DE Desktop Engineering®

TECHNOLOGY FOR DESIGN ENGINEERING

April 2013 / deskeng.com

CFD On Call

Simulation drives medical innovation.

P. 21

Realize Your Product Promise®

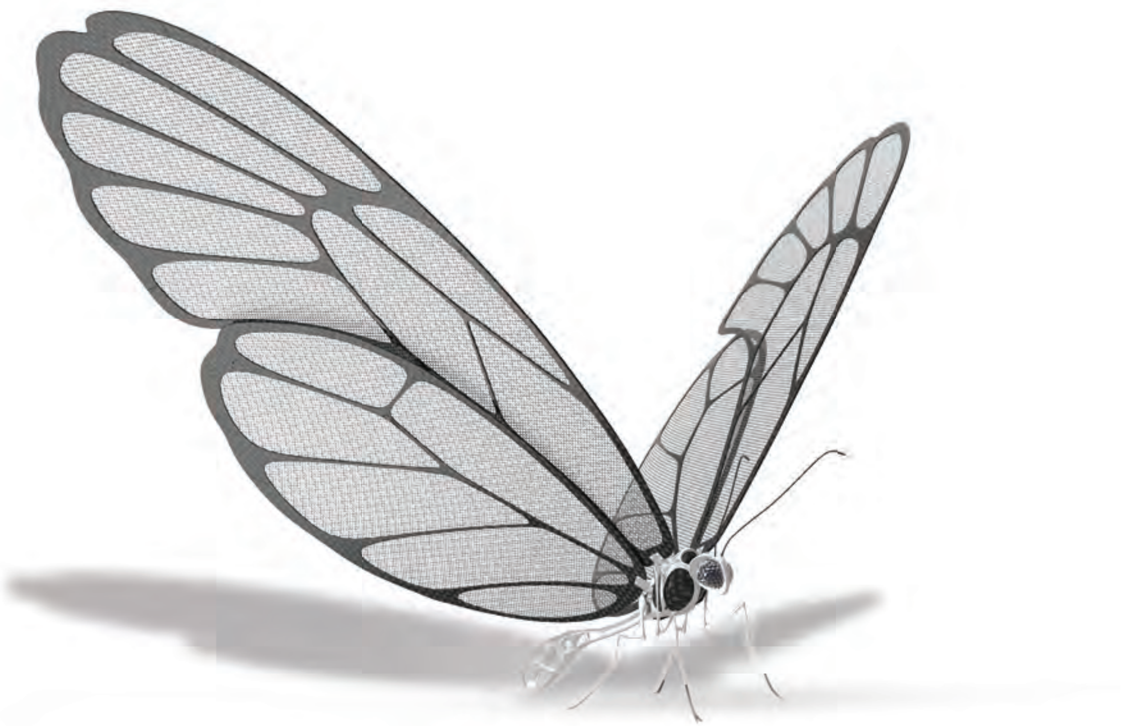
Winning the Formula One World Constructors' Championship is a monumental accomplishment. Winning it three times in a row is practically unheard of. But for Red Bull Racing, it was just another day at the office.

Using ANSYS simulation technology, Red Bull Racing is creating virtual prototypes of its racecars, so engineers can quickly and inexpensively optimize everything from aerodynamics to brakes to exhaust systems. Red Bull Racing is delivering on its product promise by remaining dominant in one of the most competitive environments imaginable.

Not a bad day at the office.

INNOVATION PARTNER

Visit ANSYS.COM/RedBullRacing to learn how simulation software can help you realize your product promise



Innovative design can make anything lighter.

Minimizing component weight with advanced engineering, technology and materials. Without sacrificing performance. It's what we do. **More at altair.com/lightweight.**

Altair

by Jamie J. Gooch

Collaborate to Innovate

There has been no shortage of pixels and ink devoted to healthcare reform in recent years, much of which surrounds the creation of an IT infrastructure that would use electronic medical records and health information exchange to share access to medical information. Billions of dollars in public grants have been awarded to create such a system, which is intended to improve the quality of care and lower costs by connecting healthcare providers, insurers and patients in a collaborative network. But there are other healthcare technology breakthroughs that are achieving those goals right now via design, testing, analysis, additive manufacturing and high-performance computing.

Like the drive to finally digitize and share health information, medical device design can benefit from collaboration. When engineers interact with doctors, inventions like the VGo Robotic Telepresence System (vgocom.com) are born. VGo allows caregivers to essentially be in two places at once to check on distant patients via a remote-controlled robot. When engineers talk with patients, it yields 3D-printed prosthesis (see page 26 and rapidreadytech.com/?p=3367), robotic exoskeletons, and vision augmented implants (see page 16). When computer-aided engineering specialists take the time to understand the healthcare industry's needs and educate regulators on technology, it leads the Food and Drug Administration to support work on a virtual patient (see page 21) and encourage the use of simulation in medical device design (see page 32).

The ideas design engineers contribute will save and improve lives in ways we can only imagine.

Unexpected Pairings

The articles in *Desktop Engineering* often stress the need for engineers from different disciplines to break through the walls that have traditionally separated mechanical and electrical design, for instance, to learn from each other and improve the design process. But if we take that idea a step further, beyond the confiners of engineering, a number of opportunities arise.

Last month's South by Southwest (SXSW) conference is a good example. It has become one of the must-attend technology venues for many companies (including 3D Systems and MakerBot this year), because it provides a place where music, independent films, and emerging technologies converge. That convergence draws thousands of people who are seen as trend setters and innovative thinkers.

Another conference, TEDMED, which takes place April 16-19 in Washington, D.C., does the same for healthcare and technology. It brings together people from many disciplines—engineers, medical professionals, designers, musicians, community activists, regulators, artists and more—to discuss healthcare's "Great Challenges," which it defines as: "complex, persistent problems that have medical and non-medical causes, impact millions of lives, and affect the well-being of all of America—beginning with patients, and extending to families and citizens everywhere," according to tedmed.com/greatchallenges. "These knotty problems are not susceptible to simple cures, magic bullets or 'one-size-fits-all' solutions because they stem from broad, interlocking social, economic and psychological sources as well as from medical or scientific triggers. What's more, each challenge creates multiple, overlapping effects that may cut across all sectors of society."

Complex Problems Require Collaborative Solutions

Does TEDMED's description of healthcare's great challenges sound familiar? It's not difficult to make the leap from medical to engineering challenges. Both can be complex, cut across multiple sections of society and involve collecting and organizing massive amounts of data (which we'll focus on in next month's issue). Likewise, both are strengthened when stakeholders venture outside their comfort zones and get a different perspective on a complicated issue—whether its personalized medicine or design optimization.

The examples of innovation in this issue barely scratch the surface of what can be accomplished at the intersection of engineering and healthcare. As computing power progresses and the medical industry continues to find creative uses for advanced simulation and additive manufacturing, the products and processes design engineers contribute to the field will save and improve lives in ways our most innovative thinkers are imagining today. DE

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

Smarter Embedded Designs,

Faster Deployment

The combination of NI LabVIEW system design software and reconfigurable I/O (RIO) hardware helps small design teams with varied expertise develop demanding embedded applications in less time. Using this graphical system design approach, you can take advantage of the same integrated platform to program embedded processors and FPGAs for faster application development in industries ranging from energy to transportation, manufacturing, and life sciences.

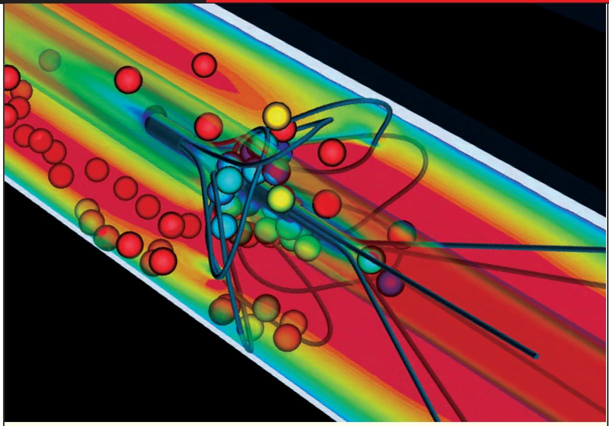
LabVIEW system design software offers ultimate flexibility through FPGA programming, simplifies code reuse, and helps you program the way you think–graphically.

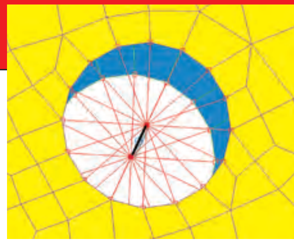
>> Accelerate your productivity at ni.com/embedded-platform

800 453 6202

NATIONAL INSTRUMENTS

DE April 2013 vol ume 18/issue 8





SIMULATION

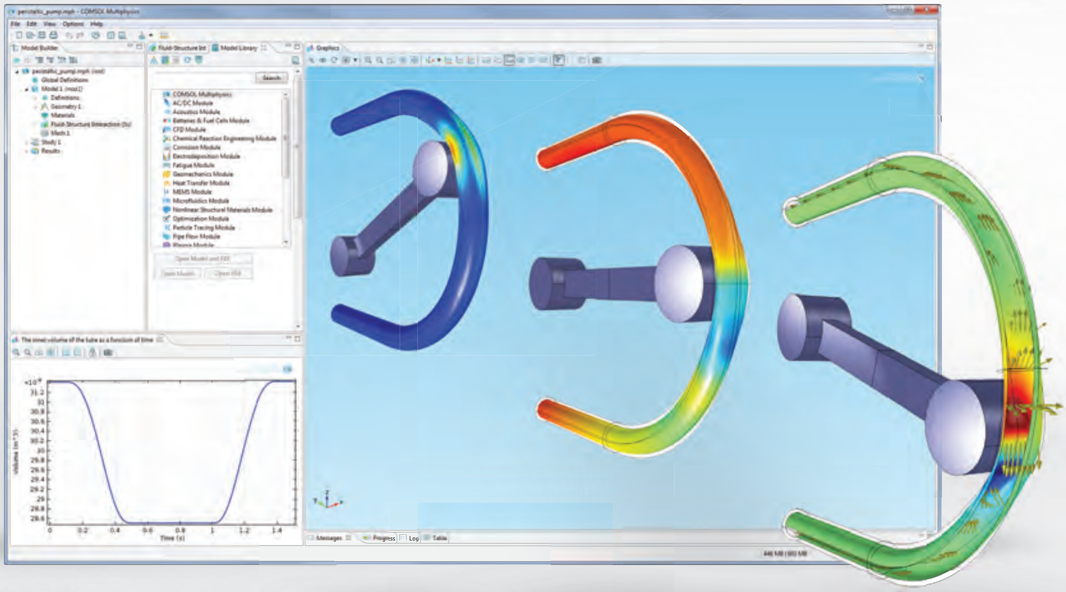
FOCUS ON HEALTHCARE

ON THE COVER: A vena cava fil er using discrete element modeling (DEM) in pulsatile fl w, mimicking embolus capture, as simulated with CD-adapco STAR-CCM+ CFD analysis software. *Image courtesy of CD-adapco.*

ENg INEERINg C OMpUTINg

TEST & MEASUREMENT

PERISTALTIC PUMP: This model simulates the fluid-structure interaction caused by the roller squeezing the tubing's wall. Large deformations, contact, and the hyperelastic behavior of the tubing material are considered. Shown are the von Mises stresses, fluid pressure, and velocity direction. Model images are provided courtesy of Nagi Elabbasi of Veryst Engineering.



Verify and optimize your designs with COMSOL Multiphysics®

Multiphysics tools let you build simulations that accurately replicate the important characteristics of your designs. The key is the ability to include all physical effects that exist in the real world. Download a free product booklet at **www.comsol.com/booklet**

Product Suite

COMSOL Multiphysics

ELECTRICAL
AC/DC Module
RF Module
MEMS Module
Plasma Module

MECHANICAL
Heat Transfer Module
Structural Mechanics Module
Nonlinear Structural Materials Module
Geomechanics Module
Fatigue Module
Acoustics Module

FLUID
CFD Module
Microfluidics Module
Subsurface Flow Module
Pipe Flow Module

CHEMICAL
Chemical Reaction Engineering Module
Batteries & Fuel Cells Module
Electrodeposition Module
Corrosion Module

MULTIPURPOSE
Optimization Module
Material Library
Particle Tracing Module

INTERFACING
LiveLink™ *for* MATLAB®
LiveLink™ *for* Excel®
CAD Import Module
ECAD Import Module
LiveLink™ *for* SolidWorks®
LiveLink™ *for* SpaceClaim®
LiveLink™ *for* Inventor®
LiveLink™ *for* AutoCAD®
LiveLink™ *for* Creo™ Parametric
LiveLink™ *for* Pro/ENGINEER®
LiveLink™ *for* Solid Edge®
File Import *for* CATIA® V5

COMSOL

© Copyright 2013 COMSOL. COMSOL, COMSOL Multiphysics, Capture the Concept, COMSOL Desktop, and LiveLink are either registered trademarks or trademarks of COMSOL AB. MATLAB is a registered trademark of The MathWorks, Inc.. Excel is either a registered trademark or trademark of Microsoft Corporation in the United States and/or other countries. SolidWorks is a registered trademark of Dassault Systèmes SolidWorks Corp.. SpaceClaim is a registered trademark or SpaceClaim Corporation. AutoCAD and Inventor are registered trademarks or trademarks of Autodesk, Inc., and/or its subsidiaries and/or affiliates in the USA and/or other countries. Creo and Pro/ENGINEER are trademarks or registered trademarks of PTC Inc. or its subsidiaries in the U.S. and in other countries. Solid Edge is a trademark or registered trademark of Siemens Product Lifecycle Management Software Inc. or its subsidiaries in the United States and in other countries. CATIA is a registered trademark of Dassault Systèmes or its subsidiaries in the US and/or other countries. Other product or brand names are trademarks or registered trademarks of their respective holders. Neither COMSOL nor any of the COMSOL products listed herein are affiliated with, endorsed by, sponsored by, or supported by any of these other trademark owners.

April 2013

VOLUME 18/ISSUE 8

DEPARTMENTS

deskeng.com

RAPID READY TECH BLOG
Read all about making digital designs physical @ rapidreadytech.com.

ENGINEERING ON THE EDGE BLOG
See the future of engineering technology @ engineeringontheedge.com.

MOBILE ENGINEER
Incorporate mobile technologies into your workflow @ mobileengineer.com.

NEW

VIRTUAL DESKTOP BLOG
Read Kenneth Wong @ deskeng.com/virtual_desktop for a closer look at lifecycle components via articles, podcasts and video reports.

NEWSLETTER REGISTRATION
Newslink; Editor's Pick of the Week; Check It Out; Virtual Desktop; Focus on Analysis and Simulation; Focus on Engineering IT & Computing; Focus on MCAD; and Focus on Rapid Technologies.

DE MOBILE BETA
Check out our mobile app for Android and iOS by visiting wbxapp.com/de-mobile on your mobile device, or scan the QR code to the right.

***DE* ON TWITTER**
Follow us @ DEeditor

LIKE *DE* ON FACEBOOK
Visit *DE* @ deskeng.com/facebook

Desktop Engineering®

EDITORIAL
Steve Robbins | Editorial Director
Jamie J. Gooch | Managing Editor
Kenneth Wong | Senior Editor
Anthony J. Lockwood | Editor at Large
Heather Pi˜ inger | Copy Editor

CONTRIBUTING EDITORS
Tony Abbey, Brian Albright, Mark Clarkson, David S. Cohn, Randy Frank, Barbara Goode, John Newman, Frank Ohlhorst, Susan Smith, Beth Stackpole, Peter Varhol, Pamela J. Waterman

PUBLISHER
Thomas Conlon

ADVERTISING SALES
603-563-1631 • Fax 603-563-8192

Erich Herbert | Sales Executive (x263)
Jeanne DuVal | Account Manager (x274)

ART & PRODUCTION
Darlene Sweeney | Director (x257)

A LEVEL 5 COMMUNICATIONS PUBLICATION
Steve Robbins | Chief Executive Officer
Thomas Conlon | President

ADVERTISING, BUSINESS, & EDITORIAL OFFICES
***Desktop Engineering*® magazine**
Level 5 Communications, Inc.
1283D Main St., PO Box 1039 • Dublin, NH 03444
603-563-1631 • Fax 603-563-8192
E-mail: DE-Editors@deskeng.com
www.deskeng.com

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

***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.

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

Each separate contribution to this issue, and the issue as a collective work, is copyright © 2013 Level 5 Communications, Inc. All rights reserved. Copying for other than personal or internal reference use without the permission of Level 5 Communications, Inc. is prohibited. Requests for permission should be addressed in writing to Desktop Engineering Permissions, 1283D Main Street, P.O. Box 1039, Dublin, NH 03444. PRINTED IN THE USA.


MathWorks®
Accelerating the pace of engineering and science
Satellites that tango,
using automatically generated code.
That's Model-Based Design.
To achieve a breakthrough in two satellites performing autonomous formation flying and rendezvous, engineers at OHB Sweden automatically generated verification tests and the final flight code from system models. Discover Model-Based Design with MATLAB and Simulink at mathworks.com/mbd
MATLAB® & SIMULINK®
©2012 The MathWorks, Inc.
Image of satellite Tango transmitted by Mango. © OHB Sweden

by Kenneth Wong & Beth Stackpole

Dell Gets Ready to Go Private

The PC market is dominated by just a handful of major players. It's literally a single hand, as five brands—Dell, HP, Lenovo, Acer and ASUS—account for 58.9% market share. (*Source: "Gartner and IDC: PC shipments tumbled…," Oct. 10, 2012, Engadget.com.*) The rest is made up of specialty brands. Naturally, in such a tight market, a major strategy shift by one of the Big Five is bound to produce ripple effects.

In mid-February, publicly traded Dell began taking steps to go private—an option the company's founder, chairman and CEO Michael Dell described as "an exciting new chapter for Dell" in a press release. According to the company, Dell has "signed a definitive merger agreement under which Michael Dell … in partnership with global technology investment firm Silver Lake, will acquire Dell" in a $24.4 billion transaction.

In the last few years, the PC market faced significant pressure from mobile devices and smartphones, which emerged as better alternatives for certain operations previously possible only on desktops, laptops and workstations. The lighter, portable form factors are part of the appeal. According to data from analysts Gartner and IDC, the PC market dropped 8.3% between Q3 2011 and Q3 2012.

Part of the PC market is the workstation market, accounting for the primary systems on which engineers and designers rely for their work. Although the PC market's anticipated growth looks grim statistically, Lloyd Cohen, IDC's director of Worldwide Market Analysis, has a sunnier outlook for the workstation sector.

"The workstation market has returned to healthier growth rates as users have begun to refresh their aging workstations," he reports. "At the same time, vendors have introduced workstations offering several different processors, such as i3, i5 and i7, thereby increasing the selection of machines that can satisfy specific workload applications without wasting part of their IT budget on unnecessary features." (*Source: "Worldwide Workstation 2011–2015 Forecast," IDC.*)

Lauren Mauro, Dell's communications manager for commercial clients and OEM solutions, points out that the agreement to go private "doesn't change our go-to-market strategy. By becoming private, we can more effectively proceed and execute our strategy.

"End user computing, which includes consumer PCs, business clients and workstations, is an important part of our business," Mauro adds. "We'll continue to invest in its growth."

Away from the constant scrutiny of financial analysts and performance-obsessed Wall Street, privately owned Dell is expected to be more nimble, and more responsive to technology buyers' changing computing preferences.

The transaction is financed in part by Microsoft with a $2 billion loan. With a vested interest in the shrinking PC market, both Microsoft and Dell know their fates are tied. Windows is also the primary operating system in the engineering and design software market—the backbone of CAD, CAE and CAM.

Consumer Influence

Even though the workstation market is usually treated as a separate division by PC makers, and is relatively insulated from the encroachment of mobile devices, it's not completely immune from the behaviors of consumer PC buyers. The spillover from consumer PC market should not be underestimated.

PC maker Dell prepares to go private. Founder, chairman and CEO Michael Dell, shown here at the Dell World 2012 opening party, calls the transaction "an exciting new chapter for Dell." ***Image courtesy of Dell.***

In 2011, in what some considered a misguided move, Dell's rival HP pondered getting out of the PC business altogether. At the time, HP's then-CEO Leo Apotheker argued it made more sense for the company to focus on software, services and specialized hardware for enterprises, like IBM does. Later, HP reversed course and remained in the PC business.

Currently, multicore workstations with graphics accelerators remain the only appropriate systems for power-hungry professional designers and engineers. The increased size and complexity of assemblies also push the demand for parallel processing, only available in workstations and high-performance computing (HPC) servers. However, users' flirtation with cloud computing, remote desktops, and other innovative computing modes could someday redefine the role and importance of workstations.

—K. Wong

START WITH PTC Creo®
STOP AT NOTHING.

The Soleus® - innovative prosthetic foot from College Park.
Learn how it became a reality at **www.ptc.com/go/college**

Ideas are your product team's most valuable asset. Unleashing those ideas into real products that set your company apart is where PTC Creo comes in. As the world's most scalable and easy-to-use suite of design software, PTC Creo maximizes every aspect of the design process. From creativity to productivity, teamwork to efficiency. All of which helps deliver the **powerful product and service advantage you can expect from PTC.**

PTC Creo®

by Kenneth Wong & Beth Stackpole

Rescale: Build Your Own Scalable Simulation Template in the Cloud

Early this year, San Francisco-based Rescale opened its doors for business, in a manner of speaking. The company tiptoed into the cloud-hosted simulation market, but with a twist. It provides a platform—a layer of software sitting on top of high-performance computing (HPC) hardware—that lets you create and run customized, repeatable, multi-solver simulation and optimization cycles. You haven't heard much about it because, according to Sunny Manivannan, Rescale's VP of business development, it has only had a "soft launch."

Let's say, in a standard design exploration, your engineers usually begin with a structural analysis in Dassault Systèmes SIMULIA. Afterward, they might use the results to run thermal analysis with MSC NASTRAN, and then perform additional calculations on certain parameters in MathWorks MATLAB. This entire loop from start to finish could be specified in Rescale's web-hosted interface, to run on Rescale's hardware.

"The types of jobs our customers want to solve are pretty compute-intense," says Joris Poort, CEO and co-founder of Rescale. "So all the management of the cluster in the back end is taken care of by us."

If one software program can take advantage of the GPU, but others perform better on CPU cores, Rescale's back-end infrastructure can balance the load and core distribution in a way that makes the most sense. Rescale is not a software reseller; however, if you need to acquire more licenses to run your simulation (for example, more HPC licenses so you can use additional cores to compute your job faster), Rescale will handle the license negotiation.

"We can run [the simulation] using the customer's existing licenses, or we can run it using on-demand licenses—weekly, monthly, depending on the vendor," says Joris. "That's a big part of what we help solve for our customers. We tell them not to worry about the licensing issues. We work with vendors to figure out the best licensing plan for our clients."

San Francisco-based Rescale offers cloud-hosted software and HPC hardware to specify, set up and run simulation loops involving multiple solver codes.

An Integrated, Scalable Approach

Manivannan says "we all believe more simulation leads to better products. But the problem that you run into is, maybe you don't have the compute power. The second problem is, it's not easy to build a simulation pipeline that's scalable for all the software involved."

Rescale's hardware-software combo platform is the outcome of Joris' experience at Boeing, where he worked for four years as a structural and software engineer on the 787 program. For a firm of Boeing's size, HPC resources weren't the problem; integrating many different software packages into one comprehensive simulation cycle was. Rescale's hosted software, which functions like middleware, addresses the integration.

The company is targeting mostly large enterprises and some midsized businesses that need to run HPC-powered simulation. Its on-demand platform could also augment manufacturers with peak simulation demands with which their in-house IT infrastructure cannot cope.

Rescale recognizes that, with simulation software, access to cloud-hosted hardware is just one part of the solution—and not even the most important part. The true value Rescale offers is a cloud-hosted HPC platform that scale up or down according to peak- and low-time demands, along with a browser-based workflow designer to specify and set up your commonly executed simulation loops.

—K. Wong

GIVE YOUR BIG IDEA A LITTLE MOJO.

Introducing A World-Class 3D Printer For Only $185/Month.

When you bring an idea to the table, the new Mojo 3D Printer brings it to life with ease. Now you can have 3D printing right at your desktop at a remarkably low cost. With the magic of Mojo at your fingertips, there's really no limit to your creativity. The affordable Mojo 3D Print Pack includes everything you need to start printing immediately – matching your design's brilliance with an equally inspiring model.

Find out more at www.Mojo3Dprinting.com/DE

Stratasys

Leasing available only in the United States. Additional options, shipping, applicable taxes and/or duties not included. ©2013 Stratasys, Ltd.

by Kenneth Wong & Beth Stackpole

Altair Engineering Unveils HyperWorks 12.0

Altair is rolling out a major release of its flagship suite, HyperWorks. The comprehensive lineup covers every phase of design development and testing, from computational fluid dynamics (CFD, with AcuSolve), crash analysis (HyperCrash), sheet metal form (HyperForm), and meshing (HyperMesh), to structural analysis (OptiStruct), and more. The latest upgrade, HyperWorks 12.0, emphasizes the growing importance of composite materials, optimization, and collaboration.

In the preparatory phase of simulation, HyperMesh now offers new algorithms that let you perform shell and solid meshing, along with a mid-plane mesh generator." The 2D mid-plane generator is a major time-saver for people who need to extract 2D planes from CAD models," said Stuart Sampson, director of modeling and visualization, Altair. "It's a major step forward in model building." It is, according to Sampson, one of the major choke points in the process.

HyperView, the application for viewing simulation results, now supports stereoscopic display, which adds realism and simulated depth to on-screen images. (You'll need stereoscopic display hardware, graphics acceleration, and glasses to take advantage of this function.)

The composite modeling and meshing tools give you a lot more controls over the orientation, layout, and character of plies.

For multiphysics problems, Altair HyperWorks lets you combine a variety of solver codes (for example, noise-vibration-hardness solver from OptiStruct, nonlinear crash test in RADIOSS, multibody dynamics in MotionSolve) to build a custom simulation loop. To encourage more users, the company now offers Multiphysics Licensing. "We just treat the whole multiphysics job as one job," observed Detlef Schneider, senior vice president, solvers, Altair. You purchase HyperWorks Units and pay for jobs using them.

For optimization, a process to automatically identify the best design to achieve your goals, you can rely on HyperStudy. The new version in 12.0, according to Altair, "is an entirely redesigned release [that] accelerates design robustness and reliability studies."

The new Display Manager enables users to run graphics-intensive applications on their cluster while visualizing those applications on their desktop, laptop, or other lighter devices.

—K. Wong

Quality Management Folded into Teamcenter

Consider the recent headlines regarding battery problems with the now-grounded and once highly lauded Boeing 787 Dreamliner aircraft, and it's not hard to see why engineering and manufacturing executives lose lots of sleep over quality issues—and why formal quality management programs are so crucial to a product's ultimate success.

With that in mind, Siemens PLM Software joins a number of other product lifecycle management (PLM) vendors folding quality management capabilities into their PLM platforms. Siemens, like fellow PLM providers PTC and Aras Software, among others, claims that the integration of the two solutions can provide greater visibility into quality management processes while aiding in faster time-to-closure for quality issues. The company's new Teamcenter Quality Management with corrective and preventive actions (CAPA) is designed to provide an enterprise-wide product quality management platform for capturing various forms of complaints, defects and non-conformances, while allowing the quality management team to share the same views of information already in place for the engineering and manufacturing teams.

"Companies want to be able to capture their intellectual capital and best practices, and avoid having to go through the full process of finding the problems and taking preventive action," explains Al Hufstetler, Siemens PLM Software's vice president of product management for manufacturing and engineering. "They want the results integrated as part of their product design process so they don't make the same mistakes again."

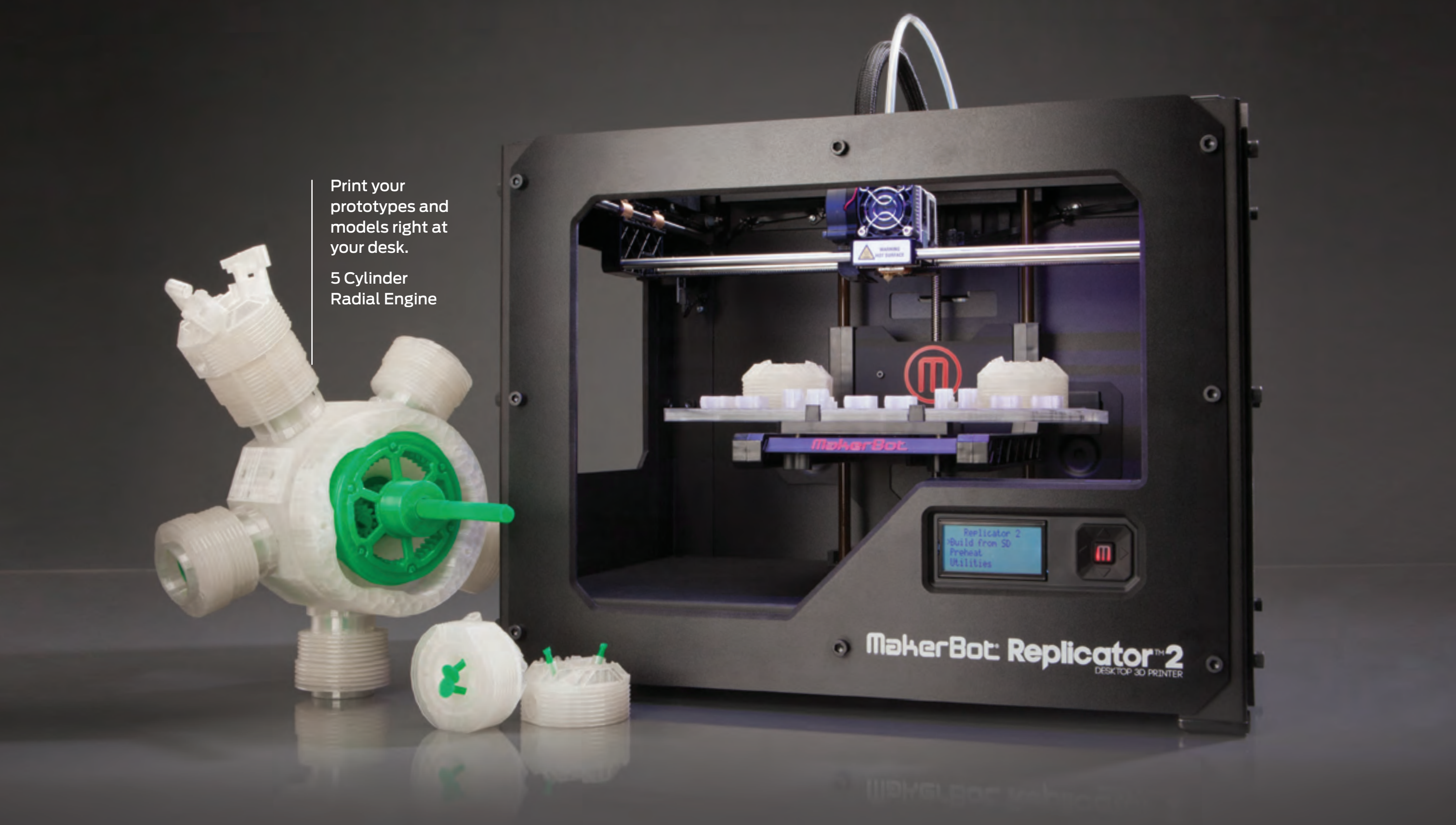
According to an Aberdeen Research report, integration of quality management systems into a core PLM can help reduce internal and external failure costs by more than 50%, while diminishing the total cost of quality by 8%. That's hardly chump change in today's still economically challenged business environment.

Teamcenter's new CAPA solution, available as a Web-based offering, integrates quality and change management processes for root-cause identification, correction, prevention and verification. The software works within the Active Workspace environment to deliver a user experience that can be customized and personalized to individual needs.

—B. Stackpole

AFFORDABLE RAPID PROTOTYPING AND MODEL MAKING

The New Standard in Desktop 3D Printing



MAKERBOT® REPLICATOR® 2 DESKTOP 3D PRINTER

- Choose the easiest, fastest, most affordable desktop tool for making professional-quality 3D prototypes and models.
- Cut costs and streamline product development and production.
- Get the best price/performance 3D printer on the market.

MakerBot is leading the Next Industrial Revolution.
Thousands of engineers, industrial designers, architects, and creators are using MakerBots to make the world a better place.

$2,199

Buy now or get a free sample print. Call 866.573.7603 or visit makerbot.com/de

by Kenneth Wong & Beth Stackpole

Introducing CFD to Design Engineers

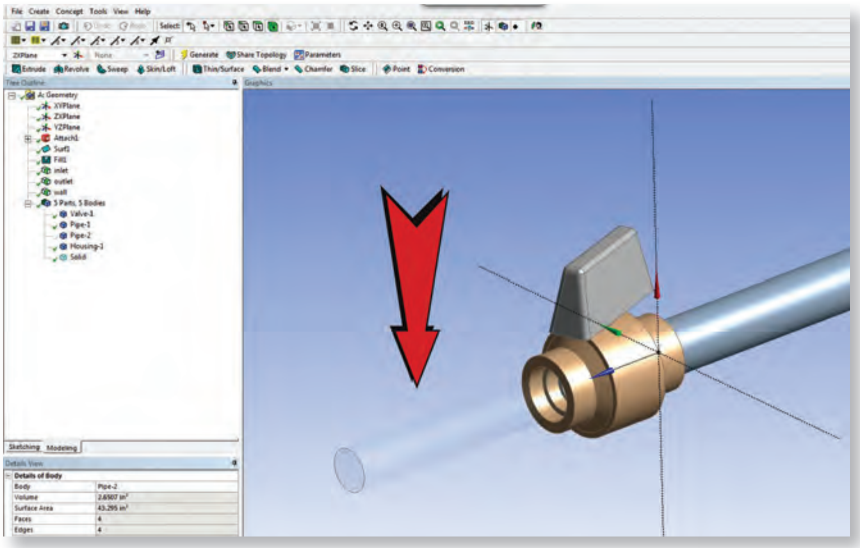
Most designers and engineers today don't think twice about running basic stress analysis on their CAD models. Mainstream mechanical design software programs—Autodesk Inventor, SolidWorks, Solid Edge and PTC Creo, to name but a few—offer integrated stress analysis, often at no additional cost. What was once considered the specialists' domain is now second nature to general CAD users.

Simulation software developers are hoping, with intuitive interfaces and simplified dialog boxes, they can make general design engineers feel more comfortable performing advanced simulation tasks earlier in the design cycle. The aim is to encourage simulation-driven design—the use of digital simulation to identify the best geometry for the product, be it a camera housing or a crane.

An Ounce of Preparation ...

ANSYS believes the key is to demystify the setup process. One way to do that is to reduce the complex mechanical, thermal and physical phenomena into a series of items users can pick and choose from a drop-down menu.

"For structural analysis, CFD simulation requires a model—often in the form of a CAD file—to be imported either automatically or manually into the simulation environment," Gilles Eggenspieler, senior fluid product line manager for ANSYS, says of the computational fluid dynamics (CFD) process. "Then you need to create the computational mesh of the fluid region, and set up the physics of the problem."



Setting up a simple CFD job to study the pressure inside a valve, as illustrated in a video podcast with Gilles Eggenspieler, ANSYS' senior fluid product line manager.

Video Presents Examples

In the first episode of the video podcast series "Introducing CFD to Design Engineers," Eggenspieler dissects what he believes to be the common stumbling blocks in preprocessing:

- identifying the fluid volume,
- creating the mesh, and
- setting up the turbulence model, boundary conditions, and thermal conditions.

He uses a basic CFD problem—analyzing the pressure exerted on a valve's wall by fluid flow—to illustrate his points.

The aim of such a simulation, he says, is to ensure that the structure of the valve can withstand the pressure from the fluid. In the second episode, Eggenspieler reviews the results from this simulation.

To watch the video, visit deskeng.com/virtual_desktop/?p=6713.

—K. Wong

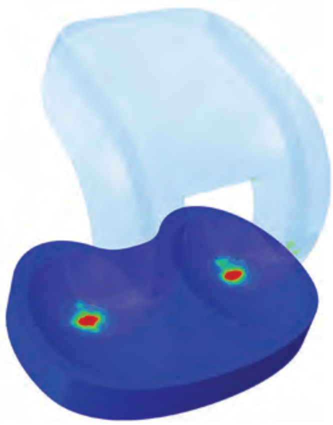
STAR Global 2013

The CD-adapco STAR Global Conference that took place last month in Orlando provided another opportunity to learn more about simulation.

Gene Kranz, the NASA Flight Control Director who led the effort to save Apollo 13, gave this year's Keynote, which preceded two full days of learning sessions.

In addition to users sharing tips and tricks to master CD-adapco's products, conference goers were also introduced to the latest version of CD-adapco's flagship product, STAR-CCM+ 8. Visit deskeng.com/virtual_desktop/?p=6806 and deskeng.com/articles/aabjkb.htm for more information on the conference and new release.

— J. Gooch



Accelerating Knee Implant Design and Patient Recovery

A preview of the Abaqus Knee Simulator from Dassault Systèmes.

Recently, *DE* talked to Cheryl Liu, Senior Life Sciences Specialist, SIMULIA, Dassault Systèmes. Her Rhode Island-based team has spent the past year developing the remarkable Abaqus Knee Simulator application. The application is part of Dassault Systèmes 3DEXPERIENCE platform which transforms the way products are designed, produced, and supported; expanding the possibilities for the virtual world to improve the real world.

Simulation Breakthrough

One of the key issues facing medical device companies is the many hundreds of thousands of dollars and months of time that testing requires when developing knee joint implants. The Abaqus Knee Simulator provides a breakthrough by enabling medical device companies to replace physical testing with a simulation process measured in hours. The innovative application guides even the non-specialist through a complex explicit finite element analysis (FEA) simulation of the knee joint using industry-standard testing procedures and evaluation methods.

Logical and Intuitive Interface

Cheryl described two ways of working with the simulator. Designer mode allows intuitive setup of the simulation, ideal for a small company without FEA expertise. Analyst mode provides the experienced user with full access to the underlying Abaqus/CAE functionality after setup in designer mode. The two modes can be switched easily.

There is clearly an enormous amount of biomechanical and FEA knowledge and experience required to setup and carry out an accurate simulation of the knee joint. Without the Abaqus Knee Simulator, the task looks daunting. Cheryl took *DE* through the five "stepping stones," or workflows, that her team has designed into the simulator to overcome that uncertainty and make the whole task logical and progressive.

Five 'stepping stones' for guidance

1. Contact Mechanics. In the early stage of the design, the simulator provides relative positions of the joint to explore a wide range of contact conditions and associated contact pressures. Good pressure prediction is crucial as this directly relates to the amount of wear the implant will see. All implant manufacturers are striving to improve reliability by minimizing wear.

2. Implant Constraint. Forward and lateral motion and rotation of the joint is now introduced into the simulation. Contact pressures and wear are further assessed, but now instability of the joint can be checked.

3. Tibiofemoral Constraint. Ligaments and bones are added into the simulation. Instability and wear are now checked under more realistic and less conservative boundary conditions. Surgical procedures, such as cutting or tensioning of ligaments, can be simulated. It is important to note that simulation leads the way here as there is no equivalent test procedure.

4. Wear Simulation. Now the design can be checked, using a standard gait scenario. It can also be tuned using available material models.

5. Total Knee Replacement Loading. Load time histories of everyday patient motion are now defined, allowing full kinematics of the joint to be simulated and wear areas balanced. Patella popping can be studied and avoided. The simulator, again, provides unique insight as no comparable physical testing is available.

Conclusion

Abaqus FEA has a long history of validated use in for the analysis of medical devices, including knee implants. Cheryl and her team have now made that technology accessible to non-specialists.

Any medical device company wanting to introduce simulation to accelerate the design process should check out the Abaqus Knee Simulator. It won't take very long to appreciate how the application provides a friendly and logical progression through the key design phases. DE

3DS SIMULIA

INFO → SIMULIA, Dassault Systèmes: www.3ds.com/simulia

Oxford Tests 'RobotCar'

Researchers at Oxford University are testing a low-cost, self-driving vehicle concept in the UK. RobotCar, a modified Nissan Leaf, uses stereo cameras

and lasers, along with a 3D mapping solution housed in a computer in the rear of the vehicle.

The Oxford team is using an array of low-priced cameras and sensors that ring up to nearly $6,000. Eventually, the researchers hope to drive the cost down to about $150. Also, unlike Google's self-driving car, there is no large (and expensive) 3D LIDAR unit on top of the car.

The vehicle acts autonomously only on familiar routes. An iPad in the dashboard prompts the driver, providing the option to let the vehicle take over. Touching the screen switches the vehicle to "auto," while tapping the brake puts the driver back in control.

MORE ➜ engineeringontheedge.com/?p=3940

FDA Approves Retinal Prosthesis

Second Sight is now able to offer its Argus II system to customers, thanks to the approval it received from the U.S. Food & Drug Administration (FDA) in February. The system is a combination of retinal prosthesis, video recorder and minicomputer, and has been designed for individuals who suffer from late stage retinitis pigmentosa (RP).

The Argus II uses a miniature camera—small enough to fit in a pair of eyeglasses—to capture images of the user's surroundings. These images are processed by a computer that attaches to the belt and are transmitted via a second eyeglass attachment to the retinal implant. The implant produces pulses of electricity that augment the user's vision by stimulating visual receptors.

MORE ➜ engineeringontheedge.com/?p=3906

CFD Simulation Helps Mini-drones Take off

The U.S. Air Force is paying $3.5 million to Virginia Tech's Wu-chun Feng, Ph.D., to develop micro-air vehicles (MAVs), tiny drones that can perform reconnaissance.

Feng previously created Green Destiny, a highly efficient supercomputer, and launched the Green500 list of efficient supercomputing systems. Feng and his team will spend the next three years modeling the airflow over the wings of these tiny, insect-sized drones to help stabilize them during flight.

The Air Force tapped Feng because it wants his team to accelerate the rate at which a supercomputer can simulate the computational fluid dynamics (CFD) of the drones. Feng's group and researchers from North Carolina State University will build CFD codes and a hardware-software system for modeling that airflow.

MORE ➜ engineeringontheedge.com/?p=3882

Tesla's Elon Musk Knocks Dreamliner Batteries

Boeing is frantically trying to save face in the wake of several electrical failures—and at least one fire—on several of its new 787 Dreamliner airliners, which caused the entire fleet to be grounded.

Investigators have targeted the lithium ion batteries in the planes, and Tesla founder Elon Musk chimed in with his own criticism.

According to Musk and some other experts, Boeing's design is susceptible to thermal runaway and a domino effect in which excessive heat in one cell can cause neighboring cells to overheat and catch fire. Tesla uses the same battery chemistry, but with a different physical structure.

MORE ➜ engineeringontheedge.com/?p=3817

Robotic Exoskeletons on the March

Parker-Hannifin has debuted its Indego robotic exoskeleton, which is designed to help paraplegics gain mobility by allowing them to walk with the aid of robotic leg braces and crutches. Indego was licensed from Vanderbilt's Center for Intelligent Mechatronics. The company is working with an Atlanta rehabilitation center to test and further develop the device.

Meanwhile, Cyberdyne's Robot Suit HAL exoskeleton will be tested in 10 hospitals in Japan. The same technology was reconfigured into a disaster recovery suit that may be used to help clean up the decommissioned Fukushima Daiichi nuclear plant, which was damaged in the 2011 tsunami and earthquake.

MORE ➜ engineeringontheedge.com/?p=3966
➜ engineeringontheedge.com/?p=3844

➜ For daily coverage on the future of engineering technology, visit EngineeringOnTheEdge.com

If product design was a sport, we'd be a banned substance.

Faster. Stronger. Lighter.

We have a confession. We've been providing performance enhancing software to our customers for many years. These tools have consistently given them an advantage over their competitors. We're sorry. To make amends, we would like **everybody** to be aware of the capabilities of HyperWorks 12.

Learn how Altair can help you design better products by visiting altairhyperworks.com/hw12

Altair | HyperWorks® 12.0

HyperWorks is a division of Altair | altair.com

ESA Considers Moon Base Built via AM

The European Space Agency (ESA) is investigating the possibility of using additive manufacturing (AM) to construct a lunar base, using materials already in

place. The ESA wants to use lunar soil as fuel for the D-Shape process developed by Monolite UK.

To test the theory, the D-Shape printer was fueled with basaltic rock mined from a volcano in central Italy that is 99.8% similar to lunar soil.

The process was tested in a vacuum to simulate the lack of atmosphere on the moon. The ESA has plenty of other challenges to overcome before this idea becomes a reality, but this presents a potential solution to the logistical problems that might otherwise make lunar construction unfeasible or too expensive.

MORE ➜ rapidreadytech.com/?p=3416

Urbee 3D Printed Car is Ready for Production

In collaboration with Stratasys, inventor Jim Kor is building a car using additive manufacturing (AM) to produce the parts. The Urbee first came to light a few years ago, when Kor first rolled out his prototype vision of what the car would look like, but now Kor claims he's ready to begin production.

According to Kor, the Urbee could only be manufactured using 3D printing. The complex internal geometries and customization offered by AM allowed him to design every piece and panel, with the result that the Urbee has far fewer parts than other vehicles, and is lighter to boot. Kor has used AM to combine the parts into complete sections. Kor claims the Urbee can be built using a grand total of 50 separate parts.

For the moment, constructing a single Urbee is more expensive than might be practical, but Kor hopes to generate enough interest in the design to develop larger-scale production printers. At press time, Kor has orders for 14 cars, plus one for himself. He plans for the first trip in the Urbee to be a cross-country jaunt.

MORE ➜ rapidreadytech.com/?p=3497

ORNL Drives Innovation

Tennessee's Oak Ridge National Laboratory's (ORNL's) Manufacturing Demonstration Facility provides research assistance, as well as opening access to industrial AM systems to a variety of businesses. Stratasys has formed a partnership with ORNL, and other companies are following its lead.

Companies that partner with ORNL receive practical experience with AM, without the expense of purchasing an AM system. This gives engineers and designers a chance to see how developing a product using 3D printing differs from more traditional subtractive methods.

For example, DeRoyal is a company that serves the medical industry, providing surgical and acute care, orthopedics,

patient care and wound care. By partnering with ORNL, the company is reducing energy and material costs by leveraging AM to produce orthopedic implant-related products.

The company says its partnership with ORNL has given it a chance to develop new implants on an expedited schedule that wouldn't otherwise have been possible. Other companies have similar stories.

MORE ➜ rapidreadytech.com/?p=3451

Cornell University Bioprints a Functional Ear

Cornell University and the Weill Cornell Medical College have taken prosthetics research to a new level with a bioprinted ear. While every prosthesis is designed to be functional, they are artificial replacements for living material. Not so with the ear developed by Drs. Jason Spector and Lawrence J. Bonassar. The bioprinting process uses living material to create a structure that remains alive after being implanted.

The research performed by Spector and Bonassar is meant to combat microtia, a congenital deformity in which the external ear is not fully developed.

The bioprinting process begins with a 3D scan of an intact ear, to generate a 3D printed mold. Researchers then add animal-derived collagen into the mold, and top it off with nearly 250 million cartilage cells. The collagen acts like a scaffold for the cartilage, directing its growth.

From there, the cartilage is given three months to fully grow, slowly replacing the collagen. Once an ear has reached full development, it can be implanted into a patient.

MORE ➜ rapidreadytech.com/?p=3565

➜ For more coverage of rapid technologies, visit RapidReadyTech.com

Simulation for Everyone – Xeon Makes it Possible

We have come a long a way in simulation, and the future is getting brighte .

By DOug Bar   NEy

Due to the limits of hardware horsepower, simulation was traditionally a back-end process. But today, with the continued advancement of Moore's Law, the arrival of multi-core architectures and advanced memory topologies, we can now do "in the loop" design and modeling of small parts and small assemblies on a standard workstation. That means we can iterate through designs faster and arrive at an optimal design in time to make product and profitability decisions right at our workstation.

Better yet, it also means that we can do complete assembly modeling in a fraction of the time, so rather than using simulation as a forensic tool, exposing why the design failed, we can use it as a design tool to bring the best possible product to market faster than ever before possible.

> Simulation should not be the last step in the design process. Early simulations spot problems, lets you iterate many designs, speeds development and ultimately creates bette , and more truly innovative products.

Gaining on the Competition

Times they are a changing. Small and medium businesses, once at a disadvantage to larger corporations, now have access to simulation and analysis tools from companies such as Dassault Systèmes SolidWorks Corp., Space Claim Corp. and Autodesk, Inc.. These companies, along with Altair Engineering, Inc., ANSYS, Inc. and Dassault Systèmes Simulia, are breaking through the glass ceiling by bringing to market tools that enable casual users to be proficient at performing simulation.

This new breed of simulation tools are not toys—they deliver meaningful and easy-to-comprehend results that drive real design decisions. Couple ease of use with access to powerful workstations and clusters based on the Intel Xeon processor—well, you have a game changer. Simulation and analysis is now within reach of small and medium businesses. In fact, these new tools are now necessary to increase the number of ideas SMB's explore while concurrently accelerating time to market and reducing development budgets. The triple crown of design is now available to small and medium business: design, analysis and simulation.

Driving Innovation

Great products are not simply designed, but instead they evolve over time through countless hours of research, analysis, design studies, engineering and prototyping efforts, and finally, testing, modifying, and re-testing until the design has been perfected. One company that is the personification of this process is Dyson Ltd., the famous UK-based vacuum machine maker that uses simulation to bolster an already innovative design process.

Dyson, according to an Aberdeen Group report on computational fluid dynamics (CFD), uses technology to help them fully experience their ideas before they are real and their impact is obvious.

For starters, Dyson performs parametric simulations and analysis during its design process. For instance, when the company built its bladeless fan, the Dyson Air Multiplier, there were no earlier designs to work from. But with the help of efficient simulation, as many as 10 new designs were analyzed every day.

Simulation also ensures that Dyson designs are accurate, in this case performing simulations based on NX software from Siemens. At Dyson, vacuum cleaner parts are developed by different groups. Simulation allows for in-depth testing to ensure all these pieces work together and lets lead designers see the entire vacuum working virtually through sequences of animation.

Supporting Simulation

Simulation should not be the last step in the design process. Early simulations spot problems, let you iterate many designs, speed development and ultimately let engineers create better, and more truly innovative products.

Much simulation can be performed right on the workstation. An ideal solution is a dual Xeon-based workstation that, by supporting efficient simulation, acts as an innovation engine. This modern hardware is fast, affordable and in reach of the typical customer. DE

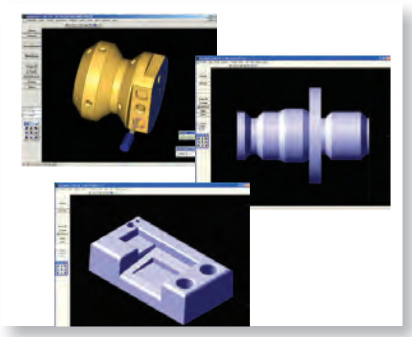
Doug Barney *is a computer journalist with nearly 30 years of experience.*

INFO ➜ Intel Corp: intel.com/go/workstation

Editor's Picks

by Anthony J. Lockwood

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



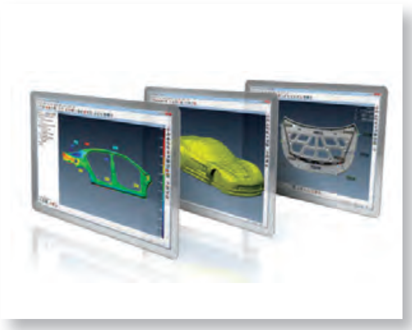
GeoPath CAD/CAM for Everyday Parts

Dynamic tool management said to accommodate various materials and CNC machines.

SolutionWare develops CAD/CAM software, and they've been at it for more than 35 years. Their flagship software system goes under the umbrella of GeoPath for Everyday Parts or just GeoPath. Version 5.1 has arrived.

GeoPath has a modular set of applications that integrates the tools any machine shop deploys or needs: lathes, milling, EDM programing, for example. Version 5.1. It has a feature called Dynamic Tool Management, so when you change the program to run on a new CNC machine, GeoPath will automatically read the tooling, feeds, and speeds then adjust them to the library for the different systems.

MORE ➔ deskeng.com/articles/aabhrg.htm



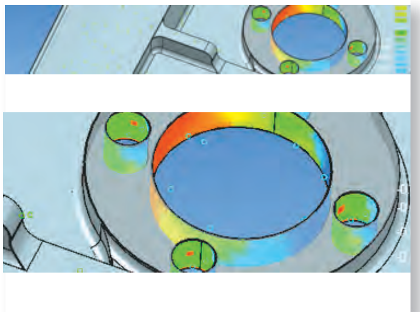
InnovMetric Adds Play Inspection Tool to PolyWorks

New tool in PolyWorks v12.1 adds automatic guided sequences to DirectReplay.

InnovMetric Software recently released version 12.1 of its PolyWorks high-density 3D metrology software system. PolyWorks is a universal point-cloud measurement, analysis, and modeling platform. Universal means comprehensive and that it works with most all major makes of point-cloud digitizers, scanners, and contact probing devices.

A new Play Inspection tool is the highlight of the PolyWorks 12.1 release. It automatically builds a guided, real-time step-by-step sequence to capture 3D datasets of a new piece, and also lets you manage digitizers and probing devices as an integrated workflow.

MORE ➔ deskeng.com/articles/aabhsp.htm



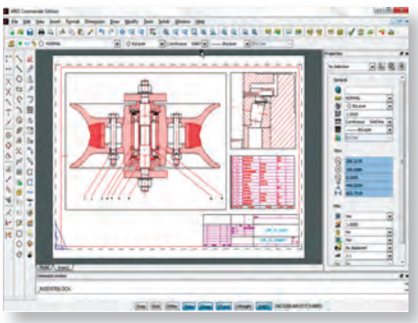
CAD-to-Part Inspection Solution Updated

Build!IT 3.2.5 features Windows 8 compatibility, customizable interface.

The Build!IT CAD-to-part inspection system from BuildIT Software & Solutions seems to be a robust and adaptable toolset. It works with scanners, CMMs, and digitizers from pretty much all the major hardware outfits, and it imports/exports common CAD formats. Because it lets you digitally collect, analyze, and share inspection data, Build!IT eliminates the need for spreadsheet calculations and manual gauges.

Among the more than 250 enhancements to version 3.2.5 is a hole axis inspection command, CATIA V5 FTA GD&T import capabilities, and a new Inspect Targets with Scanner feature.

MORE ➔ deskeng.com/articles/aabhtr.htm



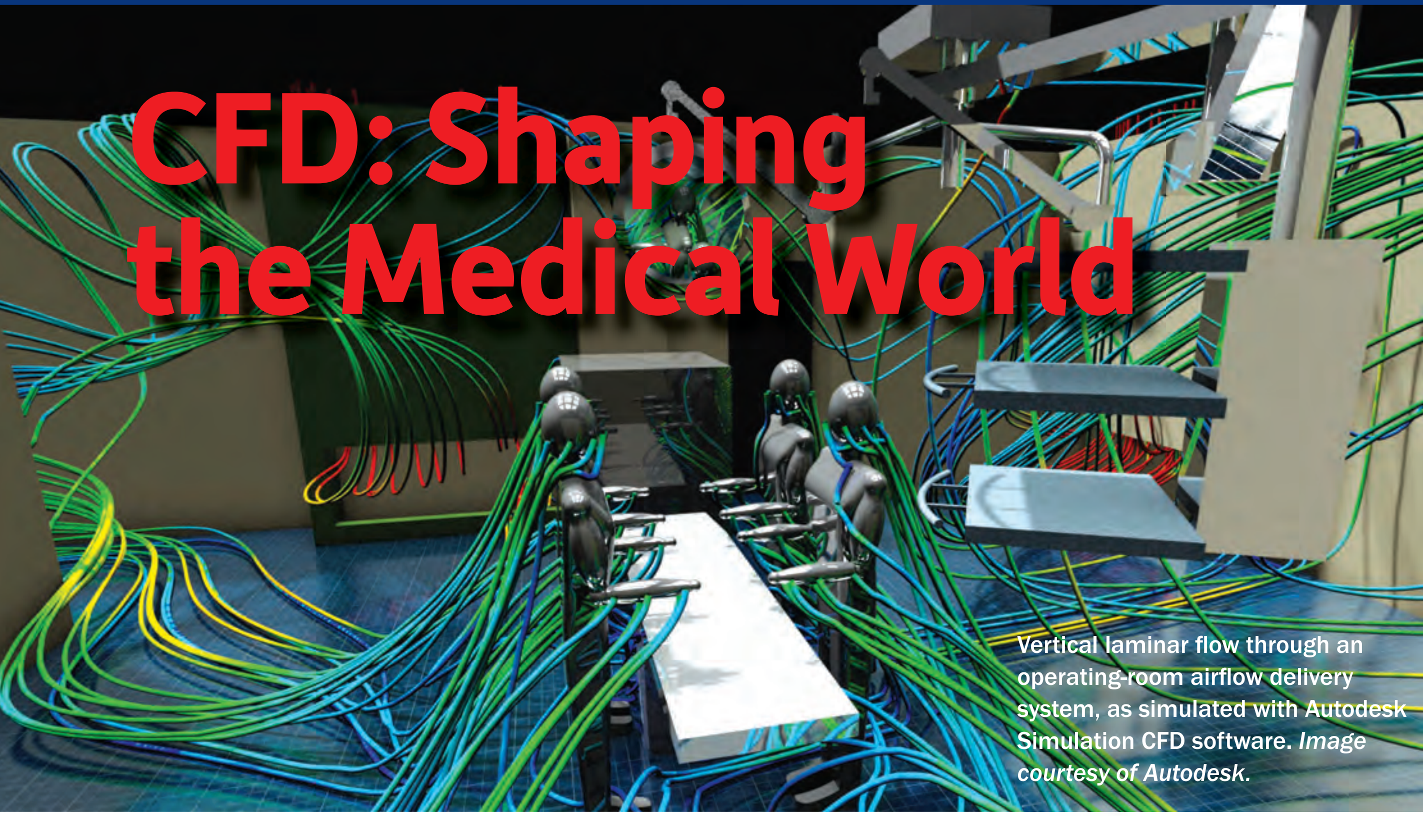
ARES Commander Edition 2013 Released

CAD system available in 14 languages for Linux, Macintosh, and Windows platforms.

ARES Commander Edition is a low-cost DWG-compatible CAD system that offers ACIS-based 3D modeling and a comprehensive programming environment. It provides all you closet Mac mavens with a cost-effective AutoCAD alternative. And you guys—you know who you are—who built a home Linux or Windows box with Lucite sides and blue running lights, the same thing. And no matter what your preferred platform, anybody into programming will find ARES Commander a code jock's paradise: It's fully programmable and customizable using C/C++, COM, Delphi LISP, Visual Studio, and the like.

MORE ➔ deskeng.com/articles/aabhwz.htm

CFD: Shaping the Medical World



Vertical laminar flow through an operating-room airflow delivery system, as simulated with Autodesk Simulation CFD software. *Image courtesy of Autodesk.*

From ensuring clean airflows to pre-planning heart surgery, CFD software increases understanding of medical applications.

BY PAMELA J. WATERMAN

When fluids are involved, simulating the function of many medical implants, surgical techniques, diagnostic systems and test stations can be an extreme challenge. It takes fine-tuned software to help engineers understand even the basic flow of air, blood or a liquid chemical—and for medical applications, the margins for design safety are extra-tight. What makes computational fluid dynamics (CFD) analysis such a useful tool when working in this field?

Although the competitive advantage offered with CFD analysis also keeps the fine details quiet for many medical applications, a number of analysis companies told *DE* why their software is particularly good at handling these complex cases.

Medical Equipment Demands Precision

Flow Science FLOW-3D CFD analysis software has found use in many medical applications, from modeling blood circulation to aiding in the placement of stents. Its capabilities in handling microfluidics can even predict transient injection forces on the components of fluids undergoing shear thinning at a needle-syringe interface. But an application that consumers might not often consider is that of designing and manufacturing the miniaturized chemical laboratory present on a diabetes test strip.

Roche Diabetes Care, a division of Roche Diagnostics, is involved in both R&D and manufacturing of glucose test strips, whose reagent film includes a mixture of up to 20 components that undergo mixing, pumping, coating and drying. The company employs CFD analysis for much of its material flow (rheological) development work, so Roche scientist Julien Boeuf, Ph.D., turned to FLOW-3D to help solve a phase separation issue that led to the production of inhomogeneous films.

Boeuf used the Elasto-visco-plasticity function and the Moving Object function in FLOW-3D to set up a series of mixing simulations, treating the mixture as a Newtonian fluid, a shear thinning fluid or as viscoelastic, depending on the actual chemical composition. By varying the rotation speed of a paddle centered on a cylinder of the reagent mixture, Boeuf says, "We were able to visualize the influence of rotation speed combined with fluid properties like yield stress on the flow at the cylinder walls, and then correlate this flow structure with the resulting amount of separation. This could be visualized in FLOW-3D using a Two Fluids Model."

The models were confirmed by several experimental results, and enabled understanding which rheological properties of the chemical components are responsible for the separation.

CD-adapco has seen so much interest in medical applications using its STAR-CCM+ CFD software that this field is one of several areas the company is now supporting with industry-specific user help. If desired, you can now be assigned a designated life sciences support engineer.

"CFD is really mushrooming," says CD-adapco's Kristian Debus, Ph.D., life science sector manager. "In microfluidics, we have a customer who wants to look at the lab-on-a-chip model; that area really has been quite silent for many years. Another customer has been working on inhalers for years and is now doing external equipment for an ICU, where fan noise needs to be diminished."

Other biomedical applications where STAR-CCM+ modeling is now more active than ever include devices from stents to heart pumps, powder-coating and mixing for pharmaceuticals. There are even diffusion studies for drug delivery, based on patient-specific data to determine the particle size needed. STAR-CCM+ also couples with Dassault Systèmes' SIMULIA Abaqus for fluid-structure interaction (FSI) modeling.

A big success, says Debus, is the software's meshing tool, easily bringing in MRI/STL data and quickly creating a usable mesh. Beyond that is STAR-CCM+'s unique ability to create a mesh "overset" whereby a major mesh is fixed on most of the geometry, while a minor mesh moves along with a moving subpart. Dubus notes the benefit: "You can do much larger motions without breaking the code."

Medical CFD, the FDA and Simulating the Virtual Patient

CD-adapco's Kristian Debus, Ph.D., says that in the medical field, many professionals are trying to get simple answers: Doctors want a yes or no. For example, in current work on aneurisms at Tufts University, a brain surgeon is studying scan data of blood vessel walls. He's examining blood flow patterns and the wall thickness at an aneurism, to try to find correlations between the visual inspection and the computational fluid dynamics (CFD) results.

So far, numerical diagnostics have not made it into real-world medical decision-making. However, CD-adapco is involved with an ASME subcommittee (ASME.org, V & V 40) for writing verification and validation guidelines for biomedical devices. The goal is to get CFD and finite element analyses (FEA) qualified to help speed up the U.S. Food & Drug Administration (FDA) approval process. When accepted, this ruling could be groundbreaking for the legal, medical and engineering realms.

One important step toward this goal is the recent FDA recognition of simulation as "essential to medical device evaluation." This opinion has just been written up by Cheryl Liu, a senior product experience technical specialist at Dassault Systèmes' SIMULIA life sciences division. (See page 32 of this issue for Liu's article that explores this in more depth.) The article explains how the FDA's Center for Device and Radiological Health is reaching out to both the medical and software industries, and provides a good baseline for discussion of the topic at any level of management.

A second major effort is the development of the Virtual Physiological Patient, a publicly available library of computational, verified and validated submodels and data. This cross-industry collection will cover different disease states in the relevant disciplines, to aid in disease-specific device innovation. (DeviceConsortium.org)

Tool for All

CFD analysis is increasingly becoming a tool for all designers. SolidWorks users can apply the insight gained from CFD analyses while working directly in their 3D CAD tools, since SolidWorks Flow Simulation is a licensed, fully embedded add-on to SolidWorks, designed for concurrent engineering. The software can handle internal and external flow of air, water and various fluids including blood, and include heat transfer effects.

Delphine Genouvrier, product manager for SolidWorks Simulation products, lists several good reasons for adding CFD analysis to the design process. "If you are designing a product that will be used in the body, it is difficult to understand how your fluid will flow," she points out. "With CFD, product engineers can see the invisible, something that they would not be able to see with testing."

One SolidWorks customer is working on a product for older people: an oxygen mask that is worn somewhat away from the face. The patient wants to speak clearly, but also obtain the proper percentage of oxygen in the airflow when it reaches the mouth. Genouvrier says, "They've been able to simulate the mixing phenomena between the oxygen from the mask and the ambient air around the face. That's the kind of application that's very difficult to measure in reality." For example, SolidWorks Flow Simulation can help identify a dead zone in the flow pattern for a given geometry.

CFD simulations can also boost the performance of systems that are indirectly, yet critically important to medical care. Huntair, an Oregon company that designs and manufactures specialized heating, ventilating and air-conditioning (HVAC) systems, uses Autodesk Simulation CFD software to analyze its CLEANSUITE airflow delivery systems. Taking a cue from the classic cleanroom systems of the semiconductor and pharmaceutical industries, Huntair engineers recently delivered CLEANSUITE vertical laminar flow systems for installation in operating rooms at Parkview Hospital, Pueblo, CO.

The CLEANSUITE systems deliver a controlled stream of low-turbulence, temperature-controlled and high-efficiency particulate air (HEPA)-filtered air over an operating table. The result is less chance of patient contamination.

"Autodesk CFD Simulation software helped us under-eastec®

14-16
MAY
2013

EASTERN STATES EXPOSITION
WEST SPRINGFIELD, MA
easteconline.com

human ingenuity.
manufacturing brilliance.

To envision a new product, it takes human ingenuity.
To bring it to life, only manufacturing brilliance will do.

Which is why so many East Coast manufacturers – local job shops, mid-level enterprises and multinational OEM's – attend EASTEC. It's where new ideas, technology and processes are highlighted through interactive exhibits, technical education and networking.

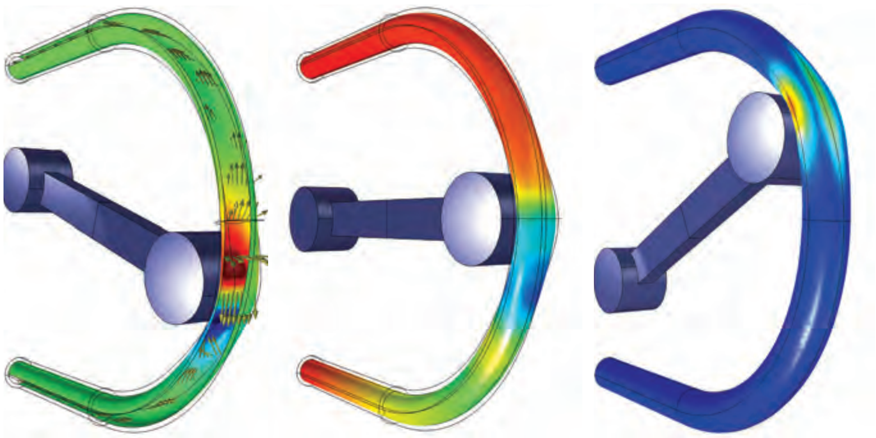
For Exhibiting and Attending Details >

Society of Manufacturing Engineers

AMT THE ASSOCIATION FOR MANUFACTURING TECHNOLOGY

EASTEC is produced by SME

7910_SME ©2013



Flow, pressure and stress results from a COMSOL multiphysics fluid-flow analysis of a peristaltic pump for non-contact fluid flow control. The COMSOL analysis was done by Veryst Engineering. *Images courtesy of Veryst Engineering.*

stand what is actually going on with airflow in the operating room vs. what should be happening theoretically," says Kevin Schreiber, global director of healthcare for Huntair. The simulation allowed the team to optimize the design for minimized turbulence and better control of airflow direction, compared to the rooms' previous horizontal-flow air systems.

Thicker Than Water

As computer processing power has increased, the time necessary to simulate actual human, or in situ, systems has become more manageable. Modeling blood-flow through vascular systems and airflow in pulmonary systems, both including moving boundary conditions, is now possible.

Stephen Cosgrove, CFD director at Altair Engineering, has watched the industry evolve. "What's really opened up the in situ market has been the ability to go automatically from the data—a CAT scan or some sort of digital data—and turn it into something for simulation. The tools have become pretty automatic at giving you, say, an STL file of the vascular system of the aorta or a vein. We've then developed automated tools to go from that geometry to a mesh that's good for your code for simulation." It's a task not handled equally by all simulation packages, he adds, but a specialty of Altair AcuSolve software.

"Generally speaking, the quality of the data you're going to get to make a mesh is pretty poor, so you end up generating a mesh that has poor element quality," Cosgrove explains. "Our AcuSolve code is finite element-based, but it uses a different formulation than other [finite element analysis, or FEA] codes like Fidap and Flotran—a Galerkin Least Squares vs. a standard Galerkin. What that means for the end-user is a high level of accuracy where the accuracy is not a function of the element topology."

He adds that blood is a non-Newtonian fluid and, generally speaking, FE formulations and their handling of gradients are more robust than finite-volume/finite difference approaches. AcuSolve has some very good non-Newtonian capabilities, he says, and supports full bi-directional coupling to SIMULIA Abaqus for FSI analyses without third-party translations.

Analyzing FSI

You may not immediately think of MSC Software as a source of medical CFD solutions, but Derek Barkey, the company's senior manager, consulting services, points out several capabilities that support this field.

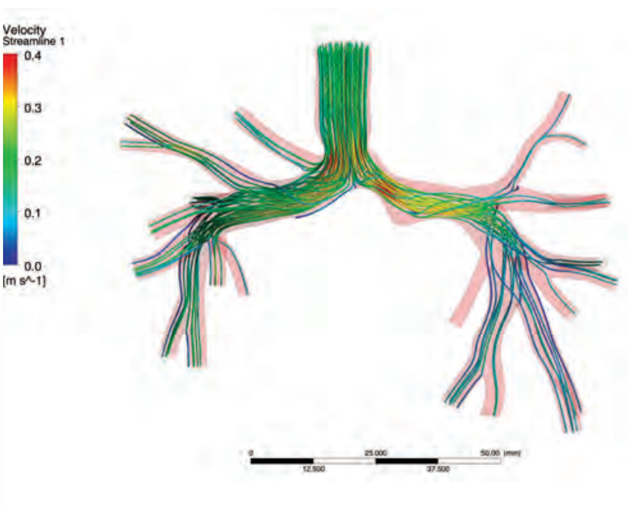
"About four years ago we took the built-in explicit code of the Dytran Eulerian fluid solver and added it to MSC Nastran," he says. "Plus, Nastran has acquired a lot of the advanced material model capabilities from LS-Dyna, under license." These additions, Barkey adds, allow MSC Nastran users to tackle complex fluid simulations.

Nastran also has an interface called OpenFSI, a standardized interface for CFD programs to talk to Nastran and vice versa, allowing the dynamic exchange of fluid forces and structural displacements. This function provides an interface to other CFD codes either directly or through the multiphysics co-coupling interface (MPCCI) developed by the Fraunhofer Institute—the same people who brought you the MP3 interface. Coupling an Eulerian fluid mesh with a Lagrangian structural mesh is Nastran's key to handling FSI.

Barkey points out that the MPCCI is also supported by the company's Marc solver for handling very non-linear problems. From his experience consulting for biomedical applications, he observes, "There's almost nothing in the medical field that is linear. Tissues don't behave in a linear way; just about everything has large deformations, and the Euler solver can handle extreme changes."

Extreme is a good word to describe the challenge of moving from simple pipe models of, say, vascular systems to working with actual patient-scan data, just one of the application areas where ANSYS CFD analysis capabilities are helping real-world physicians. Thierry Marchal, ANSYS industry director for healthcare, says at first computational time was the primary issue. Now, with projects running on hundreds or thousands of parallel processors, analysts using ANSYS Fluent are able to add even patient-specific material parameters.

"The customer can say, 'I want to run a blood flow simulation for a male patient, age 45,'" says Marchal, "then you can add this kind of specific artery-wall blood material property. First, you get more accurate results and second, you can be



Pulmonary artery blood-flow simulation done in ANSYS Fluent CFD analysis software to evaluate surgical options. The goal is to increase blood flow to lungs in children born with only one functioning ventricle. Velocity pathlines simulate the injection of contrast medium in the superior vena cava to allow assessment of blood distribution from the upper body into pulmonary arteries. *Image courtesy of ANSYS.*

much more patient-specific where you test some new device on a whole run of different patients, therefore limiting the number of clinical tests that you will do in the future."

ANSYS Fluent software is also playing a key role in predictive heart surgery, where researchers create virtual reconstructions of different surgical options, combining fluid dynamics results with a simplified model of the rest of the vascular and pulmonary systems. Simulations can actually predict blood flow distribution across the arteries and energy losses at the possible surgical connections. This multi-domain approach allows charting blood flow over time—information that could not be determined by a 3D model alone.

Sometimes surgical procedures require blood flow to be temporarily controlled in a system outside the body, as circulated through a peristaltic pump. This type of unit provides flow control by moving fluid in a tube without contacting the fluid itself. One example is an elastomeric tube squeezed from the outside, with rotating rollers pushing the contents through the tubing, either partially or fully pinching.

Nagi Elabbasi, a consultant at Veryst Engineering, used COMSOL Multiphysics to investigate the effect of pump design variations such as tube occlusion, tube diameter and roller speed, on the flow rate, flow fluctuations and stress state in a peristaltic tube. The problem seemed deceptively simple, but when Elabbasi researched previous efforts, he found little in the literature.

"This fluid-structure interaction was particularly hard," Elabbasi notes, "because you're really squeezing on the tube to practically close it. The more you squeeze, the more demanding it becomes on the solver because the fluid mesh must be moving correctly, not crashing. You start getting backflows, and whenever you start having flows in different directions, it becomes more difficult to converge. But COMSOL Multiphysics was really good at that."

COMSOL Multiphysics seamlessly integrates fluids and structures, with the same interface and capabilities, says Elabbasi, so it's not like putting two packages together. "The post-processing shows the pressure of the solid and the velocity of the fluid as if it's one unified physics, and the moving mesh is also taken care of seamlessly. It's a huge time-saver." He says his company is also working to relate the flow parameters and stresses on the tube with predictions for wear and lifespan.

Simulation for Patient Predictions

Shing Pan, Altair Engineering's senior director of product marketing, solver and optimization products, says there used to be more emphasis on modeling medical devices. Today's focus is more on predictive and preventive medicine. Physicians may not be limited by the data they can gather; rather, they will be able to make predictions based on simulation. The software trend, then, is to sell a shrink-wrapped product for a customized solution—for cardiologists to use, for example.

One more point in favor of CFD simulation: SolidWorks' Genouvrier says her group has been told, "There literally isn't enough blood available for experiments during the product development process." **DE**

Contributing Editor **Pamela Waterman**, DE's *simulation expert, is an electrical engineer and freelance technical writer based in Arizona. You can send her e-mail to DE-Editors@deskeng.com.*

INFO ➔ Altair Engineering: Altair.com

➔ **ANSYS:** ANSYS.com

➔ **Autodesk:** Autodesk.com

➔ **CD-adapco:** CD-adapco.com

➔ **COMSOL:** COMSOL.com

➔ **Dassault Systèmes' SIMULIA:** SIMULIA.com

➔ **Flow Science:** Flow3D.com

➔ **Fraunhofer Institute:** Fraunhofer.de/en.html

➔ **Huntair:** Huntair.com

➔ **MSC Software:** MSCSoftware.com

➔ **Roche Diabetes Care:** Roche.com

➔ **SolidWorks:** SolidWorks.com

➔ **Veryst Engineering:** Veryst.com

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

A Body of Work

From sockets to instruments, AM is thriving in the biomedical field.

BY KENNETH WONG

Additive manufacturing (AM) technology has branched out of its engineering and manufacturing origins into the biomedical field. Today, 3D printers are printing out surgical instruments and prosthetics; in the future, if technological and regulatory hurdles can be overcome, they could even be churning out human tissues and organs. What follow are two very different examples of the state of this art.

David Sengeh: Helping His Homeland

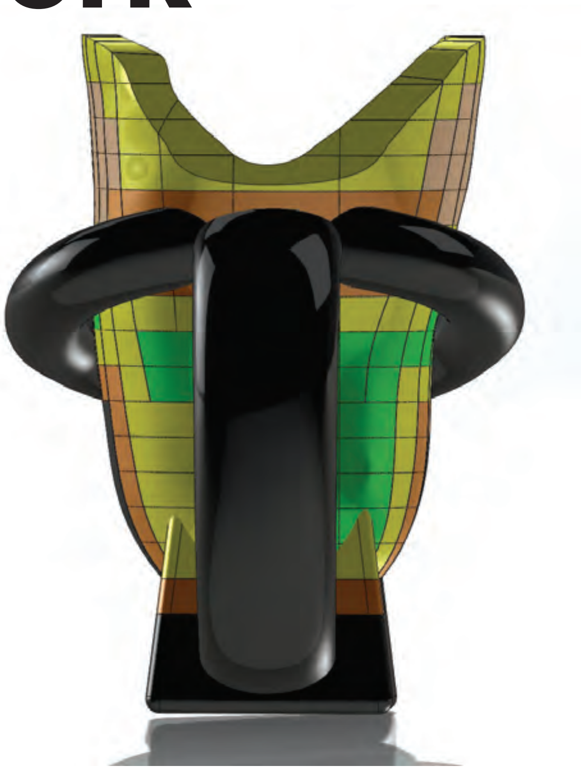
In Sierra Leone, the scars of the civil war that lasted from 1991 to 2002 are still on full display among the population. The decade-long conflict claimed approximately 50,000 lives[1]. During the war, soldiers from the Revolutionary United Front used amputation as a way to terrorize people, leaving an estimated 4,000 to 10,000 Sierra Leoneans with missing limbs[2]. Very few of these survivors have ever heard of the term "additive manufacturing (AM)"; even fewer could have envisioned machines that can literally print prosthetic pieces. But regardless of whether they know about it, they stand to benefit from the research of David Sengeh, a doctoral student at the MIT Media Lab working with 3D printers.

Sengeh discovered that getting prosthetics made for the Sierra Leoneans was easier than convincing them to wear them. "After speaking to them, I realized that they didn't want to wear [the prosthetics] because they're uncomfortable," he recalls.

Sengeh says he believes the biggest obstacle to comfort is the socket that joins the artificial limb to the body. Extended use of a prosthetic invariably puts pressure, tension and friction on the bare stump that rubs against the artificial piece; therefore, if the socket doesn't adequately address these factors, atrophy sets in, creating discomfort.

Sengeh is looking at 3D printers as a solution. The latest advances in the technology have produced machines that are capable of printing with multiple materials, comprising different tensions and strengths. It could be just what's needed to create sockets with comfortable fit, each tailored to the individual victim with the right geometric profile and sensitivity.

In addition to his biomedical study, Sengeh has another motivation—a more personal one—to help the survivors



David Sengeh, a doctoral student at the MIT Media Lab, used SolidWorks and MathWorks MATLAB to design and virtually test the prosthetic sockets to improve their comfort for amputees.

Sengeh used the Objet Connex 500 3D printer to create sockets that are customized for each patient based on an MRI scan. The printer's ability to work with multiple materials with different stiffness and flexibility increases the socket's comfort.

of Sierra Leone. He grew up in Bo, the country's second-largest city. The conflict that left many Sierra Leoneans without arms, legs, noses and ears also robbed Sengeh of two uncles.

An Integrated Approach

In Sierra Leone, prosthetic sockets are typically molded out of polyurethane. It's an efficient, inexpensive manufacturing method for high-volume production. But the resulting sockets are rigid, which discourages amputees from wearing them for extended periods.

Sengeh's idea is to produce sockets that are customized to each patient's anatomy based on an MRI scan. The process allows him to create sockets that perfectly match the patient's bone protrusion. He uses SolidWorks' mechanical modeling software to create the geometry, and MathWorks MATLAB to study the impact of stress and pressure. For producing these one-of-a-kind sockets, Sengeh relies on a mixture of 3D printing and traditional manufacturing methods.

The pieces that sit close to the patient's bare skin and bone are better produced in 3D printing using flexible, rubberlike materials. Stronger pieces that serve as structural supports could be produced using conventional manufacturing methods, like injection molding or machining.

Faculty and students of the MIT Media Lab worked with 3D printing system supplier Objet (the company merged with Stratasys in December 2012). Sengeh has access to an Objet Connex 500 printer. As part of its material repertoire, the company offers MED610, a biocompatible material intended for uses involving "prolonged skin contact of over 30 days and short-term mucosal-membrane contact of up to 24 hours," according to Stratasys. The company also offers a Tango material family, which has rubberlike flexibility. The use of digital material in Objet systems allows Sengeh to create parts made up of multiple materials with varying stiffness and strength.

"Objet parts are pretty flexible," notes Sengeh. "We've been able to show that they have remarkable reduction in pressure on different parts of the body."

Ideally, Sengeh says, he would like to be able to print with a wider range of materials to produce parts with "super-thin, super-flexible" structures with different stiffness to mimic human muscles. He hopes AM system suppliers can make that happen.

Sengeh's socket mounted on a prosthetic leg. Sengeh hopes the improved comfort will convince more amputees in his homeland, Sierra Leone, to take advantage of prosthetics.

Empowering Technology

Sengeh gets inspiration from his boss, Dr. Hugh Herr, head of the Biomechatronics Research Group, MIT Media Lab. Herr is a double amputee, the result of a climbing expedition that went awry.

"But he's not disabled," Sengeh points out. "He lives his life the way I live mine. His is probably even more exciting, because he still goes mountain climbing, running—things I don't do."

Herr is outfitted with computer-controlled bionic limbs, one of the Top 10 inventions for health featured in *TIME* magazine in 2004.

Socket comfort is important not just for Sierra Leoneans, but for anybody who has lost limbs and must wear prosthetics, Sengeh says: "It's about changing the paradigm of disability. If the users feel comfortable, they'll able to take on a wide range of activities … They can walk, run, do normal things like the rest."

3D Printing Moves into Production

Tom Weisel, president of Ventura, CA-based Arch Day Design, is also deeply involved in developing medical devices with 3D printers. Weisel and his colleagues rely on a 3D printer from Stratasys to create true-scale prototypes when they develop new devices. They used to rely on 3D-printing service bureaus to print their designs, but the typical three-day turnaround was stalling their design cycles. So they purchased an Objet Desktop unit for in-house use.

"We wanted to cut the three days down to three hours," Weisel says, noting that now, if the Arch Day design team comes up with an idea in the morning, they could be holding the 3D-printed model by late afternoon.

When Weisel suffered a soft-tissue tear on his shoulder, he was in need of corrective surgery. Because he worked closely with doctors, he had no trouble identifying top talent in the field. In post-operation chitchat, he happened to ask the doctor for the brands of the instruments involved. As it turned out, the Arch Day Design team had designed the stitching system and anchoring device used in the operation.

Print Me an Endoscopic Piece

For Weisel and his team, real-world testing of an idea means trying out 3D-printed surgical instruments and medical devices for their cadaver labs. That's where they invite doctors to experience the reach, comfort, ergonomics and effectiveness of prototyped devices (say, a new pair of surgical scissors) and collect feedback.

"We have to put something in the doctor's hands to try out an idea," Weisel says. "They're performing cutting, stitching, sewing; they're manipulating something in a human body."

For example, in certain operations, the doctor needs to pound on the instrument with a hammer. It's a process that a virtual CAD model cannot satisfy—only a tangible physical prototype would do. In strength, the 3D-printed prototypes are not an exact match to the finished metal pieces, Weisel notes, but with a careful choice of material, the printed parts offer a good representation in stiffness and profile—enough for lab tests.

Arch Day Design chose Objet's Alaris 30 desktop printer model "because it gives us the accuracy we need at a cost point we can afford," says Weisel. 3D-printed prototypes for endoscopic tips can be as small as Tic Tac breath mints. Larger pieces could be the size of a coffee cup. The Alaris 30 satisfies the need for both ends of that range, Weisel says.

The firm used to farm out its 3D printing jobs to service bureaus, at a cost of $200 to $2,000 each. The cumulative expense of those jobs over time was significant enough to justify the purchase of the in-house machine, a roughly $35,000 investment. Weisel points out that the time savings—"cutting down a three-day wait to three hours" on each print job—was the real justification for the purchase. Without the usual wait time for outsourced print jobs, the in-house 3D printer allows designers to try out three to five times more iterations, he says.

A Perfect Fit for the Biomedical Field

At the booth of AM manufacturer EOS at the recent Pacific Design & Manufacturing / Medical Design & Manufacturing West Conference (PD&M/MD&M West) in Anaheim, CA, a micro-targeting device currently used in the operating room for deep brain stimulation was on display. Andy Snow, EOS' regional director for North America, notes that "these are patient-customized devices, FDA-approved for integrated targeting and deep-probe biopsy."

AM's penetration into the biomedical market began with pre-surgical models (used in the planning of surgeries), custom hearing aids, and dental structures. That's according to Tim Caffrey, associate consultant at Wohlers Associates, who adds that "MRI or CT scan data can go straight to a 3D printer relatively easily. They're mostly point cloud data, which can then be turned into surface models in software like Geomagic."

In conventional manufacturing, the production methods are developed to create hundreds of thousands of identical units. By contrast, biomedical application usually requires one-of-a-kind objects (each pre-surgical model, hearing aid, or dental mold is customized for the individual patient). With its capacity to speedily build 3D profiles based on digital geometry, AM is uniquely positioned to address the needs of biomedical industry in a way that conventional manufacturing cannot.

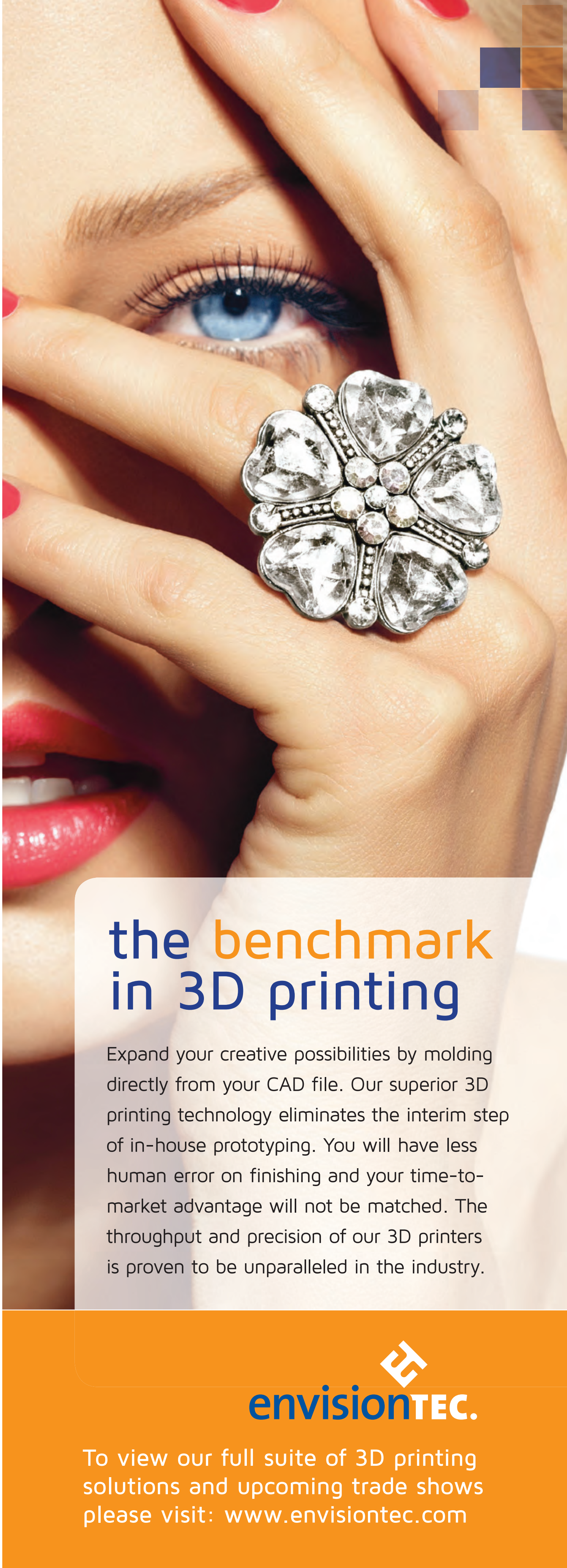
David Cox, founder and CEO of AM systems distributor Purple Platypus, observes that 3D printers' biggest advantage is speed.

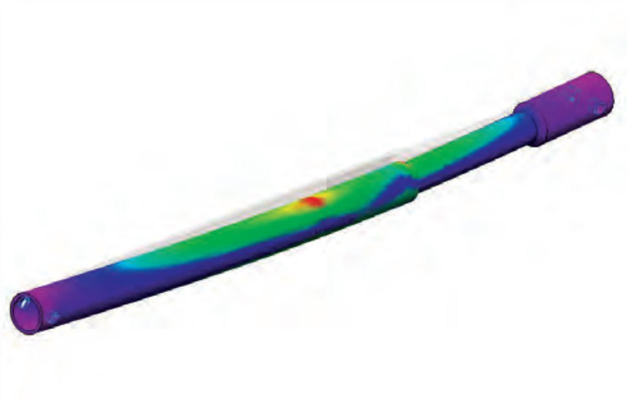
"You can move from a computer file to an in-hand part, potentially in the space of a few hours, without massive outlays for a mold and/or tooling costs," he says. "For prosthetics specifically, 3D printing is extremely valuable because it allows the designer the flexibility to customize specific fixtures.

"Multi-material printing that mixes rubber-like flexibility with rigid, plastic-like materials allows engineers to create overmold devices with varying shore values or durometers," Cox adds. "In an industry that creates medical devices, this is an incredible advancement that helps with ergonomic testing."

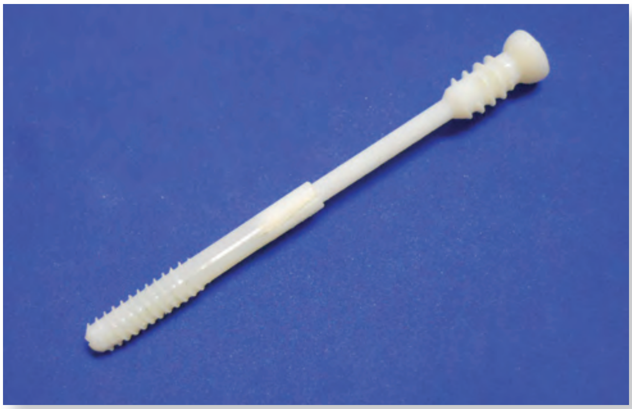
The AM industry has also done much to meet the requirements of biomedical regulatory bodies (the U.S. Food & Drug Administration for example). Wohlers' Caffrey notes that is especially true in developing materials and processes that are acceptable for producing implants. It elevates the use of AM in biomedical from a prototyping technology to a full-scale production system.

At the PD&M/MD&M West show, also on display in EOS's booth were titanium hip cups. "There are FDA-approved hip cups on the market that are manufactured using





Arch Day Design, a medical device manufacturer, uses software-based stress analysis to study the strength of a new screw, but the digital model is not sufficient for lab tests.



The use of an in-house Objet Desktop 3D printer allows Arch Day Design to create physical prototypes in a matter of hours. If the design team has an idea in the morning, the team can be holding the physical mockup by late afternoon.

Issues with 3D-Printed Tissues

Tissue printing seems to be a bit over-hyped at present. Machines that claim to be tissue printers are rather low-grade machines in terms of technology and resolution. There are a couple of groups making some real progress. A key figure is Dr. Dietmar Hutmacher, Queensland University of Technology, Brisbane, Australia. We are still at a very early stage in the technology. Most likely, the initial applications will be applications in joint prosthetics and maxillofacial (fixing problems around the mouth, jaw and neck).

No one is actually printing tissue yet. The main issues are the materials that are needed to hydrogel polymers and the fact that they need to be maintained and saturated with water. If you are trying to print tissue, all processes must be at temperatures no greater than body temperature (98.6° Fahrenheit) and totally compatible with the well being of cells. That means no toxic chemicals—including many photoinitiators. Also, all materials must be medical grade, which tends to be more expensive and more difficult to process.

The biggest challenge for AM system developers to overcome in bio-printing is, everything must be compatible with good manufacturing practice (GMP) regulation, which is a very rigorous quality control, much more severe than ISO 9000. Plus, the software needs to cope with multi-materials and internal architecture. The design of the object must be compatible with a bioreactor to incubate construct before implanting.

—Dr. Brian Derby, Professor of Materials Science, Director of Research and Deputy Head of School, School of Materials, University of Manchester, UK

EOS technology," Snow says.

The titanium powder material used for printing these hip cups, Snow says, "comes from an FDA-approved supply chain." For medical use with titanium material, EOS recommends the M 280 model, the direct metal laser sintering (DMLS) system. For use with plastic materials, EOS recommends the P 395 midrange model.

"Hundreds of patients in North America are now living with hip cups embedded in their hips that were 'grown' via EOS' DMLS," Snow adds. "This is not just prototyping technology anymore. It's now in production use." DE

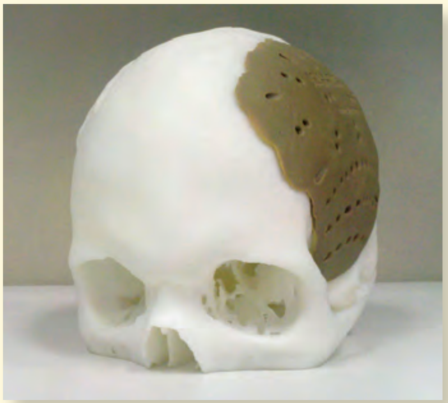
References:
1 A Dirty War in West Africa, Lansana Gberie, Hurst 2005.
2 "Disabled in Sierra Leone Make Gains," Dec. 7, 2011, Global Post, globalpost.com

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 → **Arch Day Design:** ArchDayDesign.com
→ **Dassault Systèmes:** SolidWorks.com
→ **EOS:** EOS.info
→ **Geomagic:** Geomagic.com
→ **MathWorks:** MathWorks.com
→ **MIT Media Lab:** Media.MIT.edu
→ **Purple Platypus:** PurplePlatypus.com
→ **Stratasys:** Stratasys.com
→ **Wohlers Associates:** WohlersAssociates.com

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

3D-Printed Implants Approved by FDA for Bone Replacement



Oxford Performance Materials (OPM) has received FDA approval for its OsteoFab biomedical process. "OsteoFab" is OPM's brand for additively manufactured medical and implant parts produced from PEKK polymer. OsteoFab uses an EOS P800 and PEKK material to build cranial implants. The implants can be used to repair damage and trauma to the skull, replacing missing bone and integrating with surrounding bone.

OPM's process has already been in use overseas, but this marks the first time the FDA has given approval for AM-created implants to be used in humans in the US. OsteoFab can now be used to treat a variety of patients, including veterans who have suffered severe head trauma. Approval also opens the door for other uses of AM implants.

"If you can replace a bony void in someone's head next to the brain, you have a pretty good platform for filling bony voids elsewhere," said Scott DeFelice, president of OPM. "We have sought our first approval within cranial implants because the need was most compelling; however, this is just the beginning."

OPM had traditionally sold PEKK as a raw material or in a semi-finished form, but began developing additive manufacturing technologies in 2006. In 2011, OPM established a biomedical compliant manufacturing facility in South Windsor, CT, to support its growing AM business. As an implantable polymer, OPM says PEKK is unique in that is biocompatible, mechanically similar to bone, and radiolucent so as not to interfere with X-Ray equipment. Furthermore, OPM has recently completed testing which it says confirms that the OsteoFab implant surface is, in fact, osteoconductive, so it can be used as a scaffold for new bone growth from the native bone.

Simulation **Grows** in Medical Importance

Today, the methodology is recognized by the U.S. FDA as essential to medical device evaluations.

By CHer yl l iu

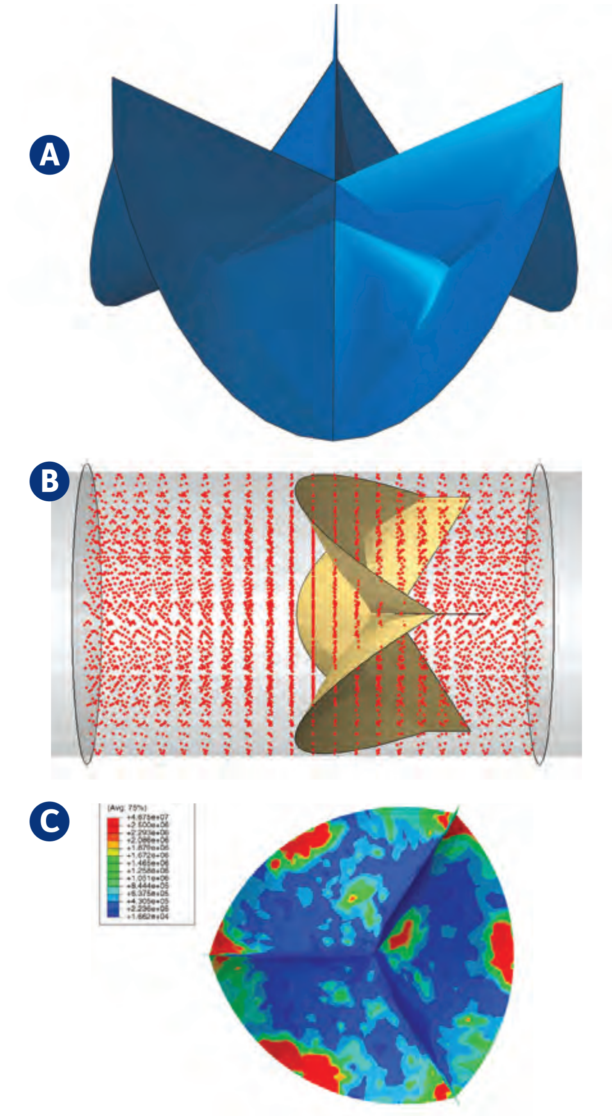
One of the toughest design engineering challenges is making a medical device that works flawlessly with the human body. The unique anatomy and physiology of every patient create physical complexities—and ever-shifting functional parameters, that must be thoroughly accounted for when producing a therapeutic product that may need to last a lifetime.

Domestic inpatient procedures involving medical devices—stents, heart valves, dental implants, spine and joint implants, surgical tools, blood pump, endovascular grafts, drug-eluting devices and more—totaled 46 million in the U.S. alone in 2006, according to the U.S. Centers for Disease Control (CDC). It's a global market that is growing along with aging populations everywhere.

Medical device companies and their designers are increasingly viewing computer simulation, already widely accepted in many industries, as an important tool. It helps them visualize what they cannot see, explore the design space more fully, refine their ideas faster and more accurately—and reduce expensive prototyping and testing.

Solid mechanics simulations can help determine proper implant size, evaluate manufacturing tolerances, compare design geometries or consider next-generation devices. Computational fluid dynamics (CFD) can be employed to identify high-shear stresses on blood vessels, regions of low flow, and potential for blood damage. And simulation-based product development processes can be linked in automated workflows—optimizing huge quantities of design data to provide fine-tuned results that are of particular value for creating patient-specific medical devices.

As life sciences engineers embrace simulation, they are achieving increasingly accurate levels of precision when evaluating device function, including the ability to evaluate aspects of device performance not possible with bench tests alone. As a result, the U.S. Food and Drug Administration's (FDA's) Center for Device and Radiological Health (CDRH) is seeing a growing number of submissions for medical devices that include a simulation-data component.



Figu r e 1: This example of modeling and simulation of a medical device shows an aortic valve geometry (A), a model of the effect of blood fl w on the valve in a blood vessel (B), and an Abaqus FEA of the stress on the valve leafl ts during the diastolic phase (C). This work was performed by Dassault Systèmes SiMuLiA in conjunction with the FDA's Center for Devices and r adiological Health.

The CDRH is responsible for regulating firms that manufacture, repackage, re-label and/or import medical devices sold in the United States. The submissions for these therapeutic devices typically contain data from four types of evaluation models—animal, bench, computational and human—to demonstrate a reasonable assurance of safety and effectiveness.

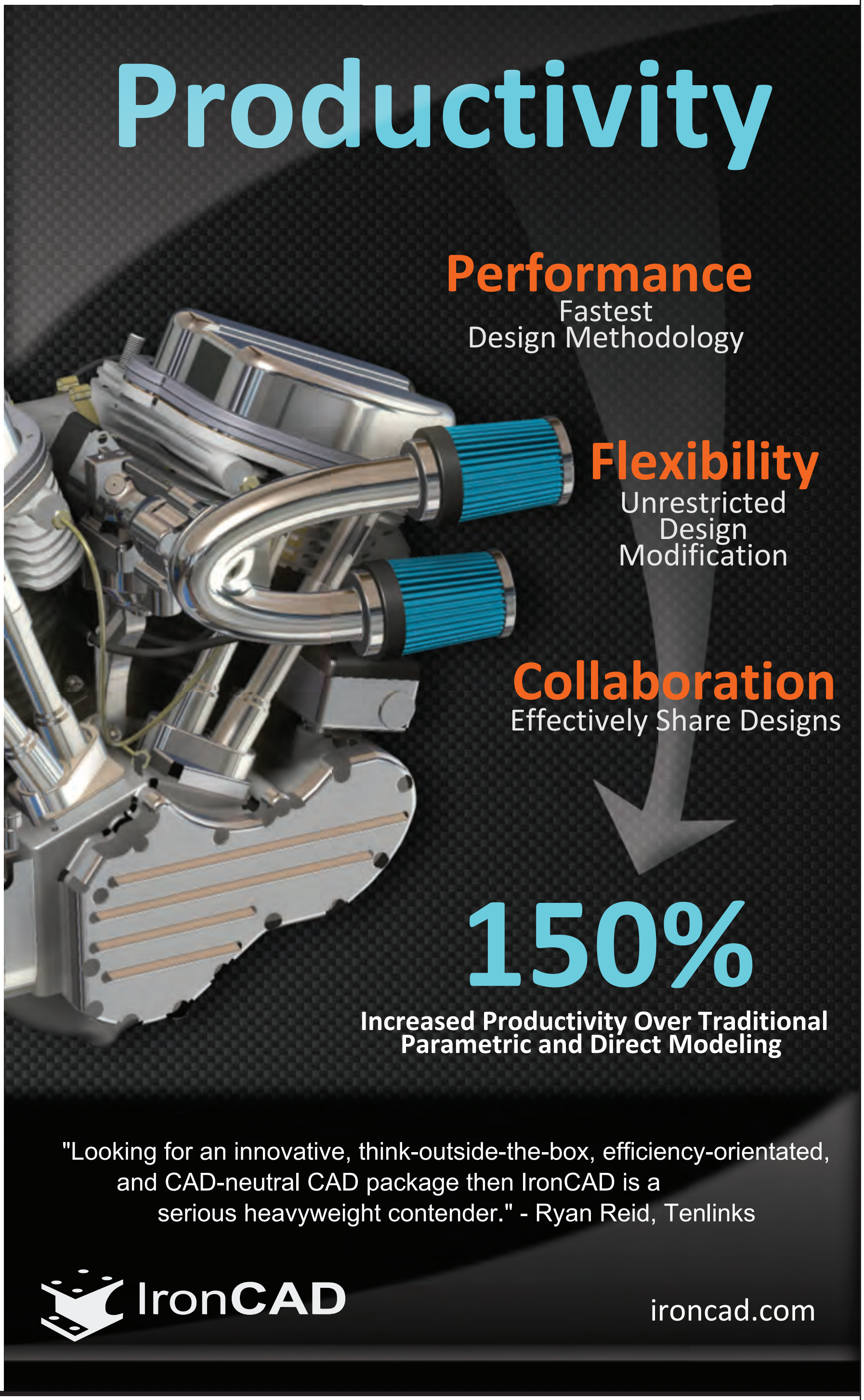
When a company submits simulation metrics that supplement bench testing, this can help promote approval by demonstrating both the integrity of the proposed device and the required realistic device failure analysis. As the ultimate safety-and-effectiveness regulatory body between medical device manufacturers and patients, the FDA recognizes the value of such advancing technologies—and its own need to stay abreast of them. The agency has now begun actively encouraging the use of simulation in device evaluation.

However, the FDA has also put the industry on notice that verification and validation must go hand-in-hand with the use of simulation in applications. The CDRH is looking to quantify when a computational model is credible enough, and that its intended purpose is appropriate for a regulatory submission. Unclear reporting standards, insufficient data about geometries and boundary conditions, lack of validation metrics, incomplete understanding of physiological loads in the body, and variations in patient populations—any and all of these uncertainties can impact the relevance of simulation outputs.

SIMULIA Contributes to Knowledge Advancement

Noticing that a significant proportion of the applications the agency has seen in recent years have included simulations with Abaqus finite element analysis (FEA) from Dassault Systèmes SIMULIA, the CDRH reached out to SIMULIA in 2010 for support in developing its own internal framework, and in-house expertise, for validating and regulating industry-submitted simulations.

SIMULIA presented at the FDA's third workshop on Computational Modeling of Medical Devices the same year. It continues to deliver on-site training courses to FDA reviewers about best practices in modeling and simulation, and to partner with the FDA on aortic valve model development (see Fig. 1). The FDA has also presented at the SIMULIA Community Conference and Regional User Meetings.



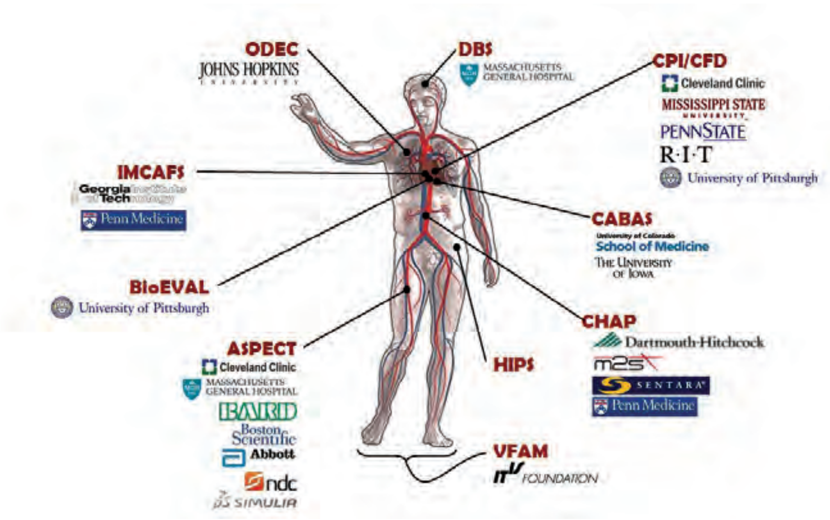


FIGURE 2: Broad cross-industry collaboration among medical device manufacturers, academia and software companies is being harnessed for the FDA's Virtual Physiological Patient project.

Realizing the importance of model verification and validation (V&V), in early 2011, ASME and FDA launched the V&V 40 subcommittee to develop V&V guidelines for the medical device industry specifically; SIMULIA is actively participating, along with others in the industry and software communities.

As one outcome of these efforts, this year the FDA will publish a guidance document titled "Reporting Computational Modeling Studies in Medical Device Regulatory Submissions." Appendices will cover fluid and mass transport, solid mechanics, electromagnetism, control loops, thermal transport, and ultrasound. Publication date updates can be found on the CDRH website at FDA.gov/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/default.htm.

The 'Virtual Patient' Idea is Born

As knowledge about the importance of simulation grows, another priority for the FDA is the creation of a publicly available "Virtual Physiological Patient" of human body computer models in different disease states (see Fig. 2). This is not intended to be a single model encompassing every function and disease at once. Rather, the project will comprise a library of verified and validated submodels and data based on the combined expertise of those groups in the relevant disciplines—cardiology, orthopedics, software and so forth.

The goal of the Virtual Physiological Patient project is a shared point of reference that will improve understanding of model attributes and limitations, and provide discrete models, data and simulations validated for regulatory evaluation. Peer review by experts in academic, government and industry will ensure robust V&V, and provide periodic assessment. SIMULIA is contributing expertise to a group that is developing a computational model for the evaluation of a diseased femoral artery for stent evaluation.

The FDA views modeling and simulation as incentives

MDIC PARTNERSHIP BENEFITS ALL

Concurrent with the development of the Virtual Physiological Patient concept, the U.S. Food & Drug Administration (FDA) is reaching outward to device manufacturers, software providers and medical professionals to form a Regulatory Science Public-Private Partnership. Launched in December 2012, the partnership is called the Medical Device Innovation Consortium (MDIC). Specific details are available at DeviceConsortium.org.

The idea is to create an opportunity for information gathering in a pre-competitive state—that is, not device-specific, but disease-specific. For example, if the heart valve community were interested in a comprehensive evaluation of the structure and function of heart valves, costs could be minimized through non-profit group funding and participation in the development of tools and resources for modeling and simulating of a range of valves. All results would be shared.

End-stage renal disease is another area recently identified by the FDA as a priority. Industry forums on this topic are already under way.

The medical device industry can only benefit from such endeavors. Individual device design copyrights certainly need to be protected, but the tradition of publishing evidence-based research results to move the entire body of medical knowledge forward has resonated in the life sciences throughout the history of medicine. A deep understanding of the function of the living body is critical to every medical-device developer, and sharing the data that lie at the core of that understanding can be accomplished without infringing on any one company's patents.

— C. Liu

to innovation that can reduce the time and cost of device design, assessment and manufacturing. It is the best interests of the medical device industry, the regulatory agency and software companies to collaborate to ensure that the power of simulation is increasingly utilized to solve the wide range of challenges in medical device development. The ultimate goal is the safety and effectiveness of medical devices for every physician who uses them, and every patient who needs them. **DE**

Author's Note: *Special thanks to Drs. Tina Morrison, Nandini Duraiswamy and Donna Lochner of the FDA for their assistance in preparing this article.*

Cheryl Liu *is life sciences senior product experience technical specialist for Dassault Systèmes' SIMULIA. Send e-mail about this article to DE-Editors@deskeng.com.*

INFO ➜ U.S. Food & Drug Administration: FDA.gov

➜ Read more about how the FDA is promoting innovation in "High Stakes Balancing Act" in Dassault Systèmes' COMPASS magazine: CompassMag.3ds.com

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

SURGERY SIMULATOR CLEARED

In addition to approving the use of simulation in medical device evaluations, the U.S. Food & Drug Administration (FDA) also recently cleared Surgical Theater, LLC's Selman Surgery Rehearsal Platform (SRP), making it the only patented and FDA cleared platform for cerebral and spine pre-surgery rehearsal, according to the company.

Using standard scanned images from any patient, the SRP generates 3D patient-specific models showing the interaction between life-like tissue and surgical instruments. The tissue responds "realistically" to actions taken by the surgeon, enabling accurate pre-surgery planning and rehearsal. The software uses flight simulator technology to permit the remote connection of multiple SRPs so participants anywhere in the world can simultaneously work together and practice the same case with real-time feedback and collaborate on the planning of a specific surgery case.

For more information, visit surgicaltheater.net.

—DE staff

Precision is Everything

Yes, it is brain surgery ... so FHC switches to EOS' plastics laser-sintering system to manufacture the patient-specific STarFix platform.

BY LYNN MANNING

The patient lies wide awake in the operating room (OR), the top of his draped head bared to the neurosurgeon. A second doctor stands at the patient's side, lifts the man's arm, and flexes it gently. The hand and wrist are stiff, with a visible tremor. The surgeon makes a slight adjustment to brain-penetrating electrodes mounted through a starburst-shaped plastic fixture fastened to the man's skull.

"How about now?" the surgeon asks.

The arm is moved again—this time naturally, smoothly, without shaking.

"That's it," says the patient, nodding his head with relief.

The procedure is called deep brain stimulation (DBS), and it is has become a lifestyle-saver for people suffering from Parkinson's disease, essential tremor, dystonia and other neurological afflictions that don't respond sufficiently to medication alone. Recent studies even point to DBS' potential in treating dementia, epilepsy and depression.

What makes the story above such a standout is not so much the symptom-relieving surgery—but that the patient was able to move his head during it.

That simple movement is the result of some truly "outside-the-frame" thinking in the concept of brain surgery. DBS, while performed effectively approximately 9,000 times a year worldwide, has traditionally involved many grueling hours of awake imaging, target identification and electrode implantation—all with the patient's head completely immobilized. But now the frameless stereotactic platform is being used in a growing number of DBS procedures around the globe, thanks in part to a Formiga P 100 plastics laser-sintering system from EOS.

MORE ➜ deskeng.com/articles/aabjkd.htm

➜ For more application articles, visit deskeng.com/fastapps

DE Desktop Engineering

Desktop Engineering Congratulates MSC Software on its 50th Anniversary!

MSC Software A NEW ERA BEGINS

50 YEARS OF INNOVATION

Join us as we celebrate our 50th Anniversary.
Be inspired as we share our vision of technology's future.

In February 2013, MSC Software achieved a major milestone: the company celebrated half a century of driving engineering simulation innovation forward. With new products, new advancements in technology and a new surge of inspiration, MSC continues the tradition of helping engineers around the world to design, develop and analyze their products with certainty.

2013 USERS CONFERENCE
May 7-8, 2013
Hyatt Regency - Irvine, California

Experts will gather to share knowledge, best practices and strategies for developing products that meet the ever-increasing pressures of time, cost, quality, and performance. Topics will range from materials engineering and systems simulation to fatigue and nonlinear analysis.

Register Today! Visit:
www.mscsoftware.com/conference-2013

The Art of *Idealization*

There's an incorrect tendency to think of a highly detailed CAD model meshed with a large number of elements as the "real" structure. It is important to remember that every FEA is an idealization of the real world.

By Tony Abbey

Editor's Note: Tony Abbey teaches the NAFEMS FEA Intro class in the United Kingdom and United States throughout the year. Contact tony.abbey@nafems.org for details.

Idealization in finite element analysis (FEA) is the art of taking a real structure and reducing it down to an assembly of finite elements. At its simplest level, the operation would consist of a single geometric model produced from CAD and fully meshed in one operation. This gives us a consistent mesh throughout the structure that we hope will adequately represent the response of the real structure.

The FEA method relies on a set of discrete finite elements to represent the structure. Each element has its own basic "understanding" of what constitutes a structural response. This may be a very primitive representation, such as a 1D rod with a constant axial force, or a sophisticated 3D element. The discrete representation suffers from two fundamental weaknesses: By definition, it can't be a continuous representation, and it is also reliant on the accuracy of the element. Most elements are now mature, stable entities—but their performance and limitations should still be understood.

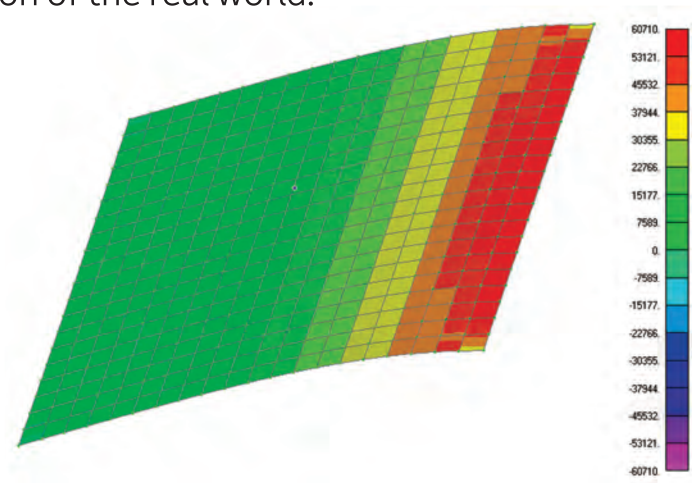


Figure 1: Top and bottom fiber stresses under bending

Why not just use 10 million elements?

If we have elements that are sufficiently accurate and we can put sufficient numbers in, is there any need to idealize?

Well, there are quite a few reasons why we may want to consider idealization in favor of just pouring elements into CAD geometry. The first question to ask: Is the CAD geometry an adequate representation of the structure?

By many definitions, the CAD geometry is the structure, so it may seem a surprising question. However, what we are really asking is: How does the structure respond, and will the geometry be able to support elements that best simulate that response? Solid elements may not be adequate unless we use unfeasibly large numbers.

In a static analysis, the structure has applied external loading and develops internal load paths to carry this to an adjacent structure or to ground. Understanding of the load path can be quite tricky.

The definition of the load application and grounding regions are also an idealization judgment. The internal load path will be affected by our choice of element type and numbers. If we make poor choices, we may find that the FE model doesn't behave in the same way that the actual structure will.

2D Shell Elements

A classic example is a structure that is relatively thin and is designed to transmit bending loads. Water tanks, building floors and walls, ship hulls, aircraft wings and fuselages are common examples. A stress gradient exists through the thickness of the shell or plate. If we use Engineers Theory of Bending and Shear through a plate or beam, we can visualize what this stress distribution looks like. There are a class of elements that are designed specifically to handle this type of structural configuration and its structural response. These are the 2D plate elements that are found in most FE solvers.

So we have a structural configuration, a structural response and an ideal element to handle it. The difficulty arises in that the element is a purely 2D entity. It means

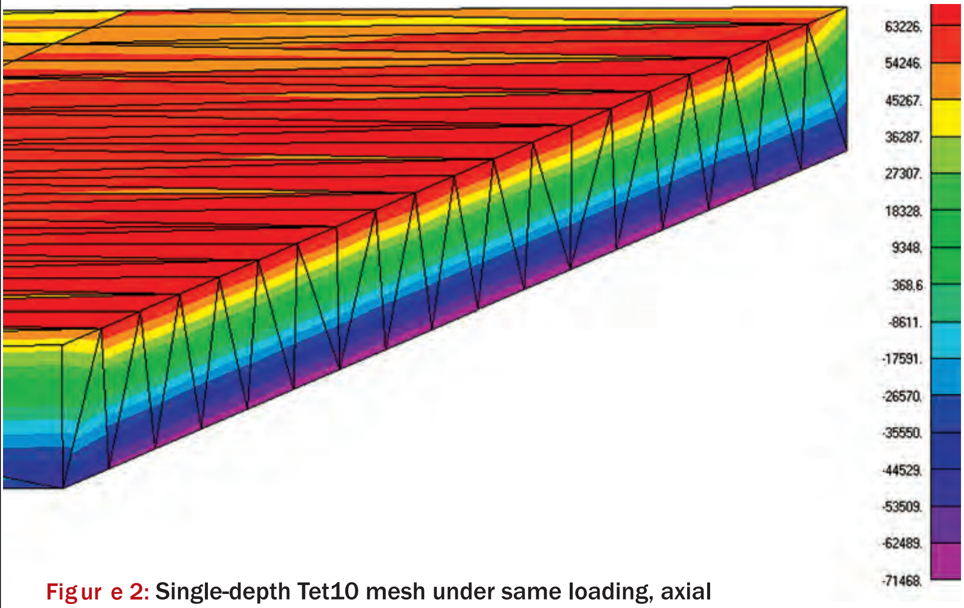


Figure 2: Single-depth Tet10 mesh under same loading, axial stresses.

we have to think about idealizing from 3D geometry to 2D layout.

If the structure comprises all thin shell or plate, then there are relatively straightforward procedures to shell mesh. This may involve using mid-surfaces, inner mold lines or outer mold lines as the datum plane on which to put the shell mesh.

If the geometry is straightforward and the component count is low, this can be done fairly quickly. However, many structures are a complex intersection of components, such as pressure walls, internal ribbing, supporting structure, etc. It can become rapidly more labor-intensive to mesh such a structure.

Fig. 1 shows a simple plate structure, cantilevered from one edge with a pressure distribution. A shell mesh gives a peak bending stress and tip deflection very close to theory.

Fig. 2 shows a Tet10 mesh that gives good deflection values, but poor stress values. The mesh is only one element deep. To get accurate stress values, the element mesh needs to be about three deep. To avoid high aspect ratios, this drives the element count up toward 1 million, vs. 400 for the shell mesh.

If the structure has regions that are "thick"—where solid elements are ideal—and some that are relatively "thin," where shell mesh is preferred, we have to now mix the meshing types. Many engineers don't like to do this, because of the difficulty of dealing with the mismatched elements.

Special precautions are needed when putting solid elements adjacent to shell elements. Shell elements have six degrees of freedom (DOF) at each node, and the solid elements have three DOF at each node. For common nodes connecting the element types, this means that we have a piano hinge created. The connecting solid cannot transmit bending or torsion.

There are ways around this issue, such as overlapping shells onto solids, special connector elements allowing transmission of the moments, and linear glued contact regions to bond an overlapped dissimilar mesh. However, they require additional effort to plan and set up.

1D Beam Elements

Sometimes the structure is predominantly a flexural or torsional member—in other words, a beam type of structure. Examples include drive shafts, bridge girders, stiffeners and frames. In these cases we again have a class of elements ideally suited to this type of structural response and load path—beam type elements. They are 1D in nature, and we are using them to idealize a 3D real structure.

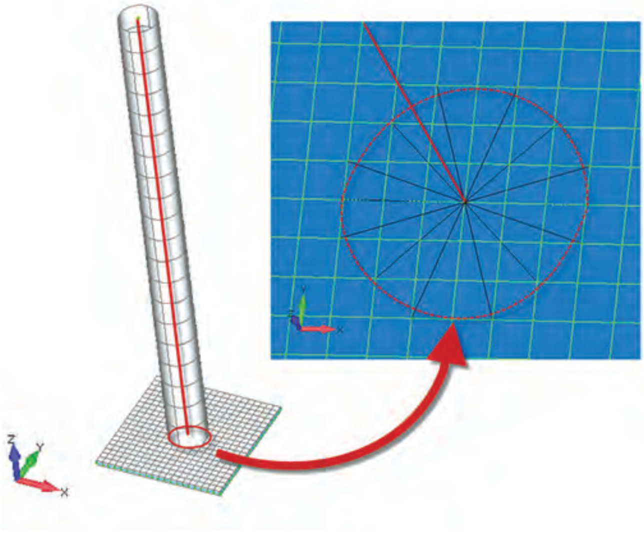
If, for example, we are looking for an overall assessment of strength and stiffness in a fabricated truss roof, it would be difficult to justify going to 3D solid elements. The geometry may well be a 3D CAD model, but if we were to mesh with 3D elements, the element count could rapidly become excessive.

Techniques for modeling such a structure with 1D beam elements are well established. We would typically take the centroid of each component cross-section and use that as the datum for our 1D element. Fig. 3 shows a simple beam structure modeled in 1D, with its base connected to a shell region via a spider element.

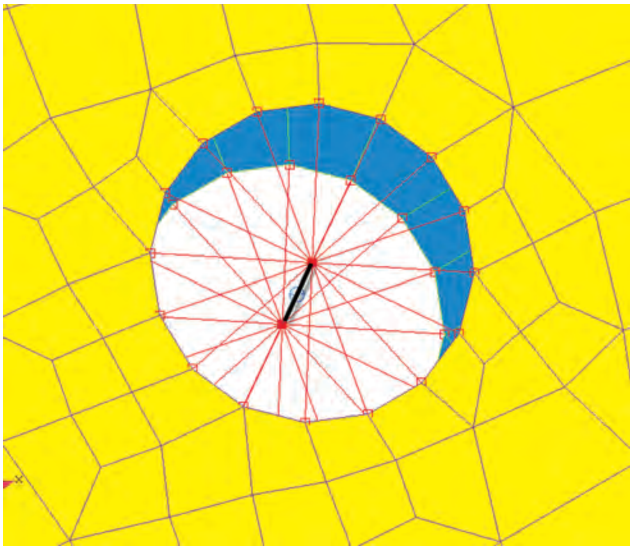
For a general structure, we may have a mix of beam-like, shell-like and solid regions. Fig. 3 shows a mix of 1D and 2D. This is often where a beam representation is avoided in favor of a full solid mesh.

For example, I have seen the rudder and rudder shaft of a ship fully modeled with solid. This gave nearly 2 million DOF in total, with half going to the rudder shaft and half to the fabricated rudder.

The shaft is an inappropriate use of solid elements. The shaft is fundamentally responding in bending and torsion. What do we want from the structural analysis of the shaft? A shear force bending moment and torque diagram. This tells an engineer everything he or she needs



Figur e 3: A 1D beam element.



Figur e 4: 1D/2D idealization of a bolted joint in a plate.

to know about the response of the shaft. Having a solid component of 1 million DOF really doesn't help us.

We can look for hotspot stresses and hopefully these will be meaningful, but if we have many load cases and want to justify why and where these hotspots are occurring, then we are in for a lot of work. We essentially have to backtrack to the shear force, bending moment and torque diagram in each case to demonstrate how the stresses occur and confirm their values. We have made a very straightforward task complex.

Connection Elements

Another common problem with a predominantly thin shell structure is how to represent the joints or connections. The CAD model will probably not attempt to represent welds as continuous geometry. It is quite adequate to define the connecting plates and to indicate the weld symbolically.

We don't need to have a 3D geometric CAD representation of, say, a partial penetration fillet weld. However, when we want to create an FE model, we have to put in a structural idealization of the load transfer path through the weld. It may be that the best way to calculate stresses locally in the weld is to do this outside of the FEA, using local stresses or forces in an external program.

Similarly, we don't want to model all of the bolts, rivets, etc., as solid elements. Fast and efficient ways of idealizing bolt stiffness and strength are available using beam elements and the very versatile "spider" connection and load distribution elements. Fig. 4 shows a spider element and beam elements being used to transmit load through a bolt.

Spider elements are useful in many scenarios, such as representing a stiff part of a structure with a rigid spider, or representing a load transfer path with a flexible spider. A future article will look in more detail at this type of element, as its uses are widespread and the terminology varies greatly.

Facing a Complex Future

I personally believe that if we're not careful, the future direction of FE modeling will bring huge models of the order of 1E9 to 1E12 DOF, where all structure is modeled with solid elements from CAD. We will have to sift through the post-processed data and try and find local stress hotspots. Once we've found the local hotspot stresses, our next job as engineers is to explain why and how the stresses get there—and then advise how to improve the design. That is going to be the challenge. A good idealization can help us picture why and how these load paths exist. **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.*

INFO ➜ FETraining: FETraining.com

➜ NAFEMS: NAFEMS.org/e-learning

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

Innovation with the Multiphysics Touch

COMSOL's multiphysics simulation solutions are designed to help engineering organizations grapple with increasing complexity.

BY BETH STACKPOLE

Some people bet on horses; for others, it's the stock market. Nearly three decades ago, a group of doctoral students saw their opportunity in a green field called multiphysics (MP) simulation.

COMSOL Multiphysics drove the design of Cochlear Ltd.'s new Codacs direct acoustic cochlear implant system. ***Image courtesy of Cochlear Ltd.***

Taking a calculated risk that hardware performance would advance significantly over time, the team set sail with its vision to bring MP to the desktop—despite the skepticism of many in academia who called the marriage improbable, and dismissed the science as far too complex for mainstream use.

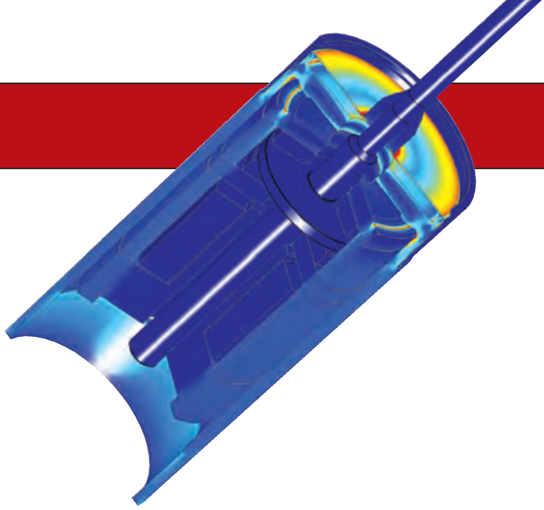
"The idea of multiphysics was borderline impossible then, but we made a bet that multiphysics would be possible in the not-too-distant future," recalls Bjorn Sjodin, Ph.D., vice president of product management of COMSOL Group, the company founded in 1986 by that group of students. "We were laughed at, but the laughter went away as computers became more powerful."

The core COMSOL team pushed forward, introducing its flagship product in 1998.

Fast-forward 15 years, and MP—and in particular, MP simulation capabilities on the desktop—is the direction in which many simulation vendors have set their sights. As the boundaries of engineering blur, organizations are in need of MP simulation tools to explore the interdependencies among electrical, mechanical and even software-dependent systems, and to do so in a cost-effective and efficient fashion.

The ongoing push for moving analysis further up in the design process is another factor driving demand for MP simulation. Upfront analysis is now widely recognized as a way for engineering organizations to zero in on the optimal design at a point when it is far easier to make changes, rather than the standard way of leveraging simulation at the end of the cycle as a means to prove out the viability of particular designs, experts say.

"If you think about what's going on with upfront simulation, it's a multiphysics and systems engineering issue," notes Keith Meintjes, Ph.D., practice manager for CIMdata. "You're making decisions about product architecture, and you're doing tradeoffs among variables like weight, price, etc. The upfront use of simulation drives you immediately to need multiphysics because you're doing cross-discipline tradeoffs."



COMSOL also played a role in investigating fatigue related to the actuator, which is one of the core components of the Codacs device. The design is set up to keep the material stress level during operation below the endurance limit. It's a goal particularly relevant for the thin titanium diaphragm (less than 0.1mm thick), which acts both as a spring and a hermetic sealing. *Image courtesy of Cochlear Ltd.*

While most industries face challenges that can only be solved by an MP, systems-engineering approach, Meintjes cites automotive as a sector where the capabilities are especially in high demand; in particular, he says, for innovations that address future fuel economy standards and for engineering the new generation of electric, battery-powered and hybrid vehicles.

Open Architecture Drives Organic Expansion

COMSOL has amassed a following in the automotive sector, but its approach has also garnered traction in other industries—from oil and gas to medical device equipment, among many others.

Rather than grow via acquisition, COMSOL has fueled its expansion organically. It's an approach the company attributes specifically to its software architecture, which is designed to accommodate new physics modules without the need for sophisticated programming—and in lieu of requiring a wholesale software rewrite each time it wants to bring new technologies on board. The software simulates coupled physics effects by solving the underlying mathematical representations based on partial differential equations (PDEs).

With this approach, various physics solvers can be

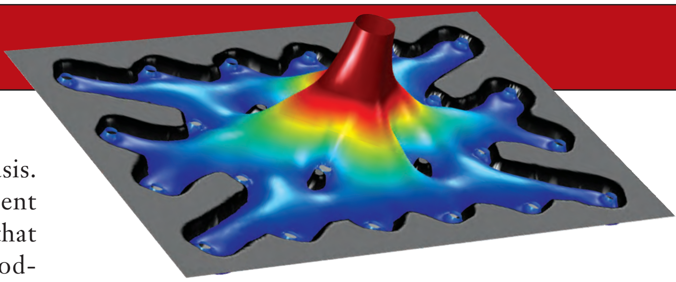
Case in Point

Being able to pick and choose among physics and not have to learn a new simulation package each time has been a huge benefit for Patrik Kennes, Ph.D. Kennes is a CAE engineer at the Cochlear Technology Centre Europe (CTCE), a Mechelen, Belgium-based research arm of Cochlear Ltd., which manufactures hearing implants, among other hearing aid products. He and his team deployed COMSOL Multiphysics from the ground up on the design of Codacs, a new type of implant now in clinical trials, which provides mechanical (acoustic) simulations directly to the cochlea.

Kennes says COMSOL was instrumental to optimizing the design of the actuator, an electromagnetic transducer based on the balanced armature principle. Through the use of structural mechanical analysis for various thickness values, his team was able to evaluate the tradeoffs between robustness and stiffness, and COMSOL's AC/DC Module was employed to calculate the magnetic flux density within the parts.

"Without COMSOL, we would have been able to develop the product, but we would have had to do more design iterations—and we probably wouldn't have come as close to the optimum solution as you can when you have software to support the design," Kennes reports. "When you have a good correlation between the measurements on the prototypes and what the [multiphysics] model predicts, you can feel confident that the model is representative of the real world."

— B. Stackpole



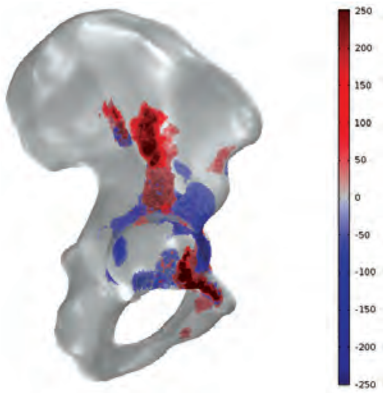
Here is an optimized fluid distribution mani old with a single circular fluid inl t in the center that feeds a number of small peripheral fluid j t outlets. The color surface shows the normalized fluid elocity contours, with larger velocity at higher elevations. The dark edges show the optimal fluid mani old geometry that balances the fl w rate to each nozzle while minimizing pressure drop. *Image courtesy of the Toyota Research Institute of North America.*

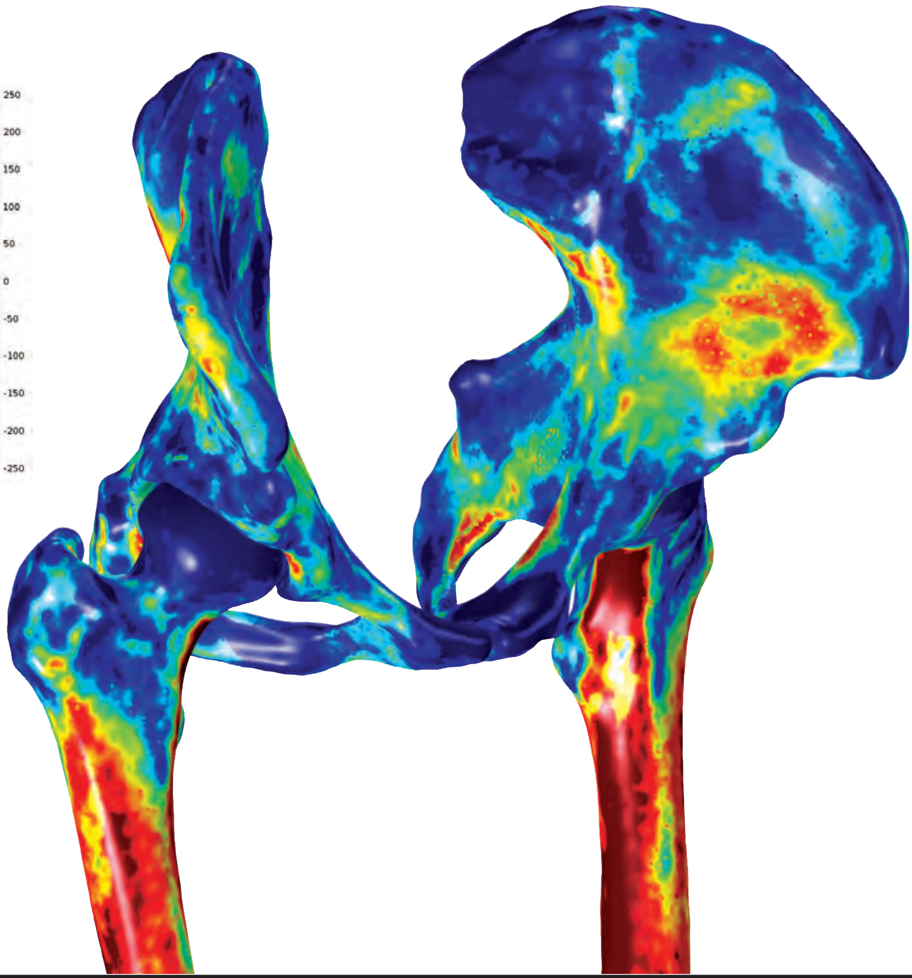
plugged into the primary engine on an as-required basis. An application programming interface (API) component makes it easy to create new physics solvers, whether that is COMSOL expanding its own portfolio of MP modules based on customer demand or individual customers creating their own solvers based on the requirements of their particular design challenge. In addition, many predefined couplings are available, including Joule heating, thermal stress, electrochemical reactions, and fluid structure interaction (FSI). For common MP problems, coupling among the physics is fully automated.

Currently, COMSOL offers 40 physics modules in the categories of electrical, mechanical, fluid, chemical and multipurpose. They cover such design trends as micro-electro-mechanical systems (MEMS) and battery and fuel cell design, with specialized offerings in areas like particle tracing and electrodeposition. The company's plan is to release seven add-on modules a year based on a combination of customer input and the feasibility of market size, notes Bernt Nilsson, COMSOL's senior vice president of marketing.

One of the key benefits to COMSOL's platform-driven MP approach is a higher fidelity model, according to Mark Yeoman, R&D director at Continuum Blue Ltd., a COMSOL Multiphysics certified consultancy.

Yeoman cites a customer example: His team was charged with creating an MP model to support research around a biomaterial equivalent for soft tissue mechanics such as arteries and skin. The model exploration would have taken about six to seven months using alternative MP simulation tools, he claims, but with COMSOL, the





This MP model looks at the implantation of a total hip replacement (femur and cup), and assesses the long-term changes in the patient's bone formation and loss because of the functional demands and changes in mechanical loading. Coupled physics includes structural, bone formation and loss. *Image courtesy of Continuum Blue.*

COMSOL at Work on Hybrids

At the Toyota Research Institute of North America, where multiphysics (MP) simulation is a driver for research being conducted in areas like hybrid vehicle power electronics, COMSOL's intuitive user interface and tightly coupled approach has transformed what has traditionally been a highly complex and iterative process into something far more accessible and streamlined. That's according to Eric Dede, principal scientist for the group. More complex design problems, including more physical interactions happening in a smaller space, means it's not always possible to zero in on the right insights simply by building and testing physical prototypes, Dede says.

"A modeling tool is critical to understanding what is going on, on a micro scale," he explains.

COMSOL Multiphysics' tightly coupled approach also has benefits when you're examining tradeoffs among two, three or even four physics—a scenario that isn't uncommon for Toyota's work in hybrid electronic components, including a recent design project for an advanced heat sink that thermally regulates the components.

Instead of pouring time and resources into trial-and-error physical prototyping, Dede and his team leveraged numerical simulation and MP topology optimization techniques to design, build and test possible prototypes of a heat sink for a future generation of hybrid vehicles. COMSOL's computational fluid dynamics (CFD) and heat transfer modules were essential to the numerical simulation piece of the project, Dede reports, while its LiveLink for MATLAB let the team leverage a high-level scripting language to optimize the cold plate's topology.

Prior to a tool like COMSOL, Dede's team would solve one physics problem, take the results and manually enter the input to frame out the second physics problem, and so on.

"It would be sequentially solved, and it required a lot of manual manipulation of data," which could be subject to mistakes, he says. With COMSOL, the type of coupling is pre-chosen based on the physics selected when you start the analysis, he explains. "As long as you understand the physics problem and how to make it mathematically relevant, then the COMSOL software takes care of the rest of it. It makes life as a designer or analyst easier."

— B. Stackpole

project took only a matter of days.

"It highlights how easy it is to implement these complex materials inside of COMSOL," Yeoman continues. "Instead of spending six months to implement an equation, we were able to do the same thing in a fraction of the time—and that's savings that's passed on to the client."

UI Enhancements Fuel Accessibility

Beyond the MP engine platform, COMSOL has poured a lot of R&D energy into refining its user interface over the last few releases to make the software more accessible to both specialists and generalist engineering users.

Prior to a major facelift with the introduction of Version 4.0 in 2010, COMSOL Multiphysics had a pretty rudimentary user interface. Going back to the drawing board, the goal was to design the software with MP in mind, serving up a smorgasbord of possible physics simulations via the COMSOL Desktop, which organizes the tools in a structured way and allows users to drag and drop and arrange the modules in any combination they desire.

"Multiphysics is an enormous field, and means different things for different users," Sjodin says. "Our platform lets users use the software in the same way no matter

what type of physics they're doing. They could be doing fluid flow one day and thermal transfer the next, and the software will look and feel the same."

Having an integrated platform for MP simulation also breaks down the silos between different engineering functions, which have traditionally relied on separate tool sets tuned to their needs of their particular function—and which don't necessarily make it easy to exchange data.

"COMSOL Multiphysics makes it possible to share files between the different areas because they are all the same files," Sjodin adds. "You can't work in a vacuum anymore."

Another major interface improvement was the introduction of the LiveLink modules also unveiled with COMSOL 4.0. These modules deliver bi-directional integration between COMSOL Multiphysics and many of the leading design tools, along with Excel and MATLAB. The LiveLink modules establish associative connectivity between the CAD and simulation applications, so if a change is made to a CAD model, the geometry of the MP model is automatically updated while the physics settings are retained. With LiveLink for MATLAB, users can run COMSOL models from within MATLAB for applications such as MATLAB programs, automatic control, statistics and geometry creation through image data.

Such integration is meant to improve workflow and help eliminate errors that can occur with having to import and export model data to and from different applications.

"This lets engineers stay in their comfortable environment to run the simulation without changing anything in the way they do design," Sjodin says. **DE**

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

INFO ➜ **CIMData:** CIMData.com

➜ **Cochlear Technology Centre Europe:** Cochlear.com

➜ **COMSOL:** COMSOL.com

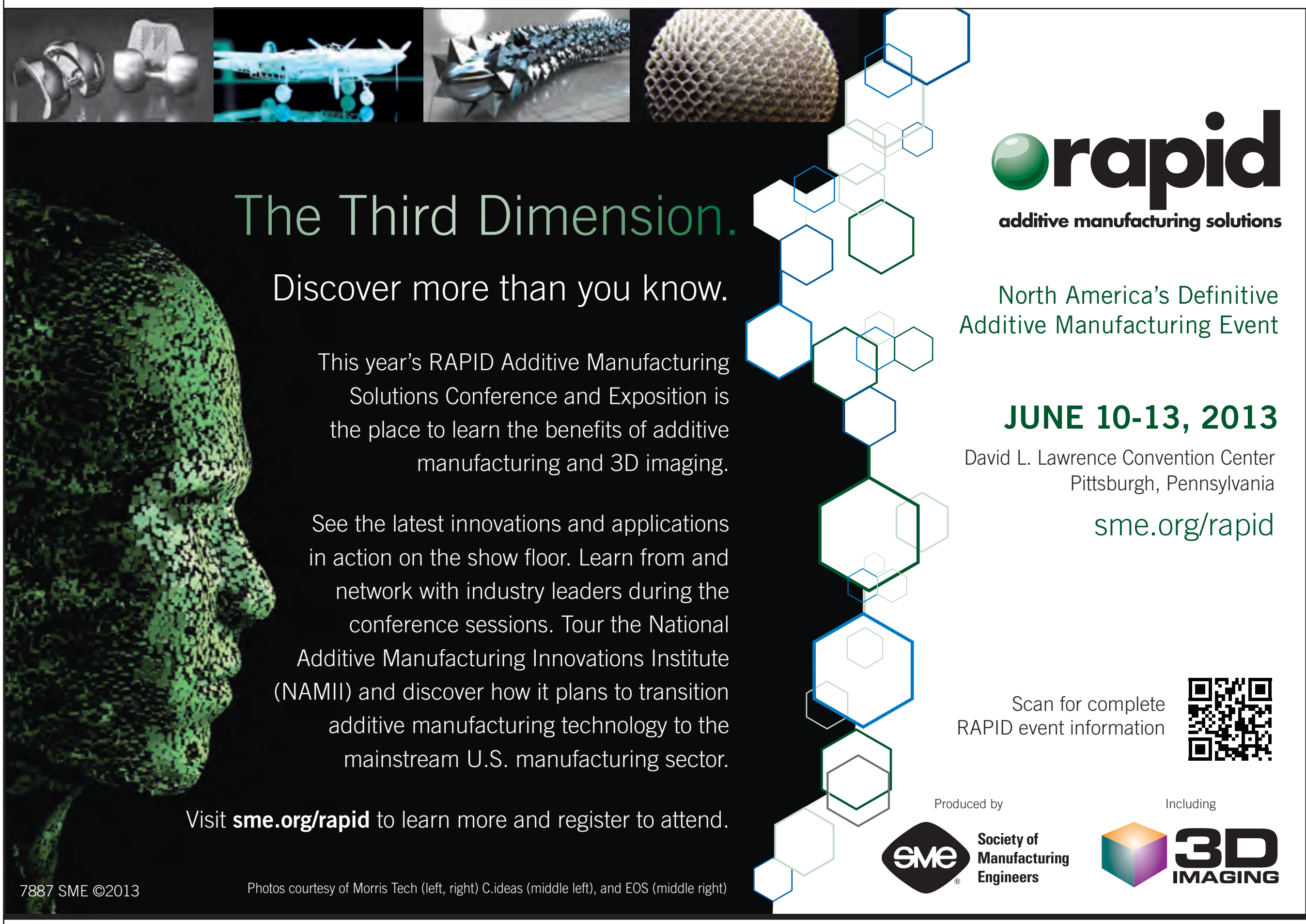
➜ **Continuum Blue Ltd.:** Continuum-Blue.com

➜ **MathWorks:** MathWorks.com/products/matlab

➜ **Microsoft:** Office.Microsoft.com/en-us/excel

➜ **Toyota Research Institute of North America:** Toyota.com

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



CPU, GPU or Both?

Finding the right multi-processing approach for engineering applications.

By PETEr Varhol

The question of whether you should load up on CPU cores or get a system with many graphics processing unit (GPU) cores is becoming more complicated, thanks to the ability of more software to use the GPUs. Analysis and simulation software vendors are increasingly porting their products to run on GPUs—and in many cases, the performance improvement can seem to justify the investment.

In general, it's apparent that GPUs have more of the floating-point computational horsepower needed for many engineering computations, but it's rarely that clear-cut. Many computations aren't strictly floating point, and even if they are, many can't be broken down to execute in parallel. That requires computations that execute the same series of instructions on different data, a process known as single instruction, multiple data (SIMD).

But for those SIMD computations that can execute in parallel, and use the floating point data, GPUs offer an enticing and high-performance alternative to the use of industry-standard CPUs. In parallel, they can perform simulation-specific computations significantly faster than CPUs. While many performance comparisons exist, most seem to cluster around a performance improvement in single-processor operations of GPUs over CPUs of about 2.5x.

Intel industry standard processors provide a high rate of throughput, especially for integer operations. They tend to work well for most engineering computations, but aren't optimized for all kinds of computation.

So, engineers seeking the highest level of performance need to look at not only at the computations they perform, but also their mix of computations. It is possible to make this analysis very detailed and specific in nature, but most engineering teams would be fine just looking at the type of work they do and their mix of computations.

Weighing the Benefits

Most GPUs lack certain features that programmers need in many types of software. For example, GPUs don't have stack pointers and therefore don't support recursion, the act of a function calling itself. That type of computation tends to be slow and not called for in graphics operations.

Lacking features such as these lets GPUs execute code more quickly, but the code itself has to be changed or simplified to do so. Porting code requires engineering effort; how much depends highly on the type of code and structure of the application. For an entire application, it is likely to be a significant effort. For only parts that can be effectively parallelized, the effort won't be nearly as great.

That's the primary reason why CPUs and GPUs are more complementary than competitive in the nature of their work-

NVIDIA's CUDA enables massively computational systems such as this one that can support hundreds of thousands of cores.

loads. They do different things well. Most, if not all engineering application vendors leave user interface code and editing code to run on the CPU. Computational code that can make use of graphics processing and parallel operations is being increasingly ported to GPUs.

One popular option for the execution of parallel code on GPUs is the compute unified device architecture (CUDA), a parallel computing platform and programming model developed by NVIDIA for use with its GPU families. It gives developers access to the virtual instruction set and memory of the parallel computational elements in CUDA GPUs, so that code can be written or ported to run directly on the GPUs.

CUDA works by having its own processor cores and shared memory. The CPU dispatches GPU-compiled code and data (it works slightly differently depending on the software technology being used) to the GPU cores, where the computation occurs. When the computation is complete, the results are passed back to the CPU that controls the application.

Vendors such as MathWorks and AccelerEyes offer independent ways of dispatching code and data to CUDA GPUs, enabling easy GPU use of the MATLAB engineering programming language. MATLAB also makes it easy to break up a computation to run on a specified number of processors and cores.

In addition to the CUDA C/C++ and CUDA Fortran programming languages, the CUDA platform supports other computational interfaces, including OpenCL, Microsoft's DirectCompute, and C++ AMP. Third-party wrappers are also available for languages such as Python, Fortran and Java. There is also native CUDA support in Mathematica.

Best of Both Worlds

One approach to take is a combination of both CPUs and GPUs, using a multiprocessing option called OpenCL. OpenCL, which has been adopted by a number of vendors (Apple, AMD and Intel, among others), is a framework for writing programs that can run across different processors. OpenCL provides the ability to dispatch computations to either a CPU or GPU (as well as digital signal processors and even programmable gate arrays), depending on what the code is designed to run on.

For engineers, it has the potential to make the dichotomy between industry-standard CPUs and GPUs seamless and transparent. It lets code run where it makes the most sense. If the OpenCL standard is used by software vendors, code should be portable within implementations that follow the standard.

AMD has integrated OpenCL as its programming framework for its FirePro family of GPUs, as well as its CPU offerings. According to Antoine Reymond, alliances manager at AMD, OpenCL is supported by The Khronos Group, an American not-for-profit member-funded industry consortium. "It is a collaborative effort that ensures there is a common program-

The AMD FirePro 5900 supports the OpenCL standard that allows for the sharing of CPUs and GPUs in a single system.

ming standard across different implementations," he explains.

OpenCL includes a programming language based on C for writing kernels that execute on OpenCL devices, plus application programming interfaces (APIs) that are used to define and then control the platforms. The C language is somewhat limited, in that it doesn't allow function pointers or recursion. That means any existing code still has to be modified to work with either GPU vendor.

OpenCL can be used to give an application access to a GPU for non-graphical computing, such as engineering computations. The intriguing thing about OpenCL is that it offers the ability to use both CPUs and GPUs in combination. Of course, code still has to be compiled for one or other, so it's not quite that straightforward.

Once again, the same computational limitations apply as with CUDA. But because the GPUs and CPUs share memory, passing computations off to GPUs tends to be faster than with CUDA. In either case, it is likely that both CUDA and OpenCL implementations on GPUs will deliver significantly better parallel execution of computational code than CPUs.

The Choice is Yours

Is there truly a timesaving value for engineers in using GPUs in parallel execution, whether using CUDA or OpenCL? It depends on the types of workstation or multiprocessing system being used, on the software, and on the types of computations being performed.

Chances are you will benefit, if you do a lot of data analysis or simulation. Depending on which multiprocessing standard your systems support, CUDA and OpenCL each offer similar performance advantages. But if you're doing single-threaded operations, such as design, or if you're engaged in a lot of more general-purpose computing, you will see little, if any advantage.

Of course, your engineering software still has to support GPU execution. That's becoming less of an issue with commercial software today, as an increasing number of vendors are compiling parts of their code for NVIDIA and/or AMD GPUs. Unless you're using a niche vendor, or have your own code, chances are you'll find a GPU solution.

All this leads to why it might be more appropriate to use a shared multiprocessing or cluster system. You're probably not going to make use of your workstation GPUs for general-purpose engineering computing. Instead, you're going to concentrate on making a single GPU system more available to engineers who can make the best use of it.

Rather than one or the other, you should be looking at a mix of both types of processors. If your work is more heavily skewed toward design, you probably want to lean toward a more CPU-heavy approach. Of course, you want those CPUs to be the fastest and most powerful in general, even if they have fewer cores.

But if you do a lot analysis and simulation, you want processors and cores—and some of them should probably be GPUs, assuming that you can get compiled GPU code for your application. For those types of computations, a mixed system using both CPU and GPU cores using CUDA or OpenCL would work equally well. **DE**

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

INFO ➔ **AcceleerEyes:** AccelerEyes.com

➔ **Advanced Micro Devices:** AMD.com

➔ **Apple:** Apple.com

➔ **Intel:** Intel.com

➔ **Java:** Java.com

➔ **The Khronos Group:** Khronos.org

➔ **MathWorks:** MathWorks.com

➔ **NVIDIA:** NVIDIA.com

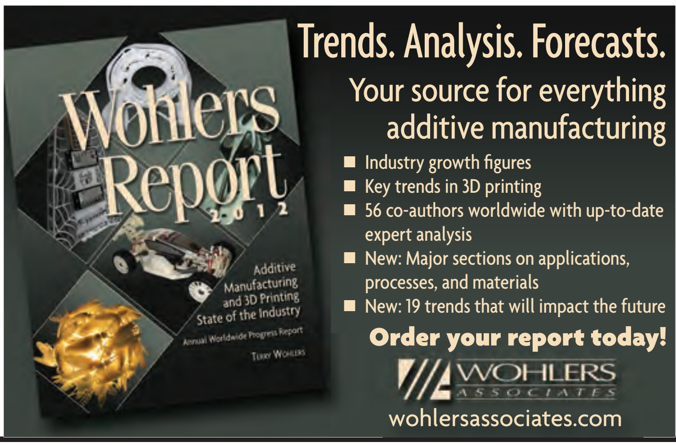
➔ **Python:** Python.org

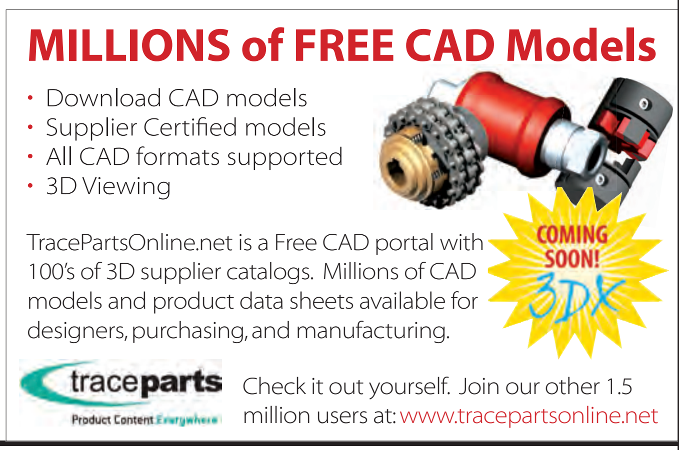
➔ **Wolfram Research:** Wolfram.com/mathematica

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

SPOTLIGHT

Directing your search to the companies that have what you need.





Compact Performer

Lenovo ThinkStation E31 SFF provides modest, but affordable pe formance.

By DaviD Cohn

The Lenovo ThinkStation E31 SFF (small form factor) is aimed squarely at entry-level CAD users. Designed around the latest-generation Intel Xeon E3-1200 V2 series "Ivy Bridge" processors and equipped with error-correcting memory, the E31 SFF offers professional-level performance and reliability in a package that should fit just about anywhere.

The E31 SFF comes housed in a matte black case measuring just 13.12x3.75x15.0 in. (WHD), and weighing only 16.5 lbs. Rubber feet support the case in a horizontal position, while a small plastic stand enables the system to stand like a miniature tower—although in that position, the tray-loading optical drive ends up in a somewhat awkward vertical orientation.

In addition to the DVD drive, the front panel provides two USB 2.0 ports, a 29-in-1 media card reader, headphone and microphone jacks, and a power button.

The rear panel provides four UBS 3.0 ports, two additional USB 2.0 ports, a nine-pin serial port, a 15-pin VGA port, a DisplayPort connection, and an RJ-45 LAN port for the integrated Intel 82579 Gigabit Ethernet—as well as microphone, audio line-in and audio line-out jacks. There are also four expansion slots.

Organized Interior

Sliding a small plastic lever on the rear panel releases the top of the case, which hinges at the rear to reveal a compact interior. The Lenovo-designed motherboard takes up about two-thirds of the interior, and is partially hidden below the hard drive and optical bays. The hard drive mounts in a novel removable plastic housing. Once removed, the optical drive cage can be pivoted forward, providing full access to the four memory sockets. The ThinkStation E31 SFF can accommodate up to 32GB of RAM. Our evaluation unit came with 8GB of memory, installed as two 4GB 1600MHz ECC dual in-line memory modules (DIMMs).

The CPU is concealed beneath a heat sink and 3-in. cooling fan. To one side of this is a diminutive, 240-watt, 85% efficient power supply; to the other, the expansion slots and one more USB 2.0 port. Lenovo offers no fewer than 18 processors to choose from, including Intel Celeron, Core i3, Core i5, Core i7, Pentium and Xeon, including the top-of-the line 3.6GHz quad-core E3-1280V2. Our evaluation unit came with a slightly more modest 3.3GHz Intel Xeon E3-1230V2. This 22nm CPU has a maximum turbo speed of 3.7GHz, 8MB of cache, and a maximum thermal design power rating of 69 watts.

While the E31 SFF provides four expansion slots—a PCIe x16 graphics card slot, a PCIe x1 slot, and two PCI slots—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 600. This board provides both a DisplayPort and dual-link DVI connection.

The hard drive cage can house a single 3.5-in. hard drive or a pair of 2.5-in. drives. Our evaluation unit came equipped with a 1TB SATA 3.5-in., 7,200rpm drive manufactured by Western Digital, and a 16X DVD+/-RW optical drive. Lenovo also offers a 2-terabyte, 7,200rpm 3.5-in. drive, as well as several 10,000rpm 2.5-in. drives and solid state drives (SSDs).

Modest Performance

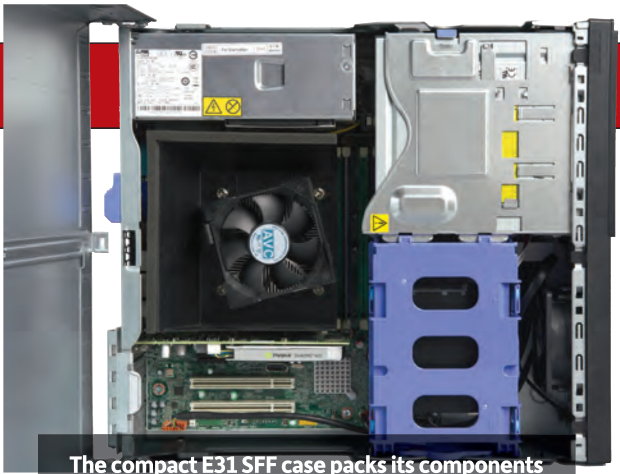
Because the E31 SFF is meant to be an entry-level system, we did not expect this ThinkStation to set any records. And like the entry-level Lenovo ThinkStation E30 we reviewed last year (see *DE*, July 2012), the small form factor workstation lived up to those expectations. The ThinkStation E31 SFF's results were measurably slower than those of other systems we've reviewed recently. But its numbers were definitely not disappointing, with benchmark results approximately twice as fast as those of workstations from just three years ago—and nearly equal to those of modern systems costing much more.

On the SPECviewperf benchmark, the NVIDIA Quadro 600 just couldn't match the performance of other systems we've reviewed recently, which came equipped with much more powerful graphics cards costing several times as much.

inFo → **Lenovo:** Lenovo.com/thinkstation

ThinkStation E31 SFF

- **Price:** $1,093 as tested ($549 base price)
- **Size:** 13.12x3.75x15.0-in. (WxHxD) tower
- **Weight:** 16.5 lbs.
- **CPU:** 3.3GHz Intel Xeon (Quad Core) E3-1230V2
- **Memory:** 8GB DDR3 ECC at 1600MHz
- **Graphics:** NVIDIA Quadro 400
- **hard Disk:** 1-terabyte Western Digital 7,200rpm
- **optical:** 16X DVD+/-RW
- **network:** integrated Gigabit Ethernet (Intel 82579), one RJ45 port
- **other:** One nine-pin serial, four USB 2.0, four USB 3.0, one internal USB 2.0, 29-in-1 media card reader, DisplayPort, VGA
- **Warranty:** three years, parts and labor



The compact E31 SFF case packs its components neatly into its small, but well organized interior.

On the SPECapc SolidWorks benchmark, which is more of a real-world test (and breaks out graphics, CPU and I/O performance separately), the E31 SFF did better, outperforming several workstations costing several times as much.

On the AutoCAD rendering test, which is multi-threaded and, therefore, clearly shows the benefits of multiple CPU cores, the Lenovo ThinkStation E31 SFF took 64 seconds to complete the rendering. These are among the best results we've recorded for a single-socket system with a standard (not over-clocked) CPU.

A base E31 SFF system starts at $549. As equipped, our evaluation unit priced out at $1,093, making the Lenovo ThinkStation E31 SFF an affordable system in a compact package. DE

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

Workstations Compared		Lenovo E31 SFF workstation (one 3.3GHz Intel E3-1230 quad-core CPU [3.7GHz turbo], NVIDIA Quadro 400, 8GB RAM)	Lenovo S30 workstation (one 3.6GHz Intel Xeon E5-1620 quad-core CPU [3.8GHz turbo], NVIDIA Quadro 4000, 8GB RAM)	HP Z1 workstation (one 3.5GHz Intel Xeon E3-1280 quad-core CPU [3.9GHz turbo], NVIDIA Quadro 4000M, 16GB RAM)
Price as tested		$1,093	$2,614	$5,625
Date tested		12/29/12	8/18/12	6/29/12
Operating System		Windows 7	Windows 7	Windows 7
SPECview 11	higher			
catia-03		18.15	48.21	39.46
ensight-04		11.08	32.18	26.19
lightwave-01		46.79	64.47	60.76
maya-03		40.36	84.50	78.65
proe-5		10.29	11.93	12.69
sw-02		31.54	53.53	47.24
tcvis-02		16.53	37.66	30.79
snx-01		13.45	33.87	27.70
SPECapc SolidWorks	lower			
Score	seconds	97.45	106.46	110.61
Graphics	seconds	33.97	38.68	38.31
CPU	seconds	26.22	26.88	30.52
I/O	seconds	37.26	40.90	41.32
SPECapc SolidWorks 2007	higher			
Score	ratio	5.26	4.80	4.46
Graphics	ratio	6.17	5.33	5.06
CPU	ratio	4.67	4.56	4.01
I/O	ratio	3.80	3.46	3.42
Autodesk Render Test	lower			
Time	seconds	64	63.8	87.92

Numbers in blue indicate best recorded results. Numbers in red indicate worst recorded results. Results are shown separately for single- and dual-socket workstations.

Workstation Evolution

Vendors fine tune orkstations for engineering applications and performance.

By Frank J. Ohlh Orst

Workstations are the bread and butter tools of the engineering sect. Today, no other tool is as important as compute cycles to the modern engineer, especially when one considers that time is money and design or simulation can quickly chew through the hours in a day.

Luckily, workstations continuously evolve, getting faster better and cheaper than previous generations. Workstation vendors have not blinded themselves to the fact that today's products may not fare well against the innovations of tomorrow and are seeking ways to future proof workstation technology with innovative designs, expansion options, and ease of service.

A quick look at the current crop of workstations reveals the evolutionary process at work. First let's take a look at the custom players on the market, who have to balance price against features to find an edge to compete against the major players:

BOXX Technologies: BOXX is a manufacturer of high performance mobile and desktop workstations that are geared toward offering the highest performance possible for visual effects (VFX) design professionals and visualization applications. As of late, the company has been promoting its multi GPU design as the wave of the future—with some systems featuring as many as four GPUs. The company also leverages liquid cooling and over clocking. Products are protected by a three year warranty, which should assuage any worries about overclocking. The company offers all-in-one workstations via their mobile workstation product line, which are powered by Intel Core series processors and feature full HD 17.1-in. displays. As far as the future is concerned, BOXX leverages the latest in CPUs, GPUs, memory and other hardware, and engineers as much performance as possible out of those components.

Xi Computer: Xi Computer has been in the workstation business for more than 25 years and offers a variety of workstations based upon both AMD and Intel Technologies. The company's most recent innovations include notebook-based workstations powered by Intel Core i7 processors as well as multi Xeon processor-based workstations. Xi Computer also offers a high level of customization for its customers using a build-to-order methodology, at a low price point.

Microway Computer: Microway is a U.S. General Services Administration (GSA) Schedule approved vendor that manufactures a variety of PCs and workstations. Microway has been building high performance systems since 1982. When it comes to modern workstations, Microway (like many other vendors) leverages the Intel Xeon platform, as well as AMD Opteron processors. NVIDIA GPUs play a major role in the graphics subsystem, as well as part of the computational capabilities of the workstations. Microway offers the WhisperStation series of workstations and, as the name implies, low noise is a primary focus. What's more, the workstations are designed to be easily linked together to build multi-node clusters. The company prides itself in its advanced research.

Rave Computer: As one of the smallest players in the workstation market, Rave Computer focuses on building highly customized engineering workstations that stress reliability and maximum performance for the CAD/CAM/CAE markets. The Rave Ignition series of Workstations can be fully customized, allowing an almost unlimited selection of chassis type, processors, GPUs and so on. The company also offers solutions built on the Intel Xeon Phi platform that brings high-performance parallel processing to the forefront of workstation design.

Eurocom: As far as workstations are concerned, Eurocom focuses on the mobility segment, where its desktop replacement systems have been engineered to offer workstation-level performance with 3D capabilities. The company refers to their products as "3D supercomputing laptops" and "ultimate mobile workstations," which feature large screens (17.3-in.), high-performance processors (Core i7 or Xeon) and 3D graphics processors.

Seneca: Seneca is primarily a systems builder that works with

OEMs and ISVs to create a multitude of computing offerings. However, the company's claim to fame in the workstation space comes from its Nexlink product line of workstations. Nexlink workstations are designed as lower cost alternatives to ultra-high performance engineering workstations, and are aimed at a more general design market. The Nexlink product line's sweet spot is for those on tight budgets who are looking for workstation-level performance that is upgradable and well supported.

Big vs. Small

The smaller workstation vendors outlined above have turned to specialized markets and niches to fill their order sheets, hoping to plug the gaps left by the major manufacturers. However, innovation is far from dead at the industry giants, who have development budgets that overshadow the total sales of some of the smaller vendors on the market.

HP: Hewlett Packard focuses a significant amount of effort on innovation, which has resulted in distinct workstation solutions that incorporate all-in-one designs, small form factors (SFF), or tool-less service. Take for example the HP Z1 series, which features an all-in-one design, incorporating the processing power into the same housing as the display. The Z1 Offers a 27-in. display with Xeon power and a tool-less chassis. The company offers models that can incorporate different processors, GPUs, storage capacities and so on. HP also offers SFF-based workstations in its Z220 series, which crams high performance processing power into a diminutive case.

Dell: PC giant Dell offers a wide array of PCs, workstations, notebooks and many other hardware products. The company offers traditional workstations in tower, desktop and desktop replacement form factors. The company's entry-level T1650 workstation features third-generation Intel core processors, while the company's top of the line T5600 series feature Intel Xeon family processors. A variety of graphics options are available, as well as a multitude of storage options. The company's most innovative workstation products come in the form of its mobile workstations, which feature ISV certification, displays as large as 17.3 in. and quad core processors.

Lenovo: PC builder Lenovo offers the Thinkstation family of PCs to those seeking high performance workstations. The product line is available under four different series, including a small form factor under the E series and ultrahigh performance units under the S series. With four product lines and multiple sub models, there is a Lenovo workstation designed for most any occasion. The products feature the gambit of Intel processors, multiple graphics options, tool-less serviceability, and a great deal of customization. Lenovo stresses reliability and ergonomics as its primary selling points, with a dash of affordability thrown in. DE

Frank Ohlhorst *is chief analyst and freelance writer at Ohlhorst.net. Send e-mail about this article to DE-Editors@deskeng.com.*

INFO → **BOXX Technologies:** boxxtech.com

→ **Dell:** Dell.com

→ **Eurocom:** eurocom.com

→ **HP:** HP.com

→ **Lenovo:** lenovo.com

→ **Microway Computer:** microway.com

→ **Rave Computer:** rave.com

→ **Seneca:** senecadata.com

→ **Xi Computer:** xicomputer.com

Advertising Index

Seeing Ray Tracing in a Different Light

Caustic Visualizer and Series2 Ray Tracing Acceleration Boards from Imagination Technologies focus on efficiency.

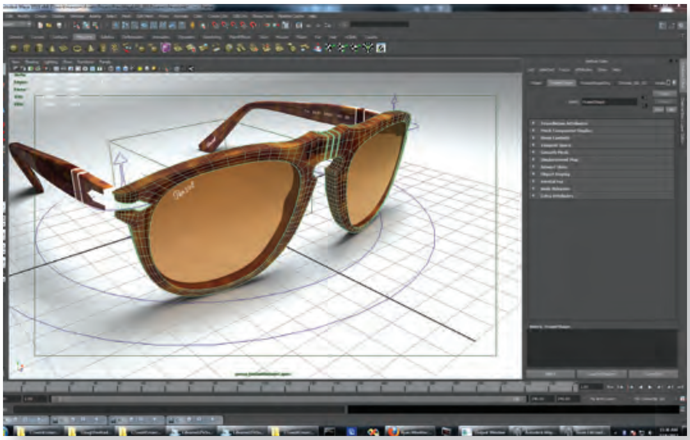
BY MARK CLARKSON

Imagination Technologies' new Caustic Visualizer viewport renderer is a software plug-in—currently available for Maya and soon to be available for 3ds Max—that provides interactive ray tracing in a working viewport. The Visualizer viewport renderer becomes another viewport option, available in any Maya or Max viewport, providing globally accurate lighting, reflections and shadows.

But Visualizer is more than just a render preview; it's a fully functional viewport. You can select and manipulate geometry and lighting—do anything, in fact, that you would do in any viewport, but with the added benefit of interactive ray tracing.

Similarly, Neon for Rhino is a fully ray-traced viewport plug-in for McNeel's Rhino 5, developed by McNeel in collaboration with Imagination Technologies/Caustic. Like the Caustic Visualizer, the Neon viewport supports all native rendering features while still allowing you to edit your models.

This tightly integrated, interactive ray tracing is cool, but to make it go really fast, you'll need hardware help in the form of one of Caustic's ray tracing acceleration cards.



Rendered directly in the viewport with Caustic Visualizer for Autodesk Maya 2013. Triangles: 538,696; LIghts 10 + IBL. Artist: Ryan Montrucchio, *Model courtesy of Pacific Digital Image Visual Studios.*

Fundamental Differences

Caustic's Series2 Ray Tracing Acceleration Boards are not your average graphics processing unit (GPU)-powered cards. Caustic cards are focused on ray tracing, and Caustic has developed a fundamentally different approach to solving the ray-tracing problem.

"GPU companies look at ray tracing as a computing problem: If I just keep adding more cores, I can solve this problem," notes Imagination Technologies' director of business development, Alex Kelley. "But that means I'm also adding more power. That's why you see these GPUs consuming 120W apiece."

But Kelley says ray tracing turns out to actually be as much a database problem as a computing problem.

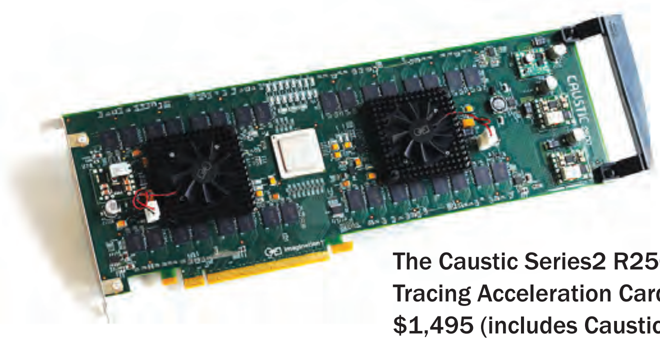
Generally speaking, he explains, ray tracing works by casting rays from an imaginary camera, through the pixel plane of the final image and into the scene. When they intersect a surface, the program computes the color of the resulting pixel by combining the surface's orientation and material properties with incoming light. That incoming light is affected by scene lights, cast shadows, reflective materials and indirect lighting (light bouncing off of other objects in the scene), and more.

It's simple in principle. You can create a ray-tracing algorithm with astonishingly little code. Here's a ray tracer that fits on a business card: cs.cmu.edu/~ph/src/minray/minray.card.c.

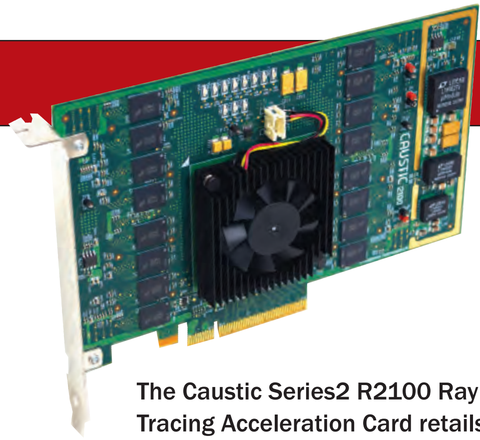
In practice, most rays don't intersect most surfaces—and your algorithm spends most of its time running down dead ends. To speed things up, you must first create an "acceleration structure" that rationally divides your scene geometry into smaller regions to minimize the amount of time spent pursuing dead ends.

The nature of ray tracing, however, remains inherently random. "When a ray hits a surface in the scene," says Kelley, "it goes off in a random direction, hits another object, goes off in another random direction, hits another object. The challenge is maintaining all the scene information in cache in order to be able to compute the final shading for [a given] pixel."

GPU cards typically solve this challenge by requiring you to fit all scene geometry and textures in cache onboard the card. High-resolution textures quickly eat into the amount of amount of geometry you can place on a card, but once you have to reach across the system bus for data from main memory, the speed advantage of your GPU card disappears.



The Caustic Series2 R2500 Ray Tracing Acceleration Card retails for $1,495 (includes Caustic Visualizer).



The Caustic Series2 R2100 Ray Tracing Acceleration Card retails for $795 (includes Caustic Visualizer).

Shifting the Focus

Caustic took a different approach to speeding things up. "The ray/surface intersection part of the problem, which is a computing matter, was solved years ago through Moore's law," says Kelley. "So we said, 'Let's focus on the database problem.'"

How do you manage the random nature of ray bounces? Caustic's solution is an algorithm that holds rays in mid-flight until it collects enough of them going in the same direction.

"You shoot an object from the camera and it hits an object," says Kelley. "We will hold that ray; we won't progress any further until we have a sufficient number of rays vectored in the same direction. That way, when a ray hits the final object in the scene, it's likely that the shading information will be there—not only for that ray but, since we've been holding all these other rays in flight, for a lot of rays that will need that same shading information."

This is a much more efficient approach to solving the database problem, minimizing the number of times a part of the scene is read from the memory.

"We developed a PCI Express card that does just that: It holds the acceleration structure and the geometry, and it does all the ray flow," Kelley explains. "Then it tells the CPU 'OK, we now know what pixel shading information is required, go shade it.'

Imagination + Caustic

Imagination Technologies, which acquired Caustic in 2010, isn't a familiar name in the desktop 3D arena; it's much better known in embedded systems. Developers of the PowerVR chip set, Imagination provides GPU cores for many smartphones and tablets.

The reason for the firm's success, says Imagination's Alex Kelley, is that it's been able to provide a fast, low-power solution—thanks to its development of technology around deferred rendering. Caustic is using a deferred rendering algorithm for ray tracing, as well, he notes.

Eventually, Kelley adds, Imagination would like to take its ray-tracing application programming interface into its PowerVR chipset.

"They want to provide that ray-tracing capability to their customers in the future and, at the same time, grow up into the professional 3D marketplace with the Caustic add-in cards," he concludes. "That's where this is going. That's the end game."

"We break the problem into two," he continues. "The database problem is solved by the card, and the shading is done—in this current generation—by the CPU. That's our secret sauce."

Caustic holds 21 patents on its approach, which it says yields efficiency gains up to 30 times over other ray-tracing algorithms.

Because the CPU does the actual shading, all the textures are kept in system RAM, freeing up space on the Caustic cards for more geometry. On the R2500 card, that amounts to about 120 million triangles. The end result is a fast, efficient card capable of supporting large geometries with comparatively low power.

Caustic's R2100 card, with a single ray-tracing unit (RTU), draws a maximum of 30W. The R2500, with dual RTUs for dual-CPU workstations, consumes a maximum of 65W.

The Bottom Line

Caustic cards provide between two-and-a-half and five times the ray-tracing performance of a CPU alone, according to the company. Rhino, with its lower overhead, tends to gain more performance than Maya and 3ds Max. Starting at $795, they're comparatively cheap and consume less power than comparably performing GPU-based cards.

Of course, GPUs are useful for other things as well—computational fluid dynamics (CFD), say, or high-end image processing. But if you're a designer who'd like better ray-tracing performance, a Caustic card might just be your solution.

The Caustic Visualize plug-in doesn't require hardware acceleration. You can download a free 30-day trial of the software at caustic.com/visualizer/maya. Rhino 5 users can download the Neon plug-in free at v5.rhino3d.com/group/neon. **DE**

Contributing Editor **Mark Clarkson** *is DE's expert in visualization, computer animation, and graphics. His newest book is Photoshop Elements by Example. Visit him on the web at MarkClarkson.com or send e-mail about this article to DE-Editors@deskeng.com.*

INFO ➜ Autodesk: USA.Autodesk.com

➜ **Imagination Technologies:** Caustic.com

➜ **NVIDIA:** NVIDIA.com

➜ **Robert McNeel & Associates:** McNeel.com

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

Automated for the People

Automated metrology increases throughput and provides greater consistency for industrial processes, but system designers can benefit f om it as well.

By Rand y FRank

Simplifying the inspection of multiple pieces, increasing the size of automated measurement and inspection, and automatic centering and leveling for fast work piece alignment and measurements are among the more recent improvements in automated metrology. These 3D tools address vastly different industrial requirements, but yield higher throughput, greater consistency and other benefits for their targeted applications.

In addition to the usually obvious advantages in the manufacturing environment, designers can (and need) to do things differently because of automated metrology. If done properly, benefits can occur in the upfront design process based on implementing automated metrology in manufacturing. The benefits for designers include minimizing design process steps and/or time—resulting in further cost savings to the enterprise.

One example is provided by InnovMetric Software's new Play Inspection tool. This tool, now fully integrated into Phase II of DirectReplay, released in version 12.1 of PolyWorks, automatically builds a guided step-by-step sequence to capture 3D datasets of a work piece.

"The purpose of the Play Inspection tools is to allow users to easily perform repetitive inspection tasks," says Marc Soucy, president of InnovMetric Software.

Properly inspecting a part is greatly improved if the designer's role is taken into account in the workflow. Designers define the geometry, controls and tolerances; measurement planners define the measurement methods, and measurement operators capture 3D data of the physical parts (see Fig. 1).

Designers need to care about the what, the first step. The how is done by the metrology specialists who know how certain projects should be measured. "What we have done in Play Inspection development is automated the third step, the when," says Soucy.

"When designers incorrectly create their dimensions in ways that cannot be easily measured, they put an additional burden onto the metrology specialist," he explains. Inadequate communication between the design and manufacturing teams adds to the problem. CAD models need to specify dimensions that can be readily understood and implemented by the metrology specialist.

"A company that wants to streamline its process should build a discussion focus group between the design and manufacturing people, and agree on certain rules," recommends Soucy.

The geometric dimensioning and tolerancing (GD&T) quality control method for 3D solid models plays a role in the process as well, he says.

"When the CAD people put GD&T in their CAD model, usually that translates very, very well," says Soucy. Done properly, he notes, the addition significantly accelerates the inspection process. The geometry, controls and tolerances are automatically transferred to the inspection application (see Fig. 2).

Inspection Requirements in the CAD Model

Hexagon Metrology's 4.5.4 SF shop floor coordinate measuring machine (CMM) adds analog scanning to its capabilities. With an optional LSP-X1c probe head, the unit's design supports standard probing—including single-point probing—self-centering and continuous high-speed scanning. Shaun Wissner, a PC-DMIS Software marketing special-

Figu r e 1: Three separate entities perform the what, how and when of part inspection. *Image courtesy of InnovMetric Software.*

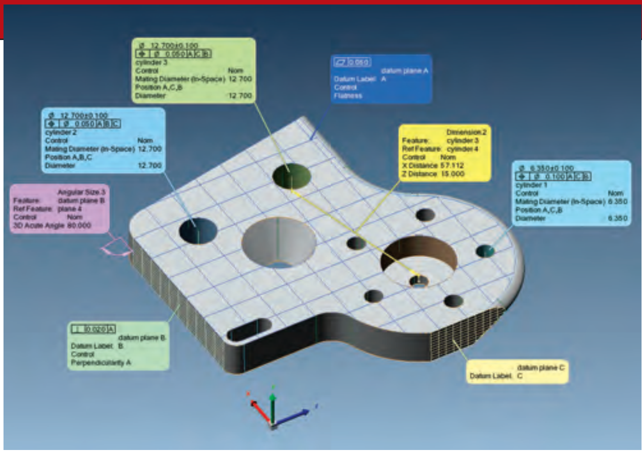


Figure 2: **A CAD model with embedded product and manufacturing information provides considerable metrology data when it is opened by an inspection solution such as innovMetric's PolyWorks.**

Figure 3: **Hexagon Metrology's 4.5.4 SF CMM is easily transported between required locations in a manufacturing facility.**

ist for Hexagon Metrology, notes that even though CMMs have been around since the 1960s, until recently, they still required heavy human interaction before, during and after the manufacturing process to conceive, collect and interpret any 3D data going in and coming out.

"We are starting to see manufacturers embracing ideas like model-based definition (MBD), where inspection requirements are added to the CAD model, which eliminates the need for part prints," says Wissner. Most current CAD/CAM software packages support embedding GD&T and linear tolerancing into native component models. As a result, this saves the CMM planner a critical step of interpreting the designer's intent for a given measurement requirement.

Wissner also observes that offline programming for direct computer controlled (DCC) CMMs is on the rise. While this has long been the standard for computer numerically controlled (CNC) manufacturing equipment, inspection software like Hexagon Metrology's PC-DMIS Planner is built to take advantage of this new data added to CAD models. This allows users to simply point and click on the GD&T feature control frames and linear dimensions.

"Inspection routines that took hours, or even days of repetitious work are now finished in minutes, as all the necessary features and dimensions are created with the same mouse click," says Wissner. When complete, the inspection routine is downloaded to the CMM for simple, one-touch execution by any machine operator (see Fig. 3).

The Future is Now

Design engineers use 3D scanners to reverse engineer a physical part to design the tools. As a result, data quality is important, especially in aiding with the associated downstream processes. To scan parts larger than 6 ft. and/or up to about 2 tons in weight, GOM mbH recently introduced the ATOS ScanBox 6130. Similar to previous models, the 6130 is an industrial measuring cell for fully automated 3D digitizing and inspection.

An accurate, high-resolution, fast and versatile 3D scanner can be used in product development stages from beginning to end. "Many of our customers have ATOS systems installed throughout design, try-out, and production departments within the same organization," says Catherine Kim, a marketing coordinator for Capture 3D, the firm representing GOM in the U.S. and Canada.

"The important thing of scanning a part for the design process is, how do you get very accurate, high-fidelity data that will help with the CAD creation changing the design layout—which in essence, saves time and money?" Kim adds. Using a system such as ATOS ScanBox, she says, allows users in aerospace turbine blade and automotive manufacturing operations and others to achieve these savings.

For all the benefits that customers can realize in the manufacturing arena, obtaining benefits earlier in the design process still takes a different approach.

"What needs to be done is improve the ways that designers use the [product and manufacturing information, or PMI] capability of CAD, so that what they give to manufacturing people is more ready to use," InnovMetric's Soucy concludes. DE

Randy Frank *is a contributor to* DE. *Send e-mail about this article to DE-Editors@deskeng.com.*

INFO → **GOM mbH: GOM.com**

→ **Hexagon Metrology:** HexagonMetrology.us

→ **InnovMetric Software:** InnovMetricSoftware.com

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

Commentary

by Mehrdad Zangeneh

Optimize with Inverse Design

You hear about design optimization, and you realize the world requires more efficient and reduced emissions products. Wouldn't it be great to automate your turbomachinery design optimization? You can, by using relatively new 3D inverse design technology.

Efficiency levels for many turbomachinery applications have matured in recent years, in part because of new regulations. The introduction of computational fluid dynamics (CFD) in the design process led to significant improvement in performance, but further improvements are increasingly more difficult to achieve. The conventional design process, which is based on iterative changes to geometry, relies heavily on previous design experience, and tends to encourage designers to stay within their comfort zones. This can limit design efficiency, making it more difficult to achieve significant breakthroughs or meet demanding multi-objective/multi-point/multi-disciplinary requirements of modern turbomachinery.

In principle, all turbomachinery applications share common challenges, whether one looks at multi-disciplinary problems, such as aerodynamic with mechanical performance, noise and efficiency in fans and compressors, or good suction performance. Robust design optimization must also be considered, the aim being to make the design performances less dependent on operating changes. Automatic optimization can help find solutions to all of these design challenges.

Automatic optimization can help find solutions

Weighing the Methods

The key in using optimization in design is to explore the design space as widely as possible. Gradient type methods are faster computationally, but tend to find local minima. The goal, then, is to use evolutionary type approaches such as a genetic algorithm (GA), which can explore the design space widely and find global minima of objective functions. GA also copes well with multi-objective criteria, and creates Pareto-optimal fronts that show trade-offs between different design parameters.

On the other hand, GA requires a large number of objective function evaluations—typically running into thousands. Because many problems are multi-point, this makes the application of GA, coupled with full CFD or finite element analysis (FEA) rather expensive computationally.

Another alternative is to use some form of surrogate model. In this approach, a design matrix is generated by using design of experiments (DOE), which is then used to create a surrogate model through a quadratic regression (response surface model) or other methods. These surrogates can then be validated—and, if accurate enough, GA can be run on them, saving computational time as each CFD or FEA evaluation becomes a polynomial evaluation. However, in general, error-free surrogate models can only be obtained with a handful of design parameters.

Enter 3D Inverse Design

The keys to making automatic optimization part of a commercial product development are 3D geometry parameterization and the number of input design parameters. One blade geometry parameterized by just 30 parameters requires close to 600 to 800 designs to be evaluated—just for the initial DOE database. Even with high computational capabilities, this is not something that allows for a design to be developed in a few weeks.

In contrast, parameterization of the same geometry via 3D inverse design methods can be done with six to 10 parameters. This means only 40 to 100 designs are needed.

So, how is blade geometry parameterized via 3D inverse design? Different approaches are used for blade geometry parameterization. In axial machines, it is customary to use some of form of surface definition. By contrast, in many radial and mixed flow applications, generally the blade angle is used to control the camber distribution. This is done using a number of control points between leading edge to trailing edge on 2D sections that are then stacked together to form a 3D geometry.

In 3D inverse design, users parameterize the blade loading, or pressure jump across the blade. The implementation is such that four to eight parameters of blade loading can cover as much design space as 30+ parameters required when using blade shape directly. This reduction in design parameters makes application of surrogate model a practical reality for 3D design.

When taking time and cost into consideration, 3D inverse design technology proves to provide the clear advantage in achieving turbomachinery efficiency and emissions reduction via automatic optimization. Examples have been widely published. In the pump industry, for example, Carver Pumps and Ebara Corp. have successfully applied this method. For axial and radial fans, papers and case studies are available for ebm-papst, Kitech and Daikin. Finally, McQuay presented the application of coupled 3D inverse design with DOE for optimization of centrifugal compressor stage for the refrigeration industry. **DE**

Mehrdad Zaneneh, *Ph.D., is a professor of thermofluids at University College London, and founding director and CEO of Advanced Design Technology (ADT). Send e-mail about this article to DE-Editors@deskeng.com.*

Design & Simulate Without the Wait!

New NVIDIA® Maximus™ Technology Provides Integrated Workflow on a Single WhisperStation™

WhisperStation – Maximus enables you to visualize on the NVIDIA Quadro® GPU, while automatically offloading simulation and rendering onto the NVIDIA Tesla® GPU. By providing explosive performance, WhisperStation – Maximus shortens your development time and accelerates your workflow.

Faster and Greener Computing with:

- NVIDIA Quadro® GPUs for visualization + NVIDIA Tesla GPUs for lightning-fast computation
- High clock speed Intel® CPUs; SSDs and/or RAID for fast I/O; up to 8 drives
- 1P Configuration – 4 or 6 core Intel CPU, 2 GPUs, and 8 DIMM sockets for up to 64 GB DDR3 Memory
- 2P Configuration – two 4, 6, or 8 core Intel CPUs, 1 to 4 GPUs, and 16 DIMM sockets for up to 512 GB Memory
- 80 PLUS™ certified power supplies, ultra-quiet fans, sound proofing materials and high-efficiency components
- Linux and/or Windows configured, tested and ready to run your applications
- PCI-E Gen3 support for future Tesla and Quadro upgrades

NVIDIA MAXIMUS™ TECHNOLOGY

Put Our Expertise to Work For You

Users worldwide pushing the limits of technology in engineering, simulation, media, and research rely on Microway's expertise and attention to detail. From configuration to integration to technical support, we've been resolving the complicated issues – so you don't have to – since 1982.

Call a Technical Advisor at 508-746-7341

Visit microway.com/maximus
Sign up for our technical newsletter at microway.com/newsletter
Visit our blog at microway.com/hpc-tech-tips

Maximus Certified Applications Include:

3d Design	Media	Engineering
3ds Max®	Adobe® CS6	ANSYS® Mechanical
Bunkspeed	Adobe CS5	SIMULIA®
CATIA® V5/V6	Maya®	SolidWorks®
PTC Creo™		MATLAB®

CUDA-Enabled Applications Supported by WhisperStation:

Abaqus, Acusim Acusolve, Fluent, MSC Nastran and Moldflow for Simulations
AMBER, CUDA-BLASTP, GROMACS, LAMMPS, NAMD, Quantum ESPRESSO, TeraChem and VMD for BioTech

Microway®
Technology can count on since 1982

NVIDIA TESLA NVIDIA QUADRO®

GSA Schedule Contract Number: GS-35F-0431N

Every day, more and more of the things we see and use every day start life as a prototype printed on a 3D printer. It's a technology that is changing the world in some amazing ways. Designers and engineers are using it to print amazingly accurate prototypes before they go to production. Manufacturers are using it to print amazingly durable end-use parts and dramatically increase production efficiencies. Animators, educators, game developers and medical and dental professionals are all using it to transform the way they work. 3D printing is the next industrial revolution. And Stratasys is here to lead it. Welcome to a 3D World.

Learn more at **StratasysForA3DWorld.com**

Stratasys is a registered trademark of Stratasys, Ltd., registered in the U.S. and other countries.

Stratasys

FOR A 3D WORLD™

THE MOST AMAZING THING YOU CAN PRINT IS CHANGE.