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DE

Digital Engineering

September 2017

FOCUS ON: Mobility P.16

CAR TALK

Vehicle-to-vehicle communication standards. P.16

by Jamie J. Gooch

Irish Roads Test Technology, Marriage

MY OLDEST CHILD is off to college this year, so before she left the nest we decided to take that family vacation to Europe we have been talking about for years. My wife wasn't too keen on flying all the way across the pond ("Can't we just drive to Canada?"), but even she eventually succumbed to the lure of the Emerald Isle and the constant nagging of my children.

Things could have begun better. Our flight from Cleveland to New York was delayed an hour. "Not to worry, we have a four-hour layover in JFK anyway, so there's plenty of time," I assured them. Upon arrival in New York, we learned our flight to Dublin was going to be delayed by four hours. My platitude about embracing the journey, not the destination was met with general disdain, bordering on outright hostility from my wife.

My attempts to sleep in unpadded chairs at the airport and cramped quarters on the plane were not successful, so, after being awake for more than 24 hours, I climbed into our rental car at the Dublin airport. Quickly realizing I was in the passenger seat, I climbed back out and got in the right side behind the wheel. "Oh God," my wife said. "Just kidding," I said to reassure her. I'd never driven from the right (wrong) side of a car or on the left side of the road, so surely she would cut me some slack. "Oh God," she said again, getting into the passenger seat. "Do they have Uber here?"

Who needs Uber when you have Google Maps? I punched in the hotel's address on my phone, quickly previewed the route and away we went—I was trying to exude confidence to my anxious wife, she was searching her purse for her Rosary beads, and my children (who had slept in the airport and on the plane) were chatting away happily in the back seat. I didn't think she needed to know about all the roundabouts coming up, so I left them as a surprise. Travel is about the joy of discovery and all that.

A Failure to Communicate

Thirty minutes later we arrived safely at the hotel. My wife didn't kiss the ground, but it wouldn't have surprised me. I had only drifted to the wrong side of the road once on a road so narrow you couldn't really say it had a right and left side anyway. The driver of the car coming around the corner didn't even honk his horn when he saw me coming right at him. I got the feeling people around the airport were used to sharing the roads with tourists. Still, as the week went on and we racked up miles seeing many of the beautiful sites of Ireland, I couldn't help but wonder how long it would be before a car could tell me a tour bus was about to take a wide turn into my lane around an S-curve or a garbage truck would be stopped in front of me around the next bend.

There was no setting in Google Maps to avoid narrow, twisty roads—and we wouldn't have been able to see much of the country if we had tried to avoid them—but Dedicated Short Range Communication (DSRC) or cellular vehicle-to-everything (C-V2X) technologies like those explained in our cover story (see page 16) may have gone a long way in reassuring my wife that we would make it there and back again. As the story notes, vehicle-to-vehicle (V2V) communications still have a number of challenges to overcome, especially when it comes to standardization.

One Irishman I spoke to wished the country would switch to right-sided driving, assuming that switching to what the majority of the world does would lower costs and provide more car-buying choices. If the world can't agree on which side of the road to use, can we agree on a V2V communications standard? Thanks to input from global manufacturers, I think we can. But I think there's an even bigger challenge to V2V than that.

Humans in the Loop

Our rental car was fancier than what we drive at home. We soon found out it had some safety smarts we weren't used to. While driving from Dublin to Cork, I almost took the wrong exit and then corrected. The car apparently thought I was getting too tired to drive and displayed a steaming cup of coffee icon on the dash, accompanied by an audible "ding" to make sure I was awake. I appreciated, but ignored, its advice.

Once V2V technologies get past standardization, security and compliance hurdles, they will still need to be designed in such a way to help overcome human nature. Some people are smart enough to take advice from sensor-laden machines, others are too stubborn. My wife, for instance, suggested we pull over if I was tired when the car suggested I take a break. Would she be more comfortable in a self-driving car? Maybe, but I think we still have a long way to go before she would agree to an autonomous driving tour of Ireland. DE

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

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TECHNOLOGY FOR OPTIMAL ENGINEERING DESIGN

INSIDE

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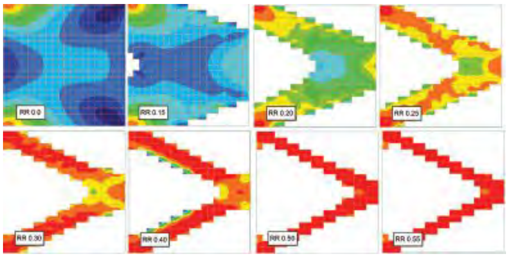
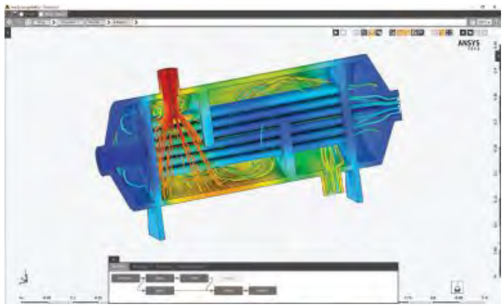
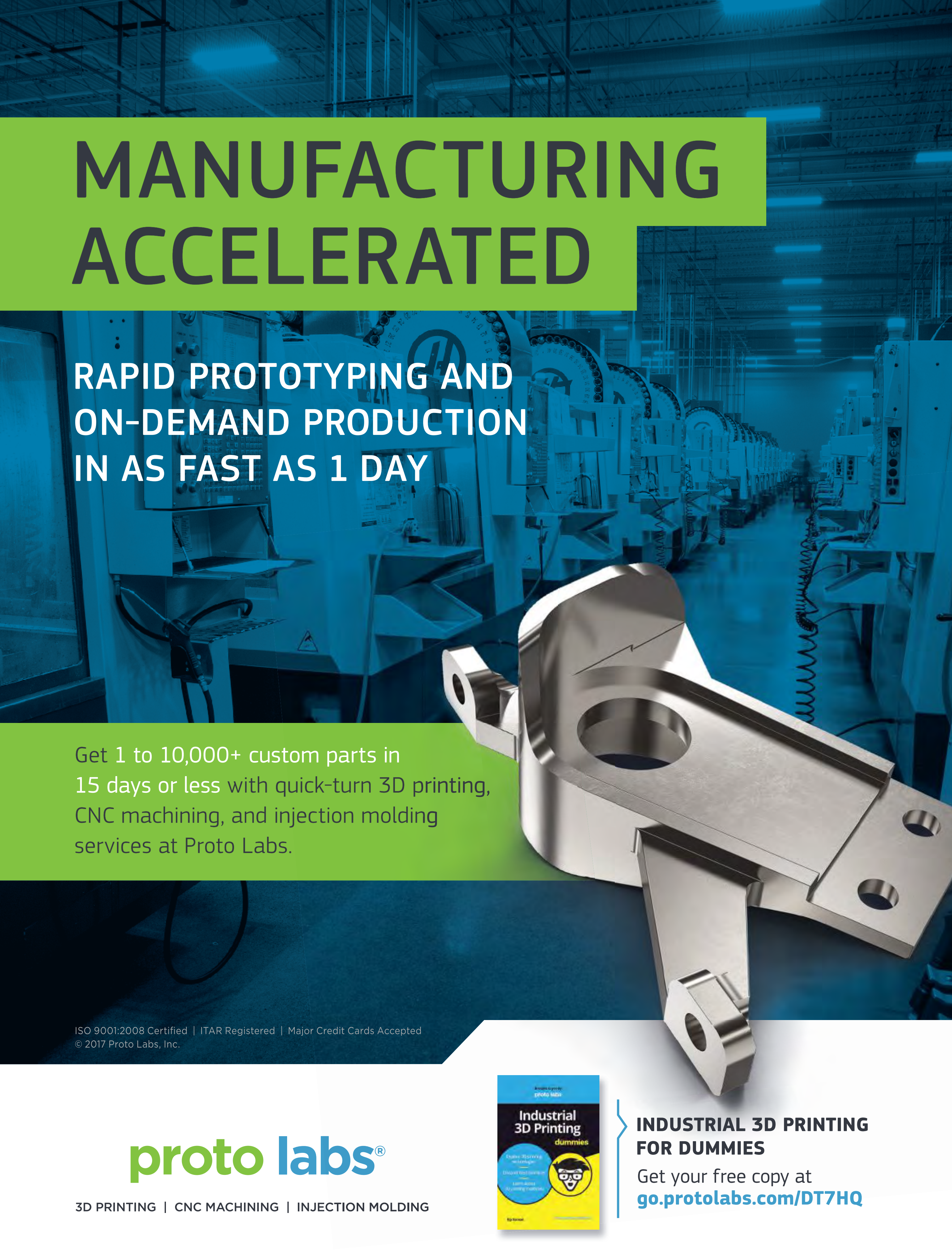
COVER STORY

FEATURES





ON THE COVER: Image courtesy iStock/Chesky_W.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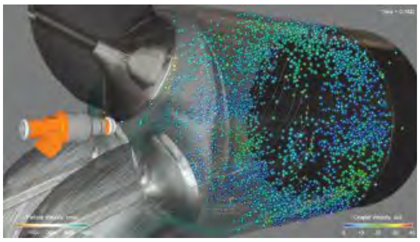
FOCUS ON MOBILITY

DEPARTMENTS



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Billions of Global, On-the-Go Connections

8.2B
Mobile Connections

Total number of global, mobile connections, including machine-to-machine connections; a 4.7% year-to-year increase.
— GSMA Intelligence, August 2017

4.3B
Mobile Broadband Subscriptions

Mobile broadband subscriptions have grown >20% annually in the last five years; expected to reach 4.3 billion globally by the end of 2017.
— "ICT Facts and Figures 2017," UN specialized agency for information & communication technologies, July 2017

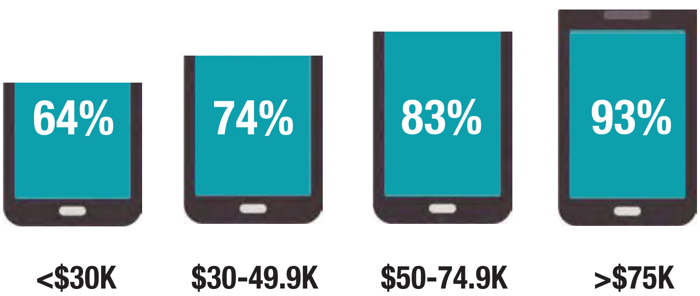
5B
Unique Mobile Users

Total number of global, unique mobile users; a 4.76% year-to-year increase.
— GSMA Intelligence, August 2017

U.S. Mobile Phone Ownership

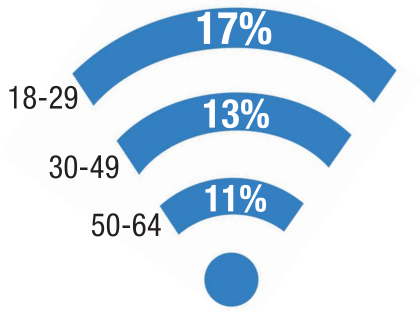
95% Nearly all Americans—95%—own a cellphone of some kind, and 77% of them are smartphones.
— Pew Research Center, January 2017

Smartphone Ownership by Income



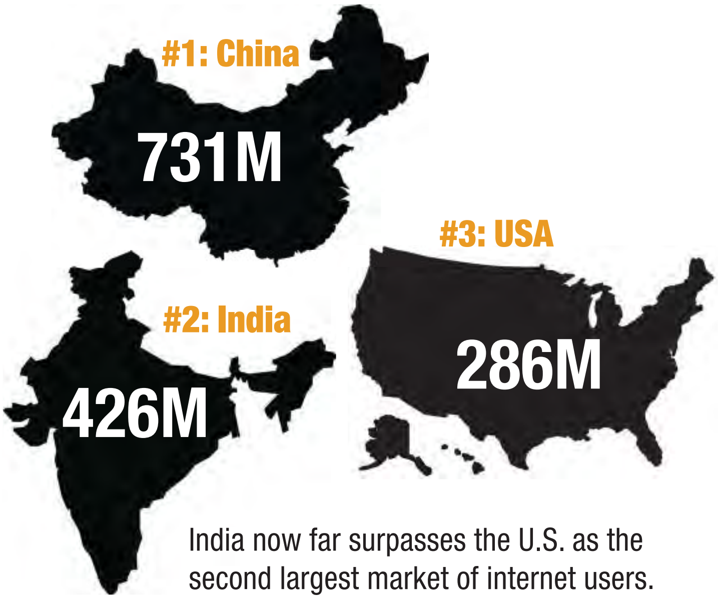
93% of Americans who earn more than $75,000 a year own smartphones.
— Pew Research Center, January 2017

Smartphone Dependency by Age



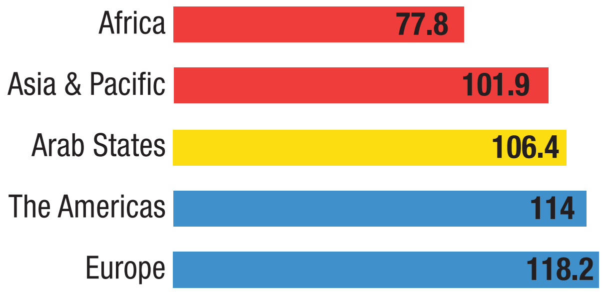
In 2016, more younger Americans were dependent on smartphones as their means of internet access. Over 10% of American adults who own a smartphone do not have traditional home broadband service.
— Pew Research Center, January 2017

Global Internet Users / Mobile Penetration



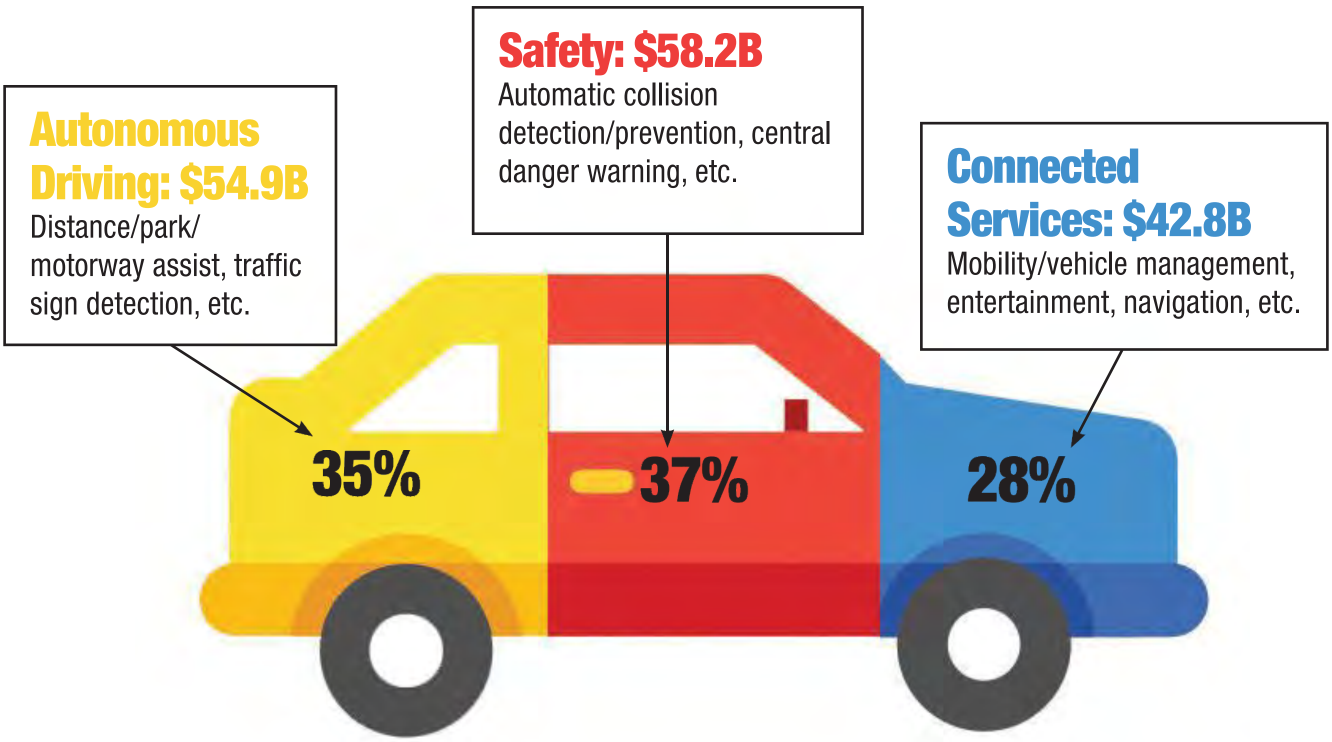
India now far surpasses the U.S. as the second largest market of internet users.
— *Internetworldstats.com, March 2017*

Mobile Penetration by Region



Estimated mobile-cellular penetration rates per 100 inhabitants for 2017.
— *"ICT Facts and Figures 2017," UN specialized agency for information & communication technologies, July 2017*

Connected Car Revenues in 2022: $155.9B



The global car market has the potential to build value from the sale of connected car packages to end customers—fully $155.9 billion in 2022, up from $52.5 billion in 2017, an average annual growth rate of 24.3%.
— *Connected Car Report 2016, Strategy&, part of PwC, September 2016*

Exploring Virtual Reality in Product Design at the Rave Cave

BY JAMIE J. GOOCH

I WENT SPELUNKING recently, but I wasn't exploring a natural cavern. I traveled to Sterling Heights, MI, to visit the Rave Cave, where I sat in the driver's seat of an armored personnel carrier, flew through a working factory and made sure everything in an operating room was within my reach for surgery. Not to worry: No expensive equipment was wrecked and no blood was spilled; it was all done through virtual reality (VR).

DE Editorial Director Jamie Gooch about to take the wheel of some heavy equipment.

Collaborating on Virtual Reality

The Rave Cave is located in the Defense Corridor Center for Collaboration and Synergy (DC3S) office building, which houses a number of technology-related companies in an attempt to promote creativity and collaboration between the businesses. DC3S is also right across the parking lot from RAVE Computer, which helped establish the Rave Cave as a nonprofit as part of a cooperative research and development agreement with TARDEC (the U.S. Army's Tank Automotive Research Development and Engineering Center). RAVE Computer is a manufacturer of commercial-off-the-shelf and custom computing solutions. One of its specialties is providing ruggedized hardware that meets MIL-SPEC standards. It also targets engineers who need computing power for modeling, simulation and visualization.

Rave Cave President Art Adlam prepares for virtual surgery in front of a more portable, but less immersive VR CAVE.

The mission of the Rave Cave is to facilitate government research into VR, promote STEM (science, technology, engineering and math) education for kindergarten through 12th-grade students, be a resource for higher education and encourage the development and retention of a high-tech workforce in the region.

"We are like a technology warehouse where people can come to see how different software is used in different areas," says Art Adlam, president of Rave Cave. "We're agnostic in hardware and software."

Visitors include schools, manufacturers, the Army and healthcare providers who want to see how VR technology could be applied to their needs. For example, manufacturers may want to use VR for product evaluation or to see how machines in a factory could be arranged. Hospitals and the Army are interested in VR for training.

"AR is a great collaboration tool," says Adlam, noting that serving VR data from a remote computer has come of age, which enhances collaboration without risking any sensitive intellectual property. "Engineering can remotely communicate and display designs with people on the factory floor before a machine is produced, for instance."

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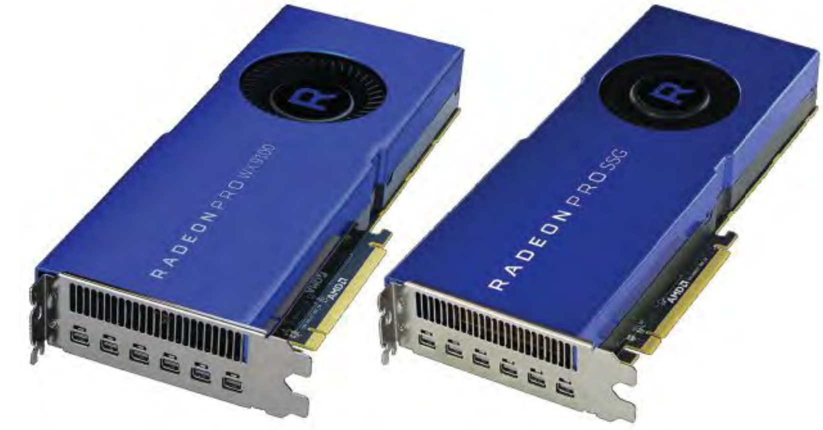
Dispatches from SIGGRAPH 2017: High Core Counts and Low Pricing Start CPU-GPU Battles

BY KENNETH WONG



The AMD Radeon Pro WX 9100 and Radeon Pro SSG are successors to the AMD FirePro line of graphics cards. ***Images courtesy of AMD.***

AS THE COMPUTER graphics fans started streaming into Los Angeles for SIGGRAPH 2017, AMD began releasing news about its Ryzen Threadripper product line, designed to challenge Intel's dominance in desktop PCs.

AMD Ryzen Threadripper is "the fastest multithreaded processor on a consumer desktop PC, ever," proclaimed AMD. "Up to 16 cores provide an astonishing 32 threads of simultaneous multiprocessing power, while up to 40MB of combined cache and vast I/O from the enthusiast-grade AMD X399 chipset stand ready to feed the beast."

Three versions were announced:

- 1950X with 16 cores, 32 threads ($999)
- 1920X with 12 cores, 24 threads ($799)
- 1900X with 8 cores, 16 threads ($549)

Their base clock speed begins at 3.4 GHz, but they can be boosted (overclocked) to reach 4.0 GHz. The first machine delivered using Threadripper is the Area-51 Threadripper Edition from Alienware (a division of Dell), priced starting at $2,999, now available for preorder.

Blurred Territorial Boundaries

The high-end PC market is the territory of the Intel Core i processor family, different from the professional workstation market that traditionally uses Intel Xeon processors. Hardware vendors differentiate gamers and digital content creators as high-end PC users; and professional engineers, architects and filmmakers as workstation users. But the divisions are not so clear in reality. With the emergence of affordably priced entry-level workstations, the Core i and Xeon machines sometimes find themselves competing for the attention of the same potential buyers.

Intel's countermeasure against the AMD Threadripper encroachment is the Intel Core i9 series, set to roll out later this year. The Core i9 7980XE, dubbed the extreme edition processor, promises a whopping 18 cores and 36 threads. But on pricing alone, AMD's Threadripper seems irresistibly competitive. AMD's Ryzen Threadripper 1950X—the model with 16 cores and 32 threads—is $999. By contrast, Intel's similarly structured Core i9 7960X—with 16 cores and 32 threads—is reportedly priced $1,699 (according to PC World).

GPU-Accelerated Indian Epics

This year's SIGGRAPH also marked the launch of AMD Radeon RX Vega and Radeon Pro GPUs. With fanfare and theatrical backdrop, AMD introduced the products to the audience at The Novo in Los Angeles' L.A. Live district. One of the highlights of the event was the cameo appearance of Indian director S. S. Rajamouli, responsible for Baahubali 1 and 2. (The two large-scale, breathtaking war epics have been compared with "The Lord of the Rings" series by some.) Baahubali is rendered on AMD Radeon Pro GPUs, featuring the AMD high bandwidth cache controller (HBCC) for handling large datasets.

Radeon ProRender is AMD's open-source rendering application, built on OpenCL. By offering ProRender as an integration option, AMD hopes to attract app developers who might use iRay, a rendering engine from competitor NVIDIA.

AMD's main competition in the GPU space is NVIDIA, known for its GeForce, Quadro and Tesla GPUs. Much of Quadro's and Tesla's workflows run on programs written in NVIDIA's CUDA programming environment. AMD has been promoting GPUOpen and ROCm software stacks for developing games and computing applications.

AMD RX Vega comes in the following:

- Radeon RX Vega 64 liquid cooled;
- Radeon RX Vega 64 with air cooled; and
- Radeon RX Vega 56 standalone.

They're offered in bundles with games and monitors. Prices start at $499.

The Terabyte-Scale GPU

For workstation users, AMD is rolling out the Radeon Pro WX 9100 and the Radeon Pro SSG. These are the successors to the product line previously known as FirePro.

The Radeon Pro SSG is equipped with a solid-state drive. With it, "video playback performance can not only meet but exceed real-time performance requirements because of the card's ability to process and present this same data at speeds that far exceed typical solid state mass storage," AMD writes. "It's the world's first GPU to break the terabyte memory barrier with 2TB of graphics memory."

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| ABBEY'S ANALYSIS |

DATA MANAGEMENT

by Tony Abbey

Grassroots Simulation Data Management

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

I HAVE JUST COMPLETED an intensive six days carrying out a series of analyses on a structural component. Two weeks ago, I knew very little about the structure, its function and what its key performance metrics would be. I had a CAD model, an outline performance specification and references to test data. I assume I'm not alone in my approach to the initial stage of a task like this. From a sea of disconnected information, I had to derive a clear understanding of the analysis objectives and develop an analysis plan.

A lot has been said about best-laid plans—and it certainly was true in my case. As I carried out trial analyses to understand the implications of the structure, the plan naturally changed. This didn't worry me too much. I don't think I have ever managed to achieve a one-shot analysis in my whole career. Finite element analysis (FEA) demos on YouTube often create a false sense of reality. Nothing is ever that simple, and FEA just never works the first time.

Archiving Angst

The series of analyses finally distilled down into what was needed to be able to simulate and predict the structural behavior. The analysis report was completed and accepted by the client. However, now comes the punchline. My office is littered with notes, jottings and sketches. My computer is equally littered with analysis files, results files, spreadsheets and Word documents. The scope of the data ranges from obsolete work, through to final sign-off justification. I know I must tidy this lot up and put it into a form that is suitable for archive—and most importantly, for easy retrieval later on. Unfortunately, this task isn't aided by the CAD tool or either of the two FEA tools used on the project. Each tool offers different approaches and formats to archiving.

So, this brings me to simulation data management or SDM. I really do want to manage my simulation data. However, the commercial applications seem to focus more on the enterprise level. Many interesting tools enable me to collaborate within a CAE and CAD community. They would enable someone to manage my (and everyone else's) data from a top-down perspective. The SDM discussions I have followed also seem to embrace more of a global vision. I may have been distracted by this, and may be missing some "grassroots" functionality that would assist me in my chaotic little CAE world.

My solution is based on Windows File Explorer, Dropbox and a master spreadsheet with hyperlinks. It is very tedious to set up, and certainly not error-proof. Over the years I've tried all sorts of different homegrown approaches—one clear lesson I learned is to keep the process as simple as possible. So, my own plea to software vendors providing SDM solutions is to let me know if a single-seat, affordable solution to my dilemma exists.

Looking Up

I do wonder if one of the reasons for the slow uptake and general uncertainty about SDM is because it takes a top-down view. I can understand the need for an enterprise-wide solution and the aspiration to control analyses across collaborative teams. However, for many small enterprises such as my own, that is overkill. We are looking for much simpler, more pragmatic solutions. Perhaps, if products are developed in a more bottom-up way, they may be more attractive to the average CAE user. I would like a basic toolkit that serves my very parochial needs. If I can see a clear migration path whereby that toolkit could connect and dovetail into a wider solution, it would be very attractive.

I have discussed this with colleagues in the FEA community. I tend to get extreme viewpoints: get to grips with Python, Excel and other linking applications, or invest in an SDM solution. Somewhere in-between must be what I'm searching for. If you have found it, or produce it, please do share. I look forward to filing a follow-up article from the trenches. DE

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

BRIEFINGS

News and New Products

AMD Rounds Out Ryzen Family for High Performance Computing

Responding to a market hungry for reasonably-priced, high-performance computing (HPC) solutions, AMD has fleshed out its Ryzen lineup of top-of-the-line processors with the Ryzen 3 desktop family designed as a budget-friendly package for mainstream users.

The new pair of processors—the AMD Ryzen 3 1300X and AMD Ryzen 3 1200 CPU—come equipped with quad-core unlocked performance, making them suitable for sophisticated computing applications, including 3D modeling, rendering and simulation. The Ryzen 3 models join AMD's Ryzen 7 processors designed for demanding power users and the Ryzen 5, which targets so-called serious "prosumers."

The workhorses of the Ryzen line, best suited for high performance engineering and simulation applications, are the Ryzen 7 processors, launched earlier this year and boasting eight cores, 16 threads and pricing structures that AMD officials tout for undercutting Intel high-end processors. The Ryzen 5 series, which is positioned as more affordable, ranges from four cores and eight threads up to six cores and 12 threads.

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Siemens Targets Auto by Integrating PLM and ALM

In a nod to the software-heavy content of today's cars, Siemens PLM Software introduces the Integrated Software Engineering solution for the automotive industry—a platform tuned to address the development challenges associated with the explosive growth of embedded software in increasingly sophisticated vehicles. The platform melds the Polarian application lifecycle management (ALM) software with the Teamcenter product lifecycle management (PLM) platform. The goal: To help automotive industry players seamlessly manage what officials say are the inherently different lifecycles of electro-mechanical systems and the software created to control those physical systems.

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AI is Instrumental to Manufacturing

Anna-Katrina Shedletsky and Samuel Weiss, both ex-Apple engineers, spent countless man hours on the ground in Chinese factories during the run-up to the Apple Watch launch, and based on the difficulty of their experiences, they saw opportunity for a new solution. Their company, Instrumental, just launched its first product—an offering that leverages artificial intelligence/machine learning and camera-equipped

inspection stations to help electronics companies remotely manage their product lines with an eye toward maximizing uptime, improving quality and accelerating time to market.

The Instrumental station combines what the company describes as easy-to-deploy hardware and software setup that snaps images of each unit at key points in the assembly process as it moves through the production line. Those images are captured, allowing remote design and manufacturing engineers to inspect and take geometric measurements of all of the units as they pass through the production line, immediately or weeks after. The images are remotely searchable and comparable, and the machine learning aspect of the software, dubbed "Detect," learns and reacts to assembly line data, which, in turn, helps identify units that appear defective, officials explained.

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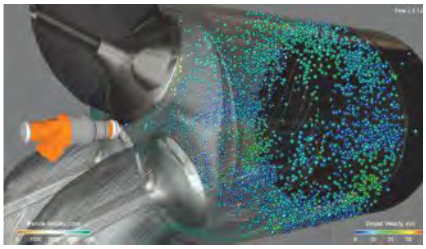
ANSYS Acquires CEI

ANSYS has acquired the North Carolina-headquartered CEI (Computational Engineering International, Inc.), a company best known for its EnSight software.

EnSight is post-processing software for



CFD (computational fluid dynamics) users. The company distinguishes its offering from the competition by the integration of photorealistic rendering into its visualization environment. The upcoming update EnSight 10.2, for instance, features raytracing—a common characteristic in high-end 3D modeling and dedicated rendering programs but a rarity in post-processing packages for simulation.

ANSYS Workbench, a collection of simulation tools, includes some tools for simulation data viewing. The integration of EnSight's features into Workbench would add a new level of realism.

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RAPID READY ROUNDUP

Tooling Up for 3D-Printable Steel

As the cost of 3D printers comes down, more and more industries have begun to explore the potential of the technology, hoping to

expand its application from prototyping to actual production roles. In the process, demand for more metal options has increased. Unfortunately, the number of metals and alloys that can be printed remains fairly limited.

Although the additive manufacturing market offers several metals suitable for production of complex parts — ranging from nickel alloys and aluminum to titanium — many simply do not offer the strength and reliability required for demanding applications. All of these factors have ramped up pressure on technology providers to deliver the means to produce a broader array of 3D-printable steel.

To understand why steel poses such a challenge for 3D printing, you have to look at the production process on the microscopic level.

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Formlabs Makes a Play for Production 3D Printing

3D printing has made great strides over the last few years as a prototyping tool, but now a 3D printer maker has released new technology designed to make 3D printing a staple of digital manufacturing.

Formlabs, founded in 2011 by a group hailing from the MIT Media Lab, has announced the Fuse 1, a new model that it says brings previously expensive and complex selective laser sintering (SLS) technology to a benchtop model, and Form Cell, an automated product solution for additive manufacturing built around the company's Form 2 stereolithography printer.

The company, now 270 people (including 100 engineers) with offices in Cambridge, MA, and Berlin, sees its mission as making 3D printing as simple as 2D printing.

MORE ➜ rapidreadytech.com/?p=11572

Affordable Metal Printing

As more industries investigate the use of additive manufacturing to create production parts rather than prototypes, metal printing capabilities are in higher demand. A new Pennsylvania company claims it can help more companies adopt the technology by offering relatively low-cost metal manufacturing systems.

Xact Metal has launched its first metal additive manufacturing printer, the XM200. At $120,000, the XM200 printer features a large build volume of 125-in. (5x5x5 in.) or 2049cc (127x127x125 mm), a 250W fiber laser and a high-speed scanner that the company claims fuses at speeds up to 1.5 meters/second.

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GE Additive Goes Big in Laser Powder

GE has made a big announcement about its additive manufacturing operations — really big. The company's GE Additive division is building the world's largest laser-powder additive manufacturing machine.

Designed for aerospace applications, the device will be able to print in a build envelope of 1 m cubed (1,000x1,000x1,000 mm). The ATLAS will debut at the Formnext Show in Frankfurt in November.

GE has partnered with Concept Laser on the project. The latter boasts the current largest laser-powder bed machine (the X Line 2000R), which features a build envelope of 800x400x500 mm.

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TOMAR Electronics Solves Carbon 3D Printing Problem

Every once in a while you run into one of those I-can't-believe-this-is-a-problem problems. There should be an easy solution — some simple part to buy — and you can't believe it doesn't exist.

Recently, engineers at TOMAR Electronics in Gilbert, AZ, ran into just such a situation. The company designs and manufactures specialty LED light bars, sirens, strobe beacons and related equipment for emergency vehicles and industrial applications.

To make a new sales display unit with various configurations of custom lighting installations, the TOMAR staff invoked a flexible, modular design. This concept included panel slots for multiple rocker-style electrical switches that are populated in different quantities per specific model configuration. For versions using fewer than the maximum number of switches, empty slots would simply be covered with fitted plugs. However, when the switch manufacturer was asked about providing such plugs (with an outline the same as the switch), their only solution was to use dummy switches that are identical but simply aren't wired up. This "solution" was just primed to confuse the potential TOMAR customer, so the company turned to Carbon's Digital Light Synthesis (DLS) technology powered by the Continuous Liquid Interface Production (CLIP) process.

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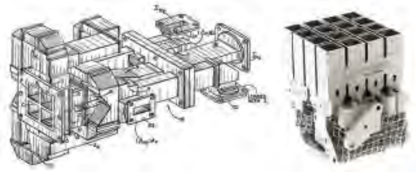

One Hundred Parts Down to One with Metal 3D Printing

Optisys LLC, a provider of 3D-printed metal micro-antenna products for aerospace and defense applications, recently completed a project that it says documents advantages of employing additive manufacturing.

The test-piece demonstrator project involved a complete redesign of a high-bandwidth, directional tracking antenna array for aircraft (known as a Ka-band 4×4 Monopulse Array). Optisys performed every aspect of the design work in-house and printed the component in a single piece on its Concept Laser machine.

Optisys conducted a profitability analysis on how its redesigned microwave antennae test piece compared with a legacy design that is traditionally manufactured. By optimizing its design for additive manufacturing, Optisys realized several benefits.

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Streamlining 3D Printing Post-Processing Opens Market Opportunities

A few companies have launched 3D printing processes that promise voxel-level control,

a capability that has the potential to enable additive manufacturing to cost-effectively take on applications like short-run, end-use parts production. That could open the door for mainstream adoption of AM technology.

Until not too long ago, design engineers contemplating harnessing the power of AM had to sift through a bewildering array of technologies, looking for one that provided speed, strength, accuracy, appropriate finish quality, safety and repeatability. The problem was that there simply wasn't a system on the market that could deliver all these features.

What AM technology needed was the ability to produce injection-molded-quality parts on demand, safely and affordably. This translates into high-resolution, 3D-printed parts with the same strength and surface finish as injection-molded parts.

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Reusing IN625 Powder for 3D Printing? What the Test Data Says

Whether you're new or experienced in powder-bed laser sintering of metals, you know that a basic operational mode for this form of 3D printing (additive manufacturing/AM) is to reuse most of the powder for the next build. But every time you 3D print with anything but 100% new material, in the back of your mind (or front), you're wondering about the effects of building parts from a mix of new and used powder. What, if anything, changes from build to build, and how does this affect part performance?

To get real data (based on one material and one additive manufacturing system, for starters), engineers at Stratasys Direct Manufacturing did an in-depth, eight-month study that measured and evaluated a number of part properties. The results are really interesting and could pave the way to analyzing powder reuse for other materials and equipment.

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➜ For more on additive manufacturing/3D printing for design engineering teams, visit rapidreadytech.com.

V2V Technology: A Work in Progress

Vehicle-to-vehicle communications promise life-saving innovations.

BY TOM KEVAN

THE GLOBAL AUTOMOTIVE INDUSTRY seems poised on the brink of a brave new world, where connectivity and sensor technologies come together to create systems that all but eliminate life-threatening collisions and enable automobiles that drive themselves. Collectively known as Cooperative Intelligent Transportation Systems, vehicle-to-vehicle (V2V) technologies open the door for vehicles to share information and interact with each other, as well as with the emerging smart infrastructure. These systems promise not only to make transportation safer and to reduce the environmental impact of automobiles, but also to reduce traffic congestion.

Although the automotive industry's engineers have laid significant groundwork to make V2V technology a reality, they still have to overcome several major hurdles before the technology can hit the road. As with many other manifestations of the Internet of Things (IoT), V2V proponents still argue over which wireless technology will best deliver connectivity for the application. And once the connectivity is in place, design engineers still must map out measures that will adequately manage the security of this new body of data.

How It's Supposed to Work

Communications represent the keystone of V2V systems. The current technology builds on a wireless standard called Dedicated Short Range Communication (DSRC), which is based on IEEE 802.11p. Transmissions of these systems consist of highly secure, short- to medium-range, high-speed wireless communication channels, which enable vehicles to connect with each other for short periods of time. Using DSRC, two or more vehicles can exchange basic safety messages, which describe each vehicle's speed, position, heading, acceleration rate, size and braking status. The system sends these messages to the onboard units of surrounding vehicles 10 times per second, where they are interpreted and provide warnings to the driver.

For these communications to prevent collisions, information has to be shared in real time. To achieve this, V2V systems leverage telematics to track vehicles via GPS, monitoring the location, movements, behavior and status of each vehicle.

V2V systems consist of a GPS module, the onboard processing units and RF transceiver modules. Communication between two vehicles requires two sets of components: one that transmits the safety message and another that confirms receipt and interprets the data.

Smart features of V2V systems promise to enhance driver awareness via traffic alerts, providing notifications on congestion, obstacles, lane changing, traffic merging and railway crossing alerts. Additional applications include the following:

- blind spot warnings;
- forward collision warnings;
- sudden braking ahead warnings;
- approaching emergency vehicle warnings;
- rollover warnings; and
- travel condition data to improve maintenance services.

In the future, V2V systems will represent one part of a larger communication system called vehicle to everything, or V2X. In this ecosystem, each vehicle will communicate with any entity that may affect the vehicle, including other vehicles, infrastructure, pedestrians, smart devices and other networks (see video: digitaleng.news/de/?p=38649).

Making V2V Connectivity Work

In performing all these tasks, V2V communications will make high demands on whatever wireless standard the industry harnesses to enable connectivity in the transportation ecosystem. To support reliable messaging services, the technology will have to contend with a dynamic operating environment. High

V2V technology promises to be the next major enabler of car safety, with the potential to save thousands of lives each year on our highways. Although much work has been done on the technology, the industry must still overcome major hurdles, standardizing communications and ensuring adequate security.
Image courtesy of NXP Semiconductors.

relative speeds between transmitters and receivers will mean that the communications system must support low latency to ensure the effectiveness of safety-related applications. The system will also have to tolerate the high message traffic created by transmissions from multiple sources in congested traffic scenarios.

Fortunately, design engineers can help minimize the effects of these conditions with established software tools. High relative vehicle speeds can be addressed by applying advanced reception algorithms. At the same time, high node density can be handled by using distributed congested control algorithms and by varying transmission power, modulation and coding rate.

What's the Payoff?

To accelerate V2V implementation, the U.S. Department of Transportation (U.S. DOT) has directed the National Highway Traffic Safety Administration (NHTSA) to issue a proposed rule to standardize the development and implementation of vehicle communications technologies in cars and trucks. The goal is to enable new crash-avoidance applications that the NHTSA estimates could eliminate or mitigate the severity of as many as 80% of non-impaired crashes.

The NHTSA rule proposes requiring V2V devices to communicate through standardized messaging technology. Each device would use DSRC communications.

V2V communications would enhance drivers' abilities in a variety of situations. For example, the system would provide the driver with the information needed to decide whether it is safe to pass on a two-lane road (to avoid potential head-on collisions), turn across the path of oncoming traffic or proceed through an intersection. In these situations, V2V communications can alert drivers of developing threatening situations hundreds of yards away, when the driver and onboard sensors cannot detect the threat. In addition, V2V systems could enhance the performance of vehicles supporting automated driving functions like automatic emergency braking and adaptive cruise control.

The rule would also mandate extensive privacy and security controls. For example, V2V systems would not exchange information linkable to an individual.

What's the Holdup?

So with this government action and the compelling applications that V2V offers, why hasn't implementation of the technology progressed further?

"It's a chicken-and-egg situation for many OEMs," says Debby Bezzina, managing director of the U.S. DOT Center for Connected and Automated Transportation at the University of Michigan Transportation Research Institute (UMTRI). "Unless U.S. DOT mandates V2V technology on new vehicles, not all OEMs may put it on their new vehicles. If not everyone has the technology, the benefits will be limited."

Another obstacle is evolving standards. Most of the standards have been updated based on the lessons learned from the Safety Pilot Model Deployment conducted by UMTRI in Ann Arbor and from Safety Pilot activities conducted by other U.S. DOT subcontractors. There is, however, still discussion around spectrum sharing, which could lead to more changes being made in the standards.

"The success of V2V will depend on the penetration rate of the technology," says Alessio Filippi, technical director, V2V, NXP Semiconductors. "The need for widespread adoption is why you see governments and other interested groups pushing for standards and why the U.S. government has proposed mandating the technology to break the vicious circle and start saving lives. It is essential that there is agreement on the critical functions."

> "The need for widespread adoption is why you see governments and other interested groups pushing for standards and why the U.S. government has proposed mandating the technology to break the vicious circle and start saving lives."
> — *Alessio Filippi, NXP Semiconductors*

The Wireless Standards Debate

Many in the industry, including the NHTSA, thought that the DSRC standard had cemented its place as the official wireless technology of V2V communications. Recent events, however, indicate that this decision is still up in the air.

An alliance of automakers and cellular service providers—including Audi, BMW, Daimler, Qualcomm, Ericsson, Intel and Nokia—advocate cellular standards as an alternative. Because the position of DSRC has not been finalized, some interested parties contend that full consideration should be given to other options.

As defined by the Intelligent Transportation Systems program, DSRC occupies 75 MHz of the wireless spectrum, from 5.85 to 5.925 GHz. This segment of the spectrum consists of seven 10 MHz channels. The standard uses 52 subcarrier OFDM modulation to achieve a data rate of 3–27 Mbps, and its range is estimated to be as much as 300 meters.

DSRC advocates see the technology as the only option currently suitable for direct V2V communication because it is the only proven technology available today. In fact, you can even buy a car with this technology. "DSRC is the only technology tested and proven for safety-critical applications," says Filippi. "There are no field trials or information from field trials with C-V2x in V2V direct communication modes that are available."

On top of this, DSRC provides robust performance. "DSRC has low latency required for safety applications," says Bezzina. "It's very robust, secure and ready for production. You don't have dropouts with DRSC like you have when using your cellphone."

Some engineers, however, dispute that DSRC's latency is up to the job. Those holding this view contend that the standard isn't fast enough for collision-avoidance actions.

The real stumbling block for DSRC is concern over the potential overlap of the DSRC spectrum and the upper channels of Wi-Fi. If DSRC's spectrum band is shared, packet loss could reach unacceptable levels.

Not all V2V developers, however, see spectrum overlap as a problem. "The current allocation of Wi-Fi in the 5 GHz is not an issue," says Filippi. "The 5.9 GHz channels are currently reserved for V2V application, and Wi-Fi can't use them." Even so, the U.S. DOT has begun testing spectrum sharing and investigating methodologies to reduce risk of packet loss.

DSRC's main competitor is known as cellular vehicle-to-everything, or C-V2X. This technology uses existing 4G cellular standards like LTE for both V2V and V2I (vehicle-to-infrastructure). Using LTE, C-V2X is also a well-developed technology, with both hardware and software available on the market. Although, to date, no one has determined what spectrum would be used.

The biggest problem with C-V2X is that its performance in this application is untried. LTE cannot broadcast vehicle to vehicle directly, and there are also limitations in how it could work in absence of a network.

C-V2X also falls short in terms of safety and security. The cellular technology simply doesn't have security experience in V2V safety critical applications, and it lacks Automotive Safety Integrity Level certification.

Is It Safe?

Like many emerging IoT devices, security is an issue for connected cars. As a result, a lot of V2V development effort focuses on securing these advanced systems.

Security concerns spring from conditions created by both reality and perception. For the connected car, the scale of security risks increased exponentially as soon as it is connected to the internet. Although cars have always been vulnerable to local attacks, internet connectivity exposed them to attacks from anywhere in the world. Compounding the problem is the fact that cyber attacks on connected cars have the potential to cause serious physical damage.

In terms of perception, many still see cars as mechanical devices, overlooking the fact that in many respects automobiles have almost become extensions of consumer electronics. Today's car relies on many electronic components—chips running countless lines of software. The components and code combined present a tempting target for cyber attacks. This nascent vulnerability becomes greater when V2V system developers integrate connectivity components adjacent to existing systems that were developed with no attention paid to security issues.

As a result, design engineers need to take additional cybersecurity measures. "Design engineers need to implement strong security measures that provide identity while maintaining privacy, manage keys and protect cryptographic operations while using those keys," says Derek Bouius, security IP product marketing manager at Synopsys. "These [advanced] operations should all be contained within an isolated hardware environment, creating a security perimeter protected from the rest of the system."

At the same time, security measures should extend all the way to the chip level. "Subsystems—as in multiple chipsets on a board—cannot have effective security without using chipsets designed to address specific security requirements," says Bouius. "At a minimum, these security measures must include authentication of instruction code—via a secure boot process—and a hardware-based random number generator. Many more advanced technologies exist to mitigate currently known attacks and threats, including side-channel countermeasures against timing and power analysis, as well as detecting targeted injection of faults."

Unfortunately, determined attackers are continually finding new methods to compromise systems and extract valuable data. It is therefore critical that designers maintain awareness of the newest technologies.

Designers should take advantage of other countermeasures as well. For example, security can be further enhanced with a secure element to store the private keys. Experts also advocate separating safety-critical and entertainment hardware and software.

Still, existing specifications have already laid much of the groundwork to secure V2V systems. "There are already specifications written to address security," says Bezzina. "A design engineer should adhere to the Security Credential Management System specifications. "The device should also have a hardware security module onboard. Each message broadcast from any DSRC device is signed by a certificate generated by the Security Credential Management System. If a device is

Technology developers see V2V systems as one part of a larger communication system called vehicle to everything, or V2X, which promises to make our highways safer. In this ecosystem, vehicles will communicate with any entity that may affect their safety, including other vehicles, infrastructure, pedestrians and smart devices. *Image courtesy of NXP Semiconductors.*

broadcasting without a certificate or with an invalid certificate, the other devices will ignore it."

Not There Yet

The NHTSA is still on track for adopting DSRC-based V2V systems, according to the notice of proposed rulemaking issued last year. If the government agency makes a final decision in 2019 as planned, a two-year phase-in period would kick in to accommodate manufacturers' production cycles. This would allow initial installations to begin in 2021, with full compliance required in 2023.

That said, if enough industry heavyweights press for consideration of a cellular option, the entire process could go back to the drawing board. This would mean significant work would have to be done not only on the communications side, but also on the security side. The whole course of V2V's implementation could pivot on whether the interested parties were willing to put off implementation.

Either way, forward movement is certain to occur. The technology simply has too much to offer. Many see advanced vehicle technologies as the silver bullet that promises to save lives on roadways. DE

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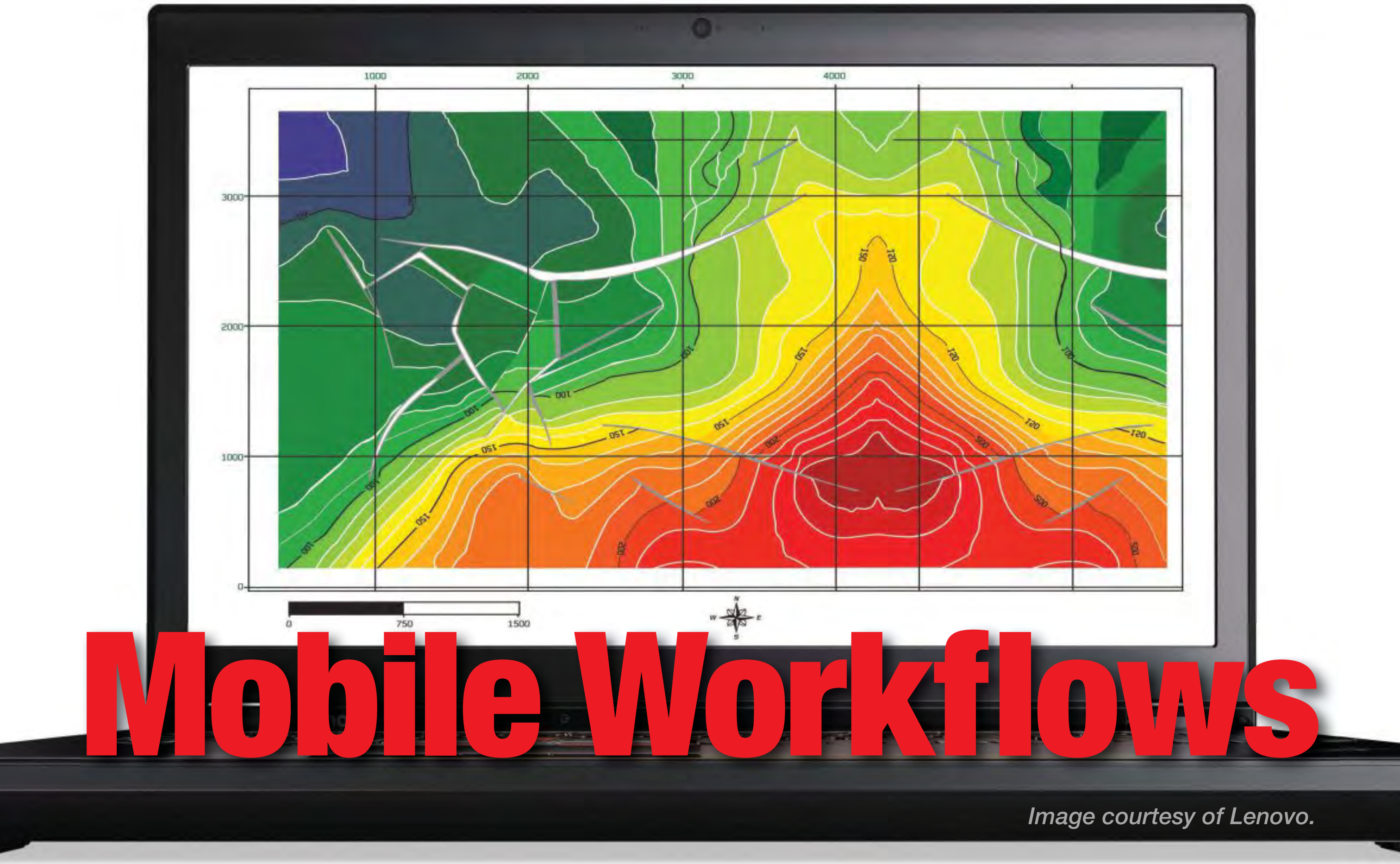


Mobile Workflows

Image courtesy of Lenovo.

Want to work away from your desk? Mobile workstation options continue to improve, as other remote access solutions emerge.

BY BRIAN ALBRIGHT

MORE ENGINEERS and designers are taking their work home, on the road and to client locations, which has resulted in increasing interest in mobile workstations and other remote work options.

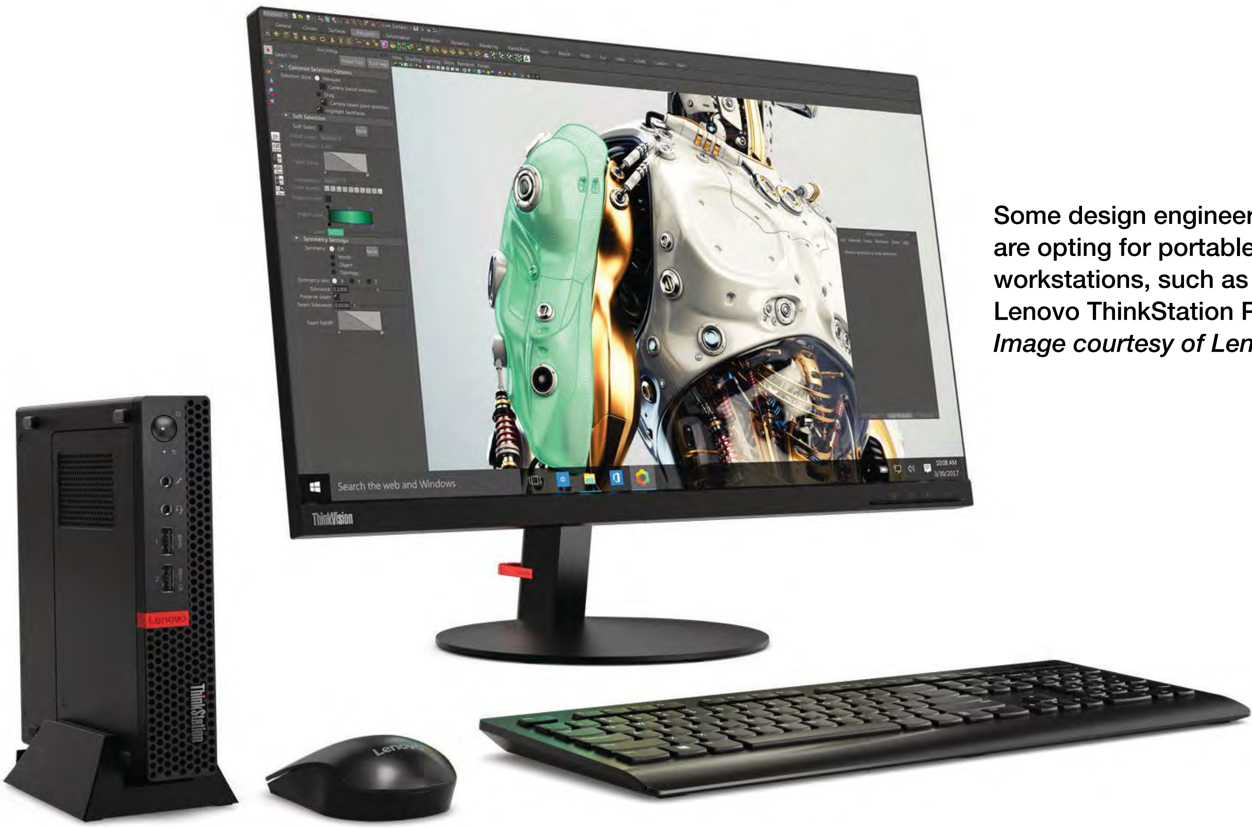
In most cases, that has meant purchasing high-end mobile workstations equipped with powerful graphics and compute resources. In some instances, designers are even working exclusively with mobile devices.

"We're seeing some migration from the tower side, and some migration from standard notebook users (who) realize they need a more powerful machine," says Lane Jesseph, Lenovo's worldwide mobile workstation product manager.

Technology advancements in the mobile space have hastened this transition along. It's now possible to get near-tower-level performance from a mobile workstation, which has expanded the way designers can use their applications.

"Having enterprise-wide engineering on the go capabilities creates additional revenue opportunities for companies," says Mark Bialic, president of Eurocom. "You can dispatch engineers to any organization and they can effectively work at the customer location and get feedback on site while interacting with clients. You can make the design process much more efficient and cut out non-productive time of traveling back and forth between sites."

Most of the time, engineers are going to need a powerful mobile workstation capable of running CAD software and other



Some design engineers are opting for portable mini workstations, such as the Lenovo ThinkStation P320. *Image courtesy of Lenovo.*

programs that can do more than work in tandem with a desktop workstation or as a replacement.

"Since the Quadro refresh, we see very little difference between the desktop and laptop side," says Maggie Chen, product manager for mobile workstations at MSI. "There are thin and light mobile workstations that are out now that are pretty powerful. We have a device that is both thin and light and still has a mid-range GPU, and we are launching VR-ready mobile workstations."

"Engineers can use these workstations to complete a design, do testing and work with a client at the customer's physical location," Bialic says. "It's not just a question of business going global, but there are opportunities outside of the engineer's primary location. If you have a client in another country, the designers will spend time working at those locations worldwide. They need to be able to do heavy design work on these mobile workstations."

Heavy-Duty Notebooks

Mobile workstations stand apart from traditional laptops in both their compute power and also their physical specifications. Because these are heavy-duty devices, they are usually larger, heavier, and are designed for 24/7 usage.

Current GPUs for mobile systems can essentially match the performance of a desktop system at this point, with a few exceptions. "You can put multiple GPUs in a desktop, but we can't match that in mobile right now," Jesseph says. "Desktops also have an advantage on the CPU side, in that you can get a tower with 22 dual-core CPUs, and mobile can't compete with that. The same is true of memory. There's much more capacity."

There is continuing pressure on manufacturers to make the workstations faster as well as thinner and lighter, but the laws of physics present some limitations on that front.

"Consider the CPU and graphics processing unit horsepower we have to put inside, the amount of memory required, the fact that a lot of users like multiple storage devices, and they want HDMI, smart card readers, and serial ports, and all of this technology has to be put in this package," Jesseph says. "We can do that, it's not going to be small and we have to be able to keep it cool."

Users also want the ability to upgrade memory and add devices, which will further constrain just how light these devices can be. "I don't see enterprise-grade mobile workstations getting much thinner than they are today," Jesseph says.

"People want something they can take comfortably on an airplane, and we see things trending toward that," adds AJ Christon, global product manager for mobile workstations at HP. "They want better looking devices with more of an emphasis on design without sacrificing horsepower."

That has resulted in the emergence of lighter weight, convertible options targeted at CAD users. Lenovo markets its ThinkPad P40 Yoga for this market, which comes in under 4 lbs. and can be used in notebook, tent, stand or tablet modes. Power users would find the performance of these devices lacking, but they are adequate for lighter design use.

Dell's Precision line of mobile workstations include the 3000 series of 15-in. mobile workstations that feature relatively low price points, the 5000 series of 15-in. workstations that are 11.1 mm thick and start at less than 4 lbs. and the 7000 Series of 15- and 17-in. workstations that can be configured with quad-core Intel Xeon or Core processors and up to 4TB of storage.

HP's Zbook Studio is another example. The 15-in. workstation is 18 mm thick with quad-core Xeon processors, NVIDIA Quadro M1000 graphics and 32GB of RAM, and it weighs just 4.4 lbs.

But Christon adds that designers are always going to want additional ports and other options that will restrict downsizing of the devices.

"Our customers don't work that way," Christon says. "You also need room for the engine to drive all that workload. You need room for thermal management and for the parts themselves. From a physics perspective, we are getting closer to the point of diminishing returns. You can't make the workstation significantly thinner with the same horsepower."

Security is another key concern for the expanding population of mobile workstation users, and manufacturers are addressing this in various ways.

"The most secure mobile workstations are going to have fingerprint readers, smart card readers and password protection," Christon says. "You don't see as much concentration on BIOS-level security. If someone gains access there, they have access to everything. So we've taken a lot of measures to make sure our BIOS is secure and non-corruptible."

When it comes to displays, 4K is becoming standard for mobile workstations. "But not everyone feels like they want that yet," says Michael Ly, associate marketing manager for mobile workstations at MSI. "We offer both 4K or 1080p and we let the customer base determine which ones they want. Most of them will eventually be 4K. The software is starting to more widely support 4K, but most users want full HD."

"Hopefully we are at the end of the pixel wars, and manufacturers will focus on improving the image on the screen," Jesseph says. "HDR [high dynamic range] is coming into the fold, and we're seeing brighter panels with more color depth and a higher dynamic range. Now you can get 10-bit color depth, which brings you up to 1.1 billion colors."

Christon at HP says that there has been increasing interest in full-HD touchscreen displays as well.

Tiny Desktop in Your Hand

For designers interested in working remotely, mobile workstations aren't the only solution available.

Another option that is not technically a mobile solution but that can be easily made mobile is the idea of the tiny desktop or mini workstation. Lenovo, for example, offers the ThinkStation P320, which measures just 1.4x7.1x7.2-in, and weighs just 2.9 lbs. It has an Intel Core i7 CPU and NVIDIA Quadro P600 graphics.

HP offers the Z2 Mini G3, which has a board architecture similar to a mobile workstation but is packaged as a very small desktop. "You get something that is very small, passes MIL-

TOP: Dell's Precision 5520 mobile workstation is available in a special 20th anniversary edition for a limited time. **BOTTOM:** The Dell Precision 7720 17-in. mobile workstation can be configured with 7th Generation Intel Core i5, i7 and Intel Xeon processors. *Images courtesy of Dell.*

STD (military standard) tests and takes up less workspace in offices," Christon says.

The 4.85-lb. device has an external power brick, a 1TB 7,200 rpm hard drive and supports Intel Xeon E3-1200v5 and Intel Core processors. These devices typically perform much like a mobile workstation in terms of processing power.

These mini workstations are not only highly portable (minus a monitor, they are much lighter than a comparable mobile workstation), but can also be used in virtual desktop infrastructure (VDI) configurations for virtual machine or cloud-based access.

"It's a different use case, and very much an entry-level workstation," Lenovo's Jesseph says. "It's a mix of technology that combines desktop and notebook elements. The desktop savings are good as far as how small the chassis is. It will be interesting to see how it fills a niche over the next few years."

Remote Access Solutions

There are other options apart from investing in these heavy-duty mobile workstations. Some companies have invested in remote desktop access or VDI using a client-server model. Users can log into desktop- or server-based compute resources on a standard mobile device.

BOXX, for example, offers a VDI solution in its ProVDI 8401R-V, which provides virtual desktop access with little or no latency. (See "Going Virtual with the BOXX ProVDI 8401R-V," July 2017, for *DE's* review.)

However, in some mobile work scenarios, designers may find themselves working with poor, unreliable connections or no internet connection at all.

"As long as you have a big fat pipe going to the desktop, you are OK," Jesseph says. "It's something people like to talk about, but it's very difficult to implement because of the expertise that's needed and the overhead cost. Very few have the resources to implement it."

"A major problem we have always encountered with (the) remote desktop is bandwidth," adds Robert Bragaglia, marketing director at @Xi Computer. "If you try to use CAD over a Wi-Fi connection you will not be very productive. If you have the bandwidth, sure it will work, but otherwise it won't."

Mobile Workstations: Future Innovations

Customers will continue to demand thinner, lighter devices, and some advancements in design will help enable that up to a point.

"Everybody wants thinner and lighter," Jesseph says. "What we have to do is balance how much we can squeeze the chassis room vs. keeping the processing power in there. It's an exercise in physics and sacrifice. What are end users willing to do without from a port set, memory or storage perspective?"

Power bricks are also due for a downsize. "A 2-lb. power supply for a 6-lb. machine is prohibitive," Jesseph says. "That's something we're looking at, and there is new technology coming. We are looking to greatly reduce the size of the power bricks over the next product cycle."

Upgrades to storage, processors and memory capacity will also help boost performance. MSI has upgraded its WS63 workstation with the Max-Q Quadro P400 GPU. The new WT73VR leverages the Quadro P5000 and can run and create virtual reality content.

Some other options are emerging for designers using less-robust notebooks. At SIGGRAPH, NVIDIA announced that users could address underpowered graphics on mobile devices using an external GPU chassis to connect NVIDIA Quadro or TITAN X graphics cards. These external GPU options will be available from partners beginning this month.

Intel's 3D XPoint Optane solutions provide a non-volatile memory option that is both faster and cheaper than DRAM. Bragaglia at @Xi says that rotational drives are dying, which will help further reduce size and weight on mobile workstations. "We envision smaller, slimmer dimensions overall," Bragaglia says.

The future of mobile design will likely involve a mix of powerful workstations, remote computing and cloud-based software options. With more designers taking their work on the road, firms will increasingly need to explore ways to affordably provide these capabilities.

"They want to carry the work with them," Bragaglia says. "They can be working anywhere in the world and have the same tools they do at their office. That's the vision." **DE**

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

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→ **NVIDIA:** NVIDIA.com

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Thin, Fast & Affordable

New MSI laptop delivers great performance at a reasonable price.

BY DAVID COHN

The new MSI WS63 7RK-290US mobile workstation is thin, lightweight and delivers great performance at a reasonable price. *Image courtesy of MSI.*

TAIWAN-BASED MSI (Micro-Star International) has been developing a reputation for delivering well-performing mobile workstations. Unlike the large, heavy desktop replacement WT72 we reviewed earlier this year (*DE*, February 2017), however, the WS63 system we recently received is a thin, lightweight laptop that delivered great performance at a reasonable price.

Housed in a brushed black magnesium alloy case with a green MSI workstation logo centered on the lid, the WS63 measures 15x9.8x0.7-in. and weighs 4.33 pounds. Its large (6x3x1.25-in.) 180-watt external power supply adds nearly 2 additional pounds. The brushed finish looks great, but tends to accentuate fingerprints. A layer of felt on the underside should make the system cooler and more stable on your lap, but is prone to picking up lint.

MSI does not let customers configure custom systems. The company offers two preconfigured systems of the WS63—the $2,399 7RK-280US and the $2,599 7RK-290US that we received. The only differences between the two are the amount of memory and the size of the solid-state drive (SSD). The less expensive model includes 16GB of 2400MHz memory installed using a pair of 8GB SO-DIMMs, while the 290US includes two 16GB chips for a total of 32GB of RAM.

And while both models of the MSI WS63 include a Samsung PCIe M.2 NVMe SSD, the 7RK-290US features a 512GB drive, vs. a 256GB in the less-expensive 7RK-280US. Both sys-

INFO ➔ MSI: MSI.com

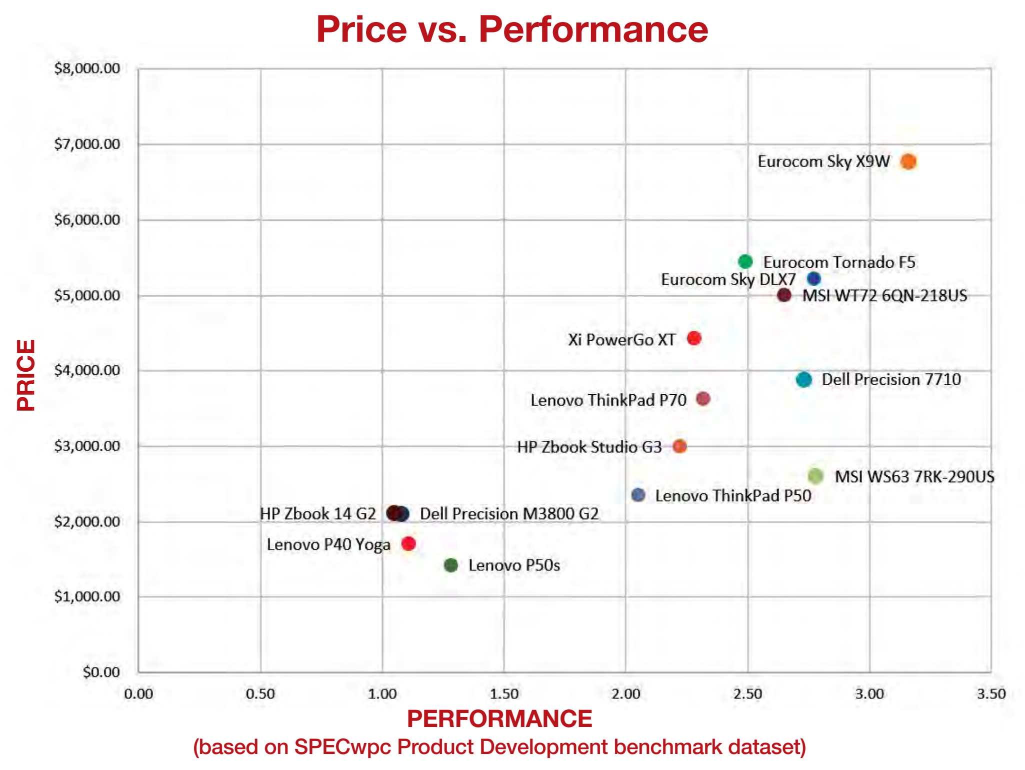
MSI WS63 7RK-290US

- **Price:** $2,599 as tested ($2,399 base price)
- **Size:** 15x9.8x0.7-in. notebook
- **Weight:** 4.33 pounds as tested, plus 1.63-pound power supply
- **CPU:** 2.8GHz Intel Core i7-7700HQ quad-core w/6MB cache
- **Memory:** 32GB 2400MHz DDR3
- **Graphics:** NVIDIA Quadro P3000M w/6GB memory and 1280 CUDA cores
- **LCD:** 15.6-in. diagonal (1920x1080), non-glare, IPS
- **Hard Disk:** 512GB M.2 PCIe SSD and 2TB 5400rpm SATA
- **Optical:** none
- **Audio:** microphone-in and headphone jacks (with S/PDIF out), plus built-in microphone and speakers
- **Network:** integrated Gigabit Ethernet (10/100/1000 NIC) with one RJ-45 port, 802.11ac wireless LAN, and Bluetooth 4.2
- **Modem:** none
- **Other:** three USB 3.0, one USB 2.0, one USB 3.1 (Type C) Thunderbolt port (with charging capability), mini-DisplayPort, HDMI-out, 2MP webcam, SD card reader
- **Keyboard:** integrated 102-key backlit keyboard with numeric keypad
- **Pointing device:** integrated touchpad with fingerprint sensor

Mobile Workstations Compared

Mobile Workstations Compared	**MSI WS63 7RK-290US** 15.6-in. mobile 2.8GHz Intel Core i7-7700HQ quad-core CPU, NVIDIA Quadro P3000M, 32GB RAM, 512GB PCIe SSD and 2TB 5200rpm SATA HD	**Eurocom Tornado F5** 15.6-in. mobile 3.6GHz Intel Xeon E3-1270 quad-core CPU, NVIDIA Quadro M4000M, 32GB RAM, 2TB PCIe SSD	**Lenovo ThinkPad P50s** 15.6-in. mobile 2.6GHz Intel Core i7-6600U dial-core CPU, NVIDIA Quadro M500M, 16GB RAM, 512GB PCIe SSD	**MSI WT72 6QN** 17.3-in. 2.9GHz Intel Core i7-6920HQ quad-core CPU, NVIDIA Quadro M5500, 32GB RAM, 256GB PCIe SSD RAID 0 and 1TB SATA HD	**Lenovo P40 Yoga** 14.1-in. 2.6GHz Intel Core i7-6600U dual-core CPU, NVIDIA Quadro M500M, 16GB RAM, 512GB PCIe SSD	**Xi PowerGo XT** 17.3-in. 4.0GHz Intel Core i7-6700K quad-core CPU, NVIDIA Quadro M5000M, 32GB RAM, 256GB PCIe SSD
Price as tested	$2,599	$5,450	$1,427	$4,999	$1,705	$4,423
Date tested	4/3/17	2/13/17	10/10/16	9/15/16	7/27/16	5/27/16
Operating System		Windows 10	Windows 10	Windows 10	Windows 10	Windows 10
SPECviewperf 12 (higher is better)						
catia-04	96.83	85.32	21.75	128.73	19.98	109.37
creo-01	87.28	80.21	25.34	103.28	24.34	94.91
energy-01	11.59	6.36	0.52	16.25	0.61	7.02
maya-04	66.22	60.58	13.27	81.64	12.25	79.26
medical-01	39.09	27.39	9.68	61.03	14.03	31.90
showcase-01	54.80	48.46	6.97	58.88	6.81	51.57
snx-02	71.52	78.14	31.85	120.83	26.46	165.04
sw-03	103.08	100.19	37.24	118.06	35.31	121.39
SPECapc SOLIDWORKS 2015 (higher is better)						
Graphics Composite	4.38	7.60	2.67	5.99	2.65	8.78
Shaded Graphics Sub-Composite	2.71	4.14	1.96	3.69	1.78	5.07
Shaded w/Edges Graphics Sub-Composite	3.50	5.46	2.52	4.84	2.40	6.54
Shaded using RealView Sub-Composite	3.14	5.64	2.01	4.77	2.00	6.65
Shaded w/Edges using RealView Sub-Composite	3.81	9.20	3.43	7.80	3.42	10.72
Shaded using RealView and Shadows Sub-Composite	3.61	6.44	1.96	5.16	2.03	7.40
Shaded with Edges using RealView and Shadows Graphics Sub-Composite	4.03	9.56	3.14	7.97	3.22	11.21
Shaded using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	11.77	16.22	3.02	9.15	3.38	18.10
Shaded with Edges using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	11.53	23.22	4.53	13.57	5.07	25.69
Wireframe Graphics Sub-Composite	3.33	3.65	2.61	3.20	2.20	3.91
CPU Composite	3.97	4.23	1.89	2.39	1.95	4.96
SPECwpc v2.0 (higher is better)						
Media and Entertainment	2.80	2.96	1.04	2.64	0.99	2.37
Product Development	2.78	2.49	1.28	2.65	1.11	2.28
Life Sciences	3.27	3.05	1.25	3.08	1.25	2.40
Financial Services	2.81	3.10	0.49	1.24*	0.49	1.39
Energy	2.74	2.60	0.96	2.61	0.87	2.34
General Operations	1.37	1.37	0.87	1.37	0.85	1.06
Time						
Autodesk Render Test (in seconds, lower is better)	52.90	78.30	172.50	73.20	149.00	53.10
Battery Test (in hours:minutes, higher is better)	4:20	3:20	11:44	3:09	9:10	2.30

Numbers in blue indicate best recorded results. Numbers in red indicate worst recorded results. ** Results provided by MSI.*



Here, you will also find a USB 2.0 port, a USB 3.1 (Type C) Thunderbolt 3 port, an HDMI port, a mini-DisplayPort, the connector for the external power supply and ventilation ports. The left side of the case includes headphone and microphone jacks, three USB 3.0 ports, a built-in SD card reader, an RJ-45 LAN connector, a Kensington lock slot and more ventilation ports. The front panel features seven LEDs for sleep state, drive activity, number lock, caps lock, Bluetooth, Wi-Fi and battery status indicators.

During our tests, the three-cell, 65Whr battery kept the system running for 4 hours and 20 minutes.

tems also include a 2TB Seagate 5400rpm SATA hard drive.

Both are based on an Intel HM175 chipset and a quad-core Intel Core i7-7700HQ CPU with integrated Intel HD Graphics 630. That seventh-generation "Kaby Lake" processor has a base frequency of 2.8GHz, a maximum turbo boost speed of 3.8GHz, a 6MB smart cache and a thermal design power rating of 45 watts.

Both versions of the WS63 also come with an NVIDIA Quadro P3000 mobile GPU, the new Pascal-based graphics card. The Quadro P3000 comes with its own 6GB of dedicated GDDR5 memory and 1280 CUDA (compute unified device architecture) cores, enabling the WS63 to deliver excellent graphics performance. The GPU powers a 15.6-in. IPS display with a native resolution of 1920x1080.

Lots of Ports But a Poor Touchpad

Lifting the lid reveals the LED panel and a nice SteelSeries keyboard with 102 backlit keys, including a separate numeric keypad. A 1080p webcam is centered above the display with a single microphone to one side. An LED adjacent to the webcam glows white when the camera is active.

A 4x2.75-in. touchpad with multitouch capabilities and an embedded fingerprint sensor is centered below the spacebar. The touchpad lacked dedicated buttons and required significant force to register a physical click. A pair of stereo speakers is located above the keyboard, beneath a perforated grill. A small LED centered in this grill glows white when the system is powered on, amber when the discrete GPU is active and flashes when the system enters its sleep state.

The small power button is located on the right side of the case. The battery is not removable and there are no user-serviceable components.

Great Performance

Thanks to its Pascal-based NVIDIA mobile GPU, the MSI WS63 7RK-290US outperformed systems costing more than twice as much on the SPECviewperf test of graphics performance.

On the SPECapc SOLIDWORKS 2015 benchmark, which is more of a real-world test, the MSI WS63 did very well, although it lagged behind systems equipped with faster CPUs. On the demanding SPECwpc benchmark, the WS63 also did quite well, sometimes surpassing the results of more expensive systems. And on our AutoCAD rendering test, the 52.9-second average rendering time was the second fastest we've ever recorded for a mobile workstation.

MSI preloads Windows 10 Professional 64-bit and backs the system with a three-year limited warranty that includes a one-year global warranty. And unlike many other lesser-known brands, MSI mobile workstations are independent software vendor certified for major CAD/CAM software from Autodesk, Siemens and SOLIDWORKS.

With a cost of $2,599, the MSI WS63 7RK-290US delivers a lot of performance at a very reasonable price. **DE**

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Go with a New **Workflow**

Research shows that increasing product complexity and a heightened focus on customer experience require solutions that democratize design tools and deliver seamless workflows

MANY THINGS in the world of engineering remain a constant: the creative spark, the iterative process, and a rigorous regimen of testing and prototyping. Yet with product complexity on the rise and digital transformation reshaping every facet of business, it's come time for design teams to bust out of traditional workflows to be better positioned for competitive advantage.

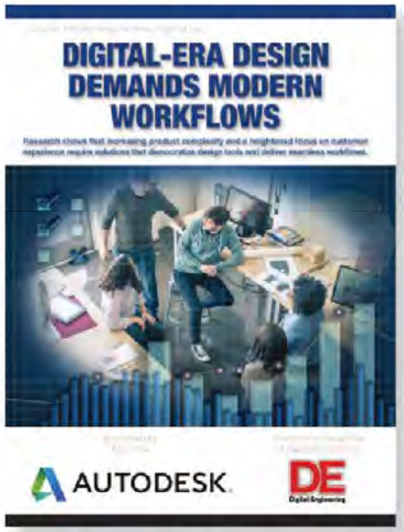
It's not just large-scale products like airplanes and automotive equipment that are becoming increasingly complex. With market forecasters projecting upwards of 20 billion connected "things" in use worldwide this year, mainstream consumer items like TVs and appliances as well as commercial offerings such as electric meters and wind turbines are being reimagined as smart, connected products and to some extent, systems of products. That means in addition to the standard mechanical and electronics content, product makeup is now more heavily weighted to include software, control systems, sensors and communications modules. This ups the requirement for engineering teams to revamp their tools and processes to support a multidisciplinary design approach that draws heavily on cross-functional collaboration.

The reliance on siloed tools and traditional design processes is no longer effective, especially in light of more complex products. Manual handoffs among engineering disciplines and file translations between disparate design tools can be fraught with errors and needlessly extend the design cycle. In addition, these longstanding engineering workflows don't adequately support the exchange of critical design data early enough in the cycle when it is easier and less expensive to make changes..

The Survey Says

Digital Engineering surveyed its audience of highly engaged design engineers on behalf of Autodesk to gauge what kind of progress is underway to transform workflows and modernize existing tool sets. The upside: The majority of organizations have made significant strides advancing their design processes with simulation-driven design, visualization and CAM practices, however, there is still work to be done to promote and make these modern tools and workflows accessible to a wider audience.

Currently, nearly three quarters of respondents to the *DE* survey (74%) are integrating simulation into their design processes, many employing the tools early, at the concept stage (28%). An even greater number (57%) are using simulation software at the front end as well as continuously throughout the design phase, the survey found. However, while simulation-led design practices are widely embraced, the software is still relegated to a select group of users. Nearly 60% of respondents said simulation software was mainly employed by a handful of experts or simulation analysts within the company, while only 33% said it was tapped by the majority of CAD users. The findings point out the need to democratize simulation so it can be used beyond a small cadre of experts, thus helping to avoid bottlenecks, reduce development time, and cut back on costly engineering change orders (ECOs).



DOWNLOAD "Digital-Era Design Demands Modern Workflows" at digitaleng.news/digitaldesign.

For more survey results, including research on CAM and Cloud use, download the free report produced by *DE* on behalf of Autodesk at digitaleng.news/digitaldesign.

DESIGN THINKING SAVVY

Image courtesy of Thinkstock/Brian A. Jackson.

Design thinking, from a business perspective, must mirror how product development teams work, experts say.

BY RANDALL S. NEWTON

TWO FORCES have arisen like a hot wind from the desert to forever change product development. Constant innovation and digitalized processes are not trends or phases: They are the new normal. Every manufactured "thing," from Crock-Pots to tractors, are expected to be programmable, responsive and connected.

Design and engineering techniques known as design thinking made these twin forces possible; companies looking for an edge over the competition have pursued design thinking strategies. In recent years such varied firms as consultancy McKinsey & Company and IBM have made appointments at their most senior levels for designers. The fast rise of mobile apps as the front end of services (rides, rentals, food delivery, consultants and more) largely came about because of design thinking.

App design and performance was given an elevated role in these new app-first companies. Instead of being the first step in a linear process, design thinking became the central operational strategy and an essential part of the business model. Books such as "Rise of the DEO (Design Executive Officer): Leadership by Design" by Maria Giudice and Christopher Ireland and "Don't Make Me Think" by Steve Krug explain how user experience is not just a way to make software easier to use. It is at the heart of an entirely new way to organize product development processes.

But such promotion of design thinking as an organizational imperative has, for the most part, not become mainstream. Design thinking has stayed hidden away, locked inside the proverbial silos of corporate culture. Such companies should be worried, says Giudice, now vice president for Experience Design at Autodesk.

"Design thinking is really design strategy," says Giudice. Design has not changed over the years, she says; it has always been strategic. "Companies were built on the backbone of technology and engineering acumen."

But companies have not been thinking about it strategically. Giudice believes the iPhone represents a "pinnacle moment," when product development became about user experience more than the technology. "Apple turned the world on its head; Nokia and the others were left in the dust. It was intuitive, easy to learn; it all pointed to user experience."

As iPhone sales soared, technology companies realized the value of designing for customer experience and making user experience a key value in articulating a product's business model. Product companies started hiring more designers, and in some cases acquiring design firms. Facebook acquired Hot Studio, Giudice's design studio, specifically for the design talent. "There was a huge focus on customer experience," Giudice says. "Today, people look at Facebook as well designed, but in 2013 it was a user experience nightmare."

Making Complex Products Easier to Use

Depending on who you ask, design thinking is either a cutting-edge recognition of a holistic approach to product development or a movement that is changing business models as well as specific products.

"Products are fundamentally getting harder; there are a lot more dots to connect," says Chris Cheung, founder of Mighty Dynamo. Best known for his product development work on the Alias Wavefront line of automotive design tools and then Autodesk Sketchbook Pro, Cheung is a champion for the emerging recognition of design thinking as a business model.

"Industrial design is getting more complicated. Today, user experience and consumer engagement transcend physical design parameters," Cheung says.

Digitalized products and connectivity requirements require multiple tracks of product design working side by side with traditional industrial design and physical engineering. Constant customer feedback and onboard sensors mean designers are no longer cut off from end-user reaction and product usage data. The linear product development process is too slow to absorb all this new information, Cheung says. But the cyclical, iterative nature of design thinking offers a new way forward.

"The cyclical nature is important; [decision] gates become points of validation. This is missing in other process definitions that tend to be more linear, the ideate-iterate-design-develop-ship model."

Cheung argues an "adaptive mentality" must be embraced at all levels and divisions of product organizations. "Industries are increasingly disrupted by progress; fewer and fewer products are immune." Consumers are too willing to shift spending patterns and adopt new products and new ideas. "Design thinking, from a business perspective, must mirror how product teams work."

Cheung believes management needs to embrace the iterative processes of design "across the board. It takes discipline to really follow it." If testing does not yield the best result, the company has to do another round of design until they get it right. "Sometimes you have to go all the way back to the definition of the problem."

Breaking Paradigms

Sometimes design thinking will push companies to change or even reject long-held methods. Onshape co-founder John McEleney recounts how designer Steven Krug, mentioned earlier, was influential at McEleney's previous CAD startup SolidWorks. Most software companies do focus group testing, where users are watched from a distance to see how they use new features. Krug insisted they sit with an engineer using an existing CAD product and talk through processes before designing the user interface. It was this shift in thinking that led SolidWorks to develop the first Feature Manager tool, now common in MCAD products.

Today, Onshape is still following Krug's advice. To test ideas, they give a user a task but stay with them to explore ideas and note where the user might experience blockages or offer a better method.

"We try to do the design thinking ahead of the user," notes McEleney.

Onshape uses the Agile method of software development, which practices daily staff "stand-ups" where everyone shares current work, and three-week development cycles between product updates. McEleney says Agile is not just for software companies, but also for companies making physical products; Onshape encourages its users to adopt Agile methods. "The challenges are the same in software and physical products," says McEleney. Companies now have multiple work groups in multiple locations, and face increased pressure to get great products to market quickly. "Traditional processes are too rigid and slow."

McEleney uses an example from fashion to prove his point about Agile product development. Traditional fashion design had a team of designers create a line of products that would move from the drawing boards (literally) to the stores in about a year; the clothing line would be what stores carried until the next fashion season arrived. Upstart fashion design house Zara saw an opportunity, and delivered product in weeks, with intentional limited production runs to encourage consumer excitement and return shopping. Sales representatives were encouraged to report what customers liked and wanted from the fashion house. "The Zara business model is rapid design iteration," McEleney notes. Everything they do as a company is based on this Agile form of fashion design.

McEleney believes that product development can take better advantage of digital technology, making such Agile notions as constant customer feedback part of the business model. One Onshape customer builds custom workbenches. A regular client needed a workbench that hadn't been built for 10 years. Photos and old invoices were uploaded as part of their Onshape design environment and used to create the "new" workbench. "They create a 360-degree record of the process, all in the design environment."

Typical "waterfall" development methods don't work well with such integration of customer intent and designer response, says McEleney. He says it is one reason that Onshape made it easy to "fork" designs with multiple options that stay connected, so that design teams can pursue options and quickly integrate the best solutions back into the final model.

Giudice echoes McEleney's views on bringing design thinking into the business model. "Business models must be based in customer wants, needs and desires. It requires understanding (of) how to delight the customer," says Giudice. "If you don't use design strategies like Agile, you might not be headed in the right direction." In firms that embrace design thinking as strategic, design is now a competitive differentiator. "In a world of three, four or five choices, who wins in the market?" asks Giudice. "The product that feels best, the one that removes the friction. This is where design becomes strategic in business."

Giudice believes the trend of moving simulation earlier into design is a result of being strategic about design thinking. Instead of delivering a document with design variables and creating a prototype to test the ideas, "now design and simulation and testing are in real time," she says. "There is immediate feedback."

> **"Industrial design is getting more complicated. Today, user experience and consumer engagement transcend physical design parameters."**
> ***— Chris Cheung, Mighty Dynamo, Inc.***

Design Rooted in Real-Time Experience

Dassault Systemès refers to its current generation of CAD, PLM and related products as the 3D EXPERIENCE platform. Valerie Pegon, experience designer & innovation strategist at Dassault, says it is the result of recognizing three "top-level challenges" where design thinking—which Pegon calls "experience thinking"—affects product development.

The first challenge is company agility. Pegon says agility remains complex for non-software industries. "Imagine, as a designer, being able to simulate your design right away, in real time. Or being able to test virtual experiences quickly."

The second challenge is responding to the Internet of Things. "Sensing and data analytics enable a continuous feedback loop to improve new designs, to adapt in real time." Connected objects can enable new services and rewrite business models.

The third challenge is harnessing social systems to inform design. Digitalization means many products are becoming ecosystems, Pegon says. "Building these ecosystems requires some level of structure to work smoothly, a high level of flexibility and a deep connection to the context and usage." **DE**

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INFO → **Autodesk:** Autodesk.com

→ **Dassault Systemès:** 3DS.com

→ **IBM:** IBM.com

→ **McKinsey & Co.:** McKinsey.com

→ **Mighty Dynamo:** MightyDynamo.com

→ **Onshape:** Onshape.com

→ **SolidWorks:** SolidWorks.com

For more information on this topic, visit digitaleng.news.

Part 2

Topology Optimization Methods

A look at two additional topology optimization methods: evolutionary and level set.

BY TONY ABBEY

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

IN THE PREVIOUS ARTICLE in this series (*DE*, June 2017, digitaleng.news/de/topology-optimization), we looked at the SIMP (solid isotropic microstructure with penalization) method of topology optimization. In this article, we cover two other important techniques: evolutionary methods and level set methods. A wide variety of methodologies are used within topology optimization, as it is a rapidly developing discipline. Over the next few years there will many new developments with additional, or even combinations of, methods. It will be intriguing to watch the new products that this activity spawns.

Evolutionary Methods

The foundations of the evolutionary range of topology optimization methods begin with a fully stressed design approach as described in part 1. The concept is intuitive; any element with a stress level below a certain limit is eliminated from the model. The limit is expressed as a "Rejection Ratio." The Rejection Ratio is the ratio of a threshold von Mises stress divided by a datum von Mises stress, typically yield stress. The threshold Von Mises stress could begin at, say, 15% of yield and hence the initial Rejection Ratio of 0.15 is defined. If yield is 100,000 psi, then the first aim is to eliminate all elements with average von Mises stress less than 15,000 psi.

I have set up a demonstrator model using only linear static analysis. The model, loading boundary condition and initial stress state are shown in Fig. 1. The contour bands are set to highlight the threshold stress levels. The initial 15,000 psi level contour is marked on the image.

Using a simple macro, the model is repeatedly updated by removing rejected elements until a configuration is reached, as shown in Fig. 2. At this stage, all remaining elements are above 15,000 psi von Mises stress. It took six analyses to converge to this state. The relative mass is now 86.5% and the compliance has increased from 0.119 to 0.132. In a simple case like this, the compliance can be estimated as:

(applied load) * (edge deflection) / 2

An important factor was that the region over which the load was being applied is shrinking. This is a common issue with topology optimizers; how should the load distribution

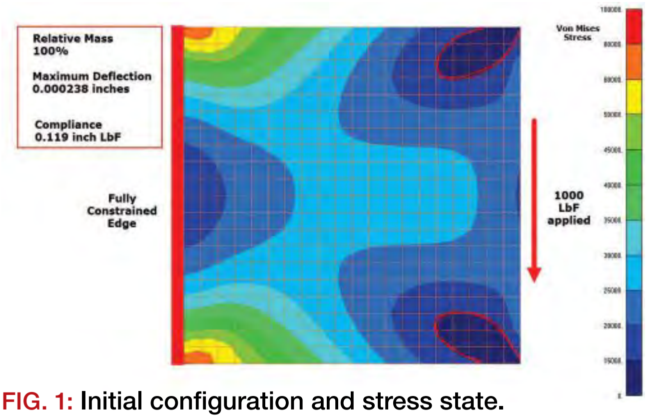


FIG. 1: Initial configuration and stress state.

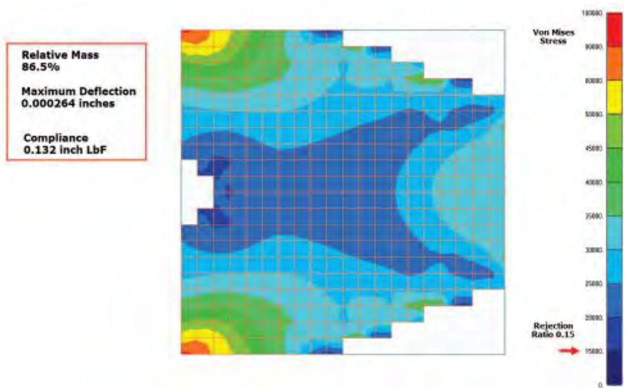


FIG. 2: Final configuration with initial Rejection Ratio of 0.15.

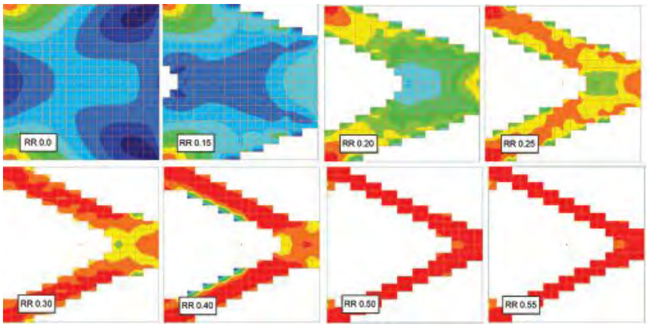


FIG. 3: Montage of configurations using the FSD (fully stressed design) approach.

be treated over a changing boundary? In this case, I manually updated the nodal load distribution to avoid eliminated nodes, being careful to apply equivalent kinematic loading.

I also found that eliminating elements completely gave bad convergence characteristics. So, I adopted the technique of reducing the stiffness of eliminated elements by a factor of 1E4, and retained them within the analysis. In commercial applications, other techniques are used to improve convergence. Indeed, one of the big advantages of the evolutionary methods is that elements can be fully eliminated. This means that as the volume of the material decreases, the number of degrees of freedom decreases and hence dramatic solution speedups can occur.

The Rejection Ratio is now increased, effectively increasing the target minimum stress throughout the model. The rate at which the Rejection Ratio is increased is called the Evolutionary Rate. I set the Evolutionary Rate to 0.05, so the next Rejection Ratio is 0.20. The target stress levels are therefore 20,000 psi, then 25,000 psi and so on. A further series of analysis is carried out, until convergence is achieved, with all elements above each new Rejection Ratio. It is clear from my simple experiments that a coarse Evolutionary Rate works well in the initial configurations, where there is plenty of material and relatively large stress variations. In the final configurations, there is little material, and stress variations are small. A much finer Evolutionary Rate is then appropriate so that the material is nibbled away more slowly.

Fig. 3 shows a montage of each of the converged configurations at Target Rejection ratios. It took 44 analyses to carry out the study. The trend is very logical and follows the classical benchmark problem. I have kept a constant maximum stress contour of 100,000 psi in the stress plots. It is evident that the component is becoming very overstressed at configuration 5. This occurs at a Rejection Ratio of 0.3; in other words no element has a stress below 30,000 psi. The volume is down to 43% of the initial configuration.

The final configuration achieves 22.5% of initial volume and all stresses are above 55,000 psi. It is unlikely that this would represent a feasible practical solution, as the stresses are very high throughout the structure.

My topology optimization approach is very simplistic and not very representative of a commercial topology optimization strategy. However, it does show some of the representative features. Stress minimization is not a direct optimization strategy. The FEA model is an assembly of "LEGO brick" type elements, which do not attempt to model a continuous structural boundary. Mathematically, this approach is called the voxel method in 3D space. I used stress smoothing options to give a better sense of the stress flow. However, some of the configurations show the influence of the stress singularities that would be occurring in each of the internal corners. This can cause numerical problems in optimization methods. All topology optimizers will require a similar "one-eyed squint" at stress and material distributions to gain a sense of the configurations and their responses. In no sense are they representing a detailed stress assessment.

Fig. 4 shows the final configuration, with all material present, including the low modulus "chewing gum" type material. The full stress range is shown.

The figure also shows another issue associated with topology optimization. The left-hand edge is fully built in. This over-constrains the model and will not permit Poisson's ratio contraction to occur. It creates stress singularities at the top and bottom corners. This affects assessment of the structure, but could easily drive the strategy of a more sophisticated technology optimizer in the wrong direction.

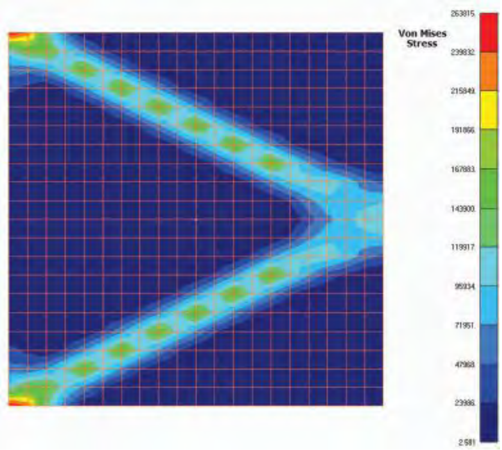


FIG. 4: Final configuration with all material shown.

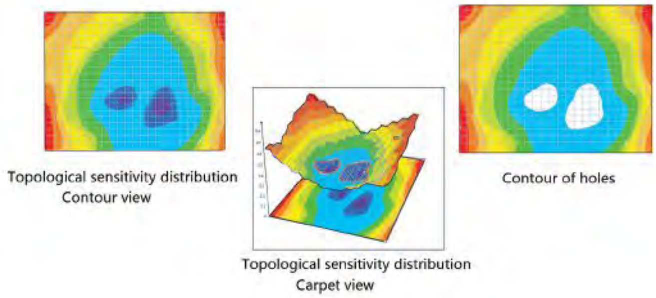


FIG. 5: The level set process.

Yet the design intent of the configuration is clearly shown. That is really the objective of any topology optimization.

Commercial Evolutionary Implementation

Commercial topology optimizers do not use the fully stressed design approach directly. It is not applicable to more complex structures and requires development of ad hoc rules to keep it on track. Instead, it has been found that working with compliance gives more stable and manageable algorithms. Recall from my previous article that minimizing the compliance of a structure will maximize the stiffness. It is possible to derive the change in the compliance of the structure as a result of changing each element stiffness, for example, by dropping the stiffness from nominal material stiffness to zero, or to a very small value. This defines the compliance sensitivity of each element. Now, the evolutionary method can be modified to remove all compliance sensitivities below a certain level. The rejection ratio and evolutionary rate are defined as before, but now in terms of the compliance sensitivity. As we have seen with my simple model, slower evolutionary rates tend to give better convergence.

This approach is the essence of the evolutionary structural optimization (ESO) method. However, it is clear that this is a one-directional method. As in my simple example, there is no way of backtracking. As the configuration evolves, it may well be that deleted material should be replaced. If this is inhibited, then an optimum configuration cannot be found. In fact, unproductive dead-end configurations would be common.

The successor to the ESO method is the bidirectional evolutionary structural optimization (BESO) method. This uses various strategies to put back deleted elements as appropriate. The methods are similar to the smoothing and filtering techniques in the SIMP method that we reviewed in the previous article. The BESO methods focus on assessing the compliance sensitivities-per-element volume, similar to a strain energy density. The distribution of sensitivities densities can be smoothed and interpolated across voids created by deleted elements. If an interpolated sensitivity exceeds a threshold value, then the element is switched back on. The BESO method uses nodal sensitivities obtained by weighted average of the connected element sensitivities. This contrasts with the SIMP methods that use element sensitivities. The sensitivities are also smoothed across each successive pair of analysis to improve convergence.

The method can also introduce an element of "soft-kill," in that elements are not fully deleted. This is done to avoid zero sensitivities associated with deleted elements. A small non-zero material stiffness is introduced instead and meaningful sensitivities can be calculated. A penalization method, similar to that of SIMP, drives material to the extreme conditions. However, the material distribution is still essentially binary, as opposed to continuously variable in SIMP.

The advantages of the BESO method include the fact that it is simple to understand as a heuristic process. It seems like a good idea to eliminate areas of low compliance, as this is understood to improve global stiffness. Because it is a hard-kill, or binary soft-kill, method, there is no gray area of intermediate densities. As long as the underlying voxel approximation to boundaries is appreciated, then interpretation of configurations is easier than the SIMP method. The computational speed-up, as elements and hence degrees of freedom are eliminated from the solution, can be very significant.

However, there are critics of the BESO method. Because it is a heuristic approach, it is difficult to identify any mathematical foundation and assess convergent qualities. Pathological test cases, where important load paths are deleted early on and never recovered, have been well publicized. However, the researchers in this field continue to develop strategies to overcome these issues, and it is currently a mainstream topology optimization technique.

The Level Set Method

There are several approaches to the level set method. The one described has evolved into commercial usage. A topological sensitivity parameter is established. This is a measure of the change in any structural response, based on the insertion of a small hole into the structure. The small hole modifies the topology. A high sensitivity means that any material removed, and hence the change in topology, will have a large effect on the response. On the other hand, low sensitivity means that

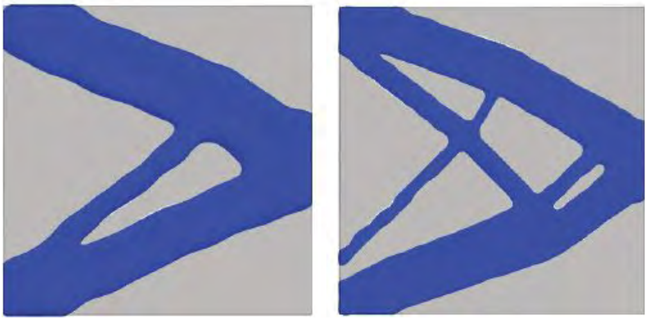


FIG. 6: (a) *left*, Level Set solution with small feature size. (b) *right*, even smaller feature size.

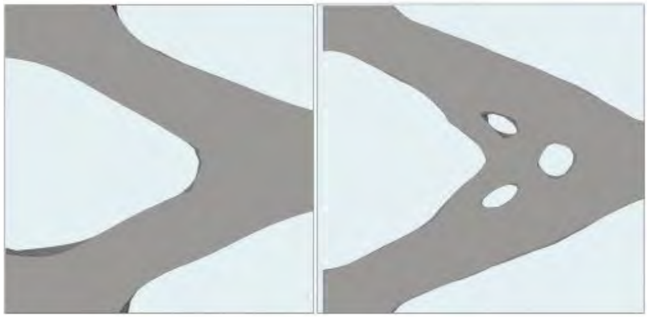


FIG. 7: (a) *left*, SIMP solution with large feature size. 7(b) *right*, medium feature size.

there is little impact from the change in topology. If compliance is used as the structural response, then analytic definitions of the topology sensitivity can be established.

Directly removing elements that have a low sensitivity will result in the dispersion of deleted elements throughout the model, as we have seen in the SIMP and BESO methods. There is no inherent connectivity associated with the "holes" generated in the structure. The level set method takes a different approach and deals with that problem by mapping the overall distribution of sensitivity onto the mesh. Fig. 5 shows the concept behind the level set method.

Assume that the left-hand diagram represents an initial sensitivity distribution shown in a typical contour plot. The middle diagram shows how this can be viewed as a 3D carpet plot. The vertical axis represents the level of relative sensitivity. The 3D plot is clipped at a particular level of relative sensitivity. I have used the value of 0.3. The purple contour regions are below this threshold. The right-hand diagram shows these regions mapped onto the mesh and elements within this region are deleted in a contiguous manner. Essentially, interior boundaries are evolving. If the value of relative sensitivity is changed, then the clipping plane is changed, resulting in a different set of hole shapes.

The value of relative sensitivity is found by adjusting its value on the vertical axis, which changes the amount of material to be deleted. The aim is to match the current target volume fraction. Once the sensitivity level is found, the elements are deleted and the analysis is rerun. This results in a new distribution of sensitivity, and the fit is again made so that the topology matches the required volume fraction. After some iterations, the solution will converge to provide the relative sensitivity required to meet the target volume fraction. This interior boundary shape then represents the topology that provides the optimum compliance level at the target volume fraction. The method can also start from a configuration with inadequate material and grow material into the optimum topology.

Methods are used to evaluate elements where the boundary cuts through their volume. This is essentially a mass and stiffness smearing process. This is challenging in a 3D mesh and is the subject of continuing development.

Solutions to the Demonstrator Model

Fig. 6 shows the block used previously in my simple example, rerun in a level set method, with the same target 43% initial volume. The first run shown in Fig. 6(a) used a coarse mesh and the largest minimum feature size the optimizer would permit. A much more sophisticated result is produced! The configuration is 11% stiffer than my result. I reran with the finest mesh possible, with minimum feature size definition permitted. Fig. 6(b) shows that the result is even more sophisticated, with 14% increase in stiffness.

I also ran a SIMP-based solution, where I could force a "chunkier" minimum feature size, as shown in Fig. 7(a) and (b). The volume ratio was set at the same target 43%. Two variations on minimum feature size were used. The compliance was close to the Level Set method result in Fig. 6(a), in both cases.

For a fair comparison in both cases, I also had to use the load footprint that developed in my crude FSD solution. The adapting load footprint is a tricky area, and I will talk more about that in part 3.

The Mathematics Behind the Scenes

The mathematics behind the topology optimization solutions can be very challenging. However, some understanding of the different processes available can give useful insight into how the methods are working behind the scenes. Perhaps the most important take-away from both articles in this series is that the configuration offered as an optimum solution is always an idea, rather than a fully defined structure. Often, the distinguishing features between topology optimizers are based on how this conceptual idea is carried forward into meaningful structure.

In the next article, I will look at more case studies using a variety of methods. This will include manufacturing constraints and development into final structural configuration. **DE**

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

Optional Multiphysics, Mandatory Multiphysics

CAD-embedded tools, designer-friendly interfaces and on-demand computing remove some barriers to adoption.

BY KENNETH WONG

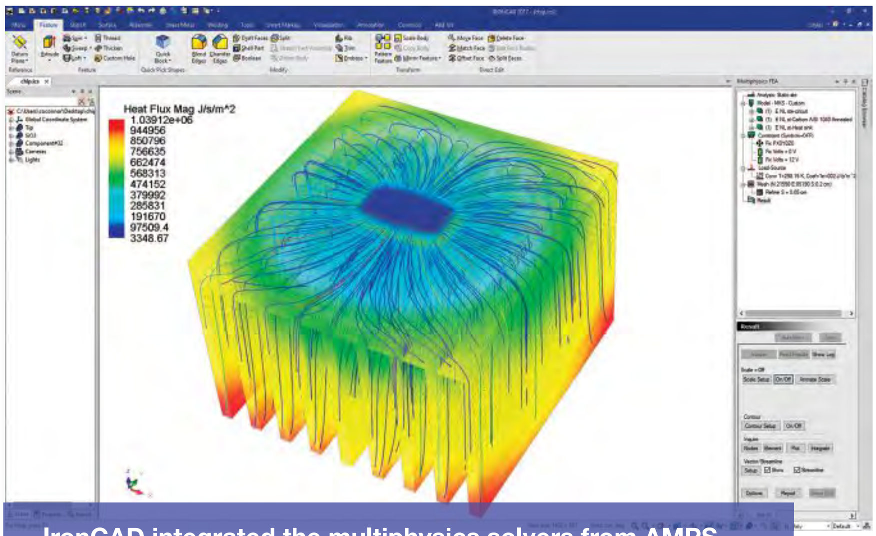
SUPPOSE YOU'RE SIMULATING how an engine component expands in response to heat buildup during a car's drive. If you use a simulation package that lets you simulate the component's expansion (structural physics) and heat propagation (thermal physics) simultaneously, the job is indisputably multiphysics. But if, due to the limitation of the software or out of your own choice, you simulate the heat buildup inside the engine chamber first and then use the result as input to figure out the component's expansion, is it multiphysics?

In the view of Chris Wolfe, lead product manager of multiphysics at ANSYS, "Multiphysics simulations happen whenever engineers need to understand the effects of multiple physics on real-world products. More specifically, any time data is shared between solvers from different traditional disciplines (computational fluid dynamics or CFD, finite element analysis or FEA, electromagnetics, etc.), an engineer is performing multiphysics simulation. In this context, both the sequential and simultaneous solving of multiple disciplines of physics are multiphysics simulations."

Similarly, Nicolas Tillet, product portfolio manager, Dassault Systèmes SOLIDWORKS, says, "Multiphysics involves different types of physics. The simulation job can be sequential or simultaneous."

Greg Fallon, vice president of simulation at Autodesk, says, "I don't see the distinction whether you solve sequentially or simultaneously, because in the end, you're dealing with various types of physics."

Perhaps what's more important is to identify the scenarios where multiphysics treatment is truly warranted. Whether it's saline fluid flow inside a medical device or airflow around a race car, if you can get the answer you need by reducing the phenomenon to a simpler study, then setting it up and solving it as multiphysics is an excessive use of resources, both in hardware and in manpower.



IronCAD integrated the multiphysics solvers from AMPS Technologies, enabling IronCAD users to set up and run multiphysics analyses from the CAD modeling environment. Shown here is the multiphysics analysis of a microprocessor chip. *Image courtesy of IronCAD.*

Inseparable Physics, Isolatable Physics

How can you tell if something truly demands multiphysics? When is it acceptable to simulate the different physics sequentially? When is it important to compute them together? Partly, the wisdom comes from industry experience and engineering tenure, neither of which a software package can teach you.

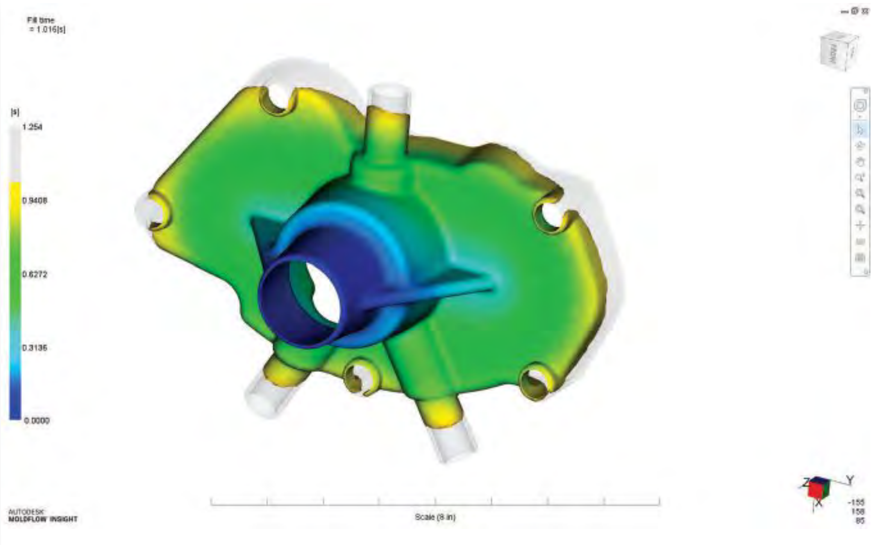
Ted Lin, general manager of AMPS Technologies, says, "Most experienced users can tell right away if a problem needs multiphysics or not. For example, take the act of pouring hot water into a glass. If you want to figure out the point at which the glass will break due to hot water temperature, typically you don't need to set it up as multiphysics, because the temperature's effect on the expansion behavior in this kind of scenario is not crucial."

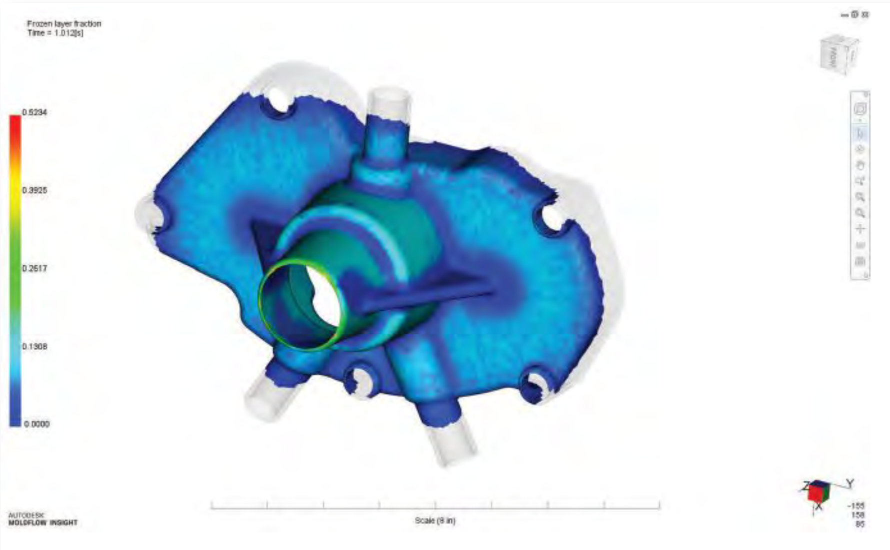
But the same phenomenon under a slightly different environment may make multiphysics a must, not optional. "If it's freezing outside, in other words, the temperature around the glass is extremely low, then the temperature gradients inside the glass and outside become important to study, because the glass will break a lot sooner," Lin adds.

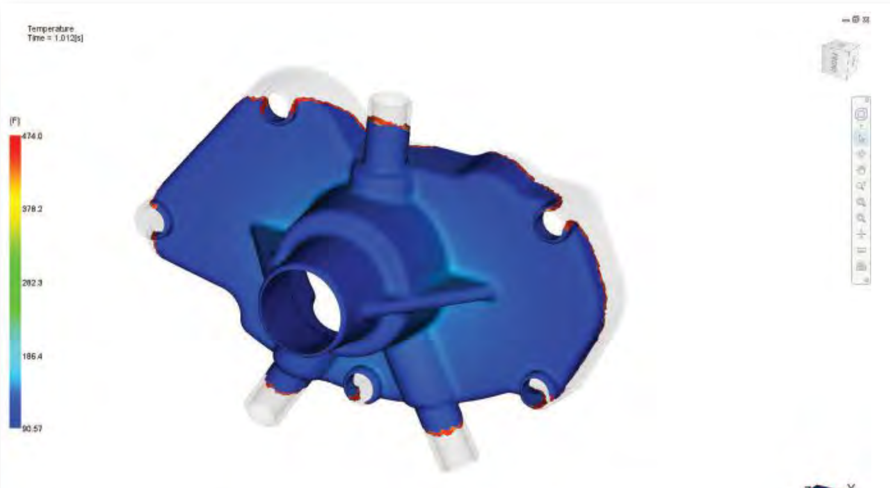
Take another example: the stresses on the side of a building due to strong winds. Technically, the scenario involves two types of physics: fluid flow (to compute the airflow) and structural (to account for the building's surface). "In that case, even if the stresses are high, the associated deformation of the surface is minimal," notes Bjorn Sjodin, vice president of product management, COMSOL. "So you may start the simulation in CFD, then use the result as input for your structural analysis. In some cases, it's beneficial to run the physics sequentially."

Wolfe points out: "Many times, solving the physics sequentially provides good enough information to guide the engineer toward a good solution. Sequential simulation is often easier for a team of analysts or engineers, with different areas of expertise and sometimes working across organizational silos."

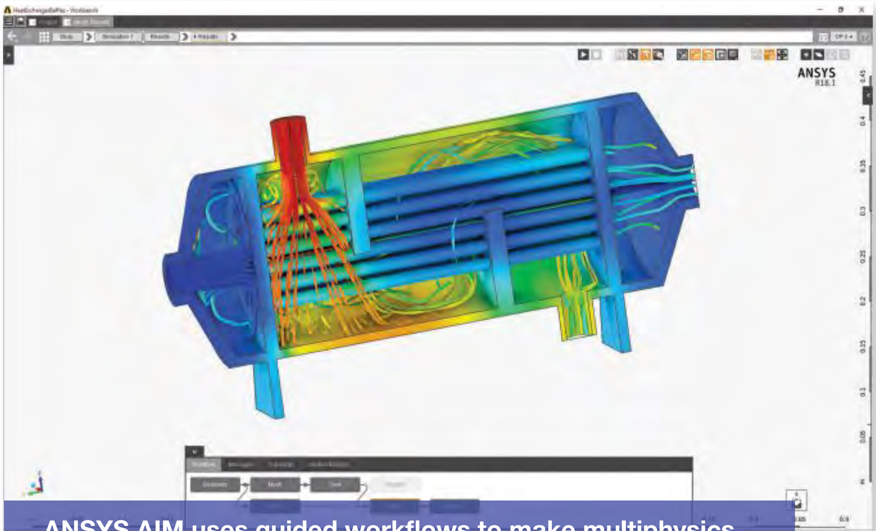
On the other hand, simulating the flow of hot plastic liquid into a mold would demand coupled multiphysics. Such a scenario is the specialty of Autodesk Moldflow, a software package that targets the injection molding industry. Fallon explains: "At first, the plastic is hot, but as it starts to cool down, the flow speed changes; it slows down. Then it starts solidifying. The problem involves thermal, fluid flow and phased changes. You just can't separate the







Autodesk Moldflow, targeting the injection molding industry, is inherently multiphysics. The above Moldflow results show: the fill time (flow), frozen layer fraction (phase change), temperature (cavity and core) and von Mises stresses (core) of a water pump housing model and the mold assembly. *Images courtesy of Autodesk.*



ANSYS AIM uses guided workflows to make multiphysics easier to set up and process. *Images courtesy of ANSYS.*

various types of physics involved. If you simulate it as viscous fluid flow inside the mold, your answer will be way off."

Similarly, the deceptively simple design of the heating coil in a cooktop oven may demand multiphysics analysis, according to Lin. "The coil design hardly has any sharp corners. The turn angle has to be smooth to prevent overheating due to heat concentration in turn corners. To analyze it, you'd need electrical-thermal-structural simulation, all three running together," he explains. "If you use a linear solution—in other words, if you solve one physics at a time and then put the answers together—you will not catch the critical peak conditions."

Wolfe points out: "A smaller number of problems, mainly those involving highly deformable solids, very short timescales, and combinations thereof, have physical interactions that are so tightly woven together and dependent on each other that they require tightly integrated co-simulation—solving the physics together—to adequately capture the phenomena occurring. But these problems are often complex and expensive to run. Hence, they are used only when the benefits outweigh the costs."

Build for Coupled Physics

When a problem *does* involve physics that are inseparably intertwined, software designed specifically for co-computation offers an advantage. COMSOL, which explicitly brands its software as COMSOL Multiphysics, is among them.

"In COMSOL's software environment, different types of physics talk to each other, if you will," says Sjodin. "If you have to merge two different software packages [for example, one for CFD, another for structural], then the engineers have to learn two programs (and) figure out the file import-export protocols, so it's more complicated."

AMPS, which licenses its technology for integration, stands for Advanced Multiphysics Simulation. "AMPS was developed from day one with multiphysics in mind," Lin says. "It was initially developed to use in glass fiber manufacturing. We designed it to simultaneously compute stress, thermal, fluid and electromagnetics in a single code, solving them in a single execution cycle. Integrated multiphysics analysis approach becomes crucial when the Joule heat generation is very high, as the temperature dependency of electrical and thermal conductivity are usually reversed. In these cases, the decoupled approach will lead to false results, or it may not converge at all."

Targeting the Designers

In 2015, IronCAD integrated AMPS Technologies' solvers into its CAD package. IronCAD users can now set up and simulate multiphysics phenomena from the design and modeling environment.

"A lot of the things in multiphysics, and even in FEA, have always been a struggle for users," says Cary O'Connor, vice president of marketing, IronCAD. "It's difficult for people to run analysis on assemblies, because they need to understand how to set up the contacts between parts. IronCAD makes that process simple. You mesh the assembly as it is; IronCAD automatically builds these contacts, using the proper mesh types, and solves quickly using patented technology. It gives users a better overall user experience."

CAD-integrated or CAD-embedded simulation tools are an offshoot of the simulation industry's efforts to expand its reach. The high-end simulation tools developed for experts tend to present a steep learning curve for generalists and design engineers. Introducing simulation through a simpler interface nested inside a CAD program is one way to lower the barrier of entry. Examples of this can be seen in SOLIDWORKS Simulation, which is tightly integrated with SOLIDWORKS CAD software, and Autodesk Fusion, which delivers CAD modeling and simulation tools in a single environment.

"In SOLIDWORKS, we focus on the ease of use," Tillet says. "It's implemented in a way that's easy to learn and use for all designers."

Fallon reasons, "In the concept phase, you're doing (a) quick design check to make intelligent decisions. The accuracy requirements in this are very different from what's needed in the detailed design phase. Our tools in Autodesk Fusion and Autodesk Inventor are very much targeted at the designers in the conceptual phase."

ANSYS attracts designers with ANSYS AIM, featuring guided workflows. "Multiphysics tools for designers need to speak the designer's language, streamline the simulation process as much as possible and guide the designer through the necessary steps," Wolfe says. "ANSYS AIM emphasizes ease of use and streamlined workflows that enable single discipline and multiphysics simulations for designers. UI (user interface) elements like guided workflows, built-in simulation guidance and customization capabilities make single physics and multiphysics simulation accessible to designers."

Internal Apps

In COMSOL Multiphysics 5.1, COMSOL began offering the Application Builder, which allows users to publish complex simulation jobs as template-driven apps. The company also offers COMSOL Server, which allows users to host their apps for wider distribution. With this approach, COMSOL lets experts set up and produce complex simulation workflows that can be executed by generalists and designers with limited simulation knowledge.

Presently, the apps published are mostly proprietary apps for internal use within different companies. Apps available to the public in online marketplaces are still a rarity, for good reasons. "If a company publishes an app, that app typically encompasses the core company secrets, basically their most proprietary industry knowledge, so it's highly unlikely they'll distribute it publicly. They might publish it for their own partners, customers and vendors in a closed ecosystem," Sjodin points out. "I believe we will start to see publicly available simulation apps emerging from academia. After all, they have an interest in spreading their knowledge."

One example of emerging apps from academia is AweSim, an offshoot of the Ohio Supercomputer Center and its partners. Its offerings include a list of simulation apps, for purposes ranging from heatsink design analysis and fixed-wing unmanned aircraft performance prediction, to ship drag and trim study.

The IoT Effect

One reason the demand for multiphysics analysis might increase is the growing number of connected devices. With heat-generating electrical components tightly packaged inside, smartphones, smartwatches and wearables must balance the effects of several types of interdependent physics. It makes multiphysics simulation the only means to study them effectively.

"In high-frequency electromagnetics, the antenna or the oscillator's performance is directly impacted by thermal conditions," says Fallon. "The sensitivity of the antenna becomes deeply intertwined with the thermal conditions."

"The miniaturized devices put serious constraints on the internal components," says Sjodin. "The deformation of components, changes in temperature and electromagnetic fields can interfere with the sensor operations."

"Twenty years ago, these MEMS (microelectromechanical systems) cost about $30. Nowadays, it's about four or five cents. So we now have cellphones with all these components," says Lin. "Because the components are getting smaller and smaller, you have to rely on simulation to design them. It's not efficient to run test cycles."

The Role of the Cloud

A complex single-physics CFD run could exhaust all available computing cores in a workstation, resulting in the machine slowing down or becoming unavailable for other usage during the analysis run. With multiphysics analysis, the computing demand increases several fold. Therefore, in the near future, simulation vendors offering on-demand access to server-class hardware could become a common practice.

"You're involving more physics, so more math is needed. That means you need more computational power," says Fallon. "And to really leverage simulation, you need to look at multiple alternatives simultaneously."

Autodesk offers Cloud Credits to subscribers, which allows CFD users to submit their jobs to remote hardware managed by Autodesk. With this approach, while the analysis job is in progress, the user's local machine remains free of the computation burden; therefore, he or she can continue to work as usual without experiencing system slowdown.

Fallon expects artificial intelligence and machine learning to also play a role in Autodesk products in the future. Autodesk Generative Design, formerly Project Dreamcatcher, is being integrated into Netfabb to predict and suggest design alternatives—options the users might not have conceived on their own. Autodesk may integrate the capability into other simulation software in the future as well.

"We want to provide not just more physics types in SOLIDWORKS but also more hardware power delivered from the cloud on demand," Tillet says. "We're currently working on it in a pilot program."

Both ANSYS and COMSOL have partnerships with Rescale, an on-demand HPC provider targeting simulation users who can choose to submit their jobs to be processed on Rescale's on-demand HPC infrastructure.

With on-demand computing becoming more ubiquitous and affordable, system requirements may no longer prevent users from exploring multiphysics. But vendors still have a responsibility to scrutinize their code to make sure the computing demand is not excessive. "We did a lot of work at the code level in Autodesk Moldflow," says Fallon. "The hardware requirements for Moldflow are very similar to typical CFD simulation, even though it's solving much more complex physics."

The hallmark of a good simulation program is the ability to perform complex analysis with the least amount of computing cycles. The economic approach goes a long way to promote wider use of simulation, especially among smaller firms with limited time and expenditure. DE

Kenneth Wong *is* DE*'s resident blogger and senior editor. Email him at de-editors@digitaleng.news or share your thoughts on this article at digitaleng.news/facebook.*

INFO ➜ AweSim: AweSim.org

➜ **Autodesk: Autodesk.com**

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

➜ **ANSYS: ANSYS.com**

➜ **COMSOL: COMSOL.com**

➜ **IronCAD: IronCAD.com**

➜ **AMPS Technologies: AMPStech.com**

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Tools, Jigs and 3D Printing: A Lucrative Trio

Use of 3D printing to create tools and jigs for manufacturing applications offers many opportunities for many industries.

BY JIM ROMEO

MANUFACTURING has been through an odyssey of digital transformation in the last decade. 3D printing is part of this transformation, which includes the ability of 3D printing to create tools and jigs that aid in production and assembly within so many industries.

Game Changer

This capability is a game changer, and one that provides a notable boost in design freedom that manufacturers and customers can enjoy.

Pradeep Amladi, global VP of manufacturing marketing solutions for SAP's manufacturing practice, agrees that 3D printing to create tools and jigs is a boon for manufacturing.

"Creating parts in-house has the potential to reduce inventory and the associated capital significantly and to reduce idle time because there is no wait time for deliveries," says Amladi. "3D printing allows tool [and] jig manufacturers to move away from reactive or schedule-based service models because digital data can be used to constantly monitor equipment health and predict future failures."

Amladi points out, however, that if production technology changes, as it does with tools and jigs produced via 3D printing, then workflows must also change. "They need tools and processes that can validate and approve or certify parts made via 3D printing from start to finish, modeling through quality assurance," he says.

Overall, 3D printing's potential to produce tooling to aid in manufacturing has not yet been fully realized.

Organic Tool Production

"There are a number of excellent materials that can be 3D printed today, including a range of thermoplastics and metals," says John Kawola, president of Ultimaker

An original aluminum fixture (top) and a 3D printed iteration (bottom) with clamp-on assemblies. ***Images courtesy of Stratasys Direct Manufacturing.***

North America. "However, materials with special additives and composites can also be extended into 3D printing. These materials often provide enhanced properties that product designers value, such as high strength or reduced weight. The traditional manufacturing processes for using specialty materials or composites is often labor intensive. So, there is potential that 3D printing these materials can be faster and easier than the traditional techniques."

Ultimaker, a provider of 3D printing technology, worked closely with Volkswagen Autoeuropa several years ago to help them create tools and jigs via 3D printing. Such tools and jigs are produced in-house, rather than by outside vendors. Volkswagen touts its transition to 3D printing as saving the auto manufacturer 91% in tool development costs and reducing development time by 95%.

Automobile manufacturing is not the only application that stands to benefit immensely from tools and jigs produced by 3D printing. The applications are many and include medical and dental products that rely on precision manufacturing and fabrication with very close tolerances. 3D printing enables custom fabrication for patient needs—a common demand and application in the production of medical and dental devices.

"Building such devices through additive manufacturing helps to remove many of the design constraints associated with more traditional manufacturing techniques such as milling, casting or welding and soldering," says Ed Littlewood, marketing manager of Renishaw's Medical and Dental Products Division in Gloucestershire, UK.

Littlewood points out that the application of such tools will be well received in any manufacturing application with a high degree of assembly and where there is standardization.

Design Freedom

"Industries that require a large degree of assembly will benefit the most," Littlewood says. "Jigs and fixtures help reduce labor time and increase quality and precision. There is also a higher degree of standardization—all products are the same—that comes with manufacturers who use jigs and fixtures, and this by itself is a measure of high quality."

Chuck Alexander is the director of product management for Stratasys Direct Manufacturing in Valencia, CA. He acknowledges that not only will 3D printed fixtures and tools change manufacturing—they already have.

The use of tools and jigs to provide more accuracy and control in assembly and testing can translate into savings of hundreds of thousands each year for firms that embrace it, Alexander says. But he notes it has other tangential benefits, too.

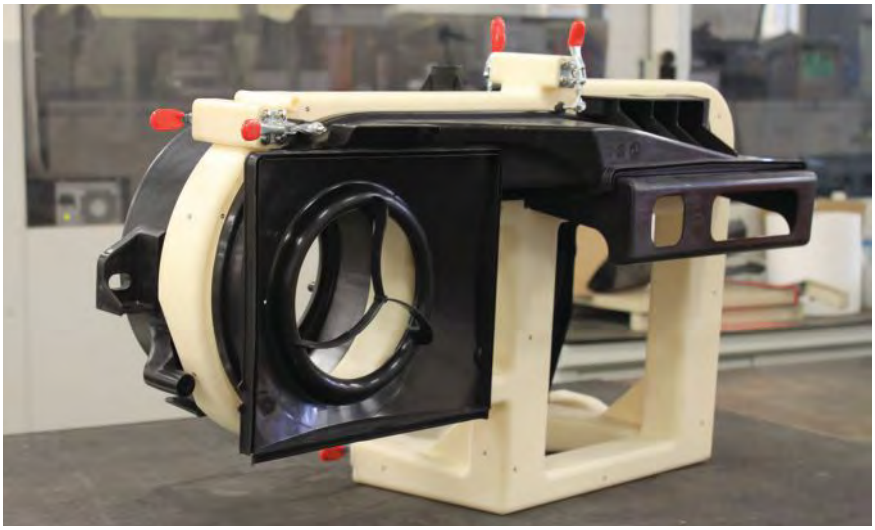
"Beyond streamlining production and reducing costs, 3D printing is helping transform manufacturing tools and fixtures because of its design freedom," he says. "Thanks to the technology's inherent design freedom, companies can use it to build parts with consolidated features, thereby reducing the total number of components and amount of material necessary to build complex parts."

Moving forward, design freedom from tools and jigs produced using additive manufacturing and the merit of 3D printing will be huge and part of what Amladi credits to an overarching digital transformation within manufacturing.

"3D printing is just one component of the overall digital transformation in the manufacturing industry and Industry 4.0," he says. He believes that recognizing its potential and the opportunity it presents is significant for companies that understand what this can do for their operations.

"In order to succeed in this new manufacturing reality, companies must be willing to redefine who they are, what they sell and how they operate," says Amladi. "Even better are those companies open-minded enough to reevaluate every aspect of operations with an eye toward new, customer-centric innovations." **DE**

Jim Romeo *(JimRomeo.net) is a freelance writer based in Chesapeake, VA.*



Stratasys Direct Manufacturing customer MAHLE wanted to consolidate a fixture from three separate components into one part. Based on the part's parameters, MAHLE was able to use 3D printing to make the fixture a reality. *Image courtesy of Stratasys Direct Manufacturing.*

INFO → **Renishaw:** Renishaw.com

→ **SAP:** SAP.com

→ **Stratasys Direct Manufacturing:** StratasysDirect.com

→ **Ultimaker:** Ultimaker.com

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3D Printing Tools to Improve Patient Prognoses

New applications in 3D printing not only allow for more accuracy in the examination room, but they also save time critical to patient prognosis on the operating table. Cases across medical disciplines show the success of leveraging 3D printing for treatment.

In identifying tumors among multiple sclerosis (MS) patients, researchers use 3D printers to better understand brain lesions. Studying 3D prints allow physicians to determine the surface traits that distinguish MS tumors from cancerous or false positives. Researchers at University of Texas Southwestern Medical Center (UT Southwestern) use magnetic resonance imaging scans for lesion imaging, creating files that are printed on MakerBot printers using ABS plastics.

Darin T. Okuda, M.D., F.A.A.N., F.A.N.A., associate professor of Neurology at UT Southwestern at Dallas, notes that his team's work represents "the first effort to appreciate a brain lesion from MS and NSWM (nonspecific white matter) disease in 3D." He adds that this advancement could challenge conventional practices.

In a Netherlands trauma unit, researchers are also using MakerBot printers to prepare for pelvic surgeries. Doctor-researcher Lars Brouwers and his team at the Elisabeth-Tweesteden Hospital in Tilburg, Brabant, The Netherlands, identified a cost-and-time-saving alternative to the conventional practice of delivering measurements to a production facility.

Brouwers' team transformed a CT file into a 3D file before printing a pelvic model out of PLA plastics.

Costs to produce these models are only USD $5 to $10 and can be prepared in a single day, providing an added benefit among surgical residents who can prepare these models for training purposes. Surgeons are then able to stage these models as a step-by-step guide for surgery (much like an architect's blueprints) and use the models to appropriately size plates and screws and get a better understanding of the fracture patterns.

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.*

EDITOR'S PICKS

3D Print Certified Aircraft Interior Parts

Stratasys solution undergoing a qualification program under FAA oversight now.

Stratasys announced its new Aircraft Interiors Certification Solution for 3D printing aircraft interior parts that meet demanding Federal Aviation Administration and European Aviation Safety Agency certification requirements.

The certification solution has two key components. The first is a new configuration of the Fortus 900mc Production 3D Printer. Second is Certified ULTEM 9085 resin, a strong, lightweight thermoplastic that meets aerospace flame, smoke and toxicity regulations, according to Stratasys.

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Software Integrates CT Scans with CAE

Software turns CT image data into tessellated models ready for further analysis.

RETOMO is part of the BETA CAE Systems' line of high-powered CAE (computer-aided engineering) solutions.

It's a toolset with high-end methods and algorithms for importing, processing, reducing, reconstructing and visualizing computed tomography (CT) images, then exporting them to a preprocessor. Essentially, you can import standard formats of CT-scanned image data and transform them into tessellated models for export and deeper engineering analysis.

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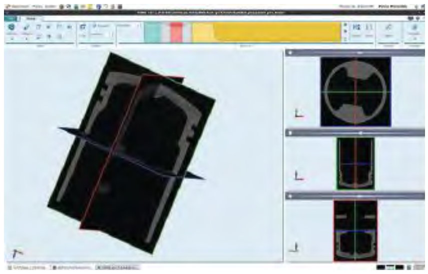

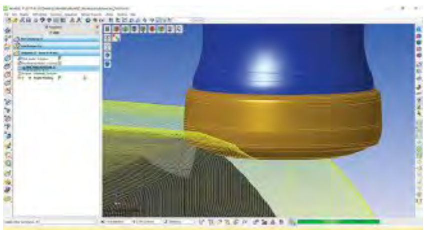

CAD/CAM Solution Sees Improved Roughing

WorkNC 2017 R2 debuts Parallel Finishing toolpath and more.

The Waveform roughing cycle toolpath optimization capabilities in WorkNC 2017 R2 now take into account the tool load during intermediate Z-step calculations.

Also, WorkNC now automates and simplifies the Machining Sequence process. Here, it helps you with toolpath programming by alerting you to missing data—views, curves, points, etc.

Collision detection functions are improved and there's a new option for radial stepovers.

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CAE Tool Integrates Discrete Element Method

Software line extends CAE systems with bulk material simulation capabilities.

This multiphysics, heavy-equipment optimization toolset from EDEM offers a numerical method that lets you model the behavior of granular materials like rocks or particles, enabling you to simulate how materials of various sizes and shapes behave as well as how they interact with your machine designs.

You select the best match material for your job, set up your bulk material simulation and run your DEM modeling in your host analysis environment.

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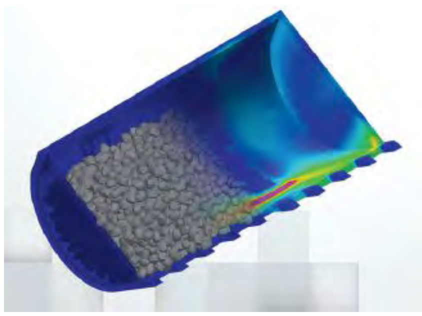
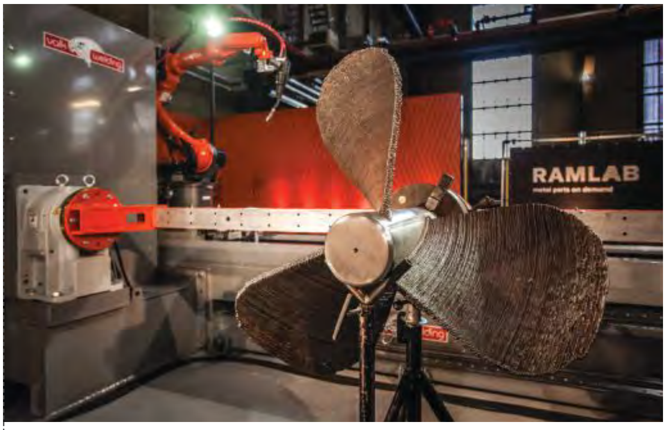


FASTAPPS
Engineering Case Studies

The Future of Making Things

Port of Rotterdam's RAMLAB and Autodesk pioneer 'on-demand' additive manufacturing for ship repair.



A ship's propeller created for the project using the new 'hybrid manufacturing' technique.

The Port of Rotterdam's Additive Manufacturing Fieldlab (RAMLAB) and Autodesk have revealed the first pilot component as they pioneer the use of additive manufacturing in the maritime industry. A ship's propeller was made via a hybrid manufacturing process combining wire and arc additive manufacturing using industrial robotic arms and subtractive machining and grinding techniques.

As the largest port in Europe, the Netherlands' Port of Rotterdam is one of the most important intersections for the flow of cargo in the world. It offers the region's best connections to global ports and handles over 460 million tons of cargo a year, so it's imperative that the facility and ships run smoothly.

Million-Dollar Wait Times

Currently, if a vessel comes into port needing a replacement part—a propeller, for example—it can take weeks or months to order and deliver, costing companies millions of dollars while they wait. It can also be quite costly for companies to keep large stockpiles of parts in warehouses around the globe.

To tackle this challenge, the Port opened the innovative RAMLAB, an onsite facility that includes a pair of six-axis robotic arms capable of additively manufacturing large metal industrial parts. The team at RAMLAB works with a dedicated network of hardware and software partners, academic and certification institutions and key end users to help the Port stay on course to become the smartest port in the world.

As a main software partner, Autodesk has played a key role in developing RAMLAB's innovative hybrid manufacturing approach, which entails combining additive and subtractive manufacturing. This style enables RAMLAB to pursue faster fabrication options: 3D printing large ship components in metal and then finishing the pieces using traditional CNC milling and grinding methods within a matter of days, saving time and money without sacrificing precision or performance.

"The Port of Rotterdam's RAMLAB initiative is a great example of how whole industries are being disrupted by industrial additive manufacturing," explains Steve Hobbs, VP of CAM and Hybrid Manufacturing at Autodesk. "Creating an 'on-demand' hybrid manufacturing capability for replacement parts will have a major impact on reducing wasted time and cost currently incurred across the maritime industry when ship parts are damaged. We're excited to be working alongside some of the key players in the marine industry to bring to reality this very tangible example of the future of making things."

"With the work being done at RAMLAB, the group hopes to accelerate the cross-industry adoption of hybrid manufacturing for making large-scale parts on-demand," says Vincent Wegener, managing director of the RAMLAB. "Our aim is to make the Port of Rotterdam not just an important gateway for Europe, but also a leader in the development of new manufacturing methods. Autodesk is a key partner for us due to its expertise in how to design and manufacture using both the latest additive manufacturing techniques and more traditional CNC and machining methods."

The ship propeller pilot project was created in close collaboration with Autodesk and the next step will be for a final, to scale, version to be manufactured and fitted to one of the partner's ships.

Collaboration Advances Hybrid Manufacturing

In addition to the work done onsite at RAMLAB, Autodesk has also assisted RAMLAB by providing access to its Advanced Manufacturing Facility (AMF) in Birmingham, UK, so that new design and manufacturing concepts could be explored. Collaborative activities by the two organizations include:

- exploring the design of components and investigating design features made possible by additive manufacturing;
- preparing these components for manufacture by creating appropriate preforms with the essential considerations;
- building these components considering the distortion and stress on macroscale geometric fidelity and thermal management; and
- postprocessing techniques to bring these components to final form in a repeatable and reliable manner.

Kelvin Hamilton is the technical liaison on the project at the Birmingham AMF, which is part of Autodesk's global network of technology centers devoted to pushing the boundaries on the future of making things. According to Hamilton, the collaboration with RAMLAB represents a leap forward for hybrid manufacturing.

"We're bringing additive manufacturing to a truly industrial scale," he says. "So much 3D printing to date has been limited to smaller components. But the technology—both software and hardware—is now ready for bigger things, and we're seizing that opportunity to show the world what's possible." DE

The Race for a New Air Inlet

Wiring in racing is becoming more and more complex. Power units are made up of several parts that need to be integrated into the final assembly. Available space is increasingly limited, so engineers frequently use flexible parts, such as cooling ducts and wiring harnesses.

CRP Technology's R&D department tackled the development of a new front air inlet for a Moto3 motorcycle racing customer to solve space issues in the front fork area. It was manufactured in Windform materials by using an SLS (selective laser sintering) additive manufacturing technique. The solution outlined here can be easily applied to the automotive racing world.

Testing had shown that increasing air flow to the airbox improved the performance of the engine at every RPM range. This led the team, as well as the engineers, to conclude that they needed to design a new track-ready inlet. This design would make the air inlet longer, and bring the opening up to the front side of the fairing, in order to have a direct airflow with less turbulence.

Among the goals to be achieved was the need to avoid modifying the existing frame and triple clamps. The design would have to fit to the existing platform in order to test the on-track advantages and disadvantages of using this solution, and to make a direct comparison with the current standard inlet.

Additive manufacturing and WINDFORM materials allowed for:

- total freedom and no limitations in design (design for functionality instead of design for manufacturing);
- creation of a mockup for assembling, fitting and functionality;
- production of parts for performance tests; and
- reduction in product and project realization timing.

The final decision to use the new inlet came from its behavior on the track, with the key points being its performance and reliability. Engineers kept the current airbox with the aim to mount the traditional air inlet as well as the new one to acquire airbox pressure data on the track.

The Project

Through the use of reverse engineering, the original airbox was scanned and virtually assembled with the CAD system.

This allowed the engineers to be able to create a new model of the air inlet by taking into account the amount of available space and the constraints of the assembly of the current airbox and frame.

Once a first draft of the air inlet was developed, a prototype in Windform GF 2.0 material was created. The decision to use Windform GF 2.0 was made to reduce costs, while being able to perform multiple tests with multiple prototypes.

The first prototype allowed engineers to see if the design fit was correct and suitable for assembly. It was revealed by the first design that some sections needed to be changed due to the lack of space available under the lower triple clamp. This problem is further complicated when the bike is cornering and under braking conditions.

To optimize the volume of the inlet duct under the lower triple clamp, the engineers adopted a creative approach and decided to use a portion of the duct in Windform RL, the new rubber-like composite material produced by CRP Technology. This would be bonded to the main structure that was made out of Windform XT 2.0 for evaluation in racing conditions. To facilitate this, they also carried out a bonding test to study the characteristics of the final assembly.

The concept was to make the bottom part of the duct with Windform RL in the fork and triple clamp area, and then assemble this into the top part

Circled in red is the zone where the front fork touched the inlet duct during testing.

produced in Windform XT 2.0. This approach would allow good clear airflow on the straightaway sections of the course, and thus an excellent flow to the airbox. Under braking, the front fender could move up and collapse the inlet duct without any damages, due to the flexible material.

In addition, it was decided after examining the part that making the ducting flexible in the same area next to the front forks would offer an additional benefit. The engineers were able to maximize the duct volume because the maximum steering actions are only reached when the bike is pushed into the paddock by the technical staff. In this situation, the front fork can touch the inlet duct—deforming it without any damages.

Second Prototype

A second prototype was made in Windform GF 2.0. Once the second prototype was mounted, the engineers noticed some changes had to be made, especially in the front fork area.

The soft section was too short and the forks could touch the area of the duct near the bonding overlap when steering travel was checked. It was also seen that toward the back of the flexible area, near the airbox, that the duct was very close to the front wheel in the maximum braking position.

During testing it was determined that when the motorcycle was under severe braking, the front fender contact area on the duct in the soft part was too large. This situation, from the rider's point of view, was not good because during hard braking, the steering must be free from movements, as the rider might need to correct the trajectory quickly.

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AD INDEX

Next-Gen Engineers

Student Design Competition Profile: Quarter-Scale Tractor Competition

Agricultural Engineering to Scale

BY JIM ROMEO

THE AMERICAN Association of Agricultural and Biological Engineers (ASABE), based in St. Joseph, MI, is the host of an International ¼ Scale Tractor Design Competition.

The competition was developed to "gain practical experience in the design of drivetrain systems, tractor performance, manufacturing processes, analysis of tractive forces, weight transfer and strength of materials." In addition to technical design skills, the competition invites students to develop and use their skills in communication, leadership, teamwork, fundraising, and test and development.

The machines are put to the test in three tractor pulls, a maneuverability course and a durability course.

Curt Thoreson works for John Deere in its Waterloo Works Tractor Cab and Assembly Operations, Chassis Engineering division. He's the past competition organizing committee co-chair for the 2016 ASABE International ¼ Scale Tractor Competition. We spoke to Thoreson to explore what the Scale Tractor Design Competition is and how it works.

Digital Engineering: Can you provide an overview of the 1/4 Scale Tractor Design Competition event?

Curt Thoreson: The ¼ Scale Tractor Competition is intended to provide college-level students a hands-on product development experience similar to what they'll contribute to within industry. The competition was first developed 20 years ago with that intent and has evolved over time to enhance that experience.

Typically 25 to 30 colleges and universities from across the United States, Canada and Israel compete in the event. Most competing students are studying engineering disciplines, although we see a variety of other fields of study, including business, accounting, ag systems and mechanics, represented as well.

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

Thoreson: The tractor starts with a 31 HP Briggs and Stratton Engine and a set of Titan tires provided by competition sponsors. From there, students bring a variety of tractor designs each year. Some represent a demonstrated formula for strong performance like using a continuously variable transmission or a Super-Cub transaxle. Some teams have an interest in trying different technologies and concepts to challenge their design abilities and creativity. Examples this year included a fully electric transmission on Iowa State University's tractor and an air-adjustable independent front suspension from Oklahoma State University. Students design their tractors in order to maximize points in the performance competition and meet their selected target market needs.

DE: Can you provide some examples of what the event has produced?

Thoreson: While the event produces a winner each year, the real target of the competition is to prepare students for the industrial world of product design when they graduate. Many of the skills and lessons learned by competing students are challenging to grasp in the classroom environment.

In the process of developing, building, testing and demonstrating their tractors, these students gain first-hand knowledge on new product development; get feedback from industry experts on their successes and failures, and exposure to potential future employers.

DE: Who sponsors the program?

Thoreson: It takes the efforts of many sponsors to make this event happen each year. The event is supported, organized and operated by the American Society of Agricultural and Biological Engineers, and sponsored by AGCO, Briggs & Stratton, Case IH, Danfoss, John Deere, New Holland Agriculture, SolidWorks, Titan, RCI Engineering, Caterpillar and Campbell Scientific; also, Katie McDonald Photography, Claas and Thompson.

Other sponsors include Central City Scale, Igus, Miller, GSI and MacDon. Many sponsors support the event because they have several competition alums operating as successful employees within the company and want to support the event that has directly benefited them. **DE**

Jim Romeo *(JimRomeo.net) is a freelance writer based in Chesapeake, VA.*

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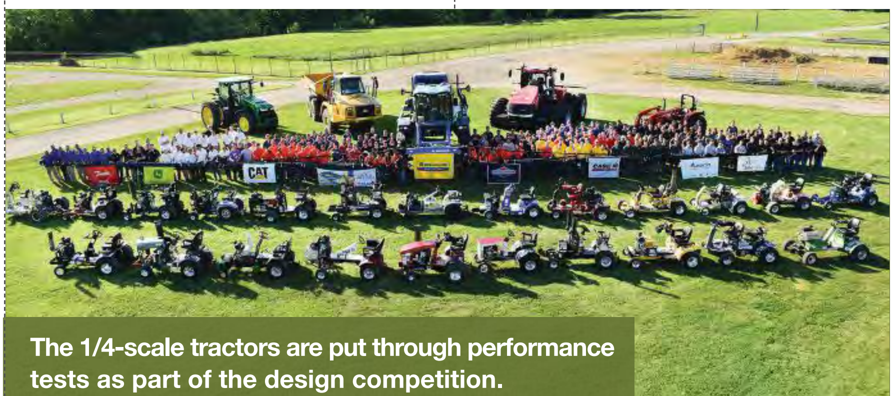

The 1/4-scale tractors are put through performance tests as part of the design competition. ***Image courtesy of Katie McDonald Photography.***

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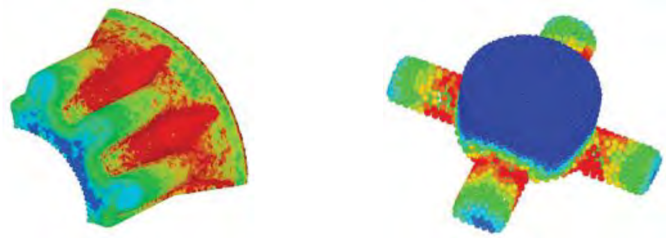
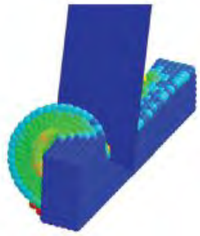
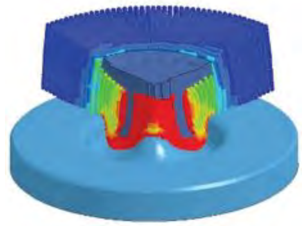


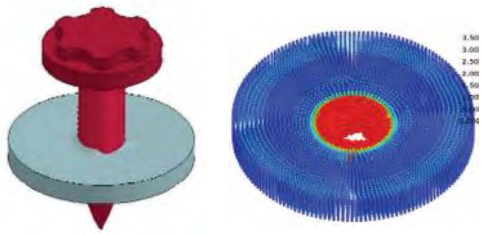
Thermal-mechanics coupled analyses of forging and extrusion (EFG adaptive re-meshing with high-order remapping scheme)



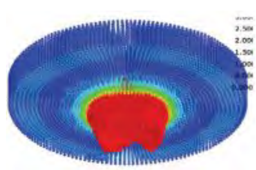
Metal cutting



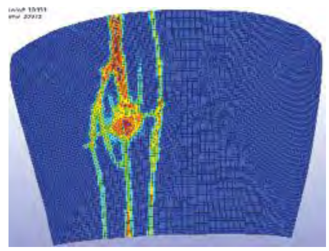
Riveting



Machining and jointing analyses (SPG)



Drilling



Damage on windshield under impact (peri-dynamics)

Crack in twisted cylinder (X-FEM)

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