digitaleng.news //////

# DE
Digital Engineering

May 2018



# ENGINEERING'S LINK TO BLOCKCHAIN

by Jamie J. Gooch

# Making Connections

ARE YOU TIRED OF HEARING about the internet of things (IoT)? If so, you're out of luck. Forecasts from industry experts vary a bit, but they all predict the billions of "things" connected to the internet will grow to tens of billions in just a few years. The IoT continues to grow by leaps and bounds because of the power of those connections.

*DE* has covered the early pilots of the IoT and today's implementations. Leading-edge companies in vertical markets from every sector have begun to reap the benefits of connected products. The real-world use cases don't always go smoothly, but the hype surrounding the IoT has always been justified because of the enormous possibilities inherent in those connections.

We're still in the early days of IoT implementations. Experts expect the future to be filled with the types of cross-industry connections that will allow smart cities and self-driving cars to flourish. For example, traffic lights and street signs could communicate with self-driving cars to provide information on everything from traffic congestion to what's around the corner.

As leaders in cross-industry IoT implementations have already found in smart city integrations in Singapore, Barcelona and London, it takes more than connecting products to reap the technology's benefits. You also have to connect people—the people from different industries who can implement the integrations and the city's residents who can make use of smart technologies to find an open parking spot, pay utilities via their phones or avoid traffic jams.

## The Human Connection

Connecting with people is just as important to advancing innovation as technology. Materialise Co-Founder and CEO Wilfried Vancraen was presented with the Additive Manufacturing Users Group (AMUG) Innovators Award at AMUG 2018 last month. During an on-stage discussion that covered the company's founding in 1990 to his outlook for the future, he shared a story that is the perfect example of making human connections to bypass technological adoption roadblocks.

During the Iraq War, Vancraen was frustrated with what he knew technology was capable of providing and its lack of widespread use. He had seen wounded soldiers benefit from 3D-printed prosthetics and medical devices via Materialise's work with the Walter Reed National Military Medical Center in Washington, D.C., but knew there were many wounded civilians in Iraq who could also benefit from the technology.

He contacted Doctors Without Borders, but the organization was already pulling out of Iraq for safety. Through his connections at the University of Leuven, Belgium, Vancraen was able to contact a student in Baghdad. "Through wartime, the internet kept working in Baghdad perfectly," he said. "We Skyped with each other and I hired him over the internet."

The new employee began finding victims with severe injuries and bringing them to hospitals to be scanned. Materialise, with the help from many in the 3D printing and medical industries who donated time and products, expanded its team in Baghdad and began delivering 3D-printed prosthetics to patients there.

"During that time, we received, from this community, on an annual basis, approximately $1 million in gifts," Vancraen said. The donations were collected in Leuven, where the company is headquartered, and shipped to Baghdad with the help of Doctors Without Borders.

Vancraen was able to connect technological innovations with the people who could benefit from them and the people willing to provide them—from 3,000 miles away, during a war.

## The Conference Connection

With the justified news coverage of IoT security concerns, Facebook's recent data breach and doomsday artificial intelligence scenarios as a backdrop, it might cause some people to pump the brakes on connectivity. But as Vancraen's story illustrates, making the right connections can do the world a lot of good.

If you've been to an industry event, you've no doubt been urged to take the time to talk to fellow attendees. I would urge you to as well. If you haven't been to a conference in a while, I would urge you to make the time. Online social networking makes it easy to connect over distances and time constraints, but it pales in comparison to meeting face to face. A gathering of engineers from different industries is the perfect place to make the types of deep connections that can help you solve product design and development technologies, as well as overcome the cultural roadblocks that often hinder innovation. **DE**

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

# DE
Digital Engineering

TECHNOLOGY FOR OPTIMAL ENGINEERING DESIGN

# INSIDE

digitaleng.news

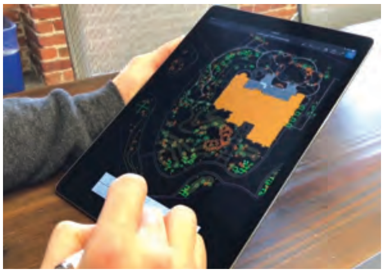
May 2018
Vol.23 • No.9

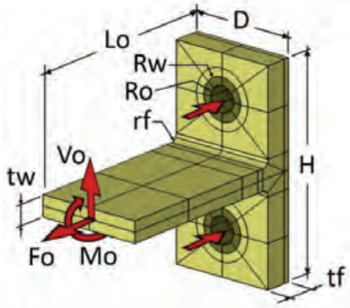
COVER STORY

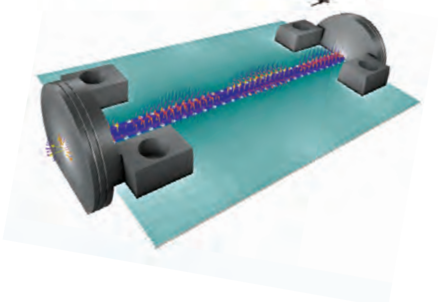


## FEATURES







**ON THE COVER**: Image courtesy of iLexx/Thinkstock

## FOCUS ON IoT



## ENGINEERING COMPUTING



## DEPARTMENTS




**PUBLISHER**
Tom Cooney

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

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

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

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

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

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

**ADVERTISING, BUSINESS, & EDITORIAL OFFICES**
*Digital Engineering®* Magazine

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

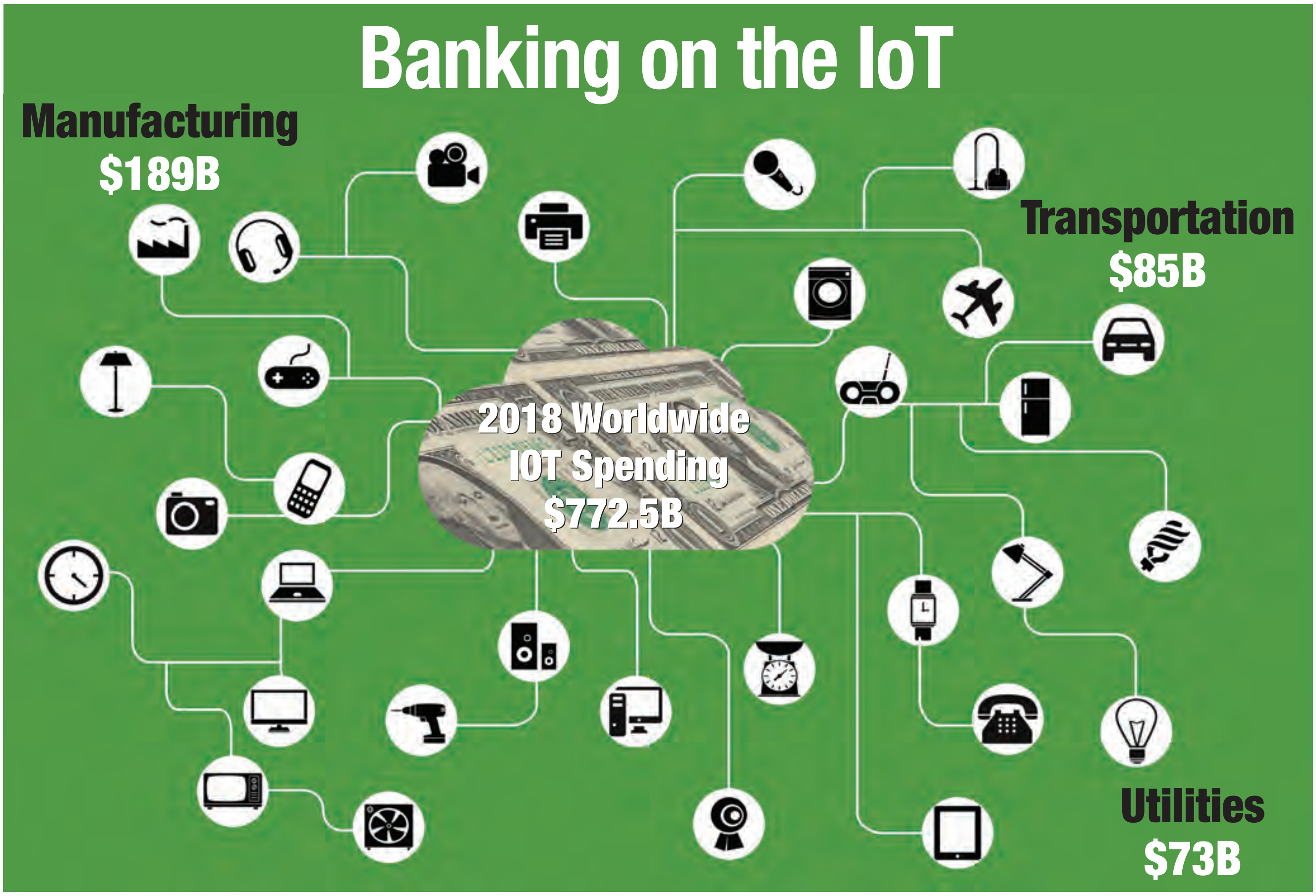
Kenneth Moyes | President and CEO, EH Media

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

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


Address all editorial correspondence to the Editor, *Digital Engineering*. Opinions expressed by the authors are not necessarily those of *Digital Engineering*. Unaccepted manuscripts will be returned if accompanied by a self-addressed envelope with sufficient first-class postage. Not responsible for lost manuscripts or photos.

# BY THE NUMBERS | INTERNET OF THINGS

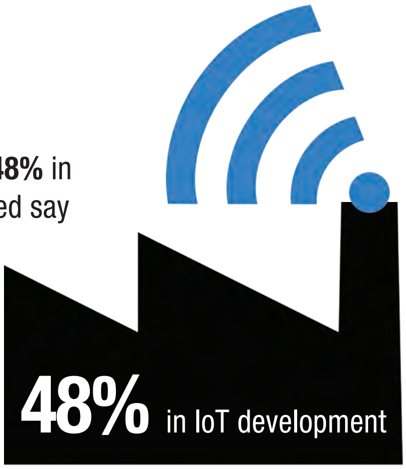



The industries that are expected to spend the most on IoT solutions in 2018 are manufacturing (**$189 billion**), transportation (**$85 billion**), and utilities (**$73 billion**). Use cases common to all industries, such as connected vehicles and smart buildings, will be nearly **$92 billion** in 2018.

Worldwide spending on the IoT is forecast to reach $772.5 billion in 2018, an increase of 14.6% over the $674 billion spent in 2017. It is expected to surpass **$1 trillion** in 2020.

*— International Data Corporation (IDC) Worldwide Semiannual Internet of Things Spending Guide, Dec. 7, 2017.*

## Industrial Strength IoT




**38%** of manufacturers are offering IoT-driven products and services, with **48%** in the process of developing them. However, only **14%** of manufacturers surveyed say they have created go-to-market IoT strategies.

**10%** Over the next five years, manufacturers expect that the revenue driven by IoT-based products and services will increase by an average 10% of total company revenue.

*— PwC, "Monetizing the Industrial Internet of Things," July 2017*

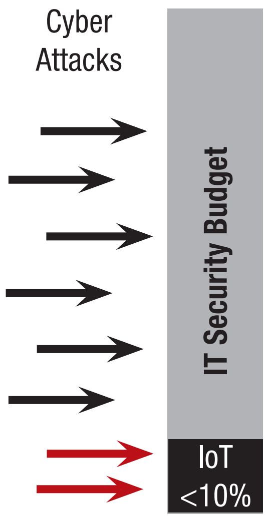
# IoT Slowed By Security?


**70%** of companies say data security and privacy concerns top the list of challenges that threaten to slow down IoT adoption.

*— CXP Group, Digital Industrial Transformation with the Internet of Things, 2017*

**25%** or more of identified cyberattacks in enterprises will involve the internet of things, even though the IoT will account for less than **10%** of IT security budgets.

*— Gartner, Leading the IoT, Gartner Insights on How to Lead in a Connected World, 2017*




**27.5% CAGR** The North American IoT security market was valued at **$136.56 million** in 2017, and it is expected to reach **$588.31 million** by 2023, a compound annual growth rate of 27.56%.

*— Orbis Research, North America Internet Of Things (IoT) Security Market, February 2018.*

# Accelerated by 5G?


The global 5G value chain will generate $3.5 trillion in output and support **22 million jobs** in 2035.

The **$3.5 trillion figure** is larger than the value of today's entire mobile value chain.

*— IHS, "The 5G economy: How 5G technology will contribute to the global economy" January 2017*

# NVIDIA GTC 2018: GPU Maker Continues to Bet Heavily on AI and Autonomous Cars

**BY KENNETH WONG**

ON MARCH 27, THE NVIDIA GPU Technology Conference (GTC 18), an annual gathering of GPU computing champions and gurus, opened with "The Greatest Show," the energetic, upbeat theme song from the film by the same name.

---

Sporting his trademark biker jacket, NVIDIA CEO Jensen Huang strolled up to the main stage inside the San Jose Convention center.

"From one frame in many hours to 60 frames per second—that fundamental difference was the gap we've been trying to close for literally four decades," he said.

Real-time ray tracing is computation intensive. It involves calculating every light ray's physical path to accurately render a virtual scene. Most users activate it only when such visuals are absolutely essential. Even minor changes to the scene, from a switch in perspective to a shifted light source, prompt recalculation of the light rays all over, putting a burden on the system.

## The Elevator Pitch

A little over 10 minutes into the keynote, Huang paused, allowing what seemed like a short Star Wars-themed movie clip to run on the oversized screen. Created with the help of Epic Games, it depicted the moment two stormtroopers had the misfortune to share an elevator ride with their high commander.

Except, it wasn't a pre-rendered movie clip but a real-time, ray-traced demo.

"What you just saw was completely rendered in real time. This demo is running completely in real time, and it's running on one DGX Station. Instead of a supercomputer, this is running on one computer with four NVIDIA Voltas in real time," explained Huang. "This is what we can do now—$68K vs. a supercomputer … It's the first time ray tracing has been done at this level in real time."

The demo represents an implementation of NVIDIA RTX technology in the Unreal game engine, according to Dr. Steven Parker, NVIDIA's VP of Professional Graphics, who was running the demo offstage.

"We're announcing the NVIDIA RTX technology," he said. "You're also seeing deep learning in action. Without deep learning, it would have been impossible to have traced all of those rays."

## NVIDIA Unleashes RTX

NVIDIA RTX gives you cinematic-quality rendering, powered by NVIDIA's Volta GPU architecture. In its explanation of the technology, NVIDIA writes: "While ray tracing has long been 'the future' or holy grail of computer rendering, we are now seeing the advent of consumer GPUs, which have enough compute capability to do interesting ray tracing workloads in real time. It is expected that many use cases will employ hybrid renderers that combine rasterization and ray tracing, so tight integration with an existing rendering API is very important."

In RTX, ray tracing and deep learning work in tandem. "[In the Star Wars-themed demo,] you are also seeing deep learning in action," said Huang. "Without deep learning, it would have been impossible to trace all these rays. We're using deep learning in predicting rays, to fill the spots."

**In his GTC keynote, NVIDIA CEO Jen-Hsun Huang discussed the importance of safety in self-driving cars. *Image courtesy of NVIDIA.***

## The Quadro GV100

The first workstation-class GPU based on the Volta architecture will be the NVIDIA Quadro GV100, Huang said. "The new Quadro GV100 packs 7.4 TFLOPS double-precision, 14.8 TFLOPS single-precision and 118.5 TFLOPS deep learning performance, and is equipped with 32GB of high-bandwidth memory capacity," NVIDIA writes in its blog.

The rendering performance in Quadro GV100 benefits from NVIDIA's AI-powered denoising, which speeds up the pixel-level ray-traced rendering using machine learning.

## DGX, Second Generation

At the halfway point into his keynote, Huang cheekily described the DGX-2 as "the world's largest GPU."

The DGX is not a single GPU but a supercomputer built with a series of GPUs inside. Last year, NVIDIA unveiled the DGX-1, a specialized system aimed at AI researchers and pioneers.

**MORE →** digitaleng.news/virtual_desktop/?p=13870

# Complexity Races Ahead, Forcing a Focus on Systems Engineering

**BY JAMIE J. GOOCH**

WHEN THE FIRST cars raced at the Indianapolis Motor Speedway in 1909, the average cost of a new car was $1,280 and transistors were decades away from being invented. Things have changed.

With the history of racing as the backdrop and the unprecedented speed of technical innovation threatening to disrupt the automotive and many other industries in the near future, Aras Corp. hosted its annual ACE Users Conference in Indianapolis March 20-22. The company markets its Aras PLM Platform as "open, flexible, scalable and upgradable." Those four features are key to helping companies capitalize on digital transformation.

The automotive industry certainly isn't alone in dealing with digital disruption in the face of increased product complexity, but it is facing the perfect storm. Digital transformation technologies and processes—such as digital twins, a connected digital thread and the model-based enterprise—are expected to help the auto industry meet the challenges of disruption. But when?

"When we talk about digital twin, digital thread, most of you have a problem," Aras CEO Peter Schroer told the 400+ attendees of ACE 2018 Aras user conference. "You're not quite ready yet. When Excel is the primary database in the company, that's a problem. We cannot build a digital thread through Excel. A PDF is not a digital data source."

An Indy car greeted ACE 2018 attendees to the Aras users group conference in Indianapolis, IN.

**MORE** → digitaleng.news/de/?p=43213

# CAASE18 Preview: Don't Be Late to the Blockchain Party

**BY KENNETH WONG**

MOST PEOPLE LIKELY ASSOCIATE blockchain technology with cryptocurrencies, not with engineering or manufacturing. But one keynote speaker at the June 5-7 Conference on Advancing Analysis & Simulation in Engineering (CAASE), Daniel R. Robles, himself a professional engineer with commercial and military aircraft design experience, thinks it's a mistake to overlook the technology's potential applications in engineering.

"We have an opportunity to modernize our compensation structure from salary to percent of contract while elevating our profession to the status of financial instruments, but will we organize ourselves to do it?" Robles wonders.

## What Is Blockchain?

A blockchain is "an incorruptible digital ledger of economic transactions that can be programmed to record not just financial transactions but virtually everything of value," write Don and Alex Tapscott, authors of *Blockchain Revolution: How the Technology Behind Bitcoin is Changing Money*.

The blockchain site Blockgeeks explains: "By allowing digital information to be distributed but not copied, blockchain technology created the backbone of a new type of internet … The blockchain network lives in a state of consensus, one that automatically checks in with itself ..."

The term blockchain describes a type of registry network—not a specific registry. Therefore, there are many different blockchains that are derived and spawned from earlier versions. The well-known blockchains include Steemit, Hyperledger, Counterparty and Bitnation. Just like cloud clusters, a blockchain can be private (controlled by a single company, accessible only to its partners, customers and employees) or public (controlled and monitored by a community).

CAASE keynote speaker Dan Robles, founder and CEO of The Integrated Engineering Blockchain Consortium (IECB). *Image courtesy of Robles*.

## Is Blockchain for Engineers?

The blockchain technology proves appealing to financial and insurance sectors because of its innovative digital record-keeping system.

By contrast, design and engineering are governed by constant changes and revisions, dictated by the need for members of various disciplines (mechanical, electrical, software and systems engineering, among others) to simultaneously develop new products. Project teams use product lifecycle management, product data management and collaboration tools as traffic cops to avoid collisions in the data flow. Could blockchain be suitable for such a change-heavy environment?

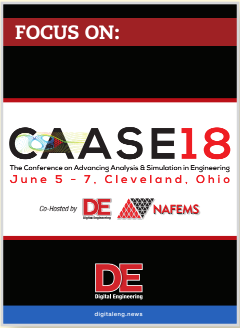
"You can use blockchain to manage the points of risk transfer," says Robles. This could be the point where specific versions of the design are released for manufacturing or delivered to a partner is completed assignments.

**MORE ➜** digitaleng.news/virtual_desktop/?p=13851

## Get a CAASE Preview

The Conference on Advancing Analysis & Simulation in Engineering (CAASE) 2018 is being co-hosted by *Digital Engineering* and NAFEMS June 5-7 in Cleveland, OH.

*DE* is publishing a special digital issue preview of the conference that explains the goals of the event, provides an overview of all the tracks and explores the key topics that will be discussed in the 190 presentations. The interactive digital resource also provides details on the night out at the Rock & Roll Hall of Fame and Museum, as well as information on other Cleveland attractions.




CAASE 2018 will bring together the leading visionaries, developers and practitioners of CAE-related technologies in an open forum to share experiences, discuss relevant trends and explore future issues. You can download the free Focus on CAASE18 digital issue at digitaleng.news/de/caase18.

# CAASE18 Preview: FDA on the Use of FEA to Simulate and Validate Medical Devices

**BY KENNETH WONG**

An officer of the Federal Food and Drug Administration and a mechanical engineer by training, Tina Morrison is well-versed in both FDA regulations and FEA simulation.

Morrison is the chair of the new FDA-wide working group on Modeling and Simulation, and one of the keynote speakers at the June 5-7 Conference on Advancing Analysis & Simulation in Engineering (CAASE). Her talk is titled, "Priorities Advancing Regulatory Science and In Silico Medicine at the FDA."

As the regulatory advisor of computational modeling for the Center for Devices and Radiological Health (CDRH), Morrison leads the group that develops guidance documents on the use of modeling and simulation in the regulatory evaluation of medical devices. The research at CDRH covers, among other topics, the use of computational fluid dynamics (CFD) to model medical devices that interact with the patient's body.

## The Human Geometry

The geometry creation and analysis tools in mainstream CAD and simulation packages reflect their roots in automotive, aerospace and industrial machinery. But the medical device industry's adoption of these tools broaden their scopes and test their capacity.

"Modeling [patient anatomy] is not a problem. We can now use a combination of CT scan data and MRI data to construct the STL file of the body, then print a 3D model," says Morrison. "But one of the challenges is uncertainty quantification—understanding the uncertainty involved in reconstructing the geometry of the patient's body."

## When Metal Meets Flesh

Simulating the mechanical operations of the medical device and the stress loads on it are straightforward enough. But the analysis gets much more complicated when dealing with the device's interaction with the human body, Morrison points out.

"Most firms are using digital tools to simulate the loads and how they affect the device itself," she observes. "But some would go so far as to simulate how the device interacts with the patient's body—for example, a medical stent or implant inside someone, or the kinematics of a replaced knee joint while the patient is performing some activities. So in those, the material science is important."

Common manufacturing materials—such as metal, steel and plastic—have known properties users can obtain from published literature. Many simulation software also comes pre-loaded with a library of standard materials, ready for the users to pick and choose from a drop-down menu.

But the digital representation of soft tissues, bones and human muscles is still under development. Therefore, to ensure accurate simulation results, most users dealing with such materials may need to run clinical tests on their own to obtain empirical data.

"People might be surprised to learn that FDA wants to advance simulation not just as a useful scientific tool but also as a regulatory tool," Morrison says. **DE**

Tina Morrison, deputy director, Division of Applied Mechanics, Office of Science and Engineering Laboratories, Center for Devices and Radiological Health, U.S. FDA. *Image courtesy of Tina Morrison.*

## Register for CAASE

Whether you're a simulation expert or want to learn more about implementing simulation into your workflow, we hope to see you at CAASE 18 June 5-7 in Cleveland, OH. You can download a preliminary agenda and register for the conference here: https://nafems.org/2018/americas/agenda

Credit: iLexx/Thinkstock

# ENGINEERING'S LINK TO BLOCKCHAIN

The technology associated with cryptocurrency offers new approaches to data security and transaction record integrity.

**BY KENNETH WONG**

IT MAY SOUND COUNTERINTUITIVE, but distrust can spawn a trustworthy technology. That idea is in the DNA of blockchain, a transactional infrastructure largely associated with Bitcoin. Blockchain "offers a way for people who do not know or trust each other to create a record of who owns what that will compel the assent of everyone concerned," according to "The Great Chain of Being Sure about Things" (October 2015, Briefings, *The Economist*).

The blockchain education site Blockgeeks writes: "By allowing digital information to be distributed but not copied, blockchain technology created the backbone of a new type of internet ... The blockchain network lives in a state of consensus, one that automatically checks in with itself every 10 minutes. A kind of self-auditing ecosystem of a digital value, the network reconciles every transaction that happens in 10-minute intervals."

Blockchain's definitions and descriptions are largely abstract. Even for tech-savvy folks, blockchain largely remains a jumble of metaphors and comparisons. Capturing its nature in a few sentences or paragraphs seems nearly impossible. "We have no word, no lexicon to describe it, so we end up borrowing words from other sectors," says Daniel R. Robles, founder of the Integrated Engineering Blockchain Consortium (IEBC).

Considering blockchain's association with the volatile cryptocurrency trade, the IEBC's tagline—"Trust as a Service"—seems extraordinary. But Robles and his colleagues believe engineers will pay a hefty price if they don't pay attention to blockchain's potential, especially its implication to data security.

## The Handshake Between Strangers

It's important to understand that the term blockchain describes a type of registry network—not a specific registry. Therefore, there are many different blockchains that are derived and spawned from earlier versions. The well-known blockchains include Steemit, Hyperledger, Counterparty and Bitnation. Blockchains, just like cloud computing clusters, can have both private (controlled by a single company, accessible only to its partners, customers and employees) and public (controlled and monitored by a community) versions.

"If blockchain becomes the norm in digital transactions, the impact is dependent only on the creativity of people using it," observes Robles. Its impact may be felt by both the geometry creation and modeling disciplines (governed by CAD, CAE and CAM software), as well as the enterprise and product lifecycle data management sectors (governed by enterprise resource planning, product lifecycle management, product data management and other software).

"What blockchain does really well is finalize a transaction between the parties, like a digital contract," says Robles. "If both you and I have a copy of that contract, it's difficult to prevent one of us from tampering with it and changing it. Computers are very good at duplicating and changing things. So it could be difficult to tell which copy is the valid contract. A blockchain prevents that."

That explains its appeal to those in the finance, insurance and other transaction-centric, contract-driven industries. It may also be applicable to construction and engineering projects, where design concepts need to be signed off and stamped, digitally or manually.

"Many blockchains are being applied to finance and insurance because they are simple 'paper' swaps that represent a real thing, but are not actually a real thing. On the other hand, engineering information has real intrinsic value, so the opportunity in our profession is enormous," says Robles.

## Blockchain for Engineers, by Engineers

The IEBC states that its goal is to create "a decentralized knowledge inventory for the infrastructure, energy, transportation and construction engineering professions, allowing engineers to shift from a collection of centralized silos into a self-aware global network to adjudicate physical risk in real-world systems."

It's launching CoEngineers.io (coming soon as of press time), described as the first blockchain designed by engineers for engineers. CoEngineers.io is intended to be a public blockchain accessible by anyone and managed with game mechanics, though maintained by the IEBC.

"Suppose you post an idea on CoEngineers.io," proposes Robles. "If later, someone copies your idea, you can use CoEngineers.io to prove to a standard that's acceptable in the court of law that you came up with it first." CoEngineers.io may function like any registry of verified engineering information such as a professional engineer stamp, observation of physical state or even a prior art citation in a patent application, he adds.

"IEBC will begin by cloning another blockchain called Steemit.com and then modifying it to meet our needs," explains Robles. "First and foremost, it is a living and breathing blockchain that people can see running—this takes away a lot of the mystery behind the technology."

The virtual signatories for the blocks of the IEBC's "proof-of-stake" blockchain, according to Robles, are distributed around the world. "Our blockchain has a three-second block time [that is, it self-checks in three-second intervals]. So, if you want to corrupt our blockchain, you'll have to intercept the target document and corrupt more than half of our participating servers—the witnesses to the transaction—within three seconds. The likelihood is astronomically small."

It's difficult to corrupt a blockchain's ledgers—but not impossible. On the other hand, the efforts involved make the attempt expensive, both in computation and time. Therefore, it's not worth attempting unless the possible gain from the ambush offsets the efforts.

## Bitcoin Security Breach

In January, hackers attacked the Japanese cryptocurrency exchange Coincheck, stealing about 500 million units of NEM cryptocurrency worth $524 million. In a Tokyo press conference following the incident, Coincheck President Koichiro Wada somberly bowed in contrition, promising to refund the customers' losses ("Hacked Tokyo Cryptocurrency Exchange to Repay Owners $425 Million," Asahi Shimbun, Jan. 27, 2018, asahi.com).

The incident follows an April 2017 bitcoin theft, in which South Korea's cryptocurrency exchange Youbit suffered a $73 million loss. Eventually, Youbit filed for bankruptcy. Both cases were blows that shook investor confidence in Bitcoin, and by extension, the backend transactional framework.

## Blockchain Explained in Brief

"The blockchain is an incorruptible digital ledger of economic transactions that can be programmed to record not just financial transactions but virtually everything of value."

*—Don & Alex Tapscott, authors of "Blockchain Revolution: How the Technology Behind Bitcoin is Changing Money"*

"[Blockchain] offers a way for people who do not know or trust each other to create a record of who owns what that will compel the assent of everyone concerned. "

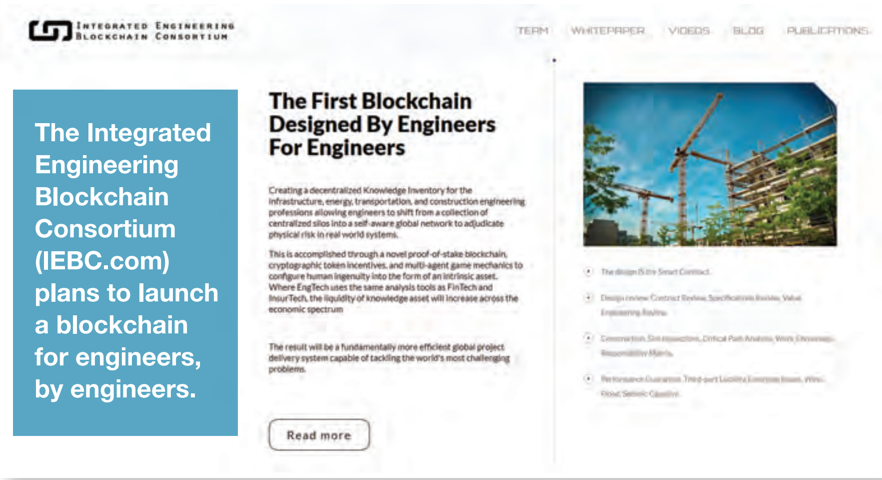
*—"The Great Chain of Being Sure about Things,"* The Economist, *Briefings, October 2015*

"Picture a spreadsheet that is duplicated thousands of times across a network of computers. Then imagine that this network is designed to regularly update this spreadsheet and you have a basic understanding of the blockchain."

*—Blockchain resource site Blockgeeks*, *blockgeeks.com*

"Blockchain technology offers a way for untrusted parties to reach agreement (consensus) on a common digital history."

*—Investment information portal CBInsights, cbinsights.com*




The Integrated Engineering Blockchain Consortium (IEBC.com) plans to launch a blockchain for engineers, by engineers.

"The hackers hacked the exchange site (bank account), not the blockchain itself, to steal the bitcoins," points out Mike Fry, analyst firm CIMdata's director of Manufacturing Systems Engineering Consulting Practice.

"Bitcoin taught us that a decentralized ledger is a feasible idea, and that it works," says Robles. "Blockchain development is often compared to powered flight where every crash taught the engineers a lesson. It is important to heed those lessons, iterate and try again. The benefits to society of its success are too great to ignore."

Lessons from the losses led to software engineers developing DEX, decentralized exchanges that are themselves on blockchains. But predictably, there are also other parties scanning and looking for vulnerabilities in the new setup, poised to strike at the right moment.

## Blockchain for PLM?

In February, CIMdata hosted a webinar titled "Blockchain Technology and PLM Usage," led by Fry. "Each block can be reviewed and audited for approval and access types of transactions," Fry says. "The trust moves from people and process to algorithms [that govern the blockchain registries], so that will be a major constraint for PLM." CIMdata aims to set up a Blockchain PLM Knowledge Council, a collaborative research panel of software and services providers.

Fry has been studying Ethereum, among others, as a possible PLM data and process backbone for recording transactions. He favors it because it's an open source, public blockchain. One use case, for example, is to "make fraud detection easier with product identification. You could verify the [3D printing] machine where a part came out of, [and] verify the program that created the part, to eliminate counterfeit parts," Fry notes.

Many manufacturers are exploring ways to adopt 3D printing for mass production. With ubiquitous access to 3D printing service bureaus, detecting counterfeit parts produced using the same production method could prove challenging. Fry's proposition is one safeguard against it.

## The Point of Risk Transfer

In product design cycles, engineers have now come to accept simultaneous changes as a fact of life. Gone is the traditional workflow where each party finishes a single part, then hands it off to another. Today, the mechanical engineer, electrical engineer, system engineer and software engineer all

## 3D Printing's Link to Blockchain

At the Additive Manufacturing Users Group (AMUG) 2018 that took place in April, blockchain-related product announcements were already being made.

LINK3D, an additive manufacturing (AM) software company, announced it has integrated blockchain into LINK3D's flagship software-as-a-service (SaaS) product, Digital Factory, which was launched last year.

The company says its 3D printing blockchain can solve problems in the 3D printing workflow including:

**File integration, IP integrity, DRM**: Blockchain technology can be used to track origin of each design file and its evolution.

**Facility matching / authentication**: Service bureau capability can be stored on blockchain and orders can be pre-verified.

**Supply chain and logistics tracking**: Once the part is shipped, the package can be tracked to ensure that it is opened by the correct parties.

**Real-time data from machines**: Machine logs can be stored in an immutable way for forensics during recalls and for traceability, according to the company.

Also at AMUG, 3D printer and software maker Rize launched what it calls "the industry's first digitally augmented parts," which "means you can now create a digital thread between the digital and physical part and accelerate Industry 4.0 technologies like blockchain and AR/VR (augmented/virtual reality) applications."

The company's Augmented Polymer Deposition (APD) hybrid process combines extrusion and material jetting, allowing parts to be embedded with markers, such as serial numbers or QR codes, as they're 3D printed to bridge the gap between the virtual and real world.

*— Jamie J. Gooch*

work simultaneously. They use product lifecycle management and product data management systems to keep an eye on what the other parties are doing. The emphasis is on file sharing, not file locking. Could such a change-heavy environment be right for blockchain?

It may not make sense to record every micro design iteration in a blockchain, but "perhaps introduce a version to the blockchain when it reaches the stage-gate phase," proposes Fry.

"You can use blockchain to manage the points of risk transfer," says Robles. This could be the point where specific versions of the design are released for manufacturing or delivered to a partner in completed assignments.

"Remember, blockchains are electrons," Robles warns. "At some point, there needs to be a way to verify that the physical state of the world matches the electronic state of the world. This is where engineers will be critical to the advancement of the technology. But like the hacked exchanges, we now need to prove that engineers cannot be corrupted. Decentralization may create a double-blind: transacting parties have no knowledge of the engineer who comes to validate; and the engineer has no prior knowledge of who they are adjudicating for."

This ignorance by design, if you will, is what makes the blockchain's involvement valuable as an incorruptible signatory for transactions.

Sometimes, Robles can't help but feel frustrated by the engineers' reluctance to explore blockchain or adopt it. "The question is whether engineers will be the innovators of our field or will someone else get there first to further commoditize our work?" he asks. "We have an opportunity to modernize our compensation structure from salary to percent of contract while elevating our profession to the status of financial instruments, but will we organize ourselves to do it?" 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** → **Blockgeeks:** Blockgeeks.com

→ **CIMdata:** CIMdata.com

→ **CoEngineers:** CoEngineers.io

→ **Don Tapscott, author of Blockchain Revolution:** DonTapscott.com

→ **Integrated Engineers Block Chain Consortium:** IEBC.com

→ **Link3D:** Link3D.co

→ **Rize:** Rize3D.com

→ **Steemit:** Steemit.com

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

# Facing the Embedded Security Crisis

Defense from cyberattacks must begin with device design.

**BY TOM KEVAN**

THE INTERNET OF THINGS (IoT) has just begun to take shape, with potentially billions of sensor-enabled devices forming a web of connectivity. This technological sea change has spawned a diverse collection of devices, ranging from small to large and simple to complex. Despite their differences, these devices have one thing in common: a woeful vulnerability to cyberthreats.

Recent experiences have caused developers and end users to reframe their view of the threats that confront them, casting security in a new context. In the past, many saw the object of cyberattacks as the misappropriation of personal or proprietary data. Over the past few years, however, technologists, businesses and governments have come to realize that just as dangerous are attacks against the devices themselves—are moves to seize control of systems and operate them in malicious ways.

At the same time, developers and IT staffs now recognize that they must do more than protect the network to ensure security. Time and again, hackers have penetrated or disabled perimeter defenses. The problem, however, doesn't stop there. Today's threats are multifaceted. A close look at cyberattacks shows that 70% of these events originate inside the perimeter. Confronted with these realities, more and more developers believe that cyber defenses must begin with the device.

But even as this realization takes root, moves to secure devices and counter security threats seem painfully slow. This isn't because of a lack of awareness. It's because of the great pressure to keep costs down, driven by end users' unwillingness to foot the bill for security that they think should be part of the product.

## Appreciating the Differences

Of all the components playing a key role in the development of the IoT, embedded systems rank near the top of the list. Yet when it comes to the movement to implement better security, these devices have remained in the background, relying on obscurity for defense against cyberthreats. Recent events, however, have shown that this approach will no longer work.

But before developers can incorporate security measures in their embedded designs, they must recognize that these devices are different than standard PCs. Embedded systems usually perform specialized, fixed functions; use a tailored operating system (for example, VxWorks, MQX, or a version of Linux); minimize processing and memory usage; and often operate with very limited resources.

Combined, these factors make standard PC security techniques inappropriate for the challenges confronting embedded devices. The fact is the level of security required for an embedded device often differs dramatically. This means that developers must come up with approaches and techniques tailored for embedded applications.

## A Good Place to Start

The best way to develop embedded system security is to adopt a holistic approach. "Planning to incorporate security should begin right from product conception," says Mike Borza, R&D engineer and principal solutions group at Synopsys. "I often like to say that security should be 'baked in, not smeared on.'"

Product designers typically have a good functional definition of their product's features and capabilities. These describe what the product should do when everything is as it should be. The goal of cybersecurity is to keep the product operating that way even when confronted by an attempt to pervert the use of the product. Therefore, a good place to begin security planning is to identify the product's key functions and associated data. With those identified, the designer can develop a set of security objectives. The objectives, in turn, lay the groundwork for the selection of key elements of the system's design.

"In the early stages of the system design, developers have to choose a system architecture that fulfills the security goals of that system," says Arvind Raghuraman, staff engineer, Mentor Embedded Systems Division, a Siemens Business. "Next comes the selection of a hardware platform. Various security requirements—such as secure boot, secure management of secrets in tamper-proof secure storage, persistent separation between secure and nonsecure software contexts and cryptographic acceleration—have implications on the choice of hardware."

Once the development team has identified the right hardware platform, it can then decide on a software architecture that effectively leverages the hardware-provided capabilities.

## Enhancing Existing Designs

These practices work well for developers designing new systems, but there's a catch. Most IoT products are not new designs. Engineers who are enhancing existing products are constrained by previous design and implementation choices. Many existing designs have hundreds, if not thousands, of potential security vulnerabilities. Therefore, understanding and addressing these is critical, but this first step is often overlooked.


**The design of a secure architecture for an embedded system must go beyond selecting the right processor and software. By adopting a holistic approach, the designer considers all the aspects of the product's lifecycle. In terms of security, this means protecting data when it is at rest, in use and in transit.** ***Image courtesy of Mentor Graphics, a Siemens business.***

"The first step to securing existing systems is to understand their vulnerabilities," says Terry Dunlap, co-founder and CEO of ReFirm Labs. "Tools like our Centrifuge Platform, which automatically analyze firmware and provide comprehensive vulnerability reports, are a great place to start. Building in security from the ground up is great for new product designs, but fixing the gaping security holes in existing products is far more relevant for most engineers."

## The Limitations of Encryption

One of the greatest challenges of the entire design process is deciding which technologies to use and how to best implement them. There are, however, some basic security technologies that should be included in any device with the resources to support them.

Perhaps the most fundamental of these is encryption, which is simply the process of converting data into a code to prevent unauthorized access. Designers use this technology to protect the confidentiality of data carried in transmissions to another system over an insecure network like the internet.

To this end, embedded systems have traditionally used encryption-enabled communication protocols, such as TLS (transport layer security), SSH (secure shell) and IPSec (internet protocol security). Today, most embedded platforms include these protocols as standard components. Current security standards, however, require more of encryption. Today, developers use the technology to ensure secure data storage, validate code for secure boot and secure firmware updates and implement strong device identity.

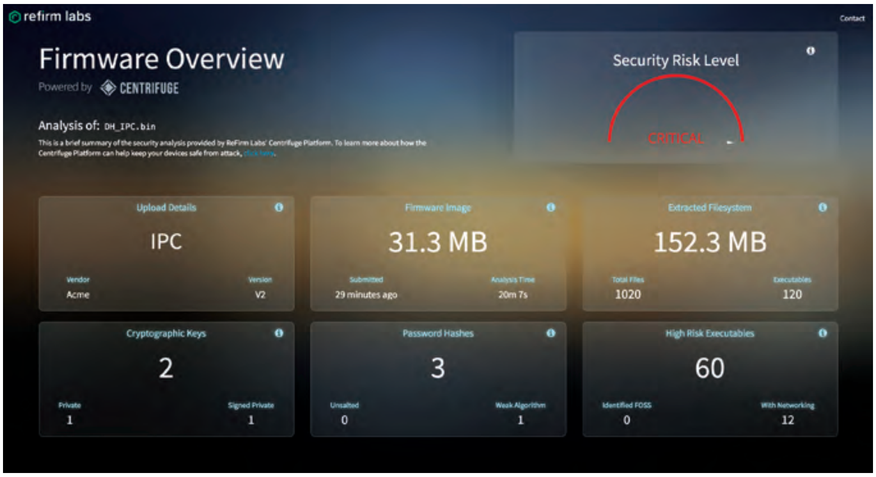
There are, however, limits to what encryption can do. "In my view, these techniques are ineffective when they are viewed as silver bullet solutions without careful consideration of how they fit into the overall security posture for the device," says Alan Grau, co-founder & CTO of Icon Labs. "For example, we have seen systems in which a secure web interface was implemented using TLS (transport layer security), but an unprotected telnet port was still enabled."

Another common flaw involves the management of encryption keys. "All encryption depends on a secret key, and that key must remain secret for the encrypted data to remain confidential," says Borza. "That seems obvious to anybody with even passing familiarity with encryption. But it's not unusual for secret keys to be found written in disk files or embedded in programs, where they can be found by adversaries fairly easily."

As a result of these issues, encryption has a role to play in securing embedded systems, but it must be viewed as one of several layers of defense.

## Controlling Access

Another security building-block technology is authentication. Using this process,




**When enhancing existing products, design engineers must contend with previous design and implementation choices, which may involve numerous potential security vulnerabilities. The designer's first step in securing the existing system is to understand the vulnerabilities. Tools like ReFirm Labs' Centrifuge platform help with this by automatically vetting and validating firmware for vulnerabilities.** ***Image courtesy of ReFirm Labs.***

a system verifies a user's identity or the origin and integrity of sensitive data before granting access to system resources.

This is one of the most important elements in the embedded system's cyber defense. "A key component of secure communication involves validating the other party in the communication is who they claim to be," says Grau. "Without this assurance, systems are vulnerable to spoofed identities and man-in-the-middle attacks. Certificate-based authentication provides cryptographically strong authentication and is critical to this process."

Authentication often begins with the use of a cryptographic hash function. When a system conveys data, the hash function computes a fixed length called a "digest." This value is unique to the data and can indicate when a change has been made to the message. It prompts the receiving system to identify the modification, as well as the source of the change. A single bit change in the data produces a different result. So a hash function provides a means of computing a unique representative of any data.

Next, the system encrypts the hash value with a private key, using an asymmetric algorithm that creates a digital signature.

The overall process looks something like this: The system transmitting the data calculates a hash value, or digest, for the data and then encrypts the hash value using the system's private key. This message is called a digital signature. The transmitting system then sends a file containing the data and the message containing the encrypted hash. The receiving system can verify the message by computing the hash and decrypting the accompanying message. If the decrypted message matches the hash, the receiving system knows that the message came from the identified sender.

This type of authentication requires that IoT devices have sufficient resources to handle the cryptographic operations. With increased processor speeds and the availability of lower cost security co-processors, this is now possible at a much lower cost than even a few years ago.

"Digital signing infrastructure implemented using a public key-based authentication is a great tool to fulfill the authentication needs of a system," says Raghuraman. "Hardware crypto-acceleration units provide hardware acceleration that enables software to implement hashing and the authentication of functions in an optimal fashion."

Designers also have another option for implementing authentication, using a shared secret key that both systems know. This approach requires less computation than using public key cryptography. Therefore, it's more efficient when large amounts of data must be authenticated.

Whatever the approach, authentication comes into play in a number of ways. For example, an embedded device may have to authenticate system firmware and associated configuration data at system boot, or applications running on embedded devices may have to authenticate and verify the origin of software and security updates delivered to the system before they can be used.

There are also use cases where the embedded device itself has to prove its origin to an infrastructure with which it is interacting. Take for example an IoT-enabled embedded device trying to interact with a back-end system. Here, the embedded device must present its credentials to the back-end system so that it can be authenticated with its identity via a registry maintained on a cloud infrastructure.

Given its effectiveness and widespread applicability, authentication represents a key element in embedded security. "Signing and authenticating messages, data files and executable files is at the heart of ensuring the data has integrity," says Borza. "If data has integrity, it is possible to know who originated it and that it is exactly the data that was sent."

## Getting off on the Right Foot

One of the best ways of seeing encryption and authentication at work is to examine the secure boot and secure firmware update functions.

In the first case, the market offers several types of secure boot to mitigate the vulnerabilities of the boot process. A common version verifies that the boot loader has been signed with a cryptographic key authorized by a database that resides in the system's firmware. With adequate signature verification, a secure boot can prevent the substitution and execution of altered boot code. This prevents hackers from introducing malware or security backdoors into a processor once it is initialized.

Another approach limits changeable parameters in the device as it loads. This technique attempts to prevent hackers from substituting false commands or security backdoors into the device setup.

A third technique aims to protect the boot code of the embedded system. The goal here is to prevent hackers from accessing the code to clone the system, insert malware or develop ways to disable the system.

Digitally signed boot files provide an important step toward preventing some of the most widespread bootloading attacks. But to be clear: Even though secure boot resists some hacks, it's still susceptible to attacks in the verification procedure if the verifying module is not integrated into the embedded processor.

Code and security updates use many of the same techniques and technologies as secure boot. Public key-based digital signing of updates provides a level of security. When implementing a software update infrastructure, however, the designer must also consider how the system will respond when the update does not go through as expected—perhaps due to a runtime error that surfaces with new firmware. In this situation, the system should be able to roll back to known working firmware.

## Compartmentalization of Resources

Another security measure that leverages general access control is privilege separation. Designers implement this cybersecurity principal by assigning a task, process or user only those privileges needed to perform their assigned tasks. This ensures that a hacker that gains access to a subsystem cannot access the rest of the system. Essentially, the hacker is limited by the privileges of the subsystem they hacked.

Privilege separation can be implemented in one of two ways. Designers can achieve compartmentalization in software, dividing a program into parts limited to the specific privileges they require to perform a specific task. Or they can implement compartmentalization in hardware.

On the software side, most operating systems include some level of control over access rights of the processes running in the system. "Some systems, such as SELinux, allow fine-grain control over security policies," says Grau. "Regardless of the implementation, privilege separation should be used to limit access to sensitive and security-critical data and processes. This can reduce the attack surfaces available for hackers to exploit and limit the damage should a hacker breach a device."

## Trusted Platforms

Designers can also leverage hardware to implement security. There are, in fact, a number of hardware security approaches that can be incorporated into IoT designs.

One such technique is the trusted platform module (TPM), which is essentially a security coprocessor. Recently, TPMs have taken on a number of new applications, including platform integrity verification using cryptographic hashes of component configuration states; remote attestation about the state of the system in which the TPM is installed and cryptographic key generation and management. These modules have proven to be most useful during the preboot and bootstrap phases of system operation, ensuring the hardware and low-level system software and firmware have integrity.

"In the embedded world, TPMs were traditionally seen only in specialized applications (for example, point-of-sale terminals). But as the need to secure systems becomes greater and the realization [is made] that embedded systems have traditionally done a poor job on security, we're seeing more and more applications where a TPM is a necessary component," says Raghuraman.

## A Question of Cost

Tasks like choosing the right technologies for a product may seem daunting, but the real challenge often appears on the bottom line. "Product teams need to make cost-vs.-benefit decisions when determining which security measures are required for the embedded systems they are designing," says Jack Ogawa, senior director of marketing for the MCU business unit at Cypress Semiconductor.

It's at this point that some developers drop the ball by letting many security considerations fall by the wayside. Designers are often quick to dismiss security as too costly to include in their product. Today, this seems to be embedded security's biggest hurdle.

"It's true that there are costs associated with security, though I also consider these as being like insurance," says Borza. "What's the value to a business of an attack that didn't succeed? That's difficult to measure. But it's easy to measure the cost of an attack that did succeed, and these costs are often high, far beyond the cost of preventing them in the first place." **DE**

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

**INFO** ➜ **Cypress Semiconductor:** Cypress.com

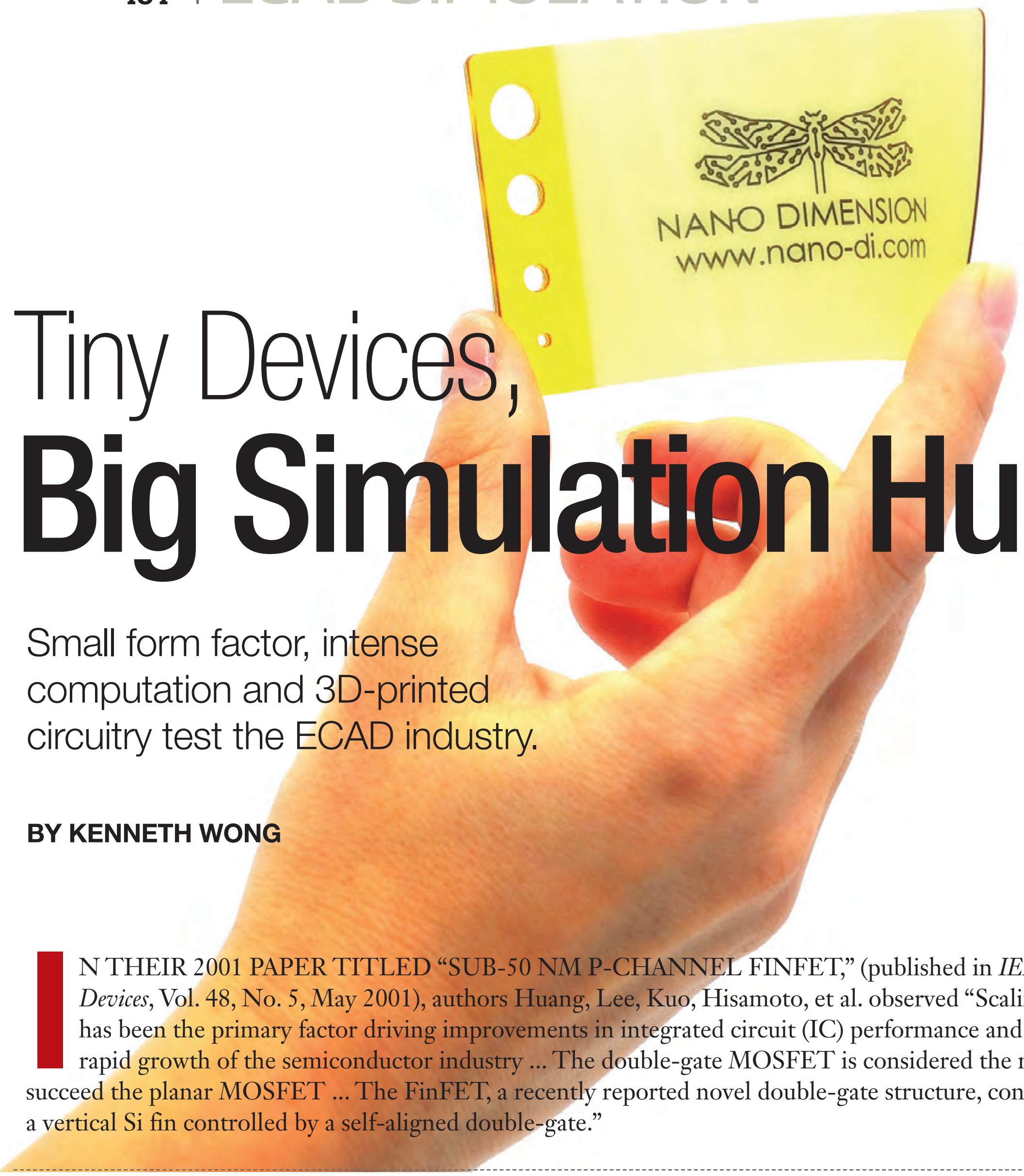
➜ **Icon Labs:** IconLabs.com

➜ **Mentor Embedded Systems Division, a Siemens Business:** Mentor.com/embedded-software

➜ **ReFirm Labs:** ReFirmlabs.com

➜ **Synopsys:** Synopsys.com

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




3D printers like Nano Dimension's Dragonfly 2020 can print circuitry embedded inside objects, but currently state-of-the-art electrical and mechanical design tools don't offer an easy way to design and analyze such objects. *Image courtesy of Nano Dimension.*

# Tiny Devices, Big Simulation Hurdles

Small form factor, intense computation and 3D-printed circuitry test the ECAD industry.

**BY KENNETH WONG**

IN THEIR 2001 PAPER TITLED "SUB-50 NM P-CHANNEL FINFET," (published in *IEEE Transactions on Electron Devices*, Vol. 48, No. 5, May 2001), authors Huang, Lee, Kuo, Hisamoto, et al. observed "Scaling of device dimensions has been the primary factor driving improvements in integrated circuit (IC) performance and cost, which have led to the rapid growth of the semiconductor industry ... The double-gate MOSFET is considered the most attractive device to succeed the planar MOSFET ... The FinFET, a recently reported novel double-gate structure, consists of a channel formed in a vertical Si fin controlled by a self-aligned double-gate."

Nearly two decades later, FinFET is no longer a novel technology but something "the industry is moving toward," according to *Semiconductor Engineering*. (See FinFET in a Few Words, page 22.) The move from planar to 3D transistors also demands innovative thermal strategies.

"When the heat trapped in the FinFET's 3D structure needs to escape, it usually finds the weakest thermal resistance as the point for exit. Just like how heat rises to the top floor in tall buildings, FinFET heat goes to the top, to the metal routing layer on the die. The accumulated heat on the die, which is called self-heating, along with the Joule heat from metal flow, can cause electromigration (EM) violation," explains Jerry Zhao, product management director in the Digital & Signoff Group, Cadence.

Depending on how the affected IC is deployed, the outcome of EM violation could be a minor inconvenience (a failed smartphone) or a major disaster (a failed self-navigating automobile). The key to EM prevention rests with figuring out the right kind of simulations to run.

## Mimicking User Behavior in Time Steps

Typical IoT devices reflect their multitasking users' behavior. A smartphone is not running one operation at a time. It's managing the command streams of several apps simultaneously. That calls for rule-based power-jostling among the internal components, known as "throttling."

"You put an upper-bound limit of temperature on the device," explains CT Kao, software engineering director in the Custom IC & PCB Group, Cadence. "If it reaches that upper-bound, the device has to play with throttling—the allocation of the power to components." Improper throttling—getting the power allocation strategy wrong—means burned chips, device failures and potentially lawsuits and public relations disasters for the brand.

One of the keys to figuring out throttling is the use of simulation to identify hot spots—regions in the device that will heat up to an unacceptable level during certain combinations of operations. "Most people do multiple things in a transient fashion, so things are going on and off frequently," says Kao."You have multiple chips, multiple power schemes. For example, in one scheme, one chip is on and two chips are off. You have many such combinations, so each configuration needs to be simulated."

To understand the heat accumulation, it's not enough to simulate a snapshot in time. The engineers must instead simulate a power scheme in operation for a reasonable span of time to be able to see where and how hot spots emerge. These so-called transient simulations are costly, both in time and money.

"If a designer wants to study one time step in detailed resolution, say, it takes about an hour. If your overall interest is a 10-second event, you need to be looking at [time slices of] 0.1- or 0.01-second intervals. From a simulation point of view, each time step is a new simulation run essentially, so if you have a simulation with a 1,000 time steps, you're basically running the same simulation a thousand times. And if you have 100 power schemes to look at, you'll effectively run out of time," Kao adds.

It's not that it's impossible to simulate all 100 power schemes. But doing that would push the product design cycle so far behind, or add so much computation cost in server usage, that it becomes an impractical solution. That forces the designers to make difficult choices, in what to simulate—and at what level of detail.

### Computing Time Slices

There's no one-size-fits-all solution. Or rather, there's no single solution that can tackle the problems of different sizes. That's one of the challenges that electronics design software makers like Cadence are working to overcome.

In the now industry-preferred FinFET transistors, at the substrate level, objects are measured in nanoscale, indiscernible to the naked eye. At the board level, objects are solid, discernible and measurable using traditional metrology tools. The heat generated in the FinFET travels through the integrated circuits (ICs) and the printed circuit board PCB. But what kind of partial differential equations can effectively be applied to solve the math governing the thermal behaviors observable at both the substrate level, the board level and the product level?

"You don't want to solve heat problems for a large solid object, like a watch, using the simulation formulation aimed for solving microscopic silicon-level behaviors," says Kao. A single tool that can simulate the entire device at different resolution levels remains elusive to the industry, he notes.

It comes down to resolution, or mesh size, as simulation software users call it. In subdividing the geometry into tiny sections for analysis, applying nanoscale meshes to larger objects would unnecessarily increase the complexity of the job and the computation time. By the same token, meshing the geometry at the product level may not be fine-grained enough to identify heat build-ups at the transistor level. Engineers have to decide, based on experience and intuition, the critical question: What level of accuracy is sufficient for a given product or design?

"The designer needs to know the hot spots that appear at a specific time. If the resolution of the tool cannot provide that within the critical power cycle, the designer won't catch that," says Kao.

### Getting the HPC Marching Order

For the computation bottleneck, ubiquitous access to high-performance computing (HPC) via affordable private clusters and on-demand cloud service provides an outlet. But the accuracy of the results in HPC remains a concern, notes Zhao.

SPICE simulation (which stands for an open source Simulation Program with Integrated Circuit Emphasis) remains "the mother of all simulation," says Zhao. It's possible to run such simulation jobs on multi-core, multi-node clusters to speed up the job, but you need a good parallel solving technology, he adds.

"[HPC-based simulation] is like a military march or a band march. The last row needs to keep up with the first row. Otherwise, the pattern falls apart," says Zhao. "You need something like a brain that controls the movements."

Zhao and his colleagues continue to develop and refine what they call "the matrix-solving technology," a feature in the software that ensures the results are the same whether the job is executed on a single machine with multiple cores or across a network with dozens of nodes and hundreds of cores. "This technology is unique to us. It can take advantage of multiple cores in the cloud and artificial intelligence (AI)," he says.

Cadence offers 3D IC design and analysis tools, PCB design and analysis tools, and system-level design and verification tools. "We have unified solution at the die level, board level and package level," says Zhao.

### Bending, Flexing Circuits

The IoT trends favor thin, light, form-fitting devices with aesthetically interesting surfaces over the manufacturing-friendly oval, rectangular and cylindrical products. This has resulted in the use of flexible PCBs, dubbed Flex Rigid boards. Many of them were incorporated into the flip phones that now seem quaint. Because of their bendable, flexible, fabric-like connectors, they can fit into tighter, smaller spaces that a rigid board cannot.

"Flex Rigid boards have been a common feature for a long time, but it's increasing in adoption in smaller factors," says Dave Wiens, business development manager for Mentor Graphics' board division. "What's less common are 100% or 75% flexible boards—that means, instead of the board being mostly rigid with some flexibility, it's mostly flexible. That's when you're dealing with printed electronics and shaved silicon die so the silicon can flex along with the structure."

3D printing vendors like Nano Dimension further test the industry with the ability to print objects with embedded conductive materials, effectively making it impossible to differentiate the object and the circuitry within.

"These new designs represent structures that we're not used to seeing—PCBs that look like a round orb, or any possible shape you might think of," observes Wiens. "People who are looking to push the limits of 3D printing won't print box-shaped objects. They'll print shapes that are much more unique."

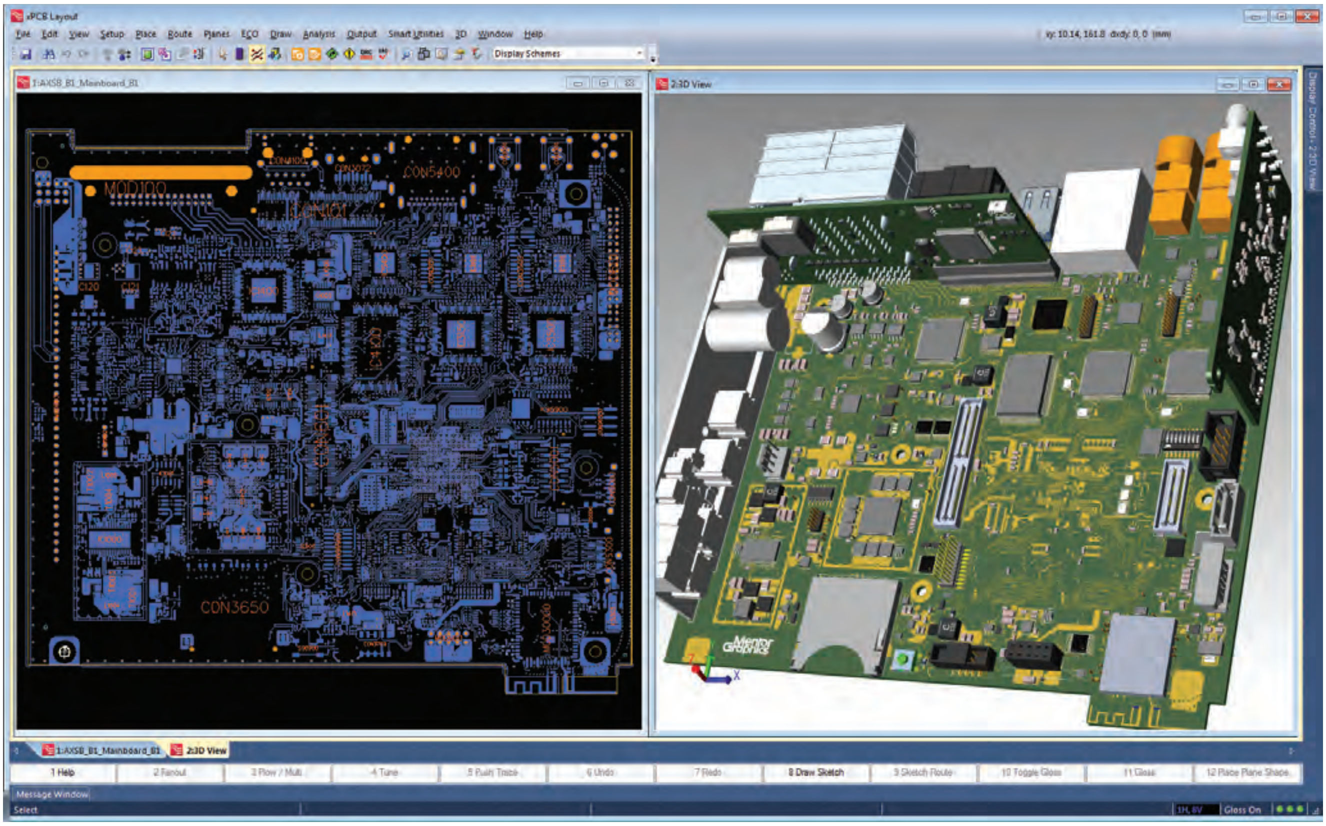
"Additive manufacturing of PCBs is at this stage primarily a rapid prototyping tool. The time from concept to testing can be shortened dramatically and the cost, at prototype volumes, can be reduced significantly also," explains Simon Fried, president of Nano Dimension.

But it may not remain so for long. Customized 3D-printed PCBs are an ideal solution to the tight-fitting IoT

## FinFET in a Few Words

FinFET technology takes its name from the fact that the FET structure used looks like a set of fins when viewed, according to Radio-Electronics.com ("FinFET Technology & Basics," radio-electronics.com). Unlike previous transistors that rest on planar surface, FinFET transistors are 3D.

*Semiconductor Engineering* points out: "The industry is moving toward FinFET transistors. Intel moved into production with FinFETs at the 22nm node ... [They] form conducting channels on three sides of a fin structure, providing a fully depleted operation. This enables chips to operate at lower voltage at lower leakage." ("FinFET: A three-dimensional transistor," Knowledge Center, updated April 2017, semiengineering.com)




The convergence of ECAD and MCAD results in tools that allow the two disciplines to work closely together in a single environment. Shown here is Mentor Graphics Xpedition, with 3D visualization and validation within the PCB/ECAD environment. *Image courtesy of Mentor Graphics.*

devices. And the use of 3D printing for mass production is no longer a pipe dream; it's proven to be feasible for the automotive industry, medical device industry and others.

## The Need for New Analysis Capabilities

As always, invention in one space creates a new need in another. Such a cycle has already seemingly begun in ECAD. "Now, you may have a piece of flexible electronics that can bend and stretch, like a Band-aid on a wound," notes Wiens. "That kind of electronics moves in various directions that their predecessors haven't. For design and analysis, that represents a challenge: How do you design them correctly? How do you analyze them?"

"Current state-of-the-art ECAD packages do not offer a solution to design, simulate or validate free-form geometry circuits. Nevertheless, the worlds of ECAD (electronics CAD) and MCAD (mechanical CAD) are converging," says Fried.

In March 2017, Mentor Graphics was acquired by the manufacturing titan Siemens and folded into the Siemens PLM Software division. SOLIDWORKS, a division of Dassault Systèmes, struck up a partnership with ECAD developer Altium, resulting in CAD-friendly PCB design solution. Two years ago, Autodesk acquired EAGLE, which develops the PCB design software. The outcome is Autodesk EAGLE, a free download available for hobbyists and makers.

"It's fair to assume that integration of ECAD and MCAD considerations into a single tool is inevitable. This is not yet the case, however," says Fried. "This is why Nano Dimension has developed a convenient plug-in to SOLIDWORKS in order to facilitate freeform circuit and part design. This allows you to design items such as coils, antennas and new solutions to bracketing and harnessing." **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 ➜ Altium:** Altium.com

➜ **Autodesk:** Autodesk.com

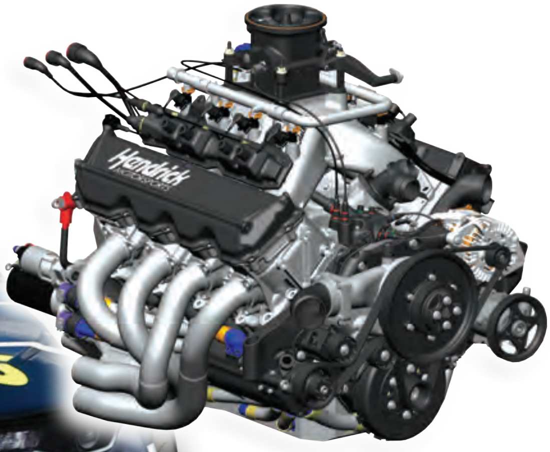
➜ **Cadence:** Cadence.com

➜ **Dassault Systèmes:** 3DS.com

➜ **Mentor Graphics:** Mentor.com

➜ **Nano Dimension:** Nano-di.com

# ROADBLOCKS Slow the Digital Twin Race


Digital twins will give Hendrick Motorsports the speed and agility to make competitive design changes. *Images courtesy of Hendrick Motorsports.*

Companies are proceeding with caution on the digital twin journey, slowed by varying interpretations of the technology, the complexity and the lack of a packaged tool set.

**BY BETH STACKPOLE**

ALTHOUGH AN ENGINE TWEAK or a small part change can deliver the win, the frenetic pace of the NASCAR race season means a good idea has a shelf life of only about a week or two. To accelerate its process, Hendrick Motorsports is throttling up a digital twin effort to test drive changes quickly before building physical prototypes and to leverage real-time engine performance data to fine-tune winning designs.

"Our schedule is pretty rigorous with 36 race events a year, which means we are reinventing ourselves every week," explains Jim Wall, Hendrick Motorsports' senior director of engine programs. "The digital twin gives us the freedom to explore design options and variations without committing to a physical model."

Like at Hendrick Motorsports, the digital twin is starting to take shape at manufacturers that are building everything from cars to aircraft to wind turbines. Hendrick Motorsports got an early jump and lapped the concept for its powertrain components, but it hasn't yet crossed the finish line on a complete digital master, Wall says. Other front-runners are also pacing digital twin efforts, hitting the brakes for a variety of reasons, including varying interpretations of the concept, differences in scope and the lack of a packaged toolset to create a holistic digital twin model.

"There are lots of variations in interpretation and definitions of what a digital twin is, and it's lumpy in terms of the maturity of models," notes Jonathan Scott, chief architect at Razorleaf, a

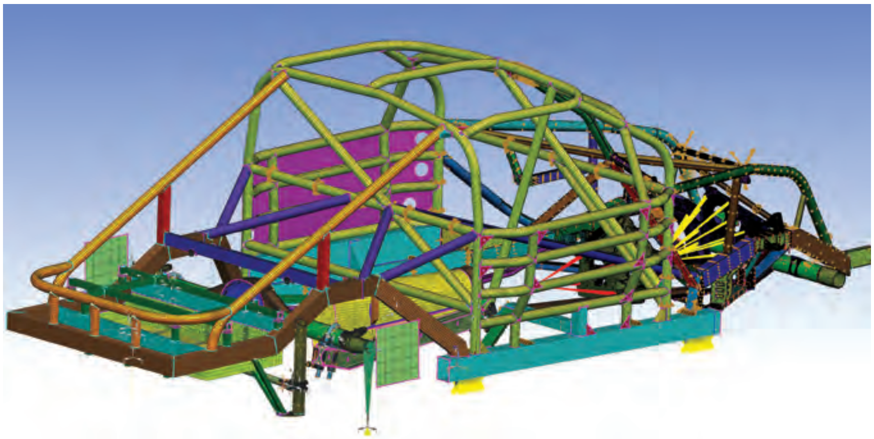
PLM consultancy. "Organizations may not have the whole product ready, but certain parts of it are really advanced in terms of their digital 'twinness' because of the business needs."

### Mixed Interpretations

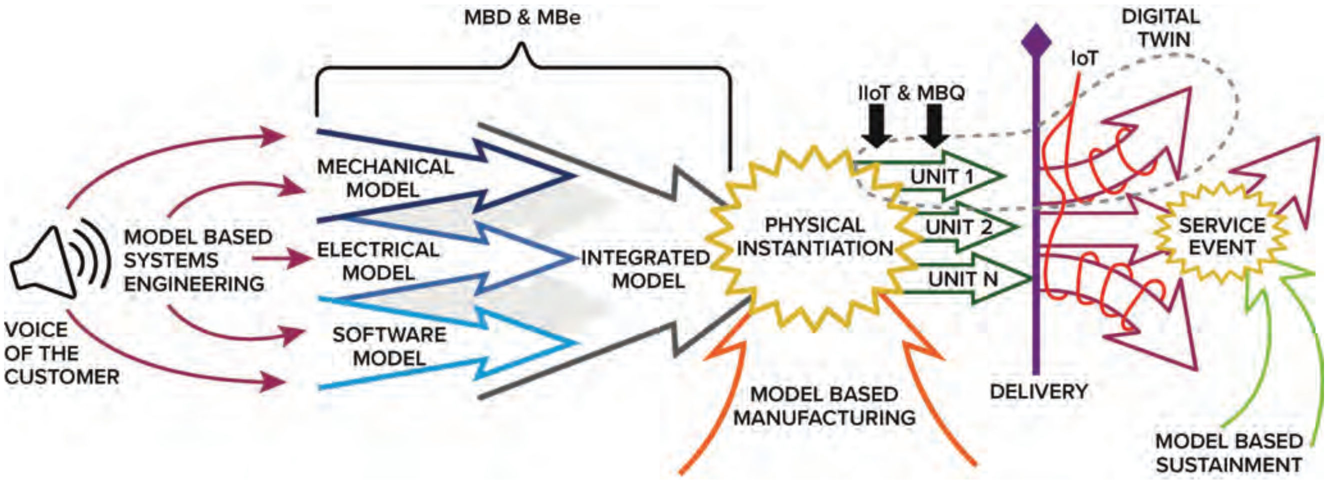
There is universal enthusiasm for the concept of a digital twin as a bridge between the digital and physical worlds as well as plenty of talk about its potential for creating feedback loops to advance product designs, optimize the operation of industrial assets and enable new use cases in areas like predictive maintenance. Spurred by the rise of internet of things (IoT), Gartner predicts that half of large industrial companies will leverage digital twins by 2021, resulting in those organizations gaining a 10% improvement in effectiveness.

Yet even Gartner indicates that the complexity of digital twins will vary based on a variety of factors, including use case and business objectives, along with the specific vertical industry. In some cases, a digital twin will constitute something familiar like a high-fidelity, physics-based digital model based on 3D CAD and CAE analysis. In other scenarios, the digital twin interpretation is even more complex, becoming a composite of multiple digital twins integrated at a systems level and including process behavior that spans activities throughout the product lifecycle, including manufacturing, the supply chain and in-field performance data.

At Siemens PLM Software, the digital twin is viewed in the context of a lifecycle view—a virtual representation of a physical product, its production processes and its performance. In addition to traditional 3D models from CAD and CAE systems, Siemens is facilitating the creation of a digital twin



**Isometric view of a chassis finite element model that is used in stress and deformation design studies.** ***Image courtesy of Hendrick Motorsports.***




**An end-to-end process flow for model-based content and IoT data streams synthesizes the digital twin.** ***Image courtesy of Razorleaf.***

through a variety of other solutions in its portfolio: Amesim, a multi-domain platform for system-level modeling and analysis, including software-in-the-loop and hardware-in-the-loop testing; Xpedition, for modeling PCB design flows and electrical hardware; Polarion, for managing complex configurations of embedded software through application lifecycle management (ALM); and Teamcenter as a central repository and workflow engine for managing the requirements, functional, logical and physical (RFLP) aspects of a product.

"The greatest value of a digital twin is when you can use the information and insights gained from a product, plant, asset or operations to improve its performance or the design or to leverage simulation to predict future performance," notes Tom Maurer, Siemens' senior director in strategic communications.

Dassault Systèmes uses a broad interpretation of the digital twin concept. What it calls a 3DEXPERIENCE digital twin is a virtual representation of the product used to understand how it will serve its need as it was designed—but also to explore how it will be manufactured and delivered to market so the entire value chain can be optimized to operate most effectively, according to Eric Green, vice president of user experience marketing for Dassault Systèmes' DELMIA brand. Dassault users would leverage CATIA, the SIMULIA simulation solutions and DELMIA digital manufacturing tools to create a 3DEXPERIENCE digital twin.

In Dassault Systèmes' vision, for example, a 3DEXPERIENCE digital twin could be called into play when a new automobile design is slated for production in a particular plant. "Say you have a large automobile being manufactured in a plant that is now slated to produce a small automobile model," Green explains. "That has a direct impact on space and the movement of the assembly line. By modeling the product, the factory and the manufacturing processes, you can determine how everything behaves during production, using simulation and optimization to make the procedure most effective without expensive trial-and-error dry runs."

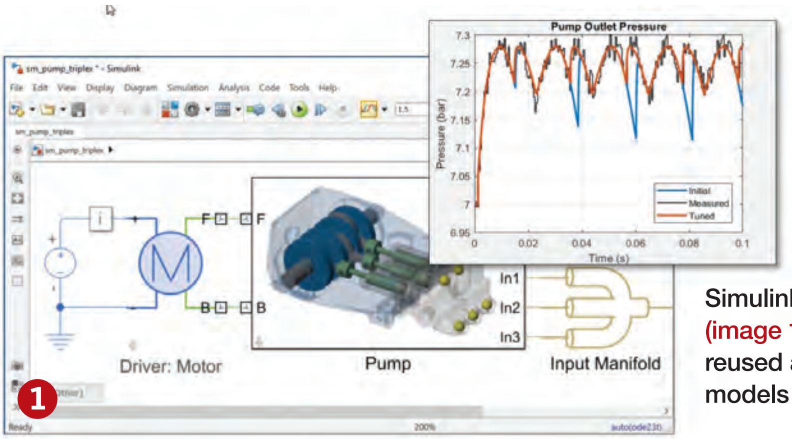
PTC's interpretation of a digital twin also includes manufacturing and supply chain as part of the digital product definition, but its concept is predicated on IoT and the notion of a connected product that captures performance, environmental and other data specific to its operation in the field. "Without the physical experience of the product, you don't really have a digital twin," says Mark Taber, PTC's vice president of marketing, explaining that it's the usage and error code data, for example, that after proper analysis, can really provide value to different stakeholders in manufacturing, engineering and service when used in context with the rest of their data.

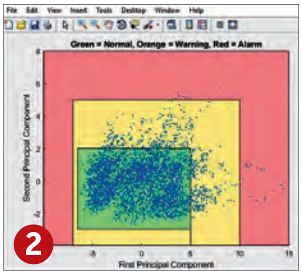
PTC also believes that the entire digital twin isn't necessarily relevant to everyone—that a solution should serve up different variations relative to an individual's role and use case. Key to this strategy is the company's Navigate technology, which taps into different systems of record like PLM, ECAD systems or simulation platforms and serves up the relevant information in a role-based app. "There's one digital twin but different views of the digital twin depending on the role and what kind of information is necessary for the job," explains François Lamy, vice president, solutions management, for PTC's IoT Solutions Group.

"You don't need a complete definition of a digital twin to get some value out of it," he adds. PTC is currently working with customers to pilot Navigate digital twin apps, but has not made any formal announcements.

## Overcoming Obstacles

It's certainly possible that companies will engage different digital twins with varying degrees of fidelity for different types of applications—for example, leveraging IoT data for predictive maintenance or a high-level model for refinement of supervisory control and data acquisition (SCADA) systems, explains Jim Tung, a fellow at MathWorks. Companies can create a digital twin to monitor the behavior of a specific, serialized asset like a wind turbine or can also expand the use case




Simulink models developed for model-based design (image 1) can be synced to deployed assets and reused as digital twins, as can MATLAB data-driven models (image 2). *Images courtesy of MathWorks.*

to multiple digital twins of several like individual assets (such as a wind farm), treating them as a population upon which they can direct operations in a fleet management capacity.

"Customers are implementing digital twin strategies starting with what their objectives are for a particular asset," Tung explains. "Those business objectives are driving the kind of digital twin to implement … because it's an awful lot of baggage to carry around models of everything."

In addition to highly advanced algorithms and machine learning capabilities, companies are making strides to better understand the data necessary to drive their specific digital twin application while solutions like MathWorks' MATLAB and SIMULINK, along with CAD and simulation packages, have been enhanced to work more directly with big data.

"What we see are companies being more refined in understanding what data they need to keep, where they need to keep it and where in industrial IoT they want to process it," Tung says, adding that automatic code generation and the ability to integrate to enterprise systems like Hadoop databases provide additional flexibility.

Data challenges aside, aggregating and integrating the different models to create a holistic digital twin is likely one of the biggest challenges to implementation. Because there is so much variety in the type, complexity and number of systems required to manage and model, much of the effort to create digital twins is currently done in a do-it-yourself (DIY) fashion without the benefit of purpose-built, off-the-shelf frameworks or software functionality, experts say.

It's a gap ANSYS hopes to address in the next iteration of its simulation platform, according to Eric Bantegnie, the company's vice president and general manager of the systems business unit.

Although ANSYS currently has a wide number of simulation tools for addressing the different physics areas of the digital twin (mechanical, fluid and engine controls, among many others), it, along with leading 3D tools providers, is currently lacking functionality to make it easier to integrate disparate models into a holistic digital twin.

"The digital twin is nothing more than the optimal integration of a variety of simulation models into a systems-level framework," he explains. "We need to extend our multiphysics product line with a solution that aggregates all simulation models to create a system-level digital twin." To that end, the ANSYS Twin Builder, part of its next major release, will allow design teams to organize all of the disparate simulation models comprising a digital twin—FEA, CFD, electrical, embedded software, for examples—into a systems-level digital model that depicts the characteristics and behavior of a physical offering.

Back at Hendrick Motorsports, the digital twin is already helping the racing team perform as a formidable competitor, despite some remaining obstacles. The plan calls for the digital master to encompass mechanical structures, the kinematics of the vehicle, the sheet metal placement, the duct work and the bracing of the cars—all created in the digital world first before building any physical prototypes. Not only does the approach enable more design freedom, Wall says, but it also delivers cost savings because the team only creates physical prototypes of optimal designs.

The digital twin's ability to connect the virtual and physical worlds is also strategic to Hendrick Motorsports' winning performance on the track. The sensored cars and test equipment produce a tremendous amount of data that can be mined for insights to fuel quick design adjustments in response to problems that occur or the ongoing rule changes.

"The biggest thing for us is to keep the process as nimble as possible," Wall says. "The digital twin affords us a speedy response to make competitive changes, fix problems and create more performance at the track in a very tight window of time." **DE**

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

**INFO** → **ANSYS:** ANSYS.com

→ **Dassault Systèmes:** 3DS.com

→ **Gartner:** Gartner.com

→ **NASCAR:** NASCAR.com

→ **Hendrick Motorsports:** HendrickMotorsports.com

→ **MathWorks:** MathWorks.com

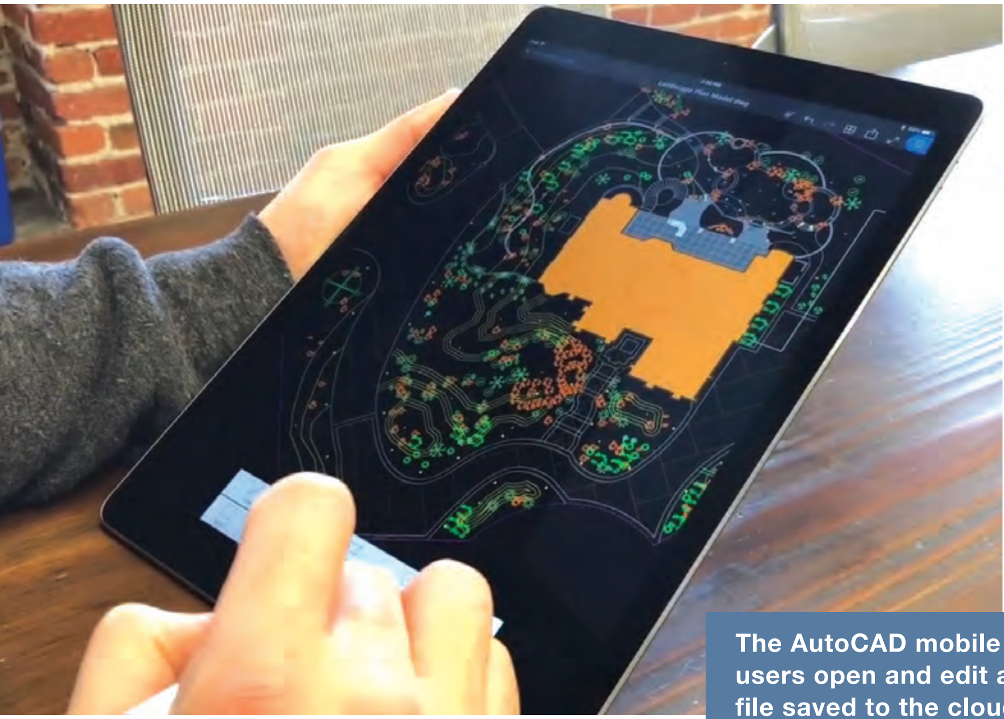
→ **PTC:** PTC.com

→ **Razorleaf:** Razorleaf.com

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

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

# AutoCAD 2019 Review



The AutoCAD mobile app lets users open and edit any drawing file saved to the cloud.

## The new release makes multiple products available for a single price.

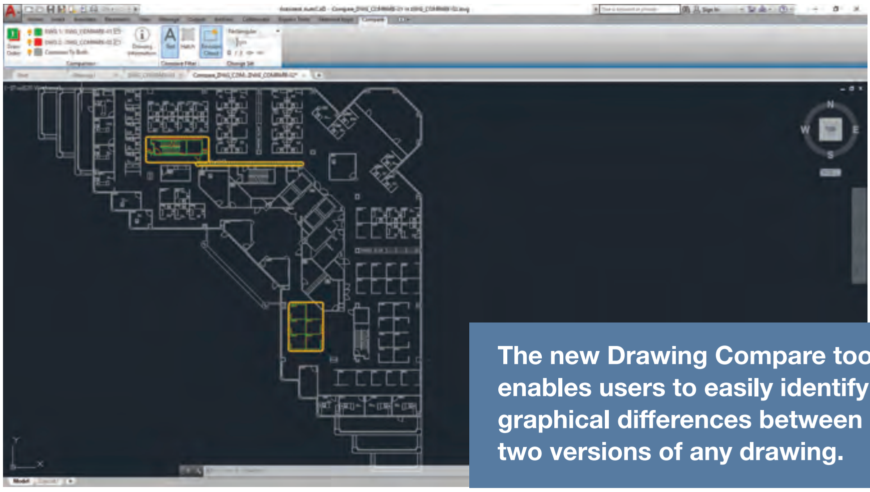
BY DAVID COHN

ON MARCH 22, AUTODESK UNVEILED AutoCAD 2019, the 33rd version of its flagship product. The company managed to announce and release the new software on the same day, although some users initially experienced technical issues that left them unable to access their subscriptions. Although that problem was quickly resolved, it prompted new CEO Andrew Anagnost to issue an apology to all Autodesk customers.

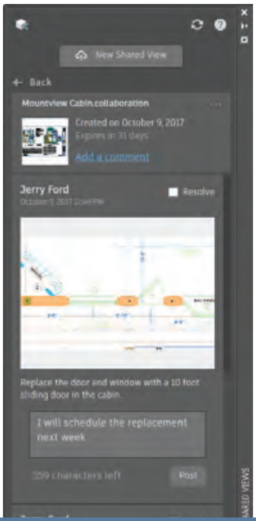
Although AutoCAD 2019 includes several new features, the big news is that every subscription to AutoCAD now bundles seven additional "specialized toolsets" into what the company is referring to as "One AutoCAD." Essentially, the vertical products formerly sold separately as AutoCAD Architecture, AutoCAD Electrical, AutoCAD Map 3D, AutoCAD Mechanical, AutoCAD MEP, AutoCAD Plant 3D and AutoCAD Raster Design are now included in the single subscription price. Users will still have to download and install each of the additional "toolsets" separately—there is no unified install—and the price represents an increase of $10 per month or $100 per year over what AutoCAD itself cost in years past. But when you consider that many of those vertical products were previously priced at $100 or more per month than the cost of AutoCAD alone, the new One AutoCAD is likely to be a hit.

In addition, a subscription to AutoCAD 2019 also includes free access to a new AutoCAD Web App and an AutoCAD Mobile App. AutoCAD 2019 includes a new feature called Save to Web and Mobile that helps to enable a seamless workflow across all devices. The new feature lets users save drawings to the cloud and then open them in a web browser or on a mobile device. AutoCAD now includes two new commands—Save to Web and Mobile and Open from Web and Mobile—accessible from both the Quick Access Toolbar and the Application menu. The first time either of these commands is used, there is a prompt to install the Save to Web and Mobile Extension. Once it has been


In addition to AutoCAD itself, AutoCAD 2019 includes seven specialized toolsets plus web and mobile apps.



The new Drawing Compare tool enables users to easily identify graphical differences between two versions of any drawing.



Users can expand any view in the Shared Views palette to read or post comments and reply to comments received from others with whom they have shared views.

installed, there is an option of making desktop files available to the AutoCAD web and mobile apps.

The new web and mobile apps are not just updates to the older AutoCAD WS or AutoCAD 360 apps, but rather entirely new programs powered by the same underlying engine as the Windows version of AutoCAD. So, users can work on drawings in a browser or on a mobile device wherever users have an internet connection. The AutoCAD Web App is essentially a full version of AutoCAD running in a browser. Any changes users make while working in the field using the web or mobile app are saved to the cloud-based version of the drawing and will be displayed when users reopen that version of the drawing in their desktop copy of AutoCAD 2019, but users will have to overwrite the local version of the drawing if they want those changes to be saved locally.

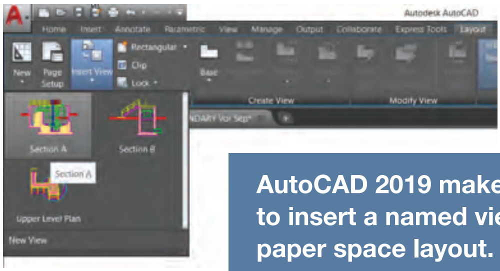
## New Look and Drawing Compare Tools

In addition to One AutoCAD and the new apps, there are multiple enhancements and new features in AutoCAD 2019, although perhaps not as many as in years past. In addition, many of the new 2019 features actually appeared in the 2018.1 incremental release.

One of the first things users will notice is a subtle change to the user interface. As part of its efforts to update AutoCAD so that it looks good at 2K (1080) and 4K (2160) resolutions, the program uses new, simplified "flat" icons that are easier to identify. The program automatically loads the icon set appropriate for the display resolution. This visual simplification also extends to the Status bar, where blue button backgrounds make it much easier to determine when a particular setting is toggled on.

Beyond these subtle differences, AutoCAD 2019 provides several new commands. Perhaps the most significant is a collection of new Drawing Compare tools that enables users to easily identify graphical differences between two versions of any drawing. Although similar tools were already available in some vertical flavors of AutoCAD—such as AutoCAD Architecture—this tool is now part of AutoCAD itself.

Users can start a drawing comparison from the Application menu or the Collaborate ribbon. After selecting the two drawings to compare, the program analyzes them and displays the results as a new drawing, with three categories of objects highlighted: those located only in the first drawing, those located only in the second drawing, and those that are identical in both drawings. Users can then use tools in a contextual ribbon to adjust the comparison display by swapping the order of the drawings, moving either to the foreground, toggling the display of either drawing, changing comparison color settings and so on.



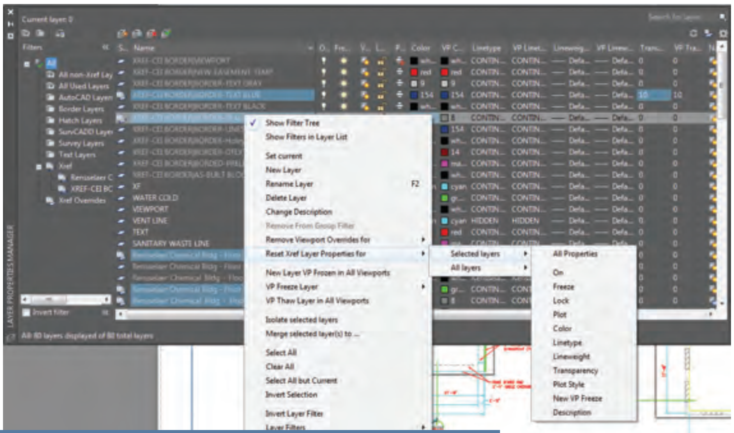
AutoCAD 2019 makes it easy to insert a named view onto a paper space layout.

Other tools let users include or exclude text and hatch objects from the comparison results. But, by far, the standout feature of the new Drawing Compare tool is the ability to automatically place revision clouds around changes and control how the program creates and displays those revision clouds.

## Safely Sharing Designs

The new Shared Views feature in AutoCAD 2019 makes it easier for users to share designs with others without releasing original drawing files. This feature is intended to replace the commonly used workflow of publishing DWF or PDF files and then emailing them. Instead, views and data are extracted from the drawing and stored in the cloud. Users can then send a shareable link, which allows the design to be viewed in a browser and commented on from any web-enabled desktop, tablet or mobile device.

Recipients of the link can view, measure, comment and mark up the design and share their feedback. An email is sent whenever someone comments on the shared view. Users can then view and reply to comments, and manage the shared view



Improvements to the Layer Properties manager make it easier to identify and reset layer property overrides.

using tools in a new Shared Views palette. Shared views automatically expire after 30 days, but users can extend or terminate the link at any time.

## Other Enhancements

AutoCAD 2019 also includes enhancements that make it easier to create and work with named views. Although being able to create named views has long existed in AutoCAD (and named views make it easier to navigate drawings), the big news here is that users can now quickly create named views and place them as paper space viewports by selecting any named view from a gallery. The program automatically applies an appropriate scale, resizes the view port and locks it, essentially reducing a multi-step process to a few simple clicks. Viewport grip enhancements then make it very easy to move and resize viewports, and a new triangular grip lets users quickly change the viewport scale.

The Layer Properties manager has also been improved to make it much easier to identify and control overrides to layer properties. For example, a new status icon indicates when an xref layer or viewport layer contains overrides. When users pause the cursor over a layer that includes an override, a tooltip appears that lists all those overrides. In addition, users can apply a background color to layers and properties that have been overridden, and even assign different background colors to identify whether the override has been applied to a layer in the host drawing or an external reference. Users can then filter layers based on overrides and use tools in right-click menus to reset any or all layer properties back to their original values. Other improvements to layer settings make it easier to control xref layer properties.

Beyond these obvious changes, the program's performance has been improved. Operations that require AutoCAD to redraw or regenerate 2D graphics have been streamlined, resulting in significantly faster execution. Navigation when working in 3D has also been enhanced. What's more, all of the improvements and new features—UI changes, web and mobile apps, 4K display support, Drawing Compare, Shared Views and so on—are included in AutoCAD LT 2019 as well.

After more than 35 years, AutoCAD remains the world's leading CAD program. The improvements made to this release set the stage for many years to come. DE

**David Cohn** *has been using AutoCAD for more than 35 years and is the author of over a dozen books on AutoCAD. As senior content manager at 4D Technologies, he creates the CADLearning courses for AutoCAD and AutoCAD LT (cadlearning.com). He is a contributing editor to* Digital Engineering, *and also does consulting and technical writing from his home in Bellingham, WA. You can contact him at david@dscohn.com or visit dscohn.com.*

**INFO ➜ Autodesk:** Autodesk.com

**PRICES**

AutoCAD 2019 and AutoCAD LT 2019 are only available by subscription. Upgrade pricing and perpetual licenses are no longer available. Customers can trade in R14 through 2016 perpetual licenses for discounts of up to 25% on a one- or three-year subscription.

***AutoCAD 2019***

- **Monthly**: $195
- **1 Year**: $1,570
- **3 Years**: $4,725
- **1 Years (with trade in of perpetual license)**: $1,181.25

***AutoCAD LT 2019***

- **Monthly**: $50
- **1 Year**: $390
- **3 Years**: $1,170
- **1 Years (with trade in of perpetual license)**: $292.50

**SYSTEM REQUIREMENTS**

- **Operating System:** Windows 10 (64-bit), 8.1 (32- or 64-bit), or 7 SP1 (32- or 64-bit)
- **CPU:** 2.5GHz processor or faster (3.0GHz or faster recommended)
- **Memory:** 8GB (16GB recommended)
- **Disk Space:** 6GB free disk space for installation
- **Display Resolution:** 1920x1080 with True Color (resolution up to 3840x2160 supported on Windows 10 64-bit systems)
- **Display Card:** 1GB GPU with 29GB/s bandwidth and DirectX 11 compliant (4GB GPU with 106GB/s and DirectX 11 compliant recommended)
- **Browser:** Google Chrome
- **Other toolsets have additional system requirements:**

– AutoCAD Plant 3D (8GB additional disk space; 64-bit OS only)
– AutoCAD Map 3D (16GB additional disk space; 16GB memory; 64-bit OS only)
– AutoCAD Architecture (10GB additional disk space)
– AutoCAD Electrical (12GB additional disk space)
– AutoCAD MEP (12GB additional disk space)

# An ESRD CAE Handbook Look

## Follow a fatigue crack problem and pre-load in a T joint.

BY TONY ABBEY

THE ESRD CAE HANDBOOK is a collection of pre-built FEA models that can be run to check strength, stiffness and other characteristics of many typical fittings and components found in aerospace and other industries. A standard library of components is available. Clicking the Browse icon in the Handbook menu tab reveals the portfolio of models available.

Each of the component models can be configured with a set of parameters to match a specific component variation. I have chosen the 3D lug with corner crack from the Fracture Mechanics library for the first half of the review. Fig. 1 shows the User Interface after opening the model and arranging some of the key windows.

The Windows icon allows for the selection of visible windows. The windows can then be arranged by the user. On the left I am showing the Model Information window, which is a document describing the 3D Lug with Corner Crack Model. This can be printed or saved as a PDF. In the center is a plot of the FEA model, which will be analyzed, showing the mesh, loads and boundary conditions. On the upper right is the input dialog box for the lug and crack geometry, loading and materials. Below that is a diagram showing lug and crack geometry definitions.

I am using the default settings for this example. The lug is 2 in. wide and 2 in. long. The hole is concentric with the lug and has a diameter of 0.5 in. The crack is at 90° to the lug axis and is situated on the lower half of the lug. It is a quarter crack starting at the corner. The aspect ratio and size are controlled via crack length and depth inputs. Fig. 2 shows the starting crack and the prebuilt mesh provided to accommodate it.

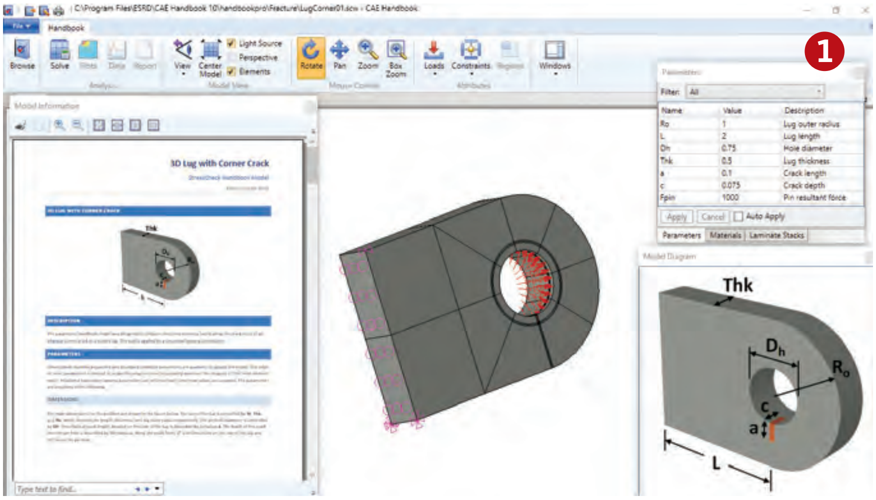



FIG. 1: CAE Handbook layout.

The load is defined as a sine distributed bearing load along the lug axis. The magnitude is set by the user, 1000 lbf in my case. The cut face of the lug is constrained axially, but free to shrink by using an additional minimum constraint set.

There are an additional set of parameter-based rules, which prevent the user from inputting inadmissible geometry (negative volumes), crack shapes that are too shallow and lug configurations outside a reasonable range.

The FEA model is analyzed using the StressCheck solver from ESRD. This solver uses an automatic p-version method focused on solution convergence [1]. Each element can develop its own required order (p value) of internal shape function. A single element can handle very steep stress gradients. This contrasts

## Editor's Note

This is one of a new series of overview articles looking at simulation and optimization software products. The full capabilities of each product cannot be covered in a few pages, but we hope to give you a feel for the basic workflow required. A set of videos documenting and expanding on the steps taken can be found at: digitaleng.news/de/esrd.

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

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

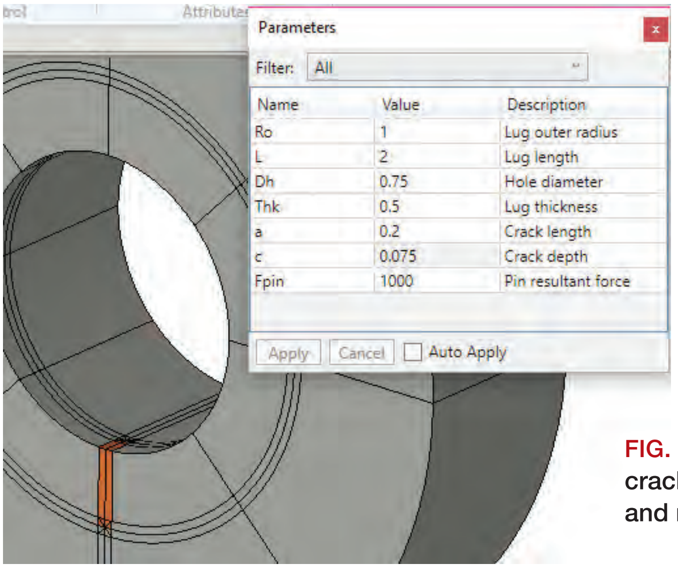



**FIG. 2:** Starting crack parameters and mesh.

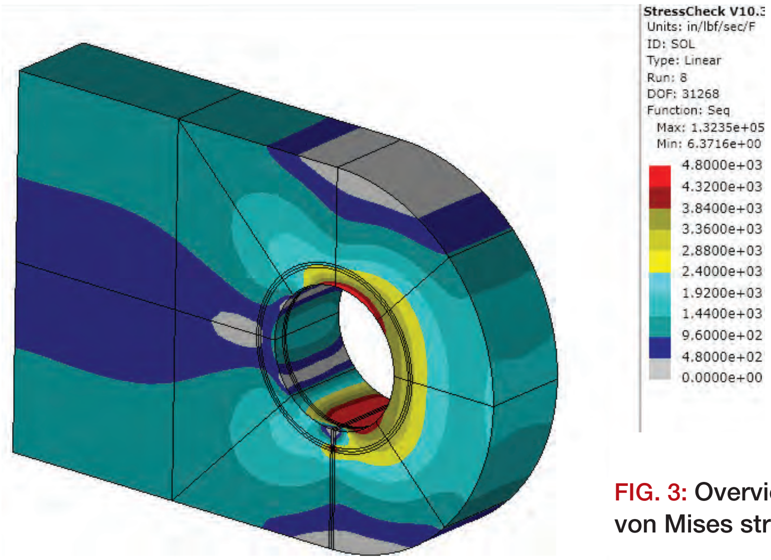



**FIG. 3:** Overview of von Mises stress.

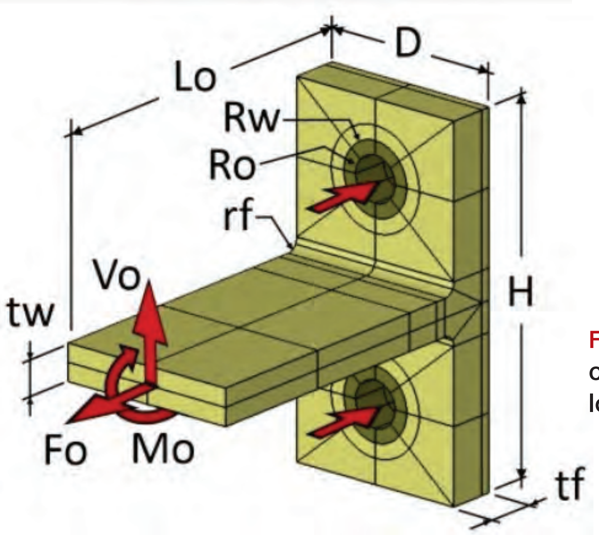



**FIG. 4:** T joint configuration and loading.

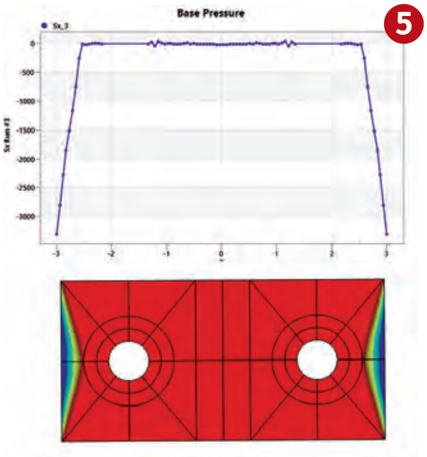



**FIG. 5:** Contact stress distribution with no preload, upper and centerline stress, lower.

with the more traditional h-element method, which requires an increasing number of elements to handle areas of steep stress gradient. The StressCheck solver allows automatic stress convergence to be achieved 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.

This approach ties in well with ESRD's CAE Handbook methodology. The initial lug mesh has been defined by the FEA expert who built the model and compiled it into the CAE Handbook example. The model has been tested within the range of geometric variations defined by the geometry and associated rules. The starting mesh is structured to optimize the convergence performance. The recommended geometric grading of the mesh to deal with the singularity at the crack tip has also been predefined. Fig. 2 shows a very simple mesh schema, with few elements, but these represent well-defined domains within which to enhance the internal shape function. This avoids the need for the user to worry about controlling the mesh and provides consistency and reliability in the usage of the model.

The CAE Handbook is a form of templating. An expert FEA user can set up a model with one or more parts using Linear, Modal, Buckling or Nonlinear StressCheck solver solutions. In the case of the cracked lug, the Contour Integral Method is used to predict the required Stress Intensity Factors. The Model Information window, Parameters window and

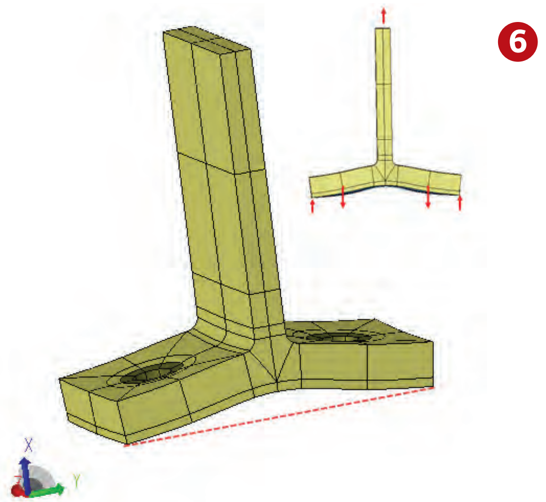


FIG. 6: Bolt reaction system (inset) and deformed shape plot.

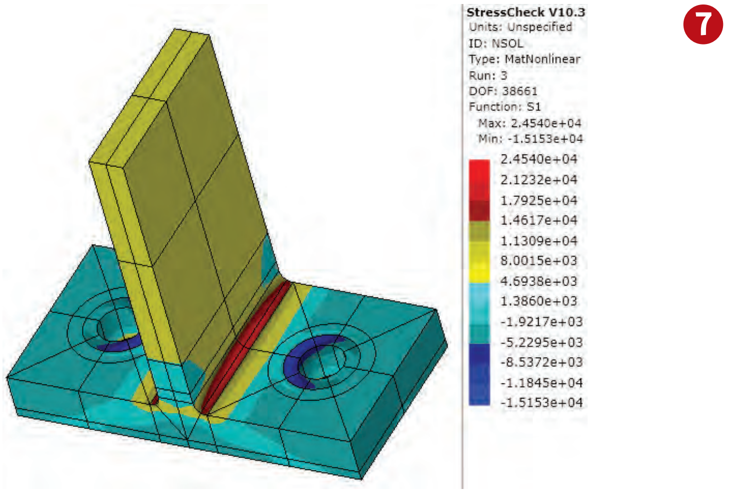



FIG. 7: Maximum principal stress for baseline model.

all the other input windows can be set up by the expert, following the guidelines in the CAE Handbook author's guide. This is ideal for companies with repetitive analysis requirements. In my case, some 40 years ago I had to carry out exhaustive lug damage tolerance analyses checks on the Tornado combat aircraft. A tool like this would have meant turning that work around far more quickly and delegating much of the analyses.

With the model parameters set up, just click on the solve icon. A solution log shows the runtime history—eight analyses are used and the numbers of degrees of freedom (DOF) increase as the polynomial order is increased.

Once the analyses are complete—the convergence history is output in graphical form. ESRD places great emphasis on convergence checking and a variety of error measures can be chosen. I selected Total Potential Energy versus DOF. However, I could have chosen Convergence Rate or Percentage Error against DOF or Run Number.

The output that the user can see in the Handbook is controlled by its original author. In this case, an overview of the von Mises stress is part of the output available, as shown in Fig. 3.

However, in my case the Stress Intensity factors around the crack front are the most important result. From these values, the tendency for crack propagation can be estimated, together with the likely configuration of the crack development. By running a series of analyses and using the Paris Law, the crack propagation rate can also be estimated.

Convergence check plots on the Stress Intensity Factor at the two ends of the crack are also available. All the images, xy plots and data tables are available in a predefined report format, available for exporting as an xps file.

Note that the parent StressCheck solver has been used extensively in the aerospace industry for modeling fatigue cracking and delamination of a wide variety of fittings and joints [2]. The CAE Handbook examples are an interesting and easily accessible subset of that work.

### The T Joint Structure

The T joint structure to be analyzed is shown in Fig. 4. The image is taken from the CEA Handbook Model Diagram. I was interested to compare the results of the StressCheck solutions against approximate hand calculation assumptions. The ESRD experts kindly helped me by modifying the T joint CAE Handbook model to prove additional contact pressure output.

The figure shows the main parameters to be input. In my case the only applied loading is a vertical tensile load. I used the default values for the handbook example, which provide for a 6-in.-wide bracket, 3 in. deep and 6 in. high. Flange thickness is 0.8 in. and vertical web thickness is 0.6 in. The fillet radius is 0.2 in. A 0.375 radius bolt is used, with a 0.6-in. radius washer face. A flexible

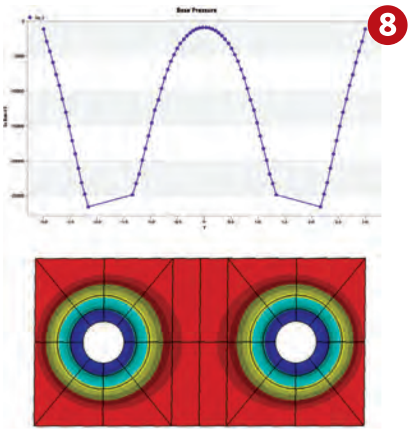


**FIG. 8:** Centerline plot (upper) and contour plot (lower) of contact stress under preload only.

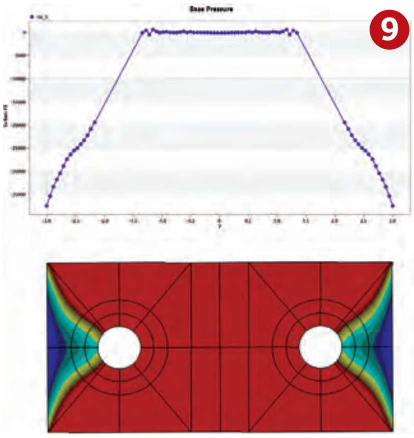


**FIG. 9:** Centerline plot (upper) and contour plot (lower) of contact stress under full load.

backing structure is assumed, with a stiffness proportional to the flange in the normal direction. Bolt shank and washer axial stiffness are set to the same stiffness value.

There is an option to apply a bolt preload via bolt elongation, but initially I wanted to check the basic bolt prying action without a bolt preload. I used 10,000 lbf applied vertically. Fig. 5, lower, shows the "prying" normal contact stress outboard of the bolt washer faces. The red contour is at zero stress. It is interesting that the variation across the depth of the flange falls to zero at the front and back edges. The distribution is assumed constant in the simple hand calculations. The graph in Fig. 5, upper, shows the centerline contact stress. The distribution agrees well with the triangular distribution often assumed in hand calculations.

The "prying" action is highlighted by the deformed shape plot, shown in Fig. 6. The end edges of the flange form the "prying" points with corresponding reactions, creating higher bolt loads than if the flange was infinitely stiff.

There are many semi-empirical methods for calculating prying force. If the prying force distribution is assumed to act at the flange edge, one classical solution is:

*Q = bF/(2a)*

Q is the prying force, 2F is total applied load, a is distance from edge to line of bolt reaction, b is distance from the web face to the line of bolt reaction.

Using this hand calculation, the bolt force is 6,653 lbf per bolt (prying reaction is 1,653 lbf).

Reference [3] includes the flange thickness in the calculation. I changed the effective distances a and b using reference 4. The calculation then becomes:

*Q = F(3b'/8a'-t^3/20)*

Where t is the flange thickness and a' = a+r , b'=b-r, where r is the bolt radius.

The bolt force is now 6,112 lbf and the prying reaction is 1,112 lbf.

The CAE Handbook result is 6,059 lbf bolt force and 1,059 prying reaction and represents a more sophisticated solution.

I have also plotted the maximum principal stress as shown in Fig. 7. The peak value is 24,540 psi.

Factors such as flange nonlinear contact and hence stiffness have historically made hand calculation difficult. I have not validated the current FEA results against test, but have used this configuration as a baseline to investigate bolt load with applied load, under constant preload. The CAE Handbook is ideal for this type of study, providing fast turnaround.

The bolt elongation due to preload is now set at 0.004 in. The bolt preload is checked by running an analysis without applied load. The preload developed is 53,042 lbf per bolt. The distribution of normal stress under contact is in Fig. 8.

The distribution is virtually concentric around each bolt. The stress falls off in a linear profile, apart from under the T joint web region.

With fully applied load of 130,000 lbf the stress distribution is very different, as shown in Fig. 9.

In classical bolt joint calculations, when a critical load is reached, the flange is assumed to separate from the backing plate to which it is clamped. This is described as preload "breakout." Fig. 9 shows that there is still contact at a high total applied load level of 130,000 lbf, with a prying type action developed at the flange edges. The flange and backing plate are flexible in this FEA study. In classical bolt joint calculations, they are assumed to be rigid, allowing a well-defined breakout point.

The variation of bolt load with applied load per bolt can be shown to see the expected preloaded bolt breakout trend, with the preload having a near constant value up to the breakout applied load and then increasing linearly with applied load. The breakout is not an abrupt transition, as in classical calculations, but by around 35,000 lbf applied load the transition is complete.

In conclusion, the examples I used from the ESRD CAE Handbook library allowed me to investigate two different scenarios quickly. In the T-joint case, a useful extension beyond classical methods is found. Because I did not have to focus on FEA model setup, I could concentrate on planning the studies and interpreting the results. All models and documentation are loaded into the library, so it was easy to pick up the thread when I revisited the studies after a long break.

I look forward to trying the next stage, building up my own CAE Handbook example using StressCheck. **DE**

..................

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

**References**

**1.** *Szabo B and Babuska I. Introduction to Finite Element Analysis. Formulation, Verification and Validation. John Wiley & Sons Ltd., Chichester, UK, 2011.*

**2.** *Szabo B and Babuska I. Computation of the amplitude of stress singular terms for cracks and reentrant corners. Fracture Mechanics: Nineteenth Symposium ASTM STP 969. T.A. Cruse, Ed., American Society for Testing and Materials, Philadelphia (1988) 101–124.*

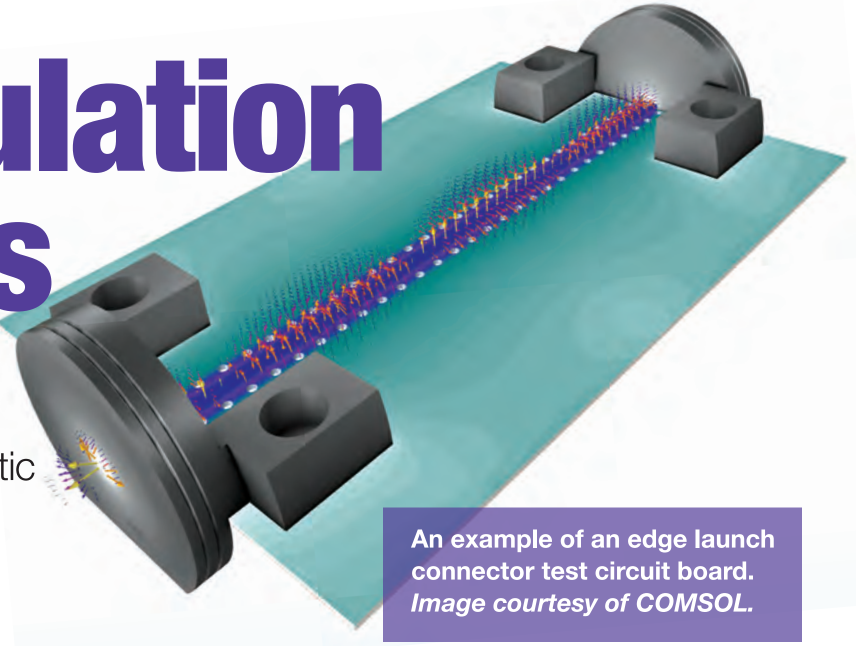
**3.** *Douty RT and McGuire W. "High Strength Bolted Moment Connections," Journal of the Structural Division, Vol. ST2, 1965, pp. 101–128.*

**4.** *Struik JHA and De Back J. Tests on bolted T-stubs with respect to a bolted beam-to-column connection," Stevin Laboratory report 6-69-13, Delft University of Technology, The Netherlands, 1969.*

# EMI Simulation Advances

An increase in embedded electronics and IoT devices is spurring the use of electromagnetic interference simulation.

**BY BRIAN ALBRIGHT**



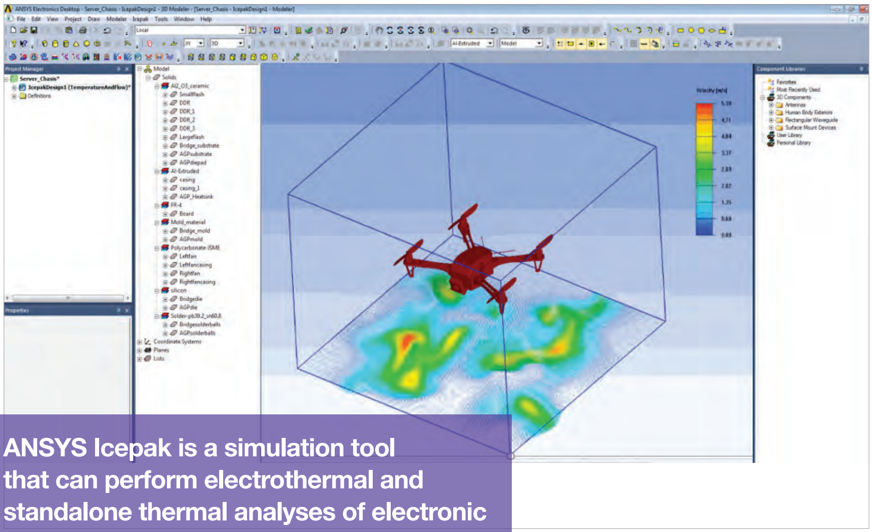
**An example of an edge launch connector test circuit board.** ***Image courtesy of COMSOL.***

ELECTROMAGNETIC INTERFERENCE (EMI) and EM compatibility (EMC) have always been key concerns for designers of electrical devices. The RF noise radiates from every electric device, potentially creating internal disruptions or interference with other nearby devices.

Next-generation RF, microwave and millimeter-wave applications like 5G wireless, the internet of things (IoT) and high-speed interconnects have resulted in an increasing interest in EMI simulation. As the IoT expands and embedded electronics become more ubiquitous, it will result in an unprecedented level of co-location scenario complexity.

"It's expected that 5G will need to utilize higher frequency spectrums in the millimeter-wave range where the quality of the signal can be more vulnerable than the conventional lower frequency applications against the noise from outside the circuit, and the performance can be easily degraded by impedance mismatch, insertion loss and crosstalk," says Jiyoun Munn, technical product manager of RF, COMSOL Inc.

Every connected device can potentially increase the amount of EM radiation and RF noise, and mitigating against the problem with shielding is a costly and complex solution that most companies want to avoid. That means designers will need to engineer that interference out of the devices that they are developing earlier in the process—relying on EM simulation tools to do so.



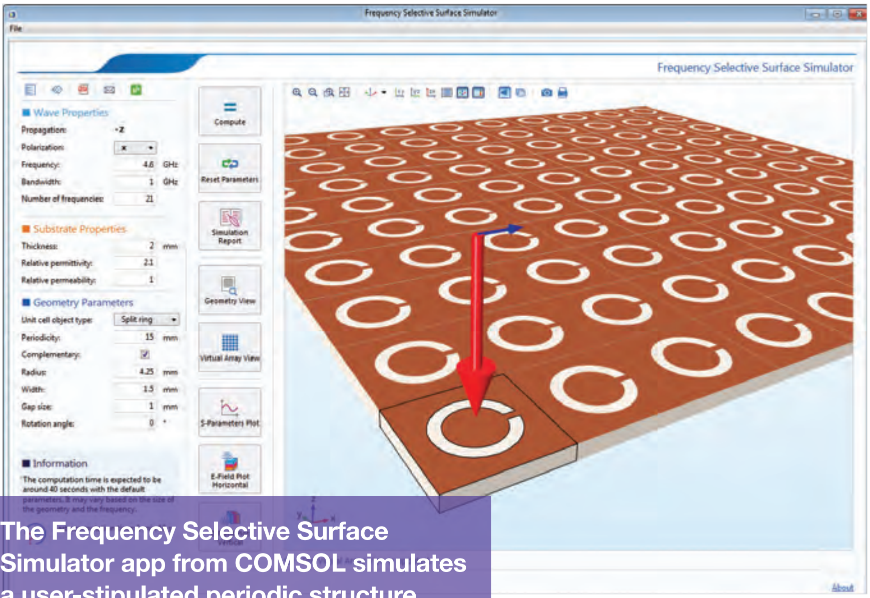
**ANSYS Icepak is a simulation tool that can perform electrothermal and standalone thermal analyses of electronic designs.** ***Image courtesy of ANSYS.***

## Buzz Around EMI Simulation

In the past, designers mostly didn't consider EMI until they presented the finished product for compliance testing. "Then they would go to the anechoic chamber and discover they don't meet the requirements for radiated emissions, or they are susceptible to internal or external inferences," says Larry Williams, director of technology at ANSYS. "EMI compliance is a process, and you have to build that process into your design activities. If you wait until the end to see if the product will radiate, you are making a mistake."

The advent of the IoT and the creation of smaller and smaller electronic components are creating greater opportunities for EMI issues, even in products where this wasn't previously even a consideration. The cost of mitigating these problems after the fact is a greater concern, particularly when it comes to lower-cost assemblies and products.

IoT devices are smaller and relatively inexpensive, so manufacturers don't want to spend a lot of money on




**The Frequency Selective Surface Simulator app from COMSOL simulates a user-stipulated periodic structure selected from the built-in unit cell types. *Image courtesy of COMSOL.***

enclosures and shielding. Components also come from a variety of suppliers, which makes it difficult to manage coexistence or to anticipate how the system will perform in advance.

"You need to do a lot of EM 3D simulation to understand a product well," says Minoru Ishikawa, market development manager at Mentor Graphics, a Siemens company. "You can have a virtual prototype that helps you identify these issues sooner."

Simulation software providers have been expanding their EMI simulation capabilities through acquisition. Siemens, for example, acquired EM simulation software company Infolytica, which was folded into the Mentor Graphics mechanical analysis division. Altair acquired FEKO, while Dassault Systèmes acquired CST, a package of tools for EM-centric multiphysics simulation.

Simulation supports designers by allowing them to virtually evaluate several design ideas and implement physical prototypes based on the most promising concepts, as well as investigate different boundary conditions without damaging a prototype.

The goal of simulation specialists is to mimic the real world as closely as possible, so that the prototype is based on numerical results that achieve the expected performance in fewer design and test iterations," COMSOL's Munn says.

The difficulty with EMI, though, is that it's difficult to simulate an entire system. "You'd have to simulate the entire product the same way it would function as when you plug it into a 110v outlet and turn on the power," says Dave Kohlmeier, senior product line director of Mentor's HyperLynx product. "There are all of these digital signals and analog signals running concurrently, producing various amounts of radiation in various directions, and it's almost impossible to recreate that stimulus."

Kohlmeier says rules-based verification has been used to predict and address the inadvertent antennas created in these systems, an approach that can improve product performance even as the ability to run complex simulation has increased.

"That's especially important in these IoT devices," says Swagato Chakraborty, director of engineering for HyperLynx Advanced Solvers. "You need to make sure the intended antennas perform correctly, and catch those unintended antennas."

That activity is difficult to profile. Mentor can simulate the effect of shielding on a given system, for example, but a rules-based approach can help determine where an antenna may have been accidentally created.

"3D simulation can work well when you want to find the optimal geometry or topology, or to understand a path or channel and how to prevent interference," Kohlmeier says. "Rules-based verification and 3D simulation help each other to develop a good board."

## Smaller Electronics, Bigger Challenges

The fact that electronics components are getting smaller, and being incorporated into smaller products, also poses an EMI challenge. Smaller and embedded electronics are especially prone to challenges involving crosstalk, coupling, interference and impedance mismatching—and adding shielding to these components is more complicated.

"Smaller embedded devices experience the electrothermal effects in an exaggerated manner because of the physical space limitations," Munn says. "Coupling between devices and signal lines in smaller embedded devices are prone to signal quality degradation due to the impedance mismatching caused by device miniaturization."

For example, engineers working on high-speed interconnects face a number of design hurdles, as geometry, size and transmission constraints must be met while matching the impedance of the connector to the rest of the transmission line. As the frequency increases, maintaining the impedance becomes more complex, as small quirks arising from the geometry or selected materials can be magnified.

"Analyzing crosstalk is particularly challenging because in situations such as extreme heat or blizzard conditions for example, you now must take into consideration not only the electromagnetic properties, but heat transfer and structural deformation to begin to get an accurate representation of the physics in the real world," Munn says. "Also keep in mind that the impact of the electrothermal effects will most likely have a much greater impact on a smaller embedded device than it would with a larger piece of equipment."

EMI issues also often result from signal integrity or power integrity issues—which are also more complicated in smaller devices. "There's a lot of energy, and it has to go somewhere," Williams says. "You need good design flow that includes signal and power integrity and that can help reduce EMI problems."

With smaller electronics, the need for high-speed access to memory and high performance, combined with compressing the electronics into a small space, work against EMI compliance. In the case of ANSYS, the company has built features into its software that can automate and customize design flows around signal and power integrity.

"We've built into our tools the ability for engineers to receive a printed circuit board layout and bring those models in, and automate those parts of the process," Williams says.

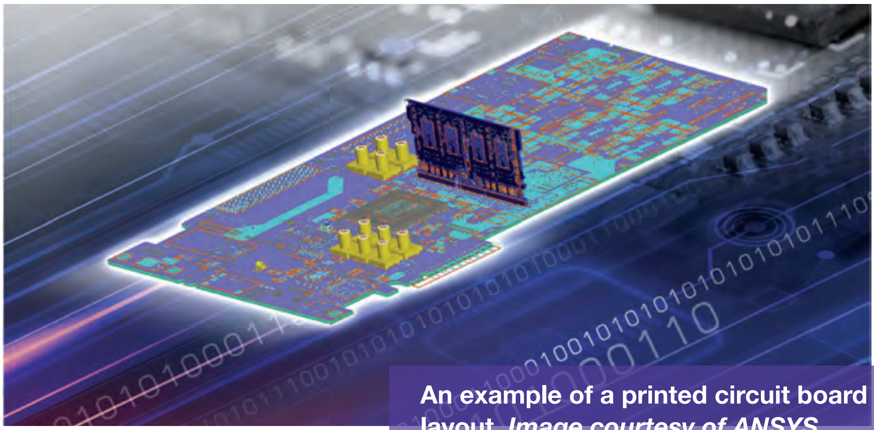
## A Multiphysics Approach

To successfully miniaturize an electronic product and reduce EMI challenges, engineers need to be able to effectively and efficiently represent the real world as closely as possible. This involves using a multiphysics simulation solution that enables modeling of components and phenomenon that you are not able to physically test in all cases.

COMSOL's AC/DC Module enables simulation of low-frequency electromagnetics and electromechanical components; the company's RF Module is designed to model high-frequency EM phenomena and optimize electromagnetics devices such as antennae and micro/millimeter wave circuits.

The AC/DC Module and RF Module can be used for electromagnetic analysis. When this simulation is set up, a user can move on from a single physics electromagnetics analysis and add physics from one of COMSOL's add-on products, such as the Heat Transfer Module, CFD Module, Structural Mechanics Module, etc.

"Compared to traditional electromagnetic modeling, multiphysics simulation enables the end user to include effects such as temperature fluctuations, structural deformations, and fluid flow to perform virtual prototyping that truly describes the real world," Munn says.



**An example of a printed circuit board layout. *Image courtesy of ANSYS.***

The ANSYS HFSS simulation tools can be combined via the ANSYS Electronics Desktop to streamline workflows and reduce development time, while rapidly testing and validating EMI and EMC compliance. Engineers can use EMI simulation tools to analyze and optimize trade-offs among speed, bandwidth, signal and power integrity, EMI and thermal performance in these devices.

"If you are putting these electrical devices inside automobiles, you want to know that they are reliable for temperature, vibration and shock," Williams says. "We can link through the ANSYS Workbench to other tools for thermal, mechanical, structural and vibration simulation and that's critical."

## Evolving Challenges

As the number of connected devices increases, EMI-related design challenges also will grow. Collaboration across departments and specialties will be important, particularly when it comes to designers who have little or no experience running these simulations.

"When designers are equipped with the right set of tools, they can freely collaborate with colleagues throughout their organization and beyond. Working cross-departmentally will be key to competing and succeeding in the ultra-competitive market we find ourselves in," Munn says.

Still, the computational scale required to simulate an entire electrical system would be massive, which is what has made that approach impractical so far. A combination of rules-based verification and multiphysics simulations will be required.

New EMC and EMI models and approaches will need to be developed that take into consideration the greater vulnerability of the IoT, larger concentrations of co-located devices, greater occupation of unlicensed frequency bands and unpredictable and highly dynamic interference scenarios.

Smart devices have to juggle and balance multiple wireless signals, from the Wi-Fi coming from a nearby access point to a GPS signal coming from space. "You have these multiple systems co-existing, and you don't want the device to destroy its own ability to operate," Williams says. "Now there are 5G systems coming and high-speed downloads. High frequency is a bigger challenge for designing devices, and having advanced field simulation is key. You can't cut corners." **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 ➜ Altair:** Altair.com

➜ **ANSYS:** ANSYS.com

➜ **COMSOL:** Comsol.com

➜ **Dassault Systèmes:** 3DS.com

➜ **Mentor Graphics:** Mentor.com

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

# Deep Learning Accelerates Product Development

A typical engineer can grasp the basics of deep learning tools in a day.

**BY RANDALL S. NEWTON**

RECENT ADVANCES IN COMPUTER science have made it possible for computers to work more like the human brain than a high-speed mechanical calculator. But for a generation, most of the research made little practical progress for two very basic reasons: limited knowledge of how the human brain works, and the computing power needed to mimic human thinking processes was not widely available. Even with these limitations, progress has been made over the years in machine learning (ML), a branch of artificial intelligence (AI) that focuses on the application of pattern recognition to automate processes.

The 1990s saw an increase in machine learning research, and practical applications emerged. The U.S. Postal Service adopted ML handwriting recognition in 1999, taking advantage of its access to millions of handwriting samples. ML has since become an essential part of factory automation as well as various products where visual recognition can improve automation, such as in food processing, security systems and image recognition (think Facebook or some smartphone apps).

In recent years, a new method of ML has emerged: deep learning (DL). It uses neural networks (from AI research) and vast databases—neither of which were practical for commercial use until recently. DL uses neural net algorithms to train itself to understand a topic, seeking connections in the characteristics of a given data set. The DL algorithm creates multiple layers of characteristics, and uses the representations with multiple levels of abstraction.

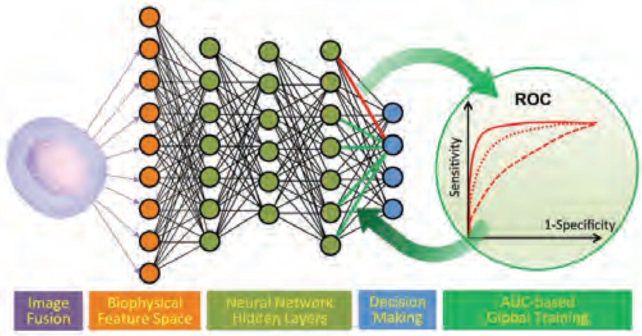
A deep learning system does not need to be trained to recognize every example of a concept, as is the case with ML. Instead, DL learns from experience, seeking hidden patterns and organizing its findings as a hierarchy of layers from simple to complex. Researchers says DL more closely mimics the human brain than previous ML techniques.

Sample size is another key difference between ML and DL. Consider an example of sorting fasteners. Machine learning algorithms do their best operating with a small sample of data so it can continually ask: "Does this fastener match my data?" DL algorithms are first taught as much as can be provided about fasteners, building up knowledge that allows it to then ask: "How does this fit into what I know about fasteners?"

**Tyan is one of several computer vendors with new systems using the latest NVIDIA GPU technology, designed for DL and other computationally intensive applications. Pictured is the Tyan Thunder HX FA77B7119.** ***Image courtesy of Tyan.***

Smart manufacturing uses the advancements of DL to improve system performance and deepen automated decision-making. DL provides the advanced analytics required to process vast manufacturing data sets.

The widespread deployment of sensors and embedded computing defines what we now call the internet of things. But the deployment of smart hardware into parts and machines means there is an ever-increasing need for analytical tools to process all this real-time data and improve system performance. Thus the need for DL as an engineering tool in product development.




UCLA researchers used MathWorks Deep Learning tools to create a new diagnostic product for examining cancer cells that gives superior results over existing methods. The researchers say modeling the system with DL saved months of experimental time. The cancer cell neural net model was then repurposed for algal cell classification, by providing new data to the algorithm. *Image courtesy of MathWorks.*

## Six Steps to Building a Deep Learning System

The tools are now available to build custom DL systems, with software from vendors like MathWorks or Microsoft, from hardware vendors like NVIDIA and from process experts like Jonathan Hurlock, Ph.D., who consults for companies looking to exploit DL.

Hurlock says there are six steps in developing a DL system, independent of the specific tools in use. The six steps are as follows:

**1. Understanding the requirements.** The first step is setting realistic goals, based on project requirements. "It is very important to understand the behavior we want to influence or allow," says Hurlock. An example would be to increase successful recognition of misshapen parts by 8%.

**2. Research appropriate models and algorithms.** Most DL projects start with one of several standard data models and algorithms that have been developed over the years. By breaking the larger problem down into several smaller problems, Hurlock says it becomes easier to match the right models and algorithms to each task.

**3. Obtain data and understand the data sources.** DL is a process of working through data to discern relationships and common elements. Hurlock says this process happens in two ways: supervised learning and unsupervised learning. Supervised is based on learning from a set of existing labeled data—such as "these are good fasteners; these are bad fasteners." Unsupervised is when the algorithm finds patterns where no labeled data exists.

**4. Feature generation and dimensionality reduction.** Feature generation is an intermediate step that is sometimes used to bridge the gap between supervised and unsupervised DL preparation. An example would be breaking down signals from a sensor into categories and adding priorities to some categories. Dimensionality reduction is used to narrow the number of features that lead toward the solution, such as eliminating fasteners outside of a certain range of sizes.

**5. Train the model.** A DL algorithm creates a model by finding patterns in the data and building a set of correlations to the target. The engineering goal in this step is to help the algorithm improve on the model by adjusting the data set until it reaches the requirements established in step 1.

**6. Evaluate the model.** This is the step where you test the DL algorithm for predictive accuracy. Hurlock says this can be an iterative process, with several adjustments to the model, to feature inputs, or by providing more data. You might also come to the conclusion that the time and cost of this particular DL scenario does not offer enough ROI or cannot hit the requirements.

## Deep Learning at MathWorks

Engineering software company MathWorks has been exploring the machine learning space since 1991, says Bruce Tannenbaum, MathWorks senior product marketing manager.

"We were doing machine learning before it was a big deal," he says.

Today it offers deep learning tools on both the MATLAB and Simulink product platforms; most engineering teams exploring DL with MathWorks tools are on the MATLAB platform.

MATLAB's DL tools focus on feature extraction. Tannen-

A new DL-powered image synthesis technique from NVIDIA makes it possible to change the look of a street simply by changing the semantic label. San Francisco becomes Barcelona or another city. Although gaming is an obvious use for such a technology, it also can be applied to training autonomous vehicles. *Image courtesy of NVIDIA.*

baum uses the example of how to get a computer to "see" a dog in an image. In ML you show the algorithm 1,000 images of dogs, then it uses that data comparatively. In DL, the algorithm studies 100,000 (or many more) photos of dogs to build a working model of "dogness."

"What makes a photo of a dog a dog to the algorithm?" Tannenbaum asks. "Edges. Shapes. It is a process of detection and extraction," in which the algorithm painstakingly, layer by layer, assembles a model that becomes the working definition.

The training time is filled with back propagation, feedback, testing and optimization. Tannenbaum says it can take days for the algorithm to arrive at a model.

As mentioned already, DL projects generally start with an existing neural net. The one most often used in MATLAB projects is called AlexNet, which was originally used for facial recognition but can be adapted to a variety of purposes. One MATLAB user worked with AlexNet to examine surface features above a mining tunnel drilling project. The retrained AlexNet was able to predict subsurface geological features well enough for field deployment. The model was able to determine when it would be necessary to call in a high-priced geologist and when the drillers could proceed without outside advice.

Reusing existing neural net models is common in DL projects, Tannenbaum says. A model might have 20 layers of understanding, with the first 10 or so the original AlexNet and the next 10 new layers of understanding created by the algorithm for the new project.

Image recognition and voice recognition are the two most common product-based applications for DL in product development today. DL has advanced the art of image recognition beyond simple tasks (identifying a screw) to finding cracks, identifying mistakes in a product, or recognizing the signs of a process failure as it happens. For voice (or sound) recognition, new algorithms have been developed that turn the sequential waveform of a sound into a spectrogram for faster analysis and classification.

## Parallel Processing Breakthrough

DL is computationally intensive. MathWorks' Tannenbaum says it is only in the last few years that engineering workstations have become powerful enough. The two most recent generations of NVIDIA GPUs offer enough power and can work with both Intel and AMD workstation or server CPUs.

At the NVIDIA GPU Technology Conference in March 2018, NVIDIA announced a series of performance advancements, which it claims will boost DL performance by 10x, compared with what the company offered only six months earlier. Specific improvements include a memory boost to the Tesla V100; a new GPU interconnect fabric called NVIDIA NVSwitch, which enables up to 16 Tesla V100 units to simultaneously communicate; and DGX-2, a new GPU-based server that delivers two petaflops of computational power. NVIDIA claims the DGX-2 "has the deep learning processing power of 300 servers occupying 15 racks of datacenter space, while being 60x smaller and 18x more power efficient."

## But How Hard is it?

This DL stuff sounds complicated, but for product development, most of the difficulty is under the hood. Tannenbaum says a typical engineer can learn the basics of DL in a day. MathWorks offers a variety of training videos, ebooks and other supportive materials. One three-minute MathWorks video shows how to create a basic DL routine with 11 lines of code. **DE**

**Randall S. Newton** *is principal analyst at Consilia Vektor, and a contributing analyst for Jon Peddie Research. He has been part of the computer graphics industry, in a variety of roles, since 1985.*

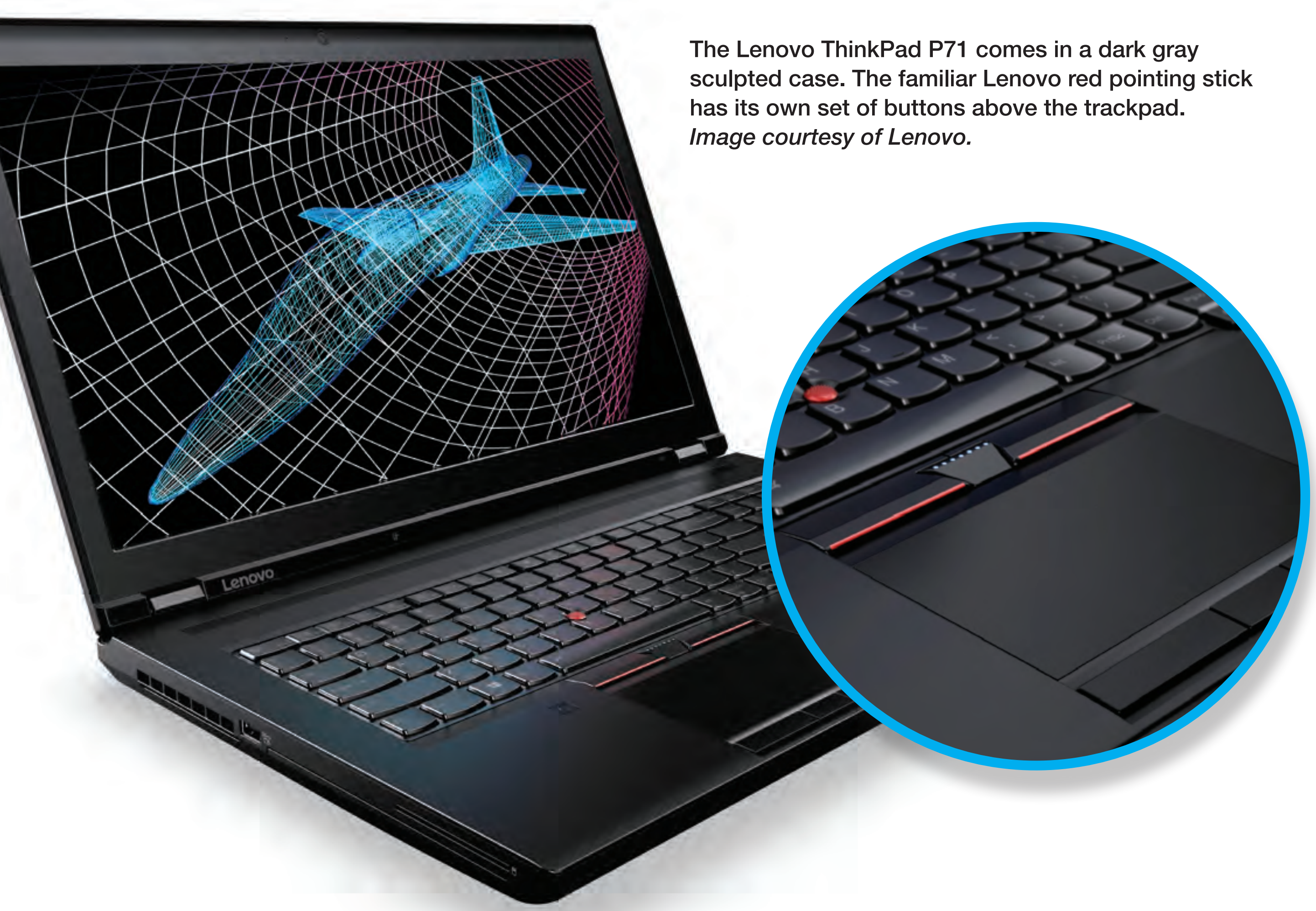
**INFO** → **AMD:** AMD.com

→ **NVIDIA:** NVIDIA.com

→ **MathWorks:** MathWorks.com

→ **Intel:** Intel.com

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




The Lenovo ThinkPad P71 comes in a dark gray sculpted case. The familiar Lenovo red pointing stick has its own set of buttons above the trackpad. *Image courtesy of Lenovo.*

# Lenovo ThinkPad P71:
## A New Performance Leader

Lenovo's new 17-in. mobile workstation delivers even faster performance.

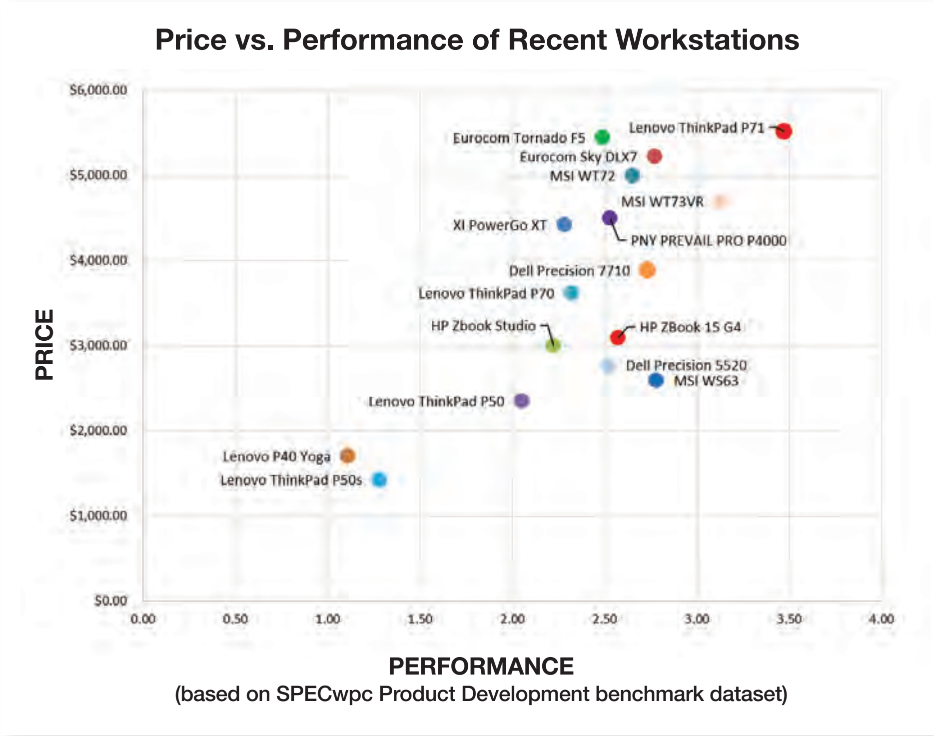
**BY DAVID COHN**

LENOVO RECENTLY SENT US ITS NEW THINKPAD P71 mobile workstation, the latest update to the P series (we previously reviewed the P70, *DE* July 2016), and the only VR-certified ThinkPad (when equipped with either an NVIDIA Quadro P4000 or P5000 graphics card). The P71 now marks the top of the ThinkPad line and is aimed at designers and engineers who run the most demanding applications and want a large screen and a high level of storage.

| **Mobile Workstations Compared** | **Lenovo ThinkPad P71** 17.3-in. 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-in. 3.0GHz Intel Xeon E3-1505M v6 quad-core CPU, NVIDIA Quadro M2200, 32GB RAM, 512GB NVMe PCIe SSD | **PNY PREVAIL PRO P4000** 15.6-in. 2.8GHz Intel Core i7-7700HQ quad-core CPU, NVIDIA Quadro P4000, 32GB RAM, 512GB NVMe PCIe SSD and 2TB 5400rpm SATA HD | **Dell Precision 5520** 15.6-in. 3.0GHz Intel Xeon E3-1505M quad-core CPU, NVIDIA Quadro M1200M, 32GB RAM and 512GB NVMe PCIe SSD | **MSI WT73VR** 17.3-in. 2.9GHz Intel Core i7-7820HK quad-core CPU, NVIDIA Quadro P5000, 64GB RAM, 512GB PCIe SSD and 1TB 7200rpm SATA HD | **Eurocom Tornado F5** 15.6-in. 3.6GHz Intel Xeon E3-1270 quad-core CPU, NVIDIA Quadro M4000M, 32GB RAM, 2TB PCIe SSD |
|---|---|---|---|---|---|---|
| Price as tested | $5,517 | $3,095 | $4,499 | $2,759 | $4,699 | $5,450 |
| Date tested | 12/14/17 | 12/1/17 | 3/5/18* | 11/27/17 | 6/28/17 | 2/13/17 |
| Operating System | Windows 10 | Windows 10 | Windows 10 | Windows 10 | Windows 10 | Windows 10 |
| SPECviewperf 12 (higher is better) | | | | | | |
| catia-04 | 145.81 | 71.62 | 110.72 | 44.56 | 157.84 | 85.32 |
| creo-01 | 119.20 | 69.15 | 94.21 | 45.88 | 129.89 | 80.21 |
| energy-01 | 14.51 | 5.29 | 12.40 | 3.66 | 12.56 | 6.36 |
| maya-04 | 92.67 | 50.99 | 73.75 | 34.47 | 100.99 | 60.58 |
| medical-01 | 66.51 | 25.62 | 50.11 | 16.48 | 59.31 | 27.39 |
| showcase-01 | 65.73 | 32.19 | 60.28 | 23.29 | 67.53 | 48.46 |
| snx-02 | 250.00 | 58.62 | 111.05 | 34.93 | 185.13 | 78.14 |
| sw-03 | 151.51 | 97.14 | 121.45 | 72.15 | 160.26 | 100.19 |
| SPECapc SOLIDWORKS 2015 (higher is better) | | | | | | |
| Graphics Composite | 3.64 | 6.60 | 3.44 | 3.44 | 4.95 | 7.60 |
| Shaded Graphics Sub-Composite | 2.11 | 3.33 | 2.00 | 2.25 | 3.06 | 4.14 |
| Shaded w/Edges Graphics Sub-Composite | 2.79 | 4.65 | 2.66 | 3.27 | 3.89 | 5.46 |
| Shaded using RealView Sub-Composite | 2.54 | 4.73 | 2.42 | 2.70 | 3.54 | 5.64 |
| Shaded w/Edges using RealView Sub-Composite | 3.22 | 7.85 | 2.98 | 4.51 | 4.27 | 9.20 |
| Shaded using RealView and Shadows Sub-Composite | 2.93 | 5.40 | 2.79 | 2.31 | 4.07 | 6.44 |
| Shaded with Edges using RealView and Shadows Graphics Sub-Composite | 3.45 | 8.34 | 3.17 | 3.69 | 4.51 | 9.56 |
| Shaded using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite | 9.61 | 15.31 | 9.00 | 4.55 | 13.46 | 16.22 |
| Shaded with Edges using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite | 9.66 | 21.43 | 9.12 | 6.69 | 13.17 | 23.22 |
| Wireframe Graphics Sub-Composite | 3.13 | 3.41 | 3.11 | 2.96 | 3.91 | 3.65 |
| CPU Composite | 2.39 | 4.07 | 2.21 | 2.22 | 4.28 | 4.23 |
| SPECwpc v2.0 (higher is better) | | | | | | |
| Media and Entertainment | 3.38 | 2.63 | 2.53 | 2.51 | 3.12 | 2.96 |
| Product Development | 3.47 | 2.57 | 2.53 | 2.52 | 3.13 | 2.49 |
| Life Sciences | 4.18 | 3.01 | 3.03 | 2.86 | 3.60 | 3.05 |
| Financial Services | 3.14 | 2.87 | 2.47 | 2.88 | 2.90 | 3.10 |
| Energy | 6.43 | 2.11 | 2.67 | 2.58 | 2.94 | 2.60 |
| General Operations | 1.90 | 1.62 | 1.11 | 1.64 | 1.45 | 1.37 |
| Time | | | | | | |
| Autodesk Render Test (in seconds, lower is better) | 48.40 | 72.70 | 58.90 | 87.10 | 67.00 | 78.30 |
| Battery Life (in hours:minutes, higher is better) | 6:05 | 13:30 | 4:00 | 9:24 | 2:55 | 3:20 |

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

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




Like its predecessor, the Lenovo ThinkPad P71 comes housed in a charcoal gray case made from magnesium and aluminum and wrapped in glass fiber and polyphenylene sulfide. The system measures 16.4x10.8x1.2-in. and weighs 8.19 pounds. The large 230-watt external power supply (7.9x3.9x1.0-in.) adds another 2.17 pounds, including its cables.

Raising the lid reveals a 17.3-in. display and a 105-key backlit keyboard with separate numeric keypad. The excellent, spill-resistant Lenovo keyboard is perhaps the best available in a current laptop. Lenovo offers a choice of two ISP matte surface displays: FHD (1920x1080) or 4K (3840x2160). Unlike the P70, however, there is no touch option. The 4K panel provided in our evaluation unit added $260 to the price. A 720p webcam flanked by a pair of microphones is centered above the display.

A round power button is located adjacent to the upper-right corner of the numeric keypad while a fingerprint reader is positioned to its lower-right corner. A newly designed 4x2.25-in. touchpad with three dedicated buttons is centered below the spacebar. There is also a red pointing stick nestled between the G, H and B keys with its own three buttons directly below the spacebar. A pair of stereo speakers is concealed beneath perforations just above the keyboard. The caps lock and number lock keys each have their own LED as do separate keys dedicated to the speakers and microphone. There is also a hard drive activity light located below the display.

Recognizing that color temperatures and screen brightness can drift over time, Lenovo also included a color sensor (a $70 option on the base model), located to the left of the touchpad. A color calibration tool appears in the Windows taskbar and turns red if you haven't calibrated the display in more than 30 days. A single click starts the X-Rite Pantone calibration software, which uses the sensor to ensure that the display quality remains consistent and accurate over the life of the computer. After choosing the desired settings, you simply follow the instructions to close the lid and allow the tool to calibrate the display, which takes just more than a minute.

## Choice of Quality Components

The Lenovo ThinkPad P71 is built around one of the latest seventh-generation Intel Core or Xeon "Kaby Lake" processors. The base configuration, which has a starting price of $1,511, comes with a 2.8GHz Intel Core i7-7700HQ CPU. Other choices include the 2.9GHz Core i7-7820HQ, the 3.0GHz Xeon E3-1505M and the 3.1GHz Xeon E3-1535M v6 processor that came in our evaluation unit, adding $690 to the price. That CPU has an 8MB SmartCache, a 45-watt thermal design power (TDP) rating, and a maximum turbo frequency of 4.2GHz.

Although these CPUs all incorporate Intel HD Graphics P630, every ThinkPad P71 model also includes discrete graphics in the form of an NVIDIA Quadro GPU. The base P71 configuration uses a Quadro M620 with 2GB of memory. Other choices include the Quadro P3000 (adding $300) and P4000 ($800 more). Our system came with an NVIDIA Quadro P5000, which added $1,400 to the total cost. That GPU includes 16GB of GDDR5 memory. This 180-watt GPU provides 2,048 CUDA cores, uses a 256-bit interface and delivers a bandwidth up to 288GB per second.

Lenovo offers many memory options. The base P71 configuration comes with 8GB of DDR4 memory. Other choices include up to 64GB, and ECC memory is an option when paired with an Intel Xeon processor. Our system came with 64GB of ECC RAM (adding $940 to the cost), installed as four 16GB 2400MHz SODIMM modules.

Although the entry-level system comes with a 500GB 7200rpm hard drive, our evaluation unit came with a pair of 512GB SSD PCIe-NVMe drives, configured in a RAID 0 array for a total storage capacity of 1TB, a configuration that added another $1,081. Although this yields the best performance, RAID 0 splits data evenly across the two drives, without redundancy or fault tolerance, so a failure of one drive will cause the entire array to fail.

As we have come to expect, the P71 includes lots of connectivity options. The right side provides a combination microphone/headphone audio jack, three USB 3.0 ports, a media-card slot, an ExpressCard slot, a mini DisplayPort connector and a security-lock slot. The left side houses an always-on USB 3.0 port that can charge USB devices whenever the computer is connected to AC power, even if the system is off. There is also a smart card slot and a drive bay that can accommodate an optical drive (as on our evaluation unit) or an additional hard drive on some models. The rear panel provides two Thunderbolt 3/USB Type-C connectors as well as an HDMI port, an RJ45 Ethernet jack and the connector for the external power supply. The bottom of the case features a docking station connector and an easily removable battery. Inside the battery compartment there is also a micro-SIM card slot. There is also a pair of holes designed to drain liquids in the event of a spill on the keyboard.

Dual-band Wi-Fi and Bluetooth come standard. Although an eight-cell 96Whr Lithium-ion battery is the only choice, it kept our ThinkPad P71 running for just over 6 hours, more than 45 minutes longer than the P70. The Lenovo mobile workstation remained cool and nearly silent throughout our tests (reaching 46dB under heavy compute loads).

## Even Better Performance

Lenovo workstations typically deliver top-of-class performance, but the Lenovo ThinkPad P71 exceeded our expectations. On the SPECviewperf benchmark, which focuses on graphics, the P71 scored at or near the top on nearly all the datasets. The P71 also did quite well on the SPECapc SOLIDWORKS benchmark, although it lagged behind other 17.3-in. mobile workstations we've tested recently.

On the very demanding SPECwpc benchmark, however, the Lenovo ThinkPad P71 delivered the top scores in all six categories and even outperformed many desktop systems on some of the individual tests. And on the AutoCAD rendering test, the P71 averaged a record-setting 48.4 seconds to complete each image, beating the ThinkPad P70.

Although the base configuration comes with Windows 10 Home, Windows 10 Professional 64-bit (which costs $30 more) is preloaded on systems equipped with an Intel Xeon CPU. The standard warranty covers the system for just one year with depot or carry-in service. Additional coverage is available at the time of purchase that can extend the warranty for up to five years, including accidental damage protection. Our system came with a three-year warranty. Lenovo also offers a ThinkPad workstation dock (on sale for $210 at press time) that works with the P51 and P71 workstations and provides lots of additional ports—a great option for anyone who travels often but works at a desk when in their office.

The ThinkPad P71 is certified for more than 100 applications from ISVs including Autodesk, Dassault, PTC and Siemens. You can build a custom configuration via the Lenovo website (where our P71 priced out at $5,517 after an automatic 10% online discount). Although that price places the Lenovo ThinkPad P71 at the high end in terms of cost, its performance exceeds that of any mobile workstation we have ever tested, making it the new price/performance leader. DE

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

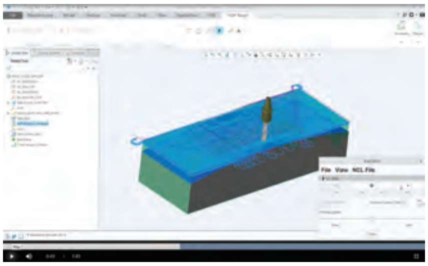
**INFO → Lenovo:** Lenovo.com

***Lenovo ThinkPad P71***

- **Price:** $5,517 as tested ($1,511 base price)
- **Size:** 16.4x10.8x1.2-in. (WxHxD) notebook
- **Weight:** 8.19 pounds (plus 2.17-pound external power supply)
- **CPU:** Intel Xeon E3-1535M v6 3.10GHz quad-core w/ 8MB cache
- **Memory:** 64GB ECC DDR4 at 2400MHz
- **Graphics:** NVIDIA Quadro P5000 w/16GB GDDR5 memory
- **LCD:** 17.3-in. 4K (3840x2160) IPS with color calibration sensor
- **Hard Disk:** two 512GB PCIe 3 NVMe M.2 SSDs in RAID 0 array for 1TB storage
- **Floppy:** none
- **Optical:** DVD burner
- **Audio:** built-in speakers, headphone/microphone jack, built-in microphone array
- **Network:** integrated Intel Dual Band Wireless AC (2x2) 8265 plus Bluetooth 4.1, one RJ45 gigabit Ethernet port
- **Modem:** none
- **Other:** four USB 3.0 (one always on), mini DisplayPort, HDMI, SmartCard reader, media card slot, express card slot, 720p webcam, two Thunderbolt 3/USB Type-C connectors
- **Keyboard:** integrated 105-key full-size backlit keyboard with numeric keypad
- **Pointing device:** integrated touchpad with three buttons, pointing stick with three buttons, fingerprint reader

*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.*

# EDITOR'S PICKS



## PTC Releases Creo 5.0

Capabilities for CFD, additive manufacturing and topology optimization debut.

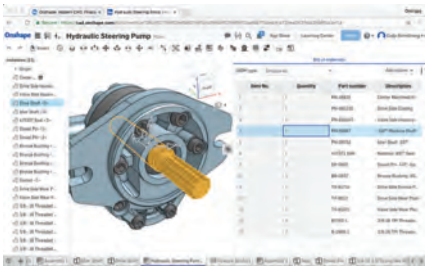
In Creo 5.0, the Creo Flow Analysis CFD extension helps simulate fluids like liquids and gases. It integrates within Creo. Run it any time from the earliest design stages on up.

A new high-speed machining extension is optimized for molds, dies, electrodes and prototypes. Additive manufacturing is extended to metal parts. An upcoming topology extension can automatically optimize designs based on objectives and constraints. There are also multiple productivity improvements.

**MORE →** digitaleng.news/de/?p=43327

## Design Data Management 2.0 Extends CAD

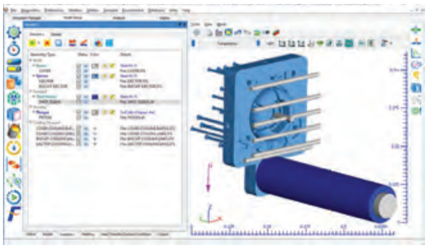
Release/approvals management and BOM functionalities leverage new paradigm.



Design Data Management 2.0 is intended to eliminate the hassles of file-based product data management so that you can find files, work on them, share them and innovate without spending half the day wrestling a product data management (PDM) system.

Release Management & Approval Workflow is integrated within the Onshape environment, which means no plodding off to PDM. A new Simultaneous Bill of Materials capability creates and updates BOMs automatically as you design.

**MORE →** digitaleng.news/de/?p=43185



## Metal Casting Simulator Sees New Release

Tools for predicting defects and hot spot identification among key enhancements.

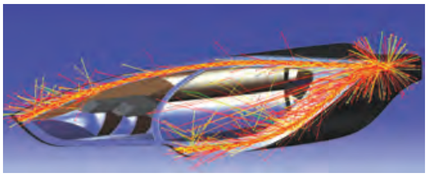
Flow Science released version 5.0 of its FLOW-3D CAST simulation solution. There's a porosity analysis tool for identifying defects and a new feature that lets you calculate the heat transfer coefficient between the spray fluid and the die surface based on the flow rate of the spray fluid at the nozzle.

A new output quantity helps locate and size risers and it identifies potential for solidification-related defects. New void particles functionality identifies filling defects caused by entrapped gas.

**MORE →** digitaleng.news/de/?p=43054

## Light Simulator Optimized for Automotive Design

Optical simulation solution speeds designing optical and optoelectronic devices.



Virtual prototyping is what OPTIS is all about. Their expertise lies in light and human vision simulation integrated with mechanical design software like CATIA, NX, PTC Creo and SOLIDWORKS as well as immersive reality design. The company just released SPEOS 2018, its core CAD-integrated light simulation software.

It now includes the ability to simulate solid-state LiDAR (light detection and ranging) technology.

**MORE →** digitaleng.news/de/?p=42956

# FAST APPS
Engineering Case Studies

## HP & Jabil Aim to **Transform Manufacturing** with 3D Printing

HP invented the commercial laser printer in 1980 and followed with the first thermal inkjet printer four years later. These breakthroughs transformed printing and established HP as a game-changer. Since then, the company's record of industry firsts continues to grow, typified by its motto to "keep reinventing."

This focus on reinvention sharpened in 2016 when HP shipped its first production units of Jet Fusion 3D Printing System in North America to Jabil's Blue Sky Innovation Center in San Jose, CA. HP's 3D printing technology promises speed, quality and cost savings.

"If we're really going to transform the $12 trillion manufacturing industry, we can't do it on our own," says Stephen Nigro, president of 3D printing, HP. "We embraced a different development model, so others can innovate in spaces where they have a point of view and expertise in high-volume manufacturing. In terms of foresight and thinking, Jabil was way ahead."

Revolutionizing an industry like manufacturing is a tall order for any one company, according to John Dulchinos, VP of Digital Manufacturing, Jabil. "What it really takes is an end-to-end solution," he says. "We really appreciate HP's open approach because it's inclusive and leverages a full partner ecosystem."

### Wanted: Partners in Innovation

HP's vision for transforming manufacturing is guided by a series of business imperatives, starting with a technology roadmap to ensure the highest levels of product quality, consistency and reliability. "We built a value chain of innovators," recalls Virginia Palacios, director of Strategic Customer Engagement, HP. "We wanted to partner with the best—in software, materials and manufacturing—so we could extend the number of applications and use cases to really explode the market. Jabil is a great partner; they know what it takes to scale manufacturing."

What stood out about Jabil was its long-running partnerships with scores of market leaders in a variety of industry sectors. "Jabil's work across lots of industries provided unique insight into particular customer needs," Palacios adds. "Jabil's engineers had all the data at their fingertips to help us understand where we could make a difference as well as where it made sense economically to use 3D printing instead of traditional manufacturing methods."

Equally important was Jabil's vision of how 3D printing could accelerate the digital transformation taking place in manufacturing. "In a traditional manufacturing environment, you make and move fixtures and tooling through a set of discrete processes," says Dulchinos. "With additive manufacturing, you put materials into the printer, eliminating that additional time and cost. We immediately saw the potential ..."

**MORE →** digitaleng.news/de/?p=43432

## Frontloading CFD Is a Win for Business

**BY BOB MILETI**

At Trlby, we have been using Siemens CAD software since 2001. In business for 34 years, our business is a diversified product design, development and manufacturing company based in Torrington, CT. We are experts at heat-sealing thermoplastics, including polyethylene, polypropylene and other polyolefin materials, and we provide product design and development services to our customers in the medical, pharmaceutical, food/beverage and consumer goods markets.

A contract can often be multiyear and run from hundreds of thousands to millions of dollars; as a small business, account renewal and expansion are critical to our success. We rely heavily on our ability to secure repeat business and on our reputation for doing so. For new customers, I have to convince them of the viability of the proposed design solution, from concept straight through to production, in the initial presentation.

Trlby presentations have to be clear and compelling to both technical and nontechnical audiences. Many people making these big purchasing decisions are not on the ground doing the work with you. They are higher up; whoever is signing the check has less direct project knowledge but they also need to be convinced that we can solve their challenges. And once we win a contract, we must deliver designs, equipment and products on time.

The right tools help us do all that. I'm excited that Siemens and Mentor Graphics have embedded CFD into CAD. Being able to simulate flow and heat analysis in our projects helps us show customers early in our relationship how our product design suits their needs and do so in detail.

### More Ways to Meet Customers' Needs

Many of our customers come to us by recommendation. We are experts in figuring out impulse heat-sealing challenges, as well as difficult to seal materials, or shapes or often a combination of both. We help develop that product and then build the tooling and equipment for manufacturing it.

For example, we are working on a custom machine that will be making the "bags" for a medical device battery pouch. The product consists of a cathode, a foil laminated with carbon that is in a pouch of material that separates it from the lithium; it's charged through the electrolyte to create power.

The machine we designed can make five different sizes of these pouches. In this case, the heart of the machine is heat sealing. We use a stainless steel alloy like a ribbon, similar to the filament in an incandescent bulb. When you apply power, it heats up, but we use controllers to monitor the element's temperature.

**MORE →** digitaleng.news/de/frontloading-cfd-win-business

# Next-Gen Engineers

Student Design Competition Profile:
The National Robotics League Competition

## Bots Battle Gladiator Style

**BY JIM ROMEO**

THE NATIONAL ROBOTICS LEAGUE (NRL) is a job-driven, project-based STEM (science, technology, engineering and mathematics) learning experience sponsored by the National Tooling and Machining Association (NTMA). In a team-oriented environment at their school, students are immersed in the manufacturing process of researching, designing, building and testing of a 15-lb. bot to compete in gladiator-style robot creation and battle competitions.

Students can attempt to fix damaged bots in pitstop-like breaks in the competition.

We spoke to Bill Padnos, director of Youth Engagement for the NTMA, to learn more about the competition.

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

**Bill Padnos:** NTMA launched the NRL in 2009. The NRL is influenced by a variety of similar educational combat robotics leagues, but it is unique in that it places a large emphasis on connecting teams to industry partners not only for financial and material contributions, but also to serve as mentors and role models who can help students see how the work they are doing translates directly into experiences and skills that are highly sought by manufacturing employers and engineering school recruiters.

The NRL is funded by a grant from the National Tooling and Machining Foundation, a 501(c)3 nonprofit designed to fund manufacturing education. Its purpose is to create a skilled, tech-savvy labor force that can meet the needs of modern manufacturing, spark student and teacher interest in manufacturing and engineering, connect students to local manufacturers to create industry exposure and address the labor shortage in manufacturing.

***DE:*** Who will be participating or who has participated?

**Bill Padnos:** The NRL attracts smart, capable students who love to build things and solve problems—exactly the type of young people who we hope will make up the next generation of manufacturing leaders. The NRL consists of 15 regional competitions involving over 200 schools and over 2,500 participants across the nation, culminating in our annual national competition (May 18-19 at the California University of Pennsylvania campus).

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

**Padnos:** One of the most important components of the NRL system and what sets it apart from other robotics leagues is the requirement of an engineering binder and its importance to final scores. You can design the greatest bot ever made, but you can't compete or go to market without an engineering binder. This facet of the competition pushes student teams to critically consider each aspect and design element of their bot much like the way a skilled worker evaluates his or her handiwork. This drives home the point that these students are developing marketable, necessary technical skills in mechanical and electrical engineering, machining and welding along with interpersonal skills. **DE**

**Jim Romeo** *(JimRomeo.net) is a freelance writer based in Chesapeake, VA. Contact him via de-editors@digitaleng.news.*

**MORE →** goNRL.org

### ADVERTISER INDEX

COMMENTARY

by Eric Bantegnie

# Fast-Tracking Safe Autonomous Vehicles with Simulation

IF THE EXPERTS ARE RIGHT, 10 years from now our automobiles and trucks will drive themselves, and delivery drones will fill the sky to hasten the arrival of the latest book we are dying to read or the pizza we are craving to eat. Robots will be doing some of our jobs, so we might have more time for both of these activities.

With so much autonomous machinery in our lives, we need to ensure that they all safely operate together, so drone-delivered pizzas are not raining on our heads and autonomous cars are not running into robots—or people. The only way to do that in this complex environment of the near future is through engineering simulation.

Consider the case of autonomous cars: RAND Corp. estimates that they will require approximately 8 billion to 11 billion hours of road testing to be certified safe. One major competitor in the race to market reports that they test drive autonomous vehicles about 0.4 million miles per year. At that rate, engineers will need four to five centuries to do sufficient testing to guarantee our safety. Obviously, that's not realistic if automakers are promising delivery in the next five to 10 years.

Using simulated driving scenarios, the same company is performing virtual road tests at a rate of 8 million miles per day. That's remarkable, but it is by no means a limit—simulation is scalable. We can greatly increase the number of simulated road miles per day by adding more compute cores to tackle the problem and exploring more driving scenarios. Scalability makes the challenge of 8 billion to 11 billion miles of road testing manageable.

For drones, safely navigating the three-dimensional open spaces of the skies will require that they avoid their fellow drones on their frantic delivery runs, as well as power lines, buildings and other obstacles as they approach the ground. Robots—depending on their application—may have to climb stairs, run into a burning building to save humans or manipulate a delicate machine part without damage.

### Extensive Sensing Capabilities Required

All three of these cases—autonomous cars, drones and robots—require remarkable sensing and actuating abilities to function efficiently and safely. Radar, lidar, infrared radiation and visual wavelength cameras must be designed so that autonomous devices can sense their environment at high enough resolution to do their jobs without fail. Photorealistic virtual reality that simulates light and human vision will add to the sensing capabilities and safety of autonomous vehicles. Signals from one device must not interfere with another, whether there are two autonomous cars driving on the same road in a small town or hundreds of them on a superhighway during rush hour in a major metropolitan city.

Simulation can help from the component level all the way up to the complex system of cars during rush hour. Engineers can use electromagnetic simulation to determine the shape and range of a radar signal coming from a single unit sitting on a laboratory bench, and also when that radar unit is installed behind the fascia of a car's bumper with tons of steel, plastic and composites behind it. Simulation can map the possible interference of these signals with each other in a traffic jam; it can also help cars to communicate with each other so they can know what the other is planning to do—unlike human drivers. The number of lives lost to traffic accidents will plummet when autonomous systems are reacting logically to incoming data without emotion or human error.

That logic will come from the software embedded in the hardware of these autonomous devices. And, that too, can be simulated, to great effect. Although the operating system that controls your computer may seem fragile, crashing at the least opportune moment, it doesn't have to be that way. Importantly, for safe autonomous systems it cannot be that way: They must work the first time and every time.

Software generated by simulation can be tested for flawless operation to meet the most stringent certifications in the world, including ISO 26262 for automobiles, DO-178C for drones and Asimov's Three Laws of Robotics (just kidding on the last one). Simulation can ensure that the software that controls the hardware that is out of our control will be safe and reliable for all involved parties.

Whether we are dealing with autonomous driving, flying or maneuvering, simulation will play an enormous role in bringing safe autonomous vehicles to market—in five years, not 500. DE

**Eric Bantegnie** *is ANSYS (ANSYS.com) vice president and general manager. Send comments on this commentary to de-editors@digitaleng.news.*