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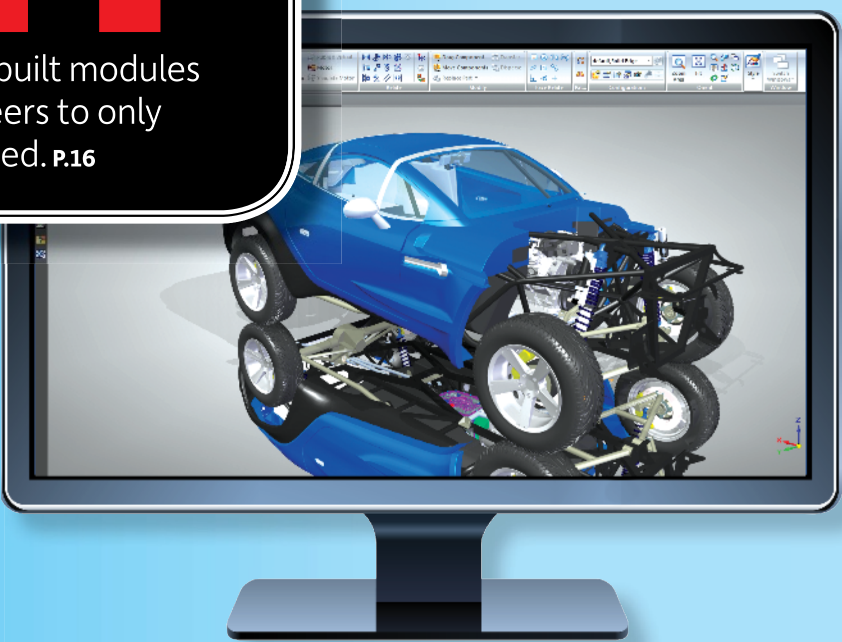
February 2014 / deskeng.com

FOCUS ON: Simulation-Led Design

SOFTWARE FOR RENT

Rental models and purpose-built modules allow entrepreneurial engineers to only buy the functionality they need. P.16



by Jamie J. Gooch

It's Time for Manufacturing

Timing really is everything when it comes to introducing a new idea. History is riddled with products that failed, in part, because they were ahead of or behind the times. We don't have to look too far for examples of ideas the world wasn't ready for, such as 1985's Sinclair C5 electric vehicle, Sony's Data Discman electronic book that launched in 1992, or the 1993 Apple Newton MessagePad. And if you listen to technology pundits, it's too late for Nintendo's Wii U, Microsoft's phone business and BlackBerry's latest operating system.

But when the timing is perfect, a little push in the right direction can have a major impact. That's the idea behind the Obama Administration's manufacturing institutes that are being launched using existing resources. Like the National Additive Manufacturing Innovation Institute pilot (now rebranded as America Makes), these new institutes are intended to bring together private industry, academia and Federal agencies to co-invest in technologies that will encourage more investment and production in the U.S.

The question is: "Are these investments too little, too late?"

The first of three planned institutes, the Next Generation Power Electronics Institute, was launched last month in North Carolina. It is focused on "enabling the next generation of energy-efficient, high-power electronic chips and devices by making wide bandgap semiconductor technologies cost-competitive with current silicon-based power electronics in the next five years," according to a White House press release. The next two institutes, one focusing on digital manufacturing and design innovation, and another on lightweight and modern metals manufacturing, were about to be launched as this issue was being sent to the printer.

The Right Idea

When the National Additive Manufacturing Innovation Institute pilot was launched in 2012, no one accused it of being a solution in search of a problem. Other countries already had such public-private partnerships to support advanced manufacturing technologies. Wide bandgap semiconductor innovations are needed to pick up where silicon leaves off, addressing crucial power efficiency issues holding back innovation in everything from laptop power adapters to electric motors. Likewise, you need look no further than the pages of *Desktop Engineering* to see the immense promise of further advancements in digital manufacturing and the use of lightweight materials.

The question isn't whether these technologies are ahead of their time. The question is: "Are these investments too little, too late?"

As part of the government's commitment of $200 million to the new institutes from multiple Federal agencies, the U.S. Department of Energy will invest $70 million in the Next Generation Power Electronics Institute over the next five years, with that amount matched by companies and state governments. While that is a drop in the bucket compared to the $1 billion plan to create a national network of 15 institutes that the president announced in last year's State of the Union address, it doesn't require congressional funding approval. A bipartisan bill introduced in July to create such a network, the Revitalize American Manufacturing and Innovation Act, is slowly making the rounds in Congress.

Moving the Manufacturing Needle

The backdrop of the president's announcement was a December jobs report that showed an unexpected slowing of job growth, with manufacturing again the bright spot.

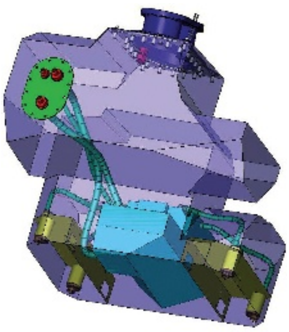
"For decades we'd been losing manufacturing jobs. But now our manufacturers have added over the last four years more than 550,000 new jobs, including almost 80,000 manufacturing jobs in the last five months alone," said President Obama during the announcement of the Next Generation Power Electronics Institute.

The total number of manufacturing jobs still has a long way to go to even get back to where it was at the turn of the century, though it is higher than its 2010 Great Recession low of 11.4 million. The good news is that it's showing some signs of life.

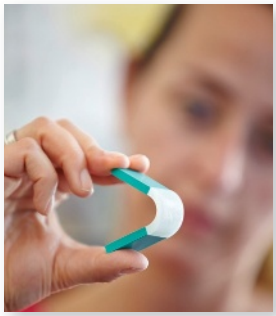
The time is right to capitalize on manufacturing's momentum. A scaled-back version of a national network of advanced manufacturing hubs is better than none at all, and the technologies being funded are well-positioned to make an impact on the future. However, until broader legislation like the Revitalize American Manufacturing and Innovation Act comes up for a vote, the relatively small investment will only give the organizations involved in the manufacturing institutes a chance to prove their potential. Without more support, that potential could be lost. **DE**

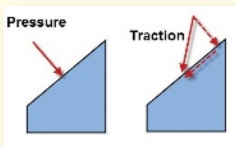
Jamie Gooch *is the managing editor of* Desktop Engineering. *Contact him at de-editors@deskeng.com.*

DE February 2014 VOLUME 19/ISSUE 6



ONTHE COVER: Software providers offer custom modules and subscription-based models to appeal to more users. *Images courtesy of Autodesk and Siemens PLM Software.*





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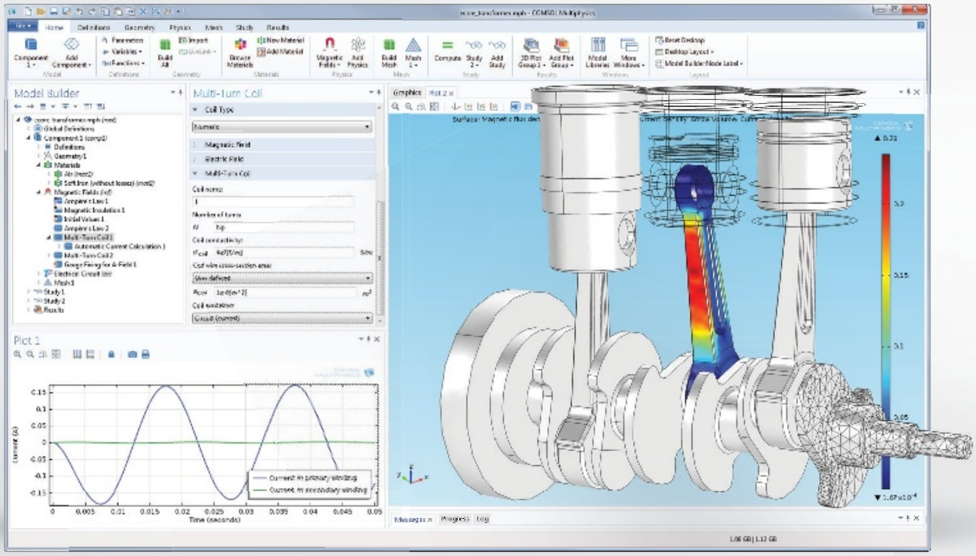
MULTIBODY DYNAMICS: Model of a three-cylinder reciprocating engine used for the design of structural components.



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A LEVEL 5 COMMUNICATIONS PUBLICATION
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***Desktop Engineering*®** (ISSN 1085-0422) is published monthly by Level 5 Communications, Inc., 1283D Main Street, P.O. Box 1039, Dublin, NH 03444, 603-563-1631. Periodicals postage paid at Dublin, NH, and at additional mailing offices. Desktop Engineering® is distributed free to qualified U.S. subscribers.

SUBSCRIPTION RATES: for non-qualified; U.S. $108 one year; Canada and Mexico $126 one year; all other countries $195 one year.

LIST RENTALS: For information on list rentals, contact Statlistics, Danbury, CT: 203-778-8700.

POSTMASTER: Send all address changes to ***Desktop Engineering***, P.O. Box 677, Northbrook, IL 60065-0677.

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by Kenneth Wong & Beth Stackpole

Desktop Engineering and Stratasys Announce Rapid Ready Sweepstakes Winner

In the wee hours of one morning, Joe Lutgen came across the *DE*-Stratasys Rapid Ready sweepstakes announcement. It offered the chance to win a Mojo 3D printer, priced around $9,900 retail. Lutgen, who owns and runs his own engineering consulting business (RSI Mechanical LLC), is no stranger to 3D printing. He has used it while working with clients in the medical equipment, automotive and aerospace sectors.

"Maybe I have a shot at this," he thought. So he entered his name. A few weeks later, he received a call from *DE* Publisher Tom Conlon. That's how Lutgen found out he was about to become the owner of a brand-new Mojo.

***DE*-Stratasys sweepstakes winner Joe Lutgen shows off the custom-designed basket he uses to retrieve 3D-printed parts from the rinse chamber of his new Mojo 3D printer.**

Hands-on Experience

Lutgen recalls working on a startup company's design for a device that attaches to a hand. "We went through probably 70 iterations just on that one design: 3D printing, SLA — the [prototyping] methods we used were extremely important," he adds. "The ergonomics of the hand played a role in the device. It was critical that we turn around an idea in a couple of days."

For manufacturers without in-house production facilities, turning ideas into tangible mockups is no quick act. Even with the dramatic speed and flexibility offered by 3D printing nowadays, Lutgen knows the process still takes about three to four days at service bureaus. Now that he has a Mojo at his disposal, Lutgen plans to augment his consulting business with printing services.

"My hope is to develop a small printing service for [clients], so if they have components from other engineers or from myself, I'll be able to print their parts overnight," he says. When that becomes a viable business, he may expand from to multiple 3D printers.

Part of Lutgen's prize was the WaveWash 55, a unit for rinsing off support materials from printed parts. The first thing Lutgen printed on his Mojo was a custom-designed basket for checking the rinse progress and retrieving components from the rinse chamber. (Think of it as a sieve to catch and check on 3D-printed parts during the rinsing process.)

Lutgen's three sons are three special clients he may be supplying free printing services to for years to come. Because they're fans of the Minecraft video game, they put the Mojo to use by printing Minecraft avatars found at a 3D content site. "I want to get them started on possibly becoming an engineer like myself," he says, noting that he plans to offer his sons' robotic class free printing services.

Stratasys' tagline for the Mojo as "the idea engine" is a fitting description for how Lutgen plans to use his prize.

"As an engineer, someone with an inventive mind, I'd go around the house and think of how I could do things better. With this printer, I can now create the idea in CAD and print it out and try it," he says. "The ability to create what you think is the best solution and print it out — to me, that's amazing."

Over the years, Lutgen has had many ideas. Some are fleeting thoughts; others could be promising and patent-worthy product concepts. "But I've never taken them to market," he says. "This [Mojo] gives me an opportunity to work on those inventions that are in the back of my mind. Now I have no more excuse. I need to start working on the ideas I want to get out to the public, to the market. It's an opportunity for me to create whatever I come up with in a short amount of time."

To watch the video interview with Lutgen, visit deskeng.com/virtual_desktop/?p=7968.

— K. Wong


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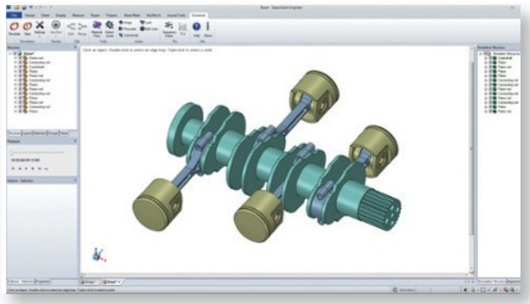
by Kenneth Wong & Beth Stackpole

As SpaceClaim Matures, 2014 Release Fills in Key Gaps



The Dynamics module provides motion dynamics for multi-body systems. *Image courtesy of SpaceClaim.*

SpaceClaim has just taken the wraps off its 11th release — filling in gaps in the areas of 3D modeling and collaboration while retaining the signature ease of use and flexibility that position it as a 3D CAD offering for non-CAD jockeys.

"We've always seen ourselves as a 3D CAD tool for the other 90%," says Justin Hendrickson, SpaceClaim's director of product marketing. "One to 2 million people describe themselves as CAD experts or designers and do the detailed design work, but in reality, there are nine times more people that want to use CAD, but can't because it's difficult to use."

With SpaceClaim Engineer 2014, the company has honed the tool across the board, from fine-tuning the inner workings to boost performance, to new modeling and collaboration capabilities, along with the incorporation of a new module for advanced simulation in the area of dynamics.

On the performance front, SpaceClaim Engineer 2014 has been optimized to better support multi-threading, particularly in file import. This results in faster operation for many functions — including a 30% boost in model load times.

The upgrade supports direct drag-and-drop file access from Microsoft Outlook, along with new semi-parametric functionality and live interference detection. Another big area of focus for the new release is leveraging the tool for pre-processing for manufacturing and simulation. There is also enhanced product manufacturing information support via more use of intelligent capabilities and numerous additional model preparation tools.

SpaceClaim Engineer 2014 also offers an add-in from Algoryx Simulation, providing motion dynamics for multi-body systems with joints and frictional contacts. When installed, users can click on the Dynamics tab within SpaceClaim to do mechanics modeling, interactive dynamics simulations, plotting and analysis, and full Luxion Keyshot integration for photorealistic simulation videos.

— *B. Stackpole*

Dassault Systèmes Acquires RTT

Near the end of 2013, Dassault Systèmes made a move to acquire RTT, a visualization software powerhouse. When completed, Dassault will own 84% of controlling stakes in RTT's interest.

A screen capture of Audi's online car configurator, powered by RTT visualization software. *Image courtesy of RTT.*

"Our clients express a growing need to fully exploit their 3D digital assets, to transform their marketing and sales as part of their ultimate customer experience," says Bernard Charlès, president and CEO of Dassault.

With its product DeltaGen, RTT offers CAD users a way to generate high-end visuals and work in ray-traced scenes interactively. The workflow is particularly attractive to the automotive industry, which seeks to replace physical mockups with digital models to cut cost. The visuals in RTT software are realistic enough for many of its customers to rely on for design review and decision-making.

With DeltaPowerhouse, RTT dabbles in cloud-hosted rendering, targeting those who seek browser-based, on-demand solutions for visualization. Furthermore, the company continues to delve into augmented reality, by finding creative ways to project interactive digital models into the physical environment.

Dassault's ongoing partnership with GPU maker NVIDIA to bring interactive ray-tracing to CATIA software, and RTT's partnership with NVIDIA to offer GPU-driven acceleration in DeltaGen — makes their products complementary. RTT's technology also supports Dassault's vision to empower product design, sales, marketing and decision-making with widespread use of digital visualization.

One conflict Dassault may have to manage is RTT's relationship with rival Siemens PLM Software. RTT offers DeltaGen for Teamcenter, Siemens' software for data management. When asked to comment on the potential conflict during the investor conference call, however, Dassault's Charlès replied, "It's not a risk. I see it as an opportunity."

— *K. Wong*

ANSYS 15.0 Evolves with New Features

Whether designing a next-generation smart phone or a state-of-the-art jetliner, there's no escape from the increasing complexity that defines today's products. Engineering teams across all industry sectors are optimizing designs via the use of advanced materials like composites, and increasing the role of electronics and embedded software to make smarter products. With this growing sophistication, however, comes a need for advanced simulation tools that help engineering teams optimize designs far earlier in the process.

This backdrop provides the context for ANSYS' latest release of its flagship simulation offering. ANSYS 15.0 adds a range of new capabilities and enhancements in the areas of advanced materials systems design, fluid dynamics and electromagnetics — in addition to new features for facilitating model setup and meshing and support for high-performance computing (HPC) scalability.

"This is a big release for us," says Barry Christenson, ANSYS' director of product management. "There are tremendous improvements across every product line and physics we have."

Branching Out into New Physics

To address the growing interest in electric motor and drive design, ANSYS 15.0 builds on the Maxwell and Simplorer solutions by extending integration into other physics. For example, the solution now features new force-coupling capabilities between low-frequency electromagnetics (Maxwell) and structural mechanical tools for acoustics analysis, to help engineers minimize noise in electric motors and machines. There is also an integration between the Simplorer circuit simulation tool and the SCADE Suite, an automatic embedded code generator. This provides a collaborative design environment to assist in optimizing interactions between control system software and hardware.

"Now you're able to define functionality and how you want a drive system to behave," Christenson says, noting that ANSYS 15.0 can simulate the actual control system as well as all the interactions. This kind of closely coupled simulation enables engineering teams to fully evaluate multiphysics (MP) effects, he adds, reducing the possibility of overdesigning or overpredicting performance.

"As you're trying to optimize motor efficiency and weight in the design of a vehicle, you can't be off by 15%," he points out. "Otherwise, you're designing something that's too big, takes up too much energy to operate — or conversely, doesn't have enough power. The ability to evaluate these things together becomes extremely important."

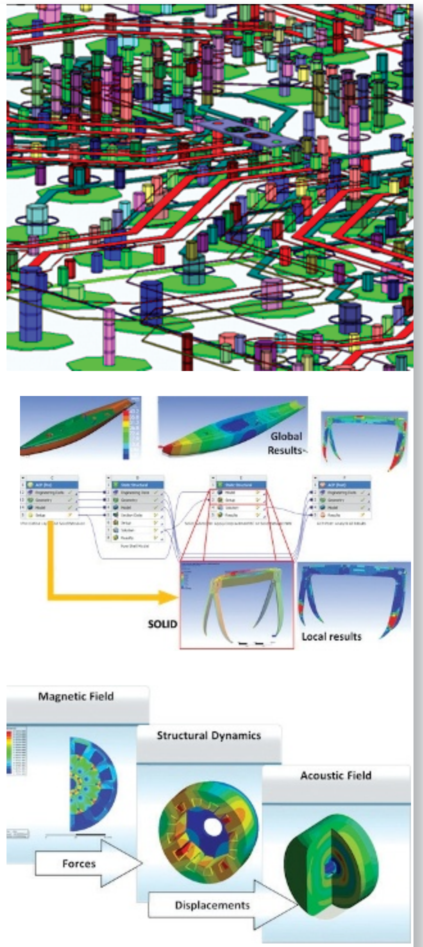
Optimize Composite Analysis

ANSYS 15.0 extends the software's support for evaluating the performance of composite materials in a number of ways. The new release reduces overall computation time by giving users the option to create high-fidelity local results while employing a coarser model globally. There is also a new MP approach to composites simulation to optimize wireless design and thermal management. It allows users to define spatially dependent material properties for electromagnetic simulation, and then couple those results to the structural analysis.

"We've had a great, streamlined workflow for the structural analysis part [of composites design], but not for looking at all the electronics effects," Christenson says. "This composite solution spans not just the structural analysis, but the electromagnetic."

Faster Overall Performance

In addition to these features and to fluid dynamics enhancements, ANSYS 15.0 ups the ante for automating model setup and meshing. It also increases support for HPC scalability, to speed up its performance across the simulation portfolio by a factor of five.



A new submodeling technique provides more insights into composites products. *Image courtesy of ANSYS.*

"With this kind of support for large clusters, we can do a lot of things we couldn't have done in the past," Christenson concludes. "We want our customers to get the best return they can out of their hardware investment."

— B. Stackpole

3D Systems Previews New Cube and CubePro

3D Systems joined the desktop market with the Cube just a few years ago. Each year has seen a new iteration of the Cube, and this year is off to a quick start with the unveiling of the Cube 3 and the new CubePro at the Consumer Electronics Show (CES.)

The new Cube has a slightly larger build envelope than the original at 6 x 6 x 6 in. (15.25 x 15.25 x 15.25 cm). It is capable of printing with both polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS) plastic to a layer thickness of 75μ. The new system also features dual extruder heads which, according to the company, allow users to mix and match with over 20 different colors.

The CubePro is a much different animal than its purely hobbyist brother. It offers a build envelope of 10.75 x 10.75 x 9.5 in. (273 x 273 x 241 mm) with the option of up to three extruder heads. The downside to multiple extruder heads is a reduction in build envelope to 7.33 x 10.75 x 9.5 in. (185 x 273 x 241 mm) for the triple head version.

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Epson Developing Industrial 3D Printers

Epson is the latest corporation to talk about moving into additive manufacturing. President Minoru Usui recently had some things to say about the 3D printing market.

Epson isn't interested in joining the ranks of home AM system providers. It wants to build industrial, multi-material 3D printers capable of making just about anything. Usui specifically mentioned cars as one type of product that could be largely constructed using AM. Epson is still five or more years away from that lofty goal, but is hard at work developing large systems that could handle that sort of build.

Usui stated he believes the current market for home 3D printers is undergoing an unsustainable boom. He went on to take a bit of a jab at the current market, calling it derivative. He claims few companies are showing anything like real innovation, and are instead simply copying each other's work. His final take on home AM is that few people need the ability to print their own plastic toys.

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Apple to Bite into AM?

Last year, we reported on HP's announcement that it intends to produce at least one 3D printer in 2014. More unusual is a series of recent patent filings by Apple that seems to indicate the electronics juggernaut is also interested in additive manufacturing (AM).

Apple filed for five new patents at the end of November related to Liquidmetal, an alloy with a number of characteristics that might make it useful for producing electronic goods. Two of the patents directly dealt with how AM might be used to build parts using Liquidmetal, including plans for the production of bulk metallic glass (BMG).

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3D Systems to Acquire Portions of Xerox R&D

3D Systems has moved to acquire portions of Xerox's Wilsonville, OR product design, engineering and chemistry group and related assets for $32.5 million in cash. Both companies expect the deal to be finalized by the end of 2013, and it deepens the ties between the companies with Xerox already having produced 3D Systems' line of ProJet printers.

3D Systems intends to increase its R&D by 75 to 100% as part of the acquisition.

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MTU Advances Inexpensive Metal AM

The average price for metal additive manufacturing systems is far beyond the means of most consumers, but that paradigm may be shifting with Michigan Technological University's (MTU) new metal 3D printer, which can be constructed for under $1,500.

MTU's research team built the system using a mix of off-the-shelf parts and reproducible materials, including a MIG welder and stepper motor. It is entirely open source, including online documentation. Associate Professor Joshua Pearce's goal is for others to improve upon his model, bringing the cost of metal AM systems down.

"Similar to the incredible churn in innovation witnessed with open-sourcing of the first RepRap plastic 3D printers, I anticipate rapid progress when the maker community gets their hands on it," said Pearce, an associate professor of materials science and engineering/ electrical and computer engineering. "Within a month, somebody will make one that's better than ours, I guarantee it."

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Google Moves into Robotics

Google has quietly built a robotics division (by way of acquisition) as part of a plan to create advanced robots for manufacturing and logistics.

At the helm of this project is former Android chief Andy Rubin, who has suggested the robots could be involved in home delivery, or could be used to assemble electronics.

Among the acquisitions are Holomni, which makes advanced vehicle casters; Industrial Perception, a robotic vision and artificial intelligence (AI) company; Redwood Robotics, which develops robotic arms for manufacturing; Bot & Dolly, which developed a robotic platform for movie cameras and design solutions, and its sister company Autofuss; and robot developer Meka.

Another acquisition, the Japanese firm SCHAFT, has designed a humanoid robot that has pulled into the lead in the U.S. Defense Advanced Research Projects Agency's (DARPA's) Robotics Challenge. During last year's trials, the robot completed most of the eight required tasks successfully. The team lost points when the wind blew a door out of the robot's reach, and because the robot could not climb out of a vehicle after navigating an obstacle course.

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A Sensor Approach to Gesture Control

Canadian startup Thalmic Labs has come up with what may be a new way to provide gesture-controlled computer interfaces.

The Myo, which looks like a black armband, uses sensors to detect electrical impulses in the muscles. It then translates them into screen commands via a Bluetooth connection. This would move gesture controls away from camera-based solutions (like Kinect).

Myo includes a nine-axis inertial measurement unit, haptic feedback, a built-in rechargeable lithium battery and a set of proprietary electromyography (EMG) muscle activity sensors. Its application programming interfaces are available for both iOS and Android, and it's compatible with both Windows and Mac.

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Life-sized Lego Hot Rod Hits the Streets

Armed with 500,000 Lego bricks, an Australian and a Romanian have built a life-sized, air-powered Lego hot rod that has taken to the streets of Melbourne at a top speed of 18 mph.

The Super Awesome Micro Project was crowd-funded via Twitter. The car is powered with four compressed-air-driven orbital engines and 256 pistons made of Legos. The wheels and a few load-bearing parts are not Lego-based.

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Army Laser Could Take Down Mortars, Missiles

The U.S. Army has announced the successful test of its new High Energy Laser Mobile Demonstrator (HEL MD) to target and hit 90 mortar rounds and unmanned aerial vehicles (UAVs) using a 10kW laser. The system is designed to intercept a wide range of targets, including cruise missiles.

Boeing installed the beam control system and other hardware on the Oshkosh Heavy Expanded Mobility Tactical Truck, which carries the laser system. The recent tests were conducted at the High Energy Laser Systems Test Facility on the White Sands Missile Range. The Army plans to test the system with 50- and 100kW lasers.

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New Wolfram Language

Stephen Wolfram has come up with a new computing paradigm that combines the Wolfram Alpha search engine, the Mathematica computation platform, and natural language programming to allow programmers to build apps that already "know" vast quantities of information.

Wolfram says he wants to "make the world computable" — and in the process make it possible to build apps with just a few hundred (or a few dozen) lines of code using his new Wolfram Language.

The Wolfram Language includes data manipulation and analysis, images, geography, sounds, scientific data, nearly automatic user interface building, social data and more.

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Yesterday's PLM Isn't Enough. It's About Tomorrow.

BY ROB MCAVENEY

There's a dirty little secret in PLM today: All of the major PLM systems have performance issues at scale. Big data, expanding user counts, complex processes: Problem, problem, problem. None of yesterday's PLM systems were ever designed for today's demands, much less tomorrow's.

Hockey legend Wayne Gretzky famously said, "A good hockey player skates to where the puck is. A great hockey player skates to where the puck is going to be."

When making strategic decisions about PLM, like Gretzky, you need to think ahead, plan for what's on the horizon, and avoid focusing on how things used to be.

PLM system selection typically starts with Engineering's need to manage CAD models, documents and Bills of Material. Whether it's for 100 engineers at your site or 1,000 people worldwide, the scope is often based on current conditions.

But, what happens when cross functional processes require Manufacturing personnel to have access? What about global supply chain partners? And Quality? Procurement, Sales and Support? Product information is the lifeblood of your company.

And what happens when you also need to manage work in process (WIP) data and processes across disciplines, such as revisions of mechanical, electronics, software and firmware for full system-level configurations? The amount of data and number of transactions will increase by orders of magnitude.

At best, PLM gets slower and slower. At worst, your PLM stops completely. If your PLM is not capable of being the master data repository for all of your product information and related processes, your company's return on investment (ROI) is being blocked. Your ability to collaborate is hindered, mistakes increase, delays occur, and revenue from next generation products can be jeopardized.

Case in Point

I recently spoke with a leading multinational medical device company who spent millions customizing every aspect of their PLM system. They had over 1,000 users running a series of custom processes, and were ready to roll out the PLM system to a newly acquired company, which would add more than 10,000 new users. Unfortunately, the system couldn't scale to handle the new users and data. It ran so slowly that people refused to use it. With the existing PLM system there was no way to move forward and no way to salvage the investment in the customizations, data migration and training.

PLM is a long-term investment. So when you make a decision today, you need to ensure that it can grow to handle your company's needs tomorrow and into the future. And that it will do so in a predictable manner with standard hardware.

Any PLM salesman will tell you that their system scales to over 10,000 users ("in theory") — that is, of course, if you purchase an exotic hardware setup and undertake an endless performance tuning science project.

No one should need to buy a Cray-style supercomputer to run a PLM system or be forced to purchase a crazy set of servers that require constant configuration.

Before you sign on the dotted line you should know what you need to add the next 10,000 users and the next petabyte of data:

- You want to know that your PLM will scale linearly.
- You want certainty that you can use off-the-shelf hardware.
- You want to rely on standard database settings and best practices.
- You want to be able to take advantage of commodity hardware in your data center.
- And when you're ready, you want to use common hardware configurations for Cloud or hybrid scenarios.

You want to be able to run anywhere and scale to any conditions — not yesterday's, but tomorrow's.

Aras recently commissioned Logic 20/20 to conduct independent scalability testing of Aras Innovator 10 on Microsoft SQL Server 2012 with standard HP server hardware for more than 100,000 concurrent users and over 10 million part and BOM records to demonstrate our ability to meet your most complex challenges today, tomorrow and into the future.

Read the report at www.aras.com/Scalability

Rob McAveney *is Chief Architect at Aras. He can be reached at rmcaveney@aras.com.*

In November 2011, Siemens PLM introduced Design1, a subscription version of Solid Edge offered to Local Motors project teams. It was the origin of what has become Solid Edge subscription, offered as monthly, quarterly or annual rental.

The Mod(ular) Squad

From own to rent, from all-in-one to pick-what-you-want — modular software and rental programs emerge to address the needs of activist-inventors.

BY KENNETH WONG

At age three, David Hutton decided he wanted to be an inventor. At 13, he began designing a water pump based on what he'd learned in a physics lesson. Dreaming big, he imagined his device would solve the irrigation problems of the Third World.

It wasn't smooth sailing for the budding engineer, however. "As it turned out, my design was technically impossible," he recalls. Subsequent research highlighted the flaws of pumps in the developing world, from lack of maintenance to unavailability of replacement parts."

So he reconsidered his concept. He reasoned that the design would have to be "a very basic irrigation water pump that required little to no maintenance, and that did not need any shop-bought replacement parts."

Watershed, an entrepreneur-nurturing program, nudged him in the right direction. Today, Hutton's debut product, Flexipump, is in the hands of farmers in South Africa, Zambia, Zimbabwe and Malawi. The simple pump can transport water from a stream or a well located 6.5 yds. below. It can push water up to nearly 11 yds. in height, or about 109 yds. along the ground. It pumps more than 420 gallons per hour.

Inventors like Hutton are a departure from the automakers and aerospace titans that design software vendors have historically targeted. Driven to tackle what they believe to be socially significant issues, this new breed of activist-inventors form ad-hoc teams scattered around the globe. They come together to solve specific problems — say, lack of clean water in India or portable shelters for cyclone victims in the Philippines — but not necessarily to form permanent, ongoing business alliances. Their teams are often too small to warrant a comprehensive product lifecycle management (PLM) or enterprise resource management (ERP) system.

Some catch the attention of angel investors with the commercial potential of their product ideas; many turn to crowdfunding sites like Indiegogo or Kickstarter for capital. Most of them are not in a position to spend a large sum up front to acquire an expensive suite of software or commit to recurring annual licensing fees. For them, the perpetual ownership of an all-inclusive software package is a burden. Their projects' comparatively shorter lifespans, along with their priority for cash flow, demand a pick-what-you-want, pay-as-you-go menu.

Bottom line: They're a growing segment of designers and engineers that software vendors can no longer afford to ignore.

Capturing the Startup Spirit

Last winter, John Fox, VP of marketing for Siemens PLM Software's Velocity Series, and Karsten Newbury, senior VP and GM of Siemens PLM Software's mainstream engineering software, checked into the Fairmont San Francisco on Nob Hill. They represent a software giant that counts NASA, Boeing, Volkswagen and Ford among its clients. But they were at the hotel to attend Lean Startup, a conference where entrepreneurs traded war stories and tips related to new ventures.

"One of the reasons we're here is because we want to apply these startup principles and create value for our customers," said Newbury. Another reason might be to attract the type of designers and engineers who are involved in these new ventures.

When Hutton began designing the Flexipump, he was using a free student copy of Solid Edge (SE), Siemens PLM Software's 3D mechanical design program that targets mainstream customers (different from the enterprise customers who usually rely on Siemens NX). Today, Hutton subscribes to SE Foundation.

The introduction of a Solid Edge subscription in September marked Siemens PLM Software's exploration of a more modular product licensing strategy: SE Design and Drafting ($130 per user per month); SE Foundation ($220 per user per month); SE Classic ($260 per user per month); and SE Premium ($260 per user per month). SE subscription is different from software as a service (SaaS). The software doesn't run in the cloud or become accessed through a browser. It installs on the user's local machine, but is controlled by license-verification to remain active.

Unlike previous licensing models — an upfront cost for software acquisition, supplemented by a yearly maintenance fee — the subscription program lets activist-inventors like Hutton adjust the functionalities they use (or discontinue) during different phases of the project. For instance, a subscriber may upgrade from Classic to Premium to get access to simulation functions in the higher-priced edition for a few months, then downgrade to the lower-priced Classic or Foundation edition when the simulation tasks are complete.

"Some companies are using subscriptions to help them more cost effectively manage the ebbs and flows of demand," Newbury notes. "We see other, smaller companies, like Flexipump, using subscriptions as an easy and affordable way to get access to professional CAD that would otherwise have been out of reach."

The origin of the SE subscription program could be traced back to the launch of SE Design1, a special version of the software the company created for project members of Local Motors, a portal for crowd-sourced automotive design and manufacturing. Priced between $19 to $299 per user per month, based on essential to comprehensive functions, Design1 proved the appeal of multi-tiered software with a pay-as-you-go option.

"Its adoption has shown us that this licensing model has an appeal, and is a way for us to reach new customers by providing

The Dawn of Purpose-Built Simulation Apps?

A similar shift from general-purpose software to function-specific modules is evident in simulation, even if the trend is not as disruptive. One example is Altair's introduction of HyperWorks Virtual Wind Tunnel, a computational fluid dynamics (CFD) program specifically re-engineered for wind tunnel simulation. Another is Dassault Systèmes' Abaqus Knee Joint Simulator, designed to virtually test and verify artificial knee joints in the biomedical market.

For users who have neither the desire nor the patience to master general-purpose simulation packages, these modules reduce the learning curve and make the solution easier to adopt. They're also a sign of pressure coming from changing consumer behavior. Instead of figuring out a way to fit a complex piece of software into an existing workflow, consumers expect the software vendors to deliver a custom-tailored product applicable to a task routinely performed in an industry.

a product that was better suited to their needs and budgets," says Newbury.

Fox and Newbury had learned quite a bit about the way small businesses operate from a survey they recently commissioned. (The survey results were not yet public at press time. Siemens PLM Software plans to release it soon.)

"Sixty percent of the survey participants are purchasing software based on projects. The issue of addressing peak demand — we have customers who are buying subscription seats exactly for that reason," Fox says. He adds that when the survey respondents were asked whether they could predict their project, and how much visibility they had into future projects, the response was a chorus of "virtually zero."

"We asked, 'How far can you see into the horizon?' For the majority, it's six months or less," he reports.

Solutions for the VUCA Era

When Autodesk CTO Jeff Kowalski looked around for a succinct phrase to describe the mood of the times, he found it in an acronym coined by the U.S. Army War College.

"We live in the age of VUCA: volatile, uncertain, complex and ambiguous," he observed in his December keynote address at the Autodesk University conference.

The design software giant is betting heavily on what it sees as the way of the future: cloud-hosted collaboration, cloud-hosted data management and cloud-augmented desktop software. Several years ago, the company began pouring R&D efforts into product offerings that would later become part of Autodesk 360, its cloud-centric modules. In February 2012, when Autodesk decided to go after the product lifecycle management (PLM) market it once dismissed, it began offering not an all-in-one bundle, but a slew of purpose-built modules. In fact, the program debuted with nearly 140 apps for project management, compliance, cost estimation, supplier management, design review, change order and more. For as little as $25 per month, users can mix and match the modules they need for different projects during different phases.

In September, Autodesk introduced a software rental program, covering popular titles like Autodesk Inventor, Revit, 3ds Max and Maya. (Maya and 3ds Max are available as individual rental title; Revit and Inventor are available for rental only as part of suites.) Under the new licensing model, users get access to the desired titles by paying a monthly, quarterly or annual fee. Monthly cost varies, but could be as low as $50 per month.

Some bundles traditionally sold as suites — like the Design Suite, Building Design Suite or Entertainment Creation Suite — were also offered under the same rental program, in prices ranging from $285 to $395 per month. This is disruptive pricing for classic 3D CAD programs that typically sell for $2,500 to $6,000.

"Now that you can rent Autodesk software, the ownership model has finally caught up to the agility of the product itself," says Kowalski. "With an access model, you can quickly scale up and then back down, giving all of those new people the tools they need for just as long as the project lasts."

Charles Bliss, designer of Lightning Motorcycle, a company currently developing an electric motorcycle, is test-driving Autodesk's rental software program.

"The beauty of pay-as-you-go is, you know what you're paying for. You're paying for what you need to use now," Bliss points out. "If we need to do something like FEA, CFD or multiphysics, being able to buy that for a couple of months for a project, and writing it off to that project makes a lot of sense."

The Autodesk PLM modules offered under the Autodesk PLM 360 brand are SaaS modules, accessible from standard browsers. The rented Autodesk software, however, consists of desktop-installed programs, similar to Siemens' rental versions.

Creating New Markets with Creo

The desire to pursue new markets and smaller, nimbler businesses also led PTC, previously known for its all-in-one program Pro/ENGINEER, to switch to a series of modules, branded as Creo apps. Today, PTC offers Creo modules for simulation (PTC Creo Simulate), markup and annotation (PTC Creo View MCAD/ECAD), direct editing (PTC Creo Direct), parametric editing (PTC Creo Parametric), technical illustration (PTC Creo Illustrate), and more.

Brian Thompson, PTC's VP of Creo product management, estimates that "approximately 40% of PTC's Pro/ENGINEER-installed base has already transitioned to PTC Creo in production. We expect that more than 75% of the install base will transition by the end or 2014."

Autodesk now offers its popular titles, including Autodesk Inventor and 3dx Max, under monthly, quarterly, and annual subscriptions. This chart shows the company's promotion of pay-as-you-go licensing.

When Creo apps were initially introduced, they were expected to let previous Pro/ENGINEER users curtail the design functions to only the ones they needed. But, as Thompson discovered, the new users over time began exploring other Creo apps.

"Over 60% of customers who adopt PTC Creo Parametric 2.0 — the latest parametric modeling successor to Pro/ENGINEER on the PTC Creo platform — purchase either a new PTC Creo app or a new extension that was not available in Pro/ENGINEER," he reports. "New PTC Creo apps displace competitive niche engineering and design applications. In other cases, new PTC Creo Apps are displacing homegrown or highly customized off-the-shelf software operating throughout our customers' engineering and design departments."

PTC currently doesn't offer on-demand or rental licensing, but the trend has caught the company's attention. "We have fielded an increasing number of inquiries regarding delivering our PTC Creo apps on a subscription basis, particularly from our indirect sales channel," Thompson says. "We are actively investigating both the technical requirements and various business aspects associated with supporting this pricing model."

Crowd-enabled Engineering

Inventing used to be a costly adventure, affordable only to those with the budget to design, prototype, test and market. The cost of physical prototyping alone would discourage most average Joes and Jane Does from attempting it. Today, however, online portals like Quirky.com offer homemakers, college students and others with bright ideas the chance to invent without emptying their bank accounts (or pestering friends and families for unsecured loans).

The site does this by allowing virtually anyone to submit his or her ideas publicly. Once the design concept is peer-reviewed online, Quirky's professional team of designers, engineers and marketers shepherd the accepted design from concept to manufacturing. Quirky's list of successes includes the Pivot Power, a circular extension cord; Versuer, a four-in-one wine opener; and Thor, a double-edged ice scraper. Quirky's founder and CEO, Ben Kaufman, has delivered keynote addresses at both Autodesk University (2013) and SolidWorks World (2012), hosted by fierce rivals competing for mechanical CAD software market share.

Once dismissed as the experiments of amateurs, crowd-enabled engineering is now getting the attention of the traditionally reticent corporate world and government institutions. GE, the household appliance titan, is striking a partnership with Quirky.com to develop smart devices, ranging from an egg carton that can detect the freshness of its content to a tabletop dashboard that displays a Twitter feed and personalized weather data. Even Defense Advanced Research Projects Agency (DARPA), an agency of the Department of Defense, adopted a crowd-driven collaborative design environment similar to Local Motors to design a fast, adaptable, next-generation ground vehicle (dubbed FANG).

For design software vendors, the inventors of the VUCA era are a double-edged sword. They represent a segment previously untapped, but they also have different expectations about software — much of it shaped by the low-cost, instant-download approach of Apple's Mac App Store. They're consumers who don't believe in the established rules that define the engineering software industry. **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 → **Altair:** Altair.com

→ **Autodesk:** Autodesk.com

→ **Dassault Systèmes:** 3DS.com

→ **DARPA:** DARPA.mil

→ **Flexipump:** Flexipump.com

→ **Lightning Motorcycle:** LightningMotorcycle.com

→ **Local Motors:** LocalMotors.com

→ **PTC:** PTC.com

→ **Siemens PLM:** PLM.automation.siemens.com

→ **U.S. Army War College:** Carlisle.army.mil

→ **Watershed:** WatershedEntrepreneurs.co.uk

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

Accuracy and Checking in FEA

PART 2

Let's take a closer look at finite element analysis model checking aspects, including supplementary or auxiliary analyses set up to confirm correct model behavior.

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.

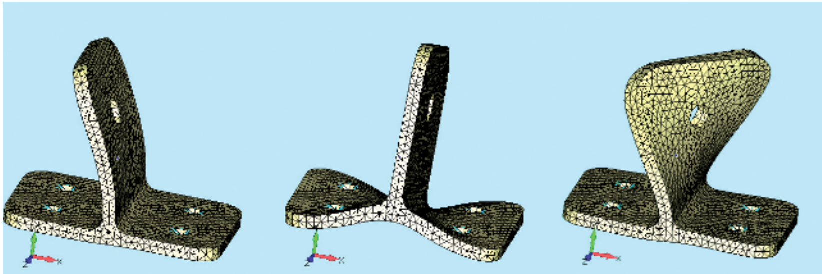


FIG 1: Three modes of a correct model.

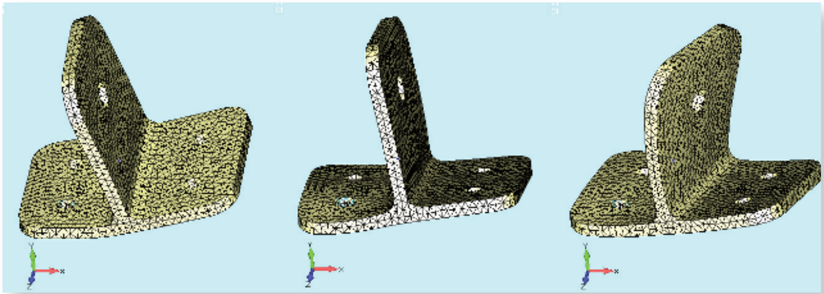


FIG 2: Three modes of an incorrect model.

Before a production run, we do special auxiliary finite element analysis (FEA), including analyses for normal modes and thermal soak. These processes are not designed to give us final answers, but to give us confidence in the analysis model. They are straightforward to set up, and only require a few extra physical properties to be defined.

There are two ways we can carry out a normal modes check analysis. The first is intuitive, and looks at the frequencies and mode shapes of the grounded structure. We can ignore any loading applied to the model, as the normal modes analysis is exploring the load-independent resonant frequencies of the model. That is useful to us because the mode's shapes and frequencies can uncover a variety of modeling errors. The only data change is to define material density, to allow calculation of mass.

Fig. 1 shows a typical result, with each mode animated in turn. Mode shapes highlight any unusual response in the structure, such as parts that seem to flap in the breeze, show apparent cracks opening and closing, or that seem strangely stiff. Fig. 2 shows an example highlighting a badly connected component caused by a modeling error.

The frequency of each mode is expressed in cycles per second or Hz. It is proportional to the square root of the stiffness contribution divided by mass contribution of that mode. Simple hand calculations, or FEA unit load cases can calculate the stiffness contribution of each mode. The modal effective mass table will give us the appropriate mass contribution.

Alternatively, we can compare against test results. However, we should have a general feel for what the natural frequencies of the structure will be, so all we are doing a ballpark check. A structure with a first natural frequency of 1,000 Hz, for example, is very stiff. If occurring in a bridge, ship or aircraft model, then we have made a mistake, probably associated with units. This type of structure should have primary frequencies of the order 2 to 10 Hz. So if your gearbox housing, conrod or mobile phone case model is this low, there is a problem.

I recommend this form of checking to everyone, but there is a more rigorous extension of this. In this case, the model is disconnected from ground and allowed to float free. Again, this seems a little bizarre, but what we are after are the rigid body modes of the structure.

Fig. 3 shows the six rigid body modes of a typical structure if modeled correctly. Less than six indicates some form of cross coupling error; each count above six indicates a spurious mechanism. My personal record is around 800!

Each rigid body mode will have a frequency close to zero, typically below 1.0E-4 Hz. We use a strain energy contour plot on each mode to ensure the strain energy is zero in each case. Any non-zero strain energy indicates some part of the structure is badly connected or numerically unstable. Mode 7 should be the first elastic mode with significant strain energy present.

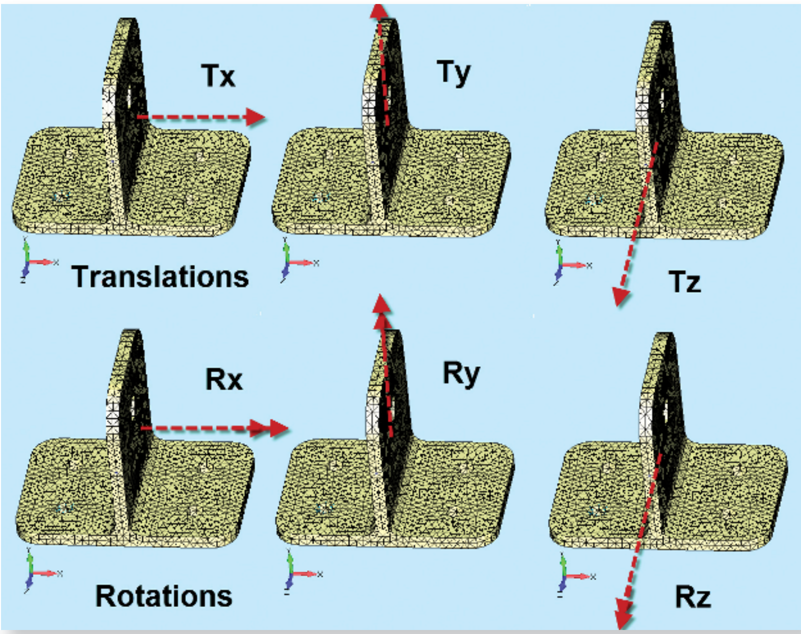
Normal modes analysis is able to solve for actual rigid body modes or spurious mechanisms. This means it is a powerful technique to search for this type of error, which will usually cause a linear analysis to fail.

Auxiliary Thermal and Gravity Analyses

With these processes, the constraints to ground are again removed and a set of minimum constraints is provided. The minimum number of degrees of freedom (DOF) required to constrain out rigid body motion is 6. In other words, three nodes have 3, 2 and 1 DOF constraints applied to each respectively. I will describe this in detail in a future article, but for the moment, follow the scheme shown in Fig. 4.

The coefficient of thermal expansion (CTE) is applied to every part of the structure. For this check, it is important to apply just a single CTE and ignore any variation in material. A thermal analysis is carried out on the structure, with an arbitrary temperature change defined. This simulates a structure hung in space by fine wires and heated up from room temperature uniformly. A real test should give a free thermal expansion of the structure. This is also the analysis objective. Any localized stress indicates modeling errors — as seen in the top image of Fig. 5, where a rigid element is defined incorrectly. Stresses are close to zero as the structure is free to expand, as shown in the lower image in Fig. 5.

The gravity checks use three load cases, with a unit of gravity applied in each of the directions X, Y and Z. A gravity load in FEA is a form of "body" load, requiring the definition of gravity direction and magnitude. Every element has a volume and corresponding density, and hence a mass. Element nodal forces balance the applied acceleration. The model gets a good workout, as no element escapes the attentions of the gravity loading.



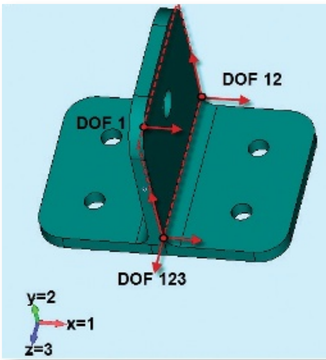


FIG 3 (LEFT): Rigid body modes of a structure.

FIG 4 (ABOVE): Minimum constraint set with 6 DOF defined.

The first check makes sure that the total applied force created in each case balances total reaction force. The next check is on the rounding error reported by the solver for each of the three load cases. The format of the rounding error varies among solvers, but reports the accuracy of the stiffness matrix inversion.

Finally, we can animate the deformed shape plot to check for any unusual behavior, in a similar way to the modal check. I strongly recommend animating mode shapes, as the eye catches unusual motion much more easily than a static plot.

Solver Checks

We have looked at auxiliary analysis running solver checks for numerical stability and numerical accuracy using the load balance and load residual. The production analysis is also checked.

Part one of this article (see the January issue of *Desktop Engineering*) discussed preprocessor element geometry checks. A preprocessor may have a different geometry definition from a solver, so we look for any inconsistencies in error checking.

Before opening the full postprocessor — and spending time and resources in loading large models — it is worth doing sanity checks on maximum stresses and displacements. In most cases, it is possible to set up a small text output stream or request an output window that just contains this data.

It is better to spot now that part of the structure has moved 27.8 km or has a peak stress of 4,000 MPa rather than after all of the result data has been read into the postprocessor.

Postprocessing Checks

Finally, we can do postprocessing checks on element results. That's often when the real detective work begins. (Remember that every analysis is guilty until proved innocent.)

In previous articles I have discussed how the traditional FEA method solves for displacements rather than stresses. This has a significant effect on the way that we should be considering stresses in the postprocessor. The displacement field throughout the structure should be continuous — and with a fine enough mesh, it should be a good representation of the actual structural deflections. However, the stress throughout the FEA model is probably not continuous. Each element back-calculates its own stress distribution independently from the common displacement field.

This means that Element A, which is a neighbor to Element B, calculates its internal element stresses and extrapolates to its nodes — with no reference to Element B. The shared nodes between A and B may well have different contributions coming from each element, as Fig. 6 shows.

If we allow the postprocessor to use nodal stress averaging on the raw data coming from the FEA solver — the data from A and B nodes independently — we will have an inaccurate and possibly non-conservative result for stresses. Nodal stress averaging should always be switched off when checking for peak stress values.

If accurate peak stress values are critical, it is always a good idea to do a convergence study. This means running the model with increased mesh density in the area of interest. We don't have to globally refine the mesh throughout the structure; that is usually prohibitive.

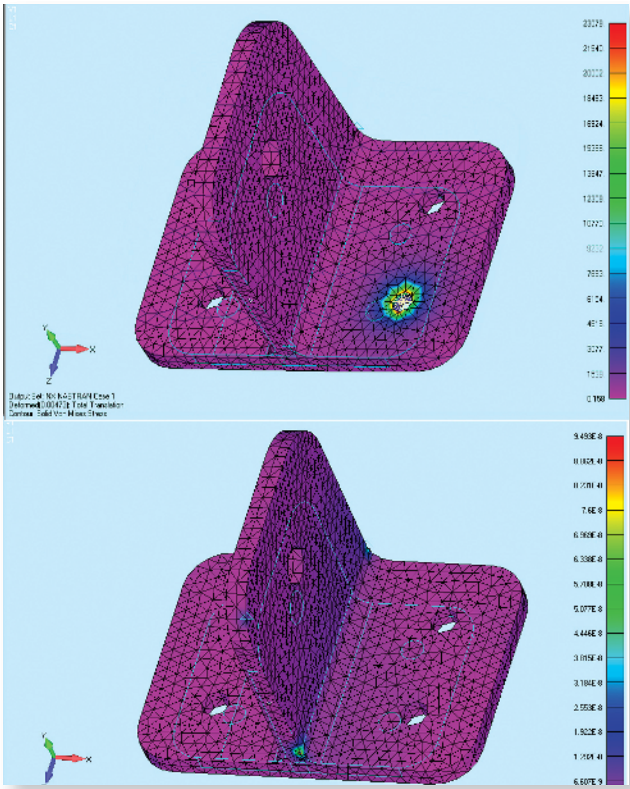


FIG 5: Free thermal expansion check: Incorrect upper and correct lower, with negligible stress.

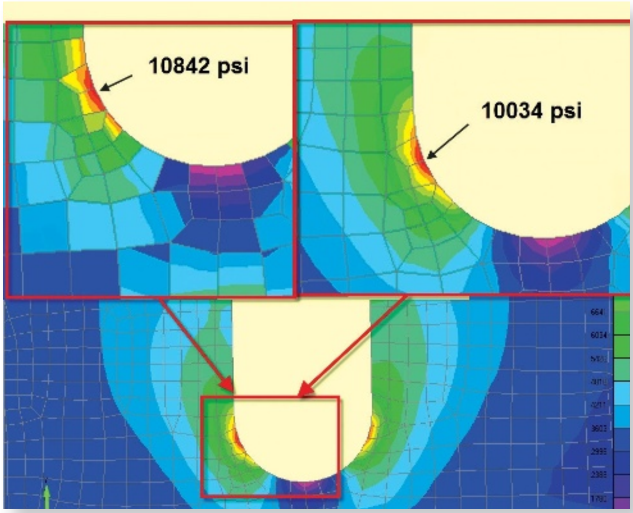


FIG 6: The effect of stress averaging.

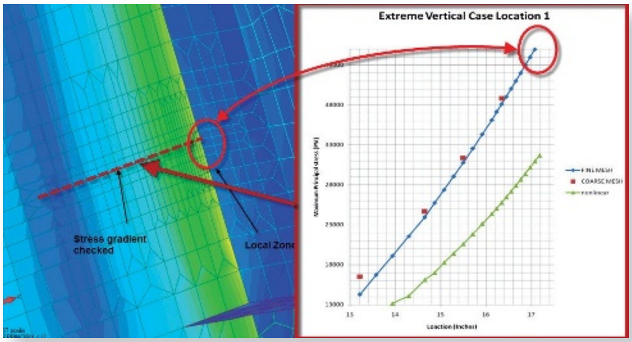


FIG 7: Mesh convergence check at a stress concentration.

Instead, focus on the key areas for speed and efficiency. Fig. 7 shows a finer mesh run to confirm whether the initial results are conservative. The initial mesh had, in fact, reached a converged value. A subsequent nonlinear analysis was needed to show that the stresses were within limits.

We should always review the regions of peak stress to make sure that there is a physical reason for their presence, rather than modeling errors. A real structure has no peak stress unless there is a local load, constraint or change in material or section. A spurious peak stress could mean modeling errors — including reversed pressure loading, spurious constraints, poor local meshing, etc.

Understand the Stresses

Understanding why and how the structure is responding to the loading and constraint environment is important. This is a complicated task requiring some experience. I'll be providing some hints and tips in a future article, but for now, consider the type of stress to check. Von Mises stress indicates whether the structure is operating above the yield limit. This is useful to see where the structural "hotspots" are.

On the other hand, the Von Mises stress masks the nature of the stress that we are seeing. Is it a tensile or compressive stress state, with implications for fatigue loading and buckling? Is the stress state dominated by direct or shear stresses? Shear stresses are always a major concern, as they are the most damaging form of stresses in general.

Plotting component stresses and principal stresses around the hotspot regions reveals the stress state and allows a more pragmatic redesign if required.

The key to a good structural analysis is in gaining an understanding of the structural load paths and stresses that are being developed. This will show through in any report presentation and will give everyone a sense of confidence in your analysis work. **DE**

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

FEA Loading Tips

The smoother your finite element analysis loading process, the easier your workload will be.

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.

One of the first things to appreciate about loading in finite element analysis (FEA) is that all loading is applied through the nodes in the model mesh. When using a modern graphical user interface in a preprocessor this might not be obvious, as in most cases we will be applying load to geometric entities such as surfaces and solid faces.

Functionality in the preprocessor allows nodes present in the mesh to be associated with the geometric surface or face. If we remesh to achieve a finer mesh, for example, the old nodes are deleted but the new nodes are associated with the surface or face — and hence to any loading that is applied.

We can also apply loads directly to the faces of elements in a preprocessor; however, behind the scenes the solver is converting that element loading to an equivalent nodal loading. Fig. 1 shows schematically this chain of events.

A good example of the solver translation from element base loading to nodal-based loading is seen in a bar element. It is quite possible to apply either a distributed loading or midpoint loading to the bar. These forms of loading are converted by the solver to equivalent nodal point forces. Fig. 2 shows the simple equivalent nodal loading in a bar with a midpoint load.

The relationship between the implied element loading distribution and the nodal loading is quite subtle, as the goal is to produce what is called equivalent kinematic loading. This means that the element internal deflections defined by its shape functions, multiplied by the distributed loading, must balance the nodal deflections and equivalent nodal forces. In other words, work done must be in balance.

For simple element shapes and loading distributions, we could work this out by hand and apply equivalent nodal forces. However, with variable loading distributions and shapes, this calculation gets horribly complex — and quite unusual nodal point force values are required. For this reason, it is recommended that we always use distributed loading forms such as pressure, rather than trying to calculate nodal point forces.

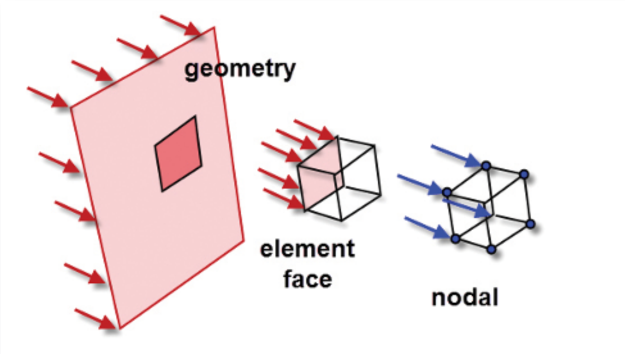


FIG 1: Loading hierarchy, from geometry to node.

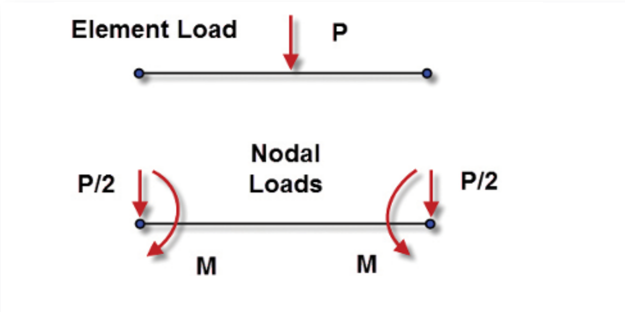


FIG 2: Equivalent nodal loads.

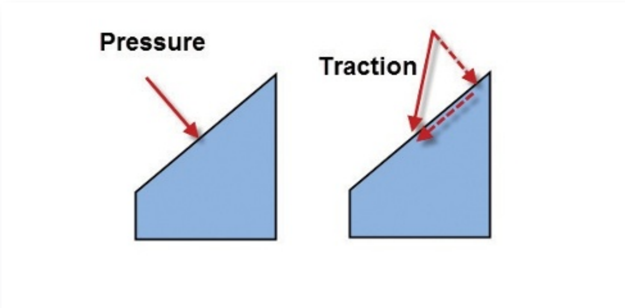


FIG 3: Pressure and traction on a surface.

Loading Types

The main types of mechanical loading that we can apply are pressures, defined by a scalar value and assumed acting normal to the element face or tractions that are applied as a vector. Fig. 3 shows the difference. We can also apply line loads and point loads. However, these are not recommended (as I will explain).

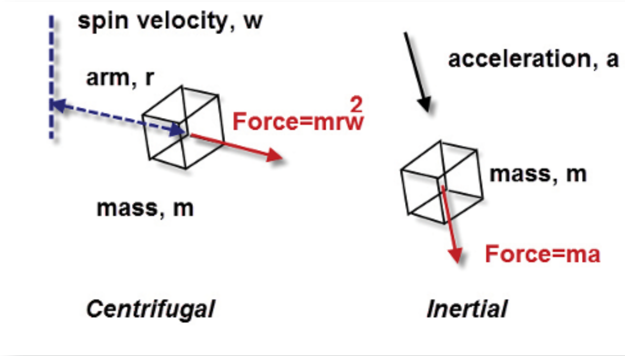


FIG 4: **Inertial and centrifugal body loading.**

We can also apply body loads. In this case, we do not have to apply loading to individual entities; instead we define a loading environment that will be applied to the whole model.

The two main examples of this are inertia loading (sometimes called gravity loading) and centrifugal loading. In both cases, material density must be defined. Every element in the model will have a volume, and hence a mass. If the model is subjected to 10G acceleration in the vertical direction, for example, then each element will see a net force equal to its mass times 10G acceleration. This is distributed to each node in the element by the solver — so we end up with a sea of nodal point forces distributed throughout the structure.

For centrifugal loading, we need to define a spin axis and rotation speed. Each element again has its own mass, and also its offset from the spin axis. With this data, the solver can calculate the centrifugal force that each element sees — and again we end up with a distribution of nodal point forces throughout the structure. Fig. 4 shows typical inertia and centrifugal loading cases.

The final important class of loading is thermal loading. The heat flux passing through a surface can be defined. This requires that the topology of the surface is defined, which makes the data construct a little bit more awkward. However, in most preprocessors, this is hidden from the user. It is analogous to the topology definition required for a contact surface.

There are several other ways to define the thermal environment that are not strictly loading, but are more analogous to boundary conditions. These include temperature distributions, and convection and radiation conditions on external surfaces.

For linear and nonlinear static analysis, each of these loading distributions is assumed fixed in space. In dynamic analysis, using a transient approach, any of the loadings can vary through time. This applies to both linear and nonlinear transient dynamic analysis. A preprocessor will typically link a spatial distribution to a time history defined by a function or table input.

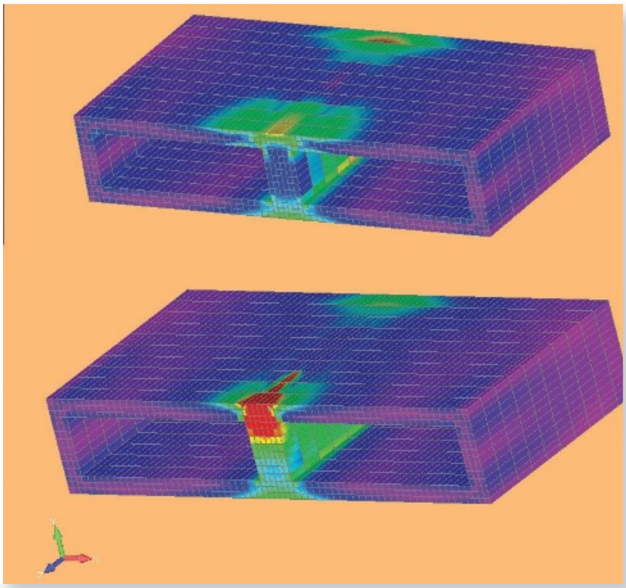


FIG 5: Bridge deck loaded with distributed load (top) and point load (bottom).

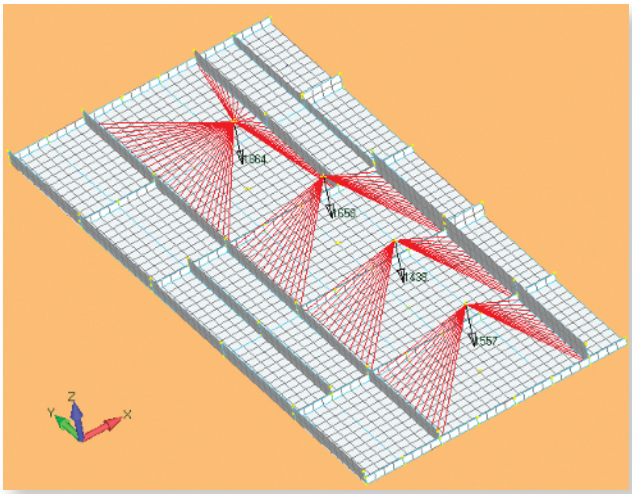


FIG 6: Helicopter floor pan loaded with spider elements.

For a frequency-based dynamic analysis, loading can also vary as a function of frequency. We can input the magnitude of the loading in a similar way to a transient or time-based dynamic analysis. However, there may well be loading phase differences occurring as a function of frequency — and also spatially across the model at each particular frequency. This is something to plan carefully in advance, as it is easy to make mistakes.

Avoid Point Loads

For some applications, it is tempting to apply all of the external load at a single point. The bottom image in Fig. 5, for example, shows a bridge deck with a large force applied vertically because of a construction crane and its payload. Knowing the thrust line and the value of the force, it is easy to set up a point load. However, there are two main reasons why we should avoid doing this.

1. If we apply a point load to a node, then we are applying a finite force value over an infinitely small area. The stress at this point is infinite. Think of a very narrow stiletto heel: The stress at the tip is high, and even with modest "loading," any thin aluminum or plywood sheet can be easily punctured. If we increase the mesh density in this area, the stress will keep going up. It is a stress singularity point. It may be that the point load represents the loading distribution into the structure quite badly, as shown in Fig. 5. This may mean that the region under the point of application sees unrealistically high stresses in the FEA model. Strengthening to deal with these may result in an overly conservative design.

2. Conversely, regions away from the point application may not see the correct load distribution — and in essence may be bypassed. The danger here would be a non-conservative design.

The goal is to assess how load is actually transferred into the structure and what that footprint looks like. Then imprint this onto the geometry so the mesh follows the shape. A distributed pressure can be applied as shown in the top image of Fig. 5.

It is essential to carefully assess the line of action of any externally applied load. Offsets will create moments and forces. Offset moments are a typical cause of high stress regions in structures.

Mapping from External Data

In many cases, pressure distribution applied to a structural surface is calculated externally. This may be a simple hand calculation of wind loading, for example, or it may be a full computational fluid dynamics (CFD) calculation. In both cases, the external data must be mapped to the structural mesh.

There are various ways this can be done; some multidiscipline solvers will allow direct mapping of a CFD pressure distribution to a structural mesh. The CFD data points are almost certainly going to be different from the nodal points in the structural mesh, and an interpolation is required. Alternatively, you may have to convert the externally calculated pressure distribution into an equivalent field or function definition in the preprocessor.

For the most accurate interpolation, the mesh density or data point distribution should be very similar between the CFD data and structural model. Ideally, the points will be spatially identical. In all cases, extrapolation should be avoided as it often results in highly inaccurate representations. The pressure distributions should be compared graphically, and also the net thrust and line of action should match.

Realistic Loading

I have mentioned that point loads are almost always going to be inappropriate to represent how load gets into a structure. But there are other examples where we need to consider how the loading will actually be distributed into our structural simulation.

For example, we may simplify a bolted connection with many discrete loading points into an equivalent pressure distribution. If we are not interested in local stresses in the connection region, then this is a good approach. A subtler example occurs where a thin-walled structure is loaded with a distributed pressure. In this case, the structure sees significant deformation — and we need to apply geometric nonlinear analysis to ensure that the induced membrane loading is modeled properly.

If we have a pin-bearing loading in a hole, for example, the traditional way of representing this is via a cosine pressure distribution acting normal to the bearing face over 180°. In practice, with passing load or interference fit present, the loading distribution may be very different from this — and it may require a nonlinear contact analysis for accuracy.

Assume we have calculated the load applied to a flange from an abutting component. We know neither the pressure distribution nor the line of action. These should be set up to be conservative, with an upper value for the resultant movement arm between the line of action of the load and the shoulder of the flange.

Alternative Loading Methods

A convenient alternative to an applied pressure distribution is to input the loading via a spider type element. An example is shown in Fig. 6, where vertical inertial loading from passengers and seats is applied to the floor pan of a helicopter. Configuration changes can be easily set up, just by changing the point force values.

In this case, the spider type element is defined as a flexible or pure load distribution type. The important thing here is the spider itself contributes no stiffness to the structure. For airframe analysis like this, it is essential that the secondary seat structure stiffness does not add to the primary floor structure stiffness.

Conversely when applying torsion or moment to shafts, beams and similar structures, a rigid type spider element may be more appropriate. A point moment or torque is easily applied to the master node of the spider.

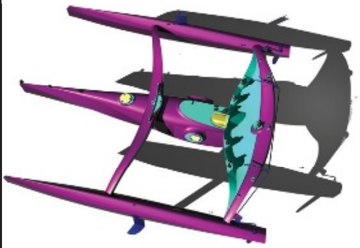
One final consideration is whether to apply displacements instead of forces to represent boundary loadings. In static nonlinear analysis, a displacement controlled loading will maintain stability more easily than force controlled loading in a structure that is softening from plasticity or buckling. In global-local modeling, displacement boundary conditions from the global model applied to the local model may deal better with mesh interpolation issues — or unrealistic local deflections.

There are many ways of applying loading. The objective should be to look at the real world loading and understand its transfer path into the structure. We want to model this as realistically as possible while staying conservative where we are uncertain of loading distributions or line of action. **DE**

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

Shaking up Yacht Design

Caustic Visualizer for Maya and R2100 ray-tracing acceleration card speed GF 42 trimaran design.



When Greg Lynn designs a trimaran, the result is no ordinary boat. The renowned designer is aiming to create not only one of the highest-performance racing yachts yet built, but a new language for boat design.

And thanks to Imagination Technologies' Series2 R2100 ray-tracing acceleration card and its Caustic Visualizer viewport plugin for Maya, the process by which the trimaran — currently code-named the GF 42 — is being designed is equally extraordinary.

"I've done some work in the boat industry over the past couple of years, and while it's very sophisticated in terms of analysis and construction, it's very backward in terms of design," says Lynn. "Although the materials are close to the level of sophistication of the aerospace industry, the way things are designed is very much the way they were done in the days of wood planks."

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Engineering a Safer Bounce

Springfree redesigns the backyard trampoline with optimization solutions from SIMULIA.

Ask a kid whether they like trampolines, and their eyes are sure to light up with joy. But ask some parents, and you may get an entirely different response. Despite tightened manufacturing standards, covered springs and frames, and safety net enclosures, approximately 90,000 children are still injured on traditional trampolines every year in the United States alone.

Keith Alexander, Ph.D., an associate professor of engineering at New Zealand's Canterbury University, was certain there had to be a safer way to enjoy the trampoline.

"I always believed that, as an engineer, I should be doing things that benefit people," he says. When his wife nixed his plans to buy a conventional trampoline for their daughter Katie, out of safety concerns, he decided to build a better one.

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The Best of Both Worlds

Automotive manufacturers have embraced an integrated workflow that incorporates elements of both direct and indirect 3D modeling.

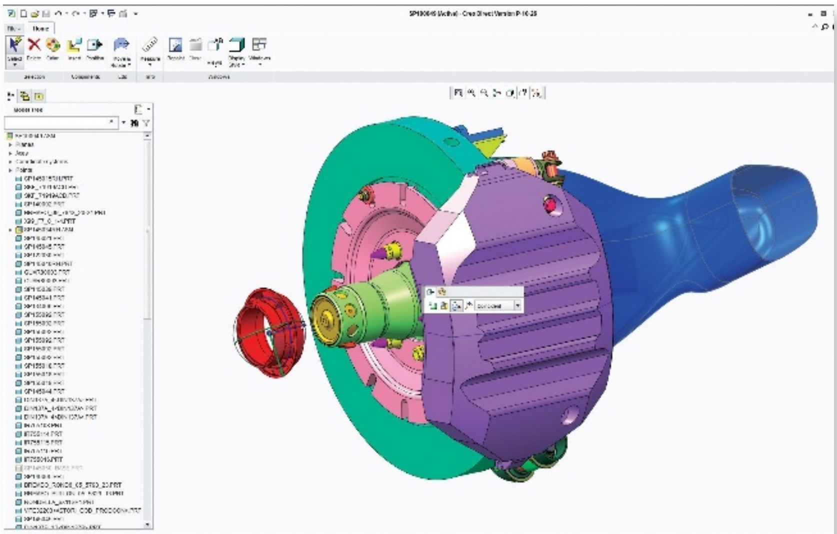
BY BETH STACKPOLE

In the aftermath of the ongoing debate over whether direct modeling or history-based modeling is the preferred approach, the automotive industry has settled into an integrated workflow that incorporates the best of both 3D modeling paradigms for different design tasks.

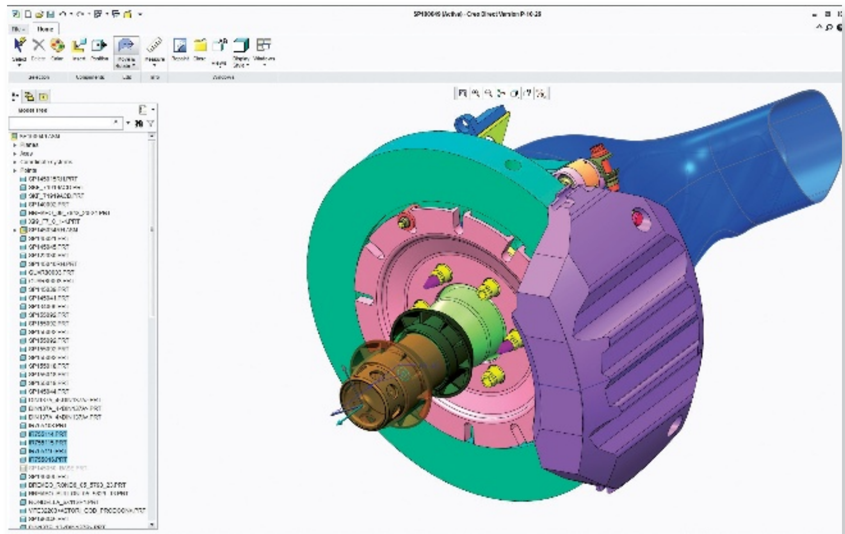
While history-based, or parametric modeling tools held court for the better part of two decades, a fresh crop of CAD programs burst onto the scene a few years ago, touting a more flexible and intuitive approach to 3D modeling. This prompted many to declare the end of an era for history-based CAD. But after the dust settled and as traditional history-based CAD vendors began to fold direct modeling functionality into their design suites, it became clear that both approaches have a place in the design workflow.

For example, while parametric CAD tools are best suited for creating the detailed geometries necessary for large model design, direct modeling tools can deliver a more efficient and flexible way to prepare models for simulation, perform early-stage concept work, or to collaborate on models in a multi-CAD environment.

"Two or three years ago, the discussion got very heated, but what's happening now is there's a realization that there is a need for both," says Paul Sagar, director of product management, CAD segment for PTC. "It really comes down to what specific use case someone is trying to tackle, and what level of competency that user has. Today, we see companies deploying both direct and indirect modeling technologies in the same organization, letting users take advantage of whatever they want for their particular task."

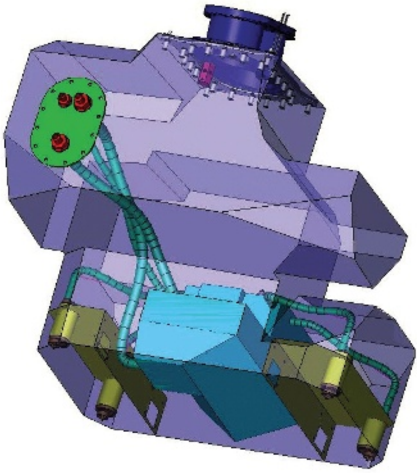


PTC's Creo Direct facilitates direct editing on a brake disc diameter. *Image courtesy of PTC.*



Creo Direct is used to simultaneously change the length of the shaft and reposition the nut. *Image courtesy of PTC.*

Proficiency with CAD systems and 3D modeling is also a factor in determining which 3D modeling paradigm fits best. "When you are using a parametric CAD system, you need a good understanding of how a parametric system works," Sagar explains. "When you are using direct 3D CAD, you require potentially less knowledge."



KeyCreator's direct editing capabilities let Aero Tec Laboratories' engineers complete tasks at least 20% faster than traditional feature-based CAD. ***Image courtesy of Aero Tec Laboratories.***

Making the 'Use' Case

In the automotive sector, there are a number of scenarios where direct modeling is the preferred approach. Consider the benefits of leveraging the technology for early-stage concept design: Automotive manufacturers, for example, are under constant pressure to explore a continuous stream of vehicle concepts to ensure they have the right innovation muscle to compete effectively on a global scale. According to Steve Hooper, director for automotive product development at Autodesk, direct editing capabilities allow automotive designers to come up with more concepts and weed out bad designs more quickly.

"Instead of having to rebuild surfaces, direct modeling capabilities in a surface environment let engineers quickly build the next design iteration," he explains. "It allows them to make subtle changes quickly to evaluate a broader range of concepts in a shorter amount of time."

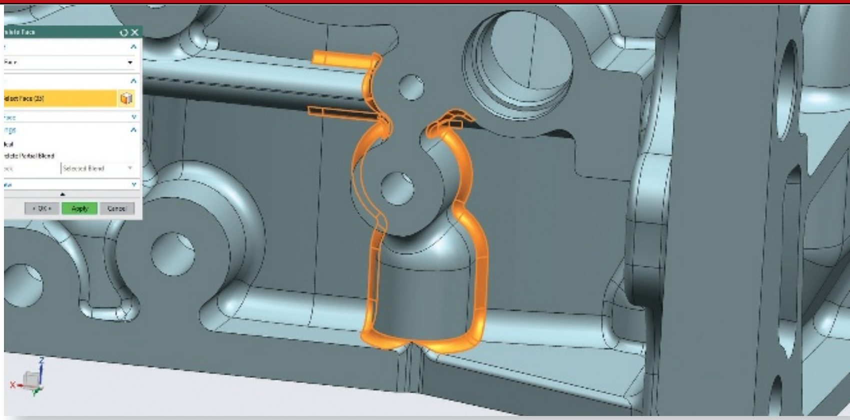
SpaceClaim, a pure play direct modeling program that sparked the debate several years back when it launched, has found a home within many automotive customers for just such early-stage design work, confirms Justin Hendrickson, SpaceClaim's director of product management. "Direct modeling is not a solution that is going to serve the end-to-end needs of an automotive customer," he admits. "But it can facilitate and speed the process in a number of individual groups within the organization."

Hendrickson says many of SpaceClaim's automotive customers prefer direct modelers over parametric 3D CAD programs when it comes time to leverage existing 3D models as a base for iterating new designs. "If you have a model with 500 features that you need to edit, it can be very cumbersome and slow to make changes with today's history-based CAD tools," he adds. "But with SpaceClaim or other direct modelers, you can just open the file of an engine block or drivetrain, slice off the one section you need, select a bunch of faces of geometry, and reuse them because there is no history."

Freedom from the history tree also plays well when preparing models for simulation. Say you want to perform some type of structural analysis on a complex engine block or casting, which could have upward of 5,000 rounds — and all the complex geometry that goes along with it.

"What you want to do is quickly and easily simplify that geometry for CAE analysis," PTC's Sagar says. "That's a fairly time-consuming task to do in a parametric system, and there are potential repercussions related to deleting features. In a direct system, what you see is what you get: You can click on a round, and it's gone."

Direct modelers have also garnered traction among automotive customers as an easier way to collaborate in a multi-CAD environment. Typically, automotive suppliers work with multiple original equipment manufacturers (OEMs) all using different CAD tools, which makes it difficult to share — let alone edit or reuse 3D models. Instead of trying to decipher the history-tree and work with native files, collaborators often opt for STEP or IGES files as a go-between because they are easier to share. However, because STEP and IGES are so-called "dumb" files that lack complete geometry, they can open the door to translation errors when trying to recreate the model in the target CAD program. This slows down design work or worse, leads to faulty engineering.



Siemens PLM Software's Synchronous Technology takes a "smart" approach to direct editing, performing direct editing operations within the feature tree. ***Image courtesy of Siemens PLM Software.***

Direct modelers, which accommodate myriad CAD file formats, can solve this problem, says Matt Carr, VP of sales and support at Kubotek. "The expense of maintaining all of the different systems and having people trained and capable of running them all is just not an option for these smaller companies," he explains.

That's certainly the case at Aero Tec Laboratories, which designs and manufactures standard and custom fuel bladder tanks for customers such as NASCAR, Ferrari, Boeing, and NASA, among others. The company employs Kubotek's KeyCreator direct modeler, formerly known as CADKEY, specifically because of the ease in which it facilitates collaborative design in a multi-CAD environment.

Aero Tec's customers send models in many different CAD file formats, from CATIA to Pro/ENGINEER (or Creo) to Rhino. KeyCreator's direct modeling paradigm lets the engineering team work directly with those files with fewer errors — and without having to perform cumbersome and error-prone translations, according to David Legemaat, the company's senior mechanical design engineer.

"Without KeyCreator, we'd have to have a copy of almost every CAD license out there, which would be cost-prohibitive," Legemaat adds. "By using a direct modeler, we can bring in native files, and it minimizes the errors we'd get having to translate IGES or STEP files." Avoiding translation errors is critical, Legemaat says, because a fuel bladder has to be fairly precise to order to ensure it fits within the final design. In addition, he says, a direct modeler like KeyCreator lets Aero Tech engineers complete tasks at least 20% faster than if they were using traditional feature-based CAD.

A Dual-path CAD Strategy

Recognizing customers' need for both types of 3D modeling, many CAD vendors have put down their swords and focused energy on reworking solutions to incorporate both direct and history-based capabilities as part of an integrated design workflow. Siemens PLM Software, for example, several years back introduced Synchronous Technology into both its NX and SolidEdge CAD offerings. Synchronous Technology supports what Siemens describes as "smart direct editing," affording engineers the flexibility to do direct editing on models within the feature tree.

"Having the freedom to modify complex models [like a powertrain] requires some pretty smart ways of editing the model," notes Paul Brown, Siemens' senior marketing director for NX product engineering. "What to do about blends, circular transitions, tangents between two faces — that's where it starts to become a tough problem. How well you can handle those transitions determines how applicable a [direct modeler] product can be for the automotive industry."

PTC, long considered the pioneer of parametric modeling, has also actively embraced direct modeling as part of its solution suite. The company purchased the CoCreate direct modeler in 2007, and introduced Creo Direct as part of its 2010 introduction of the revamped Creo design suite. The CoCreate direct modeler is still offered as Creo Elements/Direct, while Creo Direct is a new set of direct modeling capabilities that provides seamless interoperability with PTC Creo Parametric.

"The flexible modeling in Creo Direct uses the same underlying technology," Sagar says. "So you have the options of opening models in a parametric or direct environment without losing any information between the two."

Autodesk has also embraced the view that it's a dual modeling world. The CAD provider has added direct modeling features to its Inventor history-based CAD package. With Fusion 360, Autodesk is offering direct modeling as part of a broader set of functionality that unites industrial and mechanical design capabilities in a single, cloud-based platform. Autodesk's acquisition of T-Splines, direct modeling capabilities for freeform surface design, is factoring heavily into the development of Fusion 360, notes Autodesk's Hooper.

For companies in the automotive sector, in particular, having the flexibility of an integrated workflow that combines both direct and indirect modeling capabilities is critical. "The challenge is to create a continuous workflow that delivers the ability to share information from the very first sketch through manufacturing," Hooper says. "It's all about improving efficiency." DE

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

INFO ➜ Aero Tec Laboratories: ATLInc.com

➜ **Autodesk:** Autodesk.com

➜ **Kubotek:** Kubotek3d.com

➜ **PTC:** PTC.com

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

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Build It, and They Will Come

Multi-material 3D printing just might elevate your prototyping to new levels.

BY PAMELA J. WATERMAN

Whether the topic is a better mousetrap, an unexpected baseball field or a multi-talented 3D printer, customers still need to be educated before they beat a path to your door. Take multi-material printing: Do you know what company has been doing it for seven years? Do you know who just entered the market in December? And if this is all so great, why aren't more people doing it — or are they?

Sample part demonstrating hard and soft material properties, built in a single run on an Arburg freeformer system. *Image courtesy of Arburg.*

Much More Than a Black/White Mix

Multi-material additive manufacturing (AM) has three possible meanings, each referring to a single build run:

- printing multiple parts where one part is done in Material A and one in Material B;
- printing one part with different areas made of Material A or Material B; or
- creating one part where some or all of its structure is Material C1, C2 or C3, etc., where each C is a blend of different proportions of A plus B created in process.

When Stratasys and Objet Geometries merged in late 2012, the combined company became a pre-eminent supplier of multi-material AM systems that offer all three possibilities. Its PolyJet technology, applied in the Connex 3D printer line, pioneered on-the-fly material blending in 2006, with more than 100 "digital materials" now available. Based on combinations of proprietary Rigid Opaque White and rubber-like TangoBlackPlus, up to 14 blended gray materials are possible within a single build, each with a different hardness. The newest Connex 1000 system can build such parts in a volume of 39x31x19 in.

Illustrating the multi-material advantage, customer Trek Bicycle uses Connex systems to print bike prototypes where the frame is rigid white, the tires are rubbery black, the seat is somewhat soft, the handle-grips have a little give, and the brake cables feature a solid core with a flexible overmold.

Material blending is not a simple task, says Bruce Bradshaw, Stratasys marketing director for the Objet systems. "It requires a very scientific approach to put the material in the right place to create a part with properties that are repeatable such as Shore 70 hardness, independent of part geometry or which Connex system was used," he explains.

These complexities help explain the lack of competitors in the 3D printing industry, but why don't more customers and service bureaus employ existing multi-materials? Bradshaw says the public is still not aware of the benefits and, until the Connex 1000 debut, most service bureaus determined that the process' throughput was too low.

The Service Bureau Perspective

Phoenix Analysis & Design Technology (PADT) has been operating Objet systems for years. "There is a convenience of being able to run multiple materials in a single machine run without having to do multiple machine setups," says Rey Chu, PADT principal, referring to a run of flexible parts with rigid parts along with semi-flexible parts. However, demand for the multi-material capabilities is low, because parts designed for multi-material production are still few compared to parts specified for a single material. Drawbacks that Chu sees include costly materials and properties that are sometimes less than desirable: standard rigid materials are brittle, with low temperature thresholds, and flexible materials have low tear strengths.

Sample tire for a remote-control toy car, with both black rubber-tire and rigid white wheel-sections built as a multi-material part on a 3D Systems Projet 5500. *Image courtesy of 3D Systems.*

Integral clear plus opaque white sections on a part formed in a single build-run on a 3D Systems Projet 5500. *Image courtesy of 3D Systems.*

Patrick Gannon, engineering manager at rp + m, an Ohio-based design-through-manufacturing service company, also finds that clients are often surprised by the Connex option to create parts with both hard and soft properties.

"People just don't know about it enough," says Gannon. "And the multi-material, as with all the other technologies, has its limitations. The material is not going to last very long. Inside a car on a hot day it's going to warp, but for prototyping it's perfect."

For the future, he sees people seeking a higher level of durability, better thermal properties and possibly a color capability beyond the white, black and gray options currently dictated by hardness.

Old Kids on a New Block

With years of development work under its belt, Objet has basically been the lone contender in the multi-material plastics world. The company's systems give users control over a number of seriously complex parameters involved in building parts at the pixel level. Whether blending droplets, mixing powdered particles or depositing liquid resins, for anyone else to join this market — on-the-fly multi-material printing, with precise placement, properties and repeatability — would take major effort and resources.

Therefore, it wasn't a complete surprise that AM pioneer 3D Systems was next to enter this field. At the December EuroMold show, the company presented the ProJet 5500X Multi-Material 3D Printer. Using VisiJet Composite materials, the ProJet 5500X (building on existing MultiJet Printing technology) is said to offer more than 200 material configurations as multiple composites of three base materials. Color variations of the composites go from translucent to opaque, through shades of white and gray to black.

Meanwhile, in the world of metals, DM3D Technology has rather quietly spent years developing a laser-based, direct metal deposition process that is inherently well suited to multi-material operation. Building on its previous ownership under POM Group, the company offers a way to deposit surface protective cladding and/or coating solutions to rebuild and protect tooling. With systems running dual- and even quad-hoppers of powdered metals, customers can specify different metals to be deposited on different areas of the base part, or request mixed metals for certain regions.

Eyeglasses formed of multiple materials (clear and opaque black) in a single build-run on a Stratasys/Objet Connex system. *Image courtesy of Stratasys.*

Steel-clad copper cores for high productivity tooling in aluminum die casting. The steel is bonded to copper through a proprietary buffer material. *Image courtesy of DMD 3D.*

"With a dual-hopper, we do graded composites that allow you to add the ceramics as you want," says DM3D COO Bhaskar Dutta, offering a cermet (a composite material composed of ceramic and metallic materials) as an example. Another example is applying a graded tungsten carbide (WC) hardfacing edge on an oil/gas drill — starting with a 10% fill deposition on the base steel, gradually changing to 25%, 50% and finally 60% for the final outer edge. Changing the mix layer by layer greatly minimizes expansion coefficient issues during end-use, extending tool life.

Dutta says working with multiple materials is a sophisticated technology. His company has a propriety database that ties the build materials to the build parameters. A team of design, material and process engineers works together to define the best "recipe" for each combination. DM3D is currently in product development with several large customers, and expects to be in production mode in 16 to 24 months.

A Higher Profile

Interest in multi-material 3D printing is also on the rise from big-name manufacturing companies. Last year, General Electric (ranked sixth in the 2012 Fortune 500 list) solidly entered the additive manufacturing (AM) field with its acquisition of Morris Technologies' direct-metal laser sintering expertise. Recently, the company's Global Research division hosted a webinar with prominent AM industry figures, where the topic of multi-material options came up over and over again.

In follow-up discussions, Todd E. Alhart, director of media relations for the group, said, "As excited as we are about the new designs and shapes of parts that can be created with additive technologies, we're equally excited about new materials that can be engineered. The ability to form materials as you build your net shape has opened up new possibilities in the engineering of novel, better performing materials."

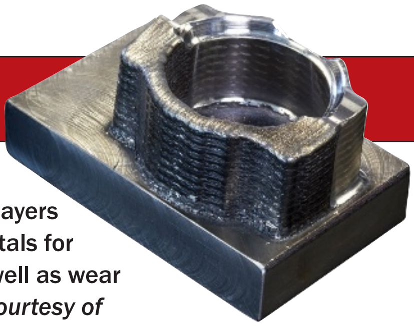
Alhart added, "We have a robust portfolio of ongoing research in multi-material AM; metals and ceramics are the classes of materials we are most interested in working with. As we work on the development of new materials in the lab, we are closely monitoring advances in technologies that can enable and enhance this discovery work." — PJW

New Entries, Even Newer Ideas

3D Systems isn't the only new entry in the multi-material marketplace: Stalwarts and newbies alike have announced relevant products and development programs. Arburg of Losburg, Germany, an equipment manufacturer since 1923, was also at EuroMold, demonstrating its freeformer AM system. The dust-free machine can deposit multiple colors and materials simultaneously, using a process based on melting plastic beads delivered through a nozzle as droplets; the part moves (in three- or five-axis versions), so no support structures are necessary.

A development group at the National Nanotechnology Manufacturing Center in Swainsboro, GA, has demonstrated an interchangeable Multi Proto Lab system that builds a part from disparate materials while the part "stays put" and the process equipment comes to it. The lab currently combines modules for precision milling, soldering and 3D printing with ABS filament; a metal drop-on-demand module is planned.

"This is the way that the industry is moving forward, with multiple processes and multiple materials," says Multi Proto Lab Marketing Manager Calvin Close. "It's a whole



A compaction tool built with alternate layers of hard and soft metals for high toughness as well as wear resistance. *Image courtesy of DMD 3D.*

paradigm shift where you only need five or 10 parts." One goal is to create functioning parts in the field — such as (but not limited to) building a printed plastic part with operational copper circuitry deposited on its surface.

Also aiming at printed circuit boards, among a wide range of end uses, is The Technology Partnership (TTP), a technology development company located south of Cambridge, England. Its website describes a new printhead, the Vista 3D, that can handle various organic and inorganic materials such as ceramics, biological cells, enzymes, metals and plastics. At press time, there was no word yet on the 3D printers it supports.

Improving build speed in resin stereolithography (SL) systems is the primary goal of a University of Southern California Viterbi School of Engineering project. However, Professor Yong Chen says the research also supports fabrication with two base materials. The system uses bottom-up mask-image-projection, then switches out the resin vats during the build process of a single layer. A key factor is cleaning off the part between materials.

Cool Developments on Tap

To increase user demand for multi-material 3D printing of any sort, original equipment manufacturers (OEMs) will have to invest in material development that improves durability for both rigid and soft materials. Color options in plastics will probably be next, along with software that helps designers specify placement of material variations precisely across part geometry — even at the pixel level.

Certain efforts on the latter subject have been underway for years: Check out the work done by engineer/software developer Jonathan Hiller, now of Modular Robotics, on open-source VoxCad. The software has been tested at MIT's Self-Assembly Lab on its 4D printing project with a mind-bending variation of Connex multi-material parts. In conjunction with Stratasys, the group has worked on programming different properties — specifically, water absorption variations — into each droplet of an experimental material. In their video, a sample rod, printed straight, bends itself into a 3D shape when immersed in water, as sections react differently to moisture. It's somewhat like a dry sponge changing shape as it soaks up water, but much more sophisticated. **DE**

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INFO ➜ 3D Systems: 3DSystems.com

➜ **Arburg:** Arburg.com

➜ **DM3D Technology:** DM3DTech.com

➜ **General Electric Global Research Division:** Research.GE.com

➜ **MIT Self-Assembly Lab:** SelfAssemblyLab.net

➜ **Multi Proto Lab:** RapidPrototypingMachine.com

➜ **Phoenix Analysis & Design Technology:** PADTInc.com

➜ **rp + m:** rpplusm.com

➜ **Stratasys/Objet:** Stratasys.com

➜ **The Technology Partnership:** TTP.com

➜ **Trek Bicycle:** TrekBikes.com

➜ **University of Southern California:** Viterbi.USC.edu

➜ **VoxCad:** VoxCad.com

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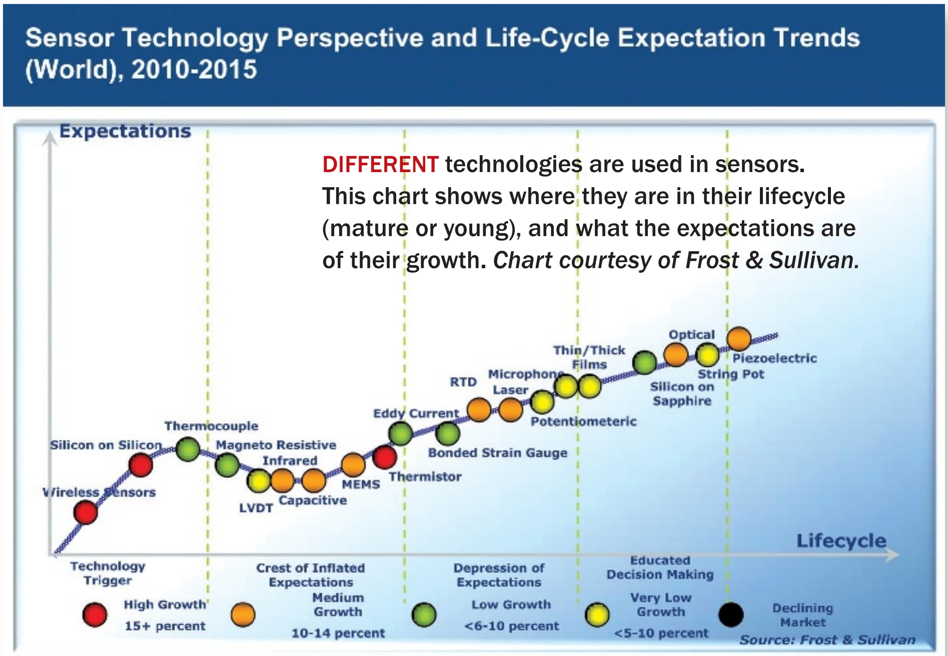
Making **Sense** of It All

DE offers some insight into successful sensor selection.

BY JIM ROMEO

They can help record a toll fare when we drive over a bridge or roadway without ever slowing down; provide remote indications of system or equipment about to fail on a pipeline or power station thousands of miles away; and are in our cell phones, garage doors, automobiles and security systems. Sensors are an integral part of nearly every design nowadays — and the quest to select ones that provide the most value is always a challenge.

"Sensors are used in the most mundane to the most critical functions," says Sudhir Sharma, electronics industry director at ANSYS, Burlington, MA. "Modern cars, for example, now include blind-spot monitors, which could be considered a safety critical feature."



DIFFERENT technologies are used in sensors. This chart shows where they are in their lifecycle (mature or young), and what the expectations are of their growth. *Chart courtesy of Frost & Sullivan.*

The best way to ensure robust field performance is to do regression simulations of models of the sensors in their operating environment, he notes. The simulations need to test for corner conditions, including variability in temperature and voltage.

Applications and Parameters

Sensor selection begins with an understanding of the sensor applications, and some basic parameters and requirements of the equipment and systems in which it will be integrated.

According to Rajender Thusu, a sensors expert and an analyst for Frost & Sullivan in Mountain View, CA, basic sensor selection is very simple: It should include a careful consideration of the type of parameter to be sensed, the level of sensitivity required, and the physical size of the sensor itself.

"As the sub-systems and systems in which the instrument/device has to work gets more complicated, the demands on sensor selection start becoming more stringent," he says. "In a wired system, connectivity is another prime consideration. As the level of automation increases, the use of field bus protocols fitted onto the sensor package becomes another criterion, which further raises the issue of compatibility."

Many of these protocols are open and the rest are proprietary, Thusu points out: "Hence, the selection of the right protocol and its compatibility are the other selection criteria for use of sensors in automated environments. In the case of the deployment of wireless systems, the set of selection criteria changes."

Key characteristics of the sensor should always be evaluated, such as the trade-off values in size, weight, cost, reliability, accuracy, longevity and frequency response.

"Engineers may validate these parameters through the simulation of vendor-supplied models — when they exist," says Sharma of ANSYS.

The environment in which the sensors will operate, both regularly and occasionally, must be factored into the selection process. But they must be balanced against the required reliability and available budget, Thusu points out.

"The measure of quality depends on the environment in which the sensor is likely to operate," he states. "In cases where the environment is very harsh, which means high temperatures, is acidic or carcinogenic — then this factor determines the material of which the sensor is made."

In normal conditions, Thusu says, a silicon-based sensor is used. But silicon carbide material can be used to manufacture sensors that offer high sensitivity under difficult working conditions and harsh environments. Recently, germanium material-based sensors have been developed, which offer better sensor quality, he says.

"Different sensors are at different stages of their product life cycle, but none of the sensors have yet reached maturity," he adds. "Although price is an important factor, it is *not* the most important criteria for any purchase decisions in sensors."

Consider the Value Chain

The original equipment manufacturer (OEM) has the ultimate responsibility to put all systems together, and look at the backward value chain of the sensor. The contribution of the sensor will contribute greatly to the overall system and product quality and functionality.

"In many cases, say in automotive, OEMs even share or fully fund R&D activities that are focused on product, function and application improvement or product innovation that the OEM requires and uses," explains Thusu. "In other words, it is an integrated approach that is prevalent within the sensor market, where companies at various levels of the value chain work closely with one another."

For example, General Electric has designed electrical generators driven by steam turbines to last 30-plus years. The formulas for power and design, while being continually improved, are also enhanced by the use of sensors to tell GE's customers — and its customers' stakeholders — many things. With the right sensor in the right place, measuring the right variable, accurate predictions can be made about the equipment, its performance, and predictable maintenance requirements.

But sensors may also help others far removed from the equipment determine things about the generator use, such as fuel costs, its relation with weather patterns, and how it reacts to changing load demand from the grid that it serves. Such information is critical, and is becoming increasingly important. Sensors are giving way to more reliability and relationships among suppliers, users and society.

"There are several factors that impact sensor quality, starting from materials to the ultimate end product," explains Thusu. "At every level, the right type of components have to be implanted that have complete compatibility with the already existing components that have already been put within the sensor package. In terms of use, the selection of appropriate sensor is the most important component to be installed in the system."

The Digital Side of Sensors

An ancillary, but important consideration when choosing sensors for design, is their incorporation in the network and control systems in which they will be used. This means that the electronics and accompanying software to support them will become increasingly important as smart phones come of age — and wireless sensors come to control many different facets of operations in our lives and that of our global industrial stratosphere. According to WinterGreen Research, the markets for wireless sensor networks were at $552.4 million in 2012, and are expected to reach $14.6 billion by 2019.

Sharma says sensors are going to be at the front end of the Internet of Things (IoT) revolution. To ensure that sensor data is interpreted correctly, he notes, engineers designing the printed circuit boards (PCB) need to perform signal integrity and power integrity (SI/PI) analysis.

"After all, if the power integrity or signal integrity is not assured, the best sensor data is rendered useless," he adds. "Assuming that the sensor data is valid and correctly received, intelligent software is needed to ensure the proper next steps. Software engineers today use sophisticated, high-level modeling tools. For safety critical applications, software design tools may need to comply with safety standards, such as DO178C and ISO 26262."

While their use may seem trivial or on the periphery of design, the overall demand for the many different categories of sensors and sensor technology is growing by leaps and bounds. The elements of sensor design and selection may have a not-so-trivial impact on larger components, equipment and systems that they help operate and control and the myriad of lives they will touch, improve and save in the years to come. **DE**

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→ Frost & Sullivan: Frost.com

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Sensors: The Value Chain

Tier I - Basic Sensor Manufacturers

Transducer, basic circuitry, signal conditioner, basic wires (two).

Tier II - Packaged Functional Sensor Manufacturers

These companies in the value chain add a protocol chip, wireless nodes, if required, and memory nodes to make them functional. Also, in many cases, they also put two different parameter measuring sensors together.

Tier III - Sub-system Manufacturers

These sub-systems are designed as per the requirements of OEM products, which are large systems.

— Source: Frost & Sullivan

A Tale of Three Monitors

These three new Z-series IPS displays from HP deliver great images at 24, 27 and 30 in., expanding the company's line of professional monitors.

By DAviD Cohn

At last summer's SIGGRAPH conference, HP introduced new 22-, 23- and 24-in. professional monitors, rebranding them as the Z-series to match the company's workstations. In September, at a product launch event in New York, HP completed the expansion of its Z-series display lineup with the announcement of new 27- and 30-in. displays. We recently received three of these new monitors so that we could do our own side-by-side, hands-on reviews of the HP Z24i, Z27i and Z30i displays.

All three monitors feature the latest generation of in-plane switching (IPS) displays. HP calls this new technology IPS Gen 2, whereas most other manufacturers call it AH-IPS (advanced high-performance IPS). Regardless of what you call it, the new technology translates into better power efficiency — HP claims up to 37% power savings compared to its first-generation IPS displays — while delivering excellent color accuracy and wide viewing angles of 178° in both horizontal and vertical directions.

Each monitor arrived neatly packed, with its panel and stand wrapped separately in recyclable bags. In addition to the power cord, HP also includes three cables: DVI, DisplayPort and USB. It took just a few minutes to assemble each display by placing the panel face down on a flat surface, sliding the stand's mounting plate under the upper lip of the recess in the back of the panel, and snapping the mounting plate into place.

Once assembled, the Z24i, Z27i and Z30i look nearly identical, the only visible variation being their size:

- Including its stand, the 24-in. (diagonal) Z24i weighs 15.35 lbs. The panel itself measures 22.02x14.37x2.54 in. It has a height adjustment range of 15.94 to 20.67 in., and needs a space just 9.37 in. deep.
- The 27-in. Z27i weighs 16.74 lbs. Its panel measures 25.24x14.93x2.58 in., adjusts from 16.55 to 21.28 in., and is 9.55 in. deep, including the stand.
- The 30-in. Z30i weighs 21.96 lbs., has a panel measuring 27.18x17.71x 2.61 in., adjusts from 18.94 to 23.66 in., and is 10.49 in. deep.

The stand included with each monitor provides a stable support, but standard 100mm Video Electronics Standards Association (VESA) mounting holes on the rear of each panel enables them to be wall-mounted or attached to other

Continued on page 40 ...

THE HP Z-SERIES AT A GLANCE

HP Z24i 24-in. IPS Display

- **Price:** $339 MSRP
- **Size:** 24 in. (diagonal)
- **Display type:** IPS LED backlit
- **Screen dimensions without stand (WxHxD):** 22.02x14.37x2.54 in.
- **Physical size with stand at highest setting (HxWxD):** 22.02x20.67x 9.37 in.
- **Weight:** 15.35 lbs.
- **Native resolution:** 1920x1200 pixels @ 60Hz
- **Horizontal frequency range:** 24 to 94kHz
- **Vertical refresh rate:** 50 to 76Hz
- **Aspect ratio:** 16:10
- **Pixel pitch:** 0.269mm
- **Dot/Pixel per inch:** 94.34
- **Brightness:** 300 cd/m2
- **Contrast ratio:** 1,000:1
- **Response time:** 8ms (gray to gray)
- **Number of colors:** 16.7 million
- **Power consumption:** 36 watts typical, >0.5 watts standby (55 watts max)
- **Video input ports:** VGA, DVI-D, DisplayPort
- **I/O ports:** USB 2.0 in; four USB 2.0 out
- **Other features:** tilt/swivel base, portrait/landscape pivot
- **Cables included:** AC power cord, DVI, DisplayPort, USB
- **Warranty:** Three years

HP Z27i 27-in. IPS Display

- **Price:** $769 MSRP
- **Size:** 27-in. (diagonal)
- **Display type:** IPS LED backlit
- **Screen dimensions without stand (WxHxD):** 25.24x14.93x2.58 in.
- **Physical size with stand at highest setting (HxWxD):** 25.24x21.28x9.55 in.9.37 in.
- **Weight:** 16.74 lbs.
- **Native resolution:** 2560x1440 pixels @ 60Hz
- **Horizontal frequency range:** 24 to 94kHz
- **Vertical refresh rate:** 50 to 76 Hz
- **Aspect ratio:** 16:10
- **Pixel pitch:** 0.233mm
- **Dot/Pixel per inch:** 108.79
- **Brightness:** 350 cd/m
- **Contrast ratio:** 1,000:1
- **Response time:** 8ms (gray to gray)
- **Number of colors:** 16.7 million
- **Power consumption:** 60 watts typical, >0.5 watts standby (75 watts max)
- **Video input ports:** VGA, DVI-D, DisplayPort, HDMI
- **I/O ports:** USB 3.0 in; four USB 3.0 out
- **Other features:** tilt/swivel base, portrait/landscape pivot
- **Cables included:** AC power cord, DVI, DisplayPort, USB
- **Warranty:** Three years

HP Z30i 30-in. IPS Display

- **Price:** $1,329 MSRP
- **Size:** 30-in. (diagonal)
- **Display type:** IPS LED backlit
- **Screen dimensions without stand (WxHxD):** 27.18x17.71x 2.61 in.
- **Physical size with stand at highest setting (HxWxD):** 27.18x23.66x10.49 in.
- **Weight:** 21.96 lbs.
- **Native resolution:** 2560x1600 pixels @ 60Hz
- **Horizontal frequency range:** 24 to 98kHz
- **Vertical refresh rate:** 50 to 70 Hz
- **Aspect ratio:** 16:10
- **Pixel pitch:** 0.252mm
- **Dot/Pixel per inch:** 100.63
- **Brightness:** 350 cd/m2
- **Contrast ratio:** 1,000:1
- **Response time:** 8ms (gray to gray)
- **Number of colors:** 16.7 million
- **Power consumption:** 85 watts typical, >0.5 watts standby (125 watts max)
- **Video input ports:** VGA, DVI-D, DisplayPort, HDMI
- **I/O ports:** USB 3.0 in; four USB 3.0 out
- **Other features:** tilt/swivel base, portrait/landscape pivot
- **Cables included:** AC power cord, DVI, DisplayPort, USB
- **Warranty:** Three years

... Continued from page 38

supports, with or without the HP Quick Release 2 mounting bracket, if desired. Each stand enables 90° of swivel, while tilt ranges from -5° to +30° for the Z24i, to -5° to +20° for the Z27i and Z30i. When raised to their maximum height, each panel easily pivots from landscape to portrait mode, with cables neatly routed through a hole in the center of the lower portion of the stand.

Similar Features

Each display features a panel with a 16:10 aspect ratio surrounded by a 1-in. black bezel. Four buttons along the lower-right edge of the bezel let you manually select the desired video input, or let the monitor automatically detect the active port. You can also access the on-screen display (OSD), which lets you adjust brightness, contrast, color balance and other image settings, change the position and orientation of the OSD menu itself, set a sleep timer, and so on. A fifth button in the lower-right corner turns the monitor on and off.

While the resolutions and dot pitch vary depending on the panel size, all three HP Z-series IPS displays feature a contrast ratio of 1000:1. They also offer 8-millisecond response time to reduce image smearing, and can display up to 16.7 million colors, for excellent coverage of sRGB color spaces — 99% in the case of the Z24i and 100% for the Z27i and Z30i. The Z30i also covers 100% of the Adobe RGB color space.

The HP Z24i has a native resolution of 1920x1200, with a 0.269mm pixel pitch and a brightness ratio of 300 cd/m2. A downward-facing panel on the lower rear of the display provides a master power switch and AC power connector, three display inputs (DisplayPort, DVI-D and VGA), an upstream USB 2.0 connector for the panel's USB hub, and two USB 2.0 ports. Two additional USB 2.0 ports are located on the left side of the panel.

The panel on the HP Z27i has a native resolution of 2560x1440 with a 0.233mm pixel pitch and a brightness radio of 350 cd/m2. A similar downward-facing panel on the rear of its display provides the same power switch and AC connector, but includes a total of four display inputs (DisplayPort, VGA, DVI-D and HDMI), an audio out port (for connecting headphones or an optional speaker bar), an upstream USB 3.0 port and two USB 3.0 ports. Two additional USB 3.0 ports are located on the left side of the panel.

The Z30i has a native resolution of 2560x1600 with a 0.252mm pixel pitch and a brightness ratio of 350 cd/m2. It features the same assortment of ports and connections as the Z27i.

All three monitors also have a concealed information card that pulls out from behind the USB connectors on the left side of the panel. The card contains the model, serial and product numbers.

HP also provides a DVD containing drivers, documentation in a multitude of languages, and a copy of the HP Display Assistant software, which provides yet another way to adjust the monitor's brightness, contrast, white balance, color balance and other image settings. It can also save custom color presets and rotate the image if you pivot from landscape to portrait mode.

Crisp, Clear Images

We used DisplayMate from DisplayMate Technologies to help evaluate the visual quality of each monitor. DisplayMate uses a series of test patterns — both to help users fine-tune the image, and to uncover any picture quality problems or video artifacts that might otherwise go unrecognized. All three HP Z-series monitors displayed excellent color and grayscale, and showed absolutely no pixel defects. We were able to read text down to 6.8 points, even at different intensity levels, and the fast response time resulted in no image smearing when viewing full-motion video.

All of the new HP Z-series displays are ENERGY STAR-qualified, EPEAT Gold-registered and backed by a three-year limited warranty, with four- and five-year coverage (including next-business-day exchange) also available. The HP Z24i has a manufacturer's suggested retail price of just $339 ($30 less than the ZR2440w that it replaces). The HP Z27i sells for $769 ($55 more than its predecessor). And the HP Z30i has an MSRP of $1,329 ($171 less than the Lenovo ThinkVision LT3053p that we reviewed in the October 2013 issue).

If you are on a tight budget, the Z24i is a perfect balance of price and functionality. But if you can afford to spend more and have the space to accommodate a 27- or 30-in. monitor, either the HP Z27i or Z30i will provide you with a gorgeous display. When it comes to CAD and graphics applications, nothing beats working at high resolution on a big screen. Regardless of which one you choose, all three are excellent additions to HP's Z-series lineup. DE

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Medical Device Manufacturers Expand PLM

Carestream's DRX Revolution Mobile X-ray System is a Class II medical device. *Image courtesy of Arena Solutions.*

In a heavily regulated industry, comprehensive product lifecycle management is fast becoming a practical necessity.

BY MARK CLARKSON

There's a joke in the medical devices industry that it takes three engineers to design anything. The first engineer defines the functional requirements, the second engineer creates the actual design and the third engineer is there to verify that the second engineer does what the first engineer tells him to. Thanks to the regulations specific to medical devices, the joke is not much of an exaggeration.

"If you ask an engineer how long it will take to implement an idea on a medical device," says Arena Solution's Yelena Bolton, "they will tell you, 'one day without the paperwork and three days with the paperwork.'"

To help them deal with all of that paperwork, much of it to comply with US Food and Drug Administration (FDA) regulations, many medical device manufacturers turn to engineering services providers to help them organize their design, simulation and test data. Additionally, software providers have developed specialized solutions to help design teams manage the various sets of data needed to comply with medical device manufacturing regulations.

Device Classification

The extent of regulation depends on the actual type of medical device we're talking about. In the U.S., medical devices are divided into three broad classes. Class I devices are the simplest—tongue depressors, bandages, crutches and so forth. Class II devices include monitoring equipment, X-ray machines and infusion pumps. Class III devices include those that are implanted in the human body, such as pacemakers and heart stents. Regulatory agencies like the FDA get quite persnickety about implanted devices. You need to be very sure you have all your ducks in a row; and be prepared for more ducks on the horizon.

Unique Device Identifiers

For example, starting September 24, each Class III medical device will have to carry a unique device identifier (UDI). The UDI is an FDA mandated 14-digit number that provides a way to identify each model, and for any versions or variants of that model, all the way down to different packaging configurations.

"There are 62 different pieces of data that need to be submitted to the FDA along with that 14-digit identification number," says PTC's Jill Newberg. "It's a whole new data management problem. The FDA says, starting September 24, every time you make a change to a Class III product that affects any one of these 62 points, you'll need a new or revised UDI submission."

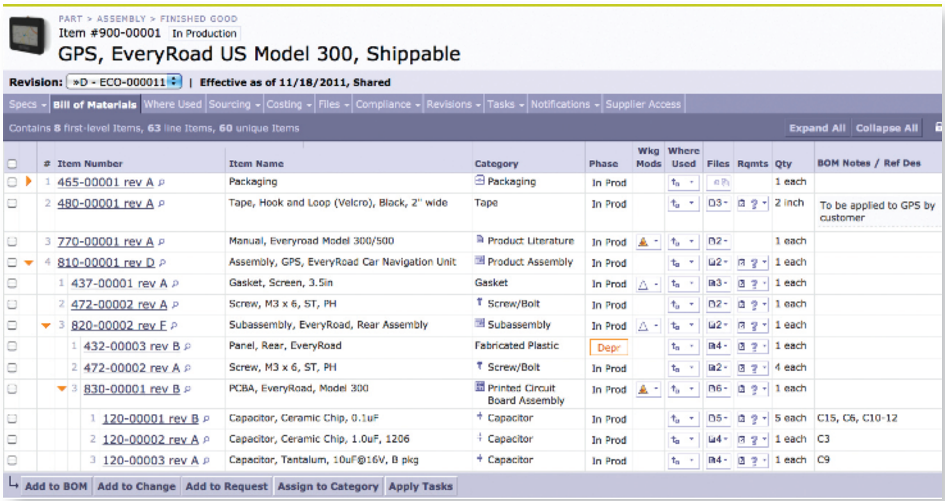
You can enter this information on the FDA's web site, manually. But for a company of any size, which may have thousands of versions and variants of products, that's not really practical.

"That's where a UDI solution like ours comes in," says Newberg. "We handle the data management problem of gathering all these unique data points [and] communicating them to the FDA. And then we can track responses and let your know where you stand, compliance-wise, across your product range."

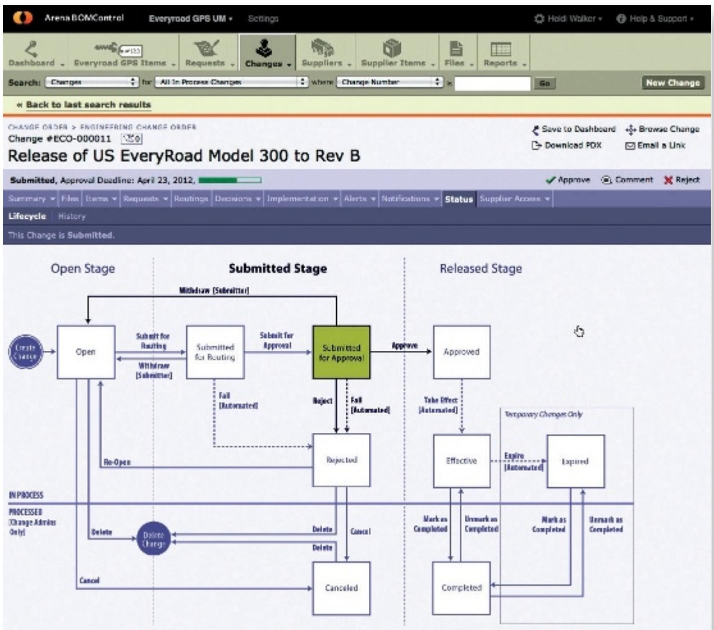
UDIs are just one of an array of special forms, regulations and requirements for which product lifecycle management (PLM) vendors offer special solutions. If you want to sell your products globally, you'll need to conform to a whole raft of new regulations for every market.

Seeking Validation

Even the PLM software itself has to meet special constraints and regulations in the medical device space. "Everyone verifies their software before they put it on a CD," says Arena Solutions' Steve Chalgren. "But then, when the medical device customer



Viewing an Indented BIll of Materials in Arena PLM. *Image courtesy of Arena Solutions.*



Viewing a Change Order's Lifecycle Phase in Arena PLM. *Image courtesy of Arena Solutions.*

installs it on their server, they have to validate that it actually works as they intended it to, that it meets the functional requirements that were defined in the product. Validation is an extra step the FDA requires for medical device companies."

Now, if you lay a finger on the software, even to apply a small hot fix, it's got to undergo some form of re-validation.

"I've seen the cost of validation for a service pack run to $50,000 or a $100,000," says Chalgren. "The result is that medical device manufacturers don't upgrade very often, so they get way behind on the tech."

Arena is a cloud-based PLM solution. "That's how we solve it," says Chalgren. "Our software is just one install serving hundreds of customers, so we can validate that one instance and charge each of our customers a slice of it."

More Than Just Breadcrumbs

"The way a regulatory body looks at it," says Integware CEO Chris Kay, "is that they're enforcing good manufacturing processes. When you're implanting something in your body, you want to know that the company that's building that product has followed a set of best practices for how they should manufacture it, and kept track of quality issues and design changes … that they're following good manufacturing practices. And these regulatory agencies are entrusted to ensure they're following good manufacturing practices."

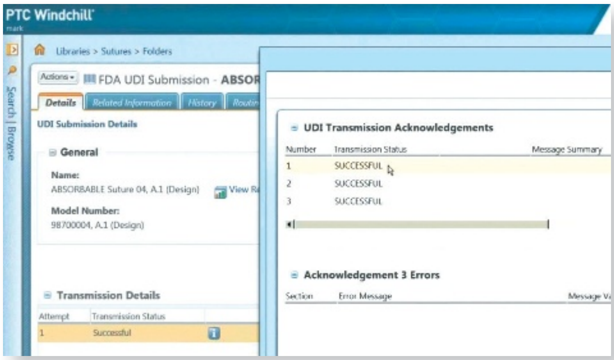
Those regulatory agencies are also very interested in exactly how you handle serious complaints, failures and other problems. Serious problems result in corrective actions. "It's a formalized quality process," says Kay, "for understanding all the criteria that led to the issue, getting to root cause, determining the countermeasures, putting those countermeasures in place, and releasing those to the market.

"Once you determine what changes need to be put in place to address the [root of the problem,] it will most likely generate multiple change orders," Kay says. "How do you trace that corrective action to those change orders? What changes were made? Why? Who made them? And were the [people] approving the change authorized to both review and approve of that change?"

The FDA is going to want to trace the root of the problem all the way back to the initial design requirements. Depending on how serious and widespread the problem is, a corrective action could be open for months or years before it's resolved.

And yet, says Kay, "many medical device companies still use a phenomenal amount of paper. Without something like PLM, which provides traceability between their product data and also their quality data, they're forced to rely on multiple repositories of disconnected and duplicative data, and to keep it all in synch."

"It's important to minimize the number of databases and point solutions that people across the company have to go to to get their jobs done," says Carestream's David Sherburne. "There's always opportunity for manual error when people are going to multiple places for information." Carestream, a manufacturer of medical and dental imaging equipment, is in



The PTC UDI Solution tracks submissions to the FDA as well as communications from them. *Image courtesy of PTC.*

the process of expanding its PLM implementation to absorb numerous local, manual and point solutions. It's a tall order, and the obstacles aren't all technical.

Licensing

Just budgeting for a PLM system can be surprisingly problematic, Sherburne says. "License models are very convoluted. With some suppliers, we had to predict where our user would be located, what modules they would use, and whether they would be consumers or producers of data. If you have a few thousand users and you try to figure out where they are and what they might be doing in the system, it becomes almost impossible to look at what your license cost would be."

Ultimately, Aras' subscription model worked for Carestream. It provided a predictable business model that allowed expansion and access the key requirements of a PLM platform.

The benefits of PLM are hardly restricted to medical device manufacturers. "I've yet to meet a customer that doesn't care about their product quality," says PTC's Tom Shoemaker. "But [with medical devices] there's a very regimented way things need to be done and tracked. There needs to be a trail in place to prove what path you took." **DE**

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Performance in a Petite Package

With the debut of the ThinkStation E32 SFF, Lenovo updates its small form factor entry-level workstation.

By David Cohn

The E32 SFF case packs its components neatly into its small interior. ***Images courtesy of David Cohn.***

Small form factor (SFF) workstations — entry-level systems aimed squarely at entry-level CAD users — remain popular, so much so that both Lenovo and HP have begun shipping new versions of their entry-level SFF systems. We recently received the Lenovo ThinkStation E32 SFF, the refresh of the E31 SFF we reviewed last year (*DE*, April 2013). The company has not managed to make this successor any smaller. In fact, at 13.3x4.0x14.8 in., the E32 SFF is slightly larger than its predecessor. But at 15 lbs., the E32 SFF is 1.5 lbs. lighter than last year's model.

With a starting price of just $749 for a system equipped with a dual-core 3.4GHz Intel Core i3-4130 CPU, Windows 8 Pro, integrated Intel HD graphics, 4GB of memory, a 500GB, 7,200 rpm SATA hard drive, and a DVD +/-RW optical drive, you can understand exactly why these reduced-form-factor systems have become so popular. We are still not big fans of the integrated graphics when it comes to running mainstream CAD applications, however, so we were pleased that the system Lenovo included a discrete graphics board among its several upgrades.

Like its predecessor, the Lenovo ThinkStation E32 SFF comes housed in a matte black case with small rubber feet that support the case in a horizontal position. There are also small rubber feet on the end, so that users can orient the system like a miniature tower. Although the system is quite stable when standing on end, setting it up this way positions the tray-loading optical drive in an awkward vertical orientation.

In addition to the DVD drive, the front panel provides two USB 3.0 ports, a 29-in-1 media card reader, headphone and microphone jacks, and a round power button. A sculpted air intake with the ThinkStation logo fills the remainder of the front grill.

The rear panel provides four additional USB 3.0 ports, as well as a pair of USB 2.0 ports, a 9-pin serial port, a 15-pin VGA port, a pair of DisplayPorts, and an RJ-45 LAN port for the integrated gigabit Ethernet as well as microphone, audio line-in, and audio line-out jacks. There are also four expansion slots. Note that the VGA and DisplayPorts on the rear panel are non-functional when the system is equipped with a CPU that lacks integrated graphics.

Updated Interior

Access to the interior is achieved by removing two non-captive thumbscrews from the rear of the case, then pressing a button on the top of the case to slide off the cover. The Lenovo motherboard takes up about two-thirds of the interior and is partially hidden below the hard drive and optical bays. Pressing a touchpoint releases the drive cage, which rotates 90° along the front of the case to provide access to the four memory sockets.

The system supports up to four double data rate 3 dual inline memory modules (DDR3 DIMMs), for a total of 32GB. Our evaluation unit came with 8GB of memory, installed as a single 8GB 1600MHz ECC DIMM.

The CPU is concealed beneath a heat sink and 3-in. cooling fan with a plastic cowl, designed to direct air over the CPU. To the right of the CPU is a small 240-watt/85% efficient power supply. To its left are four expansion slots. Lenovo offers a choice of 11 different Haswell processors.

In addition to the Core i3 processor included in the base configuration, there are Core i5 and i7 CPUS and Xeon processors ranging from the 3.1GHz E3-1220V3 to the 3.6GHz

E3-1280V3, an option that would add $1,230 to the base price. Our evaluation unit came with a slightly more modest 3.4GHz Intel Xeon E3-1240V3, a CPU with four processor cores but no integrated Intel HD graphics. With a maximum turbo speed of 3.8GHz, 8MB of cache and a maximum thermal design power rating of 80 watts, that CPU adds $210 cost of the E32 SFF.

While the ThinkStation E32 SFF does provide four expansion slots — a PCIe x16 graphics card slot, a PCIe x1 slot, a PCI card slot, and an additional PCIe x16 card slot (supporting either x4 or x1 cards) — the small profile case limits the height of the cards the system can accommodate. In addition to the integrated Intel graphics available with some of the CPU choices, Lenovo also offers NVIDIA NVS or Quadro discrete graphics cards.

Our system came equipped with an NVIDIA Quadro K600, a GPU featuring 1GB of DDR3 memory, 192 compute unified device architecture (CUDA) cores, and both a DVI-I and a full-size DisplayPort, which added $165 to the base price. Lenovo also offers the NVIDIA NVS 510 — a board with 192 CUDA cores, but twice the memory and four mini DisplayPorts. That option adds $399 to the base configuration.

The drive cage can house a single 3.5-in. drive or a pair of 2.5-in. drives, as well as an optional 128GB mSATA micro hard drive. A third drive can even be hosted in lieu of the optical drive. Our evaluation unit came with a 1TB Seagate Barracuda 3.5-in., 7,200 rpm drive. Other options include standard drives of up to 3TB, as well as solid-state drives (SSDs) ranging from 128 to 256GB.

Single-Socket Workstations Compared		**Lenovo E32 SSF 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)	**Lenovo E31 SFF workstation** (one 3.3GHz Intel E3-1230 quad-core CPU, NVIDIA Quadro 400, 8GB RAM)	**Lenovo S30 workstation** (one 3.6GHz Intel Xeon E5-1620 quad-core CPU, NVIDIA Quadro 4000, 8GB RAM)	**HP Z1 workstation** (one 3.5GHz Intel Xeon E3-1280 quad-core CPU, NVIDIA Quadro 4000M, 16GB RAM)
Price as tested		$1,479	$4,273	$5,714	$1,093	$2,614	$5,625
Date tested		11/10/13	7/31/13	5/31/13	12/29/12	8/18/12	6/29/12
Operating System		Windows 7	Windows 7	Windows 7	Windows 7	Windows 7	Windows 7
SPECview 11	higher						
catia-03		25.14	72.37	96.39	18.15	48.21	39.46
ensight-04		15.47	49.20	83.26	11.08	32.18	26.19
lightwave-01		75.52	100.78	103.15	46.79	64.47	60.76
maya-03		51.32	131.31	153.01	40.36	84.50	78.65
proe-5		15.61	24.74	22.87	10.29	11.93	12.69
sw-02		41.99	78.27	84.51	31.54	53.53	47.24
tcvis-02		23.74	55.73	77.82	16.53	37.66	30.79
snx-01		19.56	53.95	83.21	13.45	33.87	27.70
SPECapc SolidWorks 2013	Higher						
Graphics Composite		3.14	5.25	3.89	n/a	n/a	n/a
RealView Graphics Composite		3.09	5.38	4.1	n/a	n/a	n/a
Shadows Composite		2.96	5.36	4.1	n/a	n/a	n/a
Ambient Occlusion Composite		2.9	5.63	8.37	n/a	n/a	n/a
Shaded Mode Composite		3.25	5.12	3.79	n/a	n/a	n/a
Shaded With Edges Mode Composite		3.02	5.38	3.98	n/a	n/a	n/a
RealView Disabled Composite		3.31	4.74	3.15	n/a	n/a	n/a
CPU Composite		4.27	4.07	4.92	n/a	n/a	n/a
Autodesk Render Test	Lower						
Time	Seconds	48.66	42.00	58.33	64.00	63.80	87.92
Battery Test	Higher						
Time	Hours:min	n/a	n/a	n/a	n/a	n/a	n/a

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

Performance Improvements

Because the E32 SFF, like its predecessor, is equipped with rather modest components and meant to be an entry-level system, we did not expect this ThinkStation to set any records. And similar to the E31 SFF we tested last year, this new small form factor workstation lived up to those expectations. While it did outperform last year's model, the E32 SFF was significantly slower than other systems we have reviewed recently. Still, its numbers were definitely not disappointing, considering its cost.

On the SPECviewperf benchmark, the NVIDIA Quadro K600 just could not match the graphic performance of other systems we have reviewed recently, many of which came with much more powerful graphics cards costing several times as much. In fact, the only system the E32 SFF outperformed was last year's E31. The E32 even lagged behind the latest mobile workstations.

On the new SPECapc SolidWorks 2013 benchmark, however, which is more of a real-world test, the E32 SFF did a bit better. While it still scored lower than other single-socket workstations we've tested using this new benchmark, it did outperform many of the mobile workstations we've recently reviewed.

On the AutoCAD rendering test, which is multi-threaded and therefore shows the benefits of multiple CPU cores, the Lenovo ThinkStation E32 SFF took just 48.66 seconds to complete the rendering. That's the best result we have recorded to-date for a single-socket system with a standard (not over-clocked) CPU.

Lenovo offers a choice of six different keyboards and either an optical or laser mouse. Our system came with a standard 104-key USB keyboard and three-button optical mouse. The E32 comes standard with Windows 8 Pro 64, but you can opt for Windows 7 Professional pre-installed as a downgrade, which was how our system was configured. Lenovo backs the system with a three-year warranty with on-site service, and says that the E32 has a 15-month lifecycle with no planned hardware changes that affect the preloaded software image. The system comes with independent software vendor (ISV) certifications from Adobe, Avid, Dassault Systèmes, PTC, Siemens and SolidWorks, and ships with a preloaded, 60-day trial version of Autodesk AutoCAD LT.

The base E32 SFF configuration starts at $749 for a very well-appointed system. But we think most CAD users will be better served by adding the NVIDIA Quadro K600 discrete graphics card and more memory. Yet even as equipped, our evaluation unit priced out at just $1,479 — making the Lenovo ThinkStation E32 SFF an affordable, modestly powerful system in a very compact package. **DE**

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INFO → Lenovo: Lenovo.com/thinkstation

Lenovo ThinkStation E32 SFF

- **Price:** $1,479 as tested ($749 base price)
- **Size:** 13.3x4.0x14.8 in. (WxHxD) small form factor desktop/mini-tower
- **Weight:** 15 lbs.
- **CPU:** 3.4GHz Intel Xeon quad-core E3-1240V3
- **Memory:** 8GB DDR3 ECC at 1600MHz
- **Graphics:** NVIDIA Quadro K600
- **Hard Disk:** 1TB Seagate Barracuda 3.5-in., 7,200 rpm
- **Optical:** 16X DVD+/-RW
- **Audio:** integrated HD audio (front panel: microphone, headphone; rear-panel: line-in, line-out, microphone)
- **Network:** integrated Gigabit Ethernet, one RJ45 port
- **Other:** Six USB 3.0 (two front/four rear), three USB 2.0 ports (two rear/one internal), one 9-pin serial, one 15-pin VGA and two DisplayPorts (for integrated Intel HD graphics), 29-in-1 media card reader
- **Keyboard:** 104-key Lenovo USB keyboard
- **Pointing device:** Lenovo USB optical wheel mouse
- **Power supply:** 240 watts, 85%
- **Warranty:** 3 years parts and labor

Advertising Index

by Anthony J. Lockwood

Editor's Picks

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

Lenovo Workstation for 2D CAD and Entry-level 3D Released

Customizable design allows you to build out as your needs evolve.

Lenovo is rolling out its new low-cost ThinkStation E32 workstation. Actually, workstations. The E32 comes in minitower and SFF (small form factor) versions. The E32 is aimed at 2D CAD drawing and entry-level 3D designers. It's certified for a number of applications from Adobe, Dassault, PTC, Siemens, and SolidWorks. And it comes with a 60-day trial version of Autodesk AutoCAD LT pre-loaded. Also pre-loaded is your choice of operating system: Windows 8 or 8 Pro or Windows 7 (32- or 64-bit). Both versions of the ThinkStation E32 workstations are energy sippers. Their power supplies are up to 92% efficient.

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Gather Measurements in Extreme Environments

NI cDAQ-9188XT modular data acquisition system has an onboard watchdog timer.

The new NI cDAQ-9188XT can use National Instruments' C Series modules. NI-DAQmx driver software provides a single interface for programming analog input, analog output, digital I/O, and counters. It has programming support for NI LabVIEW, ANSI C/C++, C#, and Visual Basic .NET. Its DAQ Assistant configuration tool helps you generate code for LabVIEW and NI Measurement Studio. The NI cDAQ-9188XT's onboard watchdog timer lets you define safe states that can help protect tests and equipment. It works in temperatures ranging from -40 to +70°C.

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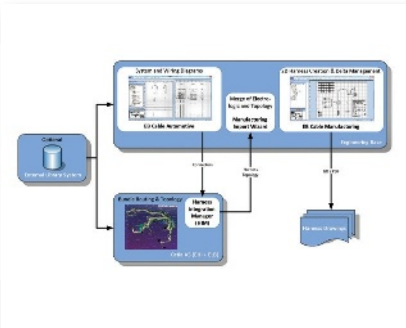

Integration Shortens Wiring Harness Design Processes

New CATIA linkage enables parallel electronic and mechanical wire harness design.

AUCOTEC has updated its Engineering Base software platform for system designers and electrical/electronic and mechanical engineers and their organizations.

The news with Engineering Base (EB) Cable is the new linkage with CATIA V5. This connection lets electrical and mechanical design engineers work in parallel and then synchronize their data at any time, which can compress the entire cycle. Automation whenever possible, such as automatic follow-up document generation, further compresses the processes. And design decisions are traceable, which should keep the compliance people content.

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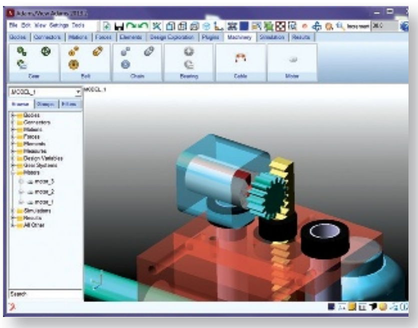

Latest Version of Adams/Machinery Software Released

Updated software includes electric motor, belt, chain and gear modules.

The characteristic that really makes Adams/Machinery something to look into is that it has modules that offer modeling automation specific to your machinery component types. For example, the newest version — version 2013.2 — introduces a module for electric motors. But if, say, cables or belts are your gig, there are targeted modules for them as well as other machinery components. It'll help you solve component-specific problems within context of full system-level dynamics situations.

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Commentary

by Sanjay Angadi

Collaborate on Simulation Data

Because simulation is now a standard business practice, the volume, velocity and variety of engineering simulation data continues to grow at an alarming rate, making its storage, traceability and management strategically important.

As products become more complex, simulation tools and design methodologies are evolving in response. ANSYS has been working with engineering organizations of all sizes to deploy collaborative simulation approaches to address these simulation data management (SDM) challenges. Often times, simulation best practices are a combination of people, process, data and technology.

Simulation Data Management Challenges

With traditional data management approaches being complex, cumbersome and often inadequate, many companies struggle with SDM challenges. These obstacles are dependent on a customer's simulation maturity level, as it will dictate their ability to deal with advanced topics such as product lifecycle management (PLM) integration.

Here are the three most notable SDM challenges that we see our customers facing today:

With simulation now standard, it is imperative to properly store and manage simulation data.

1. Growing volume, velocity and variety of simulation data. Unlike design data, simulation data is unstructured with very large file sizes (tera/petabytes) and represents a wide variety of interconnected domain-specific tools, processes and formats (e.g., noise, vibration and harshness, crash, computational fluid dynamics). Simulation data is also sometimes linked to other closely related engineering datasets. Effectively managing the increasing variety of data and understanding its relationships provide better engineering insights that are often hidden inside multiple files or native data formats. This is crucial for informed decision making.

2. Governance and managing isolated distributed data. It is also important to protect simulation data and maintain its integrity and traceability for audits, compliance and organizational policies. Ad-hoc practices of administration over multiple, unsecured platforms add to costs and also expose the organization to intellectual property (IP), security and data loss risks. Since simulation data stored in this way is not readily available or accessible, it leads to engineers spending time on non-value added tasks like manually searching for, verifying accuracy of, formatting and delivering simulation data. This is not a sustainable practice and further contributes to loss of engineering time and productivity.

3. The high-performance computing (HPC) resources, connectivity and collaboration. To solve complex multi-scale, multiphysics and multi-model engineering problems, distributed simulation teams with diverse backgrounds must efficiently collaborate. However, HPC use presents challenges like moving files to and from HPC resources, remote access to graphics resources, and more. Monitoring and executing these large, complex simulation workflows efficiently, across geographically dispersed locations, requires focus on computer aided engineering user needs.

Collaborative Simulation Practices

Collaborative simulation encourages organizations to progressively implement practices that address the challenges above, based on their maturity level.

Here are the first key steps toward overall effectiveness:

- **Collaboration via access to data and resources.** The key is closing the information gap by making existing information available in real time to all stakeholders when they need it regardless of location. At each stage of the engineering analysis process, the ability to extract contextual information, store and retrieve the insights and assumptions made is essential to the value of simulation data. Additionally, many aspects of HPC such as job management, visualization (remote and lightweight visualization) are important for quick sharing and interpretation of information without spending time moving files across the network or between sites.
- **Enhancing knowledge capture.** It is vital to rigorously and efficiently document simulation best practices throughout the enterprise to inspire continuous growth by building on experience, and collaboration between experts, analysts and design engineers. Enhanced knowledge capture better supports business decisions, leverages simulation IP more effectively and drives innovation. A flexible, easy-to-use system addressing the tools, process, data and simulation execution needs is a must. Managing engineering knowledge in a structured manner requires higher organizational maturity with supporting best practices technologies for data management.

Manufacturers of all sizes must increasingly use collaborative engineering simulation approaches and HPC to safely and effectively manage simulation data. To further maximize business value, information technology and engineering departments must objectively determine their SDM maturity level and collaborate to implement SDM solutions that effectively combine people, process, data and technology, while minimizing burdens on end-users. DE

Sanjay Angadi *is a senior project manager at ANSYS Inc. Email your thoughts about this article to DE-Editors@deskeng.com*