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Digital Engineering

August 2017

Knowledge Capture P.20

Model Reuse P.24

Simulation Visualization P.28

FOCUS ON: Data Management P.20

AUGMENT REALITY

ALGORITHM TESTING P.34

3D SCANNING P.38

AMD GPU REVIEW P.41

by Jamie J. Gooch

Ignorance Is a Miss

I HAVE A CONFESSION to make. I sometimes ignore data. When my calorie-counting app tells me I only have 400 calories left for dinner, I have been known to eat the cheeseburger *and* the fries anyway. When my watch annoys me to get up from my desk and walk around, I usually keep typing.

It's not that I specifically don't care about my health. I ignore other things, too, like when my thermostat tells me it's time to change the filter, or my operating system tells me there's an update available, or my wife tells me to take out the trash. I realize I'm ignoring all of this data at my own peril, risking an inefficient HVAC system, outdated computer virus protection or an annoyed spouse. It's just that, other than that last one, it's easy to ignore data, especially when it's not a priority.

The DIY Mindset

The challenges are multiplied for design engineers who have long had plenty of opportunities to ignore various design and simulation data points, and now software engineering data has entered the picture, and everyone's talking about incorporating data coming in from connected devices into a product lifecycle management (PLM) workflow. Meanwhile, home-grown data management workflows that focus on high-priority data are still the norm for many engineers who either tried early product data management (PDM) software options and found them lacking, were able to cobble together their own data management software stack using what was already available to them, or were never able to convince the powers that be to invest in a purpose-built solution.

One issue with proprietary data management solutions is that they often rely on "tribal knowledge" to work. In other words, the engineers who built the workflow have a thorough understanding of it. It might even be a point of pride that they know the system so well that new hires routinely come to them with questions about it. The problem arises, as we note on page 15, when those gurus retire or move on to other positions inside or outside the company, taking that knowledge with them. That problem can be solved by documenting the process and updating it each time a new feature is added to the workflow, but that isn't a priority for many engineers. It becomes another data point on the "to-do" list that gets ignored.

Another issue that arises is mission creep. Over time, different people add different data to the workflow, or create workarounds to make up for what previous employees might have once known how to do. Before too long, a simple homegrown system to make sure current files aren't overwritten or common CAD files can be reused becomes a sprawling behemoth.

The Platform Approach

Software to help engineers manage the high-priority data they need right away and the long-term data they might need to find in the future has come a long way. As we explain on page 24, everything from built-in CAD and CAE features to stand-alone PDM and full PLM implementations now address common data management headaches such as finding and reusing parts or analyses.

Another historical issue to data management was a one-size-fits-all approach by software providers. PLM software vendors are building more flexibility into their products now. Templated approaches to data management that address specific industries can be further customized based on the data that people in different roles in specific companies want to see.

Still, data management needs run a broad gamut, from simple file permission controls to full PLM. There are a lot of options in between. It's also a constantly changing target, which means engineers should think of data management as a process to implement, not a solution to buy.

"[The] bottom line is that PLM is hard and management must be convinced of its value so they will pay for it," writes Technology Consultant Jay Swindle, in response to last month's *DE* article "A Dead End for PLM?" "Everybody else had better get their best people together to figure out how these shrink-wrap box software product capabilities can best be mapped into their solution space in a way that justifies the implementation and product use cost. Good luck with that."

It may be tempting not to think of data management at all. You could ignore what could be significant long-term benefits of mining and sharing data, and just focus on the data you need to make a product that meets requirements. But as Swindle concludes: "Success is possible and worthwhile. So to them that's tryin', hang in there!" I encourage you to follow that advice, and for them that's not trying yet: Take the first steps. After all, yesterday's ignored data becomes tomorrow's high-priority problem. That and the smell of the remains of last night's fish fry remind me: I need to take out the garbage. That counts as exercise, right? **DE**

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

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TECHNOLOGY FOR OPTIMAL ENGINEERING DESIGN

INSIDE

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August 2017
Vol.22 • No.12

COVER STORY

16 Modeling for the Augmented Age

Early AR/VR developers balance new working paradigms with the mouse-and-keyboard legacy.

By Kenneth Wong

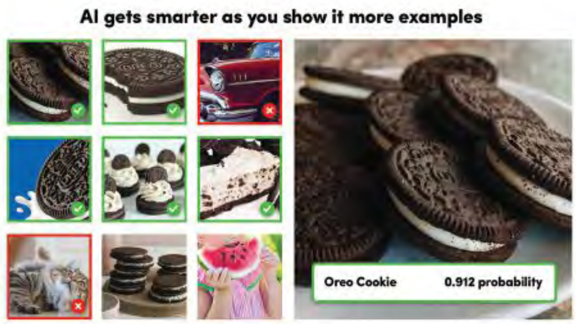
FEATURES

|| TEST

34 Supervised Machine Learning

Many of the old rules that guided software development do not apply to the testing of machine learning algorithms.

By Tom Kevan



|| PROTOTYPE

38 Cordless 3D Scanning on the Horizon

Balancing accuracy, weight and portability in professional 3D scanning.

By Kenneth Wong

|| ENGINEERING COMPUTING

41 Very Fast Entry-Level GPUs

We tested AMD's latest Radeon Pro workstation-class graphics boards.

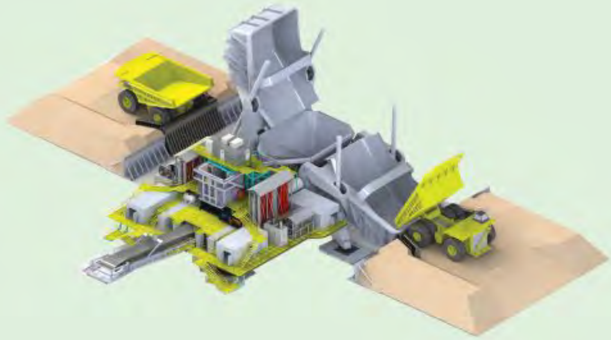
By David Cohn

ON THE COVER: Images courtesy of Autodesk, Meta and iStock/baloon111.

FOCUS ON DATA MANAGEMENT

20 Knowledge Capture and Retention in FEA
Challenges still remain in transferring simulation knowledge to new employees.
By Tony Abbey

24 Vendors Push Parts Reuse to the Next Level
CAD and product lifecycle management platforms are being modernized with parts classification, Google-like search and systems-modeling capabilities to promote model and parts reuse.
By Beth Stackpole



28 Seeing Is Understanding
Recognizing the challenges and benefits of visualizing product development data.
By Randall S. Newton

30 Mathematics Software Solves Big Data Problems
Software tools can help engineers make sense of rapidly expanding data sets.
By Brian Albright

DEPARTMENTS

2 Degrees of Freedom
Ignorance Is a Miss
By Jamie J. Gooch

6 By the Numbers:
Facts and figures about data management.

8 Road Trip
News from NAFEMS World Congress 2017, Sensors Expo 2017, ISC 2017 and HxGN Live 2017.

13 Making Sense of Sensors
There's More to Miniaturization than Size
By Tom Kevan

14 Consultant's Corner
CMMs: A Machining Accuracy Possibility
By Monica Schnitger

15 Abbey's Analysis
Interpreting a Data-Driven World
By Tony Abbey

44 Editor's Picks
Products that have grabbed the editors' attention.
By Anthony J. Lockwood

45 Next-Gen Engineers
Diving into STEM Careers
By Jim Romeo

46 Fast Apps
Reverse engineering; part quality in metal additive manufacturing; and 3D scanning.

47 Advertising Index

48 Commentary
IoT Equals PLM
By Mark Taber, PTC

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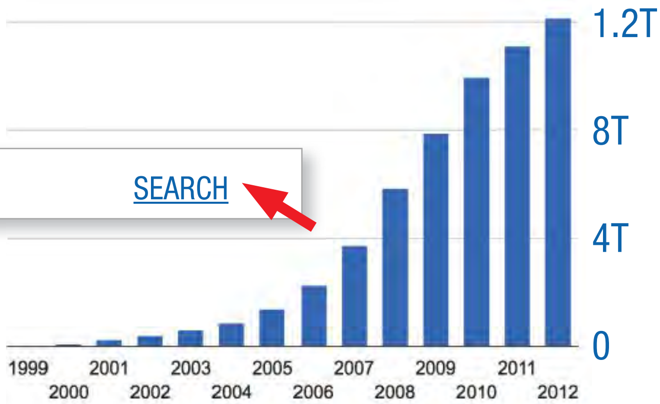
BPA WORLDWIDE

An Average Day for Data

1,000,000,000 Hours

YouTube's viewers are watching a billion hours of its videos each day, on average.

— YouTube, February 2017

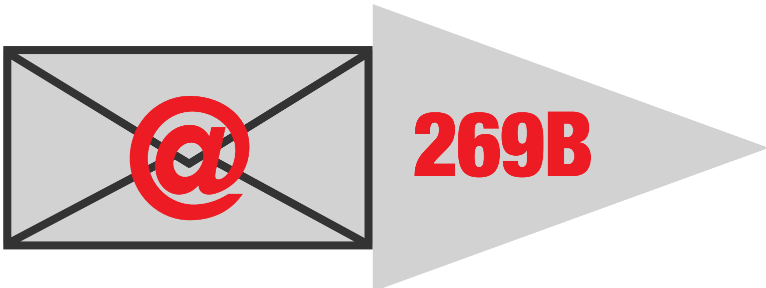


3,500,000,000 Searches

SEARCH

We perform over 40,000 searches per second on Google alone. That's about 3.5 billion searches a day, and about 1.2 trillion searches per year, worldwide.

— internetlivestats.com



269,000,000,000 Emails

The number of email users sent per day is around 269 billion. That's about 74 trillion emails sent per year. And you thought your inbox was full?

— Radicati Group estimates, February 2017

2.5 EB Generated

Five years ago, IBM estimated 2.5 exabytes (that's 2.5 billion gigabytes) of data was being generated every day. It has only grown since then.

— Anjul Bhambhri, former IBM VP of Engineering, Big Data Platform, "Looking for Data Scientists from Within – Start with Marketing," Dataversity, July 25, 2012

PLM Market Growth

6.7% CAGR

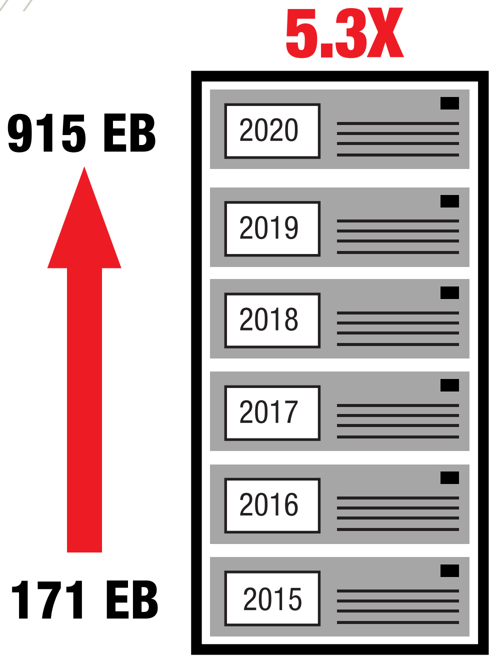
The overall product lifecycle management market is forecast to grow at a compound annual growth rate (CAGR) of 6.7% to $56.3 billion in 2021, up from $40.6 billion in 2016, which was a 5% growth over 2015.

— PLM Market and Solution Provider Analysis Report, CIMdata June 2017.

16.8% CAGR

The cloud-based PLM market size is estimated to grow from $18.65 billion in 2016 to $40.55 billion by 2021, at an estimated CAGR of 16.80% from 2016 to 2021.

— Cloud-Based PLM Market by Application, Organization Size, Vertical, and Region - Global Forecast to 2021, Markets and Markets, September 2016



Globally, the data stored in data centers will quintuple by 2020 to reach 915 exabytes, up 5.3-fold (a CAGR of 40%) from 171 exabytes in 2015.

— Cisco Global Cloud Index (2015-2020), Nov. 10, 2016

Self-Driving Data

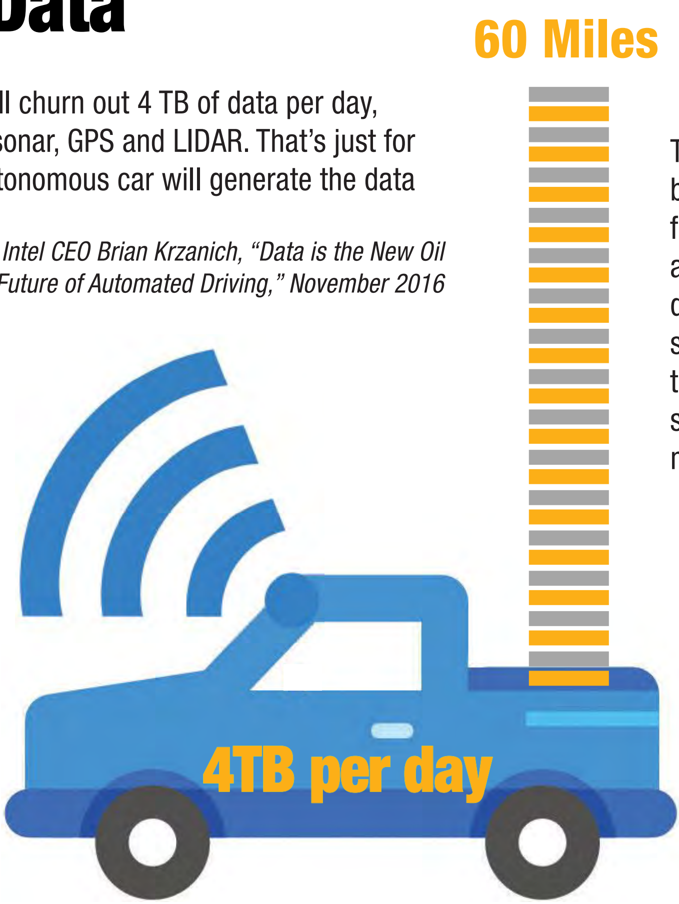
On average, an autonomous car will churn out 4 TB of data per day, when factoring in cameras, radar, sonar, GPS and LIDAR. That's just for one hour of driving a day. Every autonomous car will generate the data equivalent of almost 3,000 people.

— Intel CEO Brian Krzanich, "Data is the New Oil in the Future of Automated Driving," November 2016

50% More M2M

By 2024, mobile networks will see machine-to-machine (M2M) connections jump 10-fold to 2.3 billion from 250 million in 2014, according to Machina Research — and half of those connections will be in automobiles.

— "M2M growth necessitates a new approach to network planning and optimisation," Machina Research, May 2015



The data collected by BMW's current fleet of 40 prototype autonomous cars during a single test session would fill the equivalent of a stack of DVDs 60 miles high.

— *"BMW and Volkswagen Try to Beat Apple and Google at Their Own Game,"* The New York Times, *June 22, 2017*

NAFEMS World Congress 2017 Tackles the Big Issues in Simulation and Analysis

BY JAMIE J. GOOCH

STOCKHOLM, Sweden, thought to be founded in 1252, spans 17 islands that are connected by bridges. Its Old Town is on one such island. The more modern, minimalist aesthetic often associated with Sweden surrounds it. It was an appropriate site for the NAFEMS World Congress (NWC) 2017, held June 11-14, which connected the engineering analysis, modeling and simulation community to discuss solutions to old and new challenges.

NWC 2017 incorporated the third International Conference on Simulation and Process Data Management (SPDM), and provided training for Professional Simulation Engineer (PSE) certification. More than 600 attendees from 34 different countries had the opportunity to attend sessions that covered everything from simulation of additive manufacturing to stochastics and cloud computing. The organization focused the keynotes to address eight big issues:

1. Simulation Governance
2. Democratization
3. Certification by Simulation
4. Systems Simulation
5. Simulation Data Management Implementation
6. Manufacturing Process Simulation
7. High-Performance Computing
8. Simulation and Additive Manufacturing

Simulation and Test Data Reuse

In the opening day's plenary session, Steve Chisholm, director of Structures Engineering, Boeing Commercial Airplanes, touched on many of those big issues to drastically reduce the amount of expensive tests needed for aircraft certification.

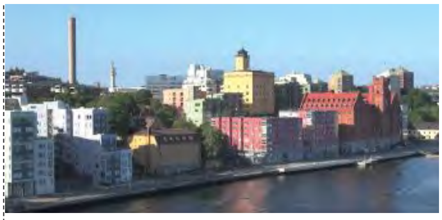
"For a typical development program, it's thousands, tens of thousands of tests," he said. From material coupon tests to components to large, static tests—it's a huge expense that is critical not only for certification but for confidence that the aircraft it produces are safe.

The company found it could accurately simulate the effects of older tests, and then modify those simulations to match newer aircraft tests. By not starting from scratch, and building upon its history of testing and simulation of failure mechanisms, Boeing wants to eliminate a number of tests in an approach Chisholm calls "smarter testing."

"Imagine if you're a regulatory authority, and I come to you and I say: 'I would like to do certification by analysis. We've always used all these tests, but I'm really smart and want to do analysis to just show you the end results, and I want you to accept it.' What they're going to hear is: 'I would like to get out of something really expensive.' If, instead, I approach the authority and say: 'I want to be really smart about how I approach testing. I want to show you the result before I do my validation ...' and then I'm right. Do you think over time I'll be doing less testing? Most likely."

For example, Chisholm said some hugely expensive static tests, such as lifting up a wing, pressurizing and bending the fuselage, haven't produced any new knowledge for quite awhile. They have the potential to eliminate some of those tests because they can simulate them so accurately using existing data.

"Going forward, we have to under-



stand how to use a templated approach with advanced finite element analysis (FEA)," Chisholm said, "so non-experts can apply this (knowledge) in a valuable way."

Democratization Dangers

There is a danger in the democratization of simulation, said Dr. Barna Szabó, who is co-founder and chairman of Engineering Software Research and Development, Inc. (ESRD) in his keynote on day two of the conference.

Szabó was careful to say extending analysis to "people with expertise in fields other than numerical simulation … (rather than non-experts) can become a liability if it's not used properly, because it's possible for them to inject misinformation into the design process."

Szabó said deployment of a democratized approach needs to be considered as part of a company's simulation governance. "Management is responsible for command and control of numerical simulation, so management is responsible for simulation governance."

Another potential wrench thrown into the works of both democratization and data reuse is additive manufacturing. New parts created via 3D printing makes it difficult to go into a design manual or pull up a classical analysis method and apply that to a margin of safety.

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Sensors Expo 2017:
The Little Things at the Heart of IoT

BY KENNETH WONG

MARK BENSON, CTO of Exosite, thinks many current IoT projects are rather like assembling puzzles: Lots of different pieces, but very little direction.

Benson's firm offers its expertise, services and cloud-based IoT platform Murano to manufacturers. Last month, at the Sensors Expo 2017 (San Jose, CA, June 27-29), Benson shared his insights as a keynote speaker.

"I'm a father. I have three kids at home. We do puzzles pretty often … Sometimes puzzle fever takes over, so we start opening multiple puzzles at the same time. Some pieces get intermixed. As a more advanced puzzle builder, I need to help my kids understand that we need to be working on the same puzzle, or we won't get satisfying results," said Benson.

Global consultancy McKinsey & Company offers some numbers that reveal the size of the irresistible IoT pie. In 2013, the total number of connected objects was estimated to be 7-10 billion. That number is expected to grow annually at 15%-20%, reaching 26-30 billion by 2020. McKinsey & Co.'s numbers scale back the 50 billion connected devices by 2020 predicted by Ericsson's President and CEO Hans Vestberg in 2010 at a shareholder meeting.

At the heart of these connected devices are sensors, actuators and SoCs (systems on chips) small enough to fit inside watches and smartphones but strong enough to power them for hours or days. These little things transform passive accessories and household appliances into data-collecting, data-transmitting, self-diagnosing IoT products.

"Because many applications would require devices that are self-sustaining and rely on energy harvesting or long-life batteries, semiconductor companies must address the need for optimal power consumption and outstanding power management in their products. Connectivity load will be another critical concern, since hundreds or even thousands of devices may need to be connected at the same time," McKinsey & Co. pointed out.

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HPC Needs of Industry and Institutional Research Highlighted at ISC

BY JAMIE J. GOOCH

MORE THAN 3,250 high-performance computing (HPC) enthusiasts from 60 countries attended ISC 2017, the international supercomputing conference in Frankfurt, Germany, June 18-21. Nearly 150 vendors demonstrated their HPC products—including cloud computing services, HPC storage solutions, cluster management software, interconnects and more.

The ISC 2017 show floor. ***Image courtesy of Philip Loeper.***

The 32-year-old conference is known for targeting academics, government researchers and other institutional users of HPC. With the increased need for more computing power by commercial industries, however, this year ISC featured an Industrial Day, which focused on the future benefits of exascale computing (a quintillion calculations each second) for industrial users, how to purchase HPC infrastructure and use cases for high performance data analytics (HPDA), such as machine/deep learning, artificial intelligence (AI) and the internet of things (IoT).

Many large manufacturers have been using HPC clusters, data centers and cloud computing for years to power large simulations or realistic renderings, for example. With so much attention now being given to the possibilities of machine/deep learning and AI for everything from consumer voice-recognition devices to self-driving vehicles to design optimization, even more engineering firms are feeling the constraints of their enterprise computing power.

According to the Hyperion Research (the HPC research unit spun off from IDC) presentation at ISC, the worldwide HPC server market reached $11.2 billion in 2016. Industry is making up a growing share of that market. The firm says the mechanical design market spent $57 million on HPC in 2016, while $1.251 billion was spent by the CAE market. That still pales in comparison to the $2.059 billion spent by government labs and the $1.934 billion spent by academia, however.

A CFD Solver from Scratch

While some may question whether industry needs the fastest computing available today, there were numerous examples of how commercial applications could benefit from HPC, especially as machine learning and virtual twins become more commonly used. One example came from Dr. Norbert Kroll of the German Aerospace Center (DLR), Institute of Aerodynamics and Flow Technology, in his keynote titled "High Performance Computational Fluid Dynamics for Future Aircraft Design." Kroll described the DLR as "the German NASA," explaining that they are developing a next-generation computational fluid dynamics (CFD) software code, known as Flucs.

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Student Cluster Competition

Eleven student teams were on the ISC show floor this year, vying against each other for the top honors in the sixth annual ISC Student Cluster Competition. Tsinghua University from China emerged as the Overall Competition Winner, marking their third win in the contest. Second place was captured by the South African team hosted by CHPC, and the third place went to Beihang University, also from China. The Fan Favorite Award went to Universitat Politècnica De Catalunya from Barcelona, who garnered over 2,100 ISC 2017 participant votes to win the title for the second year in a row. The High Linpack award went to competitors from the Friedrich-Alexander University Erlangen in Nuremberg. The three-day competition was co-organized with the HPC Advisory Council (HPCAC).

HxGN LIVE 2017: MSC Software's Debut Under the Hexagon Banner

BY KENNETH WONG

WHEN Ola Rollen, president and CEO of Hexagon, presented his keynote to the audience at the HxGN LIVE 2017 conference (Las Vegas, June 12-14), he felt he needed to travel back in time to recall an important lesson. So he virtually sailed 200 years back to the battle of Trafalgar, conjuring up the spirit of Horatio Nelson.

"According to navel warfare textbooks, Nelson should sail his ships straight up to the combined French and Spanish ships, line up his against theirs, then fire at one another," Rollen pointed out. "But Nelson didn't do that. When he approached, he came from two sides."

When recounting the decisive battle, historians often pointed to Nelson's unorthodox and risky strategy as the primary reason for his victory over the enemy's numerically superior fleet. The British victory was a costly one. Lord Nelson, the architect of the victory, died from a French musket shot during the engagement.

"If you disobey the rules, if you do the unexpected, you can reach new heights," Rollen noted.

One of Hexagon's recent surprise acts was the acquisition of MSC Software, a CAE vendor. In February, Hexagon announced its intent. By April, the transaction was complete, making MSC Software part of Hexagon's Manufacturing Intelligence (MI) Division.

Widely known for its MSC Nastran solver, MSC Software is a household name in the tight-knit CAE community. Such vendors make attractive M&A targets for the CAD and product lifecycle management (PLM) market leaders, due to the complementary nature of digital design and digital simulation technologies. For a metrology solution provider like Hexagon, the acquisition may warrant some explanation.

"In the factory, it's no longer clear what's physical and virtual," said Norbert Hanke, president of Hexagon MI. "We're talking more and more about virtual integration of functions and activities that turn ideas into finished products … With the acquisition of MSC Software, we're on our way to bringing together the real world and the virtual world."

Ola Rollen, president and CEO of Hexagon, delivers his keynote speech to HxGN LIVE attendees. *Image courtesy of Hexagon*.

MSC Software Under the Hexagon Umbrella

On Wednesday July 14, Dominic Gallello, MSC Software's president and CEO, shared the stage with Hanke. Even though MSC Software and Hexagon appear to exist in different universes, the two have about 70%-80% customer overlaps, according to Gallello. Sometimes, without realizing it, the two companies supplied software and hardware to the same automotive and aerospace firms.

"In autonomous vehicle development, for example, we have the broadest portfolio for simulation," Gallello pointed out. "And Hexagon has a wide range of sensing technologies. Marrying these two can bring synergy."

Because both companies are interested in industrial scale additive manufacturing (commonly known as 3D printing), there could also be opportunities to develop ways to analyze the strength of a part as it's being printed.

"Let's say you're printing a titanium part," said Gallello. "It can cost you $100-150K per part, and it takes days to grow that part. If there is distortion and flaws after the first half an hour, you'd probably want to know so you can stop the machine. This kind of capability doesn't exist today."

CAE solvers can be used to analyze and predict a part's strength and potential for failures. Similarly, metrology and precision measurement equipment, like those offered by Hexagon MI, can detect deviations that are difficult or impossible to detect with the naked eye. The combination of these two technologies can spawn ways to prevent errors in large-scale metal-based 3D printing projects.

Hexagon acquired Vero Software, the makersof Edgecam, in late 2014. The company also acquired Apodius, a composite measurement and analysis vendor, in late 2016. In both cases, the pre-existing brands live on long after the acquisitions. There's no reason to believe the company will treat the highly visible MSC Software brand any differently.

Acquiring While Being Acquired

Just one month after Hexagon announced the completion of the MSC Software acquisition, MSC Software announced it had closed the deal to buy VIRES GmbH, an autonomous vehicle development tool provider.

"We are just in the very early days of testing with confidence vehicles that need to reach Level 5 autonomy," said Gallello. "VIRES' outstanding environmental simulation technology fits perfectly into our overall strategy of connecting the off-line, real-time, Big Data and analytics technology chain. With this acquisition, we will enable vehicles that are not only safe but that also retain the special driving characteristics of their brands."

Level 5 autonomy is the highest form of self-driving car, where the steering wheel is optional.

"Up to now, our simulations have been about the car, its structures, whether it might break and all of that," Gallello said. "But in our simulation, we now need to figure out how to replace the human driver's decision making, and burn it all onto a chip."

Data-Driven Processes, Data-Driven Simulation

Two-and-a-half quintilian (25 followed by 17 zeroes) bytes is the volume of data people on this planet create every day, Rollen reminded the audience. Data and server giant IBM cites the same number in its online discussions about Big Data.

"If we have 10 times more data, why isn't our decision making 10 times better?" asked Rollen.

With this amount of data, it's impossible to identify the scientific breakthroughs and innovations that hide in plain sight. Metrology equipment contributes to the growing data output. Simulation offers the opportunity to use the data to develop better vehicles, planes and products. But finding nuggets of wisdom and insights in Big Data—that would take machine learning and artificial intelligence.

Alas, the days of finite possibilities and calculable risks—when someone like Lord Nelson could map out on a hand-drawn chart how his 27 ships would engage the 33 Franco-Spanish ships—are long gone.

| MAKING SENSE OF SENSORS |

MINIATURIZATION

by Tom Kevan

There's More to Miniaturization than Size

PRINTED ELECTRONICS STAND POISED to transform the semiconductor industry, but probably not in the way that you expect. Early adopters of the technology hoped that lower manufacturing and material expenses would help reduce the cost of devices entering the market, but these benefits have yet to be realized. On the brighter side, the rewards delivered by the new fabrication process are turning out to be more profound than lower sticker prices.

The reason printed electronics have not delivered the expected cost reductions is that the complexity of the manufacturing processes has eliminated much of the cost savings. According to IDTechEx (https://goo.gl/m23vMZ), the technology will likely experience "pharmaceutical-like pricing" in the short term, driven by producers' need to recoup their initial investments in new equipment and materials. As a result, the technology can offer greater performance—but only at a higher price than printed circuit board (PCB)-based devices.

Nonetheless, the pairing of additive manufacturing with other emerging technologies enables form factors that clear the way for a whole new class of applications, such as wearable and structural electronics. Increasingly, manufacturers focus their efforts on creating value from factors like thinness, reduced weight, stretchability and flexibility. These factors have proven to be stronger drivers than cost reduction.

Manufacturing Enters the Fast Track

Today, manufacturers rely heavily on traditional semiconductor processes to fabricate electronics. Unfortunately, these systems increasingly fail to deliver the performance necessary to meet market demands because they introduce inefficiencies that deny manufacturers the agility to react to production challenges.

The source of these inefficiencies lies in production systems' inability to handle design fixes and modifications quickly and cost-effectively. The changes range from rerouting a printed circuit board trace or modifying a component value to substituting a different part.

Making these types of alterations at the design stage can significantly impact systems all the way down to the factory floor. Plant managers may have to reconfigure production lines, change the bill of materials and update technical documentation. All this costs time and money, extending time to market and raising the price of the product.

Recent technological advances, however, enable printed electronics to address these shortcomings. Companies like Pulse Electronics and Optomec have introduced a generation of printers that enable direct printing onto 3D surfaces. The technology allows manufacturers and engineers to create and integrate various electronic components—such as antennae, sensors and electrical circuits—on a flexible substrate.

These manufacturing capabilities have the potential to revolutionize how products are made. In particular, the agility that they impart allows engineers to update designs simply by adjusting printer instructions.

Pushing the Limits of Miniaturization

As impressive as printed electronics' streamlining effect on manufacturing is, its greatest impact will be in design. By changing the mechanical properties of electronics, the flexible and stretchable technology will expand the limits of miniaturization by redefining the form of electronics and the concept of usable space.

In the wearable arena, device designs no longer have to accommodate rectangular shapes and rigid surfaces. Devices can conform to users' bodies and seamlessly integrate into what they wear. Printed electronics also give designers new opportunities for using flexible sensors and displays. Another area where transformation of the concept of usable space comes into play is structural electronics. With this technology, the electronics become part of the structure. Potential applications include cars with printed organic light-emitting diodes inside and outside of the roof, as well as printed photovoltaics over the outside of the vehicle, acting as a supercapacitor skin, replacing the battery as energy storage.

Market analysts trying to explain the rise of printed electronics point to a number of economic factors. But if you step back and look at the emergence of wearables, smart interfaces and structural implementations, you realize that printed electronics have arrived at the right place, at the right time. DE

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INFO ➜ **Optomec:** Optomec.com

➜ **Pulse Electronics:** PulseElectronics.com

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COORDINATE MEASURING MACHINES

by Monica Schnitger

CMMs: A Machining Accuracy Possibility

LET'S SAY YOU CREATE the best CAD model ever of a part that is key to your company's success. It might be immensely complicated or somewhat simpler—but it's got to be machined correctly or your customer will reject the shipment. How do you ensure that what comes out of the manufacturing process is what you intended?

Coordinate measuring machines (CMMs) are devices that use physical contact or, increasingly, laser scanners or other touchless techniques, to precisely create a digital map of the outside of an object. The simplest CMMs are portable and look like a handheld drill or glue gun; the operator passes the tip of the device, a probe or scanner, carefully around the workpiece to map it. The biggest CMMs have granite bases that provide stability for large parts and a gantry-like structure that moves the scanner over the part. In between, an arm-like structure holds the probe or scanner while it moves around the stationary part. Which CMM is right for you depends a lot on what you're measuring and where that sits in your workflow.

Mapping the Data

There are dozens of CMMs on the market today, each with a range of sensing devices and software to run it all. Their sensors map the as-is workpiece and compare it with the ideal of the CAD model to identify where tolerances are exceeded. This sounds simple: "Is this hole bigger than it should be?" has a quantifiable "yes"or "no" answer. But it is actually quite complex. First, the process needs to ensure that the measurement originates from the correct datum and acknowledges temperature and other variables that might affect the measurement. Then, it needs to be in context with CAD models that present product requirements in an as-desired form; CMMs capture the as-is and are part of the business of manufacturing. Correctly gathering data means measuring the important surfaces of a workpiece and not necessarily all; it's a balance of cost, speed and accuracy.

But what do you do with that data? This is where the magic happens. CMMs (well, their software) map the deltas or differences between the as-is and as-designed. Once you have that information, you can start to ask questions such as the following:

- Does the delta grow as you produce more units? Perhaps the tools are out of spec.
- Is there a delta consistently in one spot? Maybe the design and your machining process are not well aligned—or maybe you are not measuring accurately enough.
- Could the delta highlight a manufacturing inefficiency? Can you fine-tune the machining instructions?
- Or is it the machine setup? Can you swap out a suboptimal tool for another?

Location, Location, Location

Where you carry out your measurement process also affects outcomes. CMMs used to be located in quality control labs, making it an outside oversight and limiting the ability to practically influence the production process. After all, while parts are queued for measurement, production is still rolling. Too, any deltas that are found are much harder to trace to a specific floor operation if hours have passed since that part was produced. To make the quality process more real-time, many companies are now putting CMMs right onto the shop floor. This makes it obvious that quality is everyone's job but has implications for measured accuracy since the environment is not as controlled as in a lab. It is a tradeoff that each manufacturer needs to make.

One thing I hear time and again is that there is no one "correct" measurement method. Every measurement has some sort of variance that can affect our impression of the quality of a workpiece. We need to get comfortable with that and balance CMM data against other factors in the business such as risk (is the part still fit for purpose?), cost (if we scrap it, what's the impact?), schedule (what don't we do, if we redo this lot?). Each measurement must be considered in its context.

A quality program can be many things from a simple sorting of parts into "good" and "bad" to a more sophisticated manufacturing process control scheme. If it is the latter, it needs to identify what matters to manufacturing, which may be very different from what design has in mind. In this case, it's even more important that design and production work together to identify the tolerances that are most important to measure and track. **DE**

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by Tony Abbey

Interpreting a Data-Driven World

I HAVE BEEN RENTING OUT a very small property in the UK for many years now, and it is always a challenge when it is time to find a new tenant. This summer seems to have been particularly difficult, so while in the UK recently, I phoned the realtor to see what was happening.

I could hear her pulling up statistics on her computer. "It's actually doing really well," she said. "The number of website hits we've had over the last three months is very good. In fact, you are doing the best in this office and are in the top 10 for the region. You have over 10,000 hits."

I asked why, in that case, we had no takers for the letting. She admitted that was puzzling. I asked how many live visits occurred over that period. There was a long pause, and then I heard her counting aloud.

"Let's see. One that week. Two that weekend, there is another one …" This continued for a few minutes before the conclusion that 14 people had viewed. Sadly, she had no computer-generated statistics for visits and no insight into what people really thought of the property.

What Does the Data Mean?

There are many examples in the world of analysis and simulation where large amounts of data are output. The difficulty can be in interpreting what all this data really means.

Perhaps we can draw some lessons from my realtor experience. Our problem was in focusing on the wrong data. The website analytics showed the level of general interest in that type of property and concluded that it was high. The trouble was, high relative to what criterion? Our objective was not to maximize the number of hits on a website but to get the property let. The key metric is simply how many live bodies viewed the property. Of even greater importance would be their opinions on the property. What aspects were impeding them from interest in renting? There was no formal data capture for visits. Information on likes and dislikes was purely anecdotal and difficult to recall. It would be very useful for the accompanying agent to fill in a quick questionnaire from the viewers on the spot.

An Industrial Example

One of the most important tasks in any finite element analysis (FEA) simulation is to decide on the objectives of the analysis and how to interpret the results in a physically meaningful way. As I have mentioned in other articles, there is a danger of being a little hazy. I recall an analysis on a nuclear transportation container. The fundamental objective was to ensure breaching of the container could not occur in any accident scenario. One potential failure mode was rupture of the bolts holding the container lid.

Analyses were run across many impact orientations to understand the load levels that the bolts would see. However, it was very difficult to identify exactly what would constitute a rupture of one or more of the bolts, from viewing the analysis results. The first instinct was to look at the stress waves traveling up the bolts and to compare this with the ultimate stress of the bolt material. However, it became clear that these stresses far exceeded the ultimate value. It seemed to indicate that the bolts should not be surviving. In fact, parallel test evidence showed the container to be much more robust than we were predicting, and bolts were not failing at these load levels. It took some time to realize that we should be looking at the energy developed in a bolt under loading and compare that with the energy required to fracture that bolt. Energy accumulation in each bolt was a lot more meaningful than looking at stress waves.

> "One of the most important tasks in any finite element analysis simulation is to decide on the objectives of the analysis and how to interpret the results in a physically meaningful way."

It was lucky for us that we had the test results to bring a level of sanity to our thinking. Without tests, we would have overdesigned containers quite significantly. Please bear in mind this was many years ago before FEA methodologies in this area had really been established.

So, in summary we must make sure we look at the right data for the right reasons. This is largely associated with defining the objectives of the analysis and relating the simulation to the real world.

As a happy ending to my letting experience, it does look like the real-world data combined with some basic practical decisions have produced a positive result. **DE**

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Modeling for the Augmented Age

Early augmented and virtual reality developers balance new working paradigms with the mouse-and-keyboard legacy.

BY KENNETH WONG

AT THE AGE OF SEVEN, Ryan Pamplin discovered he needed to wear glasses. Whereas other kids might bemoan the nerdy look, Pamplin instead began dreaming of one day combining his glasses with his other favorite toy—the computer. In a way, he helped make his own dream come true.

"I'm now sitting in my office wearing my Meta glasses," he explains. "There's a Polaroid-style picture of my girlfriend and [me] floating around me. I've got a virtual monitor floating above my desk. Next to me, I have a skeleton I can fully dissect. Oh, and a little virtual campfire I keep under my desk. I jokingly tell people it keeps me warm."

The virtual campfire may be nothing more than a giggle-inducing gimmick made of pixels, but the virtual monitor and skeleton are fully functional. "I run my Windows and Mac applications on the monitor. And I can pull apart the skeleton, read the annotations and learn about body parts and muscle groups the way I never could from a textbook," says Pamplin.

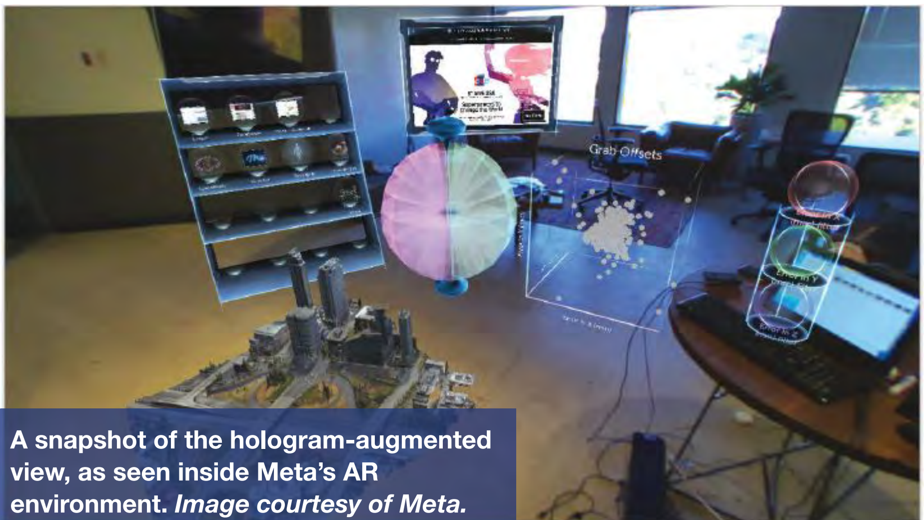
Pamplin, VP and technology evangelist at Meta, believes this is how most people in the near future would prefer to work, live and socialize—in an augmented reality (AR) where the distinction between digital and physical objects is not always clear.

It's a vision shared by graphics processing unit (GPU) maker NVIDIA, enterprise software maker IFS and CAD software giants Autodesk and Dassault Systèmes, among others. At this year's GPU Technology Conference (May 2017, The Venetian, Las Vegas, NV), NVIDIA Chief Executive Officer Jensen Huang introduced the Holodeck, a virtual reality (VR) setup for design collaboration, inspired by the reality-simulator depicted in the popular sci-fi TV show "Star Trek."

What would CAD, product lifecycle management (PLM) or enterprise resource planning (ERP) look like in the age of AR-VR? The projects under way today offer some clues. But to boldly go where AR-VR applications have never gone before, they must confront the legacies from the mouse-and-keyboard era.

A Natural Way to Interact with 3D

In February, at the annual Dassault Systèmes SOLIDWORKS user conference SOLIDWORKS World, SOLIDWORKS CEO Gian Paolo Bassi announced the partnership between its firm and Meta. "Meta designed its device with 3D holographs instead of flat screens," said Bassi in his onstage keynote address.



A snapshot of the hologram-augmented view, as seen inside Meta's AR environment. *Image courtesy of Meta.*

Meta writes, "The headset displays holograms and digital content, comes with a software development kit (SDK) built on top of Unity (the most popular 3D engine in the world) and includes Workspace, Meta's new AR operating environment that has been built based on our AR design guidelines."

A notable feature of the Meta device is what Meta CEO Meron Gribetz describes as "gestural computing." The headgear is equipped with implanted reality-based depth sensors, two cameras pointing out

Meta projects holographic objects into its eyewear to enable AR-based workflows. *Image courtesy of Meta.*

and a pair of six-axis IMUs (inertial measurement units). This allows the device to monitor your hand position and correlate it to the 3D holographic space. With this setup, you can grab, hold, move and rotate 3D holographic models with natural motion, as though you're interacting with something tangible floating mid-air.

"On a traditional flat screen, if you want to rotate the model to pinpoint a parting line or examine the area closely to see how light reflects around it, you can't really do it with dexterity. In Meta, we can give you that ability," says Pamplin. "For anyone working with 3D, they'll have a huge competitive advantage with AR."

"In our SOLIDWORKS software, we're adding a button to let you export beautifully detailed CAD models as glTF (GL Transmission Format) or STL (STereoLithography) files, compatible with most game engines," says Arnav Mukherjee, SOLIDWORKS development director for viewing and experimental technology.

From Heavy CAD to Lightweight Mesh

Uses of AR in engineering may be divided into two main categories: consumption and creation. In an AR setup for design consumption, engineers may view the digital prototype of a concept (for example, the proposed design for a new vehicle) for assessment. In an AR setup for design authoring, engineers may use a variety of operations to create the digital model of a design concept from scratch.

For the most part, the first-generation AR-VR tools will focus on data viewing, not authoring. "I've been finding that consumption is the first stage. We still have to solve a lot of issues there," says Mukherjee.

For AR viewing, the first hurdle is converting the fully detailed CAD data into a reasonably lightweight format suitable for AR. "Usually, the data coming from CAD is too heavy, too rich and in high resolution," says Brian Pene, director of emerging technology at Autodesk. "It's not easy to put this into a game engine and run it at 90 frames per second. People are now spending tens of thousands of dollars just to get the data into AR-VR apps."

Sitting at the intersection of architecture, media and entertainment, and product design, Autodesk is in a position to harvest its game and filmmaking technologies to build an easy data pipeline from CAD to AR-VR. "We created a service in Autodesk Forge that lets you push a button to send your Autodesk Revit models [3D architectural models] into the cloud, and 'automagically' create an immersive VR experience," Pene says. The same approach, he suggests, would make it possible to convert large mechanical assembly models to an AR- or VR-ready state.

Autodesk Forge, the company's subscription-based software development platform, supports more than 50 3D file formats, including many associated with software developed by Autodesk rivals. The *magic* in *automagic*, Pene explains, is a blend of cloud connectivity, high performance computing (HPC) and artificial intelligence (AI).

Untethered Future

The computing power required to deliver and sustain visual fidelity in AR-VR is intense. It usually demands the capacity of a midrange or top-tier professional workstation. This is why many AR-VR applications are not yet cordless today. Mobility usually comes in a cumbersome backpack, which you must strap to your back or carry with you as you navigate your virtual scene.

Enterprise software maker IFS envisions using AR to let field crew, technicians and maintenance workers automatically identify assets and review relevant data. ***Image courtesy of IFS Labs.***

But this is bound to change in a couple of years. "The graphics capability—particularly, the GPU you can fit into a wearable—is not powerful enough today [for AR-VR]," says Meta's Pamplin. To him, it makes sense to develop the Meta SDK to work with a desktop machine because "the current professional GPUs for the desktop matches what you'll likely get in your pocket devices in the future. Within the next few years we'll cut the cord."

Hands-free Asset Management

As Bas de Vos sees it, enterprise resource planning (ERP) interfaces need not be locked up in a mind-numbing series of grids, columns and rows. As director of IFS Labs, a division of the enterprise software company IFS, de Vos is responsible for exploring future technologies that the company can benefit from.

"There's a good business case for AR-powered ERP," says de Vos. "With it, you can provide the field technicians and engineers with the right information at the right time, in the right context, without requiring them to go into the system to find it."

For IFS customers, resources and assets could be airplane components, industrial machinery or oil rigs. "So imagine you can walk up to an asset wearing Microsoft Hololens," says de Vos, "and it could recognize the asset you're looking at, could pop up a list of relevant work orders, along with instructions on how to perform the maintenance required."

Automatic asset recognition is the easy part. You could use barcodes, QR codes, beacons or a mix of the three to let mobile devices instantly recognize what it sees in the camera view. Such a solution can even be implemented affordably today with tablets and smartphones. But AR offers another advantage.

"With Hololens, you get the hands-free experience," says de Vos. That's important in IFS's world, because field engineers need their hands to work on the asset. "You can also easily launch Skype from your headset, make a call and share your view with someone located remotely."

With view sharing, an expert far away could direct a field technician or even a trainee-level user to perform certain advanced procedures without having to travel. "Customer satisfaction would be a lot higher if we can fix something right on the spot without going back to the office," says de Vos.

In early prototypes, IFS can stream ERP and product lifecycle management (PLM) data stored in IFS applications seamlessly into Hololens. The data consolidation, however, could be challenging for firms that use systems and software from multiple competing vendors. "If an organization chooses to store information in 25 different sources, and those systems are not talking to one another, then it's that much more difficult to get a single picture of the truth, so that's something that needs to be considered continuously," cautions de Vos.

AR vs. VR

Though consumers sometimes use the terms **augmented reality (AR)** and **virtual reality (VR)** interchangeably, people in the high-tech community tend to view them as different specimens.

AR technology usually allows users to superimpose a layer of digital information onto their real-world surroundings. (In other words, the user's real-world view is augmented with digital information.) For example, wearing AR headgear, a factory manager might be able to call up and see the maintenance records of a piece of equipment he or she is inspecting.

VR setups are usually designed to give you an immersive experience of a remote place, populated with avatars and digital objects. For example, wearing VR headgear, a user situated in present-day San Francisco may experience the sights and sounds of ancient Rome. To make this possible, the VR content—in this case, ancient Rome reconstructed in pixels—is delivered to the VR headgear's display.

Don't Build Muscle Memory with Joysticks

NVIDIA describes its Project Holodeck as "a photorealistic, collaborative VR environment that incorporates the feeling of real-world presence through sight, sound and haptics." If implemented effectively, the last item—haptic feedback—would make all the difference.

Matthew Noyes, the software lead at the NASA Johnson Space Center's Hybrid Reality Lab, was one of the speakers at NVIDIA GTC. Discussing the use of AR for astronaut train-

Autodesk offers Autodesk Forge, a platform that AR-VR developers can use to power applications with Autodesk technology. *Image courtesy of Autodesk.*

ing, he pointed out, "We don't want to just teach the astronauts how to use the tools, but we want them to develop the muscle memory of actually using the tool."

Noyes and his team used 3D-printed replicas of the repair tools during the AR-driven training sessions to give the trainees a good feel for using the tool. "A maintenance drill used on the Hubble station for repair costs about a million dollars to manufacture. But a 3D-printed facsimile can be created with about $20 worth of plastic materials," Noyes said. "The 3D-printed tool is hollow inside, so we can [add artificial weight] to make it weigh as much as the real thing."

Currently, in most AR-VR setups, the visuals are stunningly realistic but the illusion is shattered once you reach out to touch a digital object. You can, for example, accurately judge the look of a luxury car's leather-coated interior, but you won't feel the texture, weight and stiffness as you would in the real world.

Joysticks and other standard devices are sufficient for navigating a 3D scene, but they are shaped differently than the real tools field technicians would use to perform the tasks. Therefore, developing joystick-based habits and intuitions could be detrimental in AR training of field work. Haptic feedback and 3D-printed replicas could add the missing layer of realism to such applications.

Holodeck is "built on an enhanced version of Epic Games' Unreal Engine 4 and includes NVIDIA GameWorks, VRWorks and DesignWorks," the company writes. In the demonstration at NVIDIA GTC, the company was able to show Holodeck handling a 50-million polygon 3D vehicle model.

Zero Learning-Curve 3D Modeling

Take a look at how a child plays with Play-Doh. When she wants a square block, she might pat the bottom, top and sides of the misshapen lump. When she wants a hole, she might poke through the surface with her fingertip. When she wants to smooth the block's edges, she might rub off some materials with her fingers. That is, in a manner of speaking, a zero-learning curve modeling application.

"I think a Play-Doh-like interface would only work if the application gives tactile feedback. Otherwise, even if you get visual clues, it would feel strange or unnatural for the user," says SOLIDWORKS' Mukherjee. "Most CAD users will probably still use keyboard and mouse for now. But they should also have a way to easily press a button and see their design in AR-VR headsets."

Meta's Pamplin says, "I want a two-year-old or an 82-year-old to be able to put on our device and understand exactly how to use it right away. I want the digital tools to resemble tools in the real world. The digital sculpting tool should look like a real sculpting tool. It should not look like an abstract icon or menu."

The emergence of affordable AR technology offers the tantalizing possibility to reinvent 3D CAD with a much more natural interface, to shed the menu-centric habits developed in the era of mouse and keyboards. But old habits are hard to break. So overcoming the keyboard shortcuts, now part of many CAD-savvy engineers' muscle memory, may be harder than solving the technical issues of AR-VR. DE

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INFO ➜ **Autodesk:** Autodesk.com

➜ **Dassault Systèmes SOLIDWORKS:** SOLIDWORKS.com

➜ **IFS Labs:** IFSworld.com/my/solutions/ifs-applications/ifs-labs

➜ **Meta:** Metavision.com

➜ **NVIDIA:** NVIDIA.com

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Knowledge Capture and Retention in FEA

Challenges still remain in transferring simulation knowledge to new employees.

BY TONY ABBEY

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

Many companies are concerned with retaining the knowledge and experience that analysts possess and that is inherent in both their day-to-day and long-term tasks. This is not a new phenomenon—I remember very similar worries when I joined the aircraft industry 40 years ago. The concern then was associated with the transition from traditional manual stressing techniques to the newfangled finite element analysis (FEA) methodologies.

It is sobering to reflect that those old concerns about stressing knowledge transfer are still ongoing. Many aerospace companies struggle to map conventional techniques to new FEA approaches in a physically meaningful and cost-effective way.

I was discussing knowledge and experience loss with senior managers at a major U.S. government research agency. They have many older analysts who are deeply immersed in FEA, with all its structural and physical implications. These staff members are reaching retirement and disappearing fast. Conversely, the agency has many new graduates with very little experience yet. To plug this gap and support ongoing work, the agency uses many contractors, whose average age is around 55. This exacerbates the problem of knowledge transfer between the new intake and the old guard. The contractors are often engaged for short periods, and hence will not settle in and act as mentors to the new staff. The challenge at the agency is how to capture the knowledge from the contractors.

Company Memory or Organizational Knowledge

There is a tendency to think of a company as a living, breathing entity that will naturally retain, develop and enhance its own range of knowledge and processes. This reflects the way an individual engineer matures over the years. Sadly, this analogy is flawed. Knowledge and experience can leak out of a company's collective "soul." I saw this firsthand some years ago when teaching an optimization class to a group of engineers. Two of the attendees were from a company I worked for in the 1970s. One was the current expert in that area. The company had been one of the leaders in structural optimization development, with several noted pioneers. It quickly became clear that the knowledge and aspirations from 20 years previously had become diluted.

There is wide literature on this topic: Company knowledge is often described as organizational and is assumed to stem from the combined knowledge of different groups or communities within that company. In the world of FEA, knowledge was often held by specific individuals who may not have considered themselves part of the community. In today's connected and interacting ethos, individual knowledge is a natural contribution to the sum total of company knowledge.

The analogy of the company as a living entity has another interesting aspect. Individuals develop most skills through failure. Negative results matter significantly in human development. I was startled to learn that bone development is basically a battle between a continual purging and building process. The process reacts to external stimuli such as gravity, biomechanical loading actions and other environmental inputs. Corporate culture tends to reject failure and disguise or ignore it. There is a danger that, with any knowledge retention approach, emphasis will be placed on successful results. The skeletons in the cupboard are actually very important. Equally, a safe and trusted knowledge base may inhibit exploration of new methodologies.

The Full Story

The emphasis so far has been on retaining knowledge in a company. However, the full knowledge management process involves learning, capture, retention and dissemination of that knowledge. This is the path for an individual and hence by extension to communities and the organization. Last-minute capturing is an unfortunate consequence of not anticipating a drastic skill shortage. It also means that there are probably unrealistic demands on solutions to retain and disseminate the knowledge captured from leavers. The knowledge is not inherent in the organization any more; it is an abstraction to be reabsorbed. So perhaps consider the full story when planning knowledge capture and retention. Learning processes, either formal external courses, or informal on the job, could form part of the knowledge management.

Knowledge Transfer Inhibitors

Knowledge transfer from contractors has always been a thorny issue. A positive desire to pass on experience to the younger generation is far from the norm. Sharing this knowledge with others is viewed as undermining value to the organization. I have seen contractors putting barely sufficient

> "Knowledge and experience can leak out of a company's collective soul."

information into reports to specifically avoid providing knowledge of methodologies.

This can also occur when using external consultants, who may avoid describing methodologies in the FEA report. I have seen initial public offering claimed on the basis that the methodology is a trade secret. It is difficult to reconcile this. A consulting house may have taken many years to develop special methodologies and be reluctant to share. However, it is difficult to see how deep-level verification can be done without full disclosure of the methods used.

A good company lawyer will write a contract to require a consultant to release sufficient information to have a proper and full verification. A reasonable nondisclosure agreement should help to offset concerns. If the consultant decides that too much intellectual property is at risk, then that contract can be declined.

A few years ago, I saw a great example of how a prime contractor can take a positive attitude toward knowledge transfer using consultants. I gave a three-day in-house dynamics course at SpaceX. There was some methodology inherent in the training, but it was primarily aimed at effective use of the software. After two days, the young engineers had fully explored the process and interface. The last day became a technology transfer session as we sat down to expand on the methodologies and see how they could be implemented at SpaceX. This was in the very early days for the company. Instead of being able to use a NASA specification for a random loading environment, with a standard PSD (power spectral density) spectrum, they had to develop their own. As questions arose, we went straight to the guys responsible for live launch data to see how it was obtained and processed. I brainstormed a methodology to synthesize a PSD spectrum that formed the basis for their process.

It was a very heady experience, and the key was that the young engineers, empowered by their CEO, saw it as their role to explore and develop these new methodologies. I met two ex-colleagues at SpaceX. It turned out that they were not there for the duration; their mandate was to transfer the knowledge to the younger engineers around them over a 12- to 18-month period.

It was a refreshing approach, as the experienced guys understood their dual role. They were there to carry out the groundwork, develop methodologies and pass everything on to the next generation. I assume that these older engineers were well paid for their work.

Formal Knowledge Management

What formal ways can be used to achieve knowledge management?

Knowledge management processes within a company can be defined and documented. On an ongoing basis, experienced engineers describe directly or through an interrogatory interview, what their processes and best practices are. This could be a broad overview of the FEA process. Or it could be specific methodologies, such as simulating bolting connections, modeling of equivalent small-scale damage and initial imperfections on buckling, and so on. This forms the

As design engineers with a wealth of experience retire, they often take that knowledge with them. *Illustration by Steve Abbey*.

basis of a company methodology and experience database. There are many other forms of knowledge capture, including surveys, brainstorming sessions, etc.

It is important to start this type of activity now and not wait for a critical exodus to trigger it. The process can be subtly blended into the full-knowledge learning and retention practices. I am a believer in peer reviews of FE analyses. An informal review at the start of an FE project, where the analyst describes objectives and methodologies to members of the team is useful. Experienced and inexperienced members can sit in. Processes discussed during the review are captured and documented to form part of the knowledge database. At the end of the analysis, prior to formal reporting, a more in-depth peer review can take place. Lessons learned and mistakes made en route to a successful conclusion can all be documented as a formal corporate knowledge, but the inexperienced engineers also have absorbed this directly. The social interaction involved in peer reviews is typical of the modern understanding of the importance of community. All the social networking tools that are underpinning our society can be used in some form or another.

If hemorrhaging of experienced staff has gone too far, then companies could use the SpaceX approach of using external consultants with dual tasking to move projects forward and at the same time build experience levels in full-time staff. On a smaller scale, a company could include expert consultants in internal peer reviews of FEA. The consultant is briefed to provide a full and open discussion on the various aspects of methodology occurring during the review of the FEA project. It is then the responsibility of the team members to make sure that that the dialogue is captured and documented.

Implementing the Knowledge Base

Building the captured documentation into a company knowledge base will vary from informal approaches to sophisticated IT solutions. The key to any implementation will be acceptance by all, which means a minimally invasive and demonstrably productive solution.

An IT solution will tend to focus on tangible assets. There is a danger that it will become just a document collection. It should form part of the ongoing analysis management process and be able to incorporate the informal and human aspects. Easier said than done, it will be a major challenge in any successful knowledge management implementation.

Many years ago, I attempted to develop an automated FEA debugging process within my analysis group. It was a strictly logic-based approach that assumed any problem would have a mechanistic solution. It was not a great success because it failed totally to capture any real experience or rationale. You have probably had similar experiences with call centers that operate from scripts.

Templating Knowledge Transfer and Retention

A popular way of defining best practices is to establish a template using specific CAD or analysis software. An experienced analyst will define the steps required to set up and run an FEA model. The steps are parameterized in a template form. This means less experienced engineers do not have to set the problem up from scratch, but instead are guided through a focused subset or analogy of the original software steps.

I recently saw an example in the automotive industry where the analysis of a range of connector rods in a suspension system could be carried out parametrically. A high-level menu overrode the usual detailed menus. The high-level menu drove a series of scripts or macros that carried out detailed work. Engineering judgment on loading and boundary conditions was enforced by limits on values and location. Warnings for inappropriate selections were built in. This tool was aimed at designers producing variants of the connector rods. It enabled them to focus on the design and carry out precautionary analysis with confidence.

There is a danger with this approach. If the understanding of the methodology behind the templating is lost, the process is at risk. The process becomes a black box. Nobody knows what it does in detail, but it forms a core part of the analysis process and cannot be changed. It can become very expensive to re-engineer and re-architect the process.

One of the requirements of templating or a macro should be a user-friendly interface, which avoids opaque programming languages that rapidly become obsolete. Instead, it should be possible to reverse engineer a transparent process. Perhaps more importantly, the physics or engineering behind the process should be fully documented and understood.

The auto industry example also highlighted another limitation. It was time-consuming to define the template and it was limited in the range of configurations it could deal with. If designers continuously want to push the envelope and explore significantly different solutions, the template creators are unable to provide the tools in time.

The Future

I imagine at some point there will be a migration toward a pure machine learning environment for learning, capture, retention and dissemination. Some form of artificial intelligence will be embodied in FEA solvers that will allow the capture of the objectives, setup, methodology and results of many thousands of analyses within a company. Engineers can then carry out variations within these analyses and be confidently guided through the process. A much bigger challenge is to develop a system that could advise on new forms of analyses outside of the scope of the learning provided. That is a scary thought. **DE**

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

Vendors Push Part Reuse to the Next Level

CAD and product lifecycle management platforms are being modernized with parts classification, Google-like search, and systems modeling capabilities to promote model and parts reuse.

BY BETH STACKPOLE

INVENTING THE WHEEL is one thing, but reinventing it time after time is a development no-no, especially in the wake of mounting product complexity and the need to push innovative products to market faster at reduced costs.

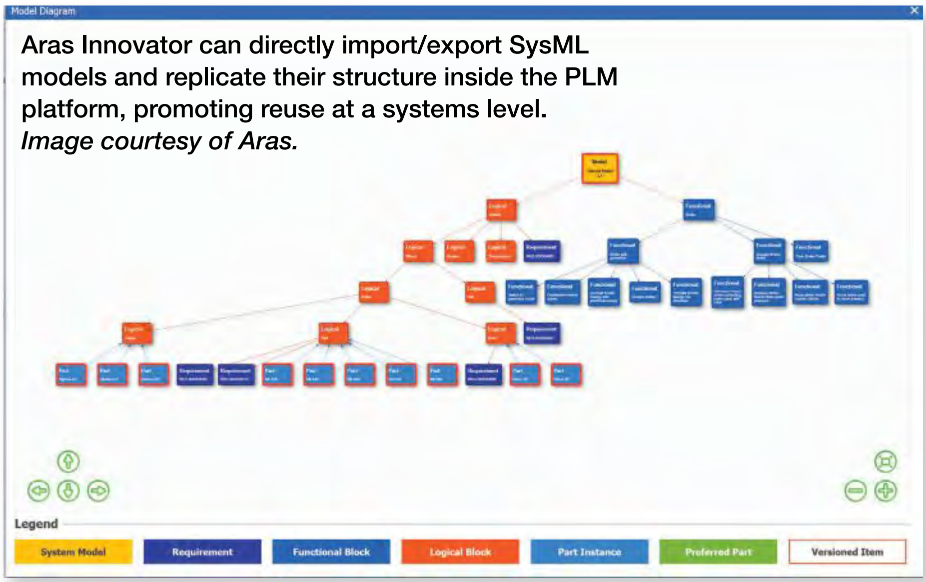
Although model storage and reuse has been an ongoing challenge for design teams, the scope of content engineers hope to reuse has been greatly expanded as software and electronics continue to edge out mechanical components as a dominant part of a product's bill of materials. CAD and PLM (product lifecycle management) platforms have been steadily enhanced with new search and classification capabilities to help design engineers readily zero in on existing 3D models of parts and assemblies that have relevance to their project, as opposed to having to recreate components from scratch for each new design.

Parts reuse practices have significant ramifications beyond simply reducing costs associated with engineering and design work, experts say. The expenses associated with sourcing, inventorying, tracking and servicing parts increase exponentially with the number of parts and models being managed, so minimizing new parts creation can deliver significant savings for most development organizations over time, according to Dr. Michael Grieves, research professor at Florida Institute of Technology and author of "PLM: Driving the Next-Generation of Lean Thinking."

Market research firm Aberdeen estimates that between 30% and 40% of a manufacturer's parts are duplicates, but the engineering costs of those duplicates are just the tip of the iceberg when it comes to controlling costs. Specifically, Aberdeen projects the annual carrying cost of producing a new part number runs between $4,500 and $23,000 for every item when you account for sourcing, transaction and inventory costs.

"There's still a lot to be said for reuse of geometric models and CAD design, and there is technology evolving to help with that," notes Bill Lewis, director of product marketing for Teamcenter at Siemens PLM Software.

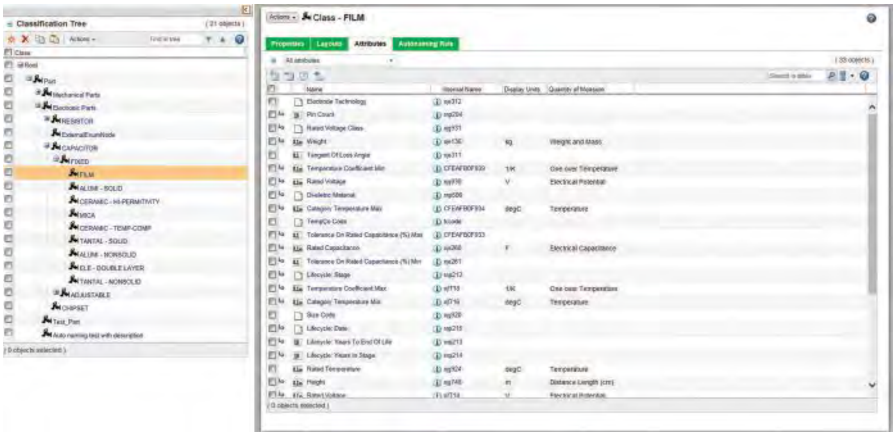
At the same time, however, Lewis says the concept of reuse is evolving to coincide with the changing makeup of products. "Reuse is evolving into new frontiers—it's not just about reusing geometry, but a more complex problem now," he says. "Products these days are rarely just geometric, but include electronics and software, and the concept of reuse has to keep pace with that in order to remain valuable."



Aras Innovator can directly import/export SysML models and replicate their structure inside the PLM platform, promoting reuse at a systems level. *Image courtesy of Aras.*

Classification and Search

Even on the CAD front, the concept of model reuse has changed signifi-



Windchill's PartsLink Classification and Reuse capabilities help users locate and reuse parts by comparing functional, physical, supply chain and environmental characteristics. ***Image courtesy of PTC.***

cantly over the years with CAD and PLM vendors doing their part to enhance search capabilities with consumer-like features to make tagging and finding parts and 3D models easier than in the past. Historically, CAD users' only hope to facilitate reuse was to manually search for specific names of files on a hard drive—an approach that improved with the introduction of product data management (PDM) and support for metadata, which allows engineers to search on other parameters like date created or assembly name to locate a part for potential reuse.

Siemens' NX CAD platform, for example, has a reuse library that integrates with Teamcenter, allowing designers to designate specific parts as reusable so others can readily take advantage of them in new designs. In addition, Teamcenter's classification capabilities enable engineers to define specific attributes about parts and assemblies as they are cataloged into the PLM system. This helps facilitate search and retrieval functionality, especially for engineering teams dealing with increasingly large databases of parts and assemblies, Lewis explains.

SOLIDWORKS, as part of Dassault Systèmes' 3DEXPERIENCE platform, also benefits from metadata classification schemas to promote parts reuse, says Milos Zupanski, director of product portfolio management. In addition, EXALEAD OnePart, also a member of Dassault Systèmes' platform, classifies parts based on shape similarity and semantic criteria, ensuring that comparable parts are associated together in families, giving engineers even greater flexibility in evaluating and choosing between parts for reuse, Zupanski says.

Say, for example, you are looking for a flange with four holes. The OnePart capability lets design teams search not just using the word flange, but with descriptions of specific shapes to find the perfect match. "We compute a shape signature based on the geometry and try to find (the) closest match," explains Shyam Venugopal, Dassault Systèmes product portfolio manager. "In this way, inside a giant database of similar looking screws, you can find what's most appropriate for your project." In the end, it's the combination of the metadata classification and shape search that makes SOLIDWORKS' parts reuse story so compelling, he claims.

For smaller companies that might not have access to PDM or PLM functionality or the broader 3DEXPERIENCE platform, Dassault Systèmes also offers 3D Content Central, an online database of 3D part models. Dassault Systèmes encourage suppliers and other partners to post certified parts and assemblies to the site, and there are also user-contributed 2D and 3D models—all available for engineering teams to leverage for reuse as part of new designs.

PTC also has poured significant energy into evolving its search capabilities for its Windchill PLM platform, according to Francois Lamy, vice president of PLM Solutions. In addition to classification and metadata capabilities that allow users to search for parts by supplier, compliance rule and other attributes, PTC has added capabilities that mirror consumer platforms like Amazon.com to make it easier to find things without having to build complex search criteria, Lamy says. Let's say, for example, that an engineer was looking for a pump to reuse for a design. He could filter pump part results by facets like size, power source or even brand just as any consumer might when shopping for an item on Amazon. "Instead of spending time to build a query, you just type in 'find a pump' and the system will provide characteristics that can be used to filter results so you don't need to be an expert," he explains.

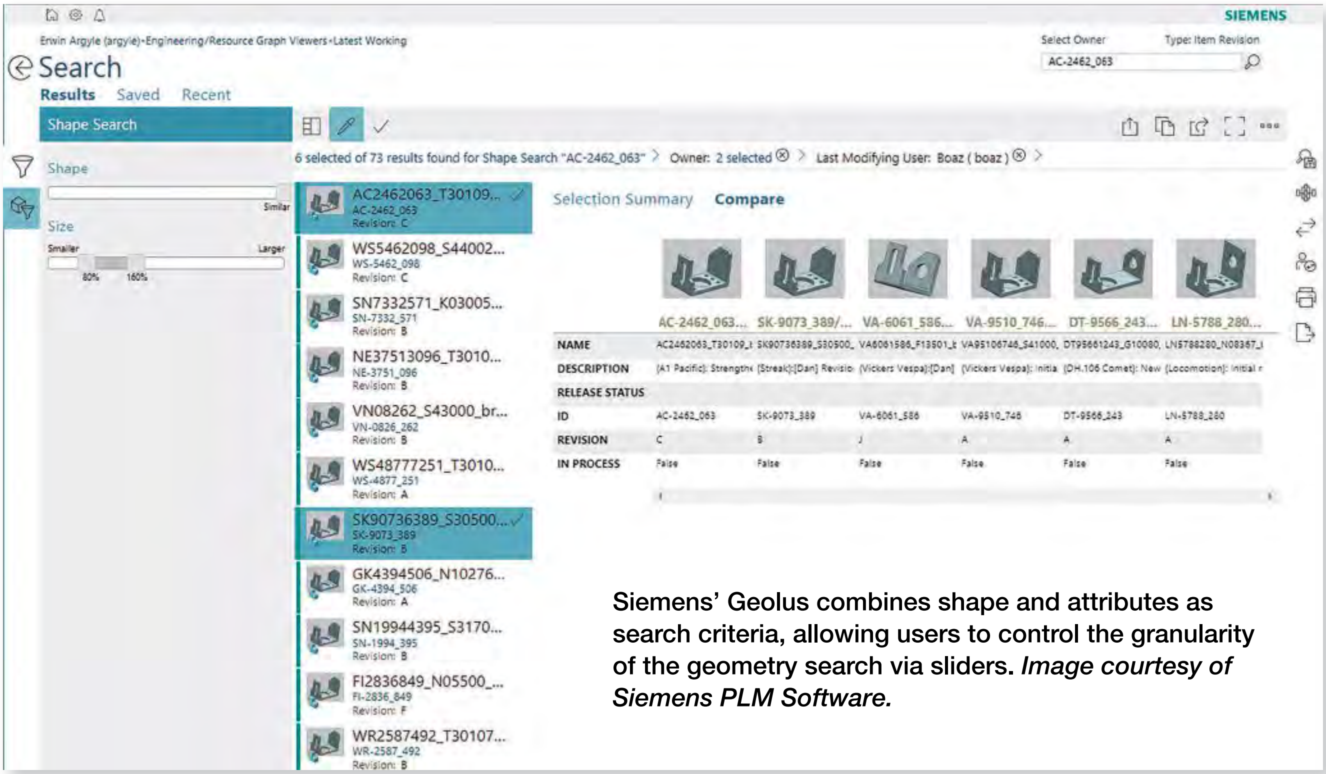
Systems Modeling Kicks Reuse up a Notch

In addition to the work being done on the classification and search fronts, companies like PTC, Aras and Siemens are starting to push the boundaries of reuse even further, introducing capabilities that address the problem at a systems level to accommodate today's multidisciplinary products. For PTC, which is aggressively steering toward the world of smart connected products, the internet of things (IoT) is a huge catalyst for evolving processes and practices to address reuse at a systems level.

"Products are becoming part of a larger system, and there is a drive to integrate across domains," says Mark Taber, PTC's vice president of marketing and go-to-market. "In the systems modeling world, you want to have a set of test cases, validations and processes that might cover one aspect of autonomous driving, for example. Through reuse, you can use that same process to verify another aspect of autonomous driving and modify it from there." Asset-based modeling and variability modeling on a systems level is addressed with PTC's Integrity Modeler, part of its application lifecycle management (ALM) portfolio.

Aras is also actively steering its Innovator PLM platform toward a model-based systems engineering (MBSE) approach, which addresses reuse at a systems level, says Doug MacDonald, the company's product marketing director. To this end, the company has come up with a reference architecture that integrates MBSE and PLM, allowing SysML (systems modeling language) models to be imported/exported and their structures replicated inside the Innovator PLM platform.

By doing so, organizations benefit from the stricter con-



Siemens' Geolus combines shape and attributes as search criteria, allowing users to control the granularity of the geometry search via sliders. *Image courtesy of Siemens PLM Software.*

figuration and release controls supported by PLM on SysML models, which encourages reuse of previously architected subsystems, extends the digital thread and addresses a gap in existing MBSE offerings, MacDonald says. In addition, there is traceability of individual system models in an overall "system-of-systems," and forward and backward integration aimed at streamlining the flow of product information across the various stakeholders and functional engineering teams.

Initially, Aras is providing this PLM/MBSE integration for No Magic's Cameo offering, but the company is evaluating and working on integrations between Innovator and other MBSE tools, MacDonald adds. "The same value and principles of reuse still apply, but you want to be able to reuse a system containing mechanical parts, electronics and software," he explains. "If you develop a braking system for a luxury hybrid drive vehicle, you want to develop it once and drop it into another vehicle. You don't want to redesign electronics and rewrite software—you want to be able to reuse everything."

For Arena, a cloud-based PLM vendor specializing in high-tech and electronics, the problem isn't so much about fostering parts reuse, but rather how to best capture the context of design decisions to help engineers meet the requirement for faster product iterations, says Steve Chalgren, executive vice president of product management and chief strategy officer. Given the accelerating time-to-market cycles in this industry segment, it is often faster for engineers to go back to the drawing board and redesign a part or component rather than spending time trying to chase down how and why a previous engineering team did what they did, he explains.

"The real problem is that one engineering team doesn't know all the context to why another engineering team may have come up with that particular design," he explains. "Without that context, they are hesitant to add that part into their product."

To address that gap, Arena added Arena Verify to the 2016 fall release, delivering an ALM/requirements and defect management capability that helps design teams manage and persist that context and knowledge across different stakeholders and throughout the product's lifecycle. "Now instead of tracing a bunch of emails that are long gone, you can look up in Arena Project and understand the context to determine whether you want to use that component," he explains.

It's that capability, rather than straight parts reuse, that has more value to engineers working in industries with fast-turn product cycles. Says Chalgren: "When it comes to high tech and IoT, reuse is potentially less important." **DE**

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INFO ➜ Aras: Aras.com

➜ **Arena:** ArenaSolutions.com

➜ **Dassault Systèmes:** 3DS.com

➜ **PTC:** PTC.com

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

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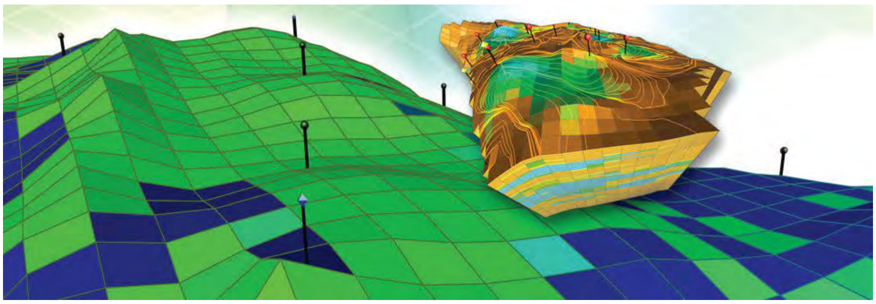
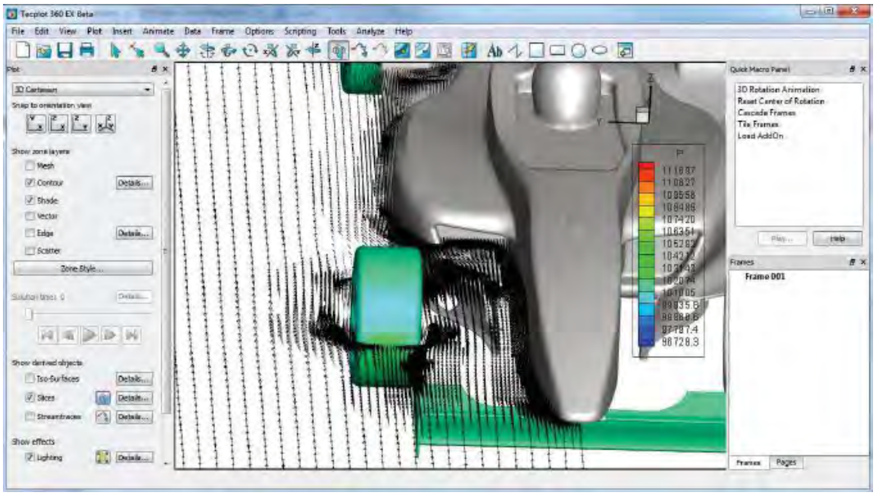
Seeing is Understanding

Recognizing the challenges and benefits of visualizing product development data.

BY RANDALL S. NEWTON

COMPUTER-AIDED SIMULATION and analysis for engineering (CAE) has become widely used throughout industry and is no longer restricted to a few key analysts. Along with this greater usage comes a greater need to share results with a wider audience. The current trend of increased digitalization—such as internet of things (IoT) and Industry 4.0—also places new demands on the use of simulation and analysis. More than ever before, visualization is key to extending the usefulness of CAE data.





TOP: Tecplot software organizes sets of simulations and can provide data plots in three dimensions as well as visualizations that can be explored.

BOTTOM: Tecplot Chorus allows multiple simulations to become part of a larger study. *Images courtesy of Tecplot.*

Data visualizations provide context, enabling engineering teams to find flaws or help explain complicated issues. As digital twin technology becomes commonplace, the simulation results will become as important as the geometric model for the ongoing relationship between the digital model and the physical instantiation. Simulation tools create visual results, but often these graphics are densely technical and require refinement to make their information accessible to a wider audience.

The growing complexity of simulation results and the use of simulation data further up and down the design cycle are two reasons why ANSYS recently acquired CEI (Computational Engineering International, Inc.), known for its EnSight simulation visualization software.

"Simulation is going from what was the verification stage to more and more engineers using it upfront in the design cycle, then also further down the cycle for additive manufacturing and digital twins," says Mark Hindsbo, ANSYS vice president and general manager. "All that data is great, but if you can't use it effectively, what good is it?"

Understanding the Uncertainties

There are two forms of uncertainty being studied by engineering analysis, says Scott Imlay, chief technical officer of Tecplot. The first is random uncertainty, more commonly explored in scientific inquiry but also an influence in engineering. The second is deterministic, the cause-and-effect processes inherent in CAE. "If you visualize the data, you must understand the uncertainties," says Imlay. "It is a risk-discovery process. If a simulation doesn't tell you about risk, you have to find ways to figure it out."

When multiple simulations are run, each with the same product specs but with changes in flow rates, speed and so on, the results need to be linked. The relationship of each CAE visualization result needs to be seen in the context of others in the set. Sometimes blank spots in the data set become obvious only when organized.

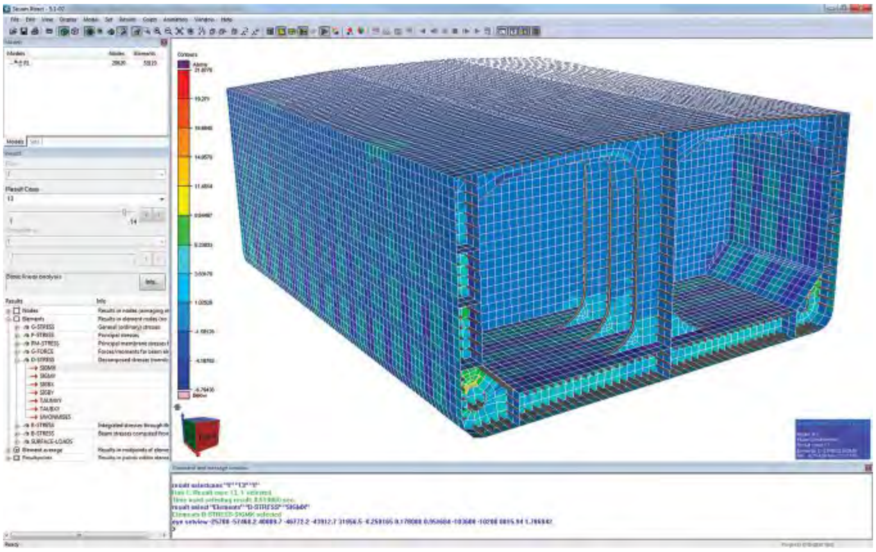
Imlay says Tecplot Chorus is most commonly used to optimize designs, develop comprehensive long-term databases that include CAE results, predict performance over time and investigate specific engineering problems by being able to review multiple simulations as a single set.

"In all these scenarios, engineers need to discover the trends and anomalies in output variables," says Imlay, "and to understand the underlying physics that cause these variations."

Not a Typical Big Data Problem

Big Data is a buzzword today in enterprise IT. Most of the time, the big databases being mined by new algorithms are unstructured in nature. It becomes the job of the inquiring business intelligence software to make sense of it before it offers insights to the user. CAE data is already highly structured; the algorithms used for business investigations aren't suitable for pass-through to engineering, thus the need for solutions specific to engineering.

Engineering data is not only different in nature from business data, but it is also inherently much larger in scale. "If you compute large amounts of data, FedEx is still the best way to transfer it," notes Fredrik Viken, technical director at Ceetron AS, a software developer specializing in post-processing simulation data for visualization, in-depth analysis and interpretation/presentation.



Ceetron products process large CAE sets on the server then send the results to the client using WebGL technology. *Image courtesy of Ceetron.*

"The largest engineering teams are generating thousands of simulations daily," he says. This adds up to terabytes of data.

Most of Ceetron's customers are vendors of CAE software, but they also sell some products directly to end users. Around 2011 Ceetron made the decision to rebuild its product line using cloud technology. A specific customer may install on a private server, but the inherent advantages of cloud technology—flexibility, infrastructure costs, location-independent access, security and reliability—are available whether using a private cloud, a service like Amazon Web Services or Microsoft Azure, or a hybrid of the two.

Ceetron applications leave the actual storage and management of CAE data to the product lifecycle management system; its products focus on the creation and use of the visualizations. Because it uses a cloud paradigm, Ceetron applications use server-side processing instead of client side, and results are rendered and presented to the client computer using WebGL. Thus the results can be viewed in any device that runs a web browser. By separating the computation of the data from the visualization, a Ceetron product like GLview Inova allows model slicing, rotation and so on at the speed of the local device processor and is not dependent on the relationship to the server.

"We are now able to simulate almost in real time the data from IoT sources, such as stresses and strains, and see the results in the web browser." Viken says, adding that this linking of simulation to real-time performance data "will make simulation part of the lifecycle and not just design. Visualization will continue to be more important to see and understand the results and observations." Ceetron GLview Inova works directly with most major CAE systems. It visualizes dynamic/transient results and creates time/frequency domain and mode shape animations. Once a database has been loaded, the user can rotate, zoom and translate interactively. Both image plots and 2D plots can be stored in various common formats. **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 → ANSYS: Ansys.com

→ Ceetron: Ceetron.com

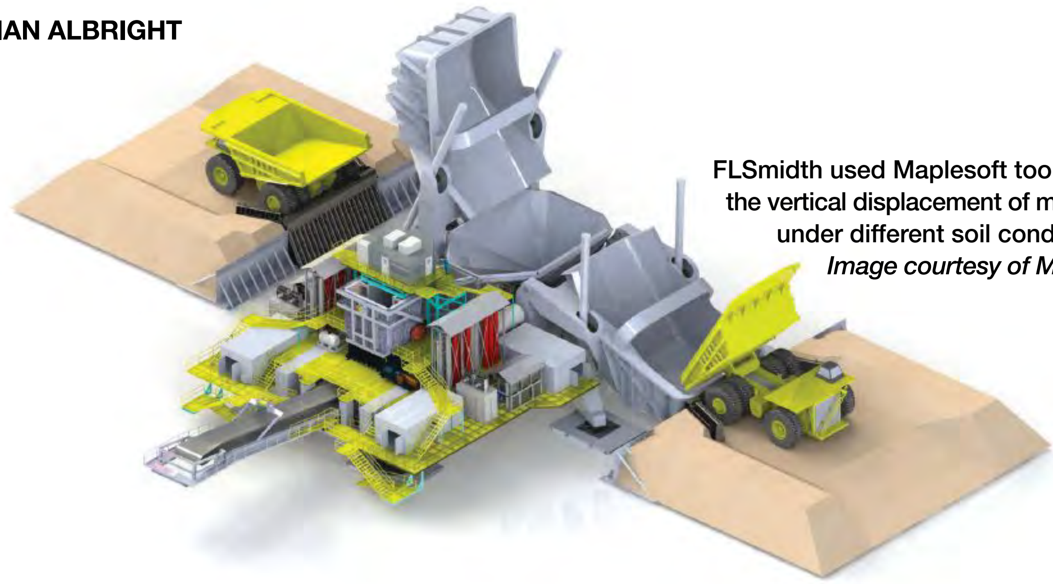
→ Computational Engineering International (CSI): EnSight.com

→ Tecplot: Tecplot.com

Mathematics Software Solves BIG DATA PROBLEMS

Software tools can help engineers make sense of rapidly expanding data sets.

BY BRIAN ALBRIGHT



FLSmidth used Maplesoft tools to determine the vertical displacement of mining equipment under different soil conditions. *Image courtesy of Maplesoft.*

HUGE AMOUNTS of detailed data are being collected from scientific instruments, manufacturing systems, connected cars, aircraft and consumer devices. But how can that data be mined to make it useful? One way is to employ mathematics software to develop algorithms to find the useful needles in the data haystack.

As firms collect these larger amounts of data, organizations are recognizing the value and putting it into specialized systems like Hadoop. Engineers need to be able to get that data from those types of platforms and run their analyses.

"It's clear that more and more data is being collected and is available for engineers to make the right decision. It is also very clear that it's a problem to easily make sense of all of that data," says Laurent Bernardin, executive vice president of research and development, and chief scientist at Maplesoft.

Engineers now have access to high performance computing (HPC) clusters, cloud-based compute resources and more powerful workstations that can handle advanced mathematics, analysis and other functions. That's given them the ability to leverage advanced mathematics tools to develop algorithms to manage Big Data.

Part of the data glut is being fed by the Internet of Things (IoT). In the past, the product lifecycle was limited to design, manufacturing and putting a product in service. With connected devices and the IoT, engineers now have the ability to understand how an item is performing and how it affects the performance of an entire operation.

That's opened up a whole new way to use analytics and specially developed, predictive algorithms. "We now have real physical data from an inductive model to get insight for future designs," says Chris MacDonald, director of analytics at PTC. "We can create this virtuous cycle that can be leveraged for the benefit of the product, both as designed and as operated."

In the past, traditional analysis focused on diagnoses and understanding how designs were done. "What we're seeing now is a move toward creating models to predict behaviors," says Dave Oswill, product marketing manager at MathWorks. "Companies want to optimize the uptime of their machines for their customers.

Big Data, Complex Modeling

As data sets grow and the number of inputs expand, mathematical solutions are more important than ever. "Just trying to find what is in the data you are collecting is a challenge," Oswill says. "We have visualization capabilities in our MATLAB product to help customers identify what they are looking for. For example, with the sensors coming off an aircraft, there are thousands of signals. Statistical methods can be used to see which signals the engineers want to use."

According to Jan Brugard, CEO of Wolfram MathCore, drawing conclusions from these models relies on increasing cross-sectional integration between mathematical models and advanced statistical methods, machine learning analysis, Bayesian models and other approaches.

In some of Wolfram's key markets like medical devices and pharmaceuticals, Big Data usage is rapidly increasing but still not widely adopted. "However, when these new technologies are used widely, it is predicated to yield significant gains both in terms of time spent as well as financial gains," Brugard says. "[T]he ability to combine different types of modeling methods will be a key factor to fully benefit from Big Data."

As an example, Brugard points to mathematical models that can be used as sophisticated "virtual patients."

"These sophisticated, high-fidelity models could be used to simulate the function of a medical device in patients, which would drastically cut cost and time spent with clinical trials as well as in early development," Brugard says. "In order to reach this goal companies have to work together and also with regulatory agencies since it requires significant resources to develop and validate these tools."

Putting Algorithms to Work

Companies are at very different levels of sophistication and adoption depending on their industry and their culture. "Whether a company has that data-driven culture really depends on how important data and analytics is within an organization," MacDonald says. "We're already seeing companies taking information and driving predictions of failure to get ahead of problems that exist. We're just starting to see the beginning of using that information in the design phase."

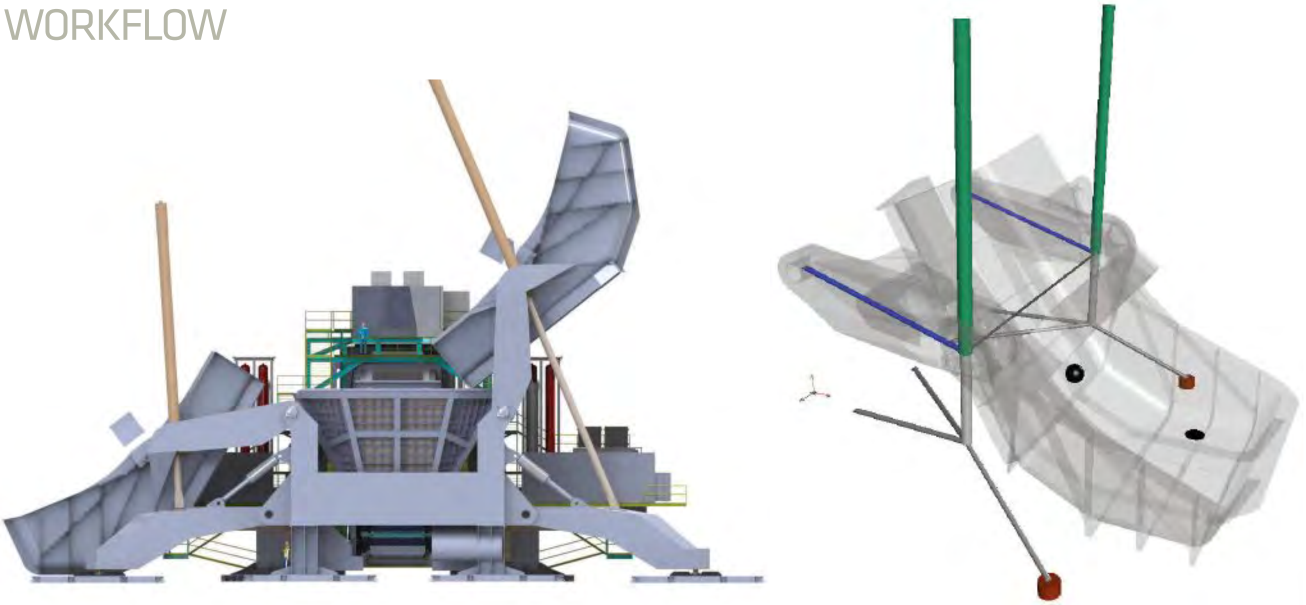
This is where math tools make it easier for companies to engage in more advanced modeling and analysis. "The data doesn't mean a whole lot on its own," Bernardino says. "You can have the ability to build a mathematical model that allows you to drill down and get insights, and map that data down into subsystems to get a deeper understanding of the how the system works and doesn't work. You can see the ways it will fail and what its uses are going to be, and how to go about fixing it."

Math tools also help determine what data is important. MATLAB allows users to bring in large sets of data and create scatterplots to help identify where there may be patterns to explore further, Oswill says. "They can use correlations and other features to identify the right signals and identify what data to use for their models," he continues.

According to Bernardin, one common scenario is that companies will use mathematics tools to create a model or hypothesis of what the data need should look like. Once enough data has been gathered, the tools can be used to improve the model.

"At the next stage, once you have a model that is validated, you can use a continuous data stream to compare the data from the actual system in use to the mathematical model," Bernardin says. "This goes into the concept of digital twins. By comparing the incoming data stream from the actual system to the mathematical model, you can detect anomalies, predict failure modes and react to that information in real time."

Predictive data analysis will be an important application for these capabilities for manufacturers moving forward. Data can be analyzed and used to minimize maintenance costs and improve future designs.



FLSmidth used Maplesoft's products to create a fully functional model of its Dual Truck Mobile Sizer equipment for mining operations. ***Image courtesy of Maplesoft.***

For example, Baker Hughes collects data from expensive pumps that extract oil out of field wells. To monitor the pumps for potentially catastrophic wear and predict failures in advance, the company analyzes pump sensor data with MATLAB and applies MATLAB machine learning algorithms.

"They can put a model together that will indicate when a pump is nearing the point where it can be taken offline, repaired and put back online quickly," Oswill says. "Being able to manage those activities better via a predictive machine health system can help both the company and its customers maintain service."

That type of data could conceivably then be fed back to engineering teams to help improve product design and operations.

FLSmidth used Maplesoft's products to create a fully functional model of its Dual Truck Mobile Sizer equipment for mining operations. The company created a fully parameterized model of the machine in MapleSim. The company's Geometric Design Evaluation system, which uses the Maple symbolic computation tool, then performed a parameter sweep. The computational abilities of the Maplesoft tools were also used to evaluate joint flexibility, center of mass variations and soil modeling to determine the vertical displacement of the equipment under different soil conditions.

Automaker Renault similarly used Maple to help reduce the mass of a rotor for its electric vehicle design. After creating first-order approximations of the rotors, they developed mathematical models based on physical equations to further test and refine the design. For example, they were able to use the models to select the appropriate thickness and material for a slot wedge to hold the rotor wire in place. That modeling exercise uncovered a way to further reduce the mass of the rotor and they validated the complete design via finite element analysis (FEA).

The company was also able to use Maple to model nonlinear features such as wire stiffness that were difficult to determine and would have required a time-consuming trial-and-error approach via FEA.

Ongoing Challenges

Companies may face cultural or operational challenges to fully leveraging mathematics tools, depending on how experienced they are with this type of data analysis. "Is there a culture there that is motivated to try out innovative projects and find ways to rapidly develop?" MacDonald asks. "On the other side is the personnel issue. Do you have the right kind of resources in place? Your people have to trust the data rather than their instincts."

Engineers also need education on how they can use these analytics and mathematics systems most effectively. "They ask us if they can do the same things with their data if it's sitting on Hadoop, for example, so we have to educate our customers so that they can still do everything they used to do," Oswill says.

MacDonald says that companies need to understand that this is a more complex endeavor than bolting machine learning on top of an existing process. "There are a lot of steps in the value chain to make this work," MacDonald says. "They have to determine what problem they are trying to solve and if they have sourced and contextualized the data in the right way. This is a journey rather than just an innovation."

Identifying the business problem is a critical first step. Companies have to determine where the right data resides and how to bring it together in a unified view to tell a descriptive story. "If it cannot be consumed in a way that is seamless, no one can use it," MacDonald adds.

Brugard sees opportunities for precompetitive collaboration in many industries to develop analytical models that can be shared. In life sciences, he says that he expects more modeling and simulation for the development and approval of medical devices (and pharmaceuticals). "The Food and Drug Administration is currently working on guidelines for how to use, validate and report mathematical models, so we are expecting these areas to grow," Brugard says. "Similar things can be seen in other fields, like social sciences, of course."

Software companies are also working together to make it easier to pull these functions into the design process. PTC and ANSYS, for example, are integrating their solutions so that ANSYS simulation technology can be rapidly added to applications built with PTC's ThingWorx IoT platform.

"That connectivity and contextualization and analytics will give you an understanding of failure, even when you can't necessarily get specific data from a sensor," MacDonald says. "We create a model zero with physics-based, raw simulation data. It may not be the most accurate model, but we can automatically tune a supervised machine learning model and use insights from deductive or the simulative model in ANSYS. Then as the data from the physical world comes in, we can understand its performance and then swap out the model for one that is based on that operational data."

Those capabilities are only going to expand as designers gain access to more advanced tools. "As compute power increases and mathematical and system-level modeling evolve, we are able to model engineering systems in more detail and more holistically," Bernardin says. "We are able to look at the entire system and consider complicated interactions between aspects of a machine and really optimize across all the different domains that are contained within a system." **DE**

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

INFO → **ANSYS:** ANSYS.com

→ **Maplesoft:** Maplesoft.com

→ **MathWorks:** MathWorks.com

→ **PTC:** PTC.com

→ **Wolfram MathCore:** MathCore.com

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Supervised Machine Learning

Many of the old rules that guided software development do not apply to the testing of machine-learning algorithms.

BY TOM KEVAN

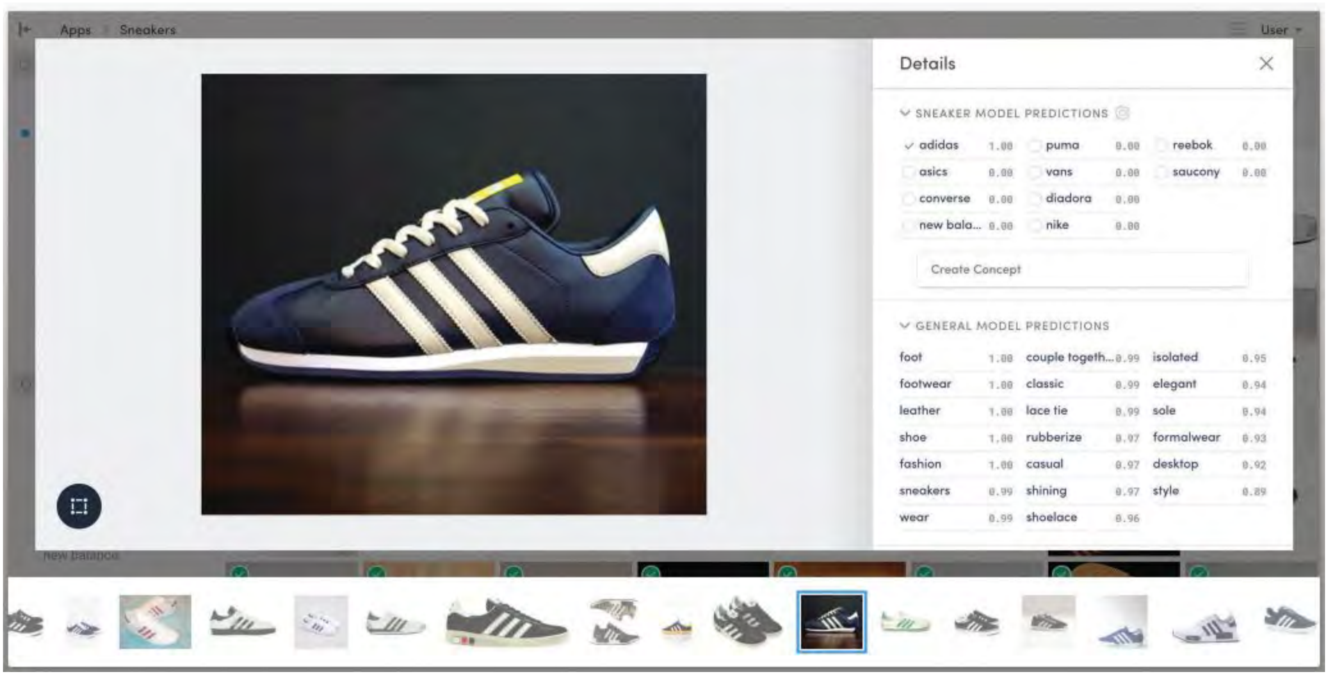
MACHINE LEARNING (ML) hit public consciousness like a thunderclap, dazzling consumers with technologies like speech recognition and computer vision. Although it may seem like it just emerged, ML has been years in the making. Now the technology promises to dramatically change the way people and machines interact. But there's a catch.

Look under the hood, and you will find software technology that doesn't play by many of the old rules that software and design engineers have grown to depend on. As a result, designers implementing ML must approach software development in a new way, using testing practices shaped by the unique nature of its algorithms.

Different Software, Different Testing Practices

Testing traditional software has long been fairly straightforward. Inputs have known outputs. But testing ML algorithms is different.

To ensure that ML software works properly, the engineer must often deal with "moving targets"—systems



Clarifai's machine learning-based image-recognition tool can learn to recognize particular groups of objects, such as Adidas sneakers. *Image courtesy of Clarifai.*

whose responses adapt to what they have learned from previous transactions. As a result, they don't always deliver the same answers. To understand ML testing practices, you need to go back to the basics and understand how the technology works.

Coming to Grips with the Basics

At its core, ML uses computational methods to "learn" directly from data, extracting information unassisted by human intervention. The system's algorithms accomplish this by finding patterns in data that provide insight and facilitate predictions. These algorithms adaptively improve their performance as the number of learning samples grows. Examples of this technology at work can be seen in the systems used by online companies like Amazon and Netflix, where their machine learning systems provide product or movie recommendations based on user preferences expressed in previous interactions.

Machine learning comes in two flavors: supervised learning and unsupervised learning. This article focuses on supervised machine learning because it is the predominant form found on the market today.

With supervised learning, the engineer builds a model—an abstraction of the outcome to be predicted—using labeled data, which are examples of the desired answers. For instance, to develop a model that identifies spam, the engineer would use samples of known instances of spam. In this way, a supervised learning algorithm takes a known set of input data and a set of desired responses, and trains a model to generate reasonable predictions.

Supervised learning uses two types of techniques to develop predictive models. Classification techniques predict discrete responses, for example, whether an email is authentic or spam. This technique is used for applications such as speech recognition. On the other hand, engineers use regression techniques to predict continuous conditions, such as temperature changes or commuter traffic volume.

A key component of supervised learning is the neural network. This consists of layered algorithms whose variables can be adjusted through a learning process. Engineers compare the network's output with known results. When the algorithms achieve the desired accuracy, the developers set the algebraic coefficients and generate production code.

The Development Process

One of the first things the designer has to do to develop a supervised learning algorithm is to determine the type of training examples to be used. For instance, when developing an algorithm seeking to identify spam, the engineer has to decide whether to focus on the sender's address, subject line or attachments.

After developing a profile of the training samples, the designer must gather the training set. To ensure robust performance, the samples must be representative of the real-world use case. This data set includes inputs and the corresponding outputs.

The next step deals with the feature characteristics. Here, the engineer defines the input feature characteristics of the learned function. The accuracy of the learned function depends greatly on how the input is defined. Typically, the designer converts the input into a feature vector containing characteristics that describe the object. Many machine-learning algorithms use a numerical representation of inputs because it facilitates statistical analysis. In deciding on the number of features to include, the engineer must strike a balance, being sure to include enough information to accurately predict the output.

The designer then determines the structure of the learned function and corresponding learning algorithm. For example, the engineer may decide to use a decision tree.

Upon completing the algorithm's design, the designer runs the learning algorithm on the training set. Some algorithms require the user to determine control parameters. The engineer may adjust the parameters, optimizing the performance of the validation set.

In the last step, the engineer evaluates the accuracy of the learned function. The performance of the algorithm should be measured on a test set that is different than the training data set.

Finding the Right Algorithm

Choosing the most appropriate type of algorithm for an application is not a straightforward process. There are several to choose from, including linear regression, decision tree, naive Bayes and random forest. Each takes a different approach to learning. Choosing the right one inevitably involves tradeoffs in speed of training, memory usage, predictive accuracy and interpretability (i.e., how easy it is to understand the reasons an algorithm makes its predictions).

Making a selection can turn out to be a trial-and-error process. Fundamentally, however, choosing an algorithm depends on the size and type of data set used, the insights that the designer wants to glean from the data and how the engineer plans to use those insights.

How Much Is too Much?

A key part of the preparation process involves defining the standard acceptable deviation—the amount of error that is acceptable. There is no single rule to guide engineers on how many errors are acceptable. It's more of a business decision, but there are techniques to help make this call.

"I recommend creating a dependency table to show the tradeoffs between different types of errors," says Triinu Magi, co-founder and chief technology officer of Neura. "This type of approach enables the business side to determine what is most important to them."

Machine Learning Resources

Engineers looking to include machine learning into their designs will find an abundance of resources to help with the process, whether they want to pursue a hands-on approach or outsource some of the work.

If engineers adopt traditional machine learning methods, they have access to a variety of open-source design and test tools, such as R and MATLAB. At the same time, there is no shortage of company-supported tools, such as H2O.

Another option is to seek the help of experts. "There are a number of data science companies who can help you quickly get up and running," says Triinu Magi, co-founder and chief technology officer of Neura. "It makes perfect sense to conduct due diligence and see if there is someone who is already solving the problem that can help boost your product and business faster."

The Stuff of Models

The model is only as good as the data used to build and train it. An inadequate model translates into inadequate algorithm performance. This means that the selection of the labeled data used to train the model must be complete.

"The challenge is collecting sufficiently large and representative labeled datasets," says Jin Kim, chief data scientist at Wave Computing.

The designer must be sure to look at all of the relevant data. Making selection decisions based on too narrow of a field of data is a recipe for trouble. "I think the main thing engineers might miss is that they do not represent the entire population of data," says Magi. "Even when an engineer sees a type of behavior in a small set of data and feels comfortable applying it to the entire set of production data, it still has a huge risk that the data might behave completely different across the entire data set. In this case, instead of expected change, it might cause unexpected system behaviors."

To ensure that the training data set is complete, the engineer must also be aware of what doesn't work. "It's important to understand your failure modes and how severe different kinds of errors are," says Ryan Compton, head of applied machine learning at Clarifai. "For example, if you're building an image classifier to spot intruders with a security camera, false negatives are much worse than false positives. When building data sets to train a high-recall classifier such as this, try to collect data with as much variance and diversity as possible. When the goal is high precision, be more specific and cautious that the data you've collected is exactly what you want."

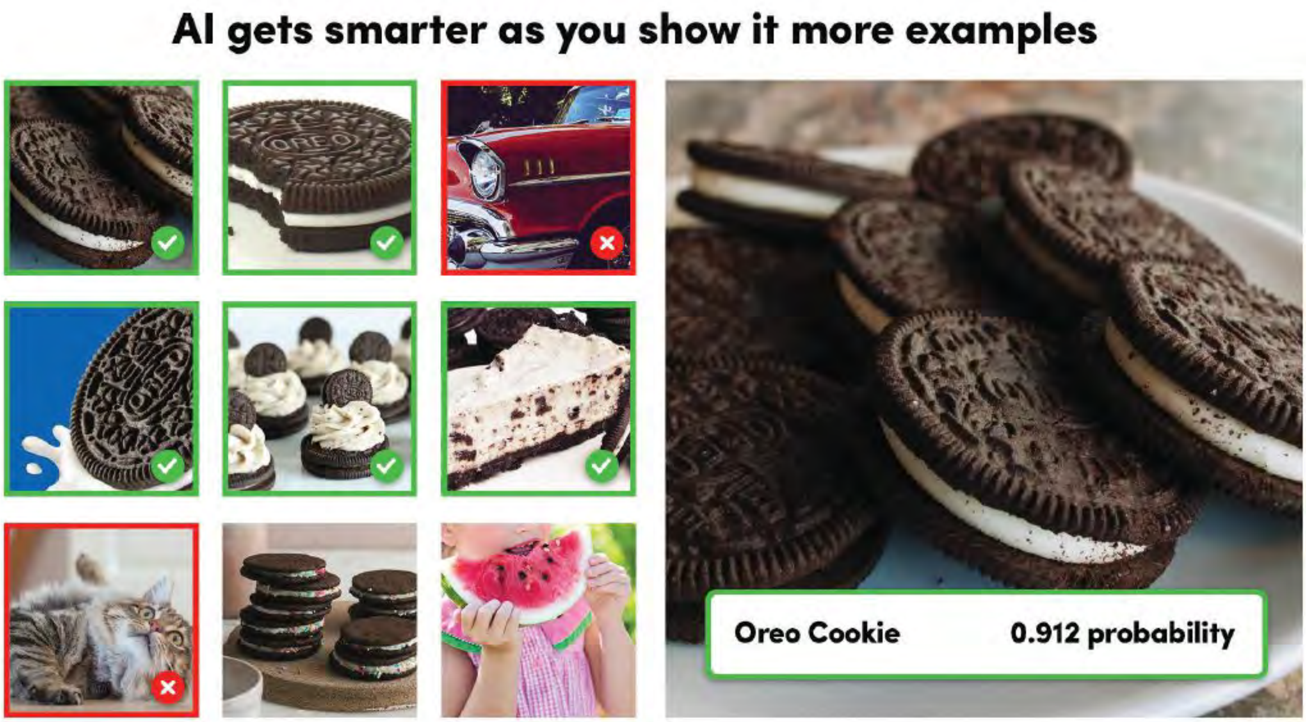
Having the Right Data

Machine learning is basically statistics—predictions that are well trained based on the data that has been collected. But if you look for precision all the time, you are going to be disappointed. It usually does not achieve 100% accuracy.

To test the performance of supervised machine learning algorithms, the designer must understand what he or she wants to achieve by using machine learning and what is expected and accepted behavior. The engineer also needs to understand how machine-learning algorithms can help and what elements to measure to test them. In the testing process, the designer needs feedback that enables him or her to measure the algorithm's behaviors.

"Establish baselines right off the bat," says Compton. "Use data as raw as possible, the simplest classifiers available, and record metrics right away. Once the baselines are established, it becomes clear how to track progress."

Perhaps the most important ingredient is data—the right kind of data. Testing data must adequately represent the general population of the data. At the same time, it should be random. Do not exclude outliers.



Using labeled samples, you can train a visual-recognition model to search for specific images. The training samples must be a diverse collection of objects that tells the model what is and is not an appropriate answer. In this case, the visual search is for an Oreo cookie. ***Image courtesy of Clarifai.***

"The key challenge is to have correct and true labeled data to validate the models," says Magi. "For example, for an algorithm to correctly detect that a person is walking, every point in time must be labeled as to whether the person is walking or not. This is very hard to achieve. So a good practice is to set the boundaries—what kind of walking events you want to measure—then try to collect correct labels per these events and measure if the machine learning model manages to detect them."

To test the algorithm, the engineer must use a data set that is different from the one you used to train it. "Representative labeled data sets need to be separated into training and testing datasets," says Kim. "You cannot use the same data set to both train and test the machine learning model."

This practice prevents the algorithm's intelligence from outsmarting you. "The data we use for training has been used, and the models 'know' it well," says Magi. "The model has learned from that data, so it has a bias to answer the question correctly in such cases. For this reason, it is very important to use new data for testing the model. This approach simulates how the model will behave in a production environment, where every day new unseen data comes in."

Evaluating Test Results

Design engineers have rules of thumb that they can fall back on when it comes time to weigh the test results of the algorithm's performance. But decisions made during the preparation phase of the project also help them sort through the many different ways to measure success and find the best approach.

For example, at the beginning of the development process, the engineering and business teams should look at the use case and decide how to weigh factors like accuracy, latency, power consumption, compute budget and real-time analysis.

From these factors, the development team establishes a baseline against which to measure test results. "As far as strictly numeric results are concerned, without a baseline you'll have no idea if your model is doing well," says Compton. "For building intuition about what the model is actually doing, investing time into a solid framework that lets engineers visualize results quickly pays generous dividends." DE

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INFO ➜ **Clarifai:** Clarifai.com

➜ **H2O:** H2O.ai

➜ **Mathlab:** Mathworks.com/solutions/machine-learning.html

➜ **R:** R-project.org/

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Cordless 3D Scanning on the Horizon

Balancing accuracy, weight and portability in professional 3D scanning.

BY KENNETH WONG

USUALLY, YOU EXPECT handheld devices to be portable and mobile. But there are some limits to this portability when it comes to professional 3D scanners. Many scanners require you to keep the device attached to a powerful computer during the scanning operation. The device relies on the processing power of the computer to align the partially scanned images into a cohesive whole. It also borrows the computer's display to show you the scan progress, scan quality and other cues.

The cord is not a major hindrance if you need to scan something small or something you can easily relocate. But if you need to scan a classic car that cannot be removed from a showroom, a piece of heavy machinery in a tight corner or a statue permanently installed in a park, the tethered scanner and the accompanying computer may demand ingenuity and workarounds.

"The request for cordless scanners comes quite often," says François Leclerc, product manager for scanning and measurement equipment developer Creaform.

"The industry does want a cordless scanner," agrees Joel Martin, product manager for Hexagon's Manufacturing Intelligence (MI) division.

In the consumer and prosumer space, a handful of cordless scanners have recently appeared. But with metrology-grade or professional-grade scanners for inspection, some vendors say what is required to go cordless at present may be too high a compromise in the scanner's capability, weight and cost.

Reverse-Engineering vs. Inspection

3D scanning can be divided into two distinct workflows: reverse-engineering and inspection. With reverse-engineering, users scan an object to digitally capture its shape so that it can be modified, refined and reproduced. This approach may be employed by artists who want to create something that mimics a natural object or a living organism; engineers who need to manufacture a legacy component that has no digital record and architects who need to virtually examine an existing site or structure for improvement options. Makers, hackers and tinkerers with DIY (do it yourself) projects also employ this approach. Thus, the pool of users in this segment is rapidly growing and the wide price range and options reflect that.

With inspection, users typically use professional, metrology-grade scanners to capture an object's shape to verify its fidelity to the original concept—or its deviation from it. Aerospace and automotive engineers, for example, use this approach to ensure the parts and components manufactured match the original design specifications as recorded in 2D and 3D CAD files. The accuracy required for inspection is generally much higher than what's needed for reverse-engineering or simple digitization. Scanners of this caliber usually have a higher price tag than those in consumer and prosumer markets.

Accurate Enough?

Scanners generally work by emitting light beam patterns toward the target object and collecting the beams bouncing back. Based on the pattern deformation resulting from the target's curvature, the scanner (to be precise, the software that comes with the scanner) can reconstruct the object's 3D geometry in point clouds.

"A consumer-grade scanner is fine if you're a tinkerer and just want to capture something's shape. But if you're in aerospace and you want to make sure the component you install fits inside a tight assembly, you need something much more," says

Leclerc. "Normally, the scanner captures the target's shape in point clouds, then converts it to STL (STereoLithography format). Our scanners build the surface model in real time."

"Consumer-grade scanners are good for someone who wants to scan their face or body and 3D-print an avatar. They also work well for those who want to capture some real-world structures and reuse them as game environments, for example," says Martin. "But metrology-grade is what you use to measure carbon composite parts in passenger jets. This is where you don't just want the general shape of the part, but you want the part digitized with all its fine details, like holes, slots, edge lines and cut lines. This is where you want things to be highly accurate, not reasonably accurate."

Without an attachment to a computer, the cordless Leo allows you to carry the device into tight corners with limited room. *Image courtesy of Artec 3D*.

Creaform offers a number of handheld scanners: Go!SCAN 3D (0.9 kg, 2.05 lbs.), HandySCAN 3D (0.85 kg, 1.9 lbs.) and MetraSCAN 3D (1.38 kg, 3 lbs.). Pricing starts at $25,000. The Go!SCAN 3D offers accuracy up to 0.1 mm (0.004 in.)—essentially a measurement thinner than human hair. HandySCAN 3D's accuracy is up to 0.04 mm (0.0016 in.). The MetraSCAN 3D's accuracy is up to 0.030 mm (0.0012 in.).

They come with the company's VXmodel software, which includes mesh editing, scan data alignment, surface generation and CAD transfer tools. Of the three, the Go!SCAN 3D is considered an entry-level device for professional work, according to Leclerc.

Hexagon's MI division offers a number of portable scanners, including the Leica T-Scan 5 and the Leica Absolute Scanner. The hardware works with Hexagon's PCD-MIS (for measurement), SpatialAnalyzer (for scan data alignment and deviation analysis) and 3DReshaper (for point-cloud processing) software products.

Going Cordless

What makes Artec 3D's handheld scanner Leo much better than its predecessors is not what's added to it but instead what's missing: the cord. The company's previous handheld scanners, Eva and Spider, work with cords attached to PCs. Leo is the first to ditch the cord.

Artec 3D straddles several different markets. It caters to the industrial design and manufacturing, healthcare and art sectors. It also operates the avatar-printing service Shapify Me. The company launched Leo at a press event hosted by GPU (graphics processing unit) maker NVIDIA in March. "Artec Leo embodies the next wave of the 3D scanning industry," says Artyom Yukhin, president and CEO of Artec 3D. "Our goal is to make professional 3D scanning as easy as shooting video for any industry, and Artec Leo is the next big step in achieving that goal."

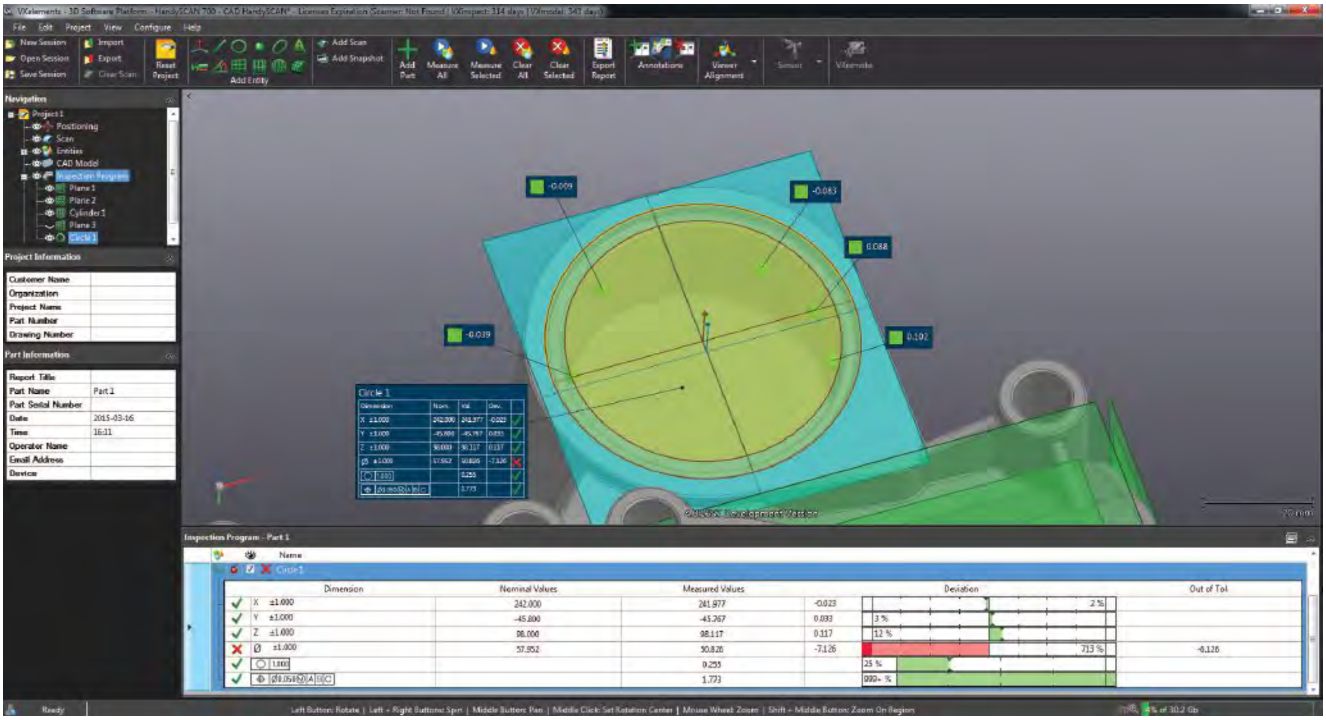
Leo has a built-in touch-panel screen. NVIDIA Jetson serves as the scanner's own internal computer. It features a quad-core ARM Cortex CPU and NVIDIA Maxwell GPU with 256 NVIDIA CUDA Cores. It comes with a touch-panel display that can also be mirrored to another PC screen wirelessly. The scanned data is saved on a 256GB solid-state drive. You can, therefore, complete the scan session on the device before offloading the data to a PC or server back at the office. You have the option to extend the storage with a microSD card.

"The fact that Leo can scan wirelessly and visualize the process onboard is the real advantage," says Andrei Vakulenko, chief business development officer at Artec 3D. "With the onboard screen, you can immediately see which section of the object you are scanning, while at the same time ensure that the device is held at the right distance from the object. Prior to this, using a handheld 3D scanner was a little like pointing a video camera at the object and, instead of looking through the viewfinder, holding another piece of equipment to look at the target—all this while walking around the object. Using a separate screen that is not embedded in a scanner requires a lot of coordination, which is far from intuitive. With Leo, the scanning process has become much simpler and therefore faster as well. The built-in screen also means you don't have to 3D scan one-handed, so you can use two hands to decrease fatigue from weight."

Leo works with Artec Studio 12 Software for scan-processing software. The program includes an Autopilot mode, which guides beginning users through the scan process. Version 12 allows direct export to Geomagic Design X and SOLIDWORKS 3D CAD programs. Leo weighs 1.8 kg (4 lbs.). Its 3D point accuracy is up to 0.1 mm. Pricing begins at $25,000.

The Added Weight of Mobility

Making a scanner cordless means adding a built-in power source, enough processing CPU and GPU power to align the



With 3D scanners, the software plays an important role to help you assemble the data from different scans into a single model. Shown here is VX Elements software from Creaform. ***Image courtesy of Creaform.***

acquired data locally, and a small screen to monitor the scan progress. All of these add weight to the device, which has ergonomic implications in routine, long-term use.

"If the operator has to hold the scanner for more than five or 10 minutes, if it's their job to scan for four or six hours a day, then the device's weight becomes a hindrance," says Martin. "We've looked at developing a cordless scanner. We do a tremendous amount of work in R&D to reduce the excess weight from our products. But as soon as we add the battery, it gets heavy. It's the photons-out, photons-back operation that really limits the metrology-grade scanners' portability."

At 4 lbs., the cordless Leo from Artec 3D weighs nearly twice as much as Creaform's Go!SCAN 3D (2.5 lbs.) or Hexagon MI's Leica Absolute Scanner (2 lbs.). For long-time usage (say, scanning a vehicle or a plane), the added weight could result in user fatigue sooner. Leo's accuracy is up to 0.1 mm, the same as Creaform's Go!SCAN 3D.

"In metrology-grade scanners the cameras are working at about 60 FPS (frames per second). There's a lot of data to transfer. And the cord is more reliable than a Wi-Fi signal," says Leclerc. "That's why we power it with a cord right now, and that's the reason the scanner doesn't need a battery pack to operate." In some Creaform scanners, the Wi-Fi-enabled remote screen option lets you project the screen to a mobile tablet, thus giving you some mobility despite the tethered setup.

Blurring the Line

Scanner technologies—such as battery, display and mobile processors—"are moving in the right direction at an aggressive pace," notes Martin. Therefore, lightweight, cordless metrology-grade scanners that are currently infeasible may soon begin to appear.

If the precedence set in 3D printing is an indicator of what could happen to 3D scanning, we might soon see the margins blurring between the consumer and professional segments. "When the two markets converge, you'll start to see really interesting products," says Martin. **DE**

Note: *Some portions of this article appeared previously as part of the blog post titled "Artec 3D's Handheld Scanner Leo: Finally, You Are Free to Roam," digitaleng.news/virtual_desktop (June 2017).*

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INFO ➜ Artec 3D: Artec3d.com

➜ **Creaform:** Creaform3d.com/en

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

➜ **Shapify Me:** Shapify.me

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Very Fast Entry-Level GPUs

We tested AMD's latest Radeon Pro workstation-class graphics boards.

BY DAVID COHN

ON JUNE 1, AMD filled out the rest of its new Radeon Pro WX workstation graphics card lineup with the introduction of the Radeon Pro WX 2100 and WX 3100. Billed as the "fastest entry-level workstation graphics cards," AMD claims performance improvements of up to 2X over its previous generation AMD FirePro products. The Sunnyvale, CA-based company also stated that its new boards outperformed its competition—the NVIDIA Quadro P400 and P600—by as much as 20% and 28%, respectively, in its own internal evaluations.

Because we had already tested the new AMD Radeon Pro WX 5100 when it was introduced earlier this year (see AMD Radeon Pro Review: A New Name and a New Look: digitaleng.news/de/new-name-new-look), we were anxious to get our hands on the new WX 2100 and WX 3100 as well so that we could put them to the test.

Nearly Identical, Except for Memory

The Radeon Pro WX 2100 and WX 3100 are based on the same fourth-generation Graphic Core Next (GCN) 14nm architecture. Both also support AMD's power monitoring and management technologies. AMD PowerTune dynamically optimizes GPU power usage and AMD ZeroCore Power technology significantly reduces power consumption when idle.

The two new boards are quite similar inside and out. Externally, they are nearly identical. Both are single-slot, low-profile boards, measuring just 2.75x6.68 in.—designed to fit into the latest small form factor workstations—with a 4.38-in. bracket to facilitate mounting in a standard workstation. Both boards offer two mini-DisplayPorts and a single DisplayPort 1.4 connection, and come with a minDP-to-DVI SL adapter. The WX 2100 and WX 3100 can each drive up to three 4K displays at 60Hz or one 5K

Specifications: Old vs. New

	AMD Radeon Pro WX 3100	AMD Radeon Pro WX 2100	AMD FirePro W2100
	NEW!	NEW!	
Manufacturer's Price (at Launch)	$199	$149	$149
Average Street Price (Today)	$187	$147	$120
SPECIFICATIONS			
Extra Power Required	No	No	No
Form Factor	2.75" x 6.68"	2.75" x 6.68"	4.38" x 6.8"
Slots Used	1	1	1
Max Power (Watts)	50W	35W	26W
PCIe Version	3.0	3.0	3.0
Processors	512	512	320
Memory Configuration	2GB GDDR5	4GB GDDR5	2GB GDDR3
Memory Interface	128-bit	64-bit	128-bit
Memory Bandwidth	96 GB/sec	48 GB/sec	28.8 GB/sec
Number of DVI Dual Link OUtputs	0	0	0
Number of Display Port Outputs	2 mini-DP, 1DP	2 mini-DP, 1 DP	2 DP
Stereo 3D Connector (3-pin)	No	No	No
Framelock/Genlock	No	No	No
Multi-GPU (CrossFire-AMD)	No	No	No
OpenGL Version	4.5	4.5	4.4
DirectS/Shader Model	12/5.0	12/5.0	11.2/12
Maximum Resolution Support (@ 60 Hz)	4096x160	4096x2160	4096x2160

Specifications for the new AMD Radeon Pro-series graphics boards compared with the previous generation AMD FirePro W-series.

display at 30Hz. In fact, the only way to visually tell them apart is by the model number emblazoned on the side of the metallic blue fan housing.

Internally, both boards use the same Polaris GPU, with eight compute units, for a total of 512 stream processors. The GPUs in both boards run at a peak clock rate of 1219MHz to deliver performance of up to 1.25 TFLOPS (single-precision). And both boards provide native support for 10-bits per color channel, for an effective 30-bits per pixel. In fact, the only significant internal difference is the memory configuration.

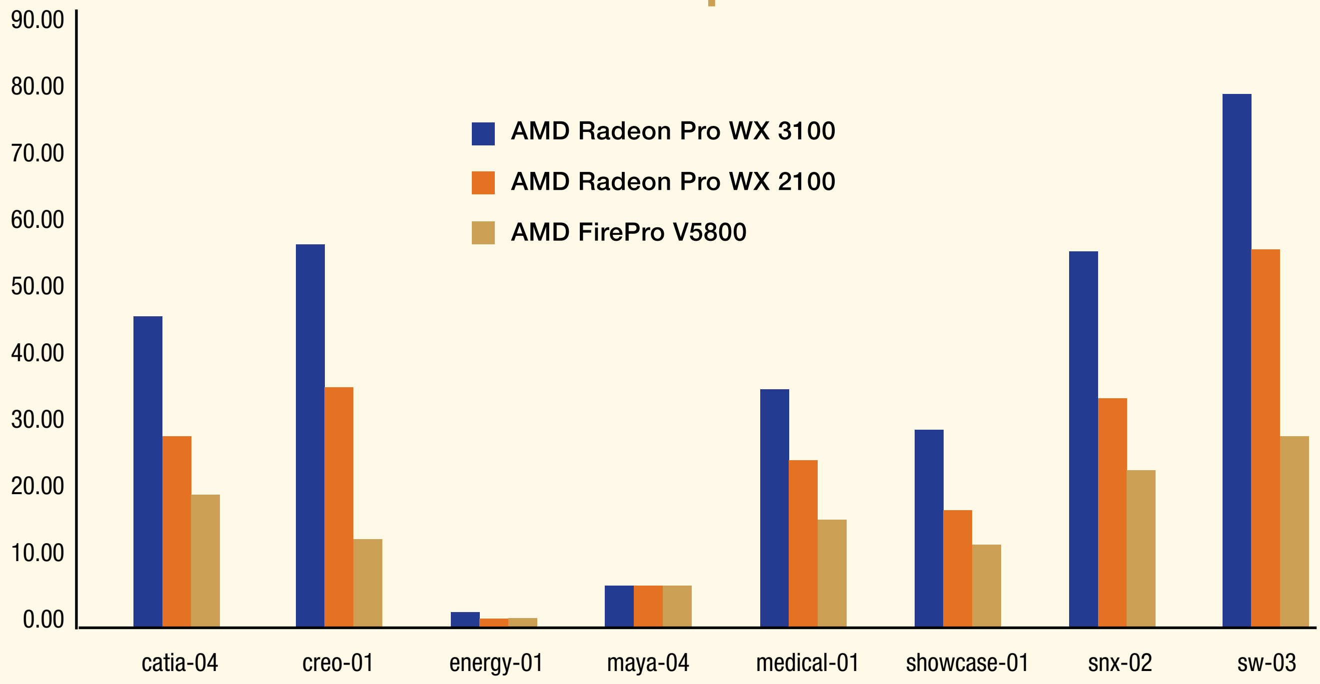
With an MSRP of $149, the AMD Radeon Pro WX 2100 comes with 2GB of GDDR5 memory on a 64-bit interface. This enables the WX 2100 to deliver a maximum memory bandwidth of 48GB/second. Although its predecessor—the FirePro W2100 (hosting five compute units for a total of 320 stream processors)—used a 128-bit memory interface, it achieved a maximum memory bandwidth of 28.8 GB/second, while consuming just 26 watts. At 35 watts, the Radeon Pro WX 2100 is still frugal but does use a bit more power.

At $199, the AMD Radeon Pro WX 3100 comes with 4GB of GDDR5 memory on a 128-bit interface. Although it runs its memory at the same 1500MHz clock rate and 6Gb/second memory data rate as the WX 2100, the WX 3100 achieves a maximum memory bandwidth of 96GB/second. Power consumption for the WX 3100 is also quite low—just 50 watts.

Testing the New Boards

Because AMD sent us both boards, we were able to perform our own tests. We ran version 12 of the SPECviewperf benchmark (spec.org) using the same workstation as in our previous reviews of the new AMD and NVIDIA GPUs—a BOXX workstation (boxx.com) equipped with an Intel Core i7-6700K quad-core CPU, 16GB of memory and a

Full SPECviewperf Results



SPECviewperf performance of the new WX 2100 and WX 3100 compared with an older-generation AMD FirePro board.

1TB PCIe SSD, running the latest version of Windows 10 Pro 64-bit (see NVIDIA Quadro Review: Super Computer Graphics: digitaleng.news/de/super-computer-graphics).

We typically compare new graphics cards to the previous generation by testing the new boards and older boards in the same workstation—using the latest certified video driver—so that the only variable is the GPU itself. But, since we never had the opportunity to test the previous generation of AMD graphics boards, we could not make that comparison. We also did not have samples of the NVIDIA Quadro P400 or P600, so we were unable to verify AMD's claims.

But we did include results for an even older, midrange AMD FirePro V5800. The performance improvement over that board was quite dramatic. Although the difference compared with more recent boards would not be as great, the similarities of our results to those published by AMD lead us to believe AMD's claimed performance improvement.

Like previous AMD boards, all the new Radeon Pro WX series graphics cards are fully certified with most CAD and DCC applications. The boards use the new Radeon Pro Software Enterprise Driver, which is different from the unified video drivers used by older FirePro cards. AMD promises regular updates to that driver on the fourth Thursday of each quarter. The new driver (64-bit only) is available for Windows 7, Windows 10 and Linux.

The new Radeon Pro boards come with 24/7 VIP customer support, a three-year limited warranty and an optional free seven-year extended limited warranty upon product and customer registration. AMD has mounted a serious challenge to NVIDIA. Game on. **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 ➜ AMD: AMD.com

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EDITOR'S PICKS

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

Benchtop Laser-Sintering 3D Printer Unveiled

Automated solution for digital manufacturing also announced.

The Fuse 1 is the first selective laser sintering 3D printer from Formlabs. The benchtop unit has a 6.5×6.5×12.6-in. build volume. There's a removable build chamber to enable continuous printing. It has networking and a live video feed so that you can monitor and inspect builds. The Fuse 1 makes functional prototypes and end-use parts with durable nylon materials. Its parts don't need supports, so you can 3D print intricate and complex parts.

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Speed Test System Design and Deployment

Standardized components said to help simplify automated test systems.

NI's ATE (automated test equipment) Core Configurations feature off-the-shelf rack assemblies with the mechanical, power and safety infrastructure as a launch platform for creating a test system. The 19-in. (24U and 40U) rack assemblies have three sets of mounting rails, removable side walls and an accessible rear door.

Safety features include a thermal shutdown switch and an emergency power-off panel. There are optional uninterruptible power supplies, too.

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CAE Tool Enables Rotating Machine Design

Standalone platform said to provide fast and accurate computations.

Altair recently announced FluxMotor, a standalone tool for the pre-design of electric rotating machines. This tool is designed so that you get yourself on the right pathway from the start and before you design-in inefficiencies you discover later in the process.

FluxMotor starts with a dedicated design interface that you use to build a rotating machine from standard parts like magnets. You can customize parts. It has four modes for adding windings.

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New Generations of LabVIEW Unveiled

LabVIEW Next Generation engineering system design software debuts.

The official name for NI's emergent tool chest is LabVIEW NXG 1.0. It's all about faster time to measurements and faster data set analyses and visualizations.

A key attribute to that end is that LabVIEW NXG has a no programming workflow to set up, acquire and visualize datasets. (Of note to experienced LabVIEW users, you can get down into the code if you need to.) LabVIEW NXG has integrated data capture and analysis tools. You can capture snapshots of data streams and much more.

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Next-Gen Engineers

Student Design Competition Profile: The International Submarine Races

Diving into STEM Careers

BY JIM ROMEO

KURT YANKASKAS is the executive director for the International Submarine Races, Foundation for Underwater Research and Education (FURE). His competition brings young minds together for technological growth by competition in submarine races.

***Digital Engineering*:** Can you provide an overview of the Submarine Races event, how it came to be and the intent of the program?

Kurt Yankaskas: The Foundation for Underwater Research and Education (FURE) is the parent organization for the International Submarine Races (ISR), providing administrative and financial support for ISR. FURE is also the education outreach arm for ISR. FURE is dedicated to increasing awareness and encouraging educational programs in marine technology and engineering. It is designed to inspire students, government and agency leaders, educators, academicians and other not-for-profits to pursue and support marine technology and engineering careers.

Teams have competed from the United States, Canada, Mexico, Germany, the United Kingdom, Venezuela, Oman and the Netherlands. The event began in 1989 and has involved over 2,800 students and hundreds of volunteers, primarily colleges and high schools representing six countries at ISR 14. Frequently, there are independent teams in for the challenge and adventure of building an underwater vehicle.

DE: Who sponsors the program? What drove them to sponsor the event and coordinate it?

Yankaskas: ISR is managed by the ISR Organization, a group of volunteers who have dedicated their personal talents and abilities to maintaining the continuity of this unique technology competition. The ISR Organization was established in 1995 to provide a new, restructured management group. The ISR Organization is led by individuals whose main concern and interest is to encourage engineering and technology students, as well as entrepreneurs of all types, in the development and evaluation of engineering designs of human-powered submarines and to expand the educational experience engendered by the underwater event.

The ISR Organization operates on a virtual basis, with support from corporate sponsors, government and academic officials and a host of private individuals. Their involvement and spirit carry on the vision of H.A. "Hap" Perry, who conceived and founded the race in 1989 and sustained it through 1993.

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

Yankaskas: These are underwater submarines with one or two persons on SCUBA (self-contained underwater breathing apparatus). Subs are filled with water (for safety). The human-powered propulsion system is either propeller or non-propeller with a drivetrain that resembles parts of a bicycle. The pilot drives with two control sticks for rudder and dive planes and is the "motor" for one-person subs. Some designs have used oscillating fins or pump jets in their designs. Others resemble fish or rays.

The biennial event produces graduating engineers and scientists ready for tasking in industry. There are numerous times when teams/individuals have gone on to Navy and/or marine industry employment. We are working on that history. There have been over 230 submarine designs in 13 races. All of them reflect the team's desire to innovate.

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

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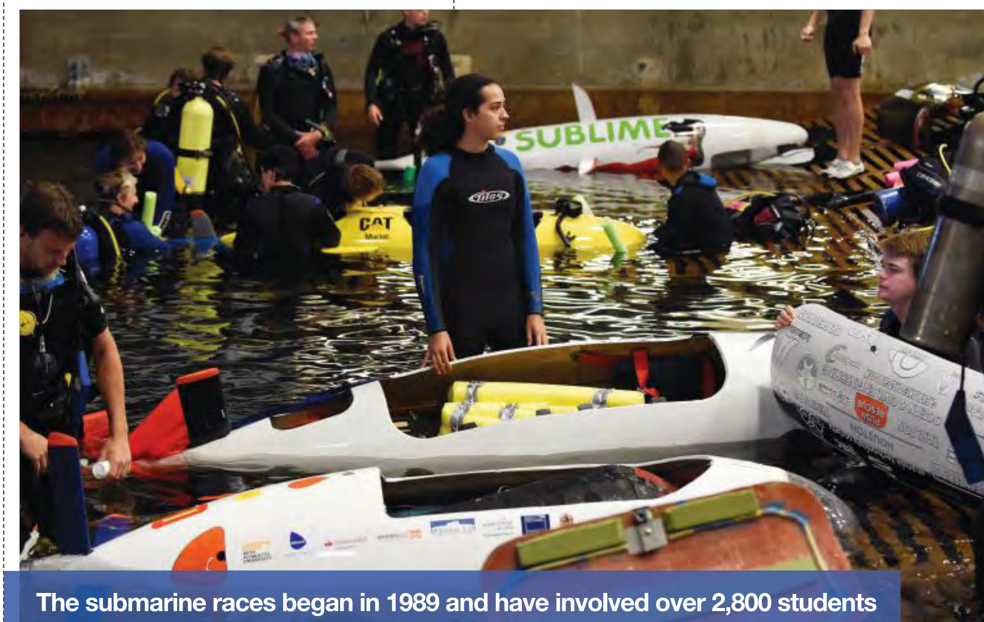
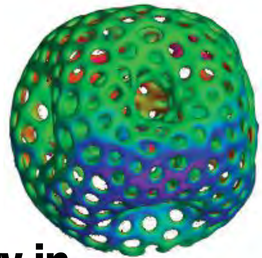


The submarine races began in 1989 and have involved over 2,800 students and hundreds of volunteers, primarily colleges and high schools.



Reverse Engineering: Reducing Production Costs

The production of functioning prototypes, that at the same time have to achieve the demands of a sports car, requires precision and durability.

From the very beginning, a project for the first Polish supercar, Arrinera Hussarya, has been arousing strong emotions and hopes that the Polish automotive industry will come back to its past glory. The production of functioning prototypes, that at the same time have to achieve the demands of a sports car, requires precision and durability.

Unlike most contemporary Polish automotive projects, Arrinera Hussarya is built from the ground up. All parts of the car body, engine and interior, despite the fact that they often use proven technologies, are redesigned to not only meet all the requirements but to also represent the aesthetics worthy of a supercar.

Reverse Engineering Reduces Production Costs

Redesigning a supercar is not only a very time-consuming, but also an extremely costly process. The Arrinera engineers searched for ways to accelerate the development and reduce the costs. They finally decided to use reverse engineering, which is the process of reconstructing the technical documentation of an existing element in order to re-design it.

By using a professional SMARTTECH 3D scanner, the engineers working on the supercar gained the ability to quickly obtain comprehensive information about the geometry of the car parts. An excellent example of the capabilities of the 3D scanning technology is the process of designing and manufacturing the clutch housing.

It is no secret that a sports clutch is subjected to completely different pressures than a normal clutch working in a standard car. An 810 Nm torque requires the use of not only a reliable but also lightweight clutch design. The 3D scanner made it possible to obtain the technical documentation of a housing already present on the market and redesign it in CAD software to install the mounts fitted to the vehicle's structure.

Green Light is the Future

A 3D scanner, MICRON3D green, with a 10-megapixel detector was used for accurate measurement. The technology, based on the green LED light, allows the measurements to achieve 30% better results than when using 3D scanners with white light, according to the company. With a field of view of 800x600mm, the 3D scanner obtains a point cloud representing the scanned shape with 0.084 mm accuracy.

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Ensuring Part Quality in Industrial Metal Additive Manufacturing

Sintavia uses Concept Laser's meltpool-monitoring system to demonstrate value of in-situ monitoring of metal AM builds.

Now that metal additive manufacturing (AM) is creating fully functional industrial parts, many OEMs are taking a closer look at how the technology might support their individual production goals. Interest has also been piqued by the commitment to AM of some very major players.

"I think the news about the GE Leap engine fuel nozzle really resonated throughout industry," says Doug Hedges, president and COO of Sintavia LLC, a metal AM service provider for aerospace, defense and other industries. "That got everyone's attention and certainly increased the pace of inquiries for us." The nozzle, produced internally at GE, was the first 3D-printed part certified by the U.S. Federal Aviation Administration (FAA) to fly inside a commercial jet engine.

Brian Neff, Sintavia CEO, had already founded Sintavia (a combination of "sintering" and "aviation") in Davie, FL in 2012, the year before the GE milestone announcement. Informed by his and Hedges mutual aerospace backgrounds, they'd had an eye on AM for quite some time.

"Additive manufacturing is a very challenging field," says Hedges. "We felt we needed to enter it in the early stages—rather than wait until the industry was more mature—in order to refine our skills." Their AM resources now include five machines from three of the leading metal manufacturers as well as an electron beam melting (EBM) system—and they are finalizing plans for a new facility, over five times the size of the current 10,000-sq.-ft. building, to open in mid-2018.

Metal AM for Aerospace

While metal AM is at the center of Sintavia's offerings, their core competencies also include full material characterization (including ISO 17025 accredited powder analysis and mechanical testing laboratories), as well as finishing processes such as Heat Treatment, HIPing (Hot Isostatic Pressing), and CNC machining—plus CT scanning to inspect the integrity of the final product. "AM gets much of the attention, but post-processing and analysis are pivotal to delivering critical parts," says Hedges. "Our customers are looking for a facility that can control the entire AM-build process."

After five-plus years in operation, Sintavia's client roster is currently about 75%-80% aerospace (including all of the top-20 OEMs) plus oil & natural gas, automotive and turbomachinery for power generation. Clients are interested in AM research and development (R&D) as well as production of finished parts.

Their aerospace customers focus on everything from aircraft to satellites to weapons, according to Hedges. "There's flight hardware that would go on a Boeing 787 and then there's flight hardware that might go on a satellite or an unmanned vehicle," he says. "To qualify parts for flight hardware of any kind is a very intensive thing but for human travel the substantiation is a lot higher. So the better monitoring of manufacturing you have, the better inspection you have, the more assurance you're going to have to say this product is capable of a flight usage."

Many of the same materials used in aerospace are also employed by Sintavia customers from other industries, Hedges points out. "An oil and gas equipment supplier may want us to build a wellhead cap, a sensor or a tool that needs to be extremely corrosion-resistant—so they use the same superalloys, often Inconel 625 or 718, as those in jet engines," he says. "With steam turbines, which are basically just jet engines on the ground, the hardware undergoes much of the same stresses as a jet. So the materials used to additively manufacture all these parts are often remarkably similar."

AM can make such superalloys easier to work with, Hedges notes. "Inconel is notoriously difficult to machine but AM allows you to create complex interior channels directly within a build, cutting down considerably on machining time."

Mastering the Complexity of AM

As their business accelerates, Sintavia's AM expertise continues to deepen, along with an understanding of the complexity of the technology. The "wishbone" roadmap, known in the industry as the Ishikawa diagram of process parameters for AM, continues to guide their inquiries into the many variances that could potentially affect part quality.

"AM has many more input parameters than traditional manufacturing and many of these factors are also more difficult to control," says Sintavia lead engineer Pavlo Earle. Prior to joining the company, he spent eight years at Rolls-Royce specializing in welding, brazing and additive manufacturing. "There are many fundamental similarities between AM and welding," he notes. "There was an intense focus on quality at Rolls-Royce; here at Sintavia we're equally devoted to learning, understanding and controlling every aspect of the pre- and post-process parameters that have an effect on the quality and cost of a product."

There is growing demand for this kind of attention to detail across industries either engaged in, or wanting to become involved with, additive manufacturing, says Hedges. "At this point in time the most pressing needs for additive manufacturing are industry standards that incorporate ASTM, AMS, implementation into the MMPDS, material and process specifications, data collection and access, post-processing, fatigue assessments and standards that include actual CT scanning instead of film.

"We differentiate ourselves by helping customers develop parameters and processes that work towards establishing such industry and company standards."

Monitoring the Meltpool

This philosophy of supporting quality production with intense R&D was behind Sintavia's latest Direct Metal Laser Melting (DMLM) machine acquisition—a Concept Laser M2 cusing system—in the autumn of 2016. German AM provider Concept Laser is known, not only for its equipment, but also for its "QM Meltpool 3D" technology, which won the International Additive Manufacturing Award (IAMA) earlier that same year.

The QM Meltpool 3D system monitors specific process parameters of a LaserCUSING build as it's actually in progress.

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Artec 3D Scanning Helps Create Hybrid Reality at NASA

With the Artec Eva 3D scanner, engineers at NASA's Hybrid Reality Lab are able to scan tools and other assets that are used in space and create 3D printed trackable versions that can be used to enhance training.

NASA is currently on a mission to send humanity deeper into the Solar System than ever before. This includes the completion of programs like the Orion capsule and the Space Launch System. Completing these programs requires the creation of new training and new procedures that astronauts will have to learn.

It is important to find ways to reduce the impact on cost and schedule while still maintaining the efficacy of traditional astronaut training methods, especially when it comes to the exploration of Mars, where missions are expected to last months or years at a time. NASA engineers can take advantage of immersive environment technologies to see how to make the training experience feel as realistic as possible while running various simulations.

In 2015 NASA founded the Hybrid Reality Lab to combine consumer virtual reality technology and tracked 3D objects (locating an object in 3D space using object tracking technology) in order to make realistic visuals and tactile feedback, giving a much stronger and better sense of immersion. The lab uses off the shelf VR headsets, and Unreal Engine 4 (a commercial game engine supporting advanced rendering, physics, and networking capabilities), and NASA-specific content to create training environments.

A major goal is to simulate reduced gravity and the sense of tactile feedback. Right now a sister branch at NASA's Johnson Space Center operates the Active Response Gravity offload system (ARGOS).

"It is essentially a smart tether, which attaches to your back, offloads your body weight and accounts for your momentum in the vertical and horizontal directions to make you feel like you are in Lunar gravity, Martian gravity, microgravity or anywhere in between," says Matthew Noyes, Software Lead at NASA's Hybrid Reality and Advanced Operational Concepts Lab.

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BOXX 9
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COMSOL 33
csimsoft 3
DE Upcoming Editorial Webcast 27
ESTECO 11
Livermore Software Technology Corp. C3
Okino Computer Graphics Inc. 35
Proto Labs Inc. 1
Siemens PLM Software 21
Tormach 31

| COMMENTARY |

By Mark Taber

IoT Equals PLM

FROM GETTING BETTER FEEDBACK from your customers to improve the product, to proactively identifying issues before they become problems for the customer—the possibilities of the Internet of Things (IoT) are well documented.

Yet what no one seems to mention about the IoT era is how to get there. How exactly can your organization move from where it is today to being the smartest, most connected manufacturer on the block? It is clear that the physical and digital worlds are colliding, but what can you/should you be doing about it *today*?

Making changes to how your organization operates can be stressful. What if the returns are not as great as promised? What if the whole thing is bungled and you end up with products that are even less smart and more disconnected than before? The flip side to those questions is: What happens if you refuse to change? You risk being left behind. Your competitors are considering IoT-enabled products and systems, too. The first to successfully implement them will gain a strong foothold in the market.

Step by Step

You don't need to completely upend your entire organization overnight to become smart and connected. There is a clear first step: *Understand* the data that is already available to you. Build out a digital product definition that contains all of the most relevant, up-to-date product information. Next—and this is where it gets really interesting—combine the "definition" of the product with the experience of the product. You then get a model-based digital twin that gives you a deep digital understanding of your physical product. But let's walk before we run.

Though implementing a digital production definition seems fairly straightforward, the vast majority of manufacturers struggle to consolidate all of their product information. Whether through mergers and acquisitions, reorganizations or siloed departments, these organizations have their data located in multiple, incompatible systems that can be difficult to upgrade.

In place of a centralized product definition, workarounds have sprung up. For example, designers might note information for downstream stakeholders on a product's CAD drawings. Although this may be one of the most popular ways to communicate product information, it also is one of the least effective. Every time an update is made to the product, a new drawing needs to be made and distributed to ensure teams are using the most current information. Because this process isn't instantaneous, downstream teams continue to use out-of-date information until they get their hands on the new information—potentially resulting in errors, decreased time-to-market and higher costs to fix mistakes.

So how do you consolidate information into a digital product definition for this new world of IoT? It comes back to bill of material (BOM) management and product lifecycle management (PLM). You need to get your digital house in order.

In a BOM, parts and product information must be streamlined into a single, easy-to-read list format. A few key components should also be included in your PLM solution; they are as follows.

- **Change Management.** Stakeholders must be able to make changes to the BOM that are immediately coordinated throughout the product lifecycle. This ensures that all stakeholders are accessing up-to-date information.
- **Parts Classification**. Multiple departments may find themselves creating the same part that they both need. Your PLM solution should be able to classify parts in related categories—such as function or physical characteristics—so that they can quickly identify parts and reduce part duplication.
- **Component and Supplier Management.** Related to part duplication is the issue of aligning the supply chain with the product development process. By providing visibility into supply chain preferences and characteristics, you can drive down inventory by optimizing parts and supplier spending.
- **Value Chain Data Sharing and Collaboration.** Rather than give your supply chain access to your systems, you should be able to consolidate a secure package of product data to share with external stakeholders.

Having a comprehensive PLM system will provide a strong foundation for all of the other goals you aim to achieve on your transformational journey: whether that means including custom data streams directly from your product to improve designs, using a digital twin to analyze assets in the field to improve the average time to repair or changing your entire business model to offer products as a service. Let's get started! DE

Mark Taber *is vice president of marketing and go-to-market marketing, IoT Solutions Group, at PTC (PTC.com). Contact him about this commentary via editors@digitaleng.news.*

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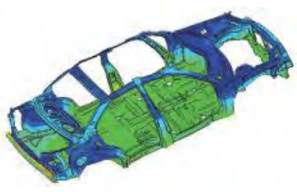
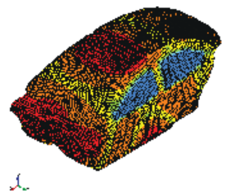
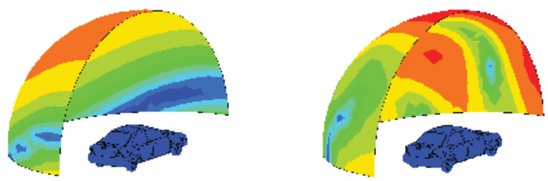
- Multiple fatigue analysis methods



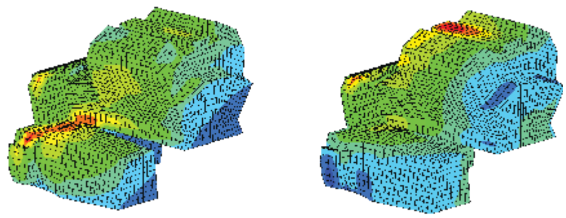
Displacement RMS of Body In White



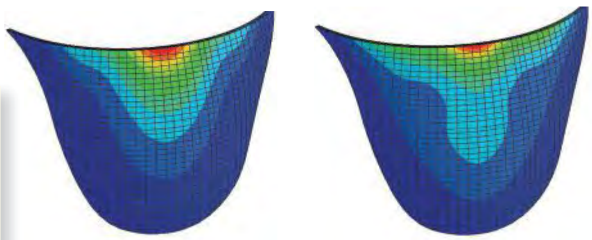
Cabin noise computation by FEM acoustic solver



Radiated noise from vehicle at 10 Hz and 140 Hz, by BEM acoustic solver



ATV plot (real and imaginary parts) for engine model, by BEM acoustic solver



Response spectrum analysis of dam under earthquake excitation

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