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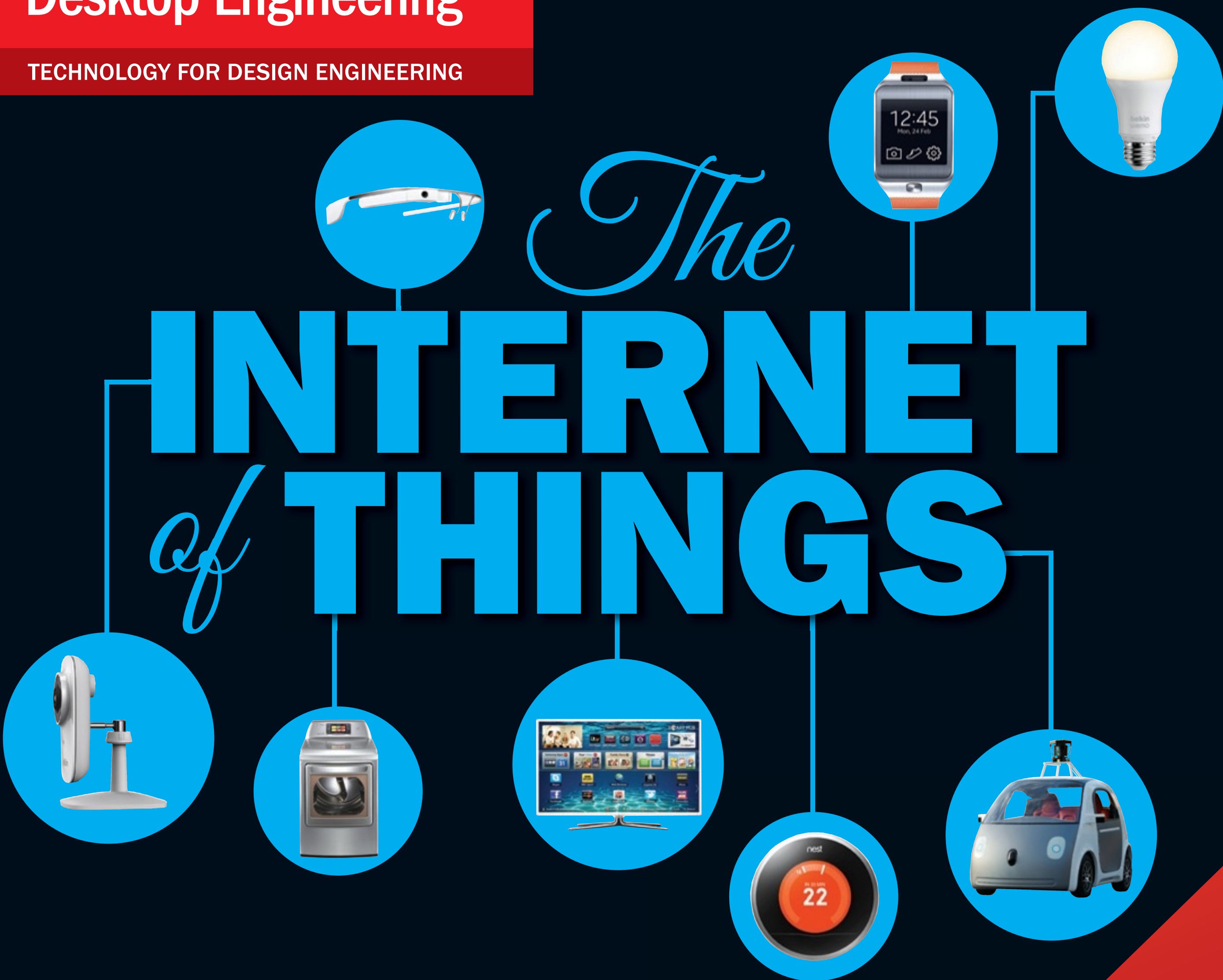
TECHNOLOGY FOR DESIGN ENGINEERING

August 2014 / deskeng.com

The INTERNET of THINGS



Enter to Win a Lenovo® ThinkStation® P300 Tower! P.7

by Jamie J. Gooch

IoT: Talking the Talk

If your alarm clock tells your coffee maker to start brewing 15 minutes before you get up, but your coffee maker doesn't speak alarm clock, you'll have to wait to get your caffeine fix. That's a problem for the future Internet of Things (IoT), in which billions of devices are expected to communicate with one another.

A lack of communications standards has repercussions beyond you having to manually start your coffee maker, however. The IoT may someday affect traffic patterns, health care options, car insurance rates, manufacturing schedules and even how farmers harvest their crops. It's been more aptly called the "Internet of Everything," but what language should "everything" speak? There is already a platform war brewing that could make VHS vs. Betamax (or Blu-ray vs. HD DVD for you younger readers) look like a minor dust-up.

The Battle Begins at Home

Apple's recently announced HomeKit framework would allow iOS apps to control connected devices in the home by talking to them via Siri voice commands. The devices would need to be MFi-certified, as in made for the iPhone, iPad or iPod. As the biggest technology company in the world, Apple's platform is something design engineers may need to take into account when developing connected hardware. While HomeKit could bring some clout to bear in organizing the array of proprietary connected home products on the market, it's unclear whether it would work with products that don't connect via Wi-Fi because of power constraints.

What language should the Internet of Things speak?

Enter Nest Labs, makers of connected thermostats and smoke detectors (thus far). Although it was recently acquired by Google, Nest has joined with six other companies to form the Thread Group to develop Thread, a new IP-based wireless IPv6 networking protocol that puts a focus on longer battery life. According to the group's press release: "Thread is not an application protocol or a connectivity platform for many types of disparate networks. Thread is an IPv6 networking protocol built on open standards, designed for low-power 802.15.4 mesh networks. Existing popular application protocols and IoT platforms can run over Thread networks."

Apple's walled ecosystem vs. Google's more open approach may sound familiar, especially to software developers who have to make multiple versions of their apps so that they'll run on both platforms. With the IoT, where hardware and software converge into connected devices, design engineers will likely face a similar increase in product complexity.

Google and Apple aren't the only tech giants interested in ensuring your fridge can tell your car to pick up more milk when you're driving past the grocery store. Atmel, Broadcom, Dell, Intel, Samsung and Wind River have established the Open Interconnect Consortium (OIC), which according to a recent announcement is "focused on defining a common communications framework based on industry standard technologies to wirelessly connect and intelligently manage the flow of information among personal computing and emerging IoT devices, regardless of form factor, operating system or service provider." The OIC is initially targeting smart home and office solutions, and expects to follow with standards in automotive, health care and industrial markets.

Will this be the one standard design engineers can use to ensure their products connect with everyone else's? Not so fast.

Late last year, Qualcomm announced the formation of the AllSeen Alliance, a cross-industry consortium intended to advance the IoT. Microsoft, LG, Panasonic and Cisco are among its 50+ members. The Alliance's framework is based on expanding Qualcomm's AllJoyn open source project.

A War Worth Fighting

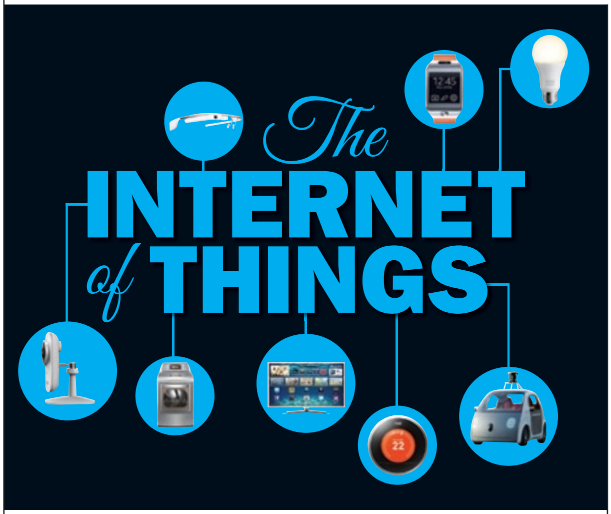
Research firm Gartner expects the IoT to add $1.9 trillion to the global economy, with 26 billion connected devices by 2020. Another research firm, IDC, predicts the IoT will grow by more than $5 trillion over the next six years to reach $7.1 trillion in 2020. Standardization efforts, even if fragmented among a handful of large players, can help make those forecasts come true.

With that kind of growth, it's too much to ask for one standard to design toward. That makes the interdisciplinary and inter-departmental collaboration efforts we focus on beginning on page 14 all the more critical to design engineers confronted with the IoT.

In a press release announcing the OIC, Glen Robson, VP and CTO for Client Solutions at Dell, noted that "consumers and businesses alike will need a strong base upon which to build the vast array of solutions enabled by a global Internet of Things." In the short term, at least, there will be multiple bases upon which to build. **DE**

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

DE August 2014 VOLUME 19/ISSUE 12



4 Skills for the Internet of Things

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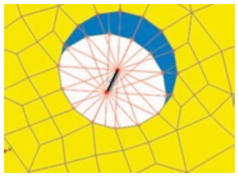
SIMULATE



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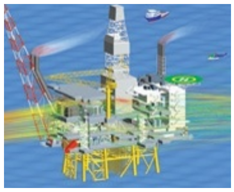

ENGINEERING SERVICES

FOCUS ON THE INTERNET OF THINGS

August 2014

VOLUME 19/ISSUE 12

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by Kenneth Wong & Beth Stackpole

Tuna Robot Navigates Biomimicry Waters

Not only is the tuna a strong swimmer, but the front portion of its body remains stable as it propels itself through water. This style of movement was the inspiration for a U.S. Navy project, which employed biomimicry practices to create the optimal design for an autonomous unmanned underwater vehicle.

The so-called tuna robot, designed in partnership with Boston Engineering, builds upon the seaworthy profile of the tuna and includes a propulsion system, a single oscillating foil, appropriately placed fins, and a finely tuned muscular and sensory control system. The full set of technology makes the tuna robot efficient at a variety of speeds — unlike a traditional thruster propulsion system.

By mimicking the tuna, the robot is optimized for a range of applications — from seeking out mines in the shallow waters of harbors or along shorelines, or for locating contraband like hidden drugs or guns. There are also possible applications in the oil and gas industry, such as using the robotic tuna to do more frequent monitoring of gas pipelines.

The fact that the tuna's front portion of the body doesn't move when in motion is essential to the in-water robot design, says Mark Smithers, VP and CTO at Boston Engineering. "It is important because when you are carrying sensors, you don't want everything moving all over the place and messing up what you are carrying on board," he explains.

PTC's Creo 3D CAD tool was critical to the modeling effort, particularly for the surfacing and simulation aspects. The team used a 40-in. tuna caught off the coast of Gloucester, MA, as the basis for the CAD model. Because nature doesn't follow easy geometric formulas, PTC Creo's Interactive Surface Design Extension (ISDX) was instrumental in capturing the exact design.

"A tuna profile changes along the length as it does along the width," says Will Ober, an engineer involved in the project. "If you took a cross-section, you'd see it doesn't produce an easily and mathematically predictable profile."

The software's parametric modeling and freeform flexibility allowed the designers to build curves in multiple planes simultaneously, Ober explains, while also ensuring they could add surfaces between curves and modify until they were satisfied with the shape.

Creo's simulation capabilities also factored into the overall design effort. "Any time you can cycle something in motion on the screen, it lets you look for 'gotchas' that engineers might not see otherwise," Smithers says. He notes that the team used Creo's simulation capabilities to calculate forces and trajectories while also checking for interferences. "Without being able to cycle something in motion and simulate the environment in CAD, you find out problems only after prototyping, which is time and money."

— B. Stackpole

Not Your Father's CAD Company

PTC has been moving away from its mechanical engineering roots for quite some time, expanding into application lifecycle management (ALM) with the 2011 acquisition of MSK Integrity and branching out even further with the Servigistics deal, which launched it into the service lifecycle management (SLM) space. But with last December's $112 million acquisition of ThingWorx, PTC set its sights on the Internet of Things (IoT) landscape. During the June PTC Live 2014 event, it revealed its roadmap for the future. Beyond the launch of Creo 3.0, the event was chock full of keynotes, customer presentations and announcements in the SLM, embedded software, and IoT space.

"Once upon a time, products were all mechanical, so you could call yourself a product development company with just a CAD offering," said PTC CEO and visionary Jim Hepplemann. "Today, if all you have is a CAD offering and you call yourself a product development company, people are going to snicker."

In PTC's vision of a closed-loop product lifecycle, Creo is used for the physical hardware design; Integrity covers the software design; systems engineering capabilities are delivered via new capabilities from its recent Atego acquisition; and Windchill comes into play to manage all the configurations and to support global collaboration. PTC's SLM suite, courtesy of Servigistics, covers the product through the distribution and service stage.

The ThingWorx technology, a platform for building IoT applications, is the linchpin, providing the core connectivity for completing the dream of closed-loop system. "If you think about that vision and concept, it dramatically transforms the way companies can create, operate and service products," Hepplemann said. "This is the most exciting time in our industry I can remember, and I've been around for a while."

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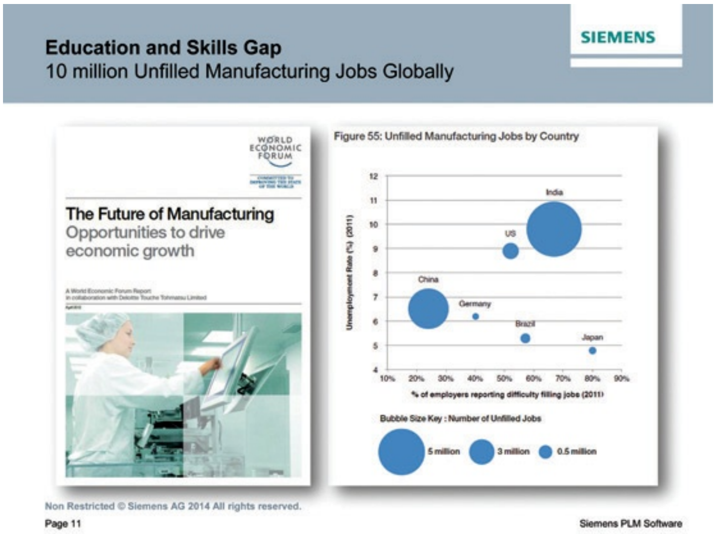
Time for Manufacturing to Shed Old Image?

"Dark, dirty, dangerous — that's what most people's perception of manufacturing is," observes Bill Boswell, Siemens PLM Software's senior director of partner strategy. "To convince students to go into manufacturing, we have to change that perception. That's not what manufacturing is today."

Boswell points to Volkswagen's Transparent Factory in Dresden, Germany, designed by architect Gunter Henn. Complete with polished hardwood floor and curved glass surfaces, the building looks more like a modern art museum or a high-tech firm's headquarters than an automotive plant.

"Not every plant is going to look like this one," Boswell admits, "but that's what the future of manufacturing is — certainly not dark, dirty and dangerous."



"*The Future of Manufacturing*" report sounds an alarm bell about unfilled jobs.

New Skills Required

Similarly, the skills needed for manufacturing have also changed, he points out. Anybody can be trained to turn a wrench, push a button or lift an engine block, but that's not what is needed to know to design and build today. "They need to know industrial automation, need to know their iPads can be used for design," Boswell says.

Siemens recently issued a free student version of its Tecnomatix Jack and Jill software, which lets users simulate and identify ergonomic issues using digital humans. The company has also begun exploring mobile tablet applications. Its Teamcenter PLM software is now available as a mobile app, for example.

According to "The Future of Manufacturing: Opportunities to Drive Growth," a report by the World Economic Forum, there's roughly 10 million unfilled manufacturing jobs globally — an indicator of a serious skill shortage. The report states, "Stories of shortages abound, including 600 openings for skilled tradespeople at AAR, a Chicago-based aviation parts maker. Indian firms have imported tens of thousands of Chinese workers to build and operate power plants, steel mills and telecommunications towers. Due in part to labour shortages, Brazilian wages and inflation are rising as the country struggles to sustain its rapid growth. The China Daily reports that the city of Dongguan, where most of the world's toys are made, is a million workers short, while other Chinese cities have been offering health benefits and housing subsidies to attract workers."

Getting the Word Out

If the U.S. doesn't make concerted efforts to invest in education to train and produce skilled graduates to fill these roughly 10 million positions, its major global competitors will. "The Competition that Really Matters," a report by the Center for American Progress, observes, "In 2007 [China] surpassed the U.S. in the number of science and engineering doctoral degrees awarded. As of 2008, Chinese institutions of higher education produced 1.14 million STEM bachelor degree graduates a year, up from about 360,000 in 2000."

Siemens is on a multi-city initiative to foster skilled graduates that would be ready for employment in major U.S. manufacturing firms, many of whom happen to be Siemens customers. It involves both schools and universities and potential employers in Detroit, Richmond, VA, Worcester, MA, and Norwood, OH. "The secret sauce is industry leaders providing internships," says Boswell, "so when the students come out of school, they'll be ready."

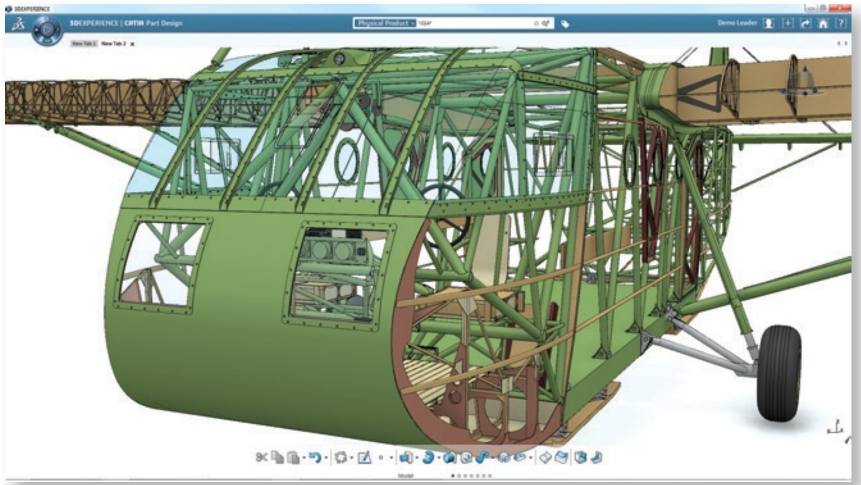
Boswell lists Procter & Gamble and GE Aviation as among the manufacturers participating in the program.

— *K. Wong*

Gliding into the Past: Dassault Systèmes Recreates Operation Overlord

It was a mission so perilous, D-Day's head of airborne operations predicted 70% of the planes and up to half the men involved would be lost, according to PBS' NOVA episode "Reconstructing the D-Day Gliders." The mission was to deliver an advanced force behind enemy lines to secure some of the bridges and crossings before the primary assault began on World War II's D-Day, June 6, 1944.

The idea was to have C47 planes tow a series of gliders across the English Channel. Upon reaching the landing site, the towropes would be cut to let the glider pilots land the planes, which were made of mostly wood and fabric. Adding to the danger, the pilot would have to land the unwieldy gliders in the dark — in about three minutes' time.



Dassault Systèmes helped the TV program NOVA recreate many D-Day operations in virtual models, including a glider-landing mission.

Reverse Engineering a Glider

Seventy years after D-Day, a few people from Dassault Systèmes got to experience what it was like to land a WWII-era glider in the tree-strewn French countryside. They were part of the production team that helped NOVA recreate the D-Day landing for a documentary series.

The first task was to build a virtual replica of the glider. Mehdi Tayoubi, Dassault's VP of digital and experiential strategy, and his colleagues couldn't easily extract meaningful volumes and measurements out of poorly preserved WWII blueprints of the gliders. Their best hope was to find a surviving aircraft.

They found a match in the American heartland, 4,000 miles away from Normandy. At the Fagen Fighters World War II Museum in Granite Falls, MN, Tayoubi and his team set out to capture the dimensions of a restored glider hanging in the museum using Faro Focus3D laser scanning equipment.

"It took two days to scan the museum plane," Tayoubi recalls. "It was in point cloud with colored points — more than 7 million points. Three-hundred-and-fifty million points were captured in an open ASCII format file. The point cloud was converted to 3D-editable mesh, and we recreated [the digital glider] manually using the different references we had. It helped a lot to understand the full structure of the glider, and to make some measurements directly to the point cloud."

A Digital Landing Site

To virtually recreate the landing operations, the team also needed a virtual landscape that closely matched the French countryside that greeted the WWII glider pilots. To get their landing site, the team rebuilt inside the computer the Arromanches Artificial Harbor. The area was considered a high priority target by the allied forces during D-Day. An artificial port set up there served to supply the invading forces with ammunition. Today, it serves as a tourist attraction.

"No gliders were used there during the [D-Day] Overlord operation," notes Tayoubi, "but it looks quite the same as the Normandy bocage with hedgerows and small fields."

The team also used a mix of maps and original aerial pictures taken in 1944 by the Allies as reference to get information such as the height of the hedgerows and field size.

Tayoubi and his team used CATIA, part of Dassault's 3D Experience Platform, and CATIA Dynamic Behavior Modeling to compute the flight dynamics in real time. "We succeeded almost 50% of the time at the end of the trial," Tayoubi reports.

While maneuvering a virtual plane behind a joystick, Tayoubi says, he came to have a better understanding of the difficulties faced by the WWII pilots. The glider landing recreation was part of a larger project that aims to turn D-Day operations into a virtual experience at 3DS.com/DDay.

— K. Wong

Pressure-Controlled SLA

An Australian start-up has announced an innovative approach to SLA 3D printing that fundamentally changes the design of the printer, at a consumer-friendly price level. Hardcotton's Elemental stereolithographic printer includes a proprietary pressure control system that regulates resin levels within the tank during the build process.

Unlike traditional SLA printers, in which the object is moved within the resin, the resin is moved around the object using the pressure system. During the build process, resin is cured onto the surface of a removable build platform in the center of the vat to create the first layer of the object. The pressure control system allows the flow of material from a control chamber in the vat into the build chamber. The 405nm laser system cures the next layer, and the process is repeated.

The Elemental is in its final stages of development, and the company plans to launch the printer through a Kickstarter campaign. Initial units will be available to backers for less than $1,000.

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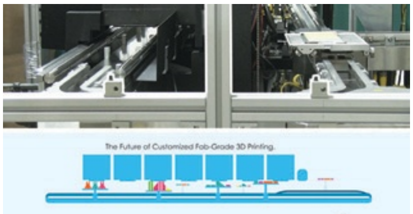
3D Systems Talks High-Speed 3D Printing



As part of its deal with Google to develop Project Ara, 3DS has been at work on a high-speed additive manufacturing system that can compete with injection molding for both speed and accuracy.

3DS is calling these new AM systems fab-grade. Instead of a print head moving over a fixed build plate, an assembly line moves build plates past print heads. This not only increases the speed of a build, but allows 3DS to manufacture parts incorporating both stereolithography and selective laser sintering.

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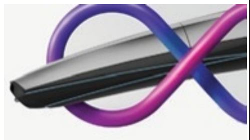
Stereolithography Pen

The next stage in the evolution of AM-capable pens has arrived in the form of the CreoPop. Although it sounds odd, CreoPop is an actual SLA (stereolithography apparatus) system built into a handheld device about the size of an extra-fat magic marker. Just as is the case with traditional SLA systems, CreoPop draws in photopolymer ink that is then hardened by UV lights built into the pen around the tip.



Cool "ink" rather than hot plastic means the new pen can be used to accentuate objects made from other materials.

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3D Printing Aids Tumor-Removal Surgery

Surgeons in Barcelona used 3D printing to create a model of a tumor and the surrounding tissues to remove the tumor from a five-year-old boy. The surgeons at the Hospital Sant Joan de Deu were able to practice the surgery multiple times before performing it live. Two previous surgeries were unsuccessful because of the number of blood vessels and arteries surrounding the tumor.

The team used CT scan and MRI data to create the model with technology from Fundacio CIM at Universitat Politècnica de Catalunya. The tumor was printed in a soft resin, while the surrounding organs, blood vessels and arteries were printed using more rigid materials. They also produced a tumor-free model of the area so they could see what the organs should like after the tumor was removed.

The surgeons practiced the procedure 10 days before the actual surgery, allowing them to determine the most effective way to remove the tumor without damaging the surrounding tissues.

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President Obama Attends First White House Maker Faire

Since his inauguration, President Obama has backed a number of alternative energy source projects, and was responsible for an increased focus on advanced manufacturing that paired government and private funding to start a network of research and development institutes across the nation. America Makes (previously NAMII) was the first institute to get under way, with two more on the horizon.

Continuing in the same vein of promoting advanced manufacturing and innovation, President Obama declared June 18 as the National Day of Making. To celebrate the day,

the White House hosted a Maker Faire. The U.S. government will also seek to support new businesses in the tech fields with the Small Business Administration's Accelerator competition, which will hand out $2.5 million in $50,000 chunks to winning startups.

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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.

AMD Unveils FirePro W9100 Graphics Card

Company describes the technology as engineered for 4K workstations.

The FirePro W9100 graphics card offers 16GB of ultra-fast GDDR5 memory, which AMD says is an industry first. It has a 512-bit memory interface and 320 GB/s bandwidth, providing more than 2.6 TFLOPS of double precision compute performance. Peak single-precision floating-point performance is reported to be 5.24 TFLOPS. All of which means that you should be able to do things like load entire datasets or large 4K files into internal memory and get great performance out of your simulations, renderings and similar compute-intensive applications.

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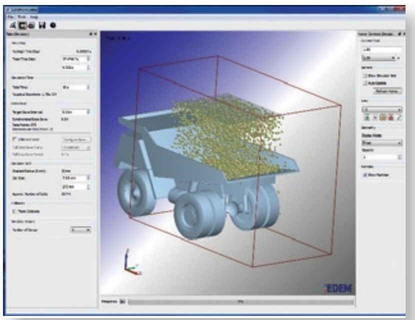

Discrete Element Method Software Updated

Platform includes preprocessor, solver, postprocessor and extension modules.

EDEM from DEM Solutions is a high-performance DEM (discrete element method) simulation software that helps you design and optimize equipment for handling and processing bulk materials through understanding how materials behave in your system and how they affect the machinery. The company says that it is the only commercially available software capable of generating the DEM simulations and analysis required to solve complex problems in the design, prototyping and optimization of equipment to handle and process bulk solid materials.

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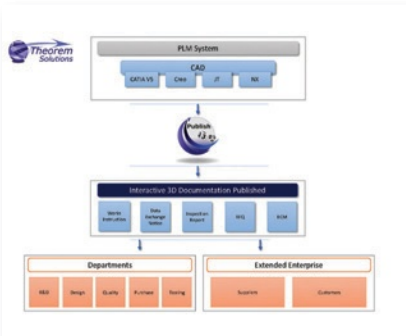

Enterprise-Wide Intelligent Document and Data Exchange

Solution allows users to create multiple specialized PDF documents.

3D PDF Publisher lets you save a file as an interactive 3D PDF document from within your native CAD environment. You can expand the utility of your document with attachments like spreadsheets, Word documents and bills of materials (BOMs). You can also have media like movies, live links to external data and annotations galore. Essentially, it makes a dynamic document out of a design file that communicates design intent and key associated data.

Publish 3D is able to scale for use by large teams, although a solo designer can use it.

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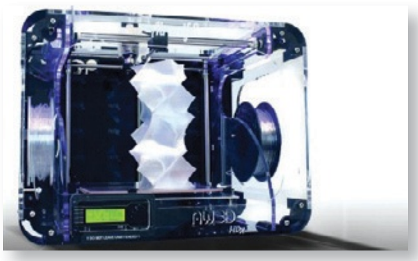

Personal 3D Printer Uses Engineering-Grade Materials

Airwolf 3D's new AW3D HDx is available for under $3,500.

The AW3D HDx 3D printer is a desktop-sized prototyping system (24 x 18 x 18 in.; 39+ lbs.). It offers a 12 x 8 x 12 in. build envelope, and resolution can be as fine as 0.002-in. Its tempered glass enclosure allows you to see the colored filaments winding around to the print nozzle, the prototype under development and lots of the unit's internal organs.

The AW3D HDx uses the company's JRx hot end for 3D printers. It can continuously hold temperatures of up to 599°F (315°C), which lets you use more durable materials.

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Get Quotes on Metal Sheet Prototypes Instantly

SolidQuote for Creo allows users to create requests for quotes in program.

Rapid Sheet Metal in Nashua, NH, has capabilities like laser cutting, forming, welding, machining, punching, wire EDM, roll forming, powder coating and silk screening. They've also released a prototype quoting application for PTC Creo.

SolidQuote for Creo automatically takes this information, applies it to your design and then identifies and prices out features such as hems and hardware in real time. And these price numbers, according to the company, are real, up-to-the minute accurate. This real-time aspect lets you play with materials, finishes, quantities and budget.

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HP Brings Virtual Workstations to Engineers

Technology is in a 2U form factor and uses the HP DL380p Gen8 server.

The HP DL380z uses Intel's Xeon E5-2600 v2 series of multicore processors, which are suitable for data center servers and cloud environments. It's your choice here: These Xeons have 6 to 12 cores, 15MB to 30MB cache memory, and clock speeds from 2.4 to 2.8GHz. The HP DL380z supports up to 384GB of DDR3 memory.

Expansion comes in the form of six internal slots. You also have seven USB 2.0, one serial, two VGA and one SD (internal) external ports to plug things into. Available network interfaces include 1GB and 10GB HP Ethernet.

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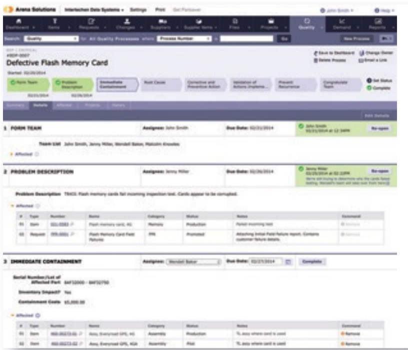

Quality Module Extends PLM Solution

Software from Arena helps build processes for ISO standards, FDA regulations.

Arena Quality embeds quality management functionality into Arena PLM's processes. It provides your teams — say, design, operations and supply chain partners — visibility into quality issues within the context of a product's complete record. You have in-context visibility and collaboration functionality on affected items, changes, requests, files and projects. You can have links to associated enterprise systems such as ERP (enterprise resource planning) and external data sources, including things like legal and warranty claims, field service reports and regulatory databases.

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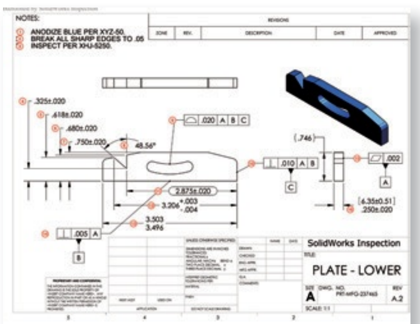

Automate Inspection Processes and Reports

Dassault Systèmes releases SolidWorks Inspection.

Among the notable benefits of SolidWorks Inspection is that it enables you to re-use existing design data and content to create inspection reports, which should speed up everything and provide greater accuracy than manual methods. This data, by the by, can be legacy data, such as a SolidWorks file, a PDF or a TIFF.

When you're working with a PDF or TIFF drawing, you can instruct SolidWorks Inspection to tell your OCR (optical character recognition) reader to read and identify the nominal dimension, plus and minus tolerances as well as the type of dimension.

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4 Skills for the Internet of Things

The Internet of Things may be the next big thing, but engineering groups need to bolster competencies in embedded software, communications, instrumentation and data security to ride the wave of the transformation.

BY BETH STACKPOLE

The Internet of Things (IoT) is the latest trend being hyped by analysts and prognosticators as having disruptive potential — so much so that it's prompting product design and engineering organizations to ramp up new competencies, and requiring manufacturers to rethink and transform their business models.

IoT generally refers to what some call the next-generation Internet, where physical objects are connected via the standard Internet Protocol (IP). Anything from cars to industrial machines to medical devices can be involved — even people and livestock. Using an array of embedded sensors, actuators and a variety of other technologies, these loosely connected "things" can sense aspects of their environment and communicate that information over wired and wireless networks, without human intervention, for a variety of compelling use cases.

Consider the potential of IoT in terms of remote diagnostics. A tractor, for example, could be outfitted with sensors that collect data about its operation in the field, providing real-time insights into performance and proactively flagging part failures before they actually occur. From a service perspective, that real-time data can provide a technician with everything he or she needs to know about how to address a particular problem, to be properly prepared with the right parts and equipment before going on-site to resolve it. Finally, all of the failure and performance data can be fed back into internal product development systems, giving engineering teams valuable insights that can drive future product generations.

National Instruments' cRIO-9068 controller, programmed with LabVIEW system design software, enables engineers to use a single, graphical development environment to build and test cyber-physical systems. ***Image courtesy of National Instruments.***

That's just a start. Beyond product development and manufacturing, experts see huge potential for the IoT to help tackle many of the global society's thorniest problems, including climate change, urban congestion and health care. IoT is already playing a role in orchestrating more efficient energy usage via the rise of smart grids, facilitating highly coordinated disaster response efforts (see "SERS Project Puts IoT in Rescue Mode," page 16). IoT is also the brains behind the new sci-fi crop of autonomous vehicles, from the Google Car to unmanned drones.

A New Economy

Big-picture, visionary applications aside, there's already significant IoT momentum thanks to the explosive growth of tablets and smartphones. Cisco estimates that there will be 25 billion devices connected to the

Internet by 2015, and 50 billion by 2020. This sets the stage for a sea change in types of products and IoT applications brought to market. In addition, a recent McKinsey Global Institute report predicts that 80% to 100% of all manufacturers will be using IoT applications by 2025, and the IoT has the potential to unleash as much as $6.2 trillion in new global economic value annually by 2025.

Industry watchers are projecting entirely new business models springing up around the IoT. In this new world, companies aren't just selling physical products, but rather the subscription services built around these next-generation products.

"Smart and connected products raise the bar on design, and smartness opens up a whole new world of possibilities in delivering value through services," Jim Hepplemann, CEO of PTC, told PTC Live 2014 conference attendees in June.

PTC is betting big on the IoT, having doled out $112 million last year to purchase ThingWorx, which makes an application platform for building IoT applications (see "PTC Rolls out ThingWorx v5.0," page 15). This is in addition to PTC's earlier acquisition of MSK Integrity, which focuses on software lifecycle management capabilities, and more recently, Atego, a developer of model-based systems and engineering (MBSE) applications.

"The fact that we are trying to keep our strategy refreshed and relevant speaks to the complexity and sophistication of products right now," Hepplemann said. "You need lot of different talents to get one of these smart connected things out the door, but you can't not make them smart and connected. If you don't, you'll be a dinosaur."

Four IoT Competencies for Design Engineers

Building smart and connected products designed to live in the world of IoT will require engineering organizations to master some new areas, and also get better at competencies that have been around awhile, like multidisciplinary and systems engineering. While there's lots of talk about the potential of IoT, and most analysts agree about its significance for the future, it's still early days in terms of companies making wholesale changes to their product development and engineering processes. That's according to Stan Przybylinski, vice president of research for CIMdata, a market research firm specializing in engineering.

"We're not really seeing it yet," he admits. "There's a lot of people out there talking, but there isn't a lot of action. People are still having problems doing basic stuff."

Companies committed to pushing their products to the next level need to consider the following four disciplines as part of an IoT engineering makeover:

1 Embedded software is fast becoming a staple of all kinds of physical products, not just cars and airplanes. With the IoT fast approaching, there is no turning back. Mechanical engineers need to interface regularly with software specialists so both design aspects of the product evolve concurrently. This is preferred over a siloed approach, which can often introduce problems later in the game, when it's more costly to address.

The level of software expertise is also critical for IoT development. "It's got to be a higher level of software knowledge, as opposed to programming," says Jim Tung, MATLAB Fellow at MathWorks. "It's important to have software architect skills while programming skills become less important.

While software skills have been a priority for many engineering organizations for some time, some traditional shops are still lacking in this area, according to CIMdata's Przybylinski.

"Software has been a creeping incompetence for a lot of companies as it's found its way into products," he explains. "A lot of the issues you see in products out in the field now can be attributed to the increased role that software plays, and its ability to throw people off their game."

2 Communication capabilities become a critical part of the design, with devices and products of all sorts connecting to the Internet to interface with other "things" (*Editor's Note: For more on this, see "Simulating M2M System Communication," page 24*). Engineers will need to choose from dozens of proprietary and standard communications protocols, and factor in things like network protocols, potential radio frequency (RF) noise and interference, and the physical fit and placement of new communication components as part of their requirements-gathering and formal design processes.

"Mechanical and electromechanical design teams now have to think about communications as a first-class citizen in the design process, and consider it as another set of domain constraints in what is now multi-domain system design," MathWorks' Tung explains.

3 Instrumentation is crucial to leverage the data collected by a smart product to institute a change (like remote programming a new function) or to initiate proactive service. First, though, the design team needs to understand how the device is to behave in the field so it can be properly outfitted with sensors to collect the right information.

Understanding the functional aspects of how the equipment is to behave will help design engineers anticipate potential failure modes much more effectively, which in turn effects how they spec the instrumentation into the design, explains Brian Thompson, vice president for Creo Product Management at PTC. At this stage, the design team needs to discern what types of sensors make the most sense for the product, and the kind of data they're trying to collect.

"Engineers should be working with field and service teams to ensure the

SERS Project Puts IoT in Rescue Mode

National Instruments, MathWorks and a variety of other organizations are trying their hand at state-of-the-art Internet of Things (IoT) applications as part of the SmartAmerica Challenge — a government mandate to explore how cyber-physical systems (another term for the IoT) can create jobs and bring socioeconomic benefits to the United States.

Nine organizations helped devise the Smart Emergency Response System (SERS), which combines numerous technologies to create a self-contained environment for disaster response. Using ground and aerial robots, human-in-the-loop telerobotics, advanced sensors, search-and-rescue dogs, adaptive electronic communications, and something called computer-enabled optimal resource allocation, the team created a coordinated and adaptable framework for smart emergency response. Volunteers can be automatically authorized and registered, and their efforts integrated with first responders. It's all accomplished through communications tools like smartphones and social networking — even when the infrastructure is seriously degraded.

A possible SERS scenario might deploy a rescue dog outfitted with a harness equipped with a camera, sensors and a GPS to transmit information back to a control center, while an overhead drone provides the on-demand Wi-Fi network to collect all the data. The drone could also deliver cell phone connectivity, so first responders could access a crowdsourcing app that might direct them in real-time to problem spots, along with funneling valuable feedback from people on the ground to help them better orchestrate the rescue mission.

"This conveys a mindset that we can create devices and systems for which, through their interconnected nature and ability to create and share data, we can substantially improve the quality of life for everyone," says Ray Almgren, vice president of marketing for National Instruments.

Learn more at SmartAmerica.org/teams/smart-emergency-response-system-sers.

instrumentation strategy covers all the bases," Thompson says. "Customers are only now just starting to think about this."

4 **Data and security** should be at the heart of any IoT-enabled product. After all, the data collected will have some sort of impact on the design, whether it's to make a change to its functionality via a software update, or to feed back into internal product development systems to direct future design iterations. Securing that data is equally important.

As a result, IT, typically the domain that has ownership of data, needs to be brought into the engineering fold so they have some sensitivity to the system design aspect of the actual devices or "things" that will be physically harvesting and responding to that data. There are also new latency and data security aspects to consider — again, areas that fall outside of the traditional domain expertise of most design engineers.

"Engineers can't be building devices in isolation if they want to take advantage of the possibilities," notes Ray Almgren, vice president of marketing at National Instruments. "It can bring in a whole other set of challenges, because your device is going to be getting data or serving up data to some database, and that information can be acted upon automatically without human intervention to make better decisions."

Case in Point

All Traffic Solutions, a manufacturer of smart traffic signs, went down the path of IoT-enabled products almost five years ago — and hasn't looked back. Initially, the company's first- and second-generation smart signs, which are primarily marketed to municipalities, collected data on traffic and speed profiles, but it had to be manually

All Traffic Solutions leveraged PTC's ThingWorx rapid application development platform to retool its street signs for the smart and connected world of IoT. *Image courtesy of All Traffic Solutions.*

downloaded from the physical sign using a traditional serial cable and eventually a portable device. Today, the third-generation signs collect data and serve it up to an Internet-based database. This not only allows for easier access, but also makes it possible to deliver robust searching and analytical capabilities, according to All Traffic Solutions President Ted Graef.

The company's engineering group had to master a number of new competencies, however, including beefing up knowledge of antennas and other communications elements. The signs incorporate a modem, which raised numerous design challenges trying to get an off-the-shelf cellular modem into the sign's already optimized footprint.

"It was a case of not letting the guts of the unit drive what the unit looks like or how it ends up functioning," explains Graef. "We had to work hard to get everything in the same package we were already using for the non-connected product."

More than any challenge to engineering, the real work came with reorienting the entire organization around IoT and transitioning the business model to be less about selling signs and more about marketing subscription services.

"The real message is that IoT is not an engineering project, it's a business project," Graef concludes. "Connectivity is a business process, not a technology. You have to get set up so you can take advantage of the product's connection so you can monetize it. Because if you're not monetizing it, why are you doing it?" DE

Beth Stackpole *is a contributing editor to* Desktop Engineering. *You can contact her at beth@deskeng.com.*

INFO ➜ All Traffic Solutions: AllTrafficSolutions.com

➜ **CIMdata:** CIMdata.com

➜ **Cisco:** Cisco.com

➜ **MathWorks:** MathWorks.com

➜ **McKinsey Global Institute:** McKinsey.com

➜ **National Instruments:** NI.com

➜ **PTC:** PTC.com

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

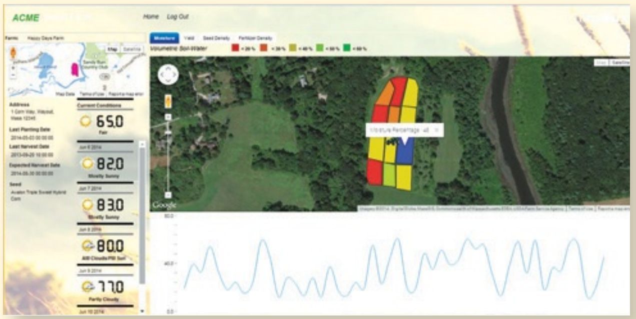
PTC Rolls out ThingWorx v5.0 Platform for The Internet of Things

As part of its push to conquer the emerging Internet of Things (IoT) landscape, PTC released v5.0 of ThingWorx, its rapid application development platform for building and running IoT applications.

Released initially in 2011 and acquired by PTC in December 2013, ThingWorx has been aggressively pursuing first mover advantage in the world of IoT. It's currently enjoying nearly 500% growth since its inception, according to Russ Fadel, president and general manager of ThingWorx. The latest release delivers a number of notable enhancements, including flexible deployment options, more efficient and secure communications protocols, and a new security model.

Citing widely used industry figures that there will be 50 billion specialized "things" connected to the Internet in 2020 and up to 1 trillion in 2035, Fadel says there is a growing need for applications to support those "things." It's a gap he notes was the impetus for starting ThingWorx. "Until recently, no one was talking about building apps — but without apps, deploying these 'things' is not practical," he explains.

ThingWorx delivers a single stack that provides all the foundational services to build IoT apps, including the communications business logic, data storage, system integration and representational state transfer application program interfaces (REST APIs), among other capabilities. This approach greatly reduces development time, Fadel says.



ThingWorx Rapid Application Development Platform v5.0 increases developer activity and offers server federation capabilities with options for cloud, on-premises and on-device deployments. ***Image courtesy of PTC.***

ThingWorx Platform v5.0 includes:

- Flexible deployment options via a new federation capability that lets apps be deployed in the cloud, on-premises, hybrid or even on-device. This feature ensures companies can put applications at the location where it is best suited from a number of perspectives, including reliability and security.
- The patented AlwaysOn Protocol is a low-latency, bi-directional communications protocol that can be tuned for minimized power consumption and bandwidth usage.
- The ThingWorx MatrixMultitenancy Security Model ensures secure visibility and access control to devices and information that directly maps to complex business ecosystems.

Learn more at ThingWorx.com.

FEELING THE HEAT

The shift to circuits, systems on a chip, and software-driven products redefines the design engineer's role.

BY KENNETH WONG

Every year, Mentor Graphics asks its customers to submit their most complex printed circuit boards (PCBs) to its Technology Leadership Award program. Over time, the submissions by Fujitsu, Samsung, Qualcomm, Johnson Controls, and other PCB makers revealed a pattern, a statistically significant PCB evolution. In 1995, Mentor Graphics saw 649 disparate components spread across 101 sq. in. In 2012, it saw 2,216 components crammed into 58 sq. in. In other words, as the number of components grew greater, the size of the PCBs got smaller.

At the end of 2013, InformationIsBeautiful.net published an infographic showing how many lines of code are in the well-known apps, devices and products we use every day. As its basic unit of measure, the widely circulated chart used 1 million lines of code (the equivalent of 18,000 printed pages of text, or 14 times the length of Tolstoy's *War and Peace*). The Chevy Volt electric car, for example, has 10 million lines of code. That's not as much as the Boeing 787's 14 million or the F35 fighter jet's 24 million. But even those numbers can't match the content of an average high-end car's software, estimated to be 100 million lines of code — far more than the 61 million lines powering Facebook.

The explosion of software code in products is a direct consequence of manufacturers' shifting emphasis from mechanical to electrical functions. To reduce the number of mechanical parts, which are costly to produce, with integrated circuits or Systems on a Chip (SoCs), engineers and designers must rely on software-driven operations. In turn, the shift encourages designers to explore more miniaturization and simplification opportunities through the use of SoCs on PCBs.

The Power Tester device from Mentor Graphics is used to test and verify the performance of printed circuit boards. The output from this test usually becomes the basis for further thermal simulation by the mechanical designer. *Image courtesy of Mentor Graphics.*

For future engineers, the embedded microprocessors and control software are an integral part of product design. It's a trend to which the current crop of mechanical CAD (MCAD) and product lifecycle management (PLM) products is seeking to adapt.

For example, Bill Boswell, senior director of partner strategy for Siemens PLM Software, participated as a judge in the recent EcoCar 2 competition, aimed at encouraging next-generation engineers to design energy-efficient vehicles.

"On those teams, there are kids working on control systems, antilock brakes, and so on," he points out. "For them, the control software is as much a part of the design as the brake pedal is."

The Impact of Software

Humair Mandavia, executive director of PCB design software maker Zuken's U.S. R&D operations

From Semantics to Numbers

Michael Munsey, Dassault Systèmes' director of semiconductor strategy, describes what at first seems like an issue of semantics, arising from the need for system-level simulation.

"Take the high-level requirement for a car," he suggests. "It says the car must have an anti-lock braking system. But as it moves down the production chain to the people who need to design the brake system, they need to translate that English language into engineering values [torques, pressure, stress, safety factor, etc.]. Then when it gets to the semiconductor level, it has to be described as electrical signals and how they interact."

Designers need a method to trace all the numerical tests and verifications done in each phase of the design development to the high-level requirements from where they originated. This traceability issue is not confined to automotive; it affects every product that incorporates software and SoCs as an integral part of design.

To an extent, the traceability problem remains invisible because "everyone has solved it at his or her own domain level," Munsey says — the mechanical engineering department has its own method for correlating the abstract requirements to mechanical engineering parameters; the electrical engineering department has done so for itself; and so on.

Dassault Systèmes offers simulation lifecycle management (SLM) products under its ENOVIA and SIMULIA brands. They were initially developed to cater to the mechanical design industry, but have been refined so they can be deployed in semiconductor design as well. Part of the software lets users visually map out the relationships between test results and the requirements they're intended to satisfy.

(dubbed SOZO), reflects on his own introduction to coding as an electrical engineering student.

"I was required to take several classes on C++ programming and other programming courses to understand the relationship between hardware and software design," he recalls. "In my program, the focus was still more on digital IC design; today, engineers need to think at the system level. Coding has always been part of engineering, but the dependencies have grown larger now."

For products in automotive and aerospace, the complexity of what the embedded SoCs must do is increasing.

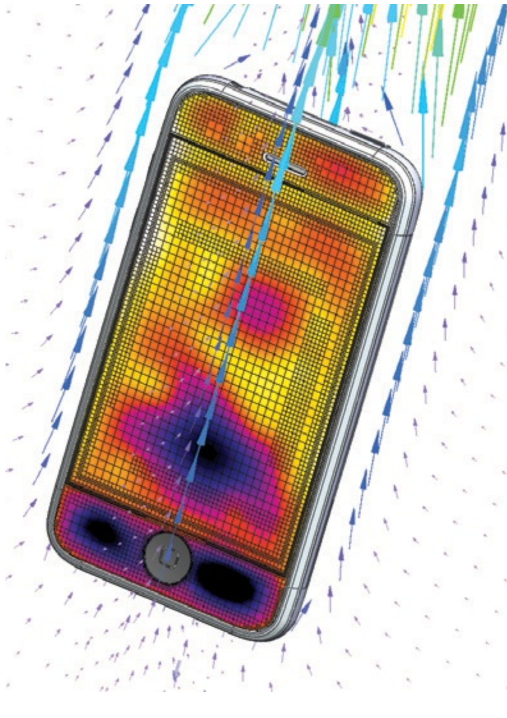
"There are so many dependencies in the system, because all these devices are talking to one another. When the Internet of Things (IoT) becomes widespread, SoCs and the software that goes into it will become even more complex," Mandavia predicts. "The more functions we put on the SoCs, the more code we'll have. There's a direct correlation."

John Winter, mechanical engineering manager for radio frequency (RF) equipment maker Bird Technologies, provides a historical perspective. "Eight years ago, we had two programmers," he says. "Today, we have eight in my department, about 12 total in the company — that's around 40% of our engineers."

The Tug of War for Space

Winter describes his firm's typical workflow: "The mechanical designer will give the contractor [hired to develop the PCB design] the board outline, mounting holes and connector placements. The contractor would give us back the design so we could place it in our assembly to check placement. Then we give the green light to buy the board. Sometimes the contractor tells us how much room they need; sometimes we tell them how much room they have."

In refinement of existing products, the established form factor (especially



The increased density of PCBs generates significant heat gain. Thus, managing the heat in consumer products like smartphones is critical. ***Image courtesy of Mentor Graphics***

the chassis) limits the room available for the PCB. But in new product development, Winter acknowledges the board design tends to take precedence over mechanical considerations.

"The electrical engineers will get the board working first, in whatever shape they see fit," he explains. "Then, when it's ready, they'll begin the back-and-forth process with mechanical engineers."

The competition for space on the PCB itself is also fierce. John Isaac, director of market development for Mentor Graphics, compares the shrinking of PCB physical space and the increase of circuits on the board to "putting 10 lbs. in a 5-lb. bag."

"What used to be a processor surrounded by 10 memory chips is now one integrated SoC," he adds. "That's going from 11 components to one."

Zuken's Mandavia agrees. "Talk about tug of war, things are getting very tight," he says. "Now we're trying to put the SoCs inside the substrate of a PCB."

Things are Really Heating up

Heat management is becoming a big issue, says Mentor Graphics' Isaac: "As the SoCs fitted on the board are getting tighter, you have very hot components getting closer and closer to one another, housed in very small factors like cellphones and tablets."

Even if the ECAD components are causing the heat, both the creation of the product's top-level assembly (represented in CAD) and thermal analysis typically fall into the responsibility of the MCAD user. Thus, the mechanical engineer will feel the heat, so to speak.

Mentor Graphics offers T3Ster hardware and software for testing and verification of SoCs and PCB packages. The thermal output from this can be imported into FloTHERM, a computational fluid dynamics (CFD) software package for simulation and analysis of board component behaviors. This allows the designers to simulate the behavior and interactions of the chip with the end product — while the product is still in development and only exists as a digital 3D model.

The Electro-Mechanical Handshake

Winter points out that the Super Video Graphics Array (SVGA), a computer display unit, is a critical component in Bird Technologies' products — and thus a critical factor in design. "It has a microchip on it, so the mechanical engineers have to manage the heat from it," he explains. "We need to position it in a way that let the heat escape through the chassis, or with fans and heat sinks."

If the heat increases beyond what's recommended by the chip maker, the chip's performance itself begins to degrade, Winter says. He and his colleagues use Siemens PLM Software's Solid Edge with Synchronous Technology (SE with ST), a direct-editing program, to design their RF devices. Unlike a history-based parametric CAD package, SE with ST lets designers quickly execute geometry changes without having to retrace the historical steps required to create the geometric features. That flexibility, Winter points out, is favorable to the iterative MCAD-ECAD back-and-forth workflow to negotiate the PCB's space envelope and location in the product.

As Zuken's Mandavia observes, "It's great to be able to put all these functions on a single package or a chip, but now you have to think about its thickness and placement inside the product." To that end, some ECAD developers like Zuken have begun working on accommodating 3D geometry transfer between ECAD and industry standard MCAD programs — what Zuken calls "3D ECAD/MCAD co-design."

Zuken's CR-8000, CR-5000 and CADSTAR products, Mandavia says, can export not only the geometry of the PCB but also the conductive information. "That only solves the problem on the MCAD side," he continues. "With CR-8000 Design Force, we support the import of mechanical data, such as housing information so that PCBs can be designed with accurate mechanical constraints to solve the problem on the ECAD side." Electronic design automation (EDA) companies are now working more closely to help realize a more collaborative design process.

Simulating the Interplay

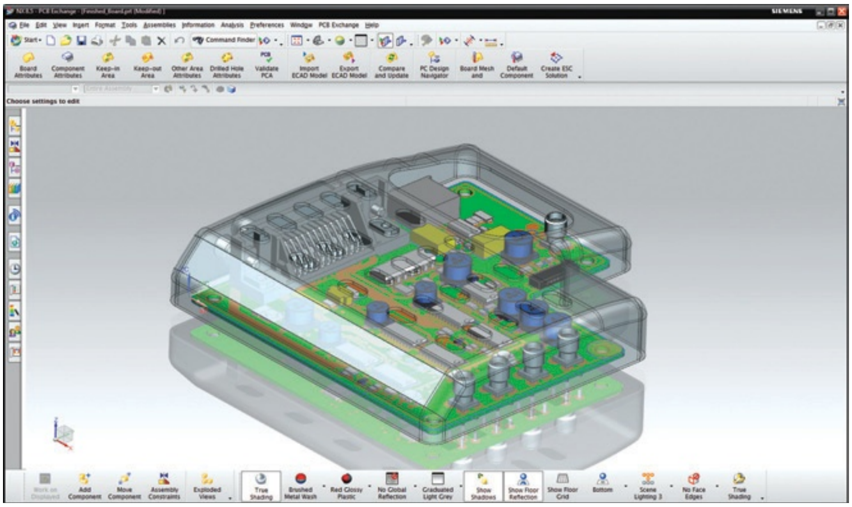
In June, the Design Automation Conference (DAC) was in full swing at San Francisco's Moscone Center. It was also where ANSYS' director of high-tech industry marketing and strategy, Sudhir Sharma, used the cell phone in his hand to illustrate a point.

"If my hand is impairing the antenna's reception in a significant way, or if I get inside a building so the reception gets weaker, the signal amplifier in the phone increases the amount of power to compensate," he said. "That drains the battery and increases the heat inside the device. The person designing the phone needs to recognize the interplay. So he needs a thermal-electrical-structural analysis that combines everything in the system; he can't treat them as discrete operations."

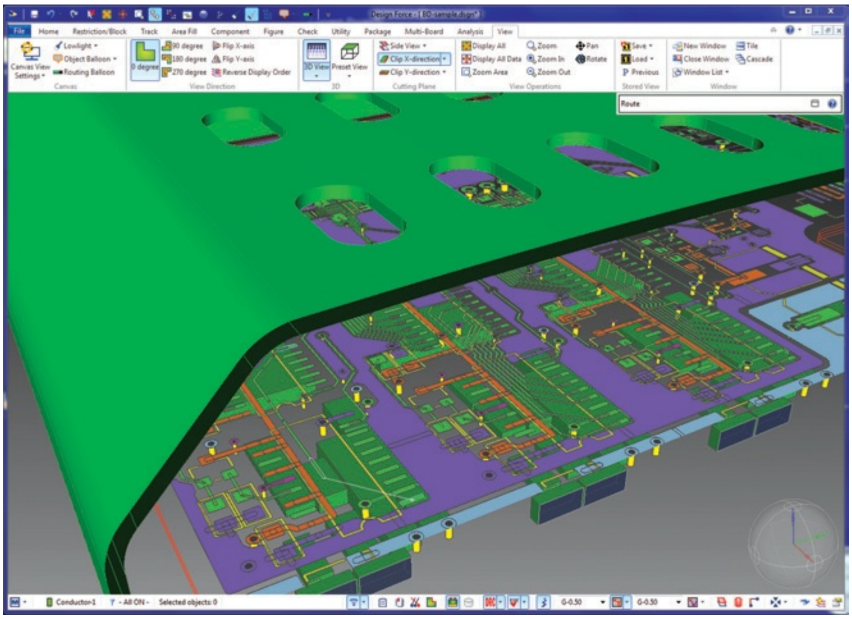
Lunchtime conversations and hallway exchanges at the DAC, Sharma pointed out, reflected the new thinking: "Everyone is talking about multidisciplinary, multi-physics simulation."

In May 2012, ANSYS made the move to acquire ESTEREL, a company founded by two French researchers who invented a control programming language. (The language was named after the Esterel Massif mountain range in southeastern France.) Today, ANSYS' portfolio includes what was formerly an ESTEREL product — the ANSYS SCADE software suite, a systems design and modeling tool for embedded software simulation and code production.

"SCADE is a modeling environ-



As MCAD and ECAD users work to define the PCB's space in the assembly, it's essential that they have a way to display the complete PCB model with conductive data inside the MCAD environment. This image shows a PCB design with enclosure within Siemens NX CAD program, a workflow made possible by Zuken. *Image courtesy of Zuken.*



A PCB model with conduct placement and routing with accurate 3D mechanical constraints, as seen in Zuken's CR-8000 PCB design program. *Image courtesy of Zuken.*

ment, but it can also automatically generate millions of lines of code that you can immediately implement in the engine control unit of a car, or your device," Sharma said.

'The Long Pole in the Tent'

The keyboard on previous-generation flip phones used to be a collection of tiny mechanical parts, manufactured at considerable cost and prone to break from stress. But today's multi-touch screens reduce the operation into software and circuits.

As Mentor Graphics' Isaac points out, in today's smartphones, you'd be hard pressed to find any moving mechanical parts beside the on-off switch and the battery. "You can design and produce your hardware, your chips, and everything else, but software development is usually what holds up the process," he adds. "The software is the long pole in the tent."

Previously, mechanical designers only had to deal with the placements of circuit boards in their design. Their concerns were more or less limited to reserving sufficient space within the assembly so the electrical components could fit within it. But perhaps that's a simplistic way of looking at design.

"Now, lots of functions are consolidated into SoCs," says Michael Munsey, director of semiconductor strategy for Dassault Systèmes. "The boards themselves are getting so small. The massive integration and consolidation have made the systems a lot smaller and complex. So we should think of new ways people can interact with these devices."

SoC and the shift to software paved the way for the iPhone's voice-activated Siri and Windows' upcoming personal assistant Cortana. Ten years from now, when software and circuits make it possible to command and control devices with natural spoken language and gestures, the term "pushing buttons" may be remembered as nothing but an outdated metaphor. **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.*

INFO ➜ **ANSYS:** ANSYS.com

➜ **Bird Technologies:** BirdRF.com

➜ **Dassault Systèmes:** 3DS.com

➜ **Mentor Graphics:** Mentor.com

➜ **Siemens PLM Software:** PLM.automation.siemens.com

➜ **Zuken:** Zuken.com

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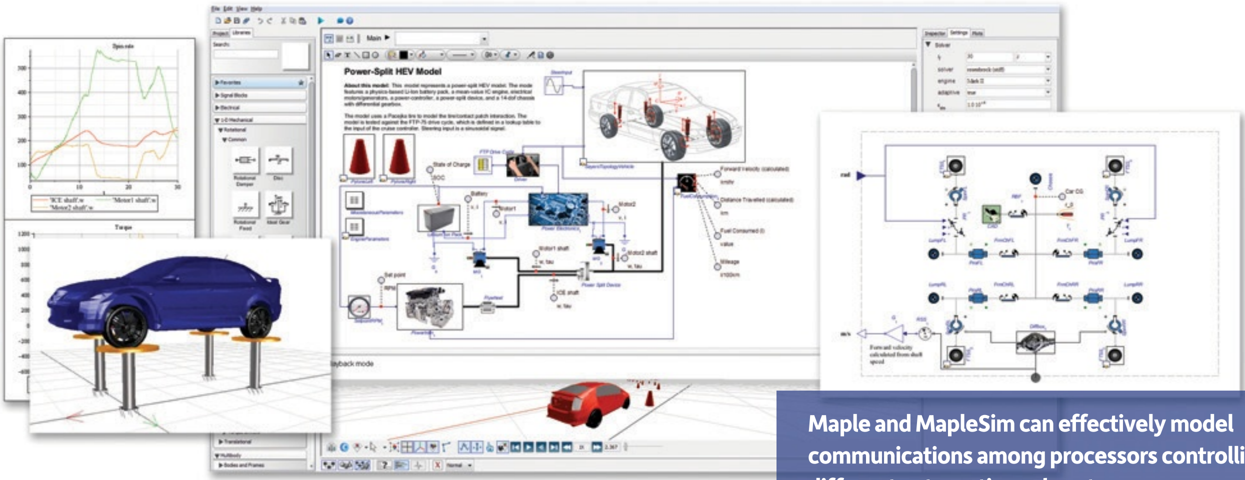


Maple and MapleSim can effectively model communications among processors controlling different automotive subsystems.

Simulating M2M System Communication

Building machine-to-machine embedded systems can be complex and error-prone without simulating the communication among devices.

BY PETER VARHOL

As the Internet of Things (IoT) ramps up and millions of devices become connected to the Internet, there is also a push to enable communication among all types of devices available on the Internet. These devices include process control systems, power line communication (PLC) devices, precision machinery, and various types of infrastructure.

For example, imagine the system of monitors and controllers it will take to control driverless cars on a highway — car sensors and control systems, manufacturing systems, traffic signals, wireless access points, systems working with Big Data, and likely even satellite monitoring. All of these components need to communicate with one another, accept and process data, and provide feedback to a variety of control systems.

Simulating these systems is a challenge, but it's necessary to understand the behavior of the system and how to make it better before actually building it. They consist of many hardware components, multiple software packages including different operating systems, different programming languages, and different types of connections. Most of the IoT for specific applications will operate on small network segments for specific purposes, but some will connect with hundreds, thousands or even millions of other devices.

Machine to Machine, Defined

Simulation is an essential element of building an IoT network. These networks are starting to become complex and ubiquitous, and the communication among these systems can be unpredictable without a lot of modeling. Many of the technologies and applications are new, necessitating creative design strategies and good technical decisions.

Machine-to-machine, or M2M, is a type of IoT design that typically involves no human interaction. It might involve feedback systems between engine and braking actions in an automobile, or control systems monitoring temperatures and chemical reactions in industrial plants. These devices have performed relatively simple, single-function tasks in the past, but are now being called upon to operate more autonomously, in conjunction with other devices.

Because many of these systems have at least soft real-time requirements, getting the timing right is a critical part of design. If engineers had to physically build it to do so, tweaking the design could take significant time and cost a great deal. Thus, simulation is increasingly the starting point to the design and implementation of these embedded networks.

Simulating Processors and Communication

System parameters and design goals may require simulating the different types of processors and processing at the hardware level. In some cases, this could be done as hardware-in-the-loop (HIL) simulation. According to Jim Tung, MATLAB Fellow at MathWorks, communication between devices can occur in multiple ways: "Ethernet, both wired and wireless, Bluetooth or LTE." During the design process, engineers are often looking at tradeoffs between cost and performance want to simulate different communications options.

Tools such as MathWorks Simulink provide a robust method of simulating both devices and communication between those devices. Simulink provides a means of executing a MATLAB model to determine the operating characteristics of a design.

For those interested in performing detailed communications simulations, MathWorks also offers downloadable toolboxes for specific media and protocols. These include the signal processing, radio frequency (RF), communications system and wavelet toolboxes — enabling modeling and simulating different types of communications to be done at a high level of abstraction.

Maplesoft's Maple and MapleSim also enable engineers and system designers to create communications designs. The two work together — Maple to produce formal analytical models based on mathematical representations of system behavior, and MapleSim to execute those models as a part of a simulation.

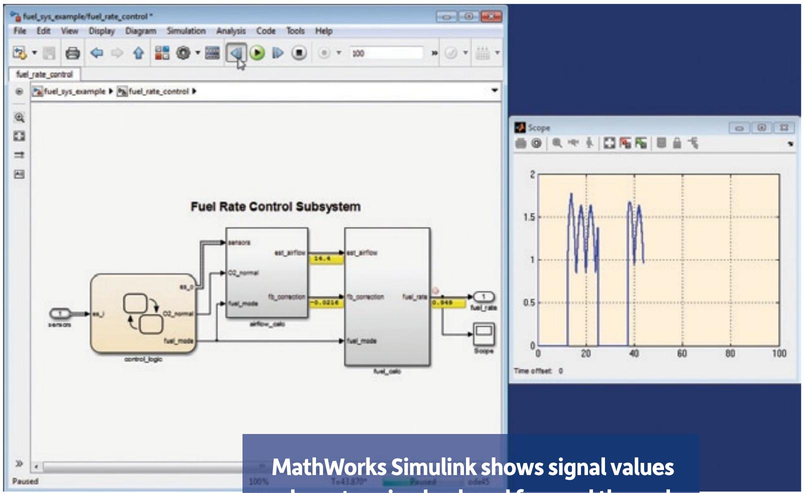
The result is a combination of mathematical tools for engineers with the ability to build and execute models of complex real world systems. While Maple is used for a lot of designs and simulations within the automotive industry, these tools can be applied to any engineering problem that requires sophisticated mathematics.

In support of HIL simulations as well as other types of integrated simulations, MapleSim offers a large and continually growing array of connectors to other engineering software and hardware systems. It enables engineers to easily connect supporting hardware devices, and simulate the communications activity among them.

Simulating processors is usually necessary only at the most basic level, if hardware isn't available yet or if the project is at the conceptual phase. Instead, designers are typically able to employ HIL to include existing processors or other hardware devices into the simulation as they look at other aspects of the distributed system, such as application performance, communications and real-time responsiveness.

Building in Applications

Verifying that the infrastructure operates as expected is an important part of the simulation exercise, but simulating what is sup-



MathWorks Simulink shows signal values when stepping back and forward through a communications simulation.

posed to happen on the processor, field-programmable gate array (FPGA) or application-specific integrated circuit (ASIC) is another matter entirely. In most cases, engineers simply simulate expected inputs and outputs, with the expected real-time lapse for data acquisition and processing. It's relatively easy to implement on devices, if the primary goal is to test communications operation and latencies.

There are cases, however, where the bulk of the on-chip application actually exists, such as in control systems that have in the past operated independently. In these cases, HIL using existing hardware and applications makes sense. In that way, engineers can run most, if not all of the actual applications — and focus specifically on the communications parameters among them.

Managing Network Communications

The last step in building and managing such a system is integration, data exchange, and control across many nodes. This requires a strategy that lends itself well to distributed management systems. While this can be difficult to simulate, there are solutions that can run in an HIL configuration with a focus on different types of communications and different media.

There is a specification and public standard for such control software, maintained by the Object Management Group. This standard, called Distributed Data Service (DDS), addresses publish-subscribe communications for real-time and embedded systems. This approach enables new components to be added to the network at any time and subscribe to global data, an essential element of any large-scale network. DDS introduces a virtual Global Data Space where applications can share information by simply reading and writing data-objects, addressed by means of an application-defined name.

Any simulation incorporating many different nodes and requiring complex data interactions must also include mitigation and control software. While DDS was intended to be a specification for operating software, it can also be implemented and run on top of a large-scale system simulation, as well as with the resulting product.

Some simpler M2M networks don't require this level of peer-to-peer control, but it is becoming more common with systems requiring real-time data and feedback for control systems. DDS specification developer Real-Time Innovations, for example, reports significant use in hospital and medical environments, command and control systems, and aviation communications.

From Simulation to Product

M2M networks are an evolving set of systems, including processors, ASICs, network communications, operating system instructions and communicating applications in a complex, interacting network. The set of systems is usually self-managed in that it uses data generated by data acquisition devices to make and implement simple decisions on the systems being controlled.

Organizations seeking to develop their own internal M2M network, or plugging into the larger and more public Internet, will find simulation to be a faster and more reliable network of devices without having to build and rebuild it multiple times. Simulating communication systems with hardware, or simulating the hardware and applications also, can make the difference between a smoothly functioning network and one that needs continuous adjustment once in production. If the network is used in a manufactured product, such as an automobile, any error or inefficiency in design could result in recalls or field adjustments of the entire product line.

A comprehensive approach requires simulating the hardware, operating system, management software and even apps. Because communications represents such a large part of the unknown and difficult to predict, HIL simulations are often appropriate. Either way, the end result of simulating communications systems can be better designs that are less costly during the design process. **DE**

Contributing Editor **Peter Varhol** *covers the HPC and IT beat for DE. His expertise is software development, math systems, and systems management. You can reach him at de-editors@deskeng.com.*

INFO → **Maplesoft:** Maplesoft.com

→ MathWorks: MathWorks.com

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Why Upgrade?

That's the question your manager might be asking when you say you need a new workstation. Here are some answers from an industry expert.

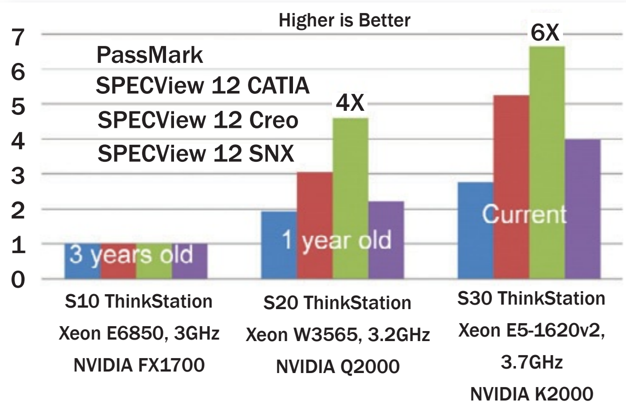
Tom Salomone has more than 17 years of experience matching computer aided design and computer-aided engineering requirements to computing solutions. He is currently worldwide segment marketing manger for Lenovo®. He shares his thoughts here on the importance of refreshing your workstation.

DE: Some design engineers are given the same computers as everyone else in the company. Why should companies invest in professional workstations for their design engineers?

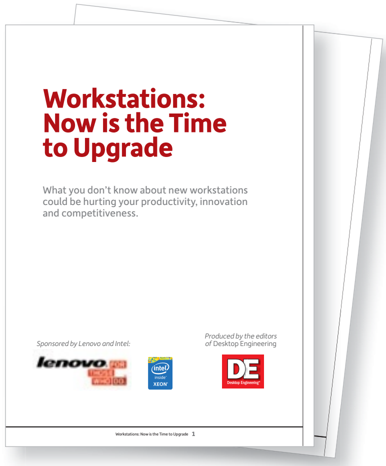
TS: Design and creation activities are critical to your success. They represent your competitive advantage. This starts with you, the engineer who conceives the idea and the design. It also includes the methods you use to design it, the software you use and the hardware that runs the software. Also very important, is how fast you design and create, as you can't afford to get behind the competition, or miss a critical due date. All these things combine to give you a creative and innovative competitive edge. Both creation and schedules are critical elements of success, and workstations are a key element of this.

DE: In the white paper, "Workstations: Now is the Time to Upgrade," you make the point that it is more critical to upgrade now than it has been in the past. Why is that?

TS: Nothing is stagnant in this world, and this is true for the world of design and creativity. For example, new features are constantly being added to your design and the design is being shared in new ways using software like product lifecycle management. Designers learn more from organizations like manufacturing and adapt their designs according to the latest technology trends available. In addition, the software they use changes, new revisions come out, new fixes and even additional software features all need to be taken into account. All of this results in larger 3D models being created. Large files of just three years ago are considered average today. It is estimated that 3D files double in size every two to three years. Larger files and applications take longer to process in the CPU and graphics card; and they take more memory, and more storage. This happens gradually, so many designers don't notice it changing. We see this change as our systems growing slower when, in fact, the models and applications have gotten larger.



Newer ThinkStations are up to six times faster than those of just three years ago. *Image courtesy of Lenovo.*



Download the new *Desktop Engineering* white paper, "Workstations: Now is the Time to Upgrade" here: deskeng.com/upgrade. The free, 9-page paper explains the benefits and costs of upgrading vs. the status quo.

DE: The white paper calculates the return on investment (ROI) in new workstations for their design engineers. But, on average, how long does it take to achieve ROI?

TS: Even if design engineers are only about 33% more productive doing their design work on a new workstation and only do design work a third of the day, the ROI on a new workstation is less than six months. That's a conservative estimate. It's a simple calculation, depending on the engineer's salary, the cost of the workstation and the time saved. If anyone looks at it, they'll see they're definitely going to get the ROI fast.

You can win a new Lenovo ThinkStation P300 in *Desktop Engineering's* Pop Quiz Sweepstakes! Answer six quick questions for a chance to win: engineerquiz.com/lenovo.

Ease of Use Drives 3D Scanner Adoption

The 3D scanning market is getting bigger, even as the scanners themselves are getting smaller.

BY BRIAN ALBRIGHT

Data from Research and Markets published last year put the 3D scanning market at roughly $2.06 billion, and set to double by 2018 with a compound annual growth rate (CAGR) of 14.6%. Much of that is being driven by medical applications and dentistry, but prototyping, reverse engineering, quality control and other applications are also expanding.

That growth has been driven in large part by the steady increase in speed and accuracy of the scanners themselves, along with falling prices. The scanners are also smaller, easier to use, and can provide an increasingly valuable service for companies that need fast, accurate measurements, or that want to quickly generate 3D models. There are now hand-held, industrial-grade scanners that can be had for less than $20,000 — providing a viable alternative for users who don't need the extremely high level of resolution and accuracy provided by large, more expensive units.

"When scanners first emerged on the market, they weren't widely accepted because people didn't trust that they could be accurate," says Burt Mason, regional sales manager at Hexagon Metrology. "Now they've proven their worth. You give up a little bit of accuracy compared to a hard probing system, but the speed, the amount of data you can capture and the color mapping you can get on the inspection side will overcome that small inaccuracy."

The growth in 3D scanning has also been affected by the introduction of lower cost scanners in the sub-$5,000 range (in some cases, sub-$1,000). Most of these scanners are targeted at consumers, who use them in conjunction with 3D printing applications. That's the case with 3D Systems' Sense scanner, MakerBot's Digitizer Desktop unit, the Kickstarter-funded Fuel3D scanner, and similar devices.

"There are a lot of people interested in 3D scanners that are not concerned about accuracy, because you can do so much with low-accuracy 3D scanners," says Thomas Tong, global

FAR LEFT: LMI Technologies' HDI 120 uses blue LED projection technology to capture 3D scans for reverse engineering, inspection measurement, and visualization applications. It is dust-proof and water resistant for harsh environment operation.

LEFT: The Hexagon Metrology WLS qFLASH is a stereo vision system with low sensitivity to machinery vibration, industrial light, and temperature changes, making it suitable for capturing 3D measurements in shop floor environments.

RIGHT: The Hexagon Metrology T-Scan 5 is targeted at non-contact laser scanning for CAD-to-part inspections and reverse engineering applications.

sales manager for high-definition imaging (HDI) products at LMI Technologies. "Not everybody needs to capture the last micron of accuracy all the time. With the emergence of the consumer 3D printer, the consumer market has really elevated the status of 3D scanning."

Although the scanners are less accurate than their industrial cousins, they are popular with home users, small businesses and hobbyists. However, in the bulk of professional applications, consumer-grade scanners do not provide the accuracy or resolution required for most design and production applications. These scanners can create point clouds, but they aren't accurate enough for inspection applications — and most of the devices aren't robust or rugged enough for the shop floor.

For companies or designers drawn to the technology by these consumer models, investigating professional-grade equipment can lead to a fair amount of sticker shock. "When we're talking to customers, we have to explain the differences to our clients," says Evgeny Lykhin, vice president of product management at Artec Group. "You have to know what applications the consumer scanners are built for, and what the industrial equipment is built for. We've had to conduct training with our distributors to discuss these issues with customers."

In addition to providing greater accuracy and resolution, higher-end scanners can monitor environmental conditions that affect measurement accuracy like temperature, air pressure and humidity, along with desk vibration or movement. "Professional scanners outperform low-cost laser scanners in accuracy, stability, resolution, software capabilities, ease of use, and overall scan time from start to finish," says Gleb Gusev, CTO at Artec Group.

"Professional grade scanners provide more dependability and repeatability," Tong adds. "They also provide a workflow from beginning to end. If you have a reverse engineering application, these scanners provide a complete workflow to get you from the original part to a digital model, at a relatively quick pace. The consumer models can get you a 3D model, but you can't depend on that data because the accuracy is so low."

Ease of Use

While technical specifications are still important to companies evaluating new scanners, ease of use has become increasingly important as the scanning function moves from trained technicians and specialists to less-experienced users within an organization.

"Users have moved beyond price, accuracy and speed," Tong says. "They are more interested in having a complete feature set or performance characteristics. They're looking for mobility and ease of use, and whether you can connect different or multiple scanners to the solution."

Scanner manufacturers have made it easier and faster to configure and set up the scanners so that users can quickly start scanning objects with minimal training and start-up time. New scanner acquisition software is handling pre-processing tasks to speed delivery to CAD systems via features like built-in data editing, alignment and merging capabilities.

Wider integration with design and engineering software solutions is another important feature. Artec, for example, is releasing a software development kit (SDK) this year that provides integrated support of the company's scanners for software developers. "What end users are looking for is an integrated experience, and a secure package where they can do all of their work," Lykhin says.

Scanner Selection Criteria

When it comes to actually selecting a 3D scanner, knowing your application is critical. It seems obvious, but many companies approach what can be a very expensive purchase without clearly defining what they want to scan, what they want to accomplish with the data, and where the scanning will take place.

Outlining the application will determine the size of the equipment, the resolution and accuracy, and the level of ruggedization the equipment requires. "You have to know what you are trying to accomplish, otherwise you wind up buying a scanner that turns into a paperweight," Tong says. "There's no point in buying a $200,000 industrial scanner if you don't need that accuracy or those performance characteristics. But it's also a waste of time to spend $10,000 on a product that will not do what you need it to do."

Application requirements will help guide the purchase decision based on technical specifications that include:

Set-up time: How long will the scanner take to warm up, mount, position and calibrate? Part preparation will also affect set-up, because some parts may require a coating, special lighting conditions, or the application of targets. Some newer units require very little warm-up time, which means scanning will occur faster.

Versatility: Not every scanner can be used to scan or measure every object. Determine whether the scanner can handle the range of parts you need to scan.

"When people buy a scanner, they assume they can scan anything, and that's a common misconception," Tong says. "Most scanners are narrowly defined devices, so if you need to scan coins, you will need a different piece of equipment than if you want to scan a car."

Also, consider whether you will need hard probing capabilities, or other measurement tools to work with the scanner. "The scanner is not a silver bullet solution," Tong

Reality Capture Devices as QA Tools

Peter Fritz and his colleagues at 3M's Automotive Aftermarket Division are currently exploring the use of additive manufacturing (AM) in what they do. Fritz, 3M's Manufacturing Technology Manager, said, "In our business, we focus on collision repair and car care. We provide our customers with total solutions for refinishing automotive bodies."

Fritz and his team have found that AM could be used to custom-produce parts—for instance, a jig or a component a body shop might need to perform the repair. But they also want to implement quality control, while the part is still in production. "We need a way to spot-check and make sure the component we're producing or what we're printing meets the desired quality criteria and dimensions, that it's within a certain range of accuracy and tolerance," he said. For that, they're looking to reality capture tools—specifically, the MicroScribe digitizer.

Fritz's division uses several 3D printers, employing a mix of fused deposition modeling (FDM) and Polyjet printing. They have begun using the MicroScribe device to measure the critical dimensions while producing the AM part to ensure the printed components meet their expectations.

"What we like about the MicroScribe is its portability," he said. "With it, we can move from location to location, set up, and run diagnostics relatively quickly. The accuracy of the dimensions we measured is adequate for what we're doing now."

Fritz acknowledges the approach and the workflow are both at their infancy at the present, so he and his colleagues are still experimenting and learning. They hope to share their findings with industry consortiums in the future.

–Kenneth Wong

says. "Most people looking for scanners have a measurement task or problem they want to solve, and they think a scanner can do everything for them. You have to understand that a scanner doesn't replace calipers or other tools. It's just another tool in the toolbox."

User requirements: Who will do the actual scanning? If a designer or non-specialist will actually use the scanner, then ease-of-use, versatility and set-up time considerations will be even more important.

Accuracy: This is the degree to which the scanned data matches the physical object, and tolerances will vary based on the application. For critical design features in engineering applications, that accuracy may need to be in the range of 0.001 to 0.010 in. However, specifying inappropriately tight design tolerances can drive up cost.

"The most demanding industrial customers are in manufacturing," Lykhin says. "They need the highest resolution and precision possible to make a comparison of the real object vs. the modeled one."

"You really have to look at how the spec is developed, because specifications for laser scanners are all over the map," says Hexagon Metrology's Mason. "If you see the scanner listed at 30 microns, what does that mean? We test our systems with the laser scanner attached to the portable arm, and certify the entire system. Some companies give you just the accuracy of the scanner by itself."

Resolution: Resolution refers to the spacing between the sampled points, and the required resolution will depend on the size of the smallest features that have to be scanned. Again, the application will determine how fine a resolution is required: Package design, for example, can have a coarser resolution than reverse engineering or digital archiving for remanufacture. Ultra-fine point resolutions can swell the size of the point cloud file, so define tolerances accordingly.

Scanner performance will also change with use. "The claimed precision of a scanner degrades with time because of temperature fluctuations and other factors," Lykhin says. "The stated precision and resolution are typically determined with factory calibration. What customers should look into is the ability to recalibrate the scanner later without sending it back to the manufacturer."

Scanner size and range: If you have to scan large objects or parts in service, the size and weight of the scanner (and its ability to be used in a mobile scenario) will be important. The range of the scanner (field of view and depth of field) will also affect scanning procedures. If the object exceeds those ranges, then stationary scanners will require multiple scans. The scanner's coverage will also affect its ability to scan line of sight constraints like holes, undercuts, and channels.

Once you have a scanner in mind, test it on the largest part you plan to scan to verify its accuracy at different distances, and see how it performs with variable materials like paint, chrome, or light-absorbing surfaces.

"Don't get overwhelmed by just having the ability to scan," Mason says. "It's easy to be impressed by the amount of data you can get, and overlook some of the realities of your environment and how they will affect the scanning performance." **DE**

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

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Simulate **Joints** and **Connections** in FEA

Here's how to make difficult decisions when simulating connections and joints within a finite element analysis.

BY TONY ABBEY

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

Most structures involve some form of jointing or connection. Using rivets to connect structural plates is almost as old as the introduction of bronze, and then iron into early civilization. Bolted connections became possible with the advent of screw cutting methods, and usage was accelerated by the standardization of pitch and thread, for example.

Even today, fabricated structures such as aircraft and ships use many thousands of bolts and rivets to connect components together. Other large-scale connection technologies include welding and spot welding. The improvement of adhesive technology, coupled with a much wider use of composites, has meant a major resurgence in the use of bonding.

Connections can be of a continuous nature, such as in large surface regions of plates, flanges and where other abutments exist. Alternatively, lugs and pins, clips or similar connectors may form discrete load paths.

The engineer is faced with a difficult decision, then, when attempting to simulate such connections and joints within a finite element analysis (FEA). In many cases, the details of each individual connection can be ignored if an overall stiffness or strength assessment is to be made and the connection is assumed reasonably continuous.

However, there may be doubts about the local flexibility and load paths developed with this assumption. It may be that the assessment of local behavior of the connector is essential to a safety case — with main attachment fittings, for example. In some cases, the interaction between the connectors and the surrounding structure is critical, as in the case of pre-loaded bolts and inter-rivet buckling.

Let's take a look at the various modeling assumptions and implications when considering bolted type connections. Other connections, such as spot welds, continuous welds and bonding, will be considered in a future article in *DE*.

Bolting Requirements

Fig. 1 shows the main characteristics of a typical bolted joint. The bolt consists of a shank and a head. The end of the shank is threaded to accept the nut. There's usually a washer underneath the nut, and possibly also the bolt head.

In some applications, the thread is allowed to extend into the grip length. The grip length is the part of the shank containing the plates, flanges or other components that are being connected.

Most bolts are preloaded, which we will discuss in more detail shortly. One

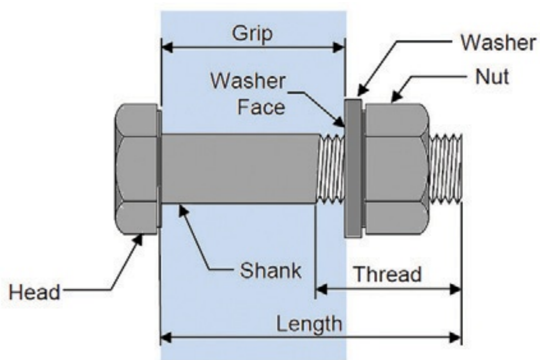

FIG. 1: Bolt terminology.

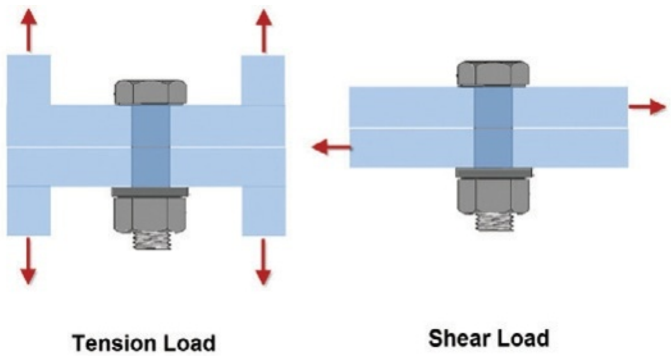

FIG. 2: Bolt tension and shear loading conditions.

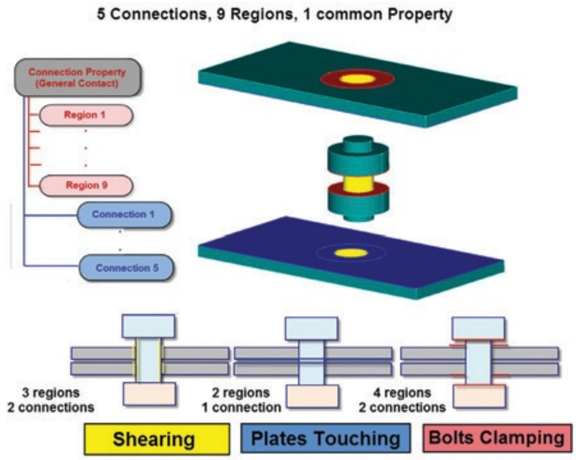

FIG. 3:. Modeling of a bolt using 3D elements and non-linear contact.

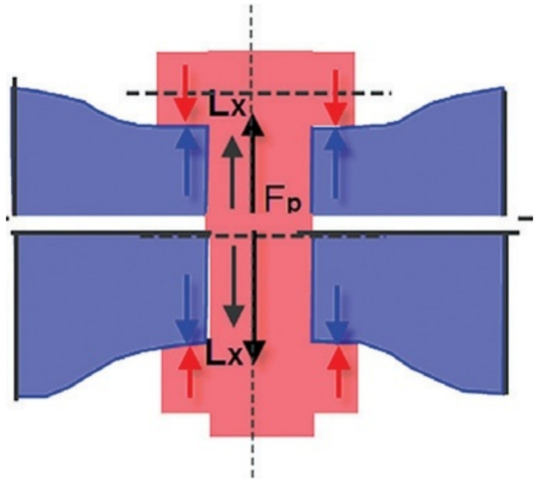

FIG. 4: Bolt pre-load schematic.

of the primary actions, therefore, is to clamp the components together between washer faces or nut washer and head face. These two faces also constrain components from separating axially as a result of external forces applied to them.

A typical tension load scenario is shown in Fig. 2, together with a single-shear load scenario. An alternative to the single shear can exist when there are three plates; this is called double shear and is preferred, as no offset moment occurs. In most industries, the shear load transfer path is by plate-bearing loads, causing shearing across the bolt shank. To balance the shears, particularly in single-shear loading, complementary bending distribution occurs in the bolt shank and can also be reacted by contact of the components under the nut and head under high distortion.

Some industries, such as civil engineering, require the load transfer via shear-only loading to occur through friction between heavily clamped components and bolt head and nut. A gap between bolthole and shank and very high pretension loads are required to achieve this type of load transfer.

FEA Simulation

The most intuitive form of FEA simulation is by using solid elements and non-linear contact surfaces. If there are relatively few bolts in the system, and CAD geometry of the bolt details is available, this becomes a viable simulation method. We will look at other alternatives shortly.

Fig. 3 shows a typical setup of transferring load between two plates via a bolt. The simplified geometry is shown for clarity, rather than the FEA mesh. In particular, we can see that the bolt head, shank, nut and washers have all been morphed into a single object. The effective stiffness of the combined bolt head and washer and combined bolt nut and washer has to be checked. There is no representation of the thread, and we assume the three primary load transfer paths are as shown in the figure.

The main challenge for this type of modeling is to make sure that the contacts are set up properly. Each contact consists of a pair of regions that are joined by a connector and have a connection property. Each contacting region is defined in the solver by a zone of element surface topology; however, for ease of preparation we can usually define this via the parent geometry.

The connection is the definition of which region pairs are potentially in contact. The property defines the contact method. The contact could be glued (permanently locked shut), general non-linear contact or various other types. Other information such as friction and interference tolerances can also be defined.

When deciding whether to use this type of connector modeling, assess the ease with which contacts can be set up. Ideally, the preprocessor or embedded CAD environment should be able to automatically detect potential contact surfaces, and present these to the user in a highly visual manner. It should then be a straightforward housekeeping exercise to allocate connector properties and delete unwanted connections. If the implementation is labor-intensive, it is probably a good idea to avoid this type of approach — as the amount of data required in even a simple situation as shown in Fig. 3 becomes unworkable.

Notice that in Fig. 3, the three main load transfer paths have been idealized as shearing, plate touching and bolt clamping as shown with the inset figures. The plate-touching zone is usually quite small and localized around the bolt. To extend the mutual contact among the plates over the complete plate surface is usually unnecessary, and adds a lot of computational effort to the solution. It can also result in convergence problems. The plates can be tied together via normal springs in this zone if difficulty arises.

In a non-linear analysis, various pitfalls arise — including stability and convergence. During initial load steps of a non-linear analysis, a full load path is not achieved. This means that the bolts have an indeterminate solution and we may observe bolt spinning or chattering in position. Remedies include moving all bolts and components into initial bearing contact, by updating the CAD geometry,

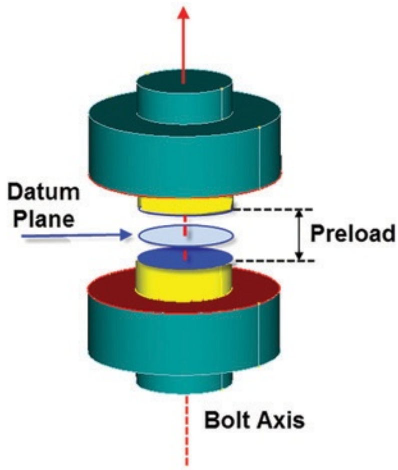

FIG. 5: Bolt pre-load method in an FEA solution, applied to parent geometry.

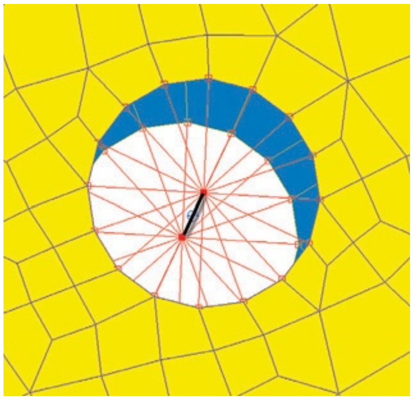

FIG. 6: An example of the 1D bolt modeling method, shown here with 2D shells.

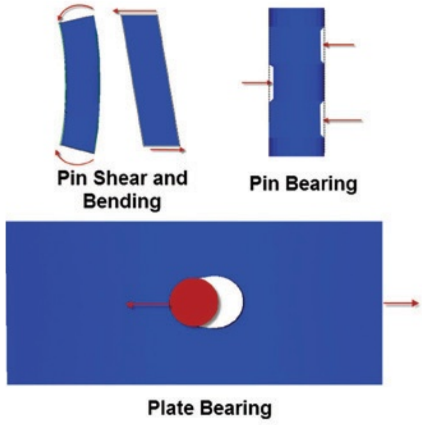

FIG. 7: Deformation modes of bolt and plate.

and preventing rigid body motion of the bolts by including very weak system springs. This is especially effective for spinning of bolts.

The contact surface technology in the solver should be mature enough to fit a continuous smooth surface through the nodal points that form contact between the bolt and the bolthole. This will smooth out any point loadings stemming from mesh discretization.

Bolt Preload

Most bolting systems involve a bolt preload. In the real world, this is applied by torqueing the bolt against the nut and pre-stressing the shank. In an FEA simulation, it would be unusual to model the full thread engagement between the bolt and the nut. Very detailed 3D models that simulate this effect are possible, but they are extremely computationally expensive — and pretension is very sensitive to correct friction properties and geometric accuracy.

The general principle of pretension is shown in Fig. 4. The tensile bolt load creates a reactive compressive load between the components and the bolt head and nut. A common goal is to keep the components in compression under external loading — to improve fatigue life, for example. One of the difficulties when calibrating this type of FE model is that hand calculation of the internal load balance when an external load is applied to the components can be difficult. Bolt load diagrams can be created, but they make simplistic assumptions about how the external load is transferred into the pre-stressed bolt, nut and component system. These diagrams can be both misleading and unrealistic.

The best approach when attempting to validate an FEA pre-load system is to carry out simple test models, such as clamping of a pair of back-to-back plates in pure tension or pure shear, similar to the loading actions shown in Fig. 2.

There are several ways that the bolt preload can be introduced into an FEA model. One of the earliest approaches gives the bolt material a coefficient of thermal expansion, and the remainder of the model zero coefficient of thermal expansion. A thermal load case applies a temperature differential to the bolt material. This creates thermal strains, which are used to simulate mechanical strains present in a preload. The temperature differential is tuned to give the correct preload value.

A more modern approach uses a dedicated bolt preload option, such as shown in Fig. 5. A datum plane splits the shank of the bolt. The datum plane can usually be defined either via pure geometry or by a group of nodes. A bolt axis is defined along which the preload will act. The elements or geometry containing the bolt head section and nut section are also defined.

The preload is applied by various methods, including a constraint equation that literally pulls the two split services through each other to apply a pre-stress. Various options include allowing an initial preload, which remains constant throughout any external loading, or a preload that can be unloaded because of external forces applied to the components. The implication of these two options should be carefully checked with the test cases described earlier.

Various other forms of pre-loading are available in some solvers, including the so-called mesh-less bolt, where the bolt itself is not modeled but a balanced pressure load is applied to the footprint of the head and nut onto the facing components.

1D Bolt Modeling

If a large number of bolts are to be modeled, the use of solid element representation can be far too burdensome in terms of setup time, contact complexity and computational cost.

One alternative is to use a 1D beam element representation. This can also use a similar preload method. A typical example is shown in Fig. 6. There are many different implementations of this approach, but we will focus on a method that uses a

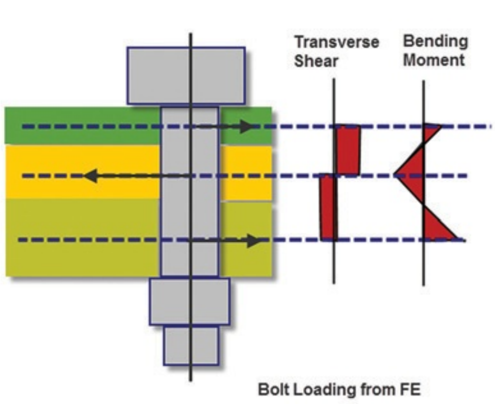

FIG. 8: **Bolt strengths assessed from FEA forces and moments.**

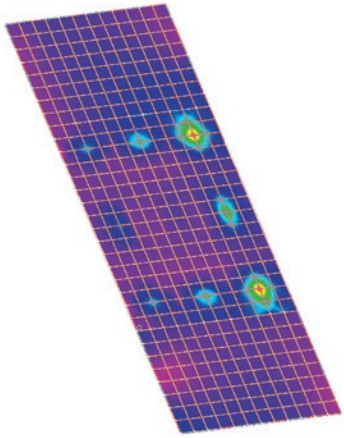

FIG. 9: **Poor local bolt connection modeling.**

FIG. 10: **Recommended local bolt connection modeling.**

rigid element to spider out the head and nut tend of the bolt to the top and bottom plate respectively, and can connect to 2D or 3D element representation.

The rigid element takes up the cross-sectional area of the bolt shank, and distributes the load out to the periphery of the plate hole. This can be used in a linear analysis, which is another big advantage. The downside, however, is that the load path in bearing between the bolt and the plate is incorrect, as the back face is being pulled in tension. This can be improved upon by having a 180° spider aligned with the bearing surface. This does mean that the load path has to be accurately predicted, so that it is aligned with the spider orientation and the bolt is still rigidly bonded into the plate over 180°.

If a beam element is used to represent the bolt, the bolt bending and shear stiffness are reasonably representative. Some FEA implementations have a more advanced form of beam representation to model the short stiff beam that a bolt represents. However, what is missing from this representation is the bearing stiffness of the plate and beam.

The stiffness can be visualized by looking at Fig. 7, which shows the deformation modes associated with the pin and the plates. We can put back the bearing stiffness by introducing springs between the top of the beam and the spider element. These springs can also be used to adjust the axial stiffness if required.

By using this technique, the stiffness of the joint can be modeled very effectively. However, as mentioned before, the local load transfer between the bolt and the plate is inaccurate — as the bolt is rigidly bonded to the hole.

Although the stresses are locally quite poor, they do not dominate the overall stress distribution in the plate, and the spurious local stress region can be ignored. Instead, the bolt transfer loads are extracted from the analysis results and used in a post-FEA solution for a plate-bearing strength assessment. This is an established process, and does not warrant detailed FEA. Similarly, knowing the forces and moments in the bolt can quickly assess the strength of the bolt. If these are extracted, one can carry out simple, but effective hand calculations, as shown in Fig. 8.

What should be avoided, though, is a point connection from the end of the beam into the plate that ignores the load distribution of the pin circumference. Fig. 9 shows a stress contour plot of a plate loaded by several bolts, where the load transfer is occurring at individual nodes. This is a situation where a finite force is transferred through an infinitely small area, and creates a singularity at each connection. If we increase the mesh fidelity, we chase the singularity and the local stresses will "blow up." This can be awkward to explain in a report, and should be avoided.

It doesn't take much effort to introduce the approach shown in Fig. 3, with stresses shown in Fig. 10. Although the stresses are not accurate, they do not dominate the loading in the plate.

Consider Your Objectives

Modeling of bolted joints needs careful consideration of the analysis' objective. Are the bolts critical members that need individual modeling, or can the load transfer path be adequately represented by 1D idealization? If strength assessment of multiple bolts is to be tackled, consider using traditional post-FEA calculations for bolt and plate strength.

The time needed to model bolts using non-linear 3D contact may be prohibitive. Pre-tension in bolts should always be checked using simple test models to understand the initial loading and stress distribution, and the subsequent redistribution under external loading. DE

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HPC Options, Part 3

Consider CAE in the Cloud

A large-scale experiment finds why and when the Cloud might make sense.

BY WOLFGANG GENTZSCH AND BURAK YENIER

Cost savings, shorter time to market, better quality, less product failures — the benefits that engineers and scientists can expect from using technical computing in their research, design and development processes can be huge. But relatively few scientists and manufacturers use servers when designing and developing their products on computers; the vast majority still performs virtual prototyping or large-scale data modeling on workstations or laptops.

Many of these professionals face problems stemming from the lack of performance of their machines. More accurate geometry or physics, for instance, may require more memory than a desktop can accommodate. System vendors have developed a complete set of products, solutions and services for high-performance computing (HPC), and buying an HPC server for a small- or medium-sized business is no longer out of reach.

Another option today is to use a cloud solution that allows engineers and scientists to keep using their workstation for daily design and development work, and to "burst" larger, more complex jobs into the cloud when needed. Thus, users have access to quasi-infinite computing resources that offer higher quality results. A cloud solution helps reduce capital expenditure, offers greater business agility by dynamically scaling resources up and down as needed, and is only paid for when used.

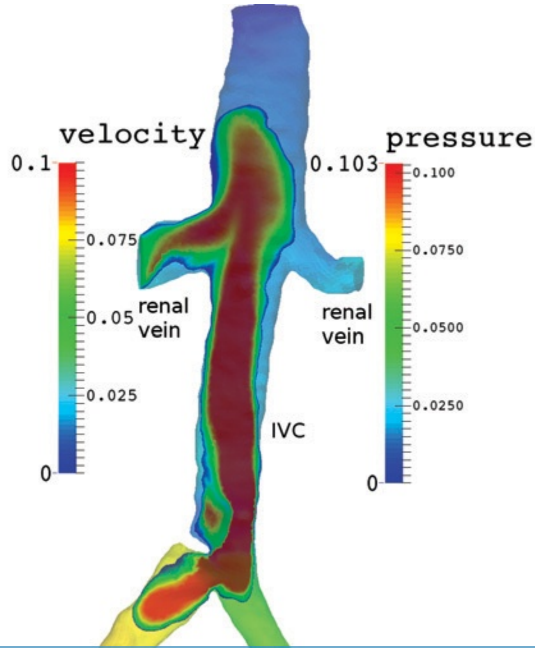

FIG. 1: Computational domain including the iliac veins (inflow), renal veins (inflow), and the inferior vena cava (IVC). The pressure on the surface of the vessels is shown; a slice, colored by velocity, down the center of the IVC is also shown.

The UberCloud Experiment

Since July 2012, the UberCloud Experiment has attracted 1,500 organizations from 72 countries. It includes 152 teams in computational fluid dynamics (CFD), finite element method (FEM), biology and other domains, and tracked their experiences and lessons learned via a compedium of case studies. UberCloud TechTalk provides educational lectures for the community. And the UberCloud Exhibit offers a cloud services catalog where community members can exhibit their cloud-related services or select the services they want to use for their team experiment or for their daily work.

Intel sponsored the first compendium in 2013, with 25 CAE case studies. In June, the second Compendium of UberCloud case studies was published, sponsored by Intel and *Desktop Engineering*. It can be downloaded for free at deskeng.com/de/simulation-cloud/.

The UberCloud Experiment provides a platform for scientists and engineers to explore, learn and understand the end-to-end process of accessing and using cloud resources, and to identify and resolve the roadblocks. End-users, software providers, resource providers and computing experts collaborate in teams to jointly solve the end-user's application in the cloud.

Let's start by defining what roles each stakeholder plays to make service-based HPC in the cloud come together:

- **End-user:** A typical example is a small or medium-sized manufacturer in the process of designing, prototyping and developing its next-generation product.
- **Application software provider:** These are software owners of all stripes, including independent software vendors (ISVs), public domain software organizations and individual developers.
- **Resource provider:** This pertains to anyone who owns technical computing resources networked to the outside world. A classic HPC center would fall into this category, as would a standard datacenter used to handle batch jobs, or a cluster-owning

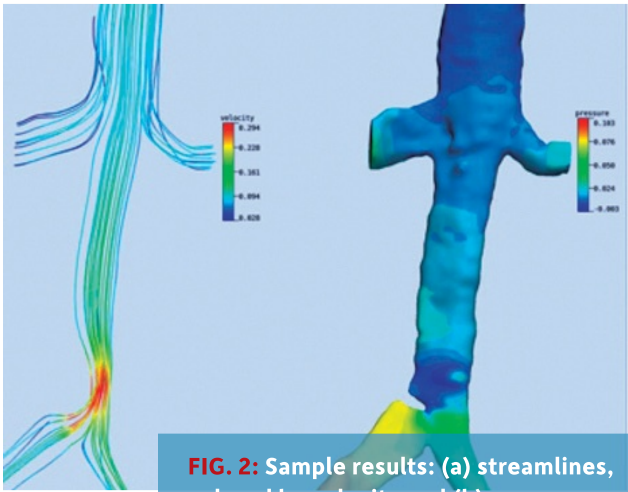

FIG. 2: Sample results: (a) streamlines, colored by velocity and (b) pressure on the surface of the vessels.

commercial entity that is willing to offer up cycles to run non-competitive workloads during periods of low CPU-utilization.

- **Computing experts:** This group includes individuals and companies with technical computing expertise in areas like cluster management and software porting. These experts work as team leaders, with end-users, computer centers and software providers to help glue the pieces together.

For example, suppose the end-user is in need of additional compute resources to increase the quality of a product design or to speed up a product design cycle. Perhaps the goal is to simulate more-sophisticated geometries or physics or to run many more simulations for a higher quality result. That suggests a specific software stack, domain expertise and even hardware configuration. The general idea is to look at the end-user's tasks and software, then select the appropriate resources and expertise that match certain requirements.

As a glimpse into the practical use cases, below is a look at four CAE cloud projects out of the 152 UberCloud experiments. More details and 17 full case studies can be found in the second UberCloud Compendium (see page 38).

Team 62: Cardiovascular Medical Device Simulations in the Cloud

Team members: End-user Mike Singer is the founder and president of Landrew Enterprises. Software and resource provider Sanjay Choudhry is the CTO at Ciespace Corp. Oleh Khoma, the HPC expert, is head of ELEKS' HPC unit.

The project investigated flow through a patient-specific blood vessel, and represents a typical CFD use case for cardiovascular flow. The patient-specific geometry is extracted from CT image data obtained during a normal medical imaging exam. The triangulated surface mesh geometry contains the inferior vena cava (IVC), the right and left iliac veins, and the right and left renal veins (see Fig. 1).

Cloud resources provide a mechanism to address the computing requirements of cardiovascular simulations. Specifically, the use of cloud-based CFD alleviates the need for large, in-house clusters. In addition, cloud resources may enable the timely execution of parameter and sensitivity studies, which are important for biofluids simulations that often contain uncertain or variable model parameters. Hence, the purpose of this experiment was to explore the use of cloud-based simulation solutions for enabling cardiovascular simulations.

Despite several obstacles, the team accomplished its goal of running a patient-specific cardiovascular flow simulation in the cloud (see Fig. 2). Also, the user experience and the results of this experiment demonstrate the potential success of further cloud-based cardiovascular flow simulations.

Team 99: North Sea Asset Life Extension, Assessing Impact on Helicopter Operations

Team members: End-user was Dan Hamilton from Atkins Energy; software provider James Britton, CD-adapco; resource provider Jerry Dixon, OCF with its cloud service enCORE HPC; and team mentor Dennis Nagy from BeyondCAE.

The team tested the feasibility of using HPC-as-a-Service (HPCaaS) for the simulation of airflow over an offshore platform using STAR-CCM+ from CD-adapco, to determine the

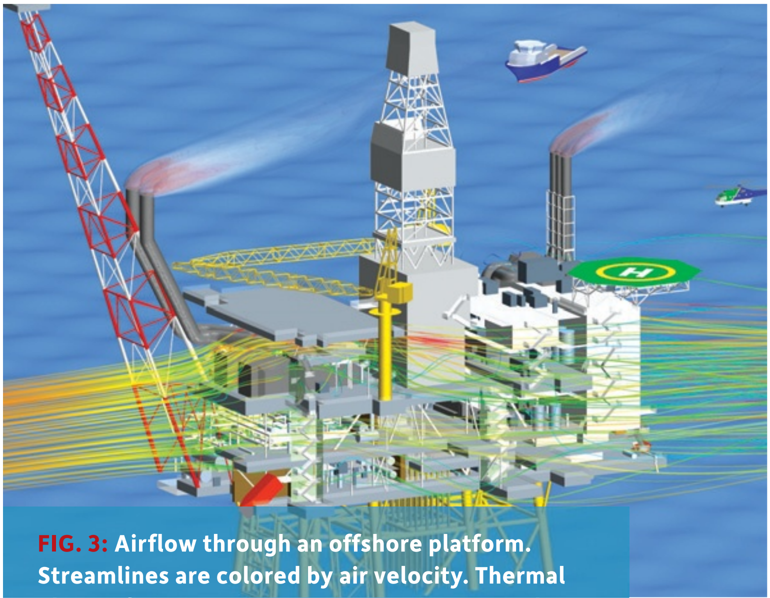

FIG. 3: Airflow through an offshore platform. Streamlines are colored by air velocity. Thermal plumes from power generation turbines are shown. In this case, these plumes do not affect the approach path of the helicopter.

change in conditions within the helideck landing area as a result of geometrical changes stemming from a life extension project on an existing North Sea asset.

High-temperature sources, such as the exhaust from power generation equipment, can result in significant variations in temperature over the topsides depending on atmospheric wind conditions; upwind structures generate downwind turbulence, for example. High variations in temperature and high turbulence can result in increased pilot workload for helicopter operations on the platform.

For this project, Atkins used CFD to assess the expected range of wind and operational conditions at the platform. A complete study requires a large number of CFD simulations to be undertaken. This is typically done using in-house hardware; however, the flexibility of HPCaaS was appealing as a potential overflow solution.

For OCF, the availability of the STAR-CCM+ "Power-on-Demand" licensing was the ideal fit for the enCORE service. Once the installation was debugged, the user experience of using STAR-CCM+ in batch on enCORE was identical to that on in-house hardware.

Because the simulation files can be large, enCORE's policy of not charging for bandwidth usage is appealing. Having a resource like enCORE allows users to bid for and propose work requiring computational resources that exceed what's available in-house.

Download the UberCloud Compendium with CAE Case Studies

This document is valuable resource for engineers, scientists, managers and executives who believe in the strategic importance of High-Performance-Computing-as-a-Service (HPCaaS) in the cloud. It's a collection of selected CAE case studies from the participants in Rounds 3 and 4 of the UberCloud Experiment. Among these case studies, you will likely find scenarios that resonate well with your own engineering computing challenges. Download a free copy to benefit from the candid descriptions of challenges encountered, problems solved, lessons learned and expert recommendations. This second UberCloud Compendium can be downloaded for free at deskeng.com/de/simulation-cloud/.

Team 118: Coupling In-house FE Code with ANSYS Fluent CFD

Team members: End user was Hubert Dengg from Rolls-Royce Deutschland, software providers were Wim Slagter and René Kapa from ANSYS, resource providers and team experts were Thomas Gropp and Alexander Heine from CPU 24/7, and Marius Swoboda from Rolls-Royce Deutschland acted as HPC/CAE expert.

In the present test case, a jet engine high-pressure compressor assembly was the subject of a transient aerothermal analysis using FEA/CFD coupling techniques. Coupling is achieved through an iterative loop, with the smooth exchange of information between the FEA and CFD simulations at each time step, ensuring consistency of temperature and heat flux on the coupled interfaces between the metal and the fluid domains. The aim of the HPC experiment was to link ANSYS Fluent with an in-house FEA code. This was done by extracting heat flux profiles from the Fluent CFD model and applying them to the FE model. The FE model provides metal temperatures in the solid domain.

This conjugate heat transfer process is very consuming in terms of computing power, especially when 3D CFD models with more than 10 million cells are required. As a consequence, it was expected that using cloud resources would have a beneficial effect regarding computing time.

The computation was performed on the 32 cores of two nodes with dual Intel Xeon processors. The calculation was done in cycles in which the FE code and Fluent CFD alternated, exchanging their results.

Outsourcing of the computational workload to an external cluster allowed the end user to distribute computing power in an efficient way — especially when the in-house computing resources were already at their limit. Bigger models usually give more detailed insights into the physical behavior of the system. In addition, the end user benefited from the HPC provider's knowledge of how to set up a cluster, run applications in parallel based on message-passing interface (MPI), create a

TABLE 1: COMPARISON OF DESKTOP, CLOUD AND HPC SOLVING OPTIONS

SIMULATION SOLVING APPROACH	APPROXIMATE TIME TO COMPLETE	INVESTMENT REQUIRED
Local Desktop Machine	800 hours (1 month)	Engineering Workstation + Simulation Software License
Local Desktop Machine + Cloud Computing	24 hours (1 day)	Engineering Workstation + Simulation Software License + $1,200 Cloud Compute Fee
Local Desktop Machine + Private HPC Cluster + Multiple Solver Licenses	24 hours (1 day)	Engineering Workstation + Simulation Software License + 30 Node Compute Cluster + 30 Simulation Solver Licenses

host file, handle licenses, and prepare everything needed for turnkey access to the cluster.

Team 142: Virtual Testing of Severe Service Control Valve

Team members: End user was Mark A. Lobo from Lobo Engineering. Autodesk provided Simulation CFD 360 (SimCFD) and the supporting cloud infrastructure. The HPC/CAE application experts were Jon den Hartog and Heath Houghton from Autodesk.

For a valve to be properly applied in fluid management systems, low control valve specifications include performance ratings. Control systems sort out input parameters, disturbances and specifications of each piping system component to react and produce a desired output. System response is chiefly a function of the accuracy of control valves that respond to signals from the control system. Valve performance ratings provide information to the system designer, then, that can be used to optimize control system response.

The premise of this project was not only to explore virtual valve testing, but also to evaluate the practical and efficient use of CFD by the non-specialist design engineer. As a benchmark, the end user had no prior experience with the Autodesk software when the project initiated, and no formal training in the software. He depended on the included tutorials, help utility and documentation to produce good results and good data.

One of the benefits for the end-user was that cloud computing enabled accessing a large amount of computing power in a cost-effective way. Rather than owning the hardware and software licenses, engineers can pay for what they need when they need it, with no substantial upfront investment.

In this project, more than 200 simulations were run in the cloud. Given the runtimes involved and allowing for data download upon completion of the runs, it is possible for all of these simulations to be solved within a day. For an engineer with one simulation license on a single workstation, this would have required 800 hours (approximately 30 days) to complete if the simulations were running nonstop one after another. Table 1 compares the approximate time and investment that would be required for various solving approaches.

For more information, download the UberCloud Compendium at deskeng.com/de/simulation-cloud/. **DE**

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INFO → **ANSYS:** ANSYS.com

→ **Atkins:** AtkinsGlobal.com

→ **Autodesk:** Autodesk.com

→ **BeyondCAE:** Home.BeyondCAE.com

→ **CD-adapco:** CD-adapco.com

→ **Ciespace Corp.:** Ciespace.com

→ **CPU 24/7:** CPU-24-7.com

→ **ELEKS:** ELEKS.com

→ **Intel:** Intel.com

→ **Lobo Engineering:** Lobo Engineering.com

→ **OCF:** OCF.co.uk

→ **Rolls-Royce Deutschland:** Rolls-Royce.com

→ **UberCloud:** TheUberCloud.com

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

Customizable Workstation

The Digital Storm Slade PRO Workstation from a California-based system integrator is much more than an entry-level workstation.

BY DAVID COHN

We first encountered Digital Storm back in 2011 when we reviewed its PROTUS workstation (*DE*, February 2011). Founded in 2002, this Fremont, CA-based company originally focused on producing fast gaming computers and delivering "bleeding edge technology and performance along with rock solid stability and support." Recently, however, it has also been selling custom-built workstations aimed at engineering professionals.

The Slade PRO is Digital Storm's latest entry-level workstation. Our evaluation unit arrived in a large box, but instead of traditional foam packing material, the computer was suspended between film membranes, providing a lightweight means of protecting the system from shocks during shipping.

As was true for the previous Digital Storm system we reviewed, before we could use the computer we had to remove foam packing material placed inside the case to help prevent components from dislodging during transit. In spite of these precautions, however, our system arrived with one hard drive completely dislodged from its cage and its power connector damaged. Digital Storm quickly sent a replacement system, which arrived in perfect condition. Normally, I would not mention this, since it was the result of careless handling by the shipping company. But after my experience, I read a report of a similar problem.

Digital Storm is not really a manufacturer; it's a system integrator, assembling computers from an assortment of components produced by others and readily available from various sources. For example, the Slade PRO comes housed in a large, black aluminum and steel ATX mid-tower case measuring 8.7x20.9x19.5 in. (WxDxH). However, that case is actually an Obsidian Series 550D manufactured by Corsair, available online for $130. What Digital Storm adds is skilled assembly, extensive testing, and a single point for support and service should it be needed.

The case lived up to its claim of providing excellent noise reduction and sound isolation. Our Slade PRO evaluation unit was nearly silent, thanks in part to front and side panels lined with sound-damping material and front air intakes angled away from the front of the case.

But the case itself proved a bit quirky. Although the entire system weighed just 34.5 lbs., moving it was hampered by a lack of any type of handle or other grip point.

The unit has two front-mounted intake fans and one rear exhaust fan. There are also press-to-release removable plastic panels on the top and left sides that can accommodate two additional fans each. While our system ran quite cool without these fans, we suspect opening these panels and adding fans would substantially increase the sound level.

COOLING is provided by a Digital Storm Vortex liquid cooling system.

Easily removable magnetic dust filters protect the front, top and side air intakes. We found it a bit too easy to dislodge these panels, however, and an additional slot-mounted filter on the bottom of the case kept sliding out whenever we moved the system.

Lots of Familiar Components

The front of the case presents a monolithic appearance. All that is visible is a brushed aluminum panel housing headphone and microphone jacks, a small reset button, a large round power button and a pair of USB 3.0 ports. This panel is actually a cutout in a large door. An unusual hinge allows the door to swing open from either side (or it can be completely removed). This door conceals four 5.25-in. drive bays. The topmost bay contained an ASUS Blu-ray Disc player/DVD writer combo drive. The bottom bay housed a media card reader with five slots and a USB 2.0 port.

Removing the left side panel revealed an incredibly spacious, well organized interior. In addition to the front panel drive bays, the Corsair case provides six internal tool-free drive bays that can accommodate either 3.5- or 2.5-in. drives. Our Slade PRO came with a 256GB Samsung 840 Pro Series solid-state drive (SSD) and a 4TB Western Digital Black Edition 7,200 rpm data drive. Both drives come standard in the Slade PRO version we received.

As we soon discovered, the Slade PRO is actually available in

Single-Socket Workstations Compared		**Digital Storm Slade PRO workstation** (one 3.4GHz Intel Xeon E3-2687W v2 eight-core CPU, NVIDIA Quadro K4000, 32GB RAM)	**HP Z1 G2** workstation (one 3.6GHz Intel Xeon E3-1280 v3 quad-core CPU, NVIDIA Quadro K4100M, 16GB RAM)	**HP Z230** workstation (one 3.4GHz Intel Xeon E3-1245 v3 quad-core CPU, NVIDIA Quadro K2000, 8GB RAM)	**Lenovo E32 SFF** workstation (one 3.4GHz Intel Xeon E3-1240 v3 quad-core CPU, NVIDIA Quadro K600, 8GB RAM)	**BOXX 3DBOXX W4150 XTREME** workstation (one 3.5GHz Intel Core i7-4770K quad-core CPU over-clocked to 4.3GHz, NVIDIA Quadro K4000, 16GB RAM)	**Ciara Kronos 800S** workstation (one 3.5GHz Intel Core i7-2700K quad-core CPU over-clocked to 5.0GHz, NVIDIA Quadro K5000, 16GB RAM)
Price as tested		$5,804	$5,918	$2,706	$1,479	$4,273	$5,714
Date tested		5/10/14	5/3/14	11/24/13	11/10/13	7/31/13	5/31/13
Operating System		Windows 7	Windows 8.1	Windows 7	Windows 7	Windows 7	Windows 7
SPECviewperf 12	Higher						
catia-04		38.41	42.23	n/a	n/a	n/a	n/a
creo-01		33.15	30.82	n/a	n/a	n/a	n/a
energy-01		0.60	1.74	n/a	n/a	n/a	n/a
maya-04		31.28	33.79	n/a	n/a	n/a	n/a
medical-01		10.75	10.34	n/a	n/a	n/a	n/a
showcase-01		20.65	21.12	n/a	n/a	n/a	n/a
snx-02		34.12	40.37	n/a	n/a	n/a	n/a
sw-03		50.78	38.66	n/a	n/a	n/a	n/a
SPECviewperf 11	Higher						
catia-03		69.41	63.80	46.17	25.14	72.37	96.39
ensight-04		47.76	61.56	29.32	15.47	49.20	83.26
lightwave-01		76.90	82.76	87.98	75.52	100.78	103.15
maya-03		101.12	128.09	92.05	51.32	131.31	153.01
proe-5		16.29	17.18	20.25	15.61	24.74	22.87
sw-02		63.66	67.75	57.31	41.99	78.27	84.51
tcvis-02		54.26	58.99	38.78	23.74	55.73	77.82
snx-01		52.98	65.58	34.09	19.56	53.95	83.21
SPECapc SolidWorks 2013	Higher						
Graphics Composite		5.37	5.67	4.38	3.14	5.25	3.89
RealView Graphics Composite		5.90	6.16	4.69	3.09	5.38	4.1
Shadows Composite		5.85	6.13	4.68	2.96	5.36	4.1
Ambient Occlusion Composite		9.46	8.48	5.81	2.9	5.63	8.37
Shaded Mode Composite		5.30	5.55	4.75	3.25	5.12	3.79
Shaded With Edges Mode Composite		5.45	5.79	4.04	3.02	5.38	3.98
RealView Disabled Composite		3.70	4.08	3.35	3.31	4.74	3.15
CPU Composite		3.70	3.12	4.15	4.27	4.07	4.92
Autodesk Render Test	Lower						
Time	Seconds	38.25	45.00	49.00	48.66	42.00	58.33

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

one of four different configurations, which can then be customized by choosing from a dizzying array of options. For example, Digital Storm offers systems with a four-core CPU, 16GB of memory, an NVIDIA Quadro K600 GPU, the same SSD in our unit, and a 1TB hard drive starting at $1,910. Or you can buy a system based on a six-core CPU, 32GB of RAM, a K2000 graphics board, and those same hard drives starting at $3,122.

The base level of the eight-core system we received starts at $4,453, which includes 32GB of RAM, a K2000 GPU, and the 256GB SSD and 4TB HDD we received. You can even buy a system with a 12-core CPU, 64GB of memory, an NVIDIA Quadro K5000, a 512GB SSD, and 4TB HDD for $8,859. You can also choose different cases and spend hundreds of dollars for exotic paint jobs.

Nestled inside our Slade PRO was an ASUS Sabertooth X79 motherboard based on the Intel X79 chipset (although Digital Storm offers two other motherboard options). This system board provides eight memory sockets, supporting up to 64GB of memory. Our unit came with 32GB of DDR3 1,866MHz RAM installed using four 8GB Corsair Vengeance Pro high-performance dual in-line memory modules (DIMMs). There are also two PCIe 3.0/2.0 x16 slots, a third PCIe 3.0/2.0 x16 slot that operates in x8 mode, two PCIe 2.0 x1 slots, and a single PCI slot. Our system came with an NVIDIA Quadro K4000 graphics board instead of the K2000, adding $430 to the base price. The K4000 comes with 3GB of GDDR5 memory and 768 compute unified device architecture (CUDA) cores, and provides one DVI and two DisplayPort connections.

CUSTOMIZATION: Digital Storm offers an array of upgrade options for the Slade PRO.

DESIGN: A front panel opens to reveal four drive bays.

While the Slade PRO's base eight-core CPU is a 2.26GHz processor, Digital Storm sent us a system equipped with an Intel Xeon E5-2687W v2, a processor with a 3.4GHz clock speed, 4GHz maximum turbo speed, and 25MB cache, which added $1,090 to the system cost.

Cooling is provided by a Digital Storm Vortex liquid cooling system (actually a branded version of the Corsair H80), but again Digital Storm offers a myriad of other options. Users can also have their systems configured with internal lighting, additional airflow controls, and other modifications. The system comes with a 750watt Corsair CX power supply, but again, there are no fewer than 11 other options.

The rear panel offers four USB 3.0 ports, six USB 2.0 ports, a PS/2 mouse/keyboard connection, RJ-45 network jack, an IEEE 1394 (FireWire) port, two eSATA connection (one powered), one optical S/PDIF output port, six audio jacks (separate microphone and line-in jacks as well as front, side, rear and base output speaker channels), and a USB BIOS flashback button, all supported by the ASUS motherboard.

Unsurprising Performance

With its fast eight-core CPU and top-of-the-line components, we were quite anxious to see how well the Slade PRO would perform. On the SPECviewperf version 11 benchmark, the system held its own, but certainly didn't set any records. We also ran SPECviewperf version 12. Because the Slade PRO marks only the third system on which we've run this newer benchmark, we still cannot really make meaningful comparisons. That said, this Digital Storm workstation lagged behind the similarly priced HP Z1 G2 we reviewed in the July issue.

The results on the SPECapc SolidWorks 2013 test were excellent, with the Slade Pro equaling or outperforming many of the other single-CPU workstations we've tested to date. And on the AutoCAD rendering test, a multi-threaded test on which faster systems with more CPU cores have a distinct advantage, the Digital Storm Slade PRO set a new all-time record for a system equipped with a single CPU, completing the rendering in just 38.25 seconds.

We also ran the new SPECwpc workstation performance benchmark. Again, the Slade PRO is only the third system on which we have run this test. Three tests is not enough yet to make any meaningful comparisons, but in general, this unit lagged behind the HP Z1 G2.

Digital Storm pre-loaded Windows 7 Professional 64-bit, but other flavors of Windows are also available. Because configuring a Digital Storm system is truly an à la carte process (and we did not request any additional options other than those already mentioned), our system came without a keyboard or mouse. Assuming that most users would likely opt to purchase these, we added a Logitech Media Combo MK200 keyboard and mouse when we priced the system using the company's online configuration website.

Digital Storm backs its computers with lifetime customer care. A three-year limited warranty covers labor costs for three years and defective part replacement for one year — something that we found a bit curious since many of the components included in the system have longer warranties. Warranties of up to six years, including four-year part replacement, are also available.

When we configured our system, it priced out at $5,979, but discounts reduced that price to $5,804 and added an additional year to the labor and parts warranty. Digital Storm originally quoted us a price of $5,888 (without the keyboard and mouse). The company no longer offers free UPS ground shipping.

The Digital Storm Slade PRO performed flawlessly throughout our review process, and its benchmark results were certainly within the expected range. You could purchase all of the same components in our evaluation unit online for around $4,650 and build it yourself. Its lack of independent software vendor (ISV) certification makes us wonder whether it is appropriate for mission-critical engineering applications. That said, the Digital Storm Slade PRO is well built, uses excellent components, and offers a lot of bang for the buck. DE

David Cohn *has been using AutoCAD for more than 25 years and is the author of more than a dozen books on the subject. He's the technical publishing manager at 4D Technologies, a contributing editor to Desktop Engineering, and also does consulting and technical writing from his home in Bellingham, WA. You can contact him via email at david@dscohn.com or visit his website at DSCohn.com.*

INFO → Digital Storm: DigitalStormOnline.com

Digital Storm Slade PRO

- **Price:** $5,804 ($1,910 base price)
- **Size:** 8.7x20.9x19.5-in. (WxDxH) tower
- **Weight:** 34.5 lbs.
- **CPU:** one Intel Xeon E5-2687W v2 (eight-core) 3.4GHz
- **Memory:** 32GB DDR3 SDRAM at 1,866MHz (up to 64GB supported)
- **Graphics:** NVIDIA Quadro K4000
- **Storage:** 256GB Samsung SSD 840 Pro Series, 4TB Western Digital Black Edition 7,200 rpm
- **Optical:** ASUS Blu-ray Disc player/DVD writer
- **Audio:** onboard integrated high-definition audio (microphone, line-in, front, side, rear and bass plus headphone and microphone)
- **Network:** integrated 10/100/1000 LAN
- **Other:** seven USB 2.0, six USB 3.0, one 1394 (FireWire), optical S/PDIF, PS/2 mouse/keyboard, two eSATA
- **Keyboard/Mouse:** Logitech Media Combo MK200 keyboard and mouse (included for pricing purposes)

Working TOGETHER

How design engineers can work with outside service providers to develop new designs and new product concepts.

BY DAVID GEER

Desktop engineers benefit from external service providers who specialize where the designer is lacking. External providers offer concept development expertise, in-depth analysis and tools, and an array of engineering disciplines to bridge the gaps in resource pools, prevent costly design errors, and keep deliverables on deadline.

Once the decision is made to bring in an outside firm, design engineers should confirm how the external provider plans to insert its services into the designer's workflow. According to Craig Winn, CEO of Maumee, OH-based Applied Technology Integration (ATI), working with an external provider should be the same as working with internal resources — except that the external resource needs to fit into the workflow in a tighter package.

"This can improve the workflow and the end result, because in order to use an outside resource whom you don't see every minute of every day, you need to have the program laid out in a detailed fashion, in the Statement of Work," he adds.

An external provider should identify deliverables and timing more accurately. This can be a difficulty or hindrance for the design engineer who hasn't previously used an external resource, or who is used to a more casual work environment.

"But it can also be helpful if he needs to get to a certain stage in the project by a certain deadline, because the contractor takes deadlines seriously," says Winn.

External services should consider communication as integral to the workflow. "We understand what the customer needs, and when, and we let them know what we need, by when, in order to meet the deliverables," says Winn.

An outsourced provider should also work hand-in-hand with the designer, communicating via phone, online and in-person meetings to clarify the progress of the design. "The relationship should be closely monitored," says Akbar Farahani, VP of Global Engineering for Troy, MI-based Engineering Technology Associates (ETA).

Protecting Intellectual Property

Design engineers should ensure that the outside vendor safeguards their intellectual property and associated rights. Winn notes there are two basic mechanisms his firm uses to protect intellectual property:

The team at Applied Technology Integration, an Ohio-based engineering services provider.

1. **Intellectual property rights document, or a statement within a document or contract:** This states that the customer owns the rights to all intellectual property that it brings to the project or that the supplier develops during the project.

2. **Two-way non-disclosure agreement (NDA):** This states that both parties will conceal any confidential information or intellectual property that they share during a project.

Protecting intellectual property requires certain types of segregation of information, too.

"There is a competitive landscape for our clients that requires that we have ways to firewall different programs within our company," says Peter Ma, VP of Engineering/R&D for San Diego-based D&K Engineering. Ma notes that some clients don't want the project team to know their identities. This helps to protect confidentiality rights and intellectual property rights. "Even when we do project prototyping, we set aside a place for that work — and the buildings are locked and secured," he says.

An external provider should offer options and flexibility in protecting intellectual property rights. "We can protect our clients' intellectual property any way they choose," says Eric Preissner, President of Ann Arbor, MI-based Preissner Engineering & Consulting, LLC (PEC). He notes that some clients want NDAs; others want patent agreements. The NDA defines any communications about the intellectual property. "We protect Customer A so that Customer B does not see their project," says Preissner.

The experts agree that design engineers should proactively participate in a living NDA, and that it's important to review and update the agreement periodically. "We work with companies in the U.S. and in Asia, and pay careful attention to the non-disclosure agreements," says Farahani. An external provider should also ensure that employees follow International Organization for Standardization (ISO) standards and requirements from the firm's human resources department as they relate to non-disclosure, so that confidentiality is maintained.

Design engineers should also require contract language that specifies appropriate communications channels for intellectual property data. "When we write proposals and contracts, we set up a process based on customer requirements about how communications and communication channels will be directed so that intellectual property is protected," says Farahani. Some discussions may be permissible by phone, while others should occur in person.

Advantages of External Provider Relationships

Design engineers should explore the advantages of working with available external firms before making a final selection.

"You can get some unconstrained thinking. The ideas our guys come up with may not meet all the requirements on Day One. We have to tighten them up over time. But we're more likely to have some fresh ideas because we're not constrained by all of the controls of the large corporation," says Winn.

An outside designer can also have more depth in certain areas than the customer or internal designer does. "We tend to have more in-depth design and analysis background than the typical design engineer because that's all we do," says Winn.

The additional engineering disciplines that are available with an outside provider are another advantage. "We have all the required disciplines to do whatever our customers want us to do," says Ma, noting that D&K Engineering works with plastic injection moldings, microfluidics and systems engineering, for example. "We can develop a product very quickly and at a lower cost than an in-house team."

Then there's the ability to leverage the detailed and robust analytical tools that the provider has to offer. "Even a mid-sized customer does not have these tools," Preissner points out. Whether it's computational fluid dynamics (CFD) or high-end finite element analysis (FEA) tools, they require a certain level of experience and buy-in financially to keep and maintain. A company that does manufacturing may need them at the beginning of a project, but not throughout. With an outside provider, a designer does not have to pay for a service when they don't need it.

Other advantages can include being faster, more efficient, and more cost-effective than in-house processes. "We enable a designer to move to a variable cost that is controlled during the different project phases," says Farahani, noting that this can reduce overall project costs.

Desirable Early-stage Concept Developments

Design engineers should ensure as large an intersection as possible between the early-stage developments they need and the ones an available firm can best offer. These can include packaging ideas and concepts, and turning a product into a device that manufacturing can produce.

D&K Engineering protects its clients' intellectual property in secure buildings.

"In almost any industry, this includes weight reduction concepts and mass production concepts," Winn says. "And then there are fuel economy concepts with almost any entity that has things that move, such as airplanes, trucks, cars and trains."

Other early-stage design concept developments customers accept include materials designs, and the use of new technologies like additive manufacturing (AM). "These are the concepts we put in front of customers quite often," says Winn.

"We work on early-stage requirements such as problem solving and establishing requirements. That takes a lot of collaboration, white boarding sessions, and talking through design needs," says Ma.

An examination of the design space is especially helpful early on, Preissner points out. "We can evaluate different choices in the design space more rapidly than a design firm can put a detailed model together," he says, noting that an external provider can look at potential solutions at the top level, and eliminate things that are not fruitful to pursue. "We can help them to more rapidly focus on viable designs." **DE**

David Geer *is a technology writer based in Northeast Ohio. Contact him via de-editors@deskeng.com.*

INFO → Applied Technology Integration: ATIIntegration.com

→ D&K Engineering: DKEngineering.com

→ Engineering Technology Associates: ETA.com

→ International Organization for Standardization: ISO.org

→ Preissner Engineering & Consulting: PEC-LLC.com

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

Design Collaboration

Good (and complex) technology can come in small packages.

BY JIM ROMEO

Designing a product for useful, but complex engineering functionality is a tall order that requires a collaborative and proactive design team. When the Tucson-based Rigaku Raman Technologies team wanted to design the next-generation material analyzer, they looked for a design partner who could incorporate all the needed ingredients, plus have the right synergy with their own personnel. This partnership was the genesis of the Progeny and Progeny X2 analyzer design.

The Progeny and Progeny X2 analyzers are portable instruments designed for high-performance chemical analysis using Raman spectroscopy — employing laser technology to decipher chemical makeup by measuring the amount of scattered light that bounces off various materials. The scattered light is compared against a library of thousands of known chemicals. Progeny analyzers are used in a variety of applications, including raw material identification, research and development, quality assurance, anti-counterfeiting, homeland security and teaching labs.

In its latest design effort, Rigaku sought an analyzer that could be used with a variety of applications. A Progeny analyzer can examine powders, liquids and solids.

"The opportunity, and challenge, of this design effort was to accommodate a large and varied group of end users and applications," says Boston Device Development (BDD) Principal Derek Hatchett.

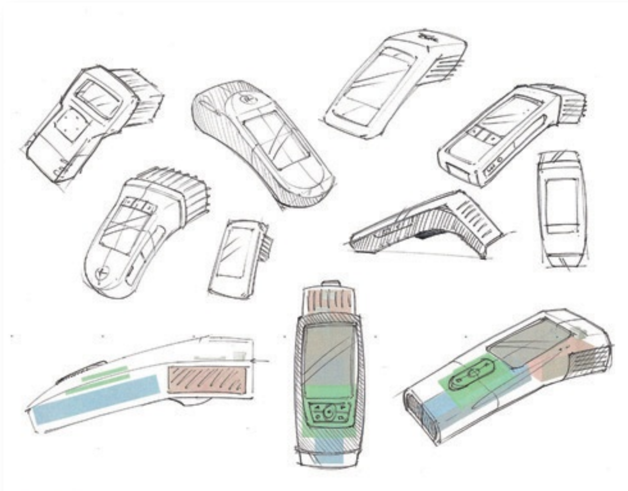
From Concept to Production

Newton, MA-based BDD was responsible for all phases of development, from early concept efforts and industrial design to engineering and production. The two teams worked closely throughout the project.

"BDD's experience in all areas of product development helped drive the project from concept to manufacturing," explains Rigaku VP of Product Development Claude Robotham. "They expertly built a physical unit that supported our unusually varied target market."

The partnership set out to define design parameters to set the objectives for the final product. This helped align all stakeholders in the design team.

"There were a number of opposing design parameters that required our careful consideration and balance. The final device needed to be extremely lightweight, while also being able to offer swappable batteries and survive a drop test," says Hatchett. "These parameters ultimately led to the device's thin walls and exterior material choice."



Early concept sketches created during the design process. ***Images courtesy of Progeny.***

The team began to develop and test configurations incrementally, so that they could isolate the functionality and performance of its characteristics. BDD worked with foam models to create Progeny's product embodiment, prototyping early and often to test different configurations.

Every subsystem had to be explored and decoupled from the whole to achieve the best result. They used a decision-matrix analysis called the Pugh method, where pros and cons are evaluated against one another in relation to a baseline option.

Process Discipline

The team structure and its interactive processes played a critical role in making productive progress. The BDD-Rigaku team collaborated every week, both remotely and in person. BDD also held regularly scheduled internal and external project meetings on a weekly basis.

As Eric Sugalski, the founder and principal of BDD, explains, "We provide real-time files through our FTP site. Our clients can watch our progress literally on a daily basis if they want to because our project management dashboard shows progress in small increments. This approach is very different than what product design firms did in the past, when client and project teams worked more or less in isolation from each other, with one big unveiling after three months of effort."

The entire project lasted for less than one year, from concept to production — ahead of schedule.

A rendering of the complete Progeny Analyzer.

"BDD's approach produced a final product much faster than what we originally anticipated," Robotham says. "By working collaboratively, we were able to meet a very aggressive timeline and budget."

Prototyping the analyzer was a key step in the process. BDD provided initial renderings based on Rigaku's vision, followed by a detailed Pugh analysis to determine the best option.

"We had a unique opportunity to develop one of Rigaku's first products in a few years," Hatchett says. "We were, therefore, in a position to look at how Progeny's design language could refresh and build upon the Rigaku brand."

Part of the development also looked at existing products with competing features and technology. This allowed them to shape the analyzer's final characteristics with its viability in the marketplace. "BDD looked at the competitive Raman spectroscopy landscape. As a team, we researched existing products and produced product positioning maps that charted where we wanted to be in comparison to others in the market," Sugalski says.

Technology Begets Technology

The specifics of the product design entailed working with various pieces of design software. The BDD team used Rhino, SolidWorks and the Adobe Creative Suite. These programs were used through both the mechanical engineering and industrial design efforts. The software allowed BDD to work easily with the Rigaku team, which used several CAD packages.

"The project benefitted greatly from using Master Models in SolidWorks. Rather than having to rebuild the database from scratch when major project changes occurred, the team remained nimble in the face of unexpected changes," notes Lead BDD Engineer Rob Colonna.

But as with any technical and complex design, the team had some stumbling blocks and challenges along the way.

"Two of the biggest design challenges included instrument weight and the desire to have a completely sealed device," Colonna reports. "The team wanted to develop a robust instrument, but also needed to keep the device weight reasonable."

The Team Machine

Project teams that pursue research and product development simultaneously will always encounter unavoidable changes.

"The result of conducting fundamental research simultaneously with product development," Hatchett explains, "is that when changes are made, it creates a ripple effect throughout the project, thus requiring a team to be flexible and pivot quickly."

The Progeny project effort also reveals the opportunity in combining a company's core internal strengths with an outside partner to provide fresh perspective on an existing product line. Rigaku showed tremendous business creativity in leveraging its expertise in optics with BDD's proficiency in product development to build a market-expanding device like Progeny.

What the team accomplished was something that probably would not have taken place years ago — they were disparately located, but acted cohesively thanks to technology and a well-structured design process. The BDD team excelled at managing a multi-faceted team located in multiple locations. Communication was critical in maintaining cohesion among BDD engineers in Massachusetts, Rigaku engineers in Arizona, and suppliers located in multiple states.

"Never underestimate the amount of communication that is required for a virtual, at-a-distance project environment," Hatchett says. **DE**

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

INFO → **Adobe:** Adobe.com

→ **Boston Device Development:** BostonDevice.com

→ **Dassault Systèmes SolidWorks:** SolidWorks.com

→ **Robert McNeel & Associates:** Rhino3D.com

→ **Rigaku Raman Technologies:** RigakuRaman.com

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★ SPOTLIGHT ★

Project Propelled Forward

Metrology and 3D printing distributor Burton Precision apply their 3D printing know-how to solve a variety of CAD issues and challenges for producing a plastic propeller design for a human-powered submarine.

Rick Kerkstra, Burton Precision vice president, performed the coordinate measuring of the propeller with a portable CMM arm at Burton's demo facility in Grand Rapids, MI.

Grand Rapids, MI-based Burton Precision is a machine tool distributor specializing in the application of metrology and 3D printing products. Their involvement in manufacturing criss-crosses the breadth of industries with technologies that have a direct impact on successful product design and manufacture.

The University of Michigan's Human Submarine Team recently contacted Burton Precision to enlist its assistance: The team was dealing with some CAD issues related to producing a propeller for a submarine that is designed and built by students.

Rick Kerkstra, Burton Precision vice president and 3D printing specialist, recounts that this particular inquiry came through a circuitous path.

"We held an open house at Burton Precision for GR Makers in Grand Rapids, which is an open community lab that incorporates elements of a machine shop, a workshop and a design studio," he explains. "Members there work on projects that range from the industrial to the delicate arts. It's a unique community that focuses on enabling personal expression, providing education and supporting entrepreneurship."

Kerkstra was demonstrating Burton's metrology and 3D printing products when one of the GR Makers staffers mentioned that his brother belonged to the Human 3D Printed Propeller for Human Powered Submarine Team at the University of Michigan.

"He said they were having problems with a point cloud file for a propeller design," Kerkstra recalls. "More specifically, they couldn't convert the file to a 'friendly' file that they could put to a cutter path on a computer numerically controlled machine to make the part. I gave him my card, and Jeremy Werner called."

Werner is with the University of Michigan's Naval Architecture and Marine Engineering Department ...

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Winging It

AM reduces tooling cost and lead time to produce composite aerospace parts.

Advanced Composite Structures (ACS) repairs helicopter rotor blades and other composite structures for fixed- and rotary-wing aircraft. The company also produces low-volume production composite parts for the aerospace industry.

Both offerings require tooling. On the repair side, the company normally uses a mold with a contoured surface to guide the repair. It creates most production components by applying composite laminate strips onto layup tools. Many jobs also require fixtures to locate secondary operations such as drilling.

Old Methods

In the past, ACS typically produced layup tools, drill fixtures and consumable core patterns on computer numerically controlled (CNC) machines. Another option was producing a model using a CNC machine or power tools and using it to mold a composite layup mandrel.

It typically cost around $2,000 to hire a machine shop to produce a metal composite mold. Producing a model and molding a composite layup tool cost about the same. In both cases, lead times were eight to 10 weeks.

Initial tooling design sometimes presented problems, however. In these cases, ACS incurred substantial additional expenses — and the project was delayed while the tooling was repaired or rebuilt from scratch.

New Efficiencies

More recently, ACS has switched to producing nearly all of its tools using additive manufacturing (AM) on STRATASYS' Fortus Fused Deposition Modeling (FDM) machine ...

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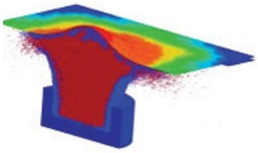
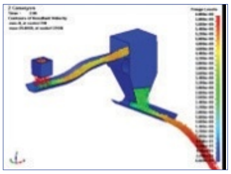
Livermore Software Technology Corporation

Four New Solvers for Multiphysics Purposes



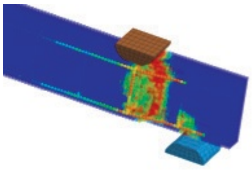
Discrete Element Sphere (DES)

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.



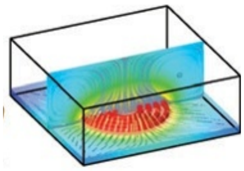
Here are some distinct features of the bond model:

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.



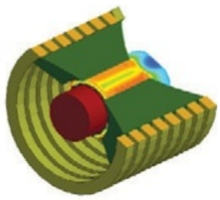
Incompressible CFD

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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