DE

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TECHNOLOGY FOR DESIGN ENGINEERING

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Design with DATA

by Jamie J. Gooch

Direct Data, Design and the Future

When my kids were younger, they liked to play the game of Telephone with their friends. If you're not familiar with the game, it begins with one person telling something to someone else, then that person repeating it to someone else and so on until the information has gone through the group and back to the person who originally provided the information. After going through so many people, the information would invariably be some giggle-inducing, garbled version of the original.

It's not just kids who have a tough time communicating what they've heard. We played the same game in a college journalism class to underscore the importance of first-hand information and not relying on a single source when reporting a story. No matter how hard we tried to accurately relay what we heard from one student to the next, the information would always come back differently than what was originally conveyed.

Design engineering teams should consider the source of outside data.

For reporters, the phenomenon can lead to some embarrassing headlines. For design engineers, it can mean the difference between producing a product your company's customers will love and something that they won't buy. It might mean producing something that is over-engineered for how it's really being used, or something that fails when used in actual field conditions.

Real-Time, Real-World Data

Simulation, prototyping and testing catch most of these issues before a product design makes it to the factory floor. Engineering teams make extraordinary efforts to ensure the products they're designing are safe, reliable and marketable — investing considerable time and expense in the product development process. But what if design decisions could be based on more real-time, real-world data? Instead of getting product use information filtered through a Telephone-like game of sales figures, maintenance records, focus groups, test data and more, a direct data route would not only help ensure the integrity of the information, but could also save product development time and expense.

That's one of the exciting promises of the Internet of Things (IoT). Predictions for the future include products "phoning home" when they are about to fail, or to provide a stream of actual usage data that can become the basis of improving the next generation of products. It sounds a lot like what happens when a software application crashes and a window pops up asking you to send a report back to the vendor. But what happens to that data once it's submitted? How is it collated and acted upon?

Not So Fast

We can assume that such real-world data would be worth the time and expense involved to make some products "smart" with various sensors to detect issues and the technologies needed to communicate those issues. Let's also assume that the security concerns threatening the IoT will eventually be mitigated. Even after those two high hurdles are cleared, there is still the issue of making sense of all that data.

There is already an over-abundance of data, much of it not being effectively harnessed to improve product design. Why? Because collecting, filtering, disseminating and analyzing massive amounts of data is still a huge challenge. It requires a workflow, IT infrastructure and advanced algorithms that don't yet exist in most organizations. Adding more data to the mix without an efficient system in place to handle it would only exacerbate the issue.

Many of the titans of technology are focused on growing the IoT and bringing the benefits of Big Data to more and more organizations. Depending on your industry, the use of real-time, real-world data may only be a matter of time. However, especially in these early days, design engineers should consider the source of the outside data coming in. The filters applied to the data that are intended to make it useful should also be thoroughly vetted. Just like in the early days of simulation solvers, you shouldn't trust the algorithms to be perfect right out of the gate. An automated process of relaying Big Data may not be plagued by the same issues humans are when playing a game of Telephone, but the old computer programming adage "garbage in, garbage out" still applies. **DE**

Jamie Gooch *is the editorial director of* Desktop Engineering. *Contact him at de-editors@deskeng.com.*

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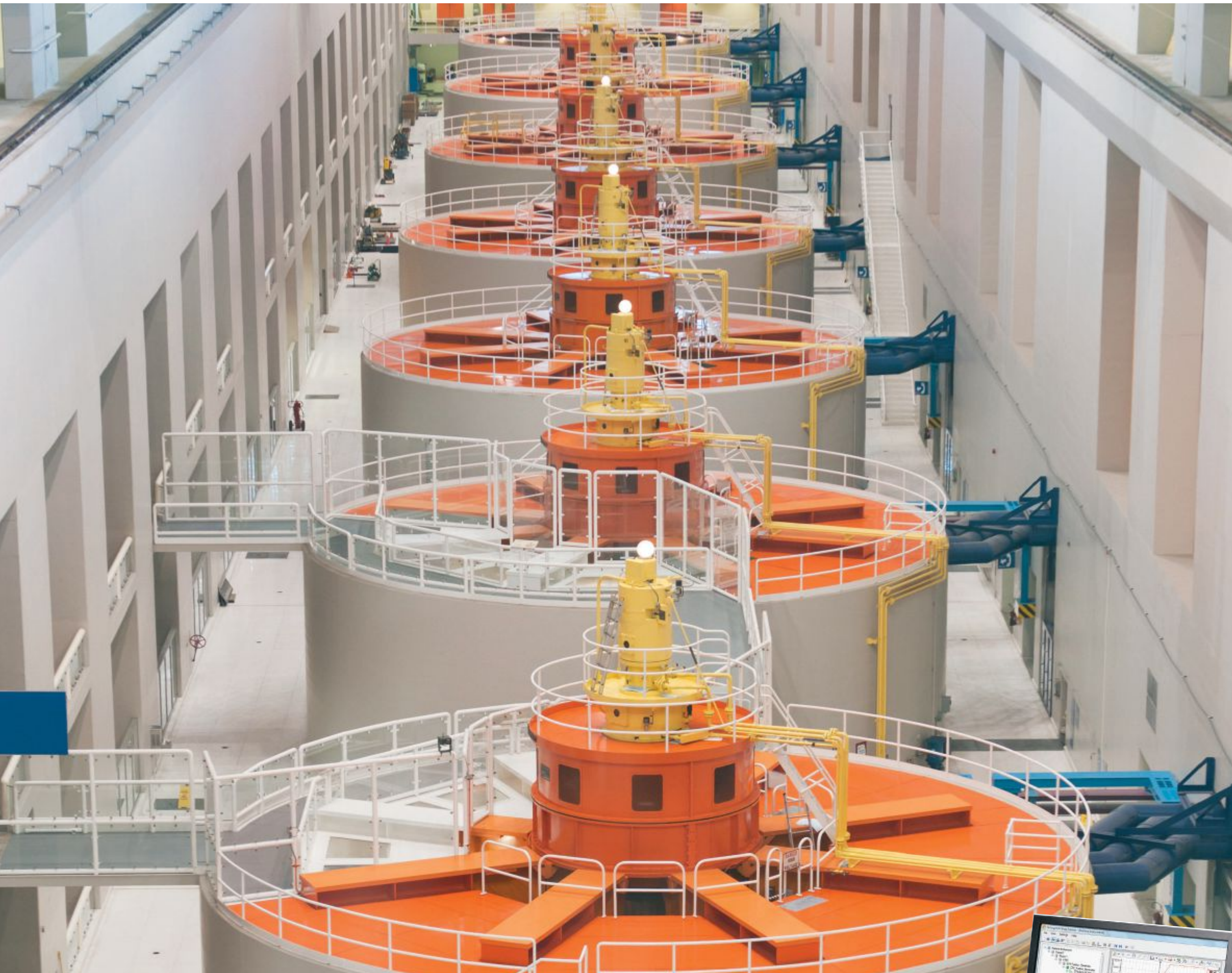

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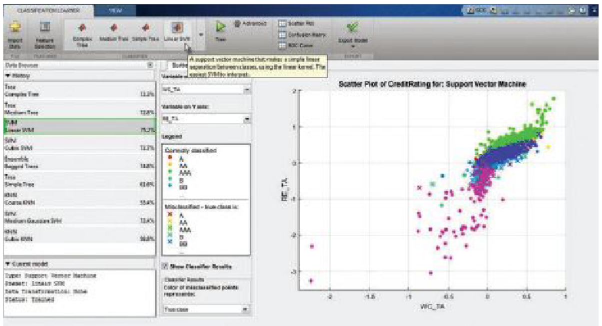
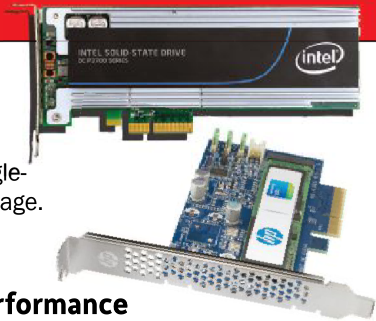
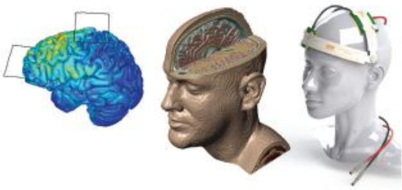




ON THE COVER: Big Data begins to make its way into designs.
Images courtesy of iStockphoto.



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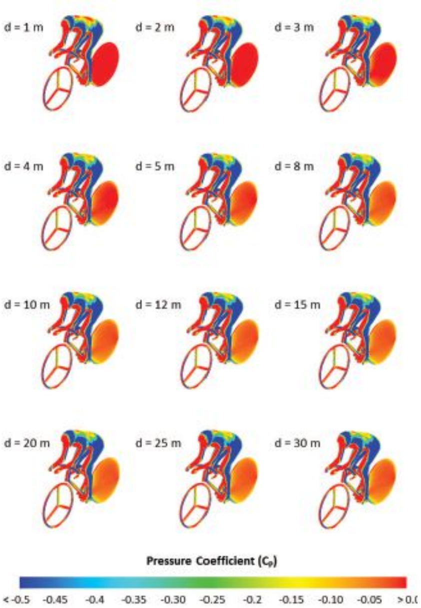
Can Simulation Predict the Tour de France's Outcome?

Professor Bert Blocken, PhD student Yasin Toparlar, and Thierry Marchal may have uncovered something that could affect the regulations of the Tour de France. The real race took place along the 3,360-km route that stretches from Utrecht, Netherlands to Sèvres, France, but Marchal pointed out: "Part of the race can be won in front of the computer."

Blocken, the chair of Building and Urban Physics at the Eindhoven University of Technology in the Netherlands and at Leuven University in Belgium, and Marchal, global industry director for healthcare, consumer product and construction at ANSYS, have spent a good part of their careers recreating physical phenomena — like the aerodynamics of moving cars and trains — in pixels inside computers. At first glance, their professional expertise seems to have nothing in common with the cycling champions who rely on their muscles, training and stamina. But it does.



The use of digital simulation in ANSYS software allows researchers to incrementally change the distance between the vehicle and the cyclist. ***Image courtesy of ANSYS and Eindhoven University of Technology.***

"We have begun working with athletes going for the Olympic Gold," says Marchal. The same ANSYS technology used to simulate and study the airflow around a passenger jet or a Formula One racecar can be applied to a swimmer or a cyclist.

"In a cycling race, the frontrunner is protecting the follower from the wind effect, so it's generally understood it's easier to be behind someone," says Marchal. "But Bert Blocken and his team found out the follower may also be influencing the frontrunner's performance by pushing the air toward the front."

In the case of a vehicle following a cyclist, Blocken and his PhD student Yasin Toparlar discovered that the effect is significant enough to change the outcome of the race.

The Race Inside the Computer

Currently, a car following a cyclist in the race is required to keep a distance of 10 meters for safety reasons. But based on the research from Eindhoven University of Technology with the ANSYS software, this distance should be re-examined.

"We were simply trying to understand the physics of the influence of a car following a cyclist on the drag of this cyclist," says Blocken. "We first did a computational fluid dynamics (CFD) simulation in ANSYS software. We then confirmed our numbers with a wind tunnel test."

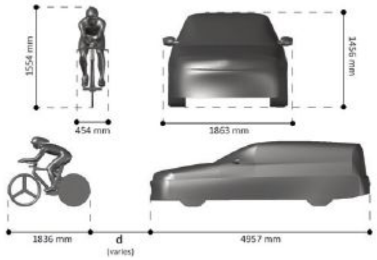
The 3D geometry of the cyclist came from a laser scan from a previous project dating back to 2006. The 3D model of the vehicle was purchased online, from one of the 3D content suppliers. The simulated scenario covers a 50-km distance. The researchers incrementally reduced the distance between the car and the cyclist to see what happened.

"When the car was following the cyclist at a 5-meter distance, the drag reduction gave the cyclist an advantage of about 24 seconds over the car following at 30 meters," says Blocken. "Conducting CFD (computational fluid dynamics) simulations allowed us to put the cyclist and the car extremely close to each other. You wouldn't be able to do that in a real experiment because it would be dangerous to the cyclist."

CFD as a Predictive Tool

CFD should be used where it counts most, Marchal suggests. "For certain segments of the race, like the stages involving mountain climbing, you might not want to do CFD for the climb, where everyone slows down. But for downhill, it makes more sense," he says.

Some sports equipment manufacturers now work with CFD experts to improve product performance. For example, bike makers and helmet makers could reshape their products to improve airflow and reduce drag. Even the cycling and swimming suits are subject to scrutiny under CFD for possible aerodynamic improvement. (For more,



Researchers from Eindhoven University of Technology conduct simulations to understand the aerodynamics of a vehicle following a bicyclist in a race. *Image courtesy of ANSYS and Eindhoven University of Technology.*

read "CFD Making Waves in Olympic Swimwear Again," deskeng.com/virtual_desktop/?p=6002.)

But it would be a mistake to think of CFD as the ultimate predictor of competitive sports. "We can boost the athlete's performance with equipment, optimize his or her situation, but the athlete is the one who must deal with tiredness, keep up morale and peddle the bike," Marchal says.

Blocken anticipates skepticism on his research from some, but he's confident in his findings. "The agreement between the digital simulation and the real wind tunnel test was even better than expected. And we have 17 years of experience in performing accurate and reliable CFD simulations with the ANSYS software," he says.

Eindhoven University of Technology and ANSYS formally notified the cycling community and the regulatory organizations of their findings. "We feel we need to go public with the findings because we are concerned with the fairness of the game," says Marchal. "We also want the UCI (Union Cycliste Internationale) to be aware of that so it could modify the regulations."

— K. Wong

Preparing for the Era of Cog-Assisted Product Development

In his keynote address at the NAFEMS World Congress (June 21-24, San Diego), Dr. Ahmed Noor, a researcher and scholar from Old Dominion University, brought up "cogs," among other things.

These cogs are not the wheels and gears that once drove the steam engine-era industrial activities; they're at the heart of what could very well be the new IoT-era industrial revolution. They are "Cognitive computing for engineering analysis and design," says Noor.

"We are witnessing a new revolution in computing and communication, brought about by the synergistic couplings of a number of technologies, including cognitive computing, Internet of Things (IoT), mobile and wearable devices, big data prescriptive analytics, among others," he says. In his talk, he identified "some of the characteristics of the coming intelligence / convergence / mass customization era, the future cognitive cyber-physical engineering systems (beyond today's autonomous systems), and their implications on the product creation tools, facilities and environments."

The human-machine interaction so far has been marred by anxiety and distrust — the fear that automation and AI (artificial intelligence) threatens human supremacy. It's a dystopian vision we have seen depicted in movies like "The Terminator" and "The Matrix." Noor has heard some of his peers express similar concerns. "With all due respect, I don't share their paranoia," he said in an interview with *Desktop Engineering*. He believes it's possible to achieve "human-machine symbiosis," where "humans are always in the loop and both work together so the overall system functions at its best." He looks to wearable computing devices as a precursor to the symbiosis.

Cognitive Computing Predictions

He envisions "cog-assisted product development technologies, where every phase is aided by cognitive computing and predictive analytics." At the moment, however, he acknowledges such tools are almost nonexistent in in the commercial market; promising versions of it are difficult to find even among university research projects. "IBM is working very hard to develop this type of intelligence," he says. "Engineering and simulation software vendors should seize the moment and work to integrate this feature in their next-generation offerings."

Considering the fast pace of change, Noor suggested we should learn to become much more nimble and agile. "We should revisit our plans and strategies once in a while, perhaps every two months, and revise them in response to the changes we see," he says.

— K. Wong

Sustaining Product Design

In March, the Cradle to Cradle (C2C) Products Innovation Institute challenged designers everywhere to contribute to the world of sustainable product design. The institute partnered with Autodesk for its first Cradle to Cradle Product Design Challenge. The winners announced this spring are certainly bringing in a new era of sustainable design. Entries were submitted from a variety of sectors, including home and furniture, apparel, electronics and automotive. The contest selected winners from three different categories: professional, student and Autodesk Fusion user.


Jerri Hobdy's stool design implements recyclable materials for a healthier piece of furniture. *Image courtesy of Jerri Hobdy*

Have a Seat

Jerri Hobdy, a furniture designer, created the PUREIIFIHIDE, a chair and stool collection. The product uses recyclable materials like solvent-free, vegetable tanned leather and steel. The growing market for non-toxic furniture and her goal to provide future customers the healthiest, best-designed product on the market inspired Hobdy's design. This objective is what drives Hobdy to incorporate reusable materials and sustainable design into product creation.

"I am interested in sustainable design because I am interested in healthy design … for the planet but even more so for people. In the U.S., especially, we are on the edge of a huge and continuing paradigm shift in how we view access to health and healthy choices in a vast range of purchase decisions. The furniture industry is a very chemical ridden, under-regulated puzzle. It will take people that have vision and passion to see the long-term and immediate benefits of cleaning up furniture manufacturing. I am one of those people. I am encouraged by [the fact that] C2C and Autodesk are willing to partner with individual designers from around the world like myself to make positive changes. Sustainability is important because it affects the big guys and the small [ones]," Hobdy says.

With her winnings, Hobdy will finish prototyping her chair and stool before submitting it for official C2C certification — then she'll start offering the first commercially available C2C certified residential home furnishings across the U.S.

Sustainability in the Bag

For consumers everywhere, student winner Tjitte de Wolff from the University of Twente, designed the Venlo Bag. Made from 99% recycled materials, the bag is suited to address pollution caused by plastic bag use. De Wolff was inspired to make this design after viewing the documentary called "Plastic Planet," and learning more about the Great Pacific Garbage Patch.

"The demand for cheap, single-use shopping bags will still exist," says de Wolff. "Therefore a Cradle to Cradle solution for plastic bags not only eliminates pollution, but also contributes to a healthy ecosystem following the credo: do more good, rather than less bad." He plans to use his winnings for his studies and for creating prototypes of the Venlo Bag.

Watching Water Usage

Cole Smith, the Autodesk Fusion 360 winner, submitted his concept for the Finite Faucet. This product is geared toward public restroom users by helping them learn how to properly wash their hands in addition to reminding them of their environmental impact.

Smith originally thought a waterfall design might be ideal for educating users on environmental impact. However, he soon discovered that current waterfall faucets on the market weren't successful in doing so — but a more visual design with graduated cylinders and measuring cups did.

This led Smith to modify the Finite Faucet to include a clear upper cylinder to act as a visual monitor for water usage. Once it empties, it must be turned off to refill. Aside from using sustainable design to create a more effective faucet, Smith also sees it as something that can bring innovation and smart business practices into product design.

"From the fun side of things, sustainable design often involves some really neat and innovative material use, in order to recycle materials in new ways," says Smith. "On a more serious note, It's easy to see sustainable design as just another part of the green movement, but it's also a really intelligent business decision. The savings in energy, cost and labor of intelligently recycling products can be immense compared to designing from stock material."

– J. Lulka

3D Printing the Internet

The backbone of the Internet is miles and miles of fiber cable, running through the ground, along the sea bed and so forth. The basic method for creating optical

fiber is still basically the same as when someone first stretched out a piece of glass. Researchers at the University of Southampton are researching new methods of optical fiber production using additive manufacturing (AM).

The new process will use ultra-pure glass powder to build optical fiber using AM, allowing researchers to specifically design each part of the fiber. In order for the project to succeed a number of hurdles need to be overcome, including, "… the high melting temperature of the glass (over 2000˚C in the case of silica); the need for precise control of dopants, refractive index profiles and waveguide geometry; and the need for transitions between the layers to be smooth, otherwise the properties of the resultant fiber will be altered."

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Dubai will be Home to First 3D-Printed Office Building

WinSun Global and the Museum of the Future have partnered to bring on the revolution. The Chinese company, which has already proven its mastery of AM (additive manufacturing) construction, has agreed to erect an office building in Dubai purely through 3D printing. It sounds innocuous enough, but once the project is completed, WinSun will have set the foundations for a whole new industry with the first commercial sale of a building made through AM.

The modest 2,000-sq.-ft. building will be constructed near the Museum of the Future and act as temporary office space for its staff. Printing will be accomplished by a 20-ft. tall AM system, which will construct the basic components of the building. These components will then be assembled in a few weeks to finish the building.

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Ares All-in-One Printer Heads for Crowdfunding

EasyArts has launched the Ares on Indiegogo. Ares is a fairly standard Fused Deposition Modeling-style 3D printer, but it also has the potential to transform into a number of other tools, including a laser engraver and 3D scanner.

In the case of the Ares, easy access to the print head is intended to allow users to swap different tools into place. Along with 3D printing, the system is capable of laser engraving, CNC (computer numerically controlled) engraving/milling and 3D scanning. It isn't quite a makerspace, but it's closer to a true utility device than a 3D printer alone.

During the Indiegogo campaign, backers can get the full Monty for less than the cost of many 3D printers alone.

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Ford Partners with Carbon3D

Although prototyping alone was enough to attract automobile manufacturers to 3D printing, companies have begun to demand more from new technology investments. Companies have not only begun to expect the systems to produce parts faster, but also expect a certain level of practical use for a 3D printed part. The need for better and faster 3D printing led Ford to form a partnership with Carbon3D.

"Carbon3D's CLIP technology has allowed us to realize our need for high-speed, high-quality printing of actual automotive-grade parts," said Raj Nair, group vice president of Global Product Development and CTO. "We are excited to further our relationship and look forward to innovating together to make 3D manufacturing a reality."

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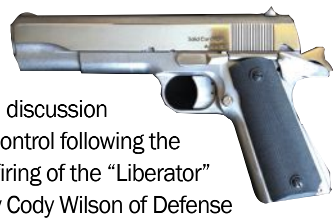
U.S. Government Moves Against 3D-Printed Guns



3D printing became part of the national discussion about gun control following the successful firing of the "Liberator" designed by Cody Wilson of Defense Distributed. Wilson quickly found his design and his company under fire from the U.S. Department of State, which issued an order to remove the plans from his website.

Although Wilson complied, he launched a lawsuit against the agency claiming the order violated his rights to freedom of speech. Regardless of Wilson's suit, the U.S. Department of State has begun to move ahead with stricter rules regarding the availability and legality of electronic files that can lead to the unauthorized production of firearms.

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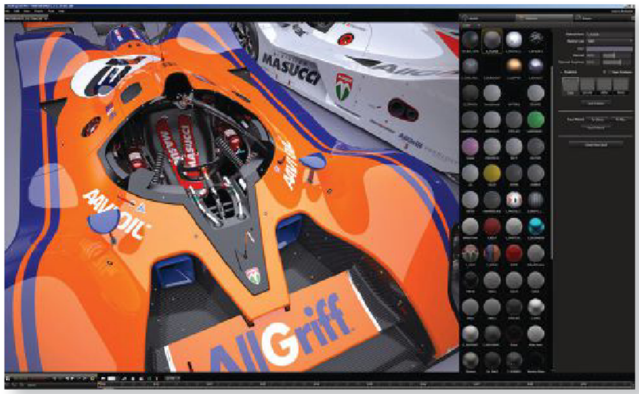
The Universal Language

Show, don't tell when it's time to explain design intent.

If you've ever visited a foreign country where you didn't speak the language, you have an idea what it must be like for non-engineers to understand design intent. Speaking more slowly or loudly doesn't help. Showing a layman schematics, Excel tables or even simulation visualizations is the engineering equivalent of a tourist asking directions to the airport by stretching out their arms to pantomime a plane. You might get your idea across, but it will take awhile — and time is a luxury most design engineers don't have.

Design engineers speak the same language. Tolerances, loads, stresses, thermal envelopes and more make it easy for engineers to communicate requirements, development issues and engineering change orders. However, not all clients and colleagues speak that language, which stymies collaboration and results in inefficiencies and lost opportunities. If only you could show them exactly what you had in mind in a way anyone could understand. That's what rendering allows you to do.

Rendering can be the universal language of manufacturing by enabling true visual collaboration among designers, clients, executives and other key stakeholders. Where in the past rendering was a complex, time-consuming task that required expert assistance and expensive computing resources, software and hardware tools now exist that put powerful rendering capabilities into the hands of designers. A picture maybe worth 1,000 words, but rendering can be worth much more as it allows you to fully express the intent of your design, help win bids, market products, identify flaws and imperfections, and explore future concepts.



RENDERING brings an idea to life in a way a 2D schematic or even a 3D CAD model cannot. ***Image courtesy of Daniel Simon.***

Communicate Early and Often

The design process has been compressed. Customers expect more complex products in an increasingly short timeframe, which has made communication throughout the process even more critical.

Prototypes, while extremely useful in communicating the look and feel of a design, are expensive to build and often aren't created until later in the design process when most of the key decisions have already been made. Lacking the ability to quickly and effectively communicate design intent and the impact of change orders to all stakeholders inhibits collaboration.

Quality rendering, however, can cut through the technical noise early in the design process, allowing colleagues and clients to experience the "ah-ha" moments that can lead to new ideas, faster change approvals, clearer communication, and ultimately better and more satisfying designs. Rendering can help you quickly lead colleagues and clients to better decisions with easily understandable visual information. From initial concepts, through multiple design changes and to the final presentation, rendering provides all stakeholders with a clear view of the project.

Equipped with the right hardware, including overclocked workstations, powerful GPUs and render nodes built to enable faster, iterative visualization of designs, engineers can work faster, provide better results and truly collaborate with other team members, customers and colleagues in various disciplines in ways that weren't previously possible.

Making the Case for Visual Collaboration

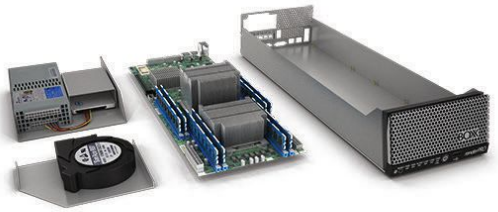
A new paper produced by *Desktop Engineering* on behalf of BOXX Technologies makes the case for investing in the hardware, software and workflow to support visual collaboration. It explains how rendering can improve the design process, enhance collaboration and enable better customer interactions through real-world examples.

Download "Making the Case for Visual Collaboration" for free at deskeng.com/de/visual.

Visual Collaboration Workflow

BOXX APEXX 2 and APEXX 4

The APEXX 2 workstation for CAD design, 3D modeling and animation workflows features support for optional overclocked processors and two full length professional GPUs. It is available with optional eight-core processors for increased rendering power and multi-tasking. The APEXX 4 is configurable with up to two Intel® Xeon® processors for total of 36 cores (72 threads), allowing it to handle rendering and simulation tasks with ease. It also supports for an optional overclocked single processor and up to four professional GPUs.



BOXX renderPRO

The renderPRO is a complete computer powered by dual Intel XEON processors that has been stripped of all the features not necessary for rendering so it can focus on CPU core count. It was built for 24/7 maximum workload operation. The all-aluminum chassis was designed to sit directly on an APEXX 4, and to be stacked several units high for a desk side render farm solution.

BOXX renderBOXX

renderBOXX is purpose-built to power render-intensive 3D graphics and animation workflows. Featuring dual Intel Xeon processors (up to 36 physical cores), a single renderBOXX can act as the cornerstone for a render farm. Ten modules fit into a 4U (7x19-in.) space, while IPMI 2.0 technology featuring keyboard, video and mouse (KVM) over Internet Protocol (IP) enables you to efficiently manage a render farm network.

BOXX RenderFarm On Wheels

RenderFarmOn Wheels is a turn-key renderfarm solution in a complete hardware package. The unit includes rack mounted dual CPU render nodes in a mobile enclosure. ROW can be completely custom configured to meet your needs. To assist your ROW deployment, BOXX offers on-site studio setup, with unparalleled expertise and support to get your ROW up and rendering in no time. It is available in a range of sizes and expandable to over 80 modules (2,880 cores).

Dealing with the Deluge of Big Data

IoT products can deliver valuable information that can help evolve future designs — but engineers need to know how to use it.

BY BETH STACKPOLE

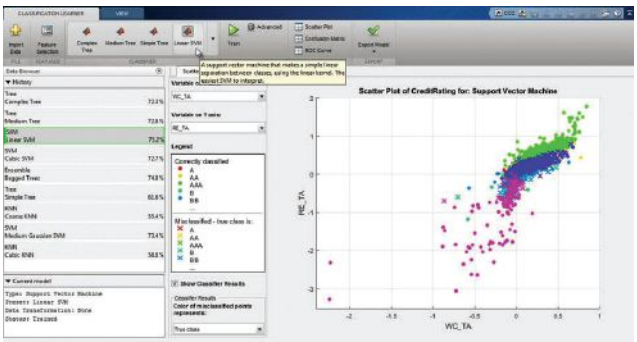
Internet of Things (IoT) data is the new currency driving strategic decision making, including helping engineers gain insight into what to build and how to build it more effectively. Yet in order to reap the full impact, organizations need a strategy for managing the data deluge so it doesn't swamp efforts to optimize product designs.

Big Data's role is to deliver insights that can steer higher quality product designs and be leveraged for predictive maintenance to more effectively service products once out in the field. The concept works by equipping products of all types with an assortment of sensors that collect and transmit critical data in real-time over the Internet to a central repository. From there, the data — recorded temperature, stress points and speed, among other variables — is massaged, potentially mingled with external data, and ultimately mined for insights that could direct any number of product development decisions.

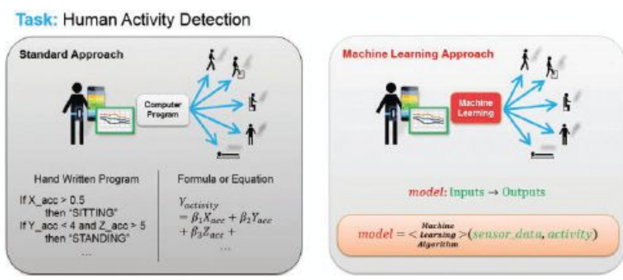
This scenario, while still nascent, has huge potential to transform the engineering and design process. Yet the problem, according to experts, is that the data coming off of smart connected products is so vast that it's next to impossible for engineering teams to come up with any of these killer insights without help from an additional technology platform that will facilitate data collection and analysis.

"The data has gotten so big that the ability for the human mind to find points of value within the data set is extremely difficult," says Rob Patterson, vice president, Corporate Strategy for ColdLight, a provider of an automated, advanced and predictive analytics platform recently acquired by PTC. "There needs to be some kind of handshake between man and machine in order to find value in IoT data."

In recognition of both the IoT's potential and the Big Data problem, traditional design tool vendors are taking aggressive measures to augment their product portfolios with new capabilities that address emerging requirements. Some, like PTC and Siemens PLM Software, have made acquisitions in the Big Data analytics space planning to meld what has historically been an unrelated enterprise information silo into the traditional engineering software workflow. Others like MathWorks are positioning their machine learning capabilities to



The Classification Learner app lets you interactively train models to classify data using supervised machine learning.



Instead of requiring the user to define a formula or equation, machine learning algorithms automatically fit widely applicable models to data. *Images courtesy of MathWorks Inc.*

help solve this challenge, and non-traditional players such as analytics companies are also jumping into the fray and tuning Big Data solutions to address the needs of engineers.

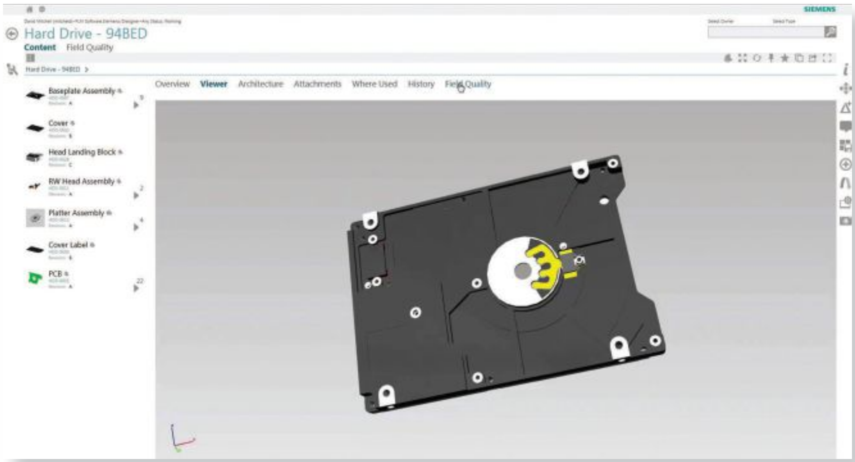
"I don't know any great answer to the problem out there today," says Mike Campbell, PTC's executive vice president of CAD products. "All I know is that design engineers trying to develop the next great products are starved for real-world information. They recognize that they've been making assumptions about requirements and real-world conditions … and they're very excited about gaining insights about how products are used or whether they are under or over designed."

Closing the Information Gap

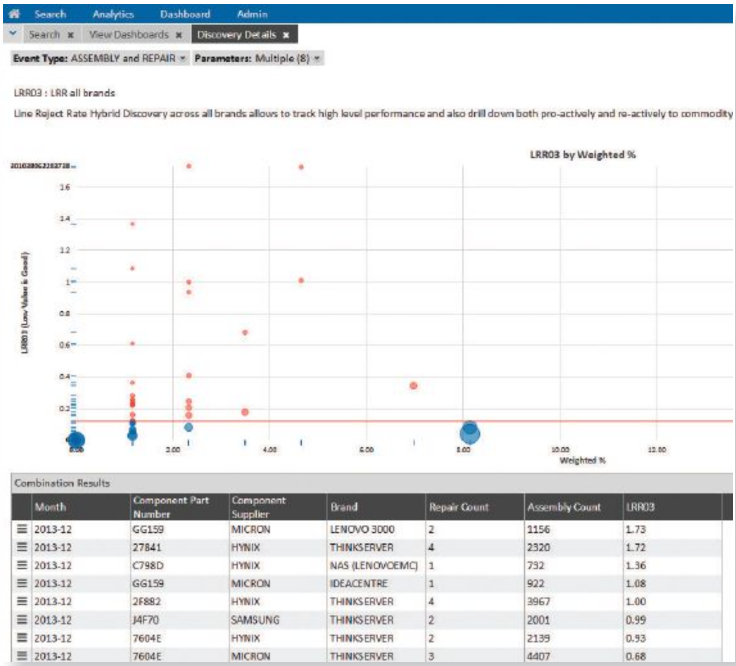
Bill Boswell at Siemens PLM Software agrees that the traditional process often leaves engineers making critical design decisions in a vacuum. While there is plenty of data — in PLM (product lifecycle management), ERP (enterprise resource planning) and voice of the customer systems — he says the problem of fragmented silos creates information chaos in companies, and traditional business intelligence tools don't help span the gap. "Today, companies are making decisions on a pretty short set of data," says Boswell, senior director of Cloud Services Marketing and Business Strategy. "Traditional business intelligence isn't taking advantage of Big Data."

To see how Big Data can change the equation, Boswell uses the example of an electronics manufacturer trying to identify a quality problem causing recalls on a hard disk drive. By combining engineering data, PLM data, field quality data, returns data, customer experience data and what Boswell dubs "call home" IoT data, engineers can ask a different set of questions they may never have considered before to get to answers they never would have found, he explains.

Cutting-edge organizations might be doing some of this kind of analysis on a very rudimentary scale, but it's next to impossible to see patterns between data stored in siloed systems without some sort of automated, analysis tool, Boswell says. To that end, Siemens recently released Omneo Performance Analytics, part of the Omneo quality management platform that came through its acquisition of Camstar, best known for its manufacturing execution system (MES). Omneo Performance Analytics, available as a Software-as-a-Service (SaaS) offering, monitors data across the entire supply chain and customer experience, analyzing billions of data combinations to uncover hidden intelligence that can proactively pinpoint the source of product issues well after a product has been released to the field.



Omneo runs billions of variable combinations to uncover hidden data trends that can used to mitigate product quality issues in future designs. *Image courtesy of Siemens PLM Software.*



The monitoring tool in Omneo Performance Analytics can be used to track and observe trends for all Big Data sources in a single place for more comprehensive analysis. *Image courtesy of Siemens PLM Software.*

Having this 360° view of the supply chain, coupled with the ability to churn through billions of data combinations in seconds, was a critical asset for Dell, an Omneo user, to proactively identify and service a problem for one of its major customers, according to Rami Lokas, senior director, R&D for Omneo. The customer was experiencing on-going issues related to laptop memory, and using the Omneo platform to connect the dots between the various data silos, a Dell quality engineer was able to determine in minutes — not weeks — the source of the problem and resolve it.

"All of a sudden, the light switch went on and the engineer realized it wasn't the processor or the motherboard, but the integration between the two," Lokas says. "The number of permutations you'd have to go through to uncover that would be humanly infeasible." Instead, Omneo's ability to automate that discovery process was essential to finding the patterns in Big Data and jumpstarting the root cause analysis for the service engineer, he explains.

MathWorks customers facing similar challenges are leveraging a variety of tools to find patterns and gain insights from an ever-expanding lineup of data sources, including data acquisition hardware, data warehouses, live and historical industrial plant data, and of course, IoT. Via its family of Toolbox offerings — the Data Acquisition Toolbox, the Database Toolbox, the Image Acquisition Toolbox, the Neural Network Toolbox to name a few — MATLAB users are attacking diverse and dynamic Big Data sets to gain insights that can be leveraged to improve existing designs or build new products and services, says Seth DeLand, MathWorks' product manager for Data Analytics.

DeLand uses the example of a large off-highway equipment manufacturer that had 40 years of stored data that was continuously collected from machines in the field. Using the MATLAB Toolbox offerings, the manufacturer could develop more accurate test models to understand how its equipment is actually performing in the field and whether it can hold up under a full range of operating conditions. Rather than use subjective tests that an engineer devised years ago based on assumption, engineers can leverage the treasure trove of historical data to create models for hardware-in-the-loop (HIL) testing and test beds that are more reflective of real-world conditions. "They might find that a subassembly was never designed for the use case that it's under in the field and although it's still working, they can deliver feedback to the design team they never would have gotten because there were no field failures," he says.

MathWorks' machine learning capabilities also have potential for helping engineers get a handle on Big Data. Engineers need to be able to explore and visualize data, eliminate noise and outliers, and develop predictive models, but the problem is they are engineers — not statisticians, says Paul Pilotte, MathWorks' technical marketing manager for Data Analytics. "When you have a lot of data, you need a more efficient way of developing models and getting data to surface to create accurate predictive models — machine learning is a powerful approach for that," Pilotte says. "It gives you the ability to build highly accurate predictive models that a human person couldn't do."

Helping human engineers make sense of Big Data is where ColdLight fits into PTC's product portfolio. The software, which also has a machine-learning component, among other data analysis capabilities, parses through incoming data, finding patterns within data sets to help with predictive analytics, ColdLight's Patterson says. "The amount of data available is very large, but it's not all relevant for actual use or the goal an engineer is trying to achieve," Patterson says. Manually detecting patterns in such a large data set is next to impossible for highly trained statisticians, let alone engineers. ColdLight automates that process, using machine learning or neural networks, among other data analysis capabilities, to detect patterns and build predictions to only send engineers the data that they need.

That's when the true value of IoT comes into play, says Patterson. "For the first time from a design engineer standpoint, we have enough data out there … to provide an unbiased view of the world," he says. "The ability to process that data and build predictions with no predisposition to the business will open possibilities for people to do things in a different manner than has been done in the past." **DE**

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INFO ➜ **ColdLight:** ColdLight.com

➜ **MathWorks:** MathWorks.com

➜ **Omneo:** Omneo.com

➜ **PTC:** PTC.com

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

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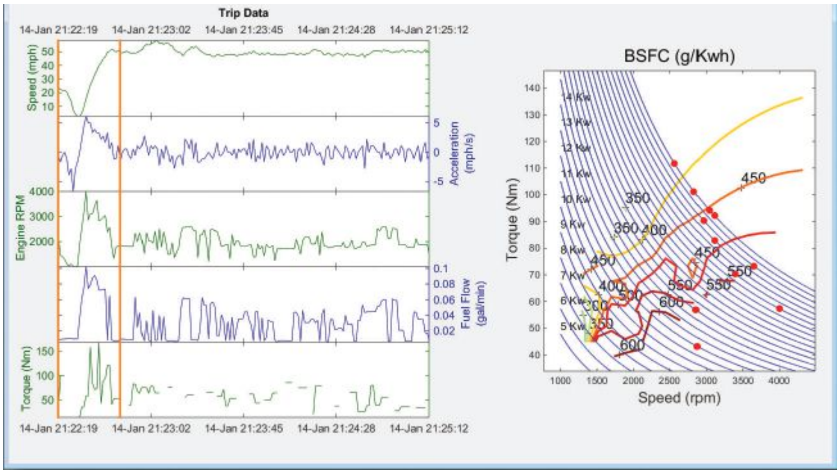
Execs, Engineers and IT Prepare for BIG DATA

As Big Data matures, so too will technology and security to support its use.

BY JIM ROMEO

For a major oil and gas exploration company using complicated algorithms to compute millions of data points taken with sophisticated sound waves, technology is vastly improving their ability to predict natural resource opportunities in their exploration efforts. They conduct these investigations from a ship at sea and use supercomputers to analyze it in a way that provides them with a predictable course for their exploration and discovery.

Welcome to the strategic age of Big Data — a growing method of building business. Big Data computes huge amounts of data points for applications that range from condition monitoring at a sprawling chemical process plant, to calculating weather patterns in regions where shipments travel. Big Data is on every business leader's mind as companies use the power of information to better compete globally. Tantamount to this effort is a parallel concern of maintaining data integrity and security in an often risky global environment of hacks and cybercriminals.



A MATLAB dashboard for visualizing data from vehicle fleets, which incorporates real-world driving data with engine maps created in test cells. ***Image courtesy of MathWorks.***

"Big Data can be fed into many parts of the design process. For example, data from real-world operations of equipment is being used as inputs and boundary conditions for simulations. We're also seeing organizations looking to improve their test coverage with Big Data by making sure that the tests they run are capturing all of the conditions the design may encounter in the field," says Seth DeLand, product marketing manager of Data Analytics at MathWorks. "More data is going to be available to design engineers. They're going to have more and more opportunities to leverage real-world data to drive decisions during the design process. Engineers are also going to see their companies looking to build new services based on their data. For example, equipment manufacturers are looking to provide predictive maintenance as a service to their customers."

Internet of Things

The Internet of Things (IoT) is accelerating the use and application of Big Data. Sensor technology and its reliability has improved greatly over the past decade; data attained may be fed into user interfaces and software computing programs all the way around the world via the Internet. As sensor technology becomes more advanced, so too do the possibilities for Big Data applications.

"One area where it is becoming prevalent though is in sensor systems," says Mike Haley, senior director, Emerging Products and Technology at Autodesk. "In this case, physical products — buildings, machines, batteries, etc. — are instrumented with sensors that track aspects of their performance over their lifetime. By downloading and correlating all of this information using Big Data technologies, it is possible to give designers more informed design choices based on real-world performance statistics.

Haley points out that certain industries adopt data picked up via IoT better than others. The utilization of such data and its incorporation into business strategy isn't fully mature. There's still a way to go.

"Specific industries where this is becoming prevalent include: buildings — sensors in concrete and beams as well as components such as HVAC (heating, ventilation and air conditioning) systems; battery technology — understand battery chemistry and performance in difference usage scenarios; and automotive, which probably has the longest history of this," says Haley. "That said, true Big Data analysis of sensor data is in its earliest stages as a large volume of data has to be acquired over time then appropriately analyzed to discover patterns and predictors that will be useful to designers."

For design engineers and companies relying on technology to drive success, IoT and Big Data relies on several things. "To understand the implications of Big Data on engineering firms, it's useful to first examine the components of IoT and how each will affect design engineers," says Ray Milhe, vice president of Enterprise Solutions for ANSYS Inc. "Designing products within this framework will have unique implications on engineering firms."

Milhe says that by 2020, industry experts estimate there will be as many as 200 billion wireless connected devices. This will provide an enormous onslaught of data. Harnessing this data is both a challenge and an opportunity for design engineers and software engineers. Customers will aggressively seek solutions to capitalize on this.

"The last component of the IoT infrastructure is Big Data and the cloud," says Milhe. "Whether performance data is sampled every millisecond or every hour, 200 billion connected devices are going to generate a tremendous amount of data, in some cases hundreds of terabytes or petabytes. Some of our customers are looking at new ways to store, index and search vast amounts of data. Some companies are using predictive analytics and trending and will apply it to simulation and test data, which they can use internally or as part of a service to their customers — for example — preventive maintenance.

Security Concerns

The IoT and more prevalent data has cultivated a concern about all data, including Big Data, in cybersecurity circles. Data in all forms is vulnerable to hacker attacks and breaches of security. Security poses a serious business risk for those enterprises hoping to capitalize on Big Data in the future. A breach of security can lead to a tacit hijacking of a company's intellectual property; a company may fall target to industrial espionage and other cybercriminal acts that endanger their business operations. Businesses are struggling to keep up with the needed security to protect volumes of data across its many disparate data silos.

According to research firm Gartner Inc., more than 80% of organizations will fail to develop a consolidated data security policy across silos, leading to potential noncompliance, security breaches and financial liabilities over the next few years. At its Security and Risk Summit last year, Gartner stated that while much data is at risk, the advent of Big Data and its interchange via cloud computing is fueling the overall concern for data security.

"Businesses have traditionally managed data within structured and unstructured silos driven by inherent requirements to deploy relational database management systems, file storage systems and unstructured file shares," said Brian Lowans, principal research analyst at Gartner. "However, the advent of Big Data and cloud storage environments is transforming the way in which data is stored, accessed and processed, and CISOs need to develop a data-centric security approach. Unfortunately this is not common practice today, and its planning is critical to avoid uncoordinated data security policies and management."

Big Data and cloud storage environments, as Lowans notes, are likely to fuel IT investments in the short run. Research recently presented by CompuCom based on its survey results revealed that 26% of IT professionals expect their organizations to focus most of their 2015 technology investments on cloud technologies, followed by security (24%), and Big Data/analytics (23%).

"Enterprises understand the enormous potential of the cloud to integrate social, mobile and Big Data," says Sam Gross, chief technology officer at CompuCom. "With the agility challenges that IT faces, we are not surprised that cloud [computing] is top of mind, even as security remains an ongoing consideration. Secure cloud-scale application and mobility solutions both drive and consume Big Data, and it is no surprise that the focus on cloud, security and Big Data technology investments rises to the top."

Continuing Trends

As Big Data investment continues to rise to the top of IT spending, technology should become even more advanced and reliable continuing a trend where smart devices, remote monitoring and data transmission have been vastly improved. This will fuel design engineers to seek more advanced software tools and technology to utilize these capabilities and optimize the performance of data on the road ahead.

According to Milhe, the future computation of more data and better data will rely on software development tools more than ever. "Over the past 10 years, we've all seen devices get smarter. Embedded software is what makes devices smart, and there has been an explosion of the lines of code in today's products," he says. "We see this trend continuing. It will be commonplace for discrete products to have millions of lines of embedded software. Engineering firms will not be able to create, test and certify this volume of code using traditional, manual methods and still get to market on time. They will have to adopt model-based software development tools to design and simulate their embedded systems and then use certified code generation to produce the actual embedded software."

Ultimately, leveraging Big Data as part of the design process is something firms should start preparing for now on a smaller scale so their resources can evolve.

"The astute engineer and progressive design firm will start small, invest in currently available comparative information about critical assets or equipment and engage experts in numerical and statistical methods to put that information into appropriate design context," says Roy Whitt, senior vice president and general manager for Asset Answers for Meridium Inc.

Whitt posits that his company will ease into Big Data computing to allow for development of effective techniques to utilize the ever-increasing amounts of data sure to come over the next decade.

"Identifying a few key or critical pieces in a design that can be improved if optimized in the short term will offer an early competitive advantage, while positioning the individual engineer and design firm for success in the future," he says. **DE**

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INFO → **ANSYS:** ANSYS.com

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Simulation Lifecycle Management's New Mission

The discipline takes on new challenges from IoT, apps and the cloud.

BY KENNETH WONG

Matteo Nicolich, product manger for Enterprise Solutions at ESTECO, identified one of the hidden costs of democracy. "By democratizing simulation, you let more people run simulation, so more data will be generated," he says.

The push to democratize simulation and the spread of design optimization has fundamentally changed simulation lifecycle management (SLM). It may have initially been developed as a version- and history-tracking tool, with some job queue management utilities on the side. But the sheer size of the source files, the number of iterations involved and the simultaneous evaluation of hundreds of design variants quickly transformed SLM's mission. It's now tasked with IP (intellectual property) guardianship, process automation, HPC (high-performance computing) management, and remote visualization (for a start).

When the Internet of Things (IoT) arrived on the scene, it also brought its own Big Data headaches. Industry watcher Gartner predicted "4.9 billion connected things will be in use in 2015, up 30% from 2014, and will reach 25 billion by 2020." The volume of data from these connected devices and products — heart-rates reported by smartphone health apps, climate data uploaded by installed wind turbines and engine performance data collected from moving vehicles, to name but a few — represent new challenges for SLM.

SLM's new challenges are also its greatest opportunities. The real-time data available from connected devices, well-defined processes captured as apps, and the (almost) infinite computing power available on demand is about to catapult simulation to new heights.

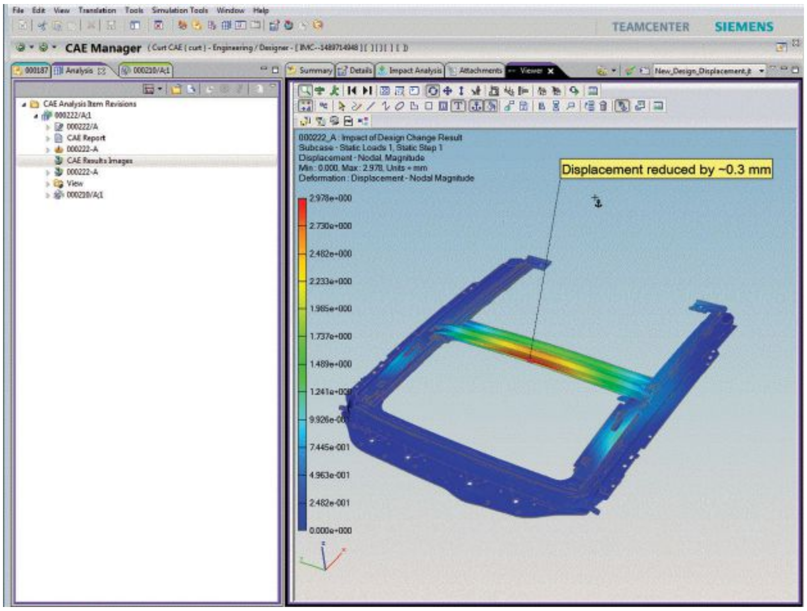
At its LiveWorx conference this May, PTC demonstrated the digital twin of a Santa Cruz mountain bike. This virtual model incorporates data streamed from sensors attached to the physical model. ***Image courtesy of PTC.***

The Impact of IoT

"Simulation data is massive; device data is much more transactional. SLM software has to address that difference. They'll need other database strategies that are more transactional," says Todd McDevitt, marketing director, ANSYS.

The database challenges notwithstanding, McDevitt foresees new types of simulation made possible by device data. "Today, simulation users use lab data and sometimes assumptions for input, for values like loads, electrical charges and aerodynamics. With industrial IoT, we have an opportunity to use real-time data, measured and collected by thousands of products in the field. At best, analytics and measured data from a device can only predict when something is going to happen, given the existing configuration of the device and its operating environment. They can't tell what will happen if you change these parameters in a substantial way, or how to optimize the performance of your product. This is where simulation fits in. It elevates Big Data from being predictive to prescriptive," he says.

The source data for simulation tends to come from controlled physical tests, covering only a limited use of the product under idealized conditions. For example, an automotive simulation might be based primarily on a professional driver's maneuvers in a closed course. However, with real-time data, the range and variety are almost infinite. "Now, with real-time data, we can simulate what happens with when a weekend warrior or a soccer mom is behind the wheel," says McDevitt.



Visualization of results without the need for specialized post-processing tools enables non-experts to quickly access critical insights that simulations can provide. ***Image courtesy of Siemens PLM Software.***

But there's also the possibility that real-time IoT data may spawn "digital twins that mimic the real physical entities the customers are using," says S. Ravi Shankar, director of Global Simulation Product Marketing at Siemens PLM Software. "As the real product goes through its lifecycle, the IoT data coming from the field and reflective of wear and tear can be used to keep the digital twin synched to the real object," he says.

With such a setup, manufacturers could, for example, periodically conduct fatigue analysis on the digital twin of a bike, not only to understand its current state, but to predict when it might break or fail. The concept has been prototyped and presented by PTC at its LiveWorx conference; an event devoted to the company's IoT offerings.

In a live demonstration at the event, Mike Campbell, executive vice president of CAD products at PTC, showed a digital twin replicating the movements and mechanical behaviors of a mountain bike from Santa Cruz Bicycles, using wheel speed, pedal cadence, pressure on suspension and steering angles reported by sensors mounted on the bike in operation in the field. The setup used real-time sensor data from PTC's ThinkWorx to animate the 3D CAD model of the bike constructed in PTC Creo Parametric software. The digital twin was presented in an iPad augmented reality viewer app.

Feeding into System-Level Simulation

The sensor data that must be incorporated into simulation is usually the domain of system-level simulation, conducted in software programs like Modelica. In such system models represented in high level abstraction, the electromechanical assemblies simulated in CFD (computational fluid dynamics) and FEA (finite element analysis) programs are considered subsystems. SLM (which governs CFD and FEA data) and system modelers have in the past remained apart from each other. But the pursuit of IoT may bring the two closer.

"We don't believe these two types of simulation need to be kept in their own silos," says Shankar.

Similarly, at ANSYS, "We see them [system modeling and FEA simulation] as coupled simulation. We have a technology that lets you create a reduced order model out of your detailed 3D model, and use that for your system level representation," McDevitt says.

ANSYS' system modeling program Simplorer is described as "an intuitive, multi-domain, multi-technology simulation program that enables engineers to simulate complex power electronic and electrically controlled systems." ANSYS customers may use ANSYS Workbench as the integration platform to bring together system modeling and finite element analysis.

Juggling Private and Public Cloud

Among small- and mid-sized businesses (SMBs), SLM may also be in the midst of a transition from in-house data centers to remote clusters and on-demand cloud resources. In the long run, the public cloud levels the playing field with its pay-as-you-go pricing and no-upfront-investment proposition. But in the transition period, SLM may need to straddle both on-premise clusters and on-demand cloud. The hybrid approach lets companies harvest the hardware they have already invested in, but also access additional horsepower from outside to address peak demands and overflows.

"We make our solvers available on Rescale, an on-demand cloud simulation platform. Customers have the option of using their existing licenses for the Siemens solvers or using licenses provided via Rescale on a pay-per-use basis. The advantage for the customer is the scalability of the IT platform," Shankar says.

Though when looking at SLM, companies should also consider its broader implications. "You can't talk about SLM without talking about process management and HPC management. HPC clusters have to be managed and monitored to keep track of the jobs' progress. Our customers simulate very large sub-systems and complete products. Workflows can involve several groups distributed around the world. Organizations need tools to coordinate the process as well as manage the data," says McDevitt.

In May, ANSYS released ANSYS Enterprise Cloud, which allows businesses to integrate public cloud resources into their simulation workflow. Users may access and manage the in-house and remote computing resources through ANSYS EKM, configurable for both individual users and collaborative teams.

Remote Visualization is Essential

Because of the size of the models involved in large-scale simulation runs, most experts recommend an IT setup and workflow that avoids or minimizes data movement. "Downloading and uploading simulation data involves a lot of wasted time and resources. So you want the data to reside in once place where people can access it and view it. Remote visualization is critical," McDevitt says.

This method can also minimize data transfer. "When you take on design optimization, you need a lot of computing power and also generate lots of data. With powerful remote visualization tools, there's no need to transfer the data back to your local systems," says ESTECO's Nicolich.

Capturing the Process in an App

In the past, developing repeatable simulation processes and protocols was just a prudent way to conduct business. But there's an added benefit. "Mapping out your process and codifying your simulation protocols takes some time and energy away from regular work, so you might think it's secondary, but to develop a SimApp and gain its benefits requires a streamlined process," says Juan Betts, managing director of Front End Analytics.

A simulation app — or SimApp, in Front End Analytics lingo — is usually built on top of general purpose simulation solvers. With limited input fields and guided steps, they have become one of best ways to make software-driven simulation more accessible to the non-experts. Front End Analytics specializes in developing and deploying SimApps. "There have been cases where we had to diplomatically tell our customer that their processes are too ad-hoc to create a SimApp. We have then worked with these customers to mature their processes to the point where we can create a SimApp for them," says Betts.

The company can build apps directly on enterprise SLM systems such as SimManager (from MSC Software) or SIMULIA SLM (from Dassault Systèmes). It also uses EASA's app-building platform to serve the clients. "If you have processes that don't change a lot, your simulation steps are established, and data management is important to you, then we can probably build our apps directly on your SLM system," says Betts. "But the drawback with that is, the 'app-ification' capabilities in SLM systems are still very limited. The variety and range of apps you can build in something like EASA is much higher."

The best-case scenario, Betts pointed out, is where the app-building exercise leads to well-defined simulation processes in a company. "Because when you're architecting an app, you're also architecting a process," he says.

Keeping the Data Clean and Lean

As a way to curb the exponential growth of SLM data, many experts recommend carefully selecting the type of data to archive. "Even if your model is just a few hundred megabytes, in a complicated process that involves a few hundred simulation runs, you will generate terabytes of data," says Nicolich.

Even for large enterprises with considerable financial muscle, accumulating and maintaining terabytes of data for every project is not a pragmatic solution. The cost and IT burden of storage aside, the sheer volume of data would make analysis and reuse impossible.

"For design optimization or design of experiment, you may not need to keep the resulting models. You can just keep the input parameters, output responses, and key performance indicators. If you need to, you can run the simulation job again. Otherwise you end up keeping lots of useless data you that you won't look back," says Nicolich. In ESTECO's simulation optimization platform, "You can set an expiration date on a data set or a model. So even if you forget to delete it, when the expiration date comes, the system automatically removes the data," he says.

Balancing the archival needs and the preference for data cleanliness is more difficult for those who manufacturer products with longer lifecycles. "With aircraft, you may need to support the analysis of a model designed 50 years ago. With a wearable consumer device, the data is obsolete two years later," says Siemens' Shankar.

Cloud storage offers a viable alternative to those who prefer to archive SLM data for decades. But for some, security concerns still remain a barrier. "The reluctance to go to the cloud for a long time had to do with data security. That attitude may be changing now, especially among small- and mid-sized companies. But ironically, the big guys are the ones who generate those large-volume simulation data, and they are usually the most reluctant to go to the cloud," says Christine Wolfe, lead product manager for multiphysics offerings at ANSYS.

SLM is relatively young, certainly younger than its cousins PLM (product lifecycle management) and ERP (enterprise resource planning). The rapid expansion of SLM offerings in the last five years or so reflects manufacturers' increased reliance on digital prototyping and simulation. Deployed with tools for HPC management, remote visualization and IP security, SLM could help consolidate ad-hoc simulation jobs into a well-defined company-wide infrastructure for simulation-driven design. It should be treated as part of your simulation strategy, not a necessary evil. **DE**

Kenneth Wong *is* Desktop Engineering's *resident blogger and senior editor. Email him at kennethwong@deskeng.com or share your thoughts on this article at deskeng.com/facebook.*

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Blending Reality with Pixels

The new age of augmented- and virtual reality-integrated design tools has humble beginnings.

BY KENNETH WONG

zSpace's display tablet with stereoscopic glasses and virtual cutting tools allow those outside engineering and manufacturing to interact with 3D technology. *Image courtesy of zSpace.*

Two years ago, while attending Dassault Systèmes' SOLIDWORKS World user conference, Bob Conley saw a demonstration of the eDrawings mobile app, a CAD file viewer for tablet users. What won him over was the app's augmented reality (AR) function, which enabled users to project CAD models into a live feed from the iPad's camera view. So he promptly purchased an iPad and the eDrawings Pro app from iTunes. The $810 investment ($800 for the device, $10 for the app) laid the groundwork for AR in his design consulting business, Interactive CAD Solutions.

"In the week after I got the app, I generated more than $20,000 in sales," Conley says. On his business' home page, Conley offers a downloadable PowerPoint deck with a bullet list of services. Augmented reality is on the very top of that list.

Conley belongs to a small but growing group of CAD users who see AR as a legitimate design and engineering tool, not a purposeless novelty. The adoption of augmented reality may be slow among small businesses with limited expenditure for experimentation. However, according to CCS Insight, an analyst firm that tracks mobile communication and Internet commerce, AR is "starting to gain traction in industrial and business arenas … Europe is currently the largest test bed for this technology, with numerous blue-chip companies across all sectors evaluating its capabilities."

CCS Insight predicts devices powered by AR and its twin VR (virtual reality) could become a "$4 billion-plus business in three years." With the promise of such real money, some hardware and software vendors are already shifting their R&D strategies and IP (intellectual property) acquisitions to cater to early adopters of AR and VR.

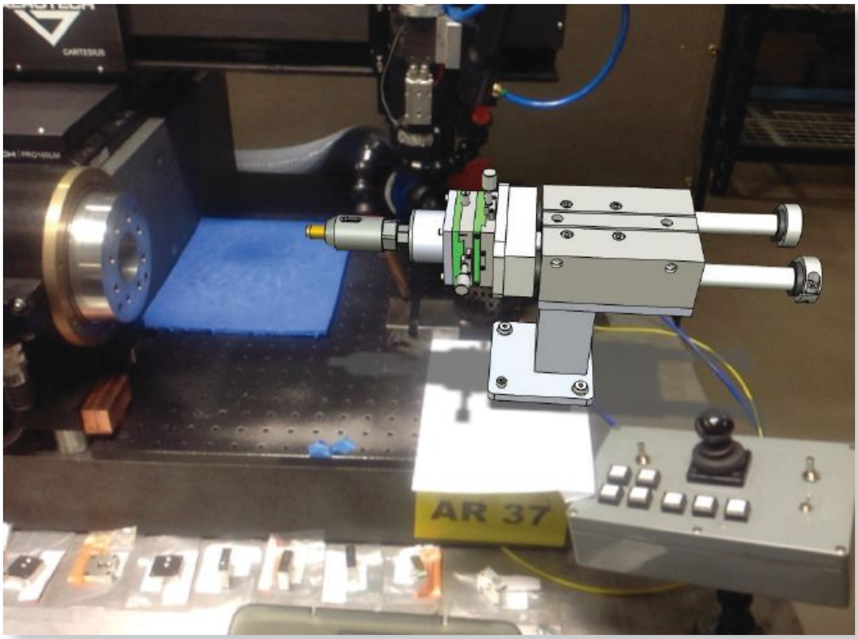
Augmented Reality to Go

For Conley, AR is more than showmanship and razzle-dazzle. Some parts are physically too big or bulky for him to haul to the client's site during design reviews. For those, Conley used to rely on onsite measurements and some educated guesses to determine how the designed part would fit into the client's facility or existing machinery setup. These days, he uses his business card as the digital replica of the new part.

"My two-fold business card has a global marker for [the] eDrawings iPad app," he said. "I just put down my card where the part was supposed to go, and check interferences." The app recognizes the marker as the placeholder for a specific digital model; therefore, through the tablet's camera view, the app projects the digital part into the real world. Through XYZ coordinates, the digital part's orientation is aligned to match the physical environment where the marker sits.

In early experiments with eDrawings' AR tools, Conley learned a valuable lesson about the computer-recognizable markers. "When I printed the global marker on my card the first time, I shrank it to fit the card," he recalled. That, he found out, caused his digital model to appear in a smaller scale in the app's window.

Being portable and lightweight, the tablet offers a tremendous advantage to Conley. It allows him to deploy AR at any given location. On the other hand, the device's limited memory capacity proves to be a current drawback. "One of the biggest challenges is working with large models," says Conley. "I haven't found a way to overcome that yet."



Bob Conley from Interactive CAD Solutions uses iPad-powered augmented reality to check how SOLIDWORKS models would fit into the client's machinery. *Image courtesy of Interactive CAD Solutions*.

eDrawings displays SOLIDWORKS models and industry standard neutral 3D formats (such as STEP or STL). But sometimes the clients give Conley files that are not supported by eDrawings. Conley's solution is to use GrabCAD Workbench, an online collaboration platform, to convert them to the right file format.

The Heart Beats Faster in Stereo

At the NAFEMS World Congress in June, Steve Levine, Dassault Systèmes' SIMULIA chief strategy officer, stood in an exhibit booth with a pair of stereoscope glasses dangling on his nose. He invited visitors to dissect a virtual heart, known as the Living Heart Project, loaded into the zSpace virtual reality display as a 3D model.

According to Levine, what stereoscopy offers is a sense of scale and the ability to experiment without jeopardizing a real patient. "If you show surgeons a computational fluid dynamics (CFD) model or a finite element analysis (FEA) model, they have a tough time grasping it," he said. "But if you show them this, they got it instantly. They'd take the heart apart, look at its cross-sections, and talk about how they might have operated on a particular patient's heart."

Dassault Systèmes, a 3D software powerhouse, is betting heavily on the notion that, in the future, consumers will want to pay for experiences (a combination of hardware, software,

Augmented Reality vs. Virtual Reality

Augmented reality (AR) uses special displays to inject a layer of digital objects and information into the user's observable reality. Google Glass is a good example of AR-capable hardware. It could enhance your view of the surroundings by streaming digital data relevant to the site, such as interactive maps and Wikipedia articles.

Virtual reality (VR) uses special displays to let you experience an artificial digital environment. A good example of this is the Pure Land exhibit from the City University of Hong Kong. The exhibit lets you take a virtual tour of an ancient cave adorned with Buddhist murals. In this case, the artificial environment is a digital replica of the real site in Dunhuang, China; however, VR environments could also be completely fictional.

VR content is created by capturing physical environments in digital form or modeling digital worlds from scratch. VR environments might also be incorporated into AR experiences. For example, while a factory worker inspects the physical plant, the detailed CAD model of the same plant could be streamed to his or her Wi-Fi connected AR eyewear.

apps and services); therefore offering them products alone will no longer be sufficient. Life sciences is one of the new markets the company is actively courting. Levine and his colleagues recognize a high-end CAD program like CATIA would be more an obstacle than a tool for the surgeons and medical professionals. The learning curve alone would be discouraging to those who are outside the engineering and design disciplines. The Living Heart on zSpace is a tailor-made solution, comprising a detailed 3D heart model loaded on a portable stereoscopic tablet with virtual cutting tools. It's the type of offering that can help Dassault Systèmes break into new markets beyond traditional manufacturing.

From Entertainment to Engineering

"VR is one of the most exciting things to happen to CG in the last decade," says Vladimir Koylazov, co-founder and lead developer for V-Ray rendering software at Chaos Group. He and his colleagues are laying the groundwork for the era of stereoscope VR content. In June, the company announced the release of V-Ray 3.2 for 3ds Max, a free upgrade that includes two new VR camera types to "render stereo cube maps and spherical stereo images for VR headsets such as Oculus Rift and Samsung Gear VR."

The technology offers a more in-depth look and added element of interactivity that traditional designs may not. "With VR, you can make informed decisions about whether something would work correctly," says Lon Grohs, chief commercial officer at Chaos Group. "Virtual prototypes in VR are so much more realistic than what people have seen before. I could inspect the virtual prototype as if it were the real thing, before the real thing is available."

Additionally, stereoscopic content offers a sense of scale, a critical factor in all engineering judgments. "If you walk into a VR atrium, it's far closer to walking into the real atrium than you would feel with another medium. If you're designing a car, for example, you'd be able to judge if the door handles are in the right places," says Christopher Nichols, creative director at Chaos Group.

You can explore VR environments in regular flat panel displays, using the mouse and keyboard for path finding. However, experiencing VR content through immersive devices like the Oculus Rift or Samsung Gear VR gives you a more natural way to interact with the environment, also a better understanding of the volumes and distances represented by the 3D models.

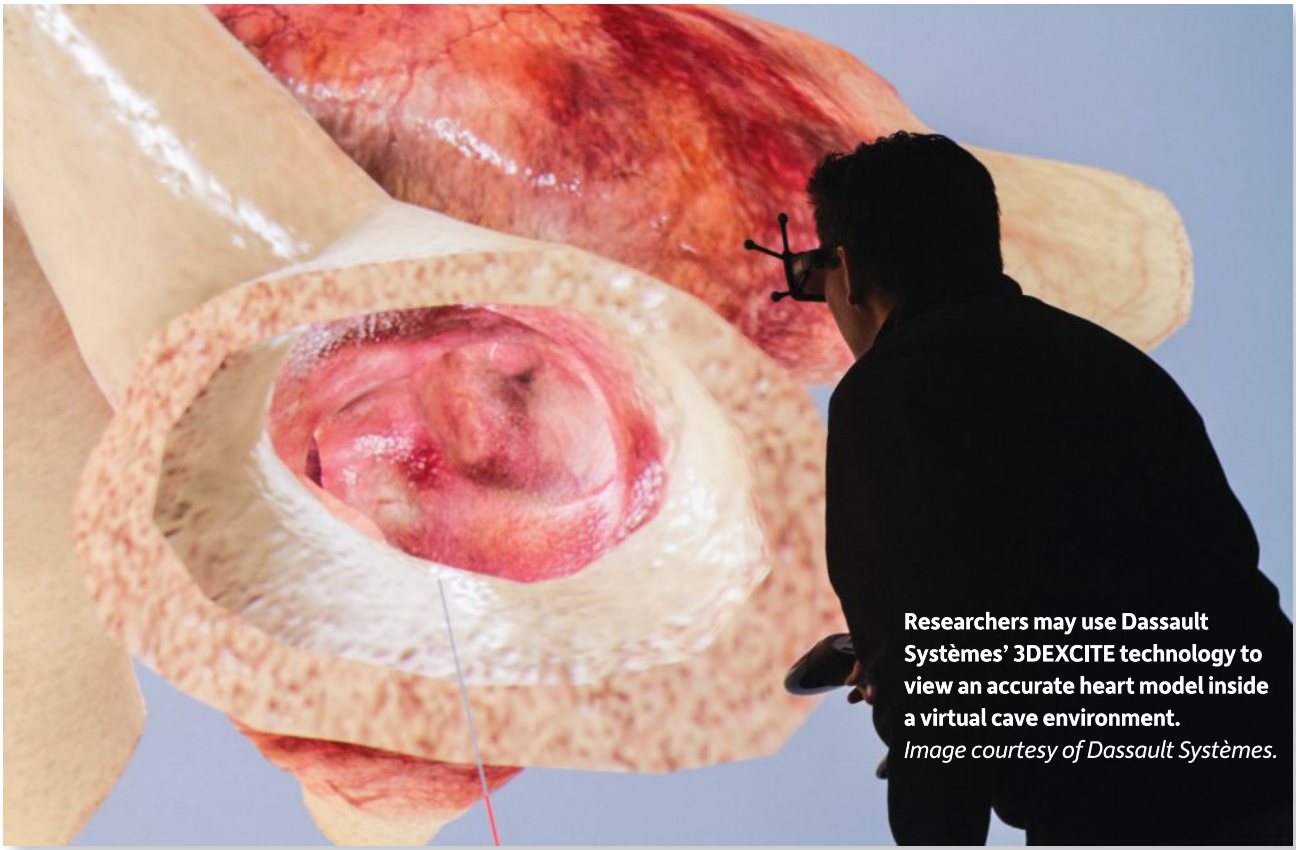
Using VR for product development, however, adds a greater burden on the content creator, the one who produces the digital prototype or environment that will be uploaded to the VR goggles. The dimensions of the objects in the VR world have to be geometrically precise, not approximations (as they might be in VR-powered videogames and movies).

Currently, there's no straightforward way to create VR content in CAD software; therefore, VR content will most likely be created by importing CAD-authored 3D content into rendering programs like 3dx Max or Maya.

For the novice VR content creators, Nichols offered a tip. "You have to pay attention to the intraocular distance [the distance between the virtual observer's eyes, represented by the distance between the two cameras in a stereoscopic rendering program]. Getting that distance wrong is like shrinking or expanding the [virtual observer's] head. If that distance is too big, then the world looks a lot smaller; if it's too small, the world looks too big," he says.

Cognitive Computing Coming Up

"We're moving from cloud computing to cloud, mobile and wearable computing — the convergence of the three," said Ahmed Noor, a scholar from Old Dominion University, as


Researchers may use Dassault Systèmes' 3DEXCITE technology to view an accurate heart model inside a virtual cave environment.
Image courtesy of Dassault Systèmes.

part of his keynote speech at the NAFEMS World Congress 2015.

He envisioned a future where designers and engineers might work with "cognitive systems that mimic the way humans work through natural language processing, data mining and pattern recognition." This, according to Noor, is the precursor to the next phase, "anticipatory computing, in which cyber-physical systems can recognize the user's needs by watching the user, and provide them with tools without being asked." Whereas today's human-machine interaction is limited to robotics and software, Noor thinks we will eventually interact with "multimodel virtual holography."

Some groundwork for Noor's vision may already be on the way. This April, Vuzix Corporation, which supplies video eyewear and smart glasses, snatched up U.S. Patent numbers 6243054 and 6559813 for an undisclosed sum.

"Gesture control with AR applications and managing the ambient light, especially in optical see-through glasses, is critical in the operation of wearable display technology and especially augmented reality in smart glasses. Vuzix acquired these additional patents to secure a stronger IP position for its current and soon to be released products," says Paul Travers, CEO of Vuzix, in his explanation of the IP acquisition.

According to the patent office's public records, Patent 6243054 is described as "a computer system [that] stereoscopically projects a three dimensional object

Gaming Reality

Virtual and augmented reality technologies are being driven, in large part, by the computer gaming industry. AMD and NVIDIA are no stangers to migrating technologies from the entertainment to the professional design industries. Both have virtual reality efforts underway.

According to the company's website, "LiquidVR is an AMD initiative dedicated to making VR as comfortable and realistic as possible." The company is focusing its VR efforts on what it calls "presence," or how immersive the virtual world seems to be.

NVIDIA's approach is called GameWorks VR, which it describes as "a set of APIs, libraries, and features that enable both VR headset and game developers to deliver amazing VR experiences."

The companies' solutions could go a long way toward reducing the hardware requirements needed for immerseve VR and allowing software developers to make it more accesible to other industries.

having an interface image in a space observable by a user. The user controls the movement of a physical object within the space while observing both the three dimensionally projected object and the physical object."

Patent 6559813 is "a virtual reality system [that] stereoscopically projects VR images, including a three dimensional image having an interface image in a space observable by a user. The display system includes a substantially transparent display means, which also allows real images of real objects to be combined or superimposed with the virtual reality images." Both patents promise "a way to contact user interface images without contacting a keyboard or a mouse or the display itself."

Rethinking the Human-Machine Interface

Finding the prevalent terms AR and VR inadequate to describe its new product HP Sprout, HP introduced another term — blended reality (BR). At its core, HP Sprout may be an all-in-one multi-touch computer, but the mounted projector and a camera, a paper-like surface for projection and sensors offer multiple methods of interacting and capturing content, both in 2D and 3D.

The emerging AR, VR and — to borrow HP's vocabulary — BR devices will likely colonize the general consumer market and entertainment industry before they find acceptance in the more conservative engineering market. But when they do, design and engineering software vendors may confront one of their biggest challenges. Adapting legacy CAD software code that relies on the mouse and keyboard to a new breed of portable, wearable, head-mountable computers that invite touch, natural speech, and gesture input won't be easy. **DE**

Kenneth Wong is Desktop Engineering's *resident blogger and senior editor. Email him at kennethwong@deskeng.com or share your thoughts on this article at deskeng.com/facebook.*

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→ **CCS Insight:** CCSInsight.com

→ **Chaos Group:** ChaosGroup.com

→ **Dassault Systèmes:** 3ds.com

→ **HP:** HP.com

→ **Interactive CAD Solutions:** IntCADSol.com

→ **NVIDIA:** NVIDIA.com

→ **SOLIDWORKS eDrawings:** eDrawingsViewer.com

→ **Vuzix Corp:** Vuzix.com

→ **zSpace:** zSpace.com

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VR Speeds Design

The FIVE Lab uses a virtual reality headset in conjunction with a specialized glove to control designs. *Images courtesy of Ford.*

The technology gives engineers at Ford and other companies an early look at designs.

FRANK J. OHLHORST AND JESS LULKA

Ford Motor Company is leveraging virtual reality technology to eliminate many of the design challenges faced by today's automobile manufacturers. The company, which says it is the first automaker to use ultra high-definition immersive virtual reality, has made impressive strides in speeding up the design process and prototyping products without having to physically construct them first.

The secret behind the company's success comes in the form of the Ford Immersive Vehicle Environment (FIVE) Labs. The FIVE Labs function as virtual vehicle prototyping rooms. They include a dummy car rig with a seat and steering wheel, an 80-in. 4K monitor and a computer rig.

Users wear a pair of VR (virtual reality) goggles and a glove, each of which are monitored by 19 motion tracking cameras dotted around the walls to capture the precise location and orientation of the wearer. The goggles allow users to observe realistically interpreted CAD models of a vehicle, which can be placed in a variety of different environments. The users can walk around the virtual vehicle, as if it was parked in an actual environment, such as a new vehicle showroom.

"We now have Ford designers and engineers around the world working together virtually — inside and side-by-side — on the same product," says Elizabeth Baron, Ford Virtual Reality and Advanced Visualization technical specialist. "By using this technology, designers and engineers can quickly transition from one car design proposal to another, and they can study and identify which is the best option."

Users can also sit down in the test rig and experience the interior of the vehicle. Baron describes this experience as "uncanny, and feeling just like sitting in a real car." She says the level of detail is extraordinary. Ford uses the virtual rigs to test for quality, engineering issues, fit and finish of the CAD designs long before engineers move toward creating a clay model or any other physical prototype.

A New Approach to Design

Baron describes the virtual lab as a collection of high-performance computing (HPC) components, which are integrated with advanced simulation software elements to create a 3D virtual world that allows designers and engineers to experience automotive designs. Simply put, by using a totally immersive virtual environment, Ford's designers and engineers can experience a vehicle the same way a customer would in a showroom.

Beyond the immediate benefit of visualizing design changes before actual production, the virtual lab offers many other advantages. For example, engineers collaborate in real-time, simultaneously experiencing the same point-of-view. By creating a shared 3D virtual reality, Ford's designers and engineers are able to quickly overcome traditional design challenges. The lab also allows multiple designers and engineers from different geographic locations to work together in real-time on vehicle design, without having to travel to a central location. Ford has accomplished that by integrating the virtual immersion capability of the virtual lab across multiple locations.

"Thanks to a host of recent upgrades to the lab and its establishment in other Ford development centers around the world, Ford became the first automaker to use the technology on a global level, thereby enabling simultaneous input from designers and engineers working on the same product at the same time," says Baron.

Throughout 2013, Ford designers and engineers examined over 135,000 details on 193 virtual vehicle prototypes, all of which were virtually built in the Immersion Lab. "Such an achievement would have been impossible just a few years ago," says Baron.

The benefits of 3D immersive design validation have become easy to identify and have been demonstrated by delivering improvements for the customer in such vehicles as the Ford Fusion and 2015 Ford Mustang. For example, engineers were able to examine the placement of the side view mirror and rear brake light in the Ford Fusion before creating a physical representation of the vehicle.

In the case of the side view mirror, the goal was to optimize visibility without impacting the design of the car. The position of the side view mirror went through several virtual iterations before the team decided that a door-mounted design was optimal. The LED center brake light underwent a similar process, with engineers determining that an ultra-thin unit maximized visibility without losing style.

Baron and her team were able to offer several other solutions to design problems before any production or physical prototyping took place. Those improvements ranged from the placement of pedals in right-hand drive vehicles to the integration of entertainment systems and environmental controls.

The benefits derived from the system have led Ford to expand the capabilities of the FIVE labs since their introduction as a proof of concept. The transition from concept to reality actually took place very quickly, even though Baron faced several internal challenges.

"One of the most difficult goals was getting buy in from various departments. We had to convince stakeholders of the viability of the technology and overcome the resistance to adopting virtual design concepts," says Baron. "However, users have quickly realized the benefits offered and have had a profound realization that observing a vehicle's design using a 1:1 relationship is far superior to looking at numbers on an Excel spreadsheet."

Constantly Improving Technology

Ford continues to improve and distribute FIVE Lab technology by adding it to design centers in Australia, Germany, China, India, Brazil and Mexico. Recent enhancements to the system include 4K "power-wall" displays, which offer four times the resolution of a high-definition television, enabling Ford designers and engineers to better evaluate and review 3D models of vehicles in real time, globally.

"We moved to the global One Ford plan so that international collaboration could lead to the development of globally appealing vehicles," Baron says. "With this technology, designers and engineers can enhance their ability to achieve that goal — while also improving vehicle quality."

New software enables engineers to study hundreds of elements inside and outside of a vehicle, ensuring that vehicles coming to market "have been painstakingly inspected for usability, consistency and design effects that are now discernible in the sophisticated shadows and real-world lighting conditions the

Engineers can place the virtual model in a variety of realistic environments, including roads, urban landscapes and vehicle showrooms.

tools provide," according to Ford.

"Other enhancements, such as the new 4K-resolution power-wall, give Ford engineers a life-sized view of issues that arise in vehicle development. That life-sized view is further enhanced by pairing the actual movement of designers and engineers with virtual movement, regardless of their physical location," says Baron. "The system links Ford workers globally to simultaneously analyze and inspect the same virtual vehicle on a scale not possible before. The newest software provides a virtual experience almost indistinguishable from a real vehicle."

In its quest to improve the immersive experience, Ford has deployed a technology called the Programmable Vehicle Model, which allows engineers to be immersed in a lifelike virtual vehicle. Content evaluators are able to sit in the Programmable Vehicle Model, which consists of an interior laid out with a steering wheel and seats, and be able to both visualize and feel components.

Engineers can test steering wheels, door handles and other major touch points for placement relative to the driver's seat. The Programmable Vehicle Model supports many virtual 3D capabilities, allowing designers who are located outside of the vehicle in the Virtual Space to collaborate with others, who may be inside the Programmable Vehicle Model.

Furthermore, the Programmable Vehicle Model is integrated with a cave automated virtual environment (CAVE), which provides a wide field-of-view virtual environment, allowing Ford engineers to rapidly test design and placement components to study visibility and customer preference.

Beyond the FIVE Lab

Even though the equipment used in Ford's labs is highly specialized, the applications for virtual reality-based product design are vast. Rave Computer, which provides some of technology for Ford's FIVE Lab, is helping companies and government organizations create in a more immersive environment with its RAVE CAVE — also known as the Reconfigurable Center for Automated Virtual Environments.

Located in Sterling, MI, the RAVE CAVE is run as a non-profit organization through a research partnership between Rave, TARDEC and DC3S. Through this collaboration, the agencies promote modeling, simulation and visualization technology, creative R&D and STEM education. In addition to giving small- and mid-sized firms access to virtual prototyping capabilities, the CAVE also provides software companies the

Virtual Reality on the Go

While the RAVE CAVE and Ford FIVE Lab are examples of completely immersive prototyping environments, you don't necessarily need an entire building to bring virtual and augmented reality into the product design process. This year, Microsoft announced the HoloLens — a holographic computing platform that is designed to integrate holograms within physical spaces. With this technology, the company hopes to usher in a new era of design that enables engineers to interact directly with the projected models.

The goal of this headset, according to Microsoft, is to provide a product that allows users to size, shape and manipulate models with their own hands and voice recognition. While some of these features are under development, the HoloLens is already being implemented in projects with the NASA Jet Propulsion Laboratory to explore 3D renderings of Mars and bring virtual reality to the International Space Station.

Virtual reality is also finding its way into the consumer market, with companies such as Oculus VR and Sony developing their own headsets for gaming and entertainment. This summer, Oculus revamped its Rift headset to have a more ergonomic design, AMOLED low-persistence displays and attachable hand controllers. Additionally, Sony's Project Morpheus promises a completely immersive gaming experience with surround audio and encompassing visuals. And while these headsets are focused on enhancing the consumer experience — they also represent increasing availability of the technology — which could mean a greater potential for eventual integration into the engineering workflow.

— J. Lulka

chance to develop and perfect their own platforms. Current software providers include Autodesk, Intel, ESI Group, RTT (now Dassault Systèmes' 3DEXCITE) and Mechadyne.

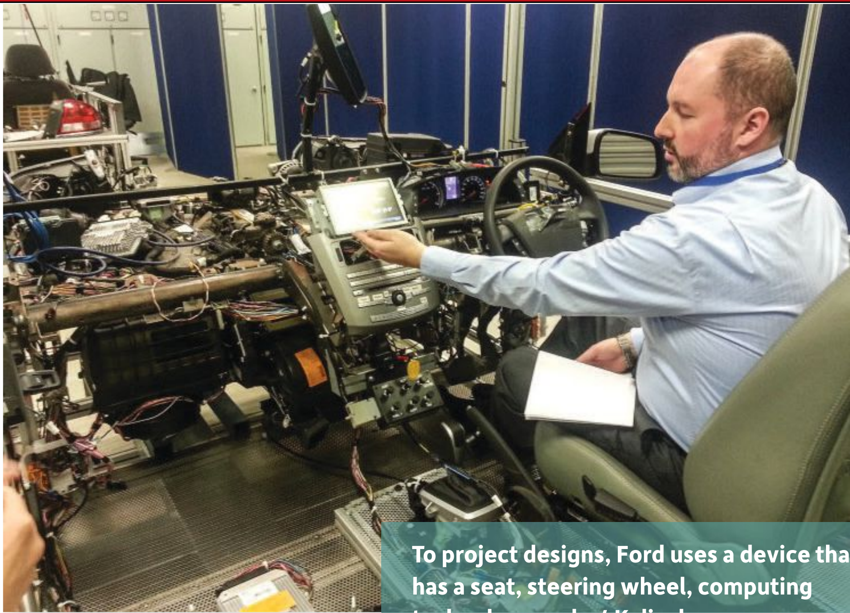
By using the CAVE for product design and testing, users have access to scenarios that might not be possible with a physical prototype. For example, engineers can place an automobile in many different environments. Within the CAVE, they can see how the car reacts to different weather conditions, a process that would traditionally require extensive physical testing over a long period of time. However, the CAVE enables teams to view all of these scenarios within several hours. "It lets engineers get a lot further along without creating a physical prototype than they otherwise would be able to," says Matt Moy from product development at Rave Computer.

Additionally, since the technology at the CAVE is all encompassing, users can see designs in a whole new light. The company recently showcased a model of the human body to a group of physicians. "These physicians were not only able to see the body, but place their head [in it] and view the heart from the inside out," says Rick Darter, president and CEO at Rave Computer. "[The technology] gives you that immersive capability of seeing underneath, inside of, as well as the actual figure of what you're trying to demonstrate."

Looking Ahead

Moving forward, this type of technology is expected to become more mainstream as firms find more uses for immersive visualization environments. "If you're an engineer and you're designing something, it's pretty much a no-brainer to take the opportunity to look at [the product] before building something to look at. And so as the cost of the technology comes down, the use of this technology is increasing," says Karl Rosenberger, director of product development at Rave Computer.

As Ford comes to rely on virtual immersion as part of the design process,



To project designs, Ford uses a device that has a seat, steering wheel, computing technology and a 4K display.

many of the engineers are requesting additions to the experience, creating a rapidly evolving virtual working environment.

"One of those additions came in the form of adding 'X-ray vision,' which gives users of the immersion lab the ability to see inside and through a vehicle structure to study how various structural, mechanical and electrical systems interact within the architecture. Our new technology is more refined, and allows us to see and understand complex engineering issues while considering aesthetics and design," Baron says. "We are incorporating light and shadow calculations in real time, which adds more depth and authenticity."

Baron is quickly able to highlight the benefits of the system, including what she calls "a holistic approach to vehicle design" and "a profound realization of vehicle design." As the system stands now, new vehicle designs can be imported and visualized in a matter of days, accomplishing what once took many weeks to create clay models and mockups of features.

Those benefits have led Ford to further expand its technological design capabilities, including the recently created Ford Research and Development Center in Silicon Valley. The new center is helmed by Dragos Maciuca, a former Apple engineer with experience in consumer electronics, semiconductors, aerospace and automotive technology.

Ford plans to build a team of 125 professionals under Maciuca, which would make the company one of the largest dedicated automotive research teams in the valley.

"We want to create a collaborative environment, an environment that's very unique to Silicon Valley," says Raj Nair, vice president of global product, Ford. Indeed, some of the projects that are already underway include collaborations with several universities and technology companies. **DE**

Frank Ohlhorst *is chief analyst and freelance writer at Ohlhorst.net.* **Jess Lulka** *is associate editor of* Desktop Engineering. *Send e-mail about this article to DE-Editors@deskeng.com.*

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→ **Oculus VR:** Oculus.com

→ **Rave Computer:** Rave.com

→ **TARDEC:** Army.mil/tardec

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Answers to Your Workstation Questions

Insights on how to assemble the right hardware for your design engineering needs.

BY BRIAN ALBRIGHT

There are a variety of factors to consider when selecting the optimal engineering workstation configuration. *Desktop Engineering* questioned leading CAD value-added resellers (VARs) to discover how they guide their clients through the hardware selection process.

Q: What factors (such as model size, use of simulation and photo-realistic rendering) go into determining a hardware recommendation for CAD users?

A. Adrian Fanjoy, technical services manager, Computer Aided Technology (CATI), SOLIDWORKS Reseller: Photo rendering and simulation have a big impact because they would determine whether or not you go with a system with more than four cores. That drives up the cost of the machine drastically.

After that, we generally look at the size and complexity of the models and the assemblies themselves.

The number of cores when dealing with just SOLIDWORKS is pretty standard; you go with four cores no matter what. What we are really doing is adjusting the amount of RAM and the processor speed. No matter how big the assembly is, you will benefit from an increase in processor speed.

A. Chris Teague, senior applications engineer, Saratech, Solid Edge Reseller: Model size and the size of the assemblies. And then, of course, whether they are going to run FEA (finite element analysis), detailed rendering or complex analysis work. Those customers will need more computer horsepower.

A. Matthew Burke, principal and CEO, M2 Technologies, Autodesk Reseller: The two most obvious factors are how large the assemblies are and how complex they are. Beyond that, are they doing FEA, CFD (computational fluid dynamics) analysis, or using a CAM package on the same workstation? More subtle factors include how often they upgrade their engineering hardware. If a customer has a regular schedule, you might not recommend the highest end machine; but if a customer only upgrades hardware every three to five years, they really need to purchase as much horsepower as they can afford today.

Q: Are there any common misconceptions about hardware needs you routinely run across with CAD customers?

A. Teague: People confuse the number of CPUs with single-thread performance. With CAD, even with FEA, single-thread performance is more important. I've seen people get a huge number of cores with a low clock speed. There are very few applications that take advantage of a huge number of cores.

A. Burke: Yes, that all machines are the same. I also think customers don't understand that part complexity is as important as assembly size with regards to performance. I once had a customer who didn't understand why his part with over 250 unique individual holes, all at unique angles, all with unique features, was causing a significant degradation in performance.

Q: Do you recommend a multi-core processor for CAD?

A. Fanjoy: Yes, four cores, and only four cores. No more than that. The caveat would be if they are going to use other applications simultaneously with CAD, they might need more cores.

A. Teague: I do recommend multi-core, but not in large numbers. For most CAD users a quad-core at a higher clock speed is all you need. Most users don't need that many cores. Even with FEA, only some of those systems need large numbers of cores. Often they are better off with a faster SSD (solid-state drive), faster memory and a higher clock speed.

Q: How do you determine the amount of RAM a CAD user should invest in?

A. Fanjoy: It's not too detrimental to over-buy. We don't recommend anybody get under 8GB, because it's almost a given anyway. But do you need 16GB or 32GB? Typically for large assemblies, 16GB is enough, and for super-large assemblies they may need 24GB to 32GB, but those are gigantic assemblies of 15,000 to 20,000 components or more.

A. Teague: The rule of thumb on that is we don't recommend anything less than 8GB for anybody. We try to push everybody to 16GB, because that's a general purpose number. If they are running larger assemblies, then 32GB on the desktop is good. More than that is for guys running dedicated servers.

A. Burke: We try and keep this simple: put as much RAM in as your budget will allow. Certainly there are published guidelines available for both minimums and recommendations, but they generally don't take into account the other applications that are going to be up and running.

Q: What processes do you recommend be carried out on an SSD vs. a traditional spinning hard disk?

A. Fanjoy: At this point, the only thing we recommend a traditional hard disk for is massive storage. If you use a PDM (product data management) system, and you're operating with local cache, and you keep that clean and keep maintaining that so you don't overburden it, a small 240GB SSD should be fine for any user.

A. Burke: In particular, FEA and CFD benefit a great deal with an SSD drive. SSDs have come down considerably in price, so they almost always tend to be worth the investment in a CAD workstation because they are simply so much faster.

Q: In your opinion should a CAD user invest in a top-of-the-line, mid-range or entry-level graphics card, or are integrated graphics sufficient?

A. Fanjoy: That's really going to depend on what you are doing. There is a point in just a couple of circumstances where entry-level graphics aren't going to do what you need. The majority of our users would get away with onboard graphics just fine, at least that's what my testing is showing. Areas where you'd need to look at a mid-range card would be with highly faceted models that have intricate details, and I mean immense amounts of small detail. What we've found is that as assemblies get larger, the ability of the graphics card to keep up with the data becomes a problem. If there's degradation, you can always lower the level of detail in the model to accommodate for that and still get smooth rotation. Onboard graphics will work for even more situations if you are willing to sacrifice that level of detail while spinning the model.

A. Teague: We don't ever recommend integrated graphics, because we have had so many problems with them not running OpenGL well. All the tools are running OpenGL, and the only cards that are tuned to that are the professional cards. There's no reason to not go top-of-the-line for graphics except for budget. That's an easy thing to upgrade later.

A. Burke: This is difficult to answer without additional context. Generally speaking our typical recommendation is a mid-range card unless we know, through qualifying, the type of design and work occurring would substantially benefit from a top-of-the-line card. Usually we say, save money here and invest in more RAM.

Q: Do you recommend professional workstations for CAD or are consumer-class PCs sufficient?

Learn More

If you'd like to learn more about the best hardware setup for SOLIDWORKS, download the "Maximize SOLIDWORKS Performance" white paper produced by *Desktop Engineering* and sponsored by Intel. This free, 12-page paper is based on CATI's in-depth research and benchmarking of the software.

Download "Maximize SOLIDWORKS Performance" here: deskeng.com/de/maximizesw

A. Fanjoy: The only time we tell people that a consumer-class PC is sufficient is if they are using a home-use license to build a deck at their house. Everything else should use quality graphics.

A. Teague: We do recommend professional workstations, because of the OpenGL issue. Consumer machines use consumer-class cards, but DirectX drivers aren't as well tuned for OpenGL.

A. Burke: CAD is expensive, and designers and engineers are expensive — give them a machine with the architecture capable of allowing them to perform their jobs efficiently. To put it another way, don't ask Jeff Gordon to win at Daytona in an SS sedan from the local Chevy dealer.

Q: Is there a rule of thumb for how long a CAD user should wait before investing in a new workstation?

A. Teague: The general rule of thumb is three years, but that can depend on a lot of things. Did you buy at the high end three years ago, or did you get a cheap workstation? After three years look around and see what the technology is now vs. what you bought. Even if the hardware isn't obsolete, a fresh install of Windows might make things faster.

A. Burke: Technology evolves at a very rapid pace, but for most folks the decision on hardware investment is happening on a corporate IT level so they have little control over it. If they do, we try and tell customers they should be on a two- or three-year upgrade cycle. Much longer than three years, we start to see the hardware becoming a constraint to the users. DE

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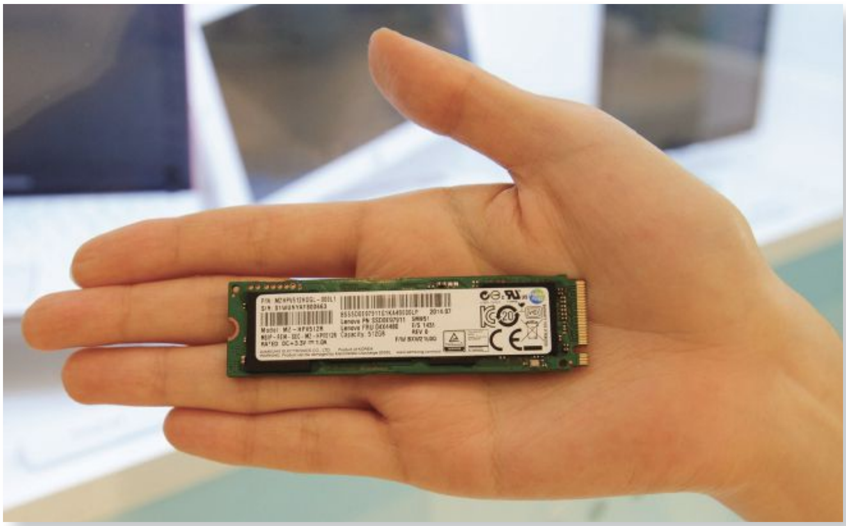
New Horizons in Data Storage

The ubiquitous hard disk drive's days are numbered, both for single-user devices and group data storage.

BY RANDALL S. NEWTON

The various technologies that define modern computing do not mature at equal rates. For example, the first smartphones caught many people by surprise; today's intense competition keeps smartphone vendors pushing the boundaries to exceed expectations. By comparison, watching PC operating systems mature feels like watching paint dry.

Data storage technology falls somewhere in between: For those who pay close attention, improvements in data storage hardware and standards are incremental and obvious. But if the only time one thinks about data storage is when you equip a new office or update a workstation, it can be like visiting a 12-year-old whom you last saw at age seven: The change is astonishing.



The new Samsung SM951 leads a new generation of ultra low-power, high performance solid-state drives (SSDs). ***Image courtesy of Samsung.***

When talking about storage technology, it is important to distinguish between single-user data storage installed in a PC or notebook, and group or enterprise data storage installed in servers. Group storage technology continues to improve at a steady pace, but there has been a recent inflection point for single-user storage technology — or two inflection points if it has been a while since you last looked.

Single-user Data Storage

The older change in single-user data storage is the rise of the solid-state drive (SSD) as an affordable option to the mechanical hard disk drives (HDD) we've been using for the last 30 years. SSDs are a permanently installed version of USB thumb drives, which have largely replaced our need for CDs and floppy disks for spontaneous and personal data sharing. Because SSDs have no moving parts, they retrieve and store data much faster than HDDs. For years the cost per megabyte difference between HDDs and SSDs was substantial, but the gap has closed considerably. The current rule of thumb for pricing HDDs is $0.06 per GB; $0.10 per GB for SSDs. Many computers for professional use now combine both technologies to achieve a cost-effective balance between size and speed; high-performance consumer and professional computers are quickly moving to SSDs only.

The newer inflection point in single-user data storage is a shift in how the storage is connected to the computer. For years the SATA design standard stood as the common standard for storage interface, supported by RAID for data integrity in workstations and servers. In recent years, the SATA design has been showing its age, becoming perceived as a bottleneck to improved performance. Instead of inventing a new standard, the computer industry has decided to switch to another interface already found inside computers, the PCIe standards used for graphics cards and custom devices.

SSDs using PCIe instead of SATA first came to market

The new HP Z Turbo Drive G2 can increase data I/O transfer speeds by up to four times, when compared to previous SSDs. *Image courtesy of HP.*

in 2014. Samsung rocked the market in January by introducing an SSD with read/write speeds roughly four times faster than the fastest SATA-based SSDs currently on the market. At first the SM951 was only sold to computer vendors, but in May it became available for retail purchase. The SM951 requires a new physical connection standard, M2, which means you can't run out and buy the new Samsung SSDs for all of the old workstations in your office. (Though, keep reading, there is a fix.)

The move to running SSDs on PCIe not only increases speed, but it also requires less space to install and less energy to operate than using SATA with SSDs or HDDs. Those benefits make it ideal for high-performance mobile workstations, where the space and power savings can be put to good use. There remains a trade-off when comparing such a cutting edge storage unit like the SM951 to mature HDD tech: the Samsung SM951 is available in 128GB, 256GB and 512GB options. Many workstation storage units today are 1TB or larger, and remain significantly less expensive than SSDs.

Not long after Samsung introduced the SM951, HP introduced a desktop SSD using the new technology. The HP Z Turbo Drive G2 puts the SM951 on a PCIe card that can be added to any desktop workstation. The G2 uses four channels of I/O to move data around, and completely bypasses the SATA connection. The speed increase remains at approximately 4x when compared to using HDDs, a speed bump that looks even better when dealing with large datasets.

Part of what gives the SM951 and products built from it such increased zip is a new hard drive controller interface — NVMe (non-volatile memory express) — designed specifically for SSDs.

Group Data Storage Trends

The growth path in single-user storage is pretty straightforward, moving from HDD to SSD technology for faster I/O and lower power consumption. But, the technology landscape for group data storage is not so simple. There are three major options today: Direct-Attach Storage (DAS), Network-Attached Storage (NAS), and Storage Area Networks (SAN). There is no single answer to the question: "Which is best for my workgroup?"

Below is a summary of each major storage system.

- **Direct-Attached Storage (DAS):** A low-cost, low-maintenance approach to data storage, in which hard drives are connected directly to a host computer. Best for small businesses and sole proprietors with a small budget and limited or no IT support. Not a good idea for sharing data among more than a small workgroup.
- **Network-Attached Storage (NAS):** Dedicated data storage and sharing through a network. NAS can provide features like RAID and swappable drives. A good approach for small businesses that have access to some IT support.
- **Storage Area Network (SAN):** A dedicated storage system offering high performance for a large number of devices or a high volume of data transfer. Compared with DAS or NAS, SANs are sophisticated and complicated; their installation and maintenance is best left to dedicated IT personnel, not a staff engineer who helps out with "computer stuff."

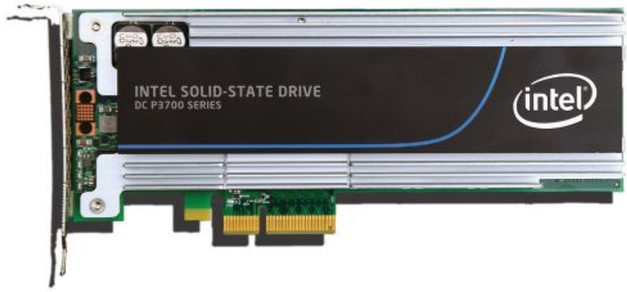
There are several important criteria to consider when evaluating group data storage systems:

- **Budget.** How much can you spend?
- **IT Staff.** Do you have dedicated IT staff to manage the storage system?

- **Backup and Recovery.** Manual or automated? Where is the backup stored? What happens if you lose files?
- **Performance.** How many users will be accessing the system? Are users all on-site or is remote access necessary?
- **Scalability.** Can the system easily expand to support more users? How much storage will you need in five years? Ten years?
- **Capacity.** How much data do you generate each month? What is the rate of data growth?

Beyond these considerations, there is the basic issue of which hard drive connection technology to use. The vast majority of PCs (business or consumer) use the SATA I/O standard to connect both HDDs and SSDs. There is also the more expensive and more reliable serial attached small computer system interface (SAS) protocol, popular in enterprise-class computing environments. If your organization is large enough to have dedicated IT staff and you want state-of-the art data throughput for long distances (as in a campus environment), SAS becomes a serious contender.

The SAS 2.0 specification was recently published, offering the possibility of 12Gbit per second multipath throughput in the coming years as manufacturers adapt. The new spec also supports adding SATA drives, although SATA speed will not increase just because they are on a SAS connection. SATA is still more popular overall as a data storage throughput standard, but the new SAS specification could mean additional market share in coming years, along with the possibility of SAS systems more suitable to small- to mid-sized business (SMB) environments.



The Intel DC P3700 is a 16TB SSD using NVMe technology designed for Xeon-based servers or workstations. *Image courtesy of Intel.*

Hitachi and Seagate are the most popular vendors of HDD SAS drives, in sizes up to 4TB, while SanDisk, Intel, HGST and Micron are the most popular vendors of SSD SAS drives. SAS technology still commands a premium price, but will fall as SAS 2.0 becomes more common.

Bigger-Faster-Cheaper Still Reigns

Demand will never stop growing for faster data access, higher read/write speeds, greater reliability, and lower prices. As long as Moore's Law means anything, storage options will continue to improve in all aspects. As with all facets of the fast-moving computer hardware industry, the time to buy is not about when a new standard or model comes out, but when your business can gain significant benefit from an upgrade or expansion.

There is still a price difference between HDDs and SSDs that will throw off some buyers, but prices continue to fall, especially as SSDs become more common in enterprise environments. **DE**

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INFO ➜ **HP:** HP.com

➜ **Hitachi:** HGST.com

➜ **Intel:** Intel.com

➜ **Samsung:** Samsung.com

➜ **Micron:** Micron.com

➜ **SanDisk:** SanDisk.com

➜ **Seagate:** Seagate.com

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

Extreme Power and Performance

The new Lenovo ThinkStation P900 delivers industry-leading results.

DAVID COHN

Lenovo unveiled its redesigned ThinkStation P Series last August at SIGGRAPH 2014. We previously reviewed the P300 entry-level workstation (deskeng.com/de/?p=21756) but had to wait awhile before we could get our hands on the company's new flagship workstation: the P900. To say that it was worth the wait would be an enormous understatement.

The Lenovo P Series has been redesigned from the ground up with the new ThinkStation P900 packing a tremendous amount of power in a large tower case that measures 7.8 x 17.6 x 24.4 in. (W x H x D) and tips the scales at 52 lbs. Thankfully, the new case includes three large handles — top front, top rear and bottom front — making it very easy to move around. Each handle is marked with a red touch point, a feature that becomes even more prominent once you open the case.

The front panel has a new FLEX module that gives users the option to only add the components they need, allowing customized configurations that can incorporate ultra-slim optical drives, 29-in-1 media card readers and iEEE 1394 FireWire and eSATA ports. In our evaluation unit, the FLEX module contained the power button, a 9-in-1 media card reader, a headphone jack and four USB 3.0 ports, including one always on and capable of charging USB devices. Below this are three vertical 5.25-in. drive bays, one of which contained a standard 5.25-in. DVD+/-RW dual-layer optical drive. An optional Blu-ray drive is also available. The rest of the front panel surrounding the FLEX module consists of a perforated metal screen with the ThinkStation logo.

The rear panel provides PS/2 keyboard and mouse ports, a 9-pin serial port, four more USB 3.0 ports, four USB 2.0 ports, two RJ45 network jacks and audio jacks for line-in, line-out, and microphone. The NVIDIA GPU (graphics processing unit) in our evaluation unit added its own pair of DVI ports and two DisplayPorts.

Totally Tool-less

Accessing the interior of the P900 could not be easier. A lever releases the left side panel, which then slides off to reveal an interior reminiscent of the HP Z Series workstations. Red touch points give a clear indication of where users can grasp components that require no tools to remove. In fact, we found that the only components inside the ThinkStation P900 that would require a screwdriver to remove were the CPU heat sinks. Even the motherboard itself can be removed without tools by pressing its unlock button. This makes customization easy.

The Lenovo ThinkStation P900 has been redesigned from the ground up. ***Image courtesy of Lenovo.***

For example, the ThinkStation P900 offers a 1300 watt power supply with a built-in self-test. The power supply can be swapped out in seconds by simply pulling on its red touch point. On the motherboard, just below the power supply, are the first of the 8 PCIe expansion slots: a pair of x16 Gen3 slots as well as an x4 Gen 2 slot. Cards inserted in these slots are held in place by a rear panel bracket with its own red touch point. In front of these slots is one of several cooling fans, which can also be removed without any tools.

Along the front portion of the case are four drive bays, separated by the FLEX module, and identified by red touch points. Each bay contains a cleverly designed tray with blind connectors that can accommodate a 3.5- or 2.5-in. drive, or a pair of 2.5-in. drives. Lenovo offers lots of drive options, including standard 7200 rpm drives ranging from the 500GB drive in the base configuration to a 4TB drive, as well as hybrid and SSD (solid-state drive) options. You can also order systems configured with multiple drives in RAID 0, 10, 1 and 5 arrays. Our evaluation unit came with a single 512GB SSD installed in the lower-most bay, adding yet another $432 to the total system cost. PCIe SSDs are also available, for a total of 14 drive options.

A large direct cooling air baffle occupies the center of the case. This baffle conceals the two CPUs and 16 memory sockets and ensures that these crucial components receive ample fresh air. The baffle is actually divided into three separate channels so that each CPU and the memory sockets receive their own direct

An air baffle conceals the CPU and memory sockets and ensures that fresh air reaches crucial components. *Images courtesy of David Cohn.*

Lenovo's modular design features red touch points, making it easy to remove and replace components.

flow of air. This baffle is also easily removed by pulling on its red touch point, as is the dedicated 4.5-in. cooling fan.

Although the base configuration comes with a single Intel Xeon E5-2609 v3 processor, the P900 is a dual-socket system and Lenovo offers 42 different CPU configurations. Our evaluation unit came with a pair of 3.1GHz Intel Xeon E5-2687W v3 processors, each with 10 CPU cores. This Haswell processor has a maximum turbo speed of 3.5GHz, 25MB of SmartCache and a 160-watt thermal design power (TDP) rating. The pair added $7,150 to the cost of our evaluation unit.

The P900 base configuration comes with 8GB of RAM, installed as a pair of 4GB modules. But this ThinkStation can accommodate up to 512GB of memory using 32GB DIMMs (dual in-line memory modules). Our system came with 128GB, installed using 16 8GB DDR4 ECC 2133MHz RDIMM modules, adding $5,625 to the total cost.

Below the CPUs is a second pair of PCIe x16 Gen 3 slots along with another PCIe x4 Gen 2 slot and a pair of PCIe x1 slots. The basic P900 comes with an NVIDIA Quadro K620 GPU. Again, Lenovo offers lots of choices, ranging from an NVIDIA NVS315 board up to a pair of NVIDIA Quadro K6000s. Our evaluation unit came with an NVIDIA Quadro K5200 graphics board installed in one of the x16 slots. The K5200 has 8GB of dedicated memory and features 2304 CUDA parallel processing cores. This double-width board added another $2,034 to the system cost and blocked access to one of the adjacent x4 slots. Again, boards are held in place by another rear panel bracket with its own red touch point and cooled by yet another easily removable cooling fan.

Other options include NVIDIA Tesla and Intel Xeon Phi coprocessors as well as a Thunderbolt I/O card, optional Ethernet server cards, an IEEE 1394 FireWire adapter, and Flex Bay storage options.

INFO ➔ Lenovo: Lenovo.com

Lenovo ThinkStation P900

- **Price:** $16,599 as tested ($1,826 base price)
- **Size:** 7.8 x 17.6 x 24.4 in. (W x H x D) tower
- **Weight:** 52 lbs.
- **CPU:** Two 3.1GHz Intel Xeon 10-core E5-2687W v3
- **Memory:** 128GB DDR4 ECC at 2133MHz
- **Graphics:** NVIDIA Quadro K6000 and NVIDIA Tesla K40 GPU accelerator
- **Hard Disk:** 500GB SanDisk SSD
- **Floppy:** None
- **Optical:** 16X DVD+/-RW
- **Audio:** Integrated HD audio (front panel: headphone; rear-panel: line-in, line-out, microphone)
- **Network:** Integrated gigabit Ethernet, two RJ45 ports
- **Modem:** None
- **Other:** Eight USB 3.0 (four front/four rear), four USB 2.0 ports rear, one 9-pin serial, PS/2 mouse and keyboard ports, two DVI ports and two DisplayPorts on NVIDIA board, 9-in-1 media card reader
- **Keyboard:** 104-key Lenovo USB keyboard
- **Pointing device:** Lenovo USB optical wheel mouse
- **Power Supply:** 1300 watts, 92%
- **Warranty:** Three years parts and labor

Amazing Performance

We have often commented on Lenovo's ability to combine and configure quality components for optimum performance, but the results we obtained from our ThinkStation P900 were nothing short of amazing. On the SPECviewperf benchmark (see page 42), the P900 scored at or near the top on every dataset, even when compared to systems equipped with more powerful GPUs and faster processors.

On the SPECapc SolidWorks benchmark, the P900 surpassed every other system we have ever tested except for the single-socket, over-clocked BOXX APEXX 2 (deskeng.com/de/?p=23627). And on the multi-threaded AutoCAD rendering test, no other system could compete against the equivalent of 40 CPU cores. The ThinkStation P900 completed our test rendering in just over 16 seconds, nearly twice as fast its nearest competition.

We also ran the new SPECwpc workstation performance benchmark, and here too the Lenovo ThinkStation P900 turned in some of the highest numbers we have ever recorded. Yet the P900 was nearly silent, even when under heavy compute loads.

Lenovo pre-loaded Windows 7 Professional 64-bit. Windows 8.1 Pro 64-bit is also available. Like other Lenovo workstations, the new ThinkStation P900 comes with a three-year on-site warranty. A 104-key USB keyboard and USB optical wheel mouse come standard. The system is ISV (independent software vendor) certified for applications from Adobe, Autodesk, Dassault, PTC, SolidWorks, Avid and Siemens.

Although Lenovo touts a P900 starting price of just $1,826, few are likely to buy a system with this much potential equipped with entry-level components. Even if you were not keeping a running tally as we listed the cost of each upgrade in our evaluation unit, you can already anticipate the bottom line. As configured, our Lenovo ThinkStation P900 priced out at a whopping $16,599, putting it among the top three most expensive systems we have ever tested, but still nearly $2,300 less than the Microway WhisperStation (deskeng.com/de/?p=18866). And we could have easily run the cost up even higher by adding more storage capacity, memory, and GPUs because our P900 still had plenty of room — and power — to spare.

Clearly, the Lenovo ThinkStation P900 is not for everyone. It is aimed at high-end CAD, CAE, research, rendering, special effects and the oil and gas industries. But if you need an extremely powerful system with lots of room to grow, your search has ended. The Lenovo ThinkStation P900 is a performance leader. **DE**

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Big, Bright, Fast & Loud

Origin PC delivers the massive ultra high-end Millennium Pro X2 workstation.

BY DAVID COHN

We agreed to review a workstation from Origin PC, a Miami-based company (founded by former employees of Alienware) that builds high-performance computers for gamers and hardware enthusiasts. According to the company's website, its systems are hand-built using only the best quality/performing components and tested for 72 hours before being shipped to customers. Origin touts the fact that it assembles its systems in the U.S. and will build a computer using any chassis available. The company sells small form factor, mid-tower and full-tower systems as well as mobile workstations.

Imagine our surprise when the system arrived in a wooden crate weighing 92 lbs. After removing 14 screws to open the crate, we found the computer itself packed in a thick cardboard box. Inside that box, the system was supported by foam inserts and inside the computer was a foam block to protect components and keep them from moving during shipping. This is standard for all large Origin systems.

Once we got it unpacked, we paused for a moment to admire its size. The Origin Millennium Pro X2 is billed as the company's mid-size professional workstation, but it is larger than many competitors' full-tower systems. The beautifully sculpted case measured 9.75 x 24.8 x 21.44 in. (W x D x H) and weighed 55 lbs. But the steel frame was clad in many places with flimsy plastic and the recesses that appeared to be handles were anything but — adhesive labels warned: "Not A Lift Point." The removable lockable side panel has a large window to show off internal components while a hinged front door conceals five 5.25-in. front drive bays plus five hot-swappable, lockable hard drive bays (the locks add $58 to the base price).

The Origin PC Millennium Pro X2 is housed in a massive case with a window in its side panel and interior lighting controlled by a small remote. Ten front panel drive bays are accessible behind a hinged door.
Image courtesy of David Cohn.

Our review unit came with a white removable panel on the left and the door hinged on the right, but the chassis can be oriented with the panel on the right and the door hinged on the left. Behind that door, two of the drive bays in our system contained a 40-in-1 media card and a 16x Blu-ray burner, options that added $21 and $86, respectively. You also have a choice of one of three standard colors a custom paint scheme.

A recessed area on the top of the case conceals the power button, four USB 3.0 ports, headphone and microphone jacks, a reset button, a manual fan control knob and a button to switch the fans to maximum cooling mode. Behind this recess, a perforated plastic panel covers the liquid cooling system's three large fans. When powered up, the Millennium Pro X2 filled the room with a constant 60dB hum that climbed as high as 75dB under compute loads — the equivalent of a vacuum cleaner's noise level. What's more, the fan controls did little to alter this constant din.

The rear panel provides six more USB 3.0 ports, two USB 2.0 ports, a PS/2 keyboard/mouse socket, two RJ-45 network connections, an optical S/PDIF output port and six audio jacks (separate microphone and line-in jacks as well as line-out/front, side, rear and bass output speaker channels).

The interior is lit by an array of LEDs and a small remote lets you select from 16 light colors and four lighting effects, including flash and strobe. You can also dim these lights or turn them off entirely. Ultimately, we found the lighting effects to be quite distracting.

Configuration Options

Origin gives customers a huge range of options to choose from and guides them through the configuration process with a multi-step online wizard. The first step is to select a single or dual CPU. The Millennium Pro X2 we received is a dual-CPU system based on an ASUS Z10PE-D8 WS motherboard with a base starting price of $3,780. A pair of 2.4GHz Intel Xeon E5-2630 eight-core CPUs, 32GB of memory and a 500GB standard hard drive are included in that price, but no graphics card. From there, the configuration fun begins. You can choose your case orientation and color and then start adding and upgrading components.

Our system included a Frostbyte 360 X2 sealed liquid cooling system with its hoses routed to the radiator mounted below the perforated grill on the top of the case (a $68 option). Our evaluation unit was also equipped with a pair of Intel Xeon E5-2687W v3 10-core Haswell CPUs. These processors, which added $3,162 to the cost of the system, have a base frequency of 3.1GHz, a maximum turbo speed of 3.5GHz, 25MB cache, and a thermal design power (TDP) rating of 160 watts. Origin offers a choice of 11 different CPUs including a pair of 18-core E5-2699 v3 CPUs.

To ensure adequate heat transfer from the CPU to the cooling system, our X2 also included the optional Gelid GC-Extreme thermal compound ($15). And because our system would be completely tricked out, Origin included its top-of-the-line 1500 watt 94% efficient Corsair power supply, which added another $327. You also have your choice of power supply cable colors.

The ASUS motherboard provides seven PCIe Gen3 x16 slots and can support up to four gaming cards or two workstation-class GPUs (graphics processing units). Origin offers six different NVIDIA gaming cards and a choice of seven NVIDIA Quadro or three AMD FirePro cards. Our system came with an NVIDIA Quadro K6000 GPU, featuring 12GB of discrete memory and 2880 CUDA (compute unified device architecture) parallel processing cores. Origin has since replaced this with the Quadro M6000, a $5,244 option with 12GB of GDDR5 memory and 3072 CUDA cores.

Origin also included an NVIDIA Tesla K40 GPU accelerator, providing an additional 12GB of GDDR5 memory and another 2880 CUDA cores. This is the same GPU accelerator provided last year by Microway in the WhisperStation we reviewed (deskeng.com/de/?p=18866). It added another $3,863 to what was already becoming an expensive system and really didn't contribute much to our benchmark results. So why buy a Tesla? There are hundreds of applications across a wide range of fields that are optimized for GPU computing. In the world of CAD/CAM/CAE, some aspects of many popular CAD programs — such as the surface and mesh modeling and rendering functions of AutoCAD, Inventor, CATIA and NX — take advantage of GPU acceleration. When you move into the realm of computational fluid dynamics (CFD), structural analysis and simulation, most directly support the Tesla GPU.

Both NVIDIA cards require auxiliary power connections, and when you realize that together they consume 485 watts, you can understand the need for the large power supply. Even with both boards installed, we still had access to three PCIe slots and more than enough capacity to power additional add-ons.

The ASUS motherboard provides eight DIMM (dual in-line memory module) sockets and supports up to 512GB of memory. Origin equipped our review unit with 64GB of RAM installed as four 16GB ECC registered 2133MHz modules, adding another $694 to the price. The company currently offers the X2 motherboard with up to 128GB of RAM.

Our system also came with an upgraded primary hard drive, a 1TB Samsung 850 Evo series SSD (solid-state drive) — a $434 option — installed in an additional drive bay nestled below the hot swap bays. That meant that there was still room in the massive case for three more drives in the standard bays plus five in the hot swappable bays. RAID arrays are also available.

Other options include an ASUS ThunderboltEX II Expansion card ($74), optional audio boards, upgraded networking cards, and so on. After completing the configuration, the next page of the wizard offers mouse pads, T-shirts, posters and hats. On this page, you will also find a choice of keyboards. Since a keyboard and mouse are not included in the base price (and were not included with our evaluation unit), we added the least expensive options — a $20 Micro-

Dual-Socket Workstations Compared

		Origin Millenium Pro X2 Two 3.1GHz Intel E5-2867Wv3 ten-core CPUs, NVIDIA Quadro K6000, 64GB RAM, NVIDIA Tesla K40	Lenovo P900 Two 3.1GHz Intel E5-2867Wv3 ten-core CPUs, NVIDIA Quadro K5200, 128GB RAM	Microway WhisperStation Two 3.5GHz Intel E5-2643v2 six-core CPUs, NVIDIA Quadro K6000, 64GB RAM, NVIDIA Tesla K40	BOXX 8980XTREME Two 3.1GHz Intel E5-2687W eight-core CPUs overclocked to 3.82GHz, NVIDIA Quadro K5000, 64GB RAM	HP Z820 Two 3.1GHz Intel Xeon E5-2687W eight-core CPU, NVIDIA Quadro 5000, 32GB RAM
Price as tested		$18,186	$16,599	$18,889	$13,454	$9,984
Date tested		5/25/15	2/20/15	5/10/14	5/9/13	7/16/12
Operating System		Windows 7	Windows 7	Windows 7	Windows 7	Windows 7
SPECviewperf 12	higher					
catia-04		107.35	94.69	94.60	n/a	n/a
creo-01		88.49	82.19	79.40	n/a	n/a
energy-01		6.85	3.91	6.22	n/a	n/a
maya-04		84.17	70.20	68.75	n/a	n/a
medical-01		44.28	31.54	33.44	n/a	n/a
showcase-01		69.44	49.20	62.54	n/a	n/a
snx-02		104.89	151.60	90.09	n/a	n/a
sw-03		122.48	113.92	99.53	n/a	n/a
SPECviewperf 11	higher					
catia-03		110.07	108.16	104.27	78.01	51.69
ensight-04		181.73	140.25	167.13	80.25	44.13
lightwave-01		82.47	75.51	81.01	77.07	59.02
maya-03		204.02	122.35	150.18	125.16	101.67
proe-05		20.16	19.72	15.45	16.14	11.72
sw-02		50.13	67.89	70.70	67.16	57.48
tcvis-02		84.57	80.68	87.47	71.58	44.52
snx-01		159.47	134.18	147.95	81.35	44.86
SPECapc SolidWorks 2013	higher					
Graphics Composite		8.63	9.55	6.89	2.69	2.15
RealView Graphics Composite		10.11	11.23	8.05	2.86	2.37
Shadows Composite		10.07	11.22	7.96	2.86	2.36
Ambient Occlusion Composite		22.14	24.38	17.83	6.16	5.19
Shaded Mode Composite		8.68	9.56	7.04	2.62	2.27
Shaded with Edges Mode Composite		8.57	9.55	6.74	2.77	2.03
RealView Disabled Composite		4.56	5.01	3.69	2.11	1.45
CPU Composite		4.75	4.77	4.20	4.84	4.50
Autodesk Render Test	lower					
Time	seconds	36.50	16.06	30.33	38.00	41.00

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

Origin PC ships its Millennium Pro X2 in a large wooden crate. *Image courtesy of Origin PC.*

soft USB keyboard and $15 Microsoft USB optical mouse to our system — but choices here go as high as $215 for a keyboard and $145 for a mouse. Other selections include monitors, speakers, webcams and more.

Price, Performance and Verdict

By the time we added everything up, the total came to $18,186, which was $703 less than the MicroWay WhisperStation. With two very fast 10-core CPUs, plenty of RAM, an ultra-high-end GPU and the Tesla GPU accelerator, we knew it was going to be fast. But would its performance match its price?

On the SPEC Viewperf tests, the Millennium Pro X2 blew away the competition on almost every data set, thanks in large part to its K6000 GPU. With the newer NVIDIA M6000, we would expect those results to be even better. But on the SPECapc SolidWorks benchmark, the Origin workstation lagged a bit behind the Lenovo ThinkStation P900, in spite of both utilizing the same CPU. And on the AutoCAD rendering test, a multi-threaded test on which faster systems with more CPU cores have a distinct advantage, the Origin PC Millennium Pro X2 came up quite short — its 36.50 second average rendering time, while still fast, was more than double that of the Lenovo P900 — despite identical CPUs and the equivalent of 40 cores.

We also ran the SPECwpc workstation benchmark. Here, the Millennium Pro X2 captured most of the honors, though it lagged behind both the Lenovo P900 and the MicroWay WhisperStation on some of the individual tests.

Origin pre-loaded Windows 7 Professional 64-bit. Windows 8.1 Pro is also available, or you can save $129 by ordering your workstation without an operating system. Ours also came with a three-year warranty, a $269 option beyond the one-year that comes standard.

Our Millennium Pro X2 was definitely equipped well beyond the needs of most *Desktop Engineering* readers. Eliminating the Tesla card and opting for a less powerful GPU would immediately save nearly $10,000. But for those running high-end engineering analysis applications, a system this powerful may be warranted.

That said, we had to ask ourselves: Would this computer be appropriate in an office environment? Our conclusion was: probably not. No matter what you put inside, the Millennium Pro X2 looks like a gaming system. Its lighted interior is distracting and the din emanating from the fancy case was more than just loud, it was annoying. A hardware enthusiast in a small shop might find the Origin PC Millennium Pro X2 quite attractive, but we doubt it will find a home in many corporate environments. **DE**

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

INFO → Origin: OriginPC.com

Origin PC Millennium Pro X2

- **Price:** $18,186 as tested ($3,790 base price)
- **Size:** 9.75 x 24.8 x 21.44 in. (W x H x D) tower
- **Weight:** 55.5 lbs.
- **CPU:** Two 3.1GHz Intel Xeon 10-core E5-2687W v3
- **Memory:** 64GB DDR3 ECC at 2133MHz (4X16GB), 128GB max
- **Graphics:** NVIDIA Quadro K6000 and NVIDIA Tesla K40 GPU accelerator
- **Hard Disk:** 1TB Samsung 850 Evo SSD
- **Floppy:** None
- **Optical:** 16x Blu-ray burner
- **Audio:** Integrated Realtek ALC1150 8-channel HD audio (front panel: headphone and microphone; rear-panel: microphone, line-in, line-out/front, side, rear, and bass)
- **Network:** Two integrated Intel I210-AT gigabit LAN controllers with two RJ45 ports
- **Modem:** None
- **Other:** Eight USB 3.0 (2 front/6 rear), two USB 2.0 ports rear, PS/2 mouse and keyboard ports, two DVI ports and two DisplayPorts on NVIDIA board, 40-in-1 media card reader
- **Keyboard:** Microsoft USB keyboard
- **Pointing device:** Microsoft USB optical mouse
- **Power Supply:** 1500 watts, 94%
- **Warranty:** Three years parts and labor

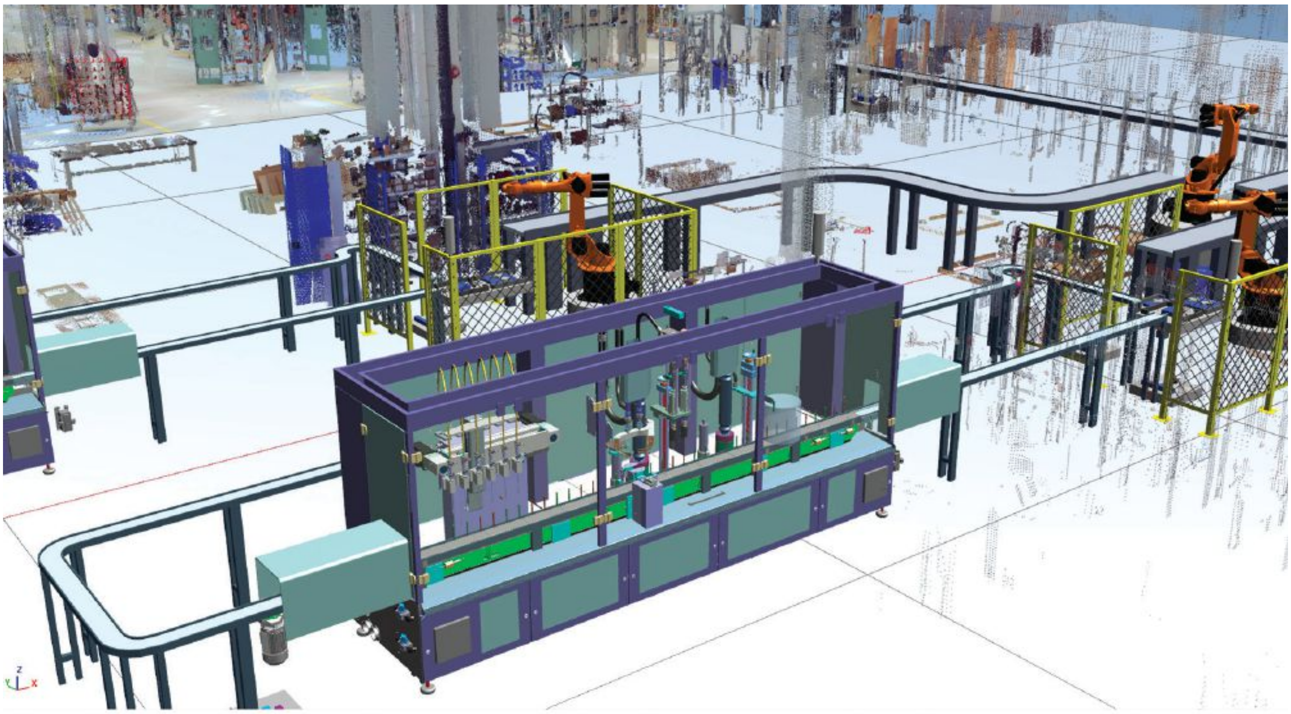
Manufacturing in the World of **Industrie 4.0**

Engineers may one day be designing for a future factory epitomized by this German initiative supported by the Siemens Digital Enterprise suite.

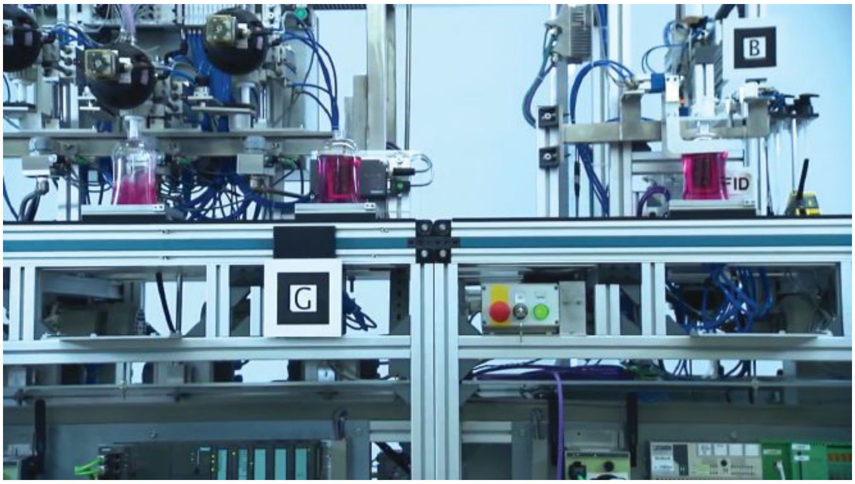
BY PAMELA J. WATERMAN

If Germany has anything to say about it, the Factory of the Future is really the Factory of the Very Near Future. Formal, repetitive assembly lines will be obsolete by 2025, replaced by flexible, smart manufacturing systems that act and react according to a two-way digital data-stream. That's a pretty bold vision to accomplish in just 10 years, but both the impetus and the solutions seem to be keeping pace.

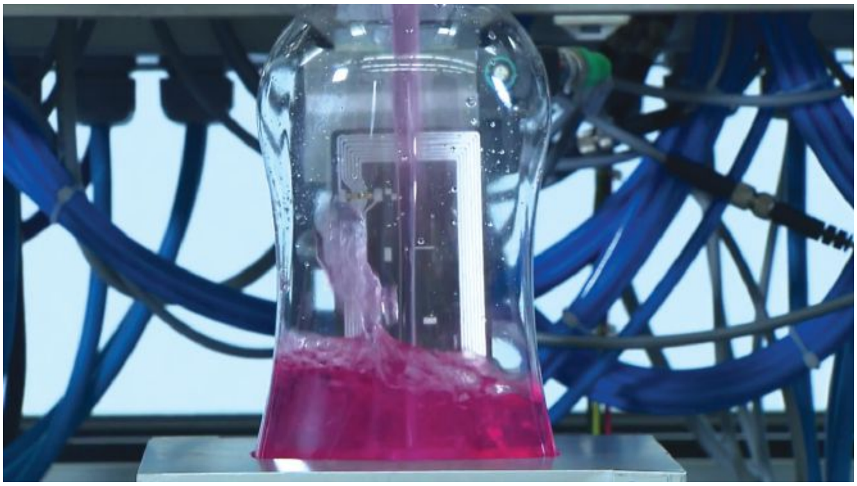
Driving this radical change are worldwide demands for improved quality, lower labor costs, individualized products, and shorter product lifecycles. Enabling the changes are complementary technologies that affect the entire value chain. Manufacturing equipment can now share highly detailed, two-way status information through Internet of Things (IoT) technology, both with other equipment and with the parts themselves. High-speed networks and cloud-based computing resources already analyze data to direct the next move. And in the coming years, fixed assembly lines will be replaced by flexible, modular systems including 3D printers that reconfigure themselves



Software products from Siemens let engineers simulate and test the digital twin of a current or proposed production line to evaluate manufacturing flexibility. ***Images courtesy of Siemens PLM Software.***



At the German Research Center for Artificial Intelligence, the RFID chip (seen close up on the back of the bottle being filled below) and Siemens hardware are used to communicate instructions to the production equipment for proper processing and quality verification.



as needed. This connected approach would help companies save production time while adding more value (especially customization) to their offerings.

Companies, and countries, that embrace this scenario will be leading a global manufacturing revival. This month, *Desktop Engineering* takes a look across the pond at German efforts to network humans, objects and systems for tomorrow's smart factory revolution, with Siemens PLM Software in a lead role.

Shaping the Next Wave of Industry

Historians have labeled significant eras of manufacturing after disruptive technologies. Steam-powered machinery, electrified equipment and computer-controlled systems each changed production methods forever. Though still in its infancy, a new, fourth industrial revolution promises to do the same, and it already has a general name: Industry 4.0.

In the U.S., support for the transition to Industry 4.0 comes from groups such as the Smart Manufacturing Leadership Coalition and its program to create the Open Smart Manufacturing Platform. In Germany, a country with a long history of manufacturing expertise, a coordinated government initiated project for intelligent production operates under the variant name, Industrie 4.0.

Both nomenclatures give a not so subtle nod to the world of software revisions, reflecting the fusion of manufacturing equipment, control systems, and data collection made possible in large part by the technology behind the Internet of Things (IoT). Small, inexpensive sensor hardware combined with targeted application software has enabled explosive growth in smart devices. Adding this capability to industrial equipment, processes and inventory has created an industrial IoT (IIoT) sub-domain of cyber-physical systems that is already helping companies monitor, communicate, analyze and apply digital manufacturing information in close to real time.

New Business Models, New Tactics

Why is this important? One perspective comes from manufacturing engineering executives at Siemens PLM Software, a company whose products are directly relevant to the interconnected world. "Next generation manufacturing offers a way to meet customer demands for new, high-quality customized offerings at ever-shorter time intervals. It also has the potential to reduce resource utilization, which will help manufacturers cope with growing cost pressures," Zvi Feuer, senior vice president of Siemens PLM Software, wrote in a recent corporate blog post.

Siemens PLM Software is an industry partner in the Industrie 4.0 initiative, which began in 2005 and formalized in 2011 as a forward looking project under the German Federal Government High-Tech Strategy. Dual goals are to maintain

RFID Tag, You're It: Defining Unique Identities

The original Universal Product Code (UPC) bar code system (begun in 1963) is slowly being replaced with the Electronic Product Code (EPC) consisting of a bar code plus numbers, whose definition has already gone through several iterations.

The basic technology used to support the EPC as a global, end-to-end supply chain standard is the radio frequency identification (RFID) tag and reader, based on the newest EPC Gen 2 definitions. Globally, such systems operate over the 860MHz to 960MHz band. North American Gen 2 uses 902MHz to 928MHz while European Gen 2 uses 860MHz to 868MHz; equipment based on EPC Global tags work across the full EPC spectrum.

In order for products to have a unique identity from birth and be traceable cradle-to-grave components, assemblies and final products from smart factories will undoubtedly be labeled with RFID tags throughout the manufacturing process. To accommodate different types of products, materials and pricing needs, subsets of the EPC bands are assigned to different power levels and capabilities. Various types of RFID tag/reader systems operate with active, semi-passive and passive tag technology as well as different read/write data structures and content.

For a good discussion of the possibilities, see skyrfid.com/RFID_Gen_2_What_is_it.php.

-- PJW

market leadership by integrating smart technologies into traditional production industries such as electronics and chemicals, and to create and serve new markets enabled by cyber-physical systems.

Feuer says that German manufacturing is already seeing use of equipment that can react to parts tagged for RFID (radio frequency identification) and assemblies in advanced industries such as automotive. "When a partially assembled vehicle is moving on the assembly line, it carries a sensor and in there is a code of what needs to be done next," he says. "When it comes into a station, the station can react automatically and show the assembly workers who are going to operate this station what needs to be done for this specific vehicle.

"This is not rocket science, but still it requires a lot of pre-planning, making sure the robotics, tools and controllers all work in synch," Feuer continues. "You will also see more of this in the process industry, for example, with bottling. The RFID tag on a bottle will tell the machine what kind of formula to fill, like in shampoo production or perfume. We're going to see this in combination with the more advanced robotic facilities."

Equipping both the parts and the manufacturing equipment with sensors supports a number of other steps critical for the smart factory evolution. First, capturing detailed information lets robotic vision systems inspect, measure and compare as-built parts to the original CAD-defined dimensions for automated go/no-go decisions. Second, information can be sent back to the design engineers, who can learn from mistakes made in part design or assembly processes. And third, real-time or near real-time data gives feedback on how the equipment operation may be deviating from the perfect virtual plan. Such digitally recorded information lets motion-control programmers know that a machine needs to be tuned, offers various ways to improve process quality and supports tooling certification (an increasingly important aspect of cradle-to-grave tracking and certification requirements).

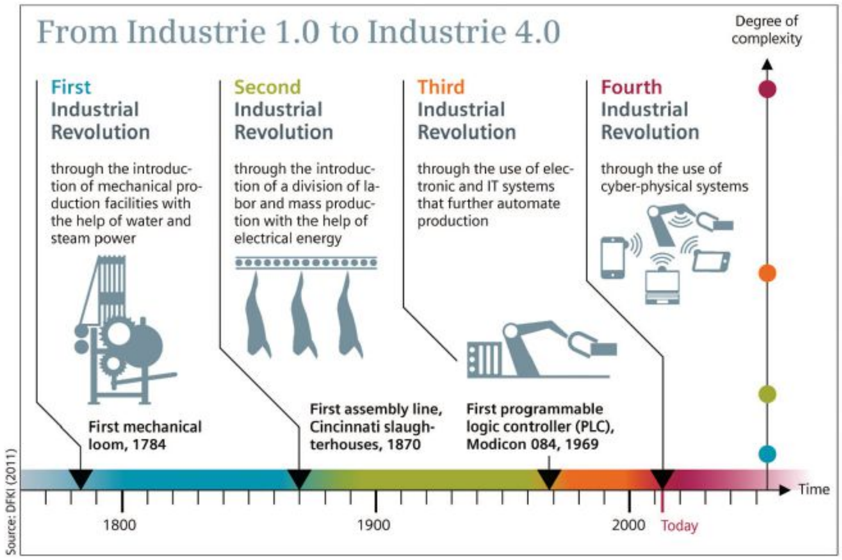
Setting up such production lines, particularly as consumers demand more customized, one-of-a-kind products, requires rapid, integrated planning. Feuer says that the Siemens PLM Software toolset is a crucial part of the Siemens Digital Enterprise Software Suite. Combining simulation, automation and data management, the suite offers a complete solution aligned with all the requirements of Industrie 4.0.

"All of our tools work on top of the PLM Teamcenter backbone," he says. "You start by designing the product then store the design information in Teamcenter. You then do the analysis, do the manufacturing process, and then go and design the production facility that can put together this product. Today all of this is done in parallel that used to be sequential."

Cooperation and Standards

Within the Industrie 4.0 effort, Feuer says there is an unbelievable open market attitude of both cooperation and competition. "Our Sinumerik CNC (computer numerically controlled) machine controls are extensively used to operate robots," says Feuer. "Each vendor has its own control system but some customers prefer to use the Siemens control because of its agility, versatility and ability to connect with various simulations of line programming and virtual commissioning (system setup) software."

With all the equipment and processes in use within any given industry segment (automotive, electrical, chemical, etc.) no single vendor can supply every type of system. It's no wonder that equipment based on a



Internet-connected autonomous systems have jump-started a fourth industrial revolution that includes big data mining, customer-driven designs and modular assembly lines.

variety of engineering and industrial standards gets used concurrently and must work together. To support widespread implementation of the Industrie 4.0 vision, these standards must be coordinated, modified or consolidated.

Areas with multiple possible standards include Ethernet implementation, data exchange related to automated manufacturing equipment and data exchange of part files created in different CAD programs. Profinet is an industrial Ethernet implementation that adds real-time performance and robustness to everyday Ethernet use and is becoming a worldwide industry standard.

Automation Mark-up Language (AutomationML) is a neutral data format based on XML that enables information exchange between cross-disciplinary automated equipment. It actually incorporates several different standards that deal with topology, geometry, kinematics and logic control. Eventually, this approach will let users connect different devices and display all process information within one system.

And Siemens PLM Software's own JT file format is seeing growing use for lightweight visualization of 3D product data. Since its beginnings in 1997 and formal publication in 2007, the JT format has supported digital collaboration at many levels, making it easier and faster to move 3D data within a company or enterprise, or between a company and vendors. Accepted as the world's first ISO International Standard for lightweight 3D visualization, JT allows multiple parties to exchange 3D information even if they do not use the same CAD programs.

Practical Steps, Long-Term Strategy

Implementing Industrie 4.0 tactics will not be a linear process, but companies can — and are — taking steps right now to bring their manufacturing processes into this new era. Adding sensors and software to equipment and components forms the first step for factories to become data-driven and responsive. Active monitoring of this information in real time allows tracking individual parts through their entire production cycle, so problems during manufacturing can be quickly identified and corrected. Step two compiles the data gathered over the course of building thousands of parts, or running machinery for thousands of hours, providing insight into deviations or faults; such information can then guide improvements to both processes and part design. A third step will require translating this data at a higher level into new product concepts offering capabilities that weren't previously possible or identified.

Siemens' long-term strategy may take 15 to 20 years, but Feuer believes many aspects of Industrie 4.0 factories will come sooner. The benefits will go beyond improving manufacturing efficiency and satisfying discerning consumers. "Industrie 4.0 is not a slogan to generate more revenues," he says. "It's a strategy started by the government and adopted by Siemens and some other big players in the industry because we want to make sure we are doing something good for the society as well as making a profit. We want to create jobs, create opportunities. Even though it sounds a bit strange because we're talking a lot about automation and robotics — yes, the types of jobs on the shop floor are going to change — but we still will be creating jobs and they are well paying jobs." **DE**

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INFO ➜ Industrie 4.0: LinkedIn.com/company/industrie-4-0

➜ Open Smart Manufacturing Platform: SmartManufacturingCoalition.org

➜ Siemens PLM Software: Siemens.com/plm

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Design for Compliance

Service providers help the medical device industry accelerate time to market and reduce risk.

BY LAUREN GIBBONS PAUL

Here's a cautionary tale for design engineers working in the medical device industry. Excited at the prospect of bringing its innovative new endoscope to market, a company rushed to get its prototype in front of the U.S. Food and Drug Administration (FDA) with an eye toward fast-track approval.

Unfortunately, the FDA immediately pointed out it would be difficult to clean the surgical scope adequately in the time allotted between patients. As a response, the company pointed out the device was "just a prototype" and not intended to represent the final form factor. But their attempts to steer the conversation to the target patient population and expected benefits fell on deaf ears. It was difficult to secure funding after this early failure and the company went out of business not long after.

This true story points out the perils involved in paying insufficient attention to regulatory compliance in the U.S. medical device industry. Some medical device manufacturers have been guilty of viewing regulations as an afterthought, especially in past years. But there are stringent requirements for medical device design and manufacturing, especially for any device that presents risk of physical harm to the end user. The good news: A host of providers offers a wide range of services to help with every possible aspect of compliance — before, during and after.

Premarket Notification vs. Premarket Approval

The FDA's Center for Devices and Radiological Health (CDRH) is responsible for regulating firms that manufacture, repackage, re-label or import medical devices sold in the United States. In addition, states may have individual laws applying to the design and manufacture of medical devices.

Medical devices are classified into Class I, II and III, with the last category reserved for devices that pose the greatest risk to consumers. Most Class I devices are exempt from filing a 501(k) Premarket Notification, whereas most Class II devices require filing a Premarket Notification 510(k) and most Class III devices require Premarket Approval (PMA). The PMA process is viewed as the most onerous of the three and the subject of some trepidation among device makers. For devices that fall into Class II, a 510(k) is done to demonstrate that the device to be marketed is safe and effective by proving substantial equivalence (SE) to a legally marketed device (predicate device) that is not subject to PMA.

Depending on the type of device, it typically takes one to three years for a device classed as "moderate risk" to attain FDA approval or eight to 10 years for medical devices that are at a high level of risk, says Cynthia Nolte, senior director of Regulatory Affairs for ICON Clinical Research, a unit of ICON plc and provider of compliance-related services.

"Rushing to market is not the right strategy," says Nolte. The regulations were created to ensure safe and effective products are delivered to the marketplace with the right risk-benefit equations. "If we are talking about a Fitbit that records things like your heart rate, there will be no regulatory control because it does not represent any risk," says Nolte. "If we talk about a corneal implant, that is a significant level of risk and much more regulatory control. Global regulatory agencies take this risk-based approach to regulation."

Ideally, designing for compliance is just as much a part of the process as designing for quality, says Pavan Kumar Garikapati, regulatory domain head, Medical Devices, Wipro Ltd., also a service provider. "It is often misunderstood that compliance just requires completing required documentation after a product is ready to sell," he says.

There is a continual balancing act between providing governmental authorities with the minimum required data needed to be — or remain — compliant, while at the same time running efficient operations.

One-Stop Shopping

There are companies that go it alone when it comes to compliance, says Nolte. Generally, in this case, there are engineering and product development teams with an understanding of the regulatory landscape and its requirements.

Most medical device companies do engage a contract research organization (CRO) such as ICON to help them clear compliance hurdles. ICON does everything from helping set strategy to guiding the client's design work so that the end product complies with the regulatory requirements of the target market. ICON consultants also interface with regulatory agencies on behalf of their clients, paving the way for smooth interactions down the road.

Along with other service providers, ICON provides guidance as to which quality management (QM) systems clients should use to meet the regulatory and quality expectations of that market.

"We help clients institute a QM system for managing design and manufacturing practices," says Nolte. Further downstream, ICON assists engineers with crafting labels, inspections for use and operator manuals. It also helps design and execute clinical studies when needed. Consultants can pinpoint the likely regulatory impact of a needed design change.

"We get involved in all phases of the product lifecycle. It's one-stop shopping," she says "We like to do it in a partnership where we participate as a member of their team."

Engaging a Partner

ICON Clinical has been in business more than 30 years and is ISO-9001 certified for quality. "That tells our clients that we conduct our regulatory and quality services in a controlled manner. This is very important to our clients because they need to show that their service provider has the appropriate credentials," Nolte says.

When sifting through a long list of compliance services providers, look for one that has proven experience on compliance for a similar type and class of device. As with any kind of outsourcing agreement, cost is always a driver in selection but it can be shortsighted to make the decision solely based on cost.

Garikapati suggests that device companies looking for compliance partners use this shorthand checklist:

- A strong QM system.
- A clearly articulated framework for handling intellectual property (IP) and sensitive information, such that confidentiality and IP protection are ensured.
- Extensive experience working with medical device firms.
- Meticulously drafted agreements, sharing all the information that is needed by the manufacturer to validate the design (including source code, QM documents, result of risk analysis and design evaluations).

For companies just beginning on the design of a new medical device: Think twice before you go it alone. The vast majority of companies need compliance services and support in order to be successful.

"Most companies wouldn't even know where to begin wading through all of the regulations," says Nolte.

Most of all, you want to avoid ending up like the scope maker at the beginning of this article. "If you mess up your one chance to speak to the agency because you didn't have your story straight, you will have a problem — especially if your product is a PMA," says Nolte. **DE**

Preparing Your Case

In preparation for review by the FDA, medical device manufacturers will need to provide the following information as a starting point:

- Proposed claims
- Preliminary instructions for use
- Target patient population
- Device classification — Class I, II, or III; exempt; 510(k); or probable PMA
- Foreign marketing strategy and additional regulatory agency requirements
- Packaging needs and labeling requirements
- Test plan to show conformance to existing standards

Lauren Gibbons Paul *is a Boston-based freelance writer. Contact her via de-editors@deskeng.com.*

INFO ➜ Food and Drug Administration: FDA.gov

➜ **ICON:** ICONplc.com

➜ **Wipro:** Wipro.com

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Linear & Nonlinear Buckling in FEA

Ensure your structures can withstand outside stresses with these methods.

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 him at tony.abbey@nafems.org for details.*

Buckling occurs as an instability when a structure can no longer support the existing compressive load levels. Many structural components are sufficiently stiff that they will never suffer any form of instability. These structures are classically described as "short." In practice, it is the relationship between radius of gyration and length that is the deciding factor, and hence longspan girders of a heavy section could easily be clear of any instability mode. This type of structure would only fail in compression by local yielding if load levels can reach that extreme.

At the other extreme, structures that are slender could fail at load levels well below what is required to cause compressive yielding. The failing mode tends to be toward the classic Euler buckling mode. For long thin rods and struts, the Euler buckling calculation can be quite accurate. The buckling here is of a bifurcation type — there is a rapid transition from axial loading response to a lateral response, which is usually catastrophic.

A lot of structures fall into an intermediate category where the Euler buckling calculation is not very accurate and tends to overestimate the critical buckling load. The transition to instability is more gradual in this category. The structure is able to carry increasing loads, with perhaps changes in deformed shape and plasticity, until a maximum (or limit) load is reached. At this point, instability occurs. This may be catastrophic, or the structure may transition to a new mode shape that can carry further load. Examples include the initial buckling of a drink can, initial buckling of a thin wing spar shear web, or the light frame of a screen door.

Linear Buckling

The most basic form of buckling analysis in FEA is linear buckling. This is directly related to the classic Euler type of calculation. A small displacement of a perturbed shape is assumed in each element that induces a stress dependent stiffening effect. This adds to the linear static stiffness in the element. Imagine a guitar string tightened — the string's total stiffness goes up and results in a higher pitch. If the string is slackened the total stiffness goes down, and the pitch corresponds. The stress dependent stiff-

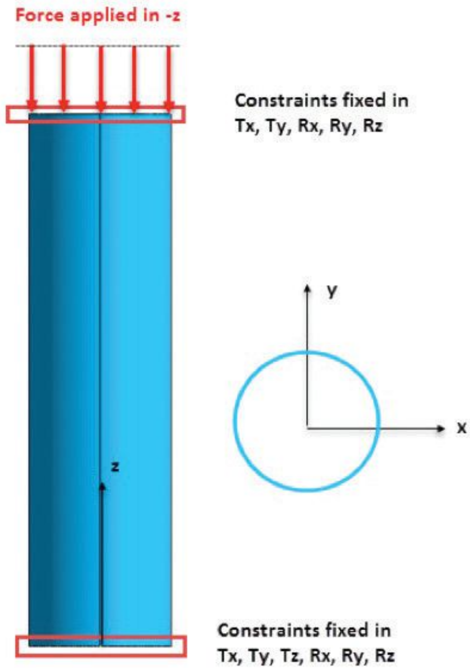


FIG. 1: Typical FEA buckling analysis set up, axially loaded cylinder.

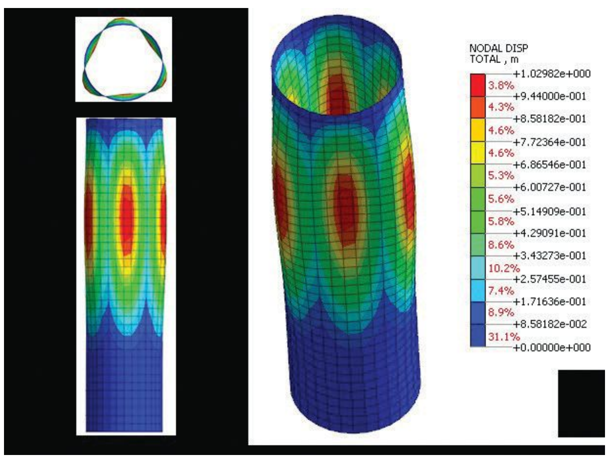


FIG. 2: First eigenvalue or mode shape.

ness is now subtracting from the linear static stiffness term. This latter effect causes buckling.

In an assembly of elements in an FEA model there will be a subtle interaction between the original linear stiffness matrix and the stress dependent stiffness matrix. This is analogous to the linear stiffness matrix and the mass matrix in a normal modes analysis. The same solution method is used — an eigenvalue extraction. For a linear buckling analysis, this will find what scaling factors applied to the nominal static load will scale the stress stiffening terms to subtract sufficiently from the linear static terms to give unstable solutions.

Fig. 1 shows a typical analysis setup. An axial load of a nominal 1KN is applied to the top of a thin-walled cylinder. The constraint systems are shown. A linear buckling analysis is carried out. The stress stiffening matrix and the linear static stiffness matrix are calculated in the first linear static step. In the second step the unstable roots are found using the two matrices in an eigenvalue solution. The user doesn't have to do anything special here because all buckling solvers are "hard-wired" to do the two steps.

The result is a table of eigenvalues and a set of mode shapes, or eigenvectors. The first mode shape is shown in Fig. 2.

The critical load that will cause the first buckling mode is calculated from the nominal load (1KN) multiplied by the eigenvalue (2.575E3 found in the table that resulted from the analysis). So the critical load is 2.575E3 KN. We can see the mode shape in Fig. 2. An important question is: Can we use the deformation values shown in the figure? The answer is a definite no. Just like a normal modes analysis, all we can get is the shape of the buckled mode. There is no meaning to the values shown in Fig. 4. The length of the cylinder is only 1.5 m, so a displacement of 0.8581m as shown would be well beyond any sensible result. We are assuming small displacement perturbations — or shapes. We have no way of allocating displacement values.

The second important question is: Can we use the stresses calculated from the mode shape and often shown in a linear buckling analysis? The answer again is a very definite no — for two reasons. The displacements are arbitrary and therefore the strains and stresses are as well. The second reason is that the mode shape is only a perturbation normal to the loading axis, so in fact does not couple with the axial load present just before the buckle.

What do we get from the linear buckling analysis? An estimate of the critical buckling load and the likely mode shape that will result at buckling. We do not know what happens next. Will the cylinder collapse or stiffen? What will the final stresses and displacements be? It is rather like a freeze frame photo just at the initiation of buckling — we are left in suspense.

The information we get is very useful in design, but it is more of an indicator than a hard number. We also have to be aware that if we use linear buckling on a structure that is more like the intermediate category, then we are likely to get a non-conservative over estimate of the buckling load. We may also find the mode shape transitions very quickly into something very different.

The boundary condition assumptions for buckling are also

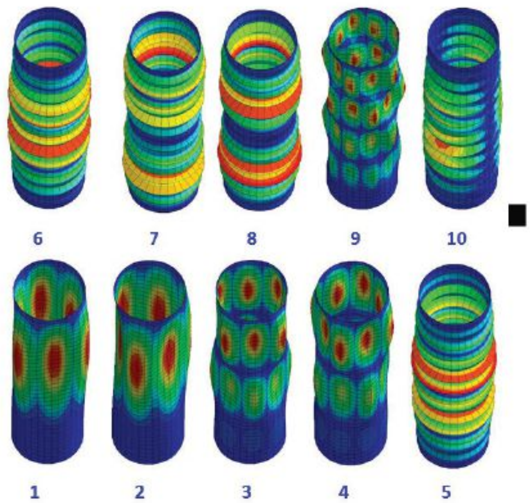


FIG. 3: Cylinder buckling mode shapes 1 to 10.

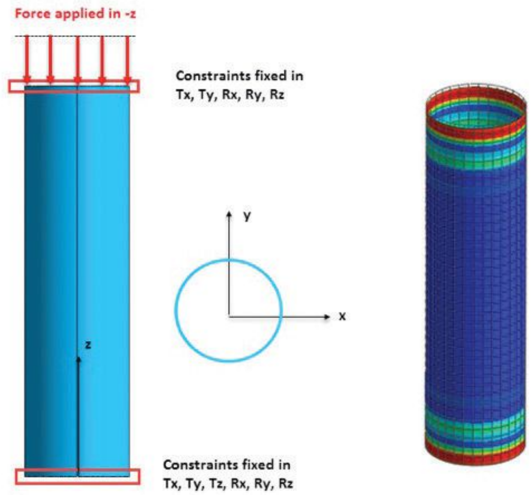


FIG. 4: Initial attempt at a nonlinear buckling analysis

critical. However, if the structure can be categorized as "slender" and we can show a good margin over the critical linear buckling load, then in many cases that is sufficient for design.

Fig. 3 shows the higher order modes shapes associated with eigenvalues 1 to 10. Often the default in an FEA solver is to just have the first eigenvalue and mode shape. In fact, the study of the higher modes is useful.

We can see that mode 1 and 2 are identical and represent a repeated mode — any arbitrary axial orientation of the fundamental shape is possible. Modes 3 and 4, 5 and 6, and 7 and 8 are also repeated roots. We can also see a distinction between "dimpled" shapes that have a low number of axial lobes and "Chinese lantern" modes, which have a high number. The range of eigenvalues is also low — and actually defines critical loads of 2.57E3 to 2.85E3 KN. The implication is that any small variation in boundary condition, component detail or load eccentricity could cause any of the modes to occur. The modes are completely independent in the linear analysis; so mode 1 or 2 or 3, etc. could occur. One way to imagine this is if mode 1 and 2 pair were not possible in practice, by snubbing against adjacent components, etc., then mode 3 and 4 pair could occur.

It is important to assess the families of higher mode shapes and eigenvalues to see if any practical response implications occur. However often there may be only one dominant first mode, with the next set of modes completely infeasible and at very high critical loads. These can be ignored.

Nonlinear Buckling Analysis

If the results of a linear buckling solution suggest the calculation is not representing the real response, then a nonlinear buckling analysis is needed. This uses a nonlinear geometric analysis to progressively evaluate the transition from stable to unstable and addresses many limitations in linear buckling analysis.

Fig. 4 shows the first attempt at a nonlinear buckling analysis. It is disappointing. All we see is axial shortening with no sign of buckling.

This uncovers another difference between linear and nonlinear buckling. In linear buckling the small perturbations the structure may see are "hard wired" into the solution. For nonlinear analysis, the perturbations have to develop geometrically as part of the solution and are not pre-defined in any way. The theoretical solution in Fig. 4 totally ignores fundamental facts of nature. No component can be perfectly straight, have perfect constraint application or perfect load application. No material content will be absolutely homogeneous. All these factors give rise in practice to small eccentricities and variations that attract offset axial loading. This in turn starts to produce offset moments that cause further eccentricity. For a very stable real structure, no buckling will occur; but for an intermediate category real structure, the eccentricities will grow until instability occurs. In a real slender category structure, it will happen more quickly — but probably not as abruptly — as the linear Euler solution predicts.

How do we overcome this limitation? Some components and loading will have such a large natural eccentricity that the solution will find instability. However, for our stubborn cylinder we have to introduce an eccentricity. There are several ways of doing this. All methods can benefit from our understanding of the linear buckling mode. The nonlinear mode may transition through this, but it is a good starting point. We can either apply a "dummy" loading to induce the mode shape, or actually distort the structure very slightly in favor of the mode shape. The first method is usually easiest, as any sympathetic load will usually work. Pressures are better than point loads as they avoid local singularities. If possible, a sympathetic pressure can be applied in the same distribution as the normal displaced mode shape from the linear analysis. It can be captured as a field function and scaled to suit. It is difficult to assess what level of load to apply, but it should be a lot smaller than the main axial loading.

In the case of the cylinder, I applied a pressure over one quarter vertical strip to give a net sideways thrust. This dummy static load was set to give a deflection of 3.5e-4 m — a small wall deflection. The best way to do this is to ramp up the dummy load as the main loading is applied, and then to ramp it down to zero until 100% main load is achieved. Alternatively, a pre-stress

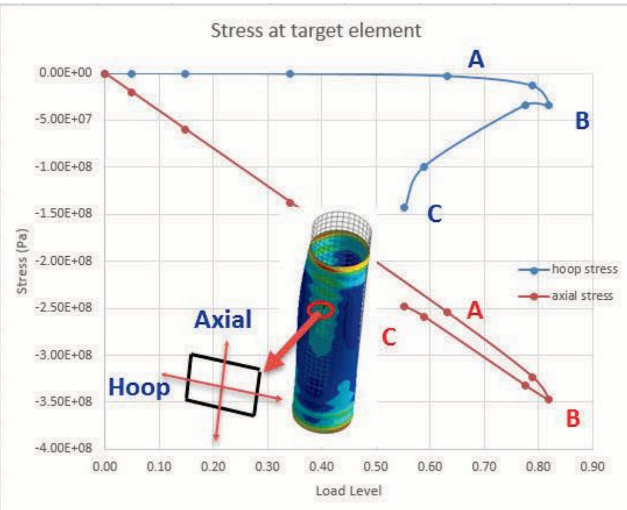


FIG. 5: **Key point plot; stress response at key element.**

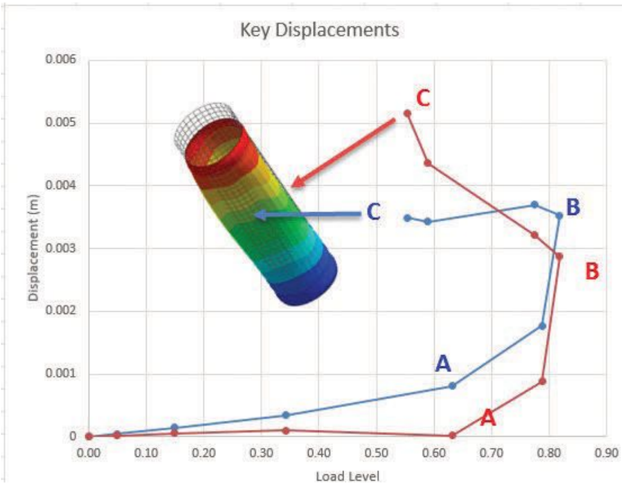


FIG 6: **Key point plot; radial displacement response at key nodes.**

load case may be possible, which will not get scaled up as the main loading is increased. The setup will depend on your FEA program. If all else fails, you may have to apply a small dummy load, which will increase with the main load and be there as an artifact at the end.

The other alternative is to capture the linear buckling mode shape and apply this back to the structural mesh as an initial distortion. Again this can use a field function from the mode which is scaled and used as an offset, or the same thing can be done via an Excel export. Your FEA solver may well have automated ways of handling this. A word of caution here though: If you make the imperfections too big you will effectively corrugate the structure and stiffen it up. Trial and error is required.

The results of the nonlinear buckling analysis shows that the cylinder configuration and the level of eccentricity assumed result in a stable structure that resists buckling until a mode occurs, similar in nature to the linear mode. There is then a transition to a highly localized mode. The initial buckling occurs at around 63% of the linear estimate for critical load. The maximum load level achievable before the structure sees a local collapse is about 82% of the linear critical load.

The nonlinear method used to track the geometric instability was the Arc Length method. This is always recommended as it enables the softening response of the structure to be tracked. When a structure buckles it has less resistance to load. A real-world load controlled test would result in a runaway collapse. Alternatively, a real-world displacement controlled test would allow us to monitor the reducing load resistance. The Arc Length method permits this, even though we are applying load.

Important considerations are: What is the effective critical buckling load level and what is the post-buckling behavior? I like to use key point plots to investigate this. Fig. 5 shows a shell element identified as being a good indicator of the changing stress state as instability occurs. Membrane hoop stress is zero and axial stress is steadily increasing up to the start of instability at point A. This is a classic linear response. From A to B the hoop stress increases as the structure distorts. From B to C a second mode occurs with a further instability local to this element, the axial stress decreases as the structure softens.

Fig. 6 shows the radial displacement response of two key nodes, one at an outward moving lobe, and one at an inward moving lobe. Corresponding points A, B and C correlate well with Fig. 5 and confirm the onset of instability.

In practice, the model should now be investigated for sensitivity to initial induced eccentricity and preferably comparing several forms of induced eccentricity. Effects of constraint and loading implications can be compared to the real-world conditions by experimenting with DOF (degrees of freedom) and using boundary spring stiffnesses. The load steps can be adjusted to give finer results closer to initial instability. Plastic behavior could also be investigated in the transition to the second instability. **DE**

Tony Abbey *is a consultant analyst with his own company, FETraining. He also works as training manager for NAFEMS, responsible for developing and implementing training classes, including a wide range of e-learning classes.*

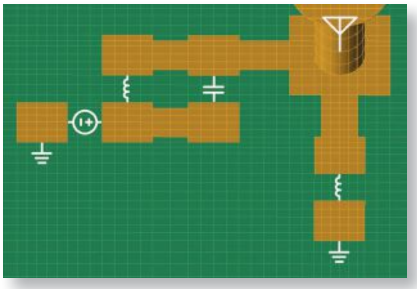
Summary of Key Points

Buckling is a critical failure condition for many classes of structure. Accurate estimates of critical load and response modes are difficult unless a structure falls well into the "slender" category. Linear solutions may suit such structures if loads and boundary conditions are carefully assessed. However for the majority of instability-prone structures, a full nonlinear analysis is required. This type of analysis is very sensitive to assumptions on eccentricity and boundary conditions. A methodology is required that will deal with structural softening. The key point method is recommended to help identify the onset of instability and subsequent transitional modes.

Editor's Picks

by Anthony J. Lockwood

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.



Remcom Launches Circuit Element Optimizer

The module is part of the company's XFdtd platform.

Remcom has a new Circuit Element Optimizer add-on module for its XFdtd electromagnetic (EM) simulation solution. They engineered the module to help antenna designers and RF (radio frequency) specialists select the optimal component values for a matching network layout, printed circuit board (PCB), antenna, filter and other RF structures.

Perhaps the neatest characteristic of this module is that circuit elements remain in the EM layout structure during optimization. This should smooth antenna-matching workflows.

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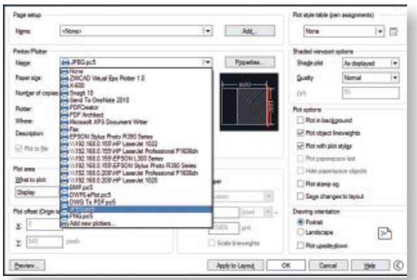

ZWCAD+ 2015 SP2.1 Released

The software is also available in a tablet version.

The thumbnail portrait is that ZWCAD+ 2015 is a low-cost yet high-performance AutoCAD alternative for mechanical CAD designers. It has tools for design and drafting, 2D/3D conversion, libraries of standard-based parts, collaboration and file comparison capabilities, customizability, enterprise and international standard support and more.

ZWCAD+ has a bunch of nifty features, including one called SmartPeek that provides a simple keystroke to preview drawings, and SmartMouse, a mouse gesture that lets you execute frequently used commands just by moving your mouse.

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CloudDDM Begins Manufacturing Services

The company's industrial-scale 3D printing offerings have a quick turnaround.

CloudDDM is for those of you accustomed to additive manufacturing technology and who want to better leverage industrial-scale 3D printing to reduce upfront production costs, manage stock, control inventory and accelerate product development.

You can interact with CloudDDM through its dedicated app. Through a Web browser, you just upload your file, select your material, settle on business details like shipping and submit your order.

Material options include the most commonly used engineering thermoplastics and resins such as ABS (acrylonitrile butadiene styrene) and ULTEM 1010.

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BOXX Technologies Expands APEXX Workstation Line

The new systems leverage eight-core Intel i7 processors.

The BOXX Technologies APEXX 4 7402 and APEXX 2 3402 both run 64-bit Windows, have NVIDIA Quadro K620 graphics accelerators and come with 256GB of SSD (solid-state drive) primary storage. Both are liquid-cooled and have filtered airflow cooling systems. Additionally, their Intel Core i7 processors can reach overclocked speeds above 4GHz.

With overclocking, these systems are suited for multithreaded simulation and rendering jobs, since everything is faster and you get more speed by reducing the bottlenecks in many CAD applications.

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Optimizing Medical Devices with Simulation

Soterix Medical uses Simpleware and COMSOL Multiphysics to perfect transcranial direct current simulation technology.

Image-based simulation is becoming increasingly common in medical device design, particularly when creating models from 3D scan data such as magnetic resonance imaging (MRI) and computed tomography (CT). Models can be used to evaluate device designs using anatomical data, and can contribute to long-term design decisions and protocols.

Soterix Medical manufactures devices and develops treatments for transcranial direct current stimulation (tDCS), a promising new method for treating neurological and psychiatric disorders through transmission of a low-level direct current (DC) current across the scalp. The New York-based company, in conjunction with the Neural Engineering Group at City College of New York (CCNY), is applying results from Simpleware software to design protocols for tDCS devices. Image-based modeling techniques are used to evaluate performance and reliability.

The Neural Engineering Group, led by Dr. Marom Bikson, focuses on prototyping and verifying tDCS devices. When developing tDCS methods, they needed to investigate the relationship between patient scan data and CAD models of tDCS electrodes through visualization, analysis and export of finite element models, with data used by Soterix Medical for device design.

Another challenge for designing tDCS protocols is to be able to easily customize models to different types of electrode placement montages and current distribution, as well as for various kinds of pathologies and material properties within the brain derived from patient data. Models have to be both high quality enough to reproduce the complex internal and external features of the brain, and able to be modified to suit different protocols.

Simpleware software was chosen as the solution for generating and modifying finite element models of the human head from MRI data, with COMSOL Multiphysics used as the solver for applying electrostatic volume conductor and other physics. This approach has allowed Soterix and CCNY to develop detailed head models to optimize device designs to specific conditions and clinical targets.

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Using Big Data and Analytics to Design a Successful Future

Siemens and Teradata partner to effectively leverage data in the transportation and supply chain industries.

Blending old world hard metal with future-focused data-driven analytics, Siemens Mobility Data Services division is capitalizing on Big Data and analytics to ensure transportation around the globe is fast, reliable and more energy efficient. Innovations includes predicting failures, ensuring a seamless supply chain for parts to reduce or eliminate downtime and using weather data to differentiate problems in the same train model in different regions.

In 2014, Siemens launched Vision 2020, defining a path to a successful future. That vision requires innovation with data and a commitment to the mission: "We make real what matters."

Now that data storage challenges are a thing of the past, Siemens engineers are leveraging tens of thousands of sensors and the data they send. Data from the trains and rails, repair process data, weather data and data from the supply chain all go into Siemens Teradata Unified Data Architecture leveraging Hadoop, Teradata Aster and the Teradata Data Warehouse.

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by Tony Christian

PLM to Support Supply Chain Collaboration

Recent developments in PLM (product lifecycle management) technology have increased substantially the potential for sharing of product data throughout the extended enterprise. Access to such technology has historically been highly variable, especially among smaller members of the supply chain. However, exploitation of cloud-based computing infrastructures and major strides in usability are democratizing PLM, making it much more accessible. As a result, accurate, up-to-date product information can be made available right across the supply chain.

In many industries, the supply chain is multi-tiered and involves complex relationships. In fact, it is arguably more accurate to use the term supply network, especially if we take the broader lifecycle view of the supply chain that encompasses product development at the front end and the product in-service life through to retirement at the back end. We have also seen shifts in responsibility throughout industrial supply chains, from the organization at the top of the chain pushing its defined requirements for, say, components and sub-assemblies down to the supplying organizations, to those supplying organizations doing the design and subsequent product definition themselves. The increased breadth of supply chain activities and distribution of responsibilities makes the problem of management of product data much more complex.

Exploitation of cloud-based computing and major strides in usability are democratizing PLM.

PLM systems have long been regarded as essential for managing the vast quantity and variety of data associated with complex products. From their early incarnations as solutions for providing version control for product data and workflow management through the product development phase (known as product data management or PDM), today's leading PLM technologies do indeed offer full lifecycle product data management. For example, Oracle talks about its PLM technology in terms of product value chain management in order to emphasize the completion of the loop that involves exploiting field experience as an input to front-end innovation.

Taking the broadest view, users of PLM would include not only the members of the design-to-delivery supply chain but also the post-sale/installation service organizations so as to give them access to the current product information as well as the opportunity to report product issues back.

Expanding the Reach of PLM

The problem has been accessibility. To take full advantage of PLM across the supply chain, it needs to involve all significant users of, and contributors to, the product data. In the past, PLM technologies have been essential components of companies' IT stacks but were rather heavyweight in terms of IT infrastructure, process definition, data structures, etc. This is changing substantially.

A combination of technology infrastructure — not only cloud, but mobile devices, especially for the field service end of the product lifecycle — coupled with and great strides in ease of use and configurability are making PLM highly accessible. A leading example of cloud-based, readily configured and affordable PLM is Autodesk's PLM 360 technology, while NVIDIA's recent GRID GPU (graphics processing unit) announcements demonstrate the progress that has been made in cloud-based infrastructures that enable a wider range of users on a wider range of devices to access complex, compute-intensive product information such as 3D models, simulations and visualizations.

Taken together, technological advances like these are expanding the reach of PLM dramatically. Things are moving quickly and we expect to see accelerating adoption of PLM and the resulting benefits across more and more industry supply chains.

I have never seen a commentary on supply chain issues that has pointed out that speed and cost pressures are decreasing. Those pressures, together with what seems to be increasing complexity as industry players take a full lifecycle view of their product/service development and delivery processes, mean that accurate single-source-of-truth product information is a necessity. PLM's role as a supply chain enabler will therefore continue to grow in importance. **DE**

Tony Christian *is director of independent industry analyst firm Cambashi. Send e-mail about this commentary to de-editors@deskeng.com.*

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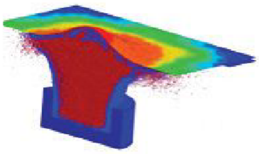
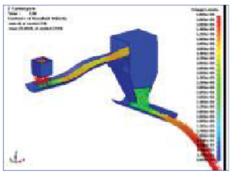
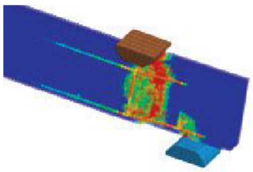


Four New Solvers for Multiphysics Purposes



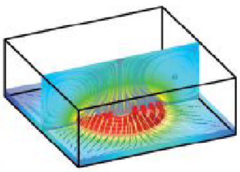
Discrete Element Sphere (DES)

The DES (Discrete Element Sphere) is a particle-based solver that implements the Discrete Element Method (DEM), a widely used technique for modeling processes involving large deformations, granular flow, mixing processes, storage and discharge in silos or transportation on belts. In LS-DYNA, each DE particle is a FEM node, making it easy to couple with other rigid or deformable structures by using penalty-based contact algorithms. The DE is highly parallelized and is capable of simulating systems containing over several hundred-million particles.



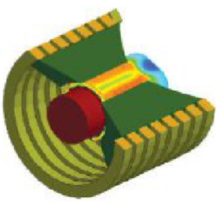
Here are some distinct features of the bond model:

1. The stiffness of the bond between particles is determined automatically from Young's modulus and Poisson's ratio.
2. The crack criteria are directly computed from the fracture energy release rate.
3. The behavior of bond particles is particle-size independent.



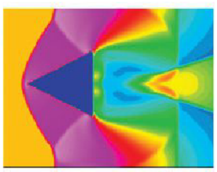
Incompressible CFD

The incompressible flow solver is based on state of the art finite element technology applied to fluid mechanics. It is fully coupled with the solid mechanics solver. This coupling permits robust FSI analysis via either an explicit technique when the FSI is weak, or using an implicit coupling when the FSI coupling is strong.



Electromagnetics

The Electromagnetism solver calculates the Maxwell equations in the Eddy current (induction-diffusion) approximation. This is suitable for cases where the propagation of electromagnetic waves in the air (or vacuum) can be considered as instantaneous. Applications include magnetic metal forming, welding, and induced heating.



CESE/Compressible CFD

The CESE solver is a compressible flow solver based upon the Conservation Element/Solution Element (CE/SE) method, originally proposed by Dr. Chang in NASA Glenn Research Center. This method is a novel numerical framework for conservation laws.

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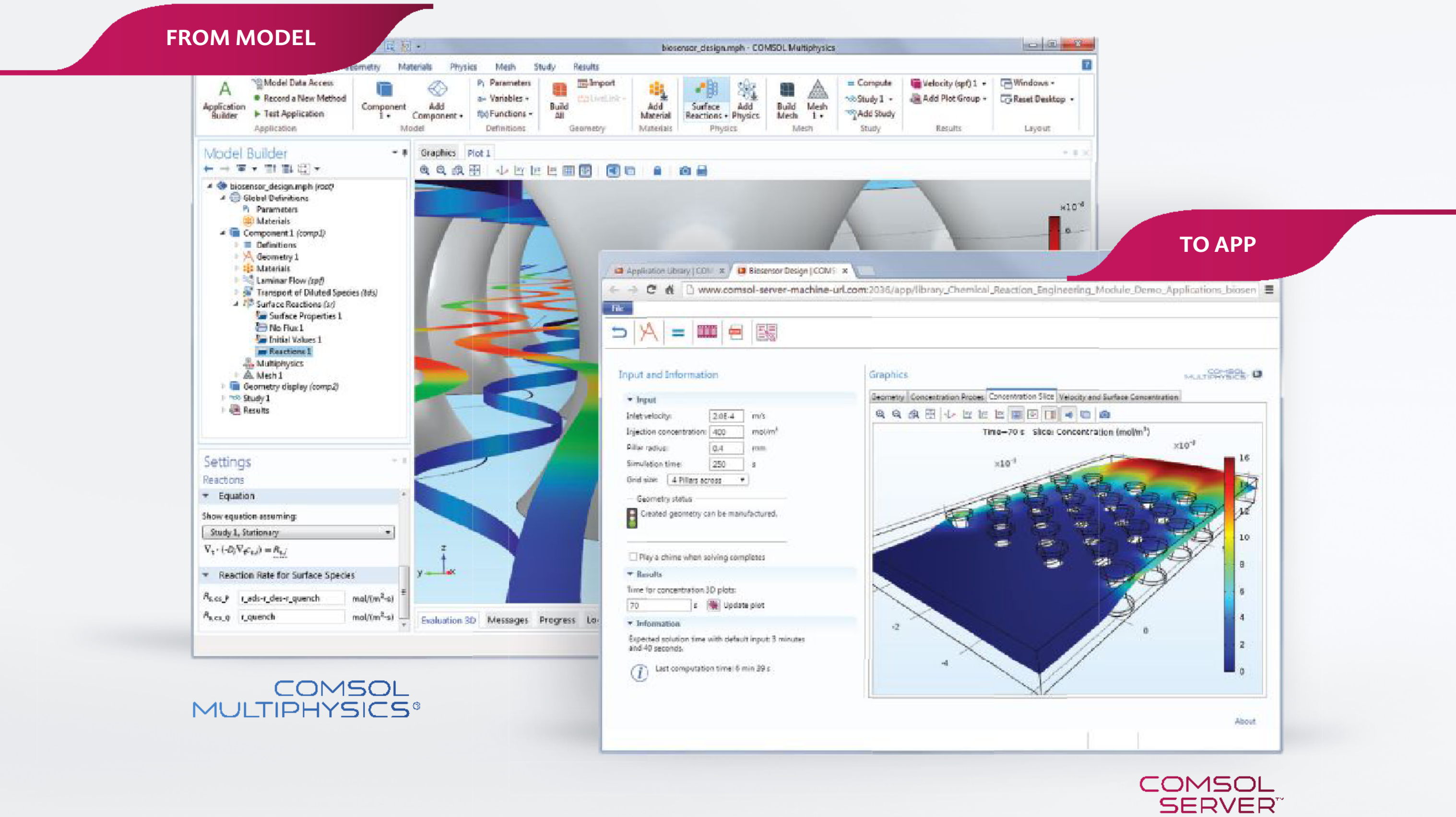

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