and point clouds. The solution is always an adaptive one. More sophisticated and denser distributions of DOFs are generated at each iteration, based on the stress distribution evaluated. Overall convergence is demonstrated by converged reaction forces.

The geometry is internally interrogated and classified. For example, a distinction is made between potato-like geometry and thin, shell-like regions or components. This controls the distribution of DOF within each of these regions. I was particularly interested in the thin shell geometry representation. This is one of the most difficult idealization and meshing areas in traditional CAD-embedded FEA, where dedicated thin shell elements are used.

SIMSOLID maps the original geometry in a 3D sense and there is no conversion to a 2D idealization. Their verification documentation contains a benchmark called the Raasch hook, shown in Fig. 3.

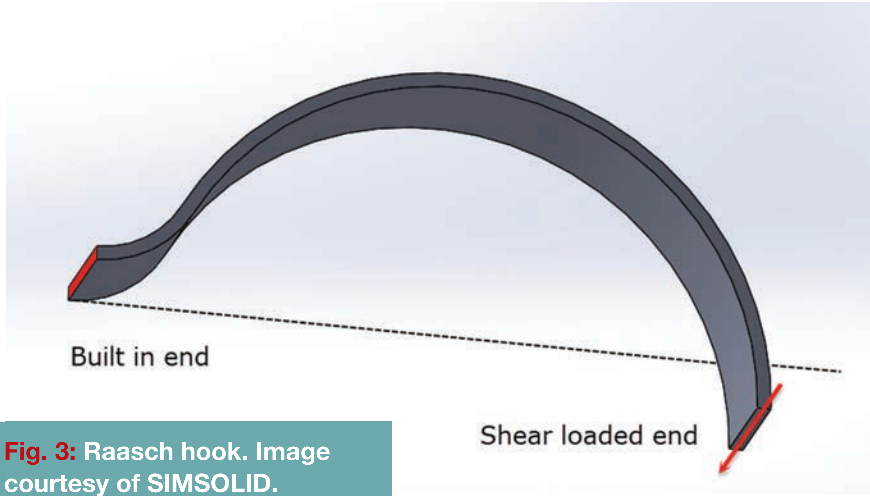


Fig. 3: Raasch hook. Image courtesy of SIMSOLID.

This consists of a strip that is bent into an "S" shape. It is fixed at one end and loaded vertically at the other end. This generates a complex distribution of axial, bending and torsional stresses. When first introduced, many existing thin shell elements gave poor deflection and stress results. As a result, FEA shell element technology improved. That SIMSOLID can handle this configuration is reassuring.

Welch and Apanovitch emphasized that SIMSOLID is aimed at design community users who want fast answers to configuration changes, both within a part and within the overall assembly. The objective is not to achieve high levels of stress accuracy, as this would require a formal stress check. The user is encouraged to think of design and analysis of complete assemblies, rather than individual parts. Meshless technology enables this in three key areas:

1. the meshing burden is removed;
2. meshless technology enables very fast analysis; and
3. the geometry classification includes automatic contact region detection, and can intelligently define bolts, seam welds and other components on the fly.

One interesting aspect is the emphasis on the reaction forces to ground and within parts, due to contact. A free body diagram of each part is always available—great for load path assessment and potential global local modeling. The concept design can be migrated into Altair's FEA products for a full assessment.

I am planning to do a full walk-through of SIMSOLID in a future article. I have not done it justice in this brief description.

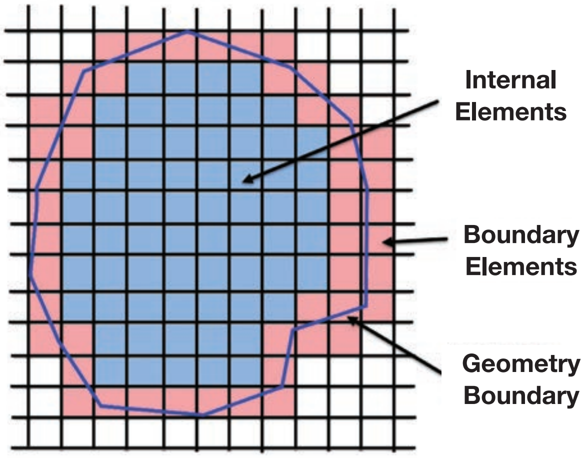


Fig. 4: The principle of volumetric meshing.

Volumetric Meshing

Volumetric meshing is based on the principle of having a very regular mesh in the interior of a geometric region and then concentrating on adapting the mesh around the boundary surface. A schematic of the idea is shown in Fig. 4.

The technique is used heavily in the computational fluid dynamics (CFD) world, where there are a tremendous number of variations on the technique.

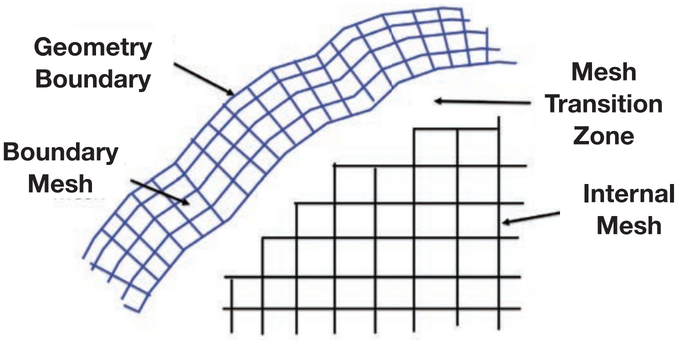


Fig. 5: Schematic of the element skinning method.

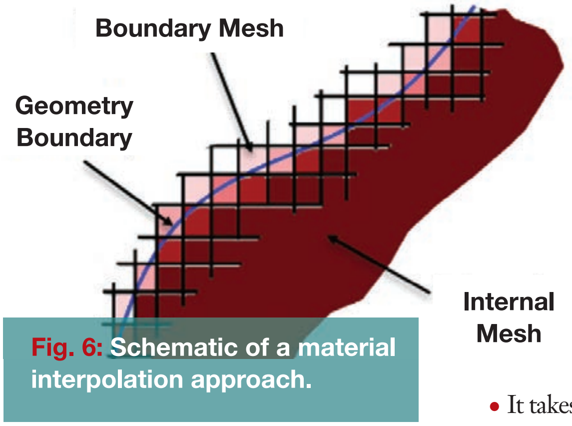


Fig. 6: Schematic of a material interpolation approach.

Because the interior mesh is not controlled by the boundary, it can be optimized for meshing speed and efficiency. The element count stays relatively low, giving big performance advantages. The boundary elements are then refined or adapted in some way.

One method remeshes the boundary region locally, giving a conforming faceted surface. An alternative is to produce a skin of high quality elements that then transitions to a regular mesh. Fig. 5 shows a schematic of this method.

Another approach is to interpret the edge mesh region as a functional fit. This is analogous to topology optimization where the moving material boundary is defined by a smoothed material density and stiffness gradient through the fixed mesh. The stress distribution is interpolated through this "virtual" region. Fig. 6 shows a schematic of this type of method.

In Fig. 6, the density varies from the full parent material in the interior shown in the dark color, through to external boundary, indicated by the lighter colors. The method provides an approximation of the stresses at the boundary smoothed through a fixed mesh.

As with the true meshless methods, there are many variations on this theme. Additions not covered include polyhedral meshing, which can fit elements of adapting high-order geometric shapes to the external boundary and to the interior.

ANSYS Discovery Live

I also talked to Justin Hendrickson, product manager for ANSYS Discovery Live. The product uses meshless technology and is aimed at users exploring conceptual designs. The approach used in Discovery Live is volumetric meshing. As before, this is proprietary technology and goes beyond the simple descriptions I have given.

Justin emphasized the roadblocks that traditional FEA presents within the design community:

- It is tough to set up an FEA model, particularly in terms of the methodology and meshing.
- It takes too long to get results, both in terms of preparation and analysis time.
- It is difficult to have a flexible approach to design.
- It is difficult to get the design assessment earlier in the workflow.

Hendrickson gave me a demonstration of the product. With ANSYS Discovery Live, the geometry environment is provided by ANSYS SpaceClaim. The other key technology, in addition to meshless FEA, is the use of NVIDIA graphical processing units (GPU) to provide very fast analysis time for models with very large numbers of elements (a typical model used in the demonstration had 15 million elements). The result of this is that analysis is continuously available, and any design change is automatically reflected in a new analysis. One loses the concept of an analysis "run," and it is more of a continuous flow of updated stress and displacement results. This becomes a very immersive experience and provides immediate and intuitive feedback on design changes.

The user can control the fidelity of the underlying mesh. At the coarse setting, the model is giving a representation of the load path, but local surface details are approximate. Increasing the setting improves the geometry fit, the number of elements and the accuracy of the result. The surface fitting technique, typical of the volumetric modeling approach, is evident. Early layout work can use the coarse setting and then as details are refined, the fine setting. Hendrickson estimated that with this setting, an accuracy of 10%–20% would be a typical target. This is enough to get the design moving along the right lines.

There is then a migration path for users to put a design into the ANSYS traditional FEA tools for formal checkout.

Other physics are also available within this environment, including CFD and thermal analysis. These are also immediate interactions.

I plan to write a more complete article on ANSYS Discovery Live. Again, I have done the product scant justice with this quick overview, within the context of meshless FEA.

Something for Everyone

This article covers three approaches to meshless FEA. The p-element method, as embodied by ESRD StressCheck, simplifies the meshing task and provides fast analysis. This is a great approach for analysts. For designers, the templating approach using the CAE Handbook is attractive if working within known design variations.

On the other hand, for working up concept designs, the SIMSOLID and ANSYS Discovery Live products both provide intuitive environments that will allow designers to assess preliminary strength, stiffness and other responses. The "acceptable results" label is limited to this level. Both products target this arena and both teams emphasized that formal FEA can follow later, if required.

This emphasis on the level of accuracy, and subsequent product positioning, should reassure many traditional analysts. However, I look forward to the technology maturing in a similar way to traditional FEA with increasing accuracy and applicability. Then perhaps my meshing nightmares will be over! **DE**

Tony Abbey *is a consultant analyst with his own company, FETraining. He also works as training manager for NAFEMS, responsible for developing and implementing training.ses, including a wide range of e-learning classes. Send e-mail about this article to de-editors@digitaleng.news.*

INFO → **ANSYS:** ANSYS.com

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IronCAD 2019: 20 Years of Innovation

A pioneering program gets a host of improvements.

BY DAVID COHN

IronCAD has an interesting history. The software made its debut in 1995 when a company named 3D/EYE introduced TriSpectives. Several years later, Visionary Design Systems added mechanical capabilities to TriSpectives and released IronCAD 1.0. In 2000, IronCAD became part of Alventive, but before that year ended, Alventive spun off the IronCAD software business, forming a new company named IronCAD LLC, which is now owned by the Chinese company CAXA.

TriSpectives was the first truly interactive MCAD program, enabling users to drag and drop 3D IntelliShapes from catalogs and mate them accurately onto models using geometric snaps. The program also featured a TriBall cursor, which simplified the interactive positioning and editing of solids.

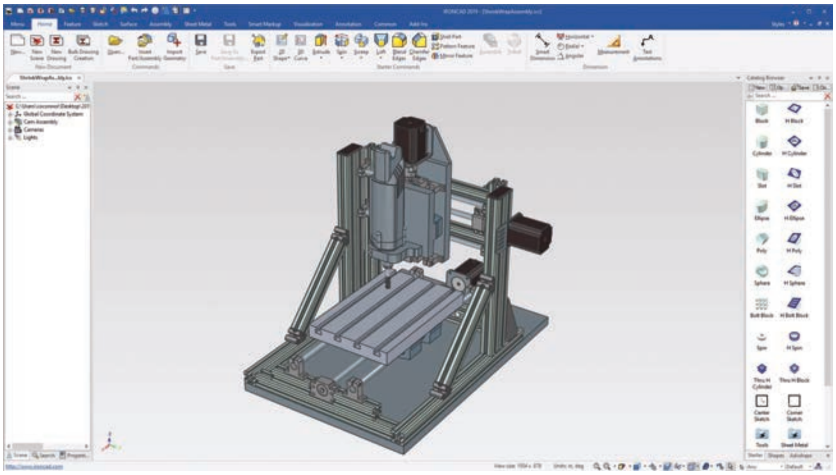
IronCAD retained all of this while adding new features, such as direct modeling, the ability to work with parts and assemblies simultaneously, and the incorporation of the ACIS and Parasolid modeling kernels.

A Different Design

IronCAD opens to a Welcome screen. From here you can start a new 3D scene or drawing in IronCAD, or a new drawing in CAXA Draft. You can also open recent documents or access resources such as Getting Started guides.

From the New Scene dialog, you can choose a metric or English unit template to begin your work. A customizable Quick Access Toolbar extends across the top of the screen, with tools to open a file, create a new part, save a file, insert a part or assembly, import or export a part and so on. Below this, the IronCAD interface presents a standard ribbon bar, which organizes commands by Feature, Sketch, Surface, Assembly, Sheet Metal and so on.

Each open scene has its own tab across the top of the workspace, so you can easily switch between open scenes. To the right of the workspace is a Catalog Browser while a Scene browser extends along the left. A status bar across the bottom of the screen provides tools for zooming, selecting a standard orientation, adjusting and saving camera settings, switching between perspective and parallel projections, changing selection modes and so on.



The IronCAD user interface includes a Catalog Browser on the right and a Scene browser on the left.

The Catalog Browser is a key tool when working with IronCAD. Unlike other MCAD programs, in which you must start a part by first sketching 2D geometry on a plane and then converting that sketch into a feature, in IronCAD you typically begin by dragging and dropping from the Catalog Browser into the scene. Shapes on the left in the browser add material (such as a rectangular block or a cylinder), while those on the right remove material. Tabs at the bottom of the Browser let you access advanced shapes, sheet metal and other catalogs.

After placing a part into the scene, you can use tools in the Scene browser, which provides information about the components in the scene. Expanding a branch in the browser allows you to drill down to see more information about the part. Tabs at the bottom of the Scene browser let you switch to a Property browser. With a part selected, you can see and alter properties of that part, whereas when no part is selected you can see and control the properties of the scene.

When you select a part in the scene, the edges highlight to indicate that you are in part mode. If you click the part a second time, you switch to IntelliShape mode. Here you see size box handles. You can resize the part by dragging a handle, entering a dimension, or enter values in the Properties browser. Clicking again switches to face and edge mode. Clicking on a selected face or edge switches back to part mode.

To create a hole in the part, you can drag and drop a hole cylinder from the Catalog Browser onto the part and then use IntelliShape handles or the Property browser to change the size of the hole. If you want to adjust the depth of the hole so that it is aligned with a face, you can press the Shift key to use SmartSnap to snap to a face or edge.

IronCAD's TriBall tool enables you to move parts and shapes in any direction, as well as rotate, copy, align and assemble parts. You first select a part in the scene and then activate the TriBall from the Quick Access Toolbar, the Assembly tab on the ribbon, or by pressing F10.

Lots of Improvements

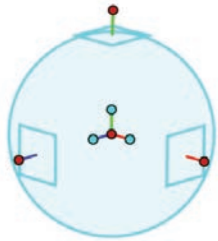
IronCAD 2019, released in early December, marks the 20th anniversary release and features a host of new and improved features. For example, models now have an improved edge display and the TriBall has a new transparent look and new sizing options. You can also now access the TriBall from the right-click menu. And when using size handles, pressing Enter now toggles to the next handle. In addition, a new toggle makes it easy to select two handles for symmetrical sizing.

Large assembly performance benefits from improvements to the Shrinkwrap command, which results in a smaller file size and offers improved ability to hide your intellectual property. You can also save shrinkwrapped models and create an associative link from your design file. This provides a simpler method to update the shrinkwrap model when you make changes to your design. You also now have the option of loading the full design model or shrinkwrap versions of parts and assemblies.

The Attachment Point Reconnection tool has been improved to work in a drag-and-drop model while in Mechanism mode, enabling you to easily connect parts that have constrained attachment points.

In past versions, when adding a flange to a sheet metal part, you had to carefully select the top or bottom edge to control the direction of the bend. Improvements to sheet metal now include a direction arrow that lets you easily reverse the bend direction. Sheet metal unfold in 3D now includes bend lines and you can add a SmartDimension to call out bend line locations. There are also new tools to allow the creation of corner reliefs on corner bend cases.

Drawing improvements include changes to the bulk creation tool, drag-and-drop image creation support, the ability to change dimension properties in the Property browser and better style control for dimension text settings.



IronCAD's TriBall has a new transparent look and new sizing options. *Images courtesy of David Cohn.*

Check It Out

You can download a 30-day free trial from the IronCAD website. The trial includes IronCAD, IronCAD Inovate (modeling only), IronCAD Draft (CAXA Draft) and IronCAD Compose (collaboration). You also get a library of nearly 30,000 drag-and-drop parametric components, development tools and a translator providing support for CATIA, CREO, Inventor, JT, NX, SolidWorks and Solid Edge.

Last, but not least, you get access to some excellent online learning resources including a 363-page "Getting Started Guide" in PDF format; a 17-part self-paced training guide; and more than 70 training videos covering all aspects of the program.

While many of IronCAD's once novel features have found their way into most modern MCAD systems, the program retains its pioneering concepts: the ability to drag and drop shapes, parts and assemblies from infinitely customizable catalogs; the ability to push and pull to make precise changes in seconds; and the ability to easily create parts and assemblies in one file. **DE**

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INFO ➜ IronCAD 2019: IronCAD.com

PRICING

IronCAD

- **Price:** $3,970 ($4,270 w/dongle) *(also available as an annual rental for $1,500/year)*
- **Annual maintenance:** $895
- **Upgrade from any earlier version:** $1,295

Inovate

- **Price:** $1,270 ($1,470 w/dongle)
- **Upgrade:** $495
- **Subscription:** $295

Draft

- **Price:** $595

SYSTEM REQUIREMENTS

- **OS:** 64-bit Windows operating system (Windows 10, 8.1, 8, or 7; Home editions not supported)
- **Processor:** Pentium 4 CPU or higher (current AMD processors supported)
- **Memory:** 4GB minimum (8GB or more for large assemblies)
- **Disk Space:** 2GB required for installation
- **Display:** Direct X and/or OpenGL compatible accelerated video graphics card (required for large assemblies)

Virtual Printing Enables Next Phase of AM Adoption

Simulating 3D prints will make it easier to create high-quality end-use parts using additive manufacturing.

BY BRIAN ALBRIGHT

AS MORE COMPANIES use additive manufacturing (AM) processes to create end-use metal parts (not just prototypes), quality and scrappage issues associated with AM have become a bigger issue. Many 3D printing technologies have demonstrated high degrees of variability regarding consistent parts creation, and because design for AM skills are often in short supply at most companies, there is great trial and error involved in creating usable parts.

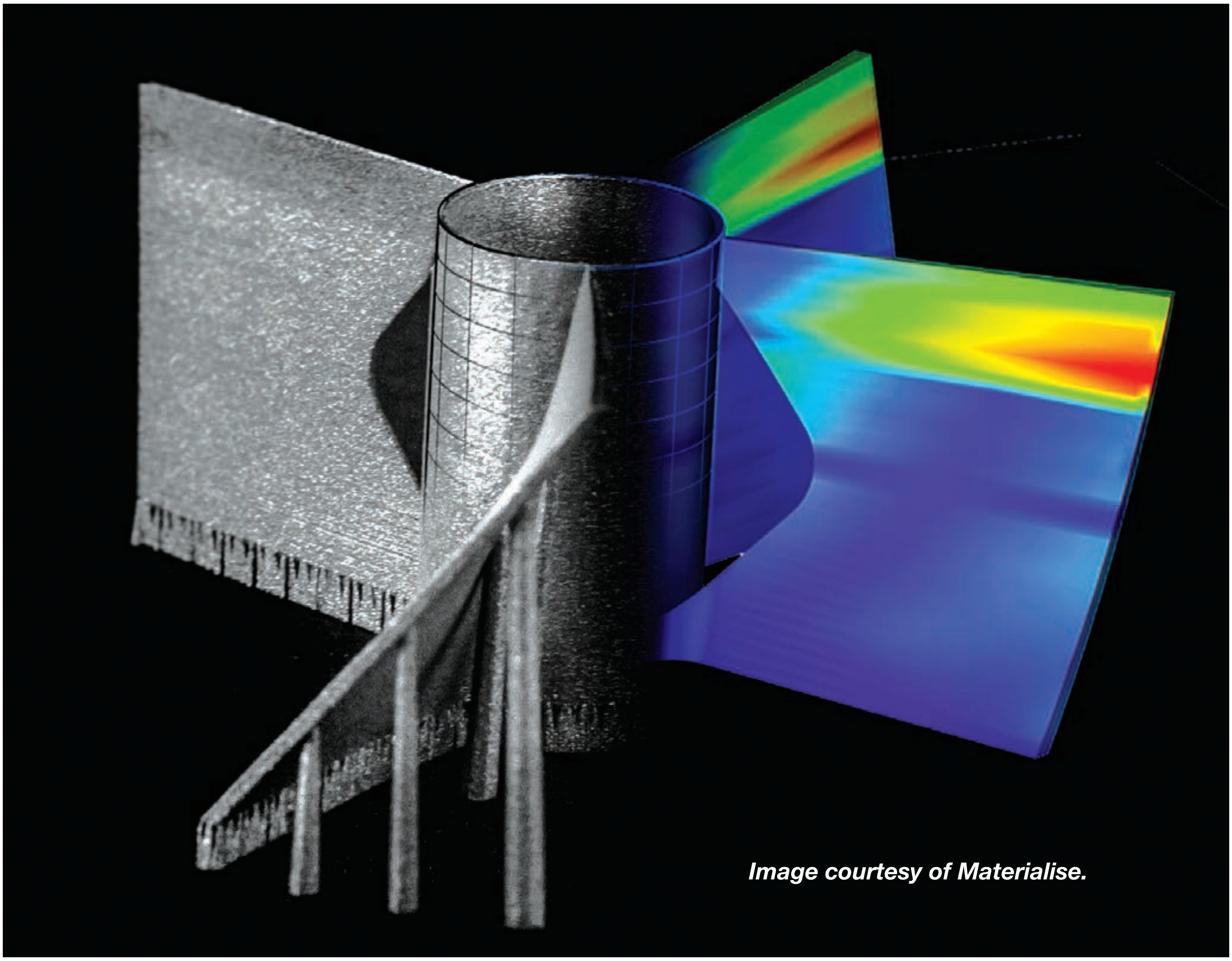
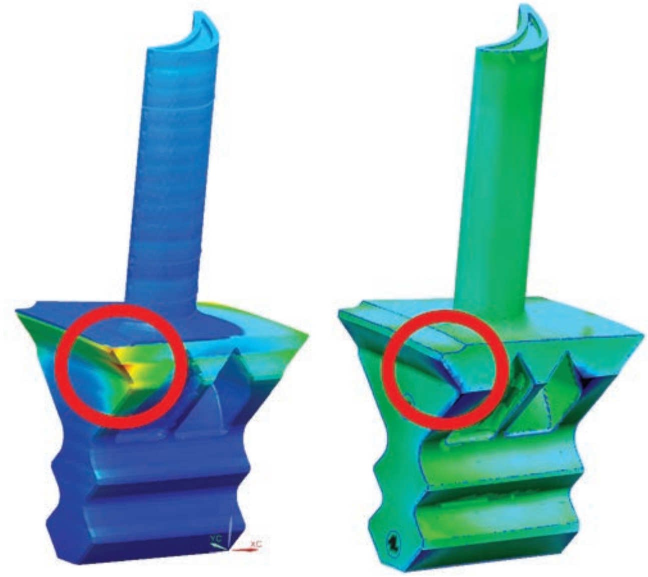


Image courtesy of Materialise.



With underlying technology like XFEM analysis, the Simcenter 3D AM Process Simulation tool shows how the predicted distortion on the left is confirmed by the real-world part via the original CAD data on the right. ***Image courtesy of Siemens.***

That has resulted in a high percentage of scrap and wasted materials. To reduce waste and improve part quality, end users need a way to virtually test builds before creating physical parts.

"What we see is that in order to industrialize and use the technology in higher volume production scenarios, we need to do a few things to get it right," says Ravi Shankar, director of global simulation product marketing for Siemens PLM Software. "One critical area is to do what we call first-time-right print. Typically, companies attempt to print a part multiple times at a high cost before they actually achieve an acceptable result. That is delaying the transition of what is a very exciting technology into real production scenarios."

"If you look at AM today, the scrap rate is still very high compared to traditional manufacturing," says Stefaan Motte, vice president and general manager of software at Materialise. "You can see anywhere from 5% to 10% to 15% scrap, depending on the parts involved."

Software vendors have responded with a variety of AM simulation tools, including solutions from Siemens PLM Software, ANSYS, Autodesk, Dassault Systèmes, Materialise and most recently ESI, which launched its AM simulation tool at Formnext in Frankfurt, Germany. Simulation helps companies predict the behavior of a part during production, so that they can optimize build preparation and reduce costs.

"Specific simulations can be done in the virtual environment to reduce errors and optimize the entire production process for a specific part or specific geometry," Motte says. "You're not just reducing scrap, but increasing productivity."

The use of simulation also helps companies address the shortage of AM experts. "You need simulation to have stability in the process, because staff come and go," says Brent Stucker, director of additive manufacturing at ANSYS. "It also helps companies get better results. We've seen an explosion of adoption of 3D printing by new companies, and they're in this conundrum of seeing other people be successful with it, but they are six months in and turning out garbage. Simulation helps them be successful."

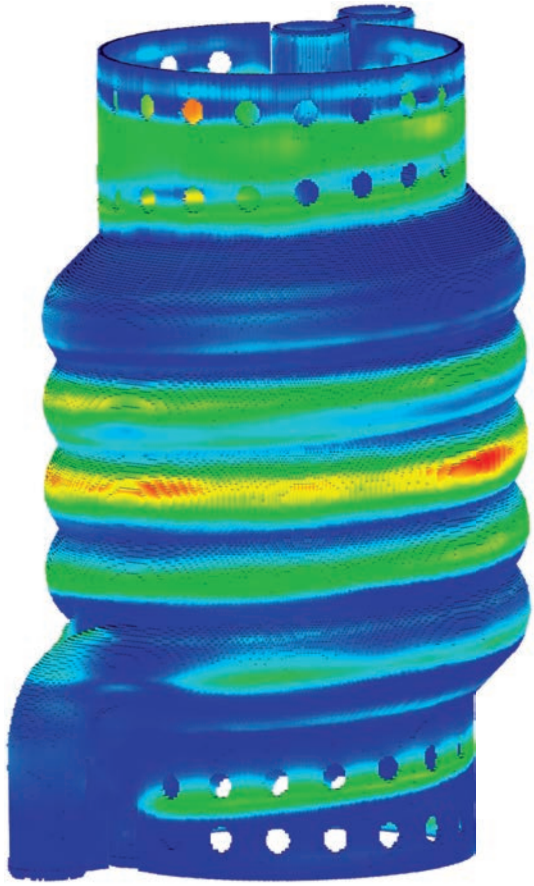
Value in Virtual Printing

Software providers have developed AM simulation tools using various approaches. Materialise offers an AM simulation module (from Simufact Engineering) for its Magics 3D software suite that allows users to simulate a print, and then work with support generation and orientation tools in Magics. ANSYS acquired 3DSIM, and merged that company's work with its own internal development program.

The ability to reduce waste and scrappage comes from being able to predict potential points of failure and provide operators with the information they need to correctly calibrate the machine and orient the part on the build plate, as well as ways to tweak designs so that they will perform well in an AM environment.

Dassault Systèmes offers simulation for a variety of 3D printing processes as well as post-processing operations. "We can capture process-dependent and machine-dependent crack initiations," says Jing Bi, technical consultant at Dassault Systèmes SIMULIA. "Often the support structures are weak and break during the print because of large residual stresses. That can affect part distortion. That's a big issue in metal printing. With the latest updates, we actually simulate and predict the exact crack initiation location, and how it propagates through the different support legs to exaggerate part distortion."

ANSYS' Stucker sees virtual printing having the same effect



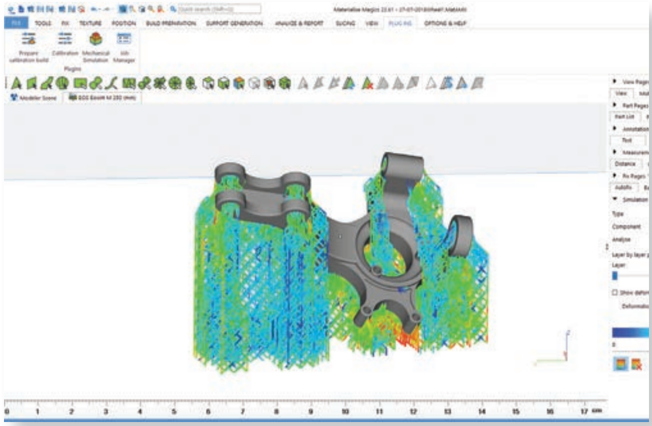
Simulation of heat exchanger displacement before being additively manufactured. *Image courtesy of Additive Industries via ANSYS.*

that "print preview" had on 2D printing decades ago—eliminating most of the frustration and mistakes that came with not being able to know whether what you'd just created on the screen was going to come out of the printer looking as you intended.

"That saved a massive amount of time in turning out something that looks correct," Stucker says. "I've been working in metal 3D printing for years, and up until eight years ago you always relied on experiments. You'd print it, see how it worked and then try it again. With virtual printing, you move beyond physical trial and error and move to a whole new paradigm for developing products. You're not only looking at the process, but also how the material performs, and how you get the microstructure so that it performs how we intended it to."

ANSYS has approached this issue based on roles. There are simple tools that designers without simulation backgrounds can use that predict the properties of interest to them. Other tool sets are targeted at machine operators. There are also tools for traditional analysts or material scientists who need expert-level insight.

At Materialise, the company has worked closely with printer manufacturers to gather machine-specific data. "We get that information from builds that have been happening," Motte says. "This is not generic information on machine type, but usage data on specific machines in a production environment."



An example of the print process in the Materialise Magics Simulation Module. *Image courtesy of Materialise.*

Complex Simulation Challenge

There are many factors that can affect how well a printed part conforms to expectations. Operator experience, machine calibration, environmental factors (temperature, vibration and humidity), position on the build plate, part orientation, material condition and the nuances of the specific print process can affect quality.

"We're trying to provide a solution that lets end users not only design the part, but understand where the support structures need to be and how the print process should work," Siemens PLM Software's Shankar says. "They want to be able to anticipate distortions and shrink lines, and avoid collisions, as well as look at areas of potential overheating."

Assuming the machine is operating properly, simulation allows users to evaluate a variety of "what if?" scenarios to determine the optimal printing approach. "To do that experimentally costs a fortune, but simulation defines the process parameters and geometry features that are the most robust. You find what works and then you lock down the machine calibration," Stucker says.

3D printing equipment has a high level of variability. Two identical machines may produce different quality parts, or the same machine may generate variability quality over the course of a shift, or with different operators. In some cases, there can be variability even across different areas of the build plate.

"If you are printing one part and print it 10 times, you might end up with different part quality among those parts," Bi says. "That could be due to certain machine parameters or environmental settings that have not been set up or correctly monitored to provide consistency."

Bi explains that simulation can be combined with topology optimization and other technologies to generatively design a part, optimize the topology in functionality and weight, and then ensure that the design is optimized for digital manufacturing so that the machine can be properly programmed.

Virtual printing solutions can provide quick info for designers, who are generally not simulation experts and need faster answers to basic questions, Motte says. "They want to reduce the potential risks that have been identified," he says. "They need quick answers. Process engineers can have immediate information without having to become experts in every single detail of simulation."

Material Science Gap is Closing

Material science has not quite caught up to the needs of 3D printing—new materials are being developed, and existing materials don't necessarily predictably behave when they are exposed to different 3D printing processes.

But new work in material science and features in some new simulation tools are helping companies grasp how these materials will perform (see page 34). "There's a far bigger interest now for materials manufacturers to make those investments in refining and better understanding materials," Motte says. "All of that know-how can feed back into simulation. But simulation can bring significant results even without some of those details."

ANSYS offers its own intellectual property that helps create phase diagrams and properties that reflect the high cooling rates and other elements that can affect material performance. There are also tools in the software that can help customers create their own material property databases.

"We are shifting from a strategy of using our own internal experts to do this, to training our customers to be successful and take into account the unique microstructures and phases you get out of additive manufacturing," Stucker says. "They can more quickly try out new chemistries and materials and come up with properties they are looking for from an as-built condition."

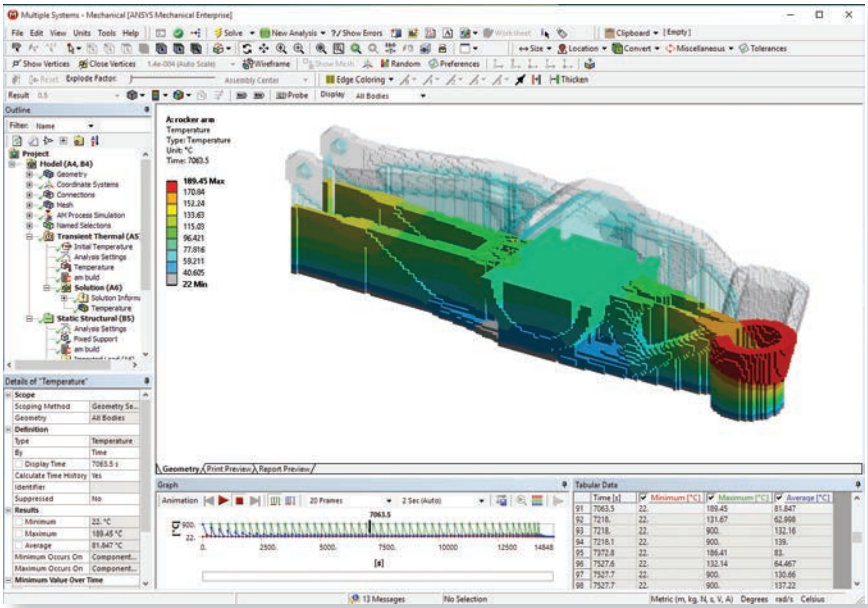
Shankar says that Siemens PLM Software offers standard materials libraries, but many customers want to calibrate materials themselves. "They are looking for the data and thermal properties being measured, and then use that measured data to feed into the database," he says. "Not only is that just the material, but also that material in combination with the 3D printer being used. The specific inputs are machine dependent."

SIMULIA has specific features that can help users better predict material performance. "For parts that have different geometries, the material microstructure may evolve differently based on different machine settings," Bi says. "With our simulation tools, we can track how the powder will evolve into a liquid state and then solidify, and we can track the microstructure phase of this. It's not just the pure material; there are different microstructure phases in the material as it's being built."

A Path to More Optimized Printing

Future AM simulation features will focus on optimizing machine performance, increasing speeds and increasing print volumes, according to the vendors interviewed for this story.

There will be more work done to optimize AM machines for high volumes of particular parts as end users will want to turn these printers to highly specific use cases, according to Motte. That means those users will want more capabilities when it comes to calibrating and customizing the equipment. "Some machine manufacturers still work in a very closed way, but there will be a lot of pressure on the manufacturers from volume production companies to open those machines and allow changes to be made," Motte says.



An example of the print process simulated with ANSYS Workbench Additive. ***Image courtesy of ANSYS.***

Motte says that Materialise worked with one customer on the plastics side that was able to decrease production time by more than 40% after simulating changes in the part orientation and machine behavior. "That shows you the power of simulation," he says. "The machine is 40% more productive after altering the production flow. That's something you'll see happening more in these volume manufacturing lines."

Stucker adds that there will be a bigger push for more microstructure and property prediction capabilities. "Long term, people want to optimize performance of the component through a combination of geometries and properties and we need simulation tools that do both," Stucker says.

The data generated by simulations can help improve the design of the printers themselves. "As this virtual testing becomes ingrained with machine manufacturers and users, and the entire supply chain, that will increase the rate of innovation and rate of success," Stucker says. "That helps us get to another inflection point to take adoption of AM to an even higher rate." 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 ➜ **ANSYS:** ANSYS.com

➜ **Autodesk:** Autodesk.com

➜ **Dassault Systèmes:** 3DS.com

➜ **ESI:** ESI-group.com

➜ **Materialise:** Materialise.com

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

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To 3D Print, or Not to 3D Print?

Consider the application, volume requirements and operational efficiencies.

BY TOM KEVAN

THE TIME HAS COME for engineers, plant managers and automation systems integrators to face the facts. Additive manufacturing (AM) will not—nor was it ever expected to—pre-empt traditional production systems. The truth is that not every production job should be 3D printed. The question, therefore, becomes: When is AM the most cost-effective means for a manufacturing application, and when are traditional production technologies like injection molding and machining the optimum choice?

AM vs. Traditional Technologies

To answer these questions, engineers must look beyond AM's strengths and determine where the technology best fits in the broader context of the manufacturing environment. Qualities like waste reduction, near-limitless customization, improved speed and reliability, hyper-local production and increased availability of replacement parts have opened a new range of applications, but consider other factors to ensure that AM is the right fit for the task at hand.

The most defining factor is the volume of parts being produced. Conventional wisdom states that traditional manufacturing is more cost-effective than 3D printing in creating parts when the tooling already exists and volumes are high.

"Everything in 3D printing is a cost calculation that involves tooling amortization, delivery times and ultimately how many parts you want to make," says Lance Kallman, vice president of business development at 3DEO. "If you have a manufacturing line already set up to assemble components that are, for example, investment casts, then you will have to compare the cost per part of the 3D printing technology vs. the existing cost of your manufacturing line. Often this comes down to volume because many 3D printing technologies simply can't produce high volumes of parts, including consolidated parts."

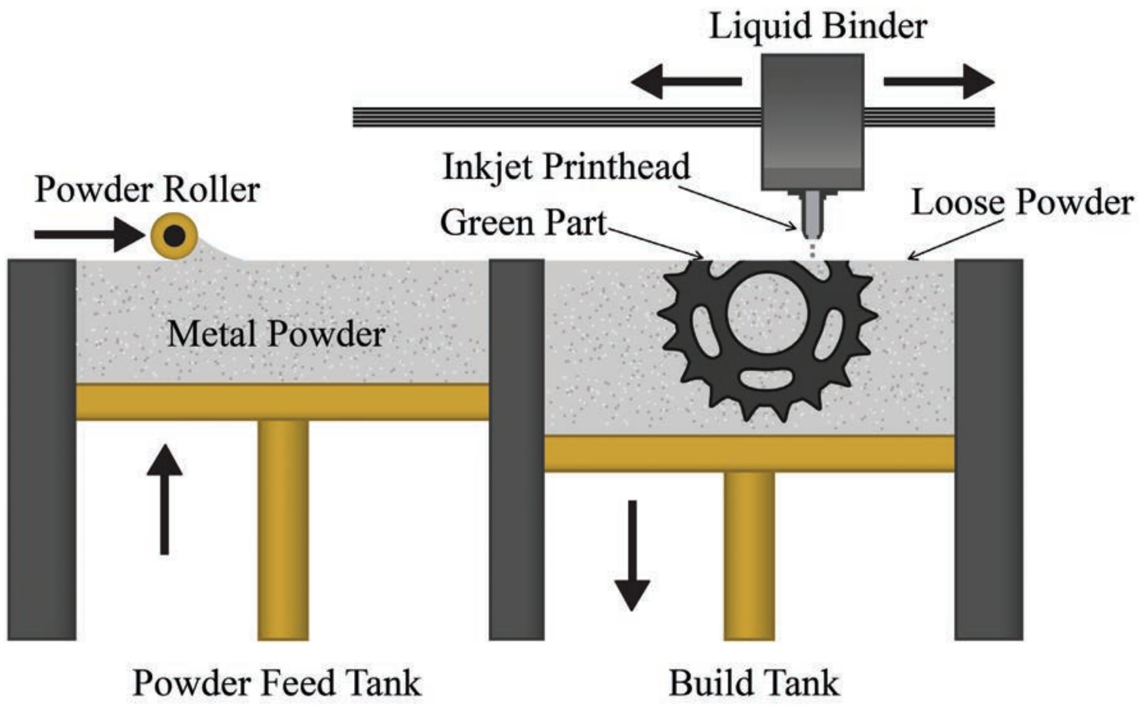
Among the most cost-effective traditional production technologies, computer numerical control (CNC) and injection molding systems rank high. A number of benchmarks can help you decide when these technologies are most effective.

"For plastics, CNC machining becomes the most cost-effective option at around 100 units, and injection molding for productions greater than 100 to 500 units," says Filemon Schöffer, co-founder and CMO of 3D Hubs. "For metals, CNC machining is almost always a more cost-effective option. Metal

Material costs and machine run time are just two factors that determine whether 3D printing is a cost-effective way to manufacture parts. Understanding the impact of all the factors that come into play and learning how to optimize each one can mean the difference between success and failure. *Image courtesy of 3DEO.*

3D printing, however, becomes competitive in two cases: when an assembly can be redesigned to consolidate a very large number of parts (30 to 50+) into one, or when a geometry is required that is impossible to manufacture with traditional technologies."

A cursory look at CNC and injection molding systems may cause you to question this rule of thumb, but a thorough examination will prove it correct. "With injection molding, even though



Binder jetting is suited for the manufacture of large parts and complex metal geometries because it is not limited by thermal effects, such as warping. ***Image courtesy of 3DEO.***

the tooling cost will look daunting at first, the rate of production will be much higher and the cost per part will be more cost-effective," says Danielle Barillas, project manager at Fictiv.

Exceptions to the Rule

Although these volume benchmarks are helpful when deciding what technology to use, other issues can pre-empt them and call for alternative approaches. These exceptions tend to revolve around business advantages and operational considerations.

"I am seeing more customers looking at 3D-printed solutions for applications that require less than 1,000 pieces per year," says Tommy Lynch, applications engineer at Xometry. "In these cases, they are willing to pay a higher piece price because they can order in lower volumes, based on demand and have parts in as little as three business days."

Demand for aftermarket parts can also come into play. In fact, there are many cases where manufactures are looking to support end-of-life replacements via 3D printing.

Consolidation savings are also a factor to consider. "In some cases, it is much easier to consolidate an assembly using 3D printing, store it digitally and print on demand, as opposed to maintaining a bill of materials that must be ordered from multiple suppliers and assembled in house," says Lynch.

Print Technology Considerations

Choosing the right technology not only involves comparing AM with traditional manufacturing systems, but also weighing the various 3D printing technologies. A plethora of technologies are on the market, but the three most common are fused filament fabrication (FFF, also known by the Stratasys trademark Fused Deposition Modeling, FDM)—stereolithography (SLA) and selective laser sintering (SLS).

In the past few years, high-resolution 3D printers across all three technologies have become exponentially more affordable, easier to use and more reliable. As a result, AM systems are becoming more accessible, so identifying what is most cost-effective fundamentally comes down to the application, production needs and cost per part.

If you examine these three elements closely, a few key factors surface when making cost-effective production parts. These include speed/throughput, volume, setup and maintenance.

Speed and throughput have advanced, raising the bar on AM's capabilities and the applications it can serve.

"There are several technologies coming to the market specifically focused on speed and throughput," says Lynch. "Two examples (already available) are Multijet Fusion (MJF) by HP and Continuous Liquid Interface Production (CLIP) by Carbon. In some cases, these technologies can build 10+ times faster than competing technologies currently on the market. As a result, pricing is becoming more palatable for low-volume production. Combine that with improved material properties, and you now have a case for investigating if 3D printing makes sense for your production needs."

Speed and throughput relate directly to practical considerations that influence the second feature: volume.

"If cost-effectiveness is the main concern, then the size of production should be considered," says Schöffer. "For example, if only a one-off part or a few parts are needed, then FDM or SLA are the most cost-effective options because they are widely available and the desktop printers can produce results comparable to the industrial printers. For larger productions (between) 50 and 100 parts, then a 3D printing technology with batch production capabilities—such as SLS for plastics or binder jetting for metals—is usually more cost-effective. The common thread of these

Support structures can work for or against the engineer. For example, they can increase the volume of material and require post-processing, both of which increase the cost of fabrication. At the same time, support structures prevent warping when used in thin-walled designs, improving quality. *Image courtesy of 3D Hubs.*

two technologies is that they do not require support structures. This means that the whole build volume can be used since the parts do not need to be attached to the build platform."

Finally, designers should factor in setup and maintenance in their selection process. Both tasks impact the time required for production, which relates to speed and throughput.

"Certain technologies require more maintenance or time to set up," says Barillas. "Maintaining an FDM PLA [polylactic acid] printer usually requires less intense attention than an SLS printer. Printing a cube using SLS will be more expensive not just because nylon is a more expensive material but because there are also higher overhead costs inherent to that type of printer."

Material Differences

The engineer's selection of printing materials also impacts how to achieve the most cost-effective outcome for many applications. To choose the best material for the application, the designer must examine the question from various angles.

For instance, the engineer must consider the linkage among printing materials, AM technology and cost. "Your choice of printing materials is a big factor in the cost-effectiveness of 3D printing parts because it determines which 3D printing technology to use and what the material costs will be," says Kallman.

Material costs can greatly vary for metal 3D printing, Kallman explains. This is because with the nature of powder-based metals, manufacturers need more than will actually be used to form a part, and the price is based on particle size. Bind and sinter technologies use standard cuts of powder and normal particle distribution, which lowers the cost.

That said, development teams cannot simply focus on material costs. Certain use cases require specific types of materials. In these instances, functionality can trump cost.

"PLA is the least expensive, followed by acrylonitrile butadiene styrene (ABS) and nylon, then Vero and rubber-like, and lastly ABS-like as the most expensive," says Barillas. "However, each material is suitable for specific purposes and applications. PLA and ABS are great for testing iterations of rough prototypes. Vero and ABS-like are best suited for finely detailed models, whose primary purpose is aesthetics. Because they can offer this level of detail, with layer heights of 0.016 mm, they are more expensive. Additionally, ABS-like is more durable than Vero, thus increasing its value. Nylon sits in the middle. It's fairly durable, and the cleaning process is more straightforward than Vero, but it can't offer the same level as aesthetic."

As a result, the engineer must navigate a series of trade-offs, pitting quality against cost, defining just what compromises are suitable for the application.

Size Equals Expense

The cost of 3D-printed parts depends to a degree on the total volume of material used and the time required to print the part. This means that larger parts will almost always cost more than smaller parts. Keep in mind that doubling the dimensions of a part increases its volume eight-fold.

There are, however, ways to combat cost through design decisions. For example, a common practice to reduce the design volume is to make it hollow (or latticed) while keeping the external volume the same. Reducing the wall thickness has a similar effect.

Designers can also reduce the volume of material used and the total print time by eliminating or minimizing the need for support structures. This technique is essential for higher production volumes.

Another approach that mitigates the impact of size on cost optimizes the layout of material based on given design space, boundary conditions and loads. For example, for high-end applications, topology optimization relies on organic-like structures that fulfill design requirements while using the minimal amount of material. This is a common practice for high-value components produced with selective laser melting (SLM) and direct metal laser sintering (DMLS).

A similar technique takes advantage of AM's proficiency at creating complicated geometries. "To mitigate the effects of size and to improve cost-effectiveness, engineers should design their parts with 3D printing in mind and take advantage of complex design geometries to cut out unnecessary sections and reduce the amount of materials used," says 3DEO's Kallman.

Leveraging Complex Geometries

Taking advantage of complex design geometries does more than help design teams come to grips with part size and total volume of material. Getting the most from part complexity, however, requires more of the designer.

"Part complexity in 3D printing comes at no additional cost, but the part must be designed using the appropriate design guidelines for the selected 3D printing technology," says 3D Hub's Schöffer. "In practice, this means that a designer should always be familiar with the basic mechanics of the manufacturing process he is using. A few basic things to watch are support removal, powder evacuation, wall thickness and post-processing requirements."

An example of post-processing best practices would involve designing internal channels for conformal cooling in metal (DMLS/SLM) using a teardrop cross-section instead of an O-shaped cross section. This practice eliminates overhangs and the need for support.

On the downside, post-processing operations can increase costs. For example, support removal—and smoothing of the surfaces that the support was attached to—is usually a manual process. When 3D printing with metal, CNC machining might be required to improve the accuracy and tolerances of critical surfaces or to reduce surface roughness.

Dimension Decisions

The engineer must make trade-offs when deciding on print dimensions such as layer height and wall thickness. This means juggling features like cost, part strength and durability, resolution and appearance. All factors come into play, complicating the process, but application requirements go a long way toward guiding the designer in making these choices.

One rule of thumb is that layer height affects build time. Simply put, increasing the layer height reduces the total number of layers and ultimately build time. Faster build times mean lower costs.

When dealing with these issues, designers must consider more than cost and build time. For example, faster build times cut costs, but they also reduce resolution, increase the layer visibility (i.e., the "stair-stepping effect") and present a less-pleasing appearance.

"A smaller layer height definitely looks better and is more precise," says Fictiv's Barillas. "However, this adds time and therefore cost. That's why it's important to understand the part's application. Is it for aesthetics, or do you only need a rough idea of what the part will physically be like? If it's the latter, it's more worthwhile to stick with ABS or PLA than to go straight to higher end materials like VeroWhite."

Using techniques such as hollowing also impacts the designer's layer height decision. "If you're hollowing a part to save money, the wall thickness is a significant part of that," says Andrew Edman, applications engineer at Formlabs. "You need to balance getting the strength you need while reducing overall material usage."

Wall thickness, on the other hand, represents less of a cost driver, but it poses more of a technical challenge. For example, thin walls without support structures tend to warp. Thick walls increase costs in laser sintering because the laser must trace more surface area, which increases the build time. Bind and SLA technologies do not use a laser, however, so they are not affected in the same way.

The design of this part uses a 45° angle build orientation and lattice-style supports to prevent warping, reduce overall surface area for each layer and minimize supports on overhanging features, promoting higher quality. ***Image courtesy of Xometry.***

Get Started

If your goal is to become familiar with 3D printing technology—what it's good for and what the materials are capable of—a common approach is to begin working with the technology, figure out the details of cost and application, and cultivate an understanding of its strengths firsthand.

"Opportunities that are well suited for 3D printing often emerge when there's a time crunch or some issue arises where doing things the typical way is costly, slow or simply not possible," says Edman. "I've seen lots of examples that can only be described as happy accidents—where they tried something on the printer, often sheepishly admitting they didn't expect it to work, and when it does, the printer often pays for itself after only a couple of parts." **DE**

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INFO → **3DEO:** 3DEO.co

→ **3D Hubs:** 3DHubs.com

→ **Carbon:** Carbon3D.com

→ **Fictiv:** Fictiv.com

→ **Formlabs:** Formlabs.com

→ **HP:** HP.com

→ **Stratasys:** Stratasys.com

→ **Xometry:** Xometry.com

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

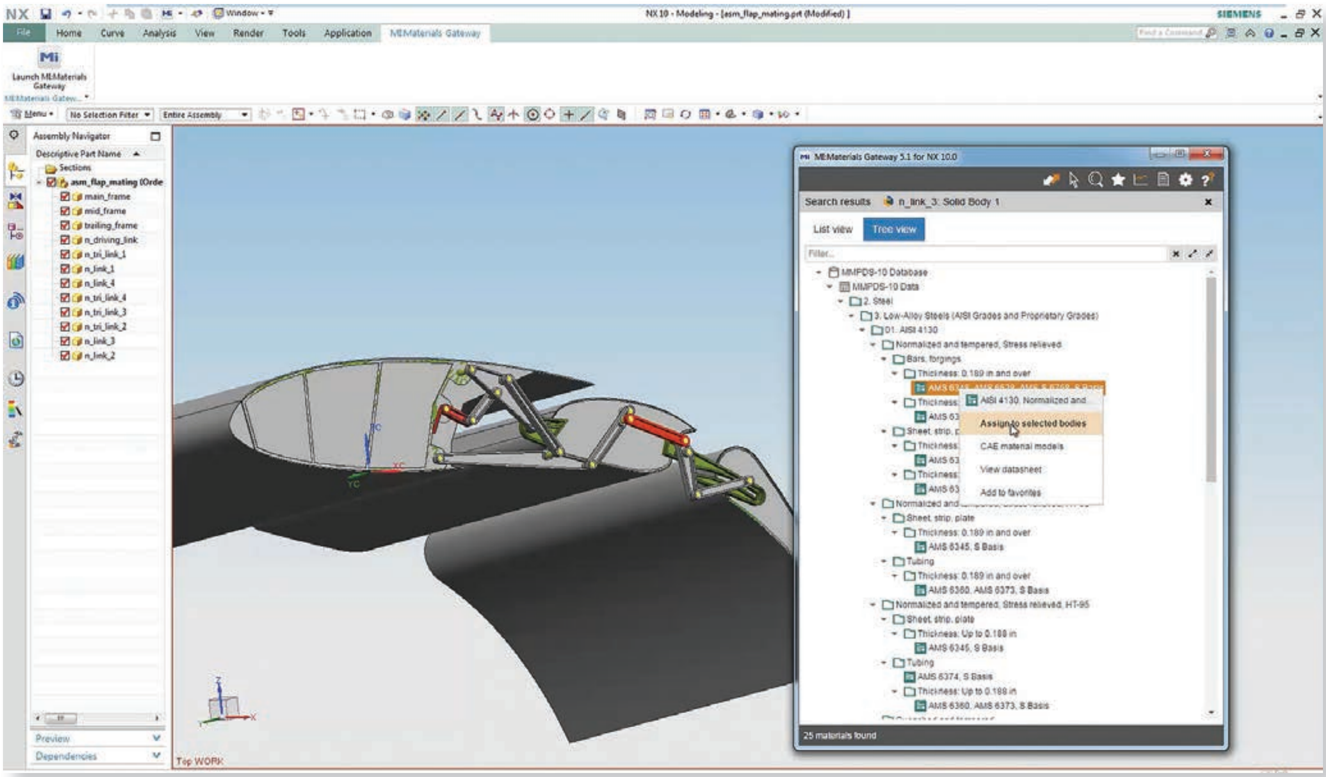
Weaving Materials into the Design Workflow

Advances in materials science offer promises of part quality improvement at the microstructure level.

BY KENNETH WONG

MATERIAL INFORMATION is one of the critical building blocks in simulation-led design. Many users don't have to think too much about it because, for most software users, the properties of the material—how it stretches, how it bends in response to stress, how much heat it can resist, and so on—are already coded into the software, often as part of a materials library.

However, a peek behind the scenes shows some industry groups and firms quietly toiling away to bring materials science to a whole new level, with tangible benefits to the simulation software and additive manufacturing (AM) sectors.



Materials intelligence from Granta is integrated with many CAD and simulation programs, including Siemens NX, shown here. *Image courtesy of Granta Design.*

> **"With the emergence of technologies such as additive manufacturing, there is a blurring of the boundary between what constitutes the development of 'a material' and the development of 'a part,' so it is likely that engineering simulation methods will to some extent merge with ICME approaches over time."**
> — James R. J. Goddin, Granta Design

The Ultimate Equation for Additive Manufacturing

In August 2018, the National Institute of Standards and Technology (NIST) awarded a grant to additive manufacturing database and analytics software developer Senvol, for a project dubbed "Continuous Learning for AM Processes Through Advanced Data Analytics." The project is expected to yield insights on how different AM parameters—such as laser power, melt pool temperature, material density and part tensile strength—affect one another.

"Machine parameters plus raw materials properties equals part properties," says Annie Wang, president of Senvol. "So if you change the machine settings (such as laser power) or material properties (such as chemical composition, particle distribution, density or flow rate), then you end up changing the properties of your printed part in some big or small ways."

The study is well underway, with Senvol applying machine learning to identify and map out the complex relationships among these input and output values. When completed, the insights from the project will be distilled as an algorithm-driven AM analytics and customization software, deployable by enterprises that produce large-scale AM production runs involving multiple machines.

"If you happen to have multiple production sites using AM, we envision that you would be able to load all the data collected from these sites into our software," explains Wang. "This means each site also learns from the data that comes from other sites."

Armed with a deeper understanding of materials, AM system makers might tune the machine settings to achieve the desired stiffness or durability for a client. Similarly, materials providers might invent a specific type of material with a client's desired parameters. And manufacturers using AM for high-volume production can use custom materials with specific machine settings to achieve the desired part characteristics (stiffness, flexibility, fatigue life or tensile strength).

Some of the relationships may be intuitive to experienced AM users. For example, simple logic dictates that denser materials lead to stronger parts. "But keep in mind, this kind of simple rule of thumb is usually not enough," Wang points out. "Usually, your requirement is that you need parts with above X or Y value in tensile strength. To get that, you need quantifiable inputs. You can't just say more laser power, or faster scan speed."

For more on this project, read "Senvol and NIST: New Project to Establish AM Process-Structure-Property Relationships," by Pam Waterman (digitalengineering247.com/r/ 21613).

The Integrated Approach

In 2013, the Minerals, Metals & Materials Society (TMS), an industry group, published a reported titled "ICME: Implementing ICME in the Aerospace, Automotive, and Maritime Industries." (ICME stands for Integrated Computational Materials Engineering). The study was made possible with a grant from the U.S. Department of Defense, U.S. Department of Energy and U.S. National Science Foundation.

"Incorporating computational methods (along with critical experiments for model verification and validation) as an integrated component of the product development cycle is a relatively new practice within the maritime industry," the study's authors wrote in their closing remarks. "Yet it shows great promise for reducing the time and cost investments required for the development of new materials, components, and/or manufacturing processes."

Dr. Georg J. Schmitz and Ulrich Prahl, co-editors of the "Handbook of Software Solutions for ICME," initially set out to compile a kind of "Yellow Pages of software solutions for ICME." Upon reflection, they concluded such a document, "even if being very comprehensive—would be quite boring to read (and also to write) and probably would even be outdated

The cover page of the ICME implementation report, published by the Minerals, Metals & Materials Society. ***Image courtesy of TMS.***

after a short time," recalls Schmitz.

The book was refashioned to be "particularly suited for young scientists and engineers seeking an overview of modern simulation tools in the area of computational materials science and ICME," he explains.

Successful implementation of the ICME approach means "components can become even less heavy by tailoring the local materials properties at different locations in the component," says Schmitz. "The process determines the microstructure, so in AM, it also allows for new microstructure designs."

"With the emergence of technologies such as additive manufacturing, there is a blurring of the boundary between what constitutes the development of 'a material' and the development of 'a part,' so it is likely that engineering simulation methods will to some extent merge with ICME approaches over time," reasons James R. J. Goddin, market development manager, Granta Design.

ICME might be unfamiliar to many simulation software users, but it has a link to finite element analysis (FEA). "ICME already integrates current structural analysis, fluid dynamics and thermal analysis workflows as boundary conditions for a spatially resolved description of the microstructure and its evolution during processing a service. The microstructure in turn provides the basis to extract the properties, ultimately entering back locally into the FEA," says Schmitz.

Realistically Materialistic

Materials information technology company Granta Design counts many of the CAD and simulation software heavyweights as its partners. On the list are Autodesk, Dassault Systèmes, Siemens PLM Software and PTC, the prominent four in the design software business; there are also Altair and ANSYS, two leading names in simulation. Explaining its involvement in ICME, Granta writes: "We help engineers to combine and manage data from experiment and simulation at different time and length scales. The aims are to gain insight and design better materials, faster, while reducing reliance on expensive experimentation."

"ICME is an approach to better understand and develop the performance of materials and processes," says Goddin. "This includes developing models to describe this performance and confirming that these models reflect reality by calibrating and validating them against experimental results where available."

The Need for a Lingua Franca

A major hurdle in ICME advancement is the lack of a common language and the cost of software, Schmitz says.

"Interoperability between various heterogeneous software tools requires a common language (an ontology)," he notes. "Another hurdle may be the number of different tools needed to do meaningful ICME, and the related costs for their procurement and maintenance. New business models like software as a service seem to emerge here."

In Europe, the European Materials Modelling Council (EMMC) has conducted two International Workshops on Software Solutions in ICME. Similar efforts are also taking place under the ITEA VMAP (Virtual Material Modeling) project, with participation from the simulation user group NAFEMS.

The organization's role will be "to lead all dissemination activities during the project including a survey of industrial requirements, the organization of an international conference and the creation a vendor-neutral Material Data Exchange Interface Standard community which will carry on the standardization efforts into the future," writes NAFEMS. 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 → Granta Design: GrantaDesign.com

→ **The Minerals, Metals & Materials Society (TMS):** TMS.org

→ **European Materials Modelling Council:** EMMC.info

→ **NAFEMS:** NAFEMS.org

→ **VMAP:** itea3.org/project/vmap.html

→ **Senvol:** Senvol.com

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

Dell Precision 3530: PLENTY OF POWER TO GO

This 15.6-in. system delivers great performance and long battery life.

BY DAVID COHN

The Dell Precision 3530 is a full-size 15.6-in. mobile workstation that packs lots of power in a package that weighs just over 5 lbs. *Image courtesy of Dell.*

ALTHOUGH WE HAVE RECENTLY REVIEWED quite a few Dell workstations, it has been a year since we last looked at one of the company's mobile systems (see *DE* January 2018; digitalengineering247.com/r/17330). We were therefore quite pleased when Dell offered to send us a new Precision 3530 mobile workstation.

The Precision 3530 is Dell's latest 15.6-in. mobile workstation, powered by an 8th-generation Intel Core or Xeon processor. Unlike the thin Precision 5520 we reviewed last year—which bore a striking resemblance to a MacBook Pro—the Precision 3530 is a full-size system measuring 14.80x9.87x0.9 in. and weighing 5.17 lbs., plus 1.32 lbs. for its 130-watt external power supply.

With prices starting at $889, the Dell Precision 3530 offers true workstation performance without breaking the bank.

Building from the Base

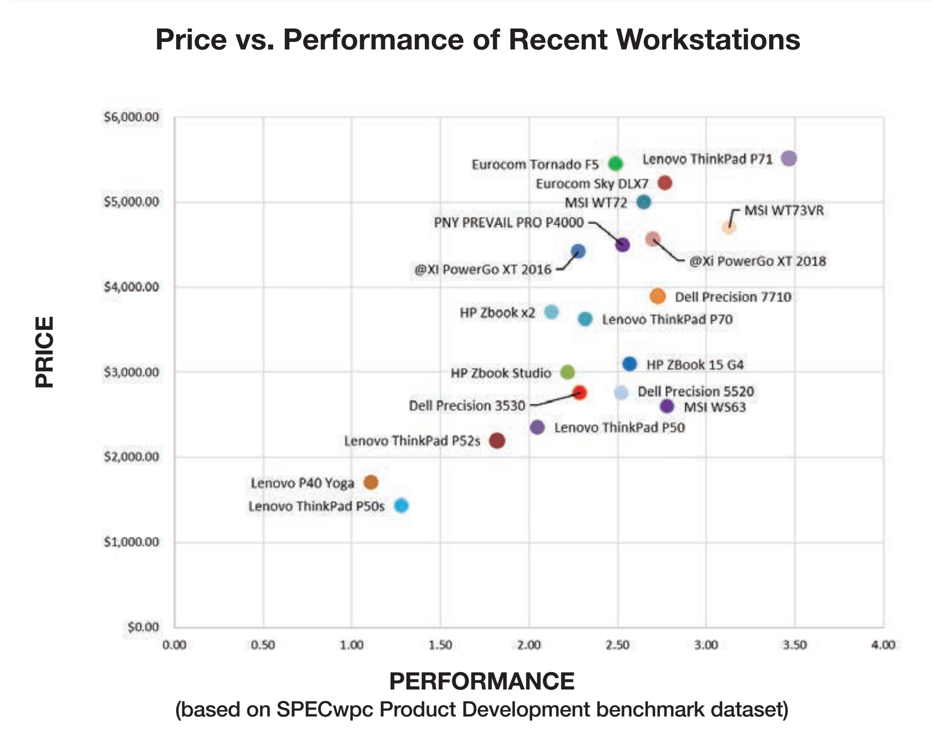
The base configuration is for a system equipped with a 2.5GHz Intel Core i5-8400H quad-core CPU, integrated Intel UHD 630 graphics, 4GB of RAM, a 500GB 7200 rpm SATA hard drive, a 1366x768 anti-glare non-touch display, a non-backlit keyboard and a 1-year warranty. But that's just the starting point.

Dell offers the Precision 3530 with a choice of one of five available Coffee Lake CPUs. The evaluation unit we received was equipped with an Intel Xeon E-2176M processor, which added $362 to the base price. This 6-core CPU, with a 12MB cache, has a base frequency of 2.7GHz and a maximum turbo speed of 4.4GHz while maintaining a thermal design power (TDP) rating of just 45 watts.

Although all available CPUs include integrated Intel graphics, our evaluation unit also included an NVIDIA Quadro P600 graphics card. This graphics processing unit (GPU), which includes 4GB of GDDR5 dedicated memory and 384 compute unified device architecture cores, is the only discrete GPU option offered on the Dell Precision 3530. Although it would normally add $94, this GPU is automatically included when selecting the Intel Xeon CPU.

Upgraded Keyboard, Display and More

Opening the sculpted charcoal gray case reveals the 15.6-in. display and a 103-key keyboard and numeric keypad with



Price/performance chart of recent mobile workstations, based on the SPECwpc Product Development benchmark.

mostly full-size keys. The keyboard on our system was backlit, a $35 option. A touchpad with two dedicated buttons is centered below the keyboard, while a pointing stick is nestled between the G, H and B keys and has its own three buttons directly below the spacebar. The keyboard had an excellent feel and ample key travel.

Although the display resolution in the base configuration is just 1368x768, Dell offers a choice of seven 15.6-in. display/camera combinations, including a 1920x1080 43% color gamut display with touch and an infrared camera. Our system included a 15.6-in. FHD WVA 1920x1080 anti-glare non-touch 72% color gamut display, with an infrared camera and microphone centered above the display, adding $125.

The Precision 3530 has two memory sockets and can be equipped with up to 32GB of RAM. Non-Xeon systems can only use non-error code correcting (ECC) memory, while Xeon-based systems can use either ECC or non-ECC memory. Most of the Xeon-based systems we've received over the years have included ECC memory, but the Precision 3530 Dell sent us included 32GB of DDR4-2666MHz non-ECC SDRAM, adding $506. That same amount of ECC memory would cost $49 more.

Dell offers a choice of 16 hard drives, including SATA drives ranging from 500GB to 2TB and M.2 drives from 256GB to 2TB. The system we received came with a 512GB M.2 PCIe NVMe Class 50 solid-state drive, adding $417. The system can support one 2.5-in. drive and one M.2 drive, or two M.2 drives. Depending on the primary drive, secondary drive options include SATA drives of 500GB to 2TB and M.2 drives from 256GB to 512GB.

Dell also offers several different wireless options. Our system included an Intel dual-band wireless AC 9560 802.11ac MU-MIMO Dual Band 2x2 plus Bluetooth 5.0, with no additional charge.

Plenty of Ports

The Dell Precision 3530 offers ample ports. The right side includes a headphone/microphone combo jack, an optional SIM card slot, one USB 3.1 port with PowerShare, a 15-pin VGA port and a security lock slot. The left side houses an optional SmartCard reader, a memory card reader, a USB 3.1 port and a USB Type-C port with optional Thunderbolt support. The case's rear sports a full-size RJ45 network jack, an HDMI port, another USB 3.1 port and the connection for the external power adapter.

Our evaluation unit included a DP Palmrest with a fingerprint reader, SmartCard and Thunderbolt support, adding another $90. The standard battery is a 4-cell 68WHr ExpressCharge-capable battery. Dell also offers a 4-cell 68WHr long-life cycle battery for $35 more. Our system came with a 6-cell 92WHr ExpressCharge-capable battery, which added $49 to the total cost and kept our system running for 9 hours and 26 minutes. Like other systems we have recently reviewed, the battery is not user-accessible.

Great Performance

The Dell Precision 3530 remained cool and nearly silent throughout our testing, although the fans became quite audible under heavy compute loads, with sound pressure levels reaching a peak of 46dB. The results for the SPECviewperf test (see page 42) placed the 3530 in the middle of the pack, on par with similar systems from HP and Lenovo but well behind desktop replacement systems equipped with more powerful GPUs.

Scores for the SPECapc SolidWorks benchmark were much better, however, illustrating that the Dell Precision 3530 is definitely a mobile workstation capable of running CAD software.

On the demanding SPECwpc benchmark, the Dell Precision 3530 performed quite well. Although its results were again mid-pack, it was clearly up to the task. On our own AutoCAD rendering test, the 63.1-second average rendering time placed the Dell Precision 3530 slightly ahead of the other 15.6-in. mobile workstations we have recently tested.

Dell preloads Windows 10 Pro 64-bit, but with a six-core CPU you must pay an additional $153 to upgrade the operating system to Windows 10 Pro for Workstations. Ubuntu Linux is also available as an option.

Dell's standard warranty is only one year, not what we have come to expect with a workstation from a major manufacturer. Our price includes $114 to upgrade this to a three-year basic warranty with onsite service.

Other support options include up to five years of Pro Support—which includes Dell SupportAssist technology that automatically detects hardware and software issues and proactively alerts customers when they occur—as well as accidental damage coverage and extended coverage of the battery. All Dell Precision workstations also include the Dell Precision Optimizer, which uses artificial intelligence to automatically optimize system performance for your current application. The Precision 3530 has also passed MIL-STD 810G tests for ruggedness.

As configured, our Precision 3530 priced out at $2,738 with free standard delivery after applying current Dell discounts when we priced it in mid-October. With great performance and a price that won't break the bank, the Dell Precision 3530 should be a great mobile workstation for any engineer on the go. **DE**

David Cohn *is the senior content manager at 4D Technologies. He also does consulting and technical writing from his home in Bellingham, WA and has been benchmarking PCs since 1984. He's a Contributing Editor to* DE *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 ➜ Dell: dell.com

Dell Precision 3530

- **Price:** $2,738 as tested ($839 base price)
- **Size:** 14.80x9.87x0.9 in. (WxDxH) notebook
- **Weight:** 5.17 lbs. plus 1.32-lb. power supply
- **CPU:** 2.7GHz Intel Xeon E-2176M 6-core w/12MB Smart Cache
- **Memory:** 32GB (2x16GB DDR4-2666MHz non-ECC SDRAM
- **Graphics:** NVIDIA Quadro P600 w/4GB GDDR5 memory
- **LCD:** 15.6 in. FHD WVA 1920x1080 anti-glare non-touch
- **Hard Disk:** 512GB M.2 PCIe NVMe Class 50 SSD
- **Floppy:** None
- **Optical:** None
- **Audio:** Built-in speakers, built-in microphone array
- **Network:** Intel Dual-Band Wireless-AC 9560, 802.11ac, MU-MIMO Dual Band 2x2 plus Bluetooth 5.0
- **Modem:** None
- **Other:** Three USB 3.1 Gen 1 (one with PowerShare), one USB Type-C/Thunderbolt 3, HDMI, 15-pin VGA, headphone/microphone combo jack, microSD card reader, SmartCard reader, RJ-45 LAN port, integrated 1MP IR webcam, fingerprint reader
- **Keyboard:** Integrated 103-key full-size backlit keyboard with numeric keypad
- **Pointing device:** Gesture-enabled multi-touch touchpad with two buttons and pointing stick with three buttons

@Xi PowerGo XT: Portable Power Champ

This powerful mobile workstation equals desktop performance.

BY DAVID COHN

WHILE WE RECENTLY REVIEWED the latest tower workstation from @Xi Computer Corporation (see *DE* October 2018; digitalengineering247.com/r/19370), it has been more than two years since we last looked at one of the California-based company's mobile workstations (see *DE* November 2016). As was true of the Xi MTower workstation, the Xi PowerGo XT retains the same name as the system we reviewed in 2016. But this latest Xi PowerGo XT is all new, from its large chassis (manufactured by MSI) to its Intel Core i7-8086K Limited Anniversary Edition CPU.

Xi PowerGo XT is actually the name @Xi assigns to its top-of-the-line mobile workstations. In fact, the company offers PowerGo XT systems in both 15.6-in. and 17.3-in. configurations, with screens providing either 1920x1080 HD or 3820x2160 QFHD resolutions. The advertised base price of $1,799 is for the smaller version with an HD display, a 2.8GHz Intel Core i5-8400 6-core CPU, 8GB of 2400MHz RAM, an NVIDIA GeForce GTX 1060 graphics board, a 500GB 5400rpm SATA hard drive, and Windows 10 Home 64-bit.

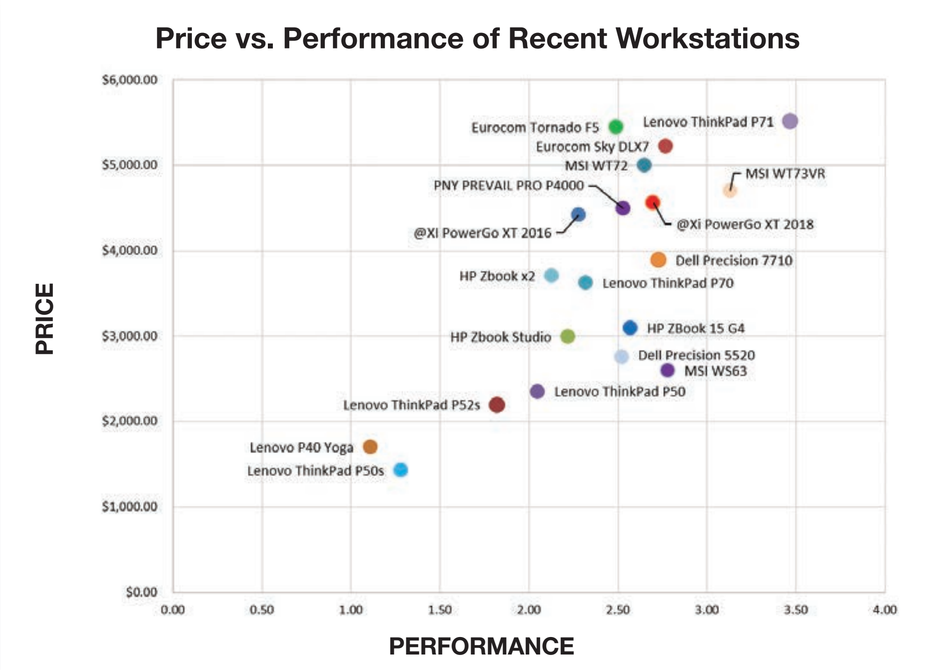
The Xi PowerGo XT delivered desktop performance. *Image courtesy of @Xi.*

The system we received was a 17.3-in. system housed in a sculpted charcoal gray case, which measured 16.85x12.3x2 inches and weighed 8 lbs. Its huge 330-watt power supply (7.87x3.87x1.62 inches) added another 2.75 lbs., bringing the total system weight to just under 11 lbs.

Raising the lid revealed the display as well as an excellent 102-key backlit keyboard and numeric keypad. A 4.25x2.5-in. gesture-enabled touchpad with a pair of buttons and fingerprint reader are centered below the spacebar. Centered above the display is a 2-megapixel webcam and microphone array. There are also a pair of speakers for the integrated audio plus a subwoofer. A V-shaped power button is located in the upper-right corner above the numeric keypad and glows when the system is powered up. Four additional buttons below this let you switch between the discrete and integrated graphics, increase the fan speed, and launch pre-defined programs. Small LEDs light up to indicate caps lock and number lock.

Mobile Workstation Has lots of Options

The right side of the case offers a pair of USB 3.1 ports, a smartcard reader, an SD card reader, a security lock slot and a large ventilator grille. The left side provides a similar air vent as well as three additional USB 3.1 ports and four audio jacks: line-in, line-out, microphone and headphone (which also doubles as an S/PDIF connector). The rear panel includes an RJ-45 network connector, a Thunderbolt (Type-C) port (that supports USB 3.1, PCIe, HDMI, DisplayPort, 4K monitor output and portable charging when AC power is connected), a power connector, a mini-DisplayPort, an HDMI port and two more large



Price/performance chart based on SPECwpc Product Development benchmark.

air vents. There are also lots more air vents on the bottom of the case. Three LEDs along the front edge of the system indicate when Wi-Fi is enabled, battery status and hard drive activity. Despite its size, there is no provision for an optical drive (@Xi sells optional external DVD and Blu-ray drives) and the battery is not user-accessible.

@Xi offers five CPU options, all of them 8th-generation 6-core "Coffee Lake" processors. Our evaluation unit came with the aforementioned Intel Core i7-8086K, a 4.0GHz CPU with a 12MB cache, a maximum turbo frequency of 5.0GHz and a thermal design power (TDP) rating of 95 watts. This processor, which also includes Intel UHD Graphics 630, added $349 to the base price.

Although the base unit comes with 8GB of DDR4 memory, you can configure your Xi PowerGo XT with up to 64GB of RAM. Our evaluation unit came with 32GB of 2400MHz memory, installed as a pair of 204-pin SO-DIMMs, adding $385. Memory with speeds of 2666MHz is also available.

All versions of the Xi PowerGo XT include an NVIDIA discrete graphics card, but you have a choice between GeForce and Quadro. All three of the Pascal-based Quadro GPUs are VR-ready. The system we received included an NVIDIA Quadro

Mobile Workstations Compared	Dell Precision 3530 15.6-inch 2.7GHz Intel Xeon E-2176M 6-core CPU, NVIDIA Quadro P600, 32GB RAM, 512GB NVMe PCIe SSD	@Xi PowerGo XT 2018 17.3-inch 4.0GHz Intel Core i7-8086K 6-core CPU, NVIDIA Quadro P4200, 32GB RAM, 500GB NVMe PCIe SSD	Lenovo ThinkPad P52s 15.6-inch 1.9GHz Intel Core i7-8650U quad-core CPU, NVIDIA Quadro P500, 16GB RAM, 1TB NVMe PCIe SSD	HP Zbook x2 14.0-inch detachable 1.9GHz Intel Core i7-8650U quad-core CPU, NVIDIA Quadro M620, 32GB RAM, 512GB NVMe PCIe SSD	Lenovo ThinkPad P71 17.3-inch 3.1GHz Intel Xeon E3-1535M v6 quad-core CPU, NVIDIA Quadro P5000, 64GB RAM, two 512GB NVMe PCIe SSDs in RAID 0 array	HP Zbook 15 G4 15.6-inch 3.0GHz Intel Xeon E3-1505M v6 quad-core CPU, NVIDIA Quadro M2200, 32GB RAM, 512GB NVMe PCIe SSD
Price as tested	$2,738	$4,558	$2,196	$3,710	$5,517	$3,095
Date tested	8/28/18	8/7/18	6/12/18	4/5/18	12/14/17	12/1/17
Operating System	Windows 10	Windows 10	Windows 10	Windows 10	Windows 10	Windows 10
SPECviewperf 12 (higher is better)						
catia-04	38.67	165.95	28.64	30.81	145.81	71.62
creo-01	42.99	138.65	33.26	34.75	119.20	69.15
energy-01	3.12	14.87	0.55	0.63	14.51	5.29
maya-04	38.42	128.84	20.96	23.25	92.67	50.99
medical-01	12.61	63.65	9.41	11.02	66.51	25.62
showcase-01	19.70	73.41	12.55	15.94	65.73	32.19
snx-02	37.25	172.95	43.91	26.33	250.00	58.62
sw-03	70.59	181.61	50.01	57.28	151.51	97.14
SPECapc SOLIDWORKS 2015 (higher is better)						
Graphics Composite	4.77	5.32	1.94	2.36	3.64	6.60
Shaded Graphics Sub-Composite	3.17	3.48	1.17	1.44	2.11	3.33
Shaded w/Edges Graphics Sub-Composite	4.06	4.38	1.64	2.22	2.79	4.65
Shaded using RealView Sub-Composite	3.59	3.87	1.48	1.72	2.54	4.73
Shaded w/Edges using RealView Sub-Composite	4.07	4.36	1.98	3.05	3.22	7.85
Shaded using RealView and Shadows Sub-Composite	4.10	4.46	1.69	1.54	2.93	5.40
Shaded with Edges using RealView and Shadows Graphics Sub-Composite	4.26	4.61	2.00	2.57	3.45	8.34
Shaded using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	11.20	14.75	3.01	3.17	9.61	15.31
Shaded with Edges using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	11.01	13.51	3.54	4.77	9.66	21.43
Wireframe Graphics Sub-Composite	3.85	4.15	2.43	2.65	3.13	3.41
CPU Composite	4.55	5.40	1.72	1.75	2.39	4.07
SPECwpc v2.0 (higher is better)						
Media and Entertainment	2.23	4.14	1.71	1.97	3.38	2.63
Product Development	2.29	2.70	1.82	2.13	3.47	2.57
Life Sciences	2.26	4.40	1.83	2.25	4.18	3.01
Financial Services	3.34	5.37	1.91	0.85	3.14	2.87
Energy	2.28	4.08	1.42	0.87	6.43	2.11
General Operations	1.30	1.55	1.20	1.68	1.90	1.62
Time						
Autodesk Render Test (in seconds, (lower is better)	63.10	29.30	89.70	78.00	48.40	72.70
Battery Life (in hours:minutes, higher is better)	9:26	3:56	5:33	5:00	6:05	13:30

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

P4200, with 2304 CUDA cores and 8GB of dedicated GDDR5 memory, increasing the system cost by $1,399. You could also opt for a P3200 ($599) or go with the high-end Quadro P5200 GPU, which would add $2,549.

As previously noted, our evaluation unit came with a 17.3-in. 1920x1080 display. @Xi offers several choices. The panel included in our system featured a 120Hz refresh and 94% NTSC color gamut, adding $109. A 3820x2160 display is also available for $339.

With a system this large, you would expect there to be lots of storage options, and indeed @Xi offers 24 choices of primary drives, including 2.5-in. SATA drives of up to 2TB and solid-state drives ranging from 500GB to 4TB. Our evaluation unit came with a 500GB solid-state NVMe Samsung 970 EVO 2 PCIe drive, which added $179. The system also supports a second 2.5-in. drive, chosen from a similar list of available drives. If you opt for two identical drives, you can also configure them in a RAID array. The Xi PowerGo XT also supports up to two M.2 SSDs, with RAID capability.

All Xi PowerGo XT systems include built-in gigabit Ethernet with Wi-Fi and Bluetooth, although you can upgrade from dual band wireless-AC 9260 to wireless-AC 1550 for $29. Systems destined for use in restricted areas can be ordered without wireless, Bluetooth or webcams. Because the system is VR-ready, @Xi also offers the HTC Vive VR headset as an add-on.

A non-removable 8-cell lithium-ion battery comes standard and kept our evaluation unit running for nearly 4 hours before shutting down. Throughout our tests, the Xi PowerGo XT remained cool and quiet, averaging just 35dB at rest (compared to 29dB ambient background noise), climbing to 52dB under compute loads (equivalent to office conversation).

Record-Setting Mobile Workstation Performance

With its fast CPU and high-end NVIDIA graphics, we expected the Xi PowerGo XT to deliver great performance, but the results still surprised us. On the SPECviewperf test, which looks exclusively at graphic performance, the Xi PowerGo XT delivered the best results we have ever recorded for a mobile workstation on almost every dataset, approaching and sometimes even beating the performance of many desktop systems.

While its performance on the SPECapc SolidWorks test did not set records, the numbers we recorded for the @Xi mobile workstation were again near the top among both mobile and desktop workstations. On our AutoCAD rendering test, which clearly shows the advantage of fast CPUs with multiple cores, the Xi PowerGo XT mobile workstation averaged just 29.3 seconds to complete our test rendering, faster than any other mobile workstation we have ever tested and just 5 seconds behind the Xi MTower PCIe workstation we recently reviewed.

We also ran the SPECwpc workstation performance benchmarks. Here again, the Xi PowerGo XT outperformed every other mobile workstation we have ever tested, turning in record-setting results on nearly every component of this very demanding test.

Although the base configuration comes with Windows 10 Home, our system included Windows 10 Professional 64-bit, which added $59. Like many other system integrators, the standard @Xi warranty only covers the Xi PowerGo XT for 1 year, with express advance parts replacement and lifetime tech support. Two- and three-year warranties are also available, and our total price of $4,558 includes an additional $279 for the three-year warranty (the standard coverage for workstations from most major OEMs).

Like its predecessor, the Xi PowerGo XT is meant to be a desktop replacement. It delivers performance comparable with a high-end desktop workstation, at a cost $500 higher than the Xi MTower PCIe workstation we recently reviewed. The Xi PowerGo XT is likely to appeal to a small set of users for whom portability trumps other concerns. For them, the Xi PowerGo XT delivers the goods. DE

David Cohn *is the senior content manager at 4D Technologies. He also does consulting and technical writing from his home in Bellingham, WA and has been benchmarking PCs since 1984. He's a Contributing Editor to* DE *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 ➜ @Xi Computer Corp.: xicomputer.com

Xi PowerGo XT

- **Price:** $4,558 as tested ($1,799 base price)
- **Size:** 16.85x12.36x2.00 inches (WxDxH) notebook
- **Weight:** 8.0 lbs. as tested, plus 2.75 lbs. 330-watt power supply
- **CPU:** 4.0GHz Intel Core i7-8086K 6-core w/12MB cache
- **Memory:** 32GB DDR4 at 2400MHz (4 sockets, supports up to 64GB)
- **Graphics:** NVIDIA Quadro P4200 w/8GB memory and 2304 CUDA cores
- **LCD:** 17.3-inch diagonal (1920x1080), non-glare
- **Hard Disk:** 500GB Samsung 970 EVO M.2 PCIe NVMe SSD
- **Optical:** none
- **Audio:** line-in, line-out, microphone, headphone (with S/PDIF-out), plus built-in microphone and speakers
- **Network:** integrated Gigabit Ethernet (10/100/1000 NIC) with one RJ-45 port, and Intel Dual Band Wireless-AC 9260 plus Bluetooth
- **Modem:** optional
- **Other:** five USB 3.1, one USB 3.1 Type Thunderbolt port, one mini-DisplayPort, one HDMI-out, 2MP webcam, one SD card reader, one Smartcard reader
- **Keyboard:** integrated 102-key backlit keyboard with numeric keypad
- **Pointing device:** integrated 2-button touchpad and fingerprint reader

Biomimicry Inspires Lightweight Lattice Design

The combination of nature and new topology optimization and simulation tools serves up a powerful approach to achieving lightweighting design goals.

BY BETH STACKPOLE

THE CUTTLEFISH, HOWEVER PRIMITIVE, is one of nature's greatest inspirations. Scientists have discovered its ability to change its skin's physical texture in a matter of seconds and its bone structure has evolved to be strong enough to withstand high pressure in the deep sea despite a relatively lightweight structure.

It's no wonder, then, that researchers and engineers are looking for a little inspiration from the cuttlefish to develop unique lattice structures to lightweight traditional components in aerospace and automotive applications, among others.

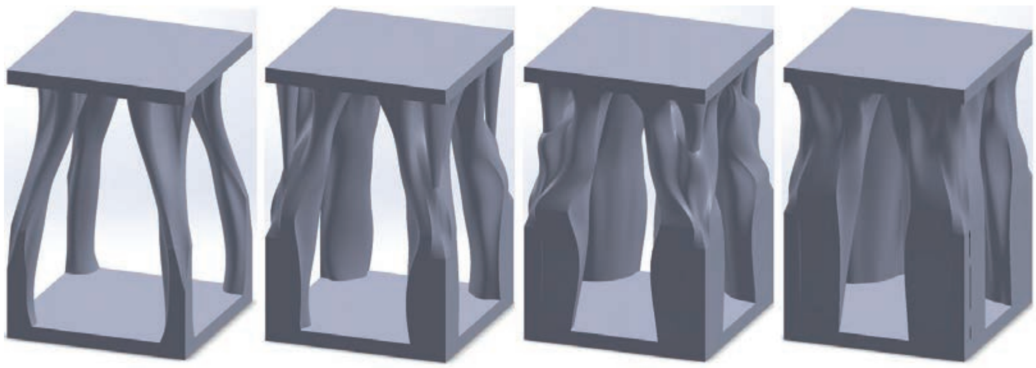
Although the practice of biomimicry has long been used as a muse to inspire creative engineering, there is a small, but growing body of work underway to meld biomimicry principles with the latest simulation and generative design tools to unleash nature's time-tested work on specific engineering challenges.

The complexity of modern engineering challenges such as creating lattice structures to achieve lightweighting and other functional design objectives demands an alternative approach to the traditional trial-and-error processes. "Nature evolves and creates a better design each time that is lighter, faster or stronger, but it takes a long time, lots of iteration and generations of failed designs," says Steve Pilz, director of additive manufacturing engineering at ANSYS. "Engineers can save time on iteration by using nature as the starting point."

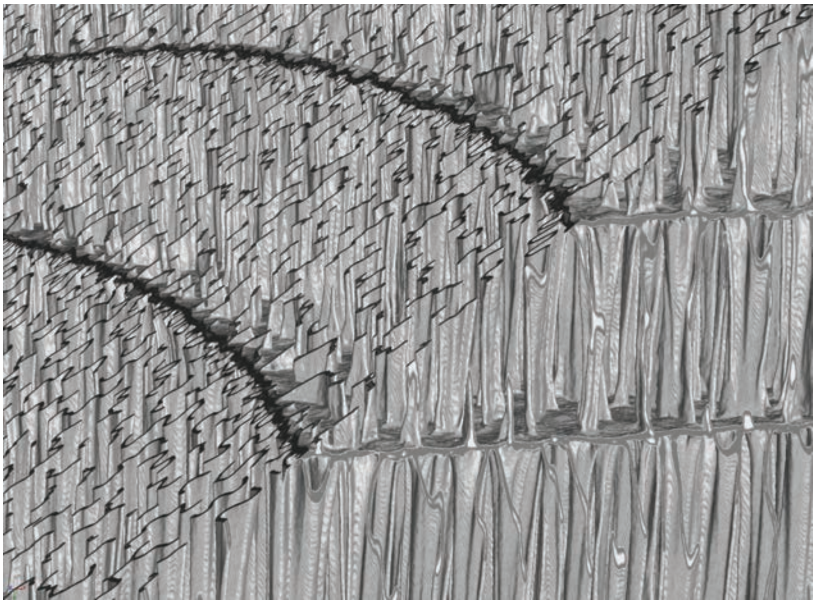
The Cuttlefish Project

Using nature as a foundation was the idea behind a research effort conducted by a mechanical and materials engineering team at South Dakota State University. Their objective was to use topology optimization to create optimal lightweight lattice structural composites by drawing inspiration from cuttlefish bones.

The tight coupling between the composition, microstructure, porous topology and lattice structural composition fabrication ruled out conventional trial-and-error development processes. This prompted the team to explore a new approach for multifunctional lattice structural composites that use biomimicry and are based on topology optimization.



The design space explored optimized 3D periodic block topologies with various porosities, from left to right: 90%, 80%, 70% and 60%. ***Image courtesy of Professor Zhong Hu, Ph.D., South Dakota State University.***



3D visualization of µCT of a sepias cuttlebone. µCT was done using CT Alpha by ProCon X-Ray GmbH, Garbsen, Germany. Visualization was done using VG Studio Max 2.1 by Volume Graphics, Heidelberg, Germany. Resolution ~5 µm/voxel. ***Image courtesy of SecretDisc; CC BY-SA 3.0 from Wikimedia Commons.***

Cuttlefish bone was chosen as the biomimicry starting point, given its exceptional combination of desirable mechanical properties, including high compressive strength, high porosity and high permeability—all desired attributes for engineering and biomedical material applications, says Zhong Hu, one of the report's authors and a professor of mechanical engineering at South Dakota State University. "The goal was to take the structure and optimize it," Hu says. "We wanted to come up with a similar structure so we could understand why the cuttlefish bone was strong."

Because the cuttlefish bone structure is said to have been optimized over millions of years of evolution, Hu's team of researchers didn't necessarily know exactly why the materials were optimized in a specific way or at all for their specific lightweighting materials application.

As a result, Hu and his team enlisted ANSYS topology optimization software to explore how the materials were optimized for a specific environment and more importantly, how to further evolve the lattice structure materials for specific applications, including fabrication and scale-up for real-world engineering use.

Although topology optimization tools like ANSYS are used widely in isotropic material design, there has been far less exploration of their applicability for design of anisotropic materials such as fiber-reinforced composites.

For this particular effort, Hu's team started with 3D periodic lattice blocks, which initially used the cuttlefish bone microstructure as inspiration. From there, the ANSYS tools were used to optimize the topology of the predefined 3D block composite structures, and the mechanical properties of the optimized lightweight lattice structural composites were then characterized by compression testing through additional simulation using ANSYS tools.

The topology optimization process was necessary because you can't apply the cuttlefish microstructure to lattice composite design as a one-to-one fit. "You won't be able to come up with the biomaterial structure of nature because evolution is complicated," Hu says. "For example, you can't duplicate bone structure exactly because you don't have bone material." In addition, natural unit cell patterns like those of cuttlefish bones have varying structures, which would be impossible to replicate without additional exploration, he says.

Topology Optimization's Role

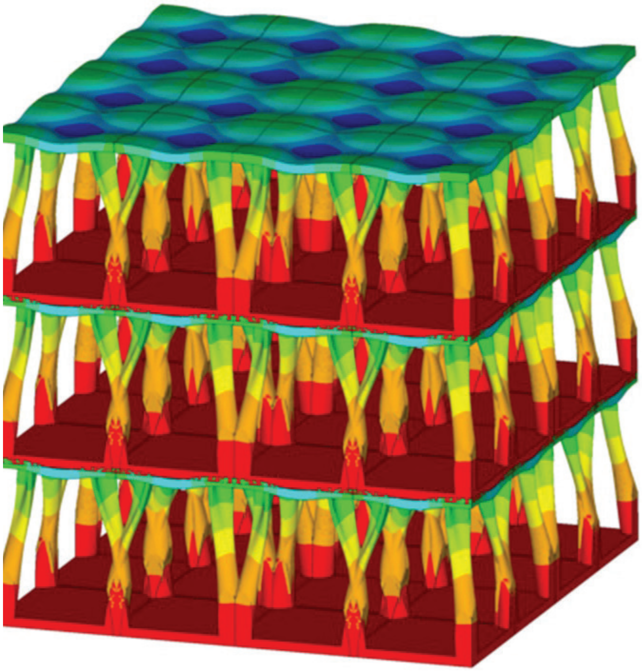
In fact, ANSYS' Pilz argues that biomimicry on its own is not really a valid engineering approach at this stage, but rather a foundational principle for unshackling engineers from conventional design constraints. The reason, as Hu's team found out, is that humans don't necessarily understand the boundary conditions and constraints that nature inherently knows so well. Take bamboo or grass, for example, which are common lightweight structures that engineers use for inspiration.

"They are strong and can resist wind loads, but they also have to perform more than holding the structure upright—they need to transport fluids and nutrients as well," he explains. "Therefore, what is the optimal shape for transporting nutrients and how do you combine that with the optimal shape for resisting torsional wind loads? If we just took a cross-section of the stem of the plant, it might be optimized for something we might not need because our understanding of what nature is using to optimize is far from complete."

On the other hand, he argues that topology optimization is the better approach to achieving lightweighting and other design objectives, invoking biomimicry principles for inspiration and as a checkpoint for validation.

"Rarely do we see topology optimization produce a structure identical to nature," Pilz says, suggesting a different design workflow whereby engineers copy a structure in nature like a dragonfly wing, model it with 3D design tools and use (finite element analysis) to validate what the lattice structure achieves. At that point, it's time for topology optimization to make improvements. "It could help create the next iteration rather than waiting for nature to create a better dragonfly wing," he says. "(High-performance computing) can work faster than nature can."

Dhruv Bhate, an associate professor for additive manufacturing at Arizona State University, goes even further, arguing that biomimicry of nature's cellular materials and structures



Using the topology optimized 3D periodic blocks (90% porosity), the research team built a lattice structure for the lightweight structural applications. *Image courtesy of Professor Zhong Hu, Ph.D., South Dakota State University.*

should not just be limited to lightweighting objectives, but also help achieve multifunctionality in design goals.

Because topology optimization and generative design have significantly advanced over the last few years and are accessible to more engineers, he argues they can achieve today's lightweighting objectives, and leave biomimicry principles for higher-level, multifunctional engineering goals.

"Most people are integrating lattice into structural components just to reduce weight, but there are other ways to achieve that, like with topology optimization," Bhate explains. "For biomimicry to justify its value in a highly machine-driven environment for design, you have to be asking questions that go beyond the realm of transitional design and go down avenues we're not typically thinking about in terms of multifunctionality."

Challenges Abound

There are other challenges to combining biomimicry principles with topology optimization in pursuit of the design of lattice structures to achieve lightweighting goals. The complexity of the current generation of tools for creating lattice structures is one big hurdle, according to Andreas Vlahinos, principal at Advanced Engineering Solutions, an engineering service provider. Most available tools lack a complete taxonomy of lattice structures, and what is available is not well-organized, making it difficult for engineers, most not familiar with the concepts, to select the right lattice structure.

"There is not enough guidance for selecting the right lattice for the right job," he says. "We need more (artificial intelligence) capabilities in these tools to guide the user to what lattice structure to use—nature has lots of experience, engineers don't."

There is also still a disconnect between the lattice structure generation software and topology optimization. Vlahinos contends that tighter integration between the two toolsets would streamline the engineering workflow and lead to more widespread use of lattice structures for lightweighting applications.

"What's needed is lattice generation driven by topology optimization, not humans," he says. "Humans don't have enough information and brainpower to tell the lattice structures we have high stress here so make this wall thicker. There are millions of these little beams, and we can't go to each one to make adjustments. We want that driven by topology optimization codes."

Finally, education and exposure—both for topology optimization's potential and where and when biomimicry principles are important—are crucial to getting engineers to embrace a different mindset along with the new generation of tools. DE

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

INFO ➜ South Dakota State University: SDstate.edu

➜ **Arizona State University:** ASU.edu

➜ **ANSYS:** ANSYS.com

➜ **Advanced Engineering Solutions:** AES.nu

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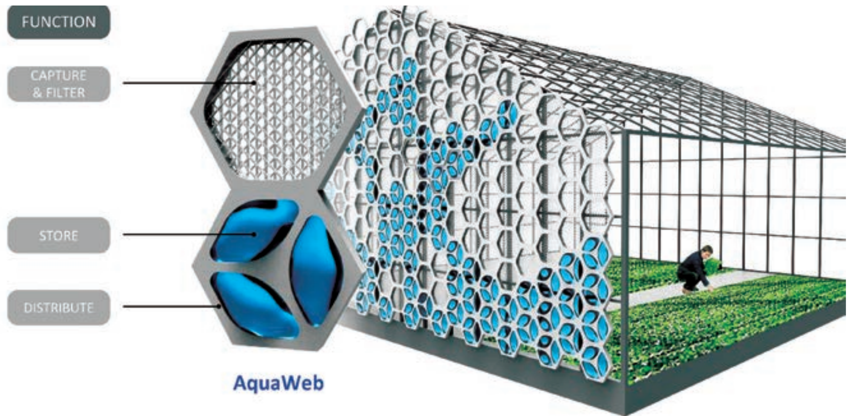
Next-Gen Engineers

The Biomimicry Institute's Global Design Challenge

Designing for Environmental Sustainability

BY JIM ROMEO



Team NexLoop won the $100,000 Ray C. Anderson Foundation Ray of Hope Prize in 2017 for its AquaWeb prototype that mimics the way living systems capture, store and distribute water. ***Image courtesy of NexLoop via the Biomimicry Global Design Challenge.***

THE BIOMIMICRY GLOBAL DESIGN CHALLENGE (BGDC) is hosted in partnership with the Ray C. Anderson Foundation. The annual competition invites university students and professionals to address sustainability issues critical to environmental stewardship and concerns, with nature-inspired solutions.

Megan Schuknecht is the director of design challenges at the Biomimicry Institute. We spoke to her to learn about the design challenge and the types of projects they see.

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

Megan Schuknecht: We created the BGDC to provide free biomimicry learning opportunities to anyone around the world and, ultimately, to help more biomimetic sustainability solutions become commercialized. We invite challenge finalists to enter the Biomimicry Launchpad, an accelerator program that supports early-stage entrepreneurs trying to bring nature-inspired technologies with significant social or environmental benefits to market. Each year, the winner of the Launchpad is awarded the $100,000 Ray of Hope Prize, which honors the late Ray C. Anderson and his belief in the power of business to be a force for good and to have purpose. Both the program and the Ray of Hope Prize are sponsored by our partner, the Ray C. Anderson Foundation.

Participants in the BGDC come from all over the world. Anywhere from 65 to 120 teams participate annually, and most teams are made up of university students or young professionals. And, because nature-inspired design can be applied anywhere, we attract participants from a wide swath of disciplines. Approximately 15% of our teams continue to evolve their designs, either as entrepreneurs or through thesis work or academic studies.

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

Schuknecht: Many of our teams use CAD, simulation software and 3D printing to produce their designs and prototypes, though we also encourage sketching and building by hand to better understand both the biology and how the technical components of their designs work. NexLoop, a team working at the food-water-energy nexus, learned lessons from epiphytes, orb weaver spiders and ice plants on how nature captures water and applied what they learned to create a product called AquaWeb (using 3D printing), which harnesses water from rain, fog or humidity to be used in urban food production. They'll be installing their first large pilot system on Governors Island in New York Harbor in early 2019.

Nucleário, a team from Brazil that is addressing challenges within forest restoration, was the winner of the 2018 Ray of Hope Prize. Traditional Atlantic rainforest restoration in remote areas is logistically challenging and requires manual work for three years after planting to maintain the seedlings. It also requires a lot of chemical inputs. The Nucleário planting system, made with biodegradable materials, ensures that seedlings survive by providing protection from leafcutter ants, collecting water from rain and dew, offering shade and protecting against invasive species, such as the Brachiaria grass that is now pervasive in much of the 17 million acres of former Atlantic rainforest that are ripe for restoration.

Next year the BGDC will be featuring categories to enter, rather than themes, so you can expect to see a broader set of solutions in the future. **DE**

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

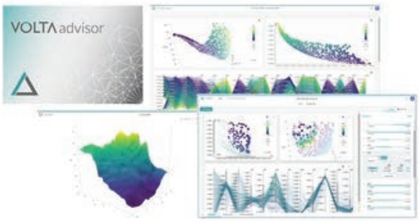
MORE → biomimicry.org/design-challenges/

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.*

Make Managing Complexity Less Complex

Labyrinthine design processes can render informed decision-making tough going.



ESTECO recently debuted VOLTA and modeFRONTIER Release 2018 Winter. Both see enhancements and functionality intended to make complex processes, optimizations and simulation data management less complex. VOLTA is a web-based, multidisciplinary platform with enterprise-wide simulation data management, design optimization and more. modeFRONTIER's modular environment is intended to help manage engineering design process steps.
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Acoustics Simulations Extended for Turbomachinery

New wizard helps predict tonal and broadband noise for turbomachinery.

NUMECA released version 8.1 of its FINE/Acoustics integrated simulation suite for aero-acoustics and vibro-acoustics projects. They also added more functions to the Python API (application programming interface) to extend scripting abilities. Still, the key new addition is a wizard for turbomachinery broadband and tonal noise analyses. It works with results generated by company's turbomachinery and multiphysics CFD environments.
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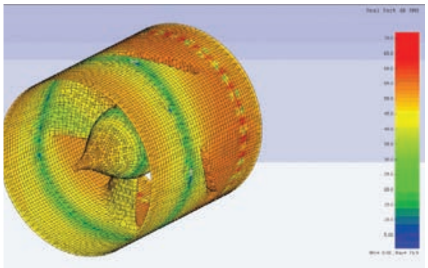
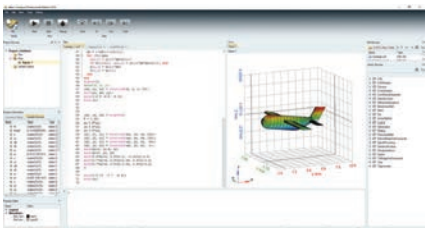


Altair Debuts Core MBD Suite for Free

Company also makes OML programming language source code open and free.



Altair launched Basic Editions of its suite of Model-Based Development software for designing multidisciplinary control and signal processing systems. At the same time, Altair opened up its OML (OpenMatrix Language) computational programming language source code. All are free downloads.

Core editions of Model-Based Development tools are for designing multidisciplinary control, signal processing and similar systems.
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Simulate Metal Part Designs Before 3D Printing

Metal AM process simulation can help you find and fix problems fast.

Materialise unveiled a metal AM simulation module for its Materialise Magics 3D printing suite. This set of tools can help you spot and repair problems with your part designs before they head off to metal AM production floor.

Part of its secret sauce is that the module leverages an OEM (original equipment manufacturer) version of the Simufact Additive Solver, a scalable, dedicated solution for simulating metal-based AM processes.
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