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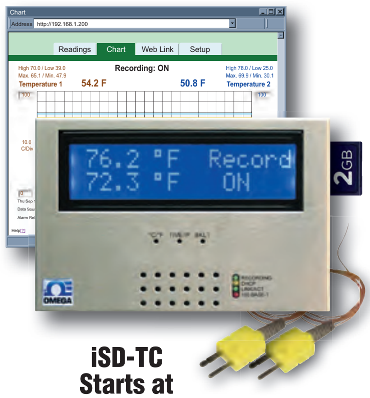

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OMEGA®

by Steve Robbins

Optimize the Outcome of Design Engineering

In the late 1990s, I had the extraordinary luck to be invited to Sunnyvale, CA, to observe a test simulating the launch of a Space Shuttle payload. This was the actual payload for a shuttle launch, mounted on a test stand that looked like an upright flatbed tractor-trailer. It would shake and vibrate, simulating the launch vehicle while nitrogen-powered acoustic horns, mounted in the ceiling of the hanger, simulated acoustic vibration

The payload was covered with 640 load cells, accelerometers, position, pressure and other sensors hardwired to an observation booth about three stories up. These sensors were processed by I/O boards, A/D converters, and data acquisition boards into a bank of Pentium workstations running Windows NT. It was all monitored by engineers and scientists who had assembled the test platform. They were ecstatic because the system had just been optimized to run in "real-time," which meant that the results from the analysis were returned in less than an hour, as opposed to the weeks of analysis it had previously taken.

> **Creating a better design is good, but creating an optimized outcome is bette .**

When they ran the test, pieces of the payload rattled and shook. Some of them actually flew off. No one knew what was going to happen. But everyone was excited that the test could be analyzed so quickly so they could put the pieces back together and run another test. The more iterations, the fewer problems with the shuttle mission.

From Inputs to Output

More recently, I met with an engineer involved in the design and simulation of jet engines. Aerospace engineers have been using simulation software since the IBM System/360 was introduced in the '60s. This manufacturer has millions of lines of legacy code that had been updated numerous times over the decades. As commercial simulation software became available, they incorporated it into their simulation practices.

Enabled by increasingly better software tools and exponentially faster compute power, they had just made the decision to move away from their in-house analysis code in favor of a multiphysics and simulation lifecycle platform that would take them to new levels of fidelity in their designs. Jet turbines are very complicated systems. I bet they are more complicated than the shuttle payload test I watched, and they are much more difficult to test.

During our discussion, the manufacturer said turbine simulation had reached the point where they could predict the outcome of the physical test. Despite the incredible complexity, they were actually simulating the physical test. The outcome was the ability to optimize the engine with confidence as they were designing it, thereby limiting the number of prototypes and tests that were needed. The tools of design technology have caught up with their design process, enabling them to find the optimal outcome.

A Process Approach

This issue introduces a change in the way *Desktop Engineering* will be reporting to our readers. While we discuss technology features and benefits in our articles—and will continue to do so when appropriate—we are becoming more engaged with the outcomes enabled by the tools engineers use today. We will explain how engineers combine the different technologies into a design process that yields the best outcomes. Outcomes are of prime importance. Creating a better design is good, but creating the best design—an optimized outcome—is better. Creating an optimized outcome months before your competition is the Holy Grail. This issue is focused on using the tools available today to optimize your designs and design processes in order to achieve the most important goal in optimization: the best outcome.

As I thought back to the shuttle payload and contrasted it with the jet engine simulations being performed today, I realized that both outcomes are equally important. The latter wouldn't happen without the former. The near future is going to bring astounding changes that we cannot predict. **DE**

Steve Robbins *is the CEO of Level 5 Communications and editorial director of* DE. *Send comments about this subject to DE-Editors@deskeng.com.*

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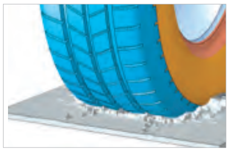

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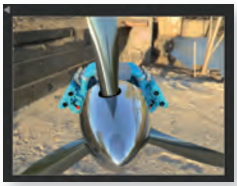

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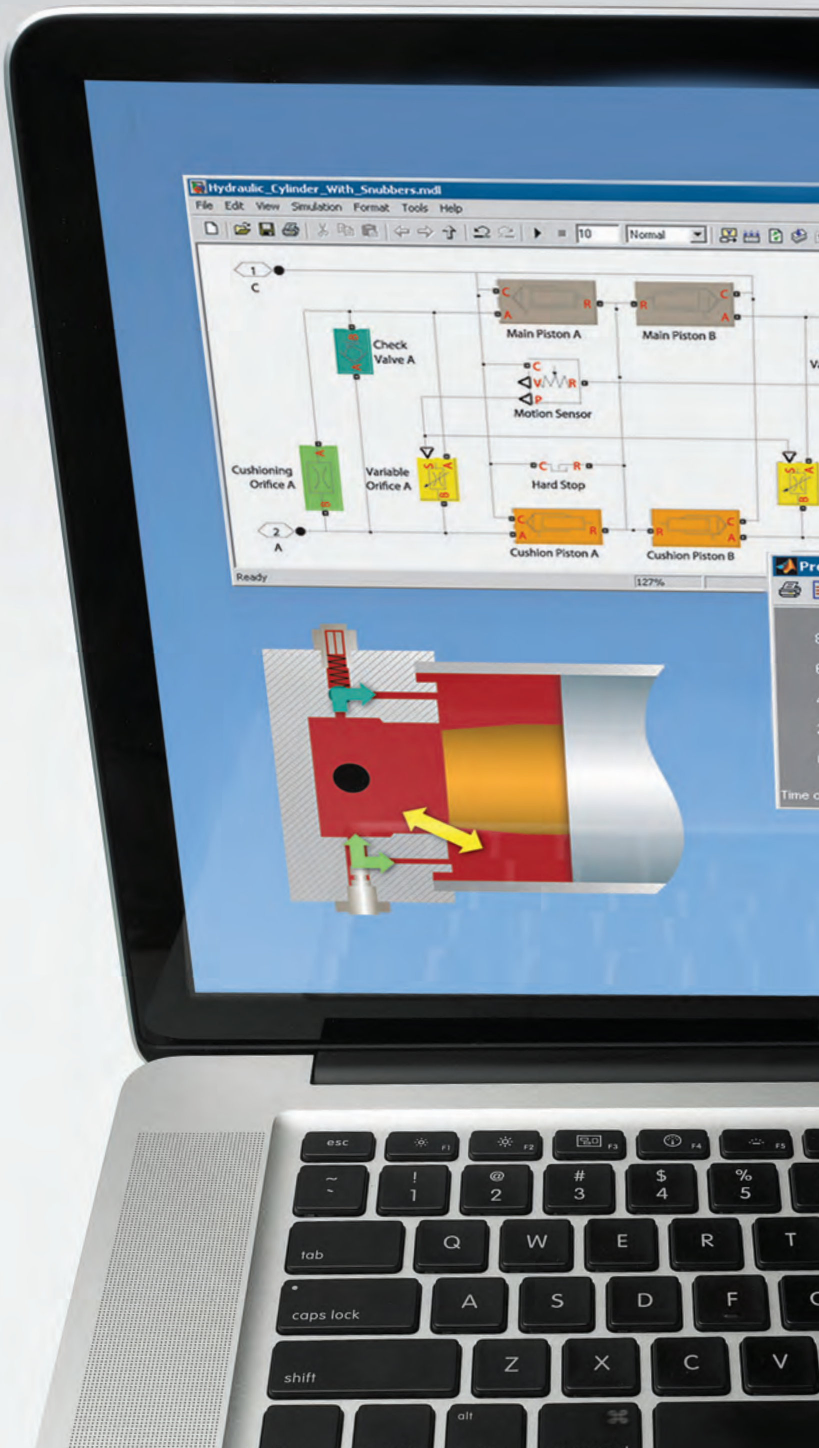
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by Kenneth Wong

DARPA's Next-Gen Amphibious Infantry Fighting Vehicle, Designed by You

If you think the development of the Defense Advanced Research Projects Agency's (DARPA's) next-generation amphibious infantry vehicle is a hush-hush project taking place in the secret halls of a military base, restricted to chief engineers from Northrop Grumman, you'd be wrong. You—and many others like you—will be designing DARPA's fast, adaptable, next-generation ground vehicle (dubbed FANG) on the web, in a three-phase contest with cash prizes ranging from $1 million to $2 million.

"DARPA has been using design challenges for the last several years, including competitions such as its Grand Challenge, Urban Challenge, and most recently, the DARPA Robotics Challenge," explains Army Lt. Col. Nathan Wiedenman, DARPA's program manager. "Although these challenges are each fundamentally different from the FANG Challenge, they all seek to leverage a non-traditional pool of innovators to increase the chances of identifying a truly revolutionary idea."

The contest asks participants to register and help develop the vehicle in three steps.

Phase One (Mobility): Design the drivetrain.

Participants of DARPA's FANG challenge will use an online collaboration hub, hosted at VehicleForge.org. Shown here is the virtual workshop.

Phase Two (Structure): Design the chassis.

Phase Three (Total): Assemble the components into a functional vehicle model.

In each phase, a winner is determined by score. Selected designs will be built and fabricated in DARPA's Instant Foundry Adaptive through Bits (iFAB) manufacturing facilities. In the challenge, you'll be working with a library of components supplied by DARPA online, accessible to you once you register. Participants use the web-hosted design environment called VehicleFORGE (vehicleforge.org), complete with a built-in CAD file viewer and a virtual design workshop for remote collaboration.

You'll also be using an open-source system design toolset called META. The software encompasses a local installation and web-hosted tools, and the use of one or both is required for final submission. According Wiedenman, "the ultimate goal of the META program is to dramatically improve the existing systems engineering, integration and testing process for defense systems … It aims to develop model-based design methods for cyber-physical systems far more complex and heterogeneous than those to which such methods are applied today … to apply probabilistic formal methods to the system verification problem, thereby dramatically reducing the need for expensive real-world testing and design iteration."

Wiedenman clarifies that "competitors will have the ability to create custom components, to include CAD data, within the META tools suite. The design process can even be conducted using any capable third-party design tools, as long as the final design is converted to a META-compatible format prior to submission for scoring."

This project falls under International Traffic in Arms Regulations (ITAR), which govern the import and export of defense technologies. To be eligible, you must be a U.S. citizen, a lawful resident of the U.S., or a business operating under U.S. laws. Only submissions from registered, verified participants with authorized log-in credentials will be considered. Registration for the FANG challenge is open now. Submission deadline for the first phase is Feb. 25, 2012.

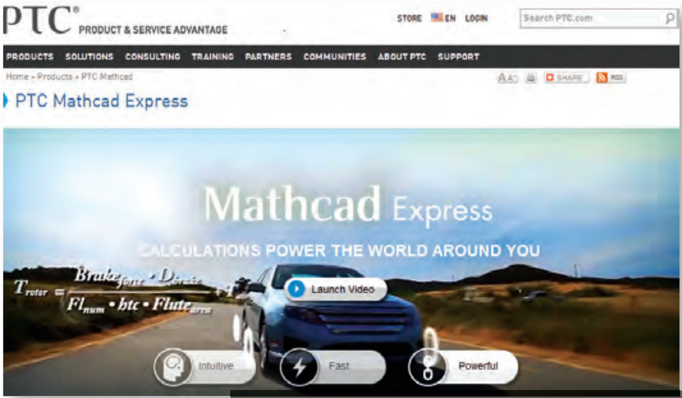
PTC Mathcad Express: Limited, but Free for Life

For ordinary folks, there's Excel; for engineers, there are technical calculation programs like MathWorks MATLAB or PTC Mathcad. The latter are designed specifically for handling equations, formulas and for importing these numbers into design programs. They're usually not cheap.

In October, PTC released a limited version of Mathcad as Mathcad Express, a free-for-life software (PTC's words). You can download it at PTC.com/product/mathcad/free-trial. For the first 30 days, you get the full functions of PTC Mathcad Prime 2.0, the commercial product, priced $1,500 on PTC's online store. After 30 days, the product becomes Mathcad Express, a limited-function version that's free for you to keep.

One of the limitations is watermarked documents. Also, the Express version does not include advanced numeric functions, programming or Excel integration. To get those, you'll need Mathcad Prime. Still, Express is a robust calculation program with basic numeric functions, equation editing, and X-Y plots.

With its direct modeling product PTC Creo Direct, PTC also adopted a similar strategy: It offers PTC Creo Elements/Direct Express as a free teaser.



PTC has released a free Express edition of its popular engineering calculation program Mathcad.

by Kenneth Wong

NVIDIA Gets Ready to Float its GPU in the Cloud

With the release of its new VGX boards, NVIDIA plans to power remote access to virtual GPUs from lightweight devices.

As NVIDIA sees it, you don't necessarily need to be sitting in front of your GPU-equipped workstation to experience the power of the GPU. You should be able to tap into your desktop machine's graphics horsepower remotely from anywhere, using a lightweight machine or a mobile device. Simply put, you could be running GPU-accelerated games, movies, modeling and simulation programs from a tablet, connected to your remote GPU-powered workstation or data center on a high bandwidth.

It's a vision previously revealed by NVIDIA's CEO Jen-Hsun Huang during the GPU Technology Conference (GTC) 2012. While introducing the company's next-generation Kepler architecture, he said, "Kepler can render and stream instantaneously right out of the chip to a remote location you choose." (*For more, read "GTC 2012: GPU, Virtually Yours," Virtual Desktop blog, May 2012.*)

For designers, engineers and digital artists, NVIDIA's virtual remote workstations promise "the experience of NVIDIA Quadro GPU on any VGX device," according to Will Wade, senior product manager, NVIDIA Quadro product line. VGX is the hardware that enables desktop virtualization, often abbreviated as VDI for virtual desktop infrastructure. (Oh, these insufferable tech acronyms!)

NVIDIA's remote desktops are made possible by combining the following:

- NVIDIA VGX Boards, designed for hosting large numbers of users in an energy-efficient way. The first NVIDA VGX board is configured with four GPUs and 16GB of memory, and fits into the industry-standard PCI Express interface in servers.
- NVIDIA VGX GPU Hypervisor, a software layer integrated into commercial hypervisors, such as the Citrix XenServer, to enable GPU virtualization.
- NVIDIA User Selectable Machines, which allows you to configure the graphics capabilities delivered to individual users in the network.

K2 Card Announced

In mid-October, NVIDIA unveiled its new VGX board, dubbed NVIDIA VGX K2 GPU and described as "cloud-based." The K2 card has "double the cores of a Quadro 5000 GPU, double the memory, all running on 245 watts," said Wade, "which means this card can fit into servers designed for Tesla GPUs [NVIDIA's product for high-performance computing servers]."

The VGX technology and hypervisor like Citrix's reduce the bandwidth requirement, according to Wade. This helps a smooth connection between the client device and the GPU-enabled host. "So now, we're talking megabyte bandwidth instead of bandwidth with tens of megabytes," said Wade.

The current VGX solution doesn't permit multiple client devices to tap into the same GPU to perform separate workloads (often called virtual GPU sharing).

"This is still on the road map for our VGX solutions," Wade revealed, "and we expect to be able to talk more about that in 2013."

The first K2 server solutions will be available from Cisco, Dell, HP, IBM and Supermicro. They're set to become available in early 2013.

Though GPUs were originally conceived as hardware for a graphics boost, in recent years, GPU makers began refining their technology for general-purpose computing. The GPU's parallel-processing architecture makes it particularly suitable for computing jobs that can be subdivided into smaller operations. GPU acceleration was previously confined to professional apps, such as finite element analysis (FEA), animation rendering and games. But it has now been incorporated into everyday computing, including Microsoft Office and Adobe Photoshop.

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by Kenneth Wong

Autodesk Snatches Up HSMWorks for Cloud CAM

HSMWorks has already done the legwork to bring computer-aided manufacturing to the private cloud. With Autodesk's acquisition of the company's assets in October, the product now appears to be heading for the public cloud.

Autodesk plans to "integrate the HSMWorks technology with its industry-leading software and cloud services for manufacturing," according to the announcement. It will continue to "make current HSMWorks products available for purchase and HSMXpress available as a free download."

Distributed Computing is Key

What distinguishes HSMWorks is its network processing function—the option to use distributed computing to speed up toolpath generation. The software's architecture allows you to take advantage of multicore CPUs, but, perhaps more important, also the computing cores distributed across the entire network. According to HSMWorks, it does so by "automatically utilizing idle PCs on the local network to reduce toolpath calculation time.˜Distributed CAM is automatically used by Autodesk HSMWorks when˜installed on selected PCs, and requires no additional setup or˜interaction from the user." (*Editor's Note: For more, read "Put your idle computing cores to work," August 2010.*)

From distributed computing in a private cloud, it's a small leap to move into distributed computing in the public cloud—the backbone of Autodesk's new on-demand offerings branded as Autodesk 360.

CAM Coming to 360?

The company recently launched Autodesk Simulation 360, a line of cloud-augmented analysis modules. For the most compute-intensive portion of analysis jobs, users of Autodesk Simulation 360 can tap into cloud-hosted processing power, delivered on demand, to speed up the process. The same setup could be deployed to repackage HSMWorks into what might be called Autodesk CAM 360, augmented by cloud-hosted computing power.

Currently HSMWorks is a Gold-certified partner product for SolidWorks, a rival of Autodesk. HSMWorks' relationship with SolidWorks will likely remain for the foreseeable future, but Autodesk may also implement strategies to make the Inventor-HSMWorks combo a more appealing alternative to the SolidWorks-HSMWorks combo.

For more on Autodesk 360, see the Virtual Desktop blog at deskeng.com/virtual_desktop for posts from me and *Desktop Engineering's* new contributing editor, Beth Stackpole.

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

GrabCAD Expands

Rising to notoriety within a short time in an established universe, two-year-old GrabCAD sometimes seems like a new kid—a space cowboy barely old enough to sport a beard or brandish a lightsaber. But things are swiftly changing. The young Padawans have just found several Jedi to help steer their Millennium Falcon into new territories.

Jon Stevenson, whose history includes several executive positions at PTC and Siemens PLM Software (known then as UGS), was previously an investor and adviser for GrabCAD. In July, he took on the role of vice president of technology. So, in the minds of younger members of GrabCAD, Stevenson is the Obi-Wan Kenobi of CAD.

GrabCAD recently nabbed Dan Dignam, previously chief architect of SolidWorks, and Stuart Reid, previously development director of Interoperability at SolidWorks. Dignam and Reid will become the core of the overseas GrabCAD office in Cambridge, UK. According to GrabCAD CEO Hardi Meybaum, the company is also looking to expand the development team in Estonia, Meybaum's homeland.

So far, GrabCAD has been focusing on building an online community for engineers. But the arrival of seasoned CAD soldiers signals a new direction. GrabCAD is currently developing a collaboration system targeting enterprise users. They've also received a fresh round of funding: $8.15 million from Charles River Ventures.

In my view, the founding team's understanding of social media (perhaps a reflection of their age range) gives them an advantage that bigger rivals don't have. Also on GrabCAD's management and adviser teams are Mart Oruaas, previously from Skype, and David Sacks, founder and CEO of Yammer. **DE**

Built-in Batteries Reduce Weight

BAE Systems has developed what it calls “structural batteries” that merge nickel-based battery chemistries with a carbon fiber composite. The batteries can be formed into any shape, and actually used as part of the structure of an item, saving space and reducing weight.

In the Lola-Drayson electric racecar, for example, the battery forms part of the rear wing of the vehicle (see page 46), and powers the onboard electronics. BAE has also used the technology to build a small, unmanned aerial vehicle. The company originally began developing the batteries to lighten the load for soldiers carrying electronic equipment.

“The beauty of what we’ve got is that, when it’s fully developed, a company will be able to go out and buy what is a standard carbon-composite material, lay out the shape, put it through the curing process and have a structural battery,” says BAE’s Stewart Penney.

Up next: a lithium-based version of the solution that can provide more juice, as well as a look at new materials that could be used, including fabrics.

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Ford Developing Carbon Fiber Body

Ford is hoping to lighten its vehicles using carbon fiber. To this point, the only reason auto manufacturers haven’t widely used the material is the cost. Ford’s European Research Center has been working with Hightech.NRW, a German research firm, on developing economical production practices to produce carbon fiber auto parts.

The prototype of the process is a hood designed for the Focus. The auto company is also working with Dow Automotive Systems to perfect the process, which, according to the company, could result in shedding around 750 lbs. from the weight of a vehicle.

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Bridgestone’s Sustainable Tires

Bridgestone has rolled out a new concept tire made of 100% sustainable materials. The company is diversifying the regions where it produces natural rubber, and expanding the range of reinforced plant fibers in the tires. In addition, fossil resource-based components in the tire were synthesized from biomass.

The company has set a target date of 2050 for commercially viable, sustainable tires, although it is targeting 2020 for “commercial sales of certain sustainable materials used in the manufacturing process.”

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Engineering a Cheap, Sustainable Cardboard Bicycle

Israeli Designer Izhar Gafni has come up with a slick, waterproof cardboard bike called the Alfa that relies on an origami-like design to provide structural strength. It can be manufactured for between $9 and $12, weighs just 20 lbs., and can support more than 450 lbs. The current version of the bike is made of 100% recycled material, and there is an option to add an electric motor. The belt-driven pedal system is supposed to make the bike maintenance-free.

Gafni is currently raising funds to mass-produce the bikes, in hopes of making cheap, environmentally friendly transportation available across the globe. Previously, the engineer developed a prize-winning pomegranate peeling machine, a smart robot for sewing shoes, and a “disabled climbing machine.”

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Hitachi Unveils Million-Year Storage Media

Working in conjunction with Kyoto University, Hitachi says it could potentially provide safe storage for millions—or even hundreds of millions—of years.

Using quartz glass, the company devised a method to etch, read and maintain data. A laser stipples dots onto a piece of quartz glass (corresponding to binary code), while an optical microscope can read the data. Four layers of dots can be etched on a storage module that is 0.8 in. square and 0.8 in. thick.

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Microsoft, Nintendo Use Rapid Prototyping

Microsoft has drawn back the curtain on how 3D printing was used to aid the

design process for its forthcoming tablet. The team responsible for the Surface says it made more than 200 custom parts during the design process, many built using 3D printing.

Digital design also simplified production of the Surface. Its production facilities in China use the same 3D printers as the Microsoft designers in the U.S. This made sending out new data as easy as emailing .stl files. Both parties could print out prototypes, and cooperate in design improvement, regardless of location.

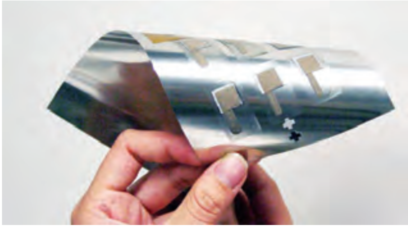
Nintendo has been similarly open about how rapid prototyping helped with the design of its Wii U GamePad. As each new iteration of the controller rolled out of a 3D printer, the team examined it and made adjustments, even going so far as to carve away bits of it by hand before printing the next prototype.

MORE ➜ rapidreadytech.com/?p=2662

Printed Batteries Show Promise

Imprint Energy, a company founded by two University of California graduates, is working on a using zinc technology to created printed, flexible batteries.

Company Co-Founder Dr. Christine Ho hypothesized that by changing the electrolyte half of the zinc battery equation, she could create batteries that wouldn't corrode. She replaced the electrolyte with a polymer film that was more conductive,



and found she had a working battery that could be recharged. Even better, the new battery could be printed as small and thin as a postage stamp.

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Mcor Releases Matrix 300+

If proof of success is in continuity, the success of Mcor's technology and signature material is the release of the Matrix 300+. According to the company, the new 3D printer is faster and features selectable layer thickness that allows for objects to be created in one of two modes: draft or presentation.

The Matrix 300+ includes new software intended to reduce build time and improve the quality of prints, and offers a new technology the company refers to as variable volume deposition (VVD). The idea behind VVD is to allow the creation of stronger and more complex objects.

Mcor's newest additive manufacturing (AM) system offers a layer thickness of either 0.004 in. or 0.007 in. for draft or presentation mode, respectively. The Matrix 300+ has a resolution of 0.004 in., and a build envelope of 9.39x6.89x5.9 in.

At press time, the Matrix 300+ was expected to go on sale globally by the end of the year.

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3D Systems Buys Rapidform

In the latest of a long line of acquisitions, 3D Systems has purchased Rapidform, a provider of 3D scan-to-CAD and inspection software tools, for $35 million in cash.

Based in Seoul, South Korea, Rapidform's XOR, XOV and XOS reverse engineering, inspection and data processing software combine scan data processing, mesh optimization, auto surfacing and CAD modeling in an integrated tool.

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Rapid Manufacturing Drives Light Aircraft

South African company Aerosud, with partner Paramount, is looking to move ahead in the military aircraft business by offering a light plane with military applications. The Advanced High-Performance Reconnaissance and Surveillance (AHRLAC) plane is a manned vehicle that is meant to operate in the same sort of capacity as unmanned aerial vehicles (UAVs).

The entire plan for the new aircraft was digitally created, and it relies heavily on additive manufacturing (AM), as well as computer numerically controlled (CNC) milling, for production. South Africa has been looking for a way to leverage its wealth of raw titanium, and has turned its sights on AM sintering systems (using powdered titanium) as one area of development.

Aerosud has been working on building a large-scale AM system to build aircraft, and it seems as though the AHRLAC is the forerunner of the program. The company has hinted that the cost of the new aircraft will be around $10 million, which is cheap by military budget standards. **DE**

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Simulation-Based Design: A Competitive Advantage

Cost advantages and faster computing solutions are driving an increased reliance on simulation during engineering design.

by Frank Soqui, Workstation Product General Manager, Intel Corporation

Simulation-based design is not a new engineering practice; it has been around since the mid 1960s. What is new is what commercial engineering software vendors and their resellers are doing to break down the simulation-based design barrier: making it faster and easier than ever before.

Companies such as Autodesk, SolidWorks, Siemens PLM Software and others are investing in software design tools that are democratizing simulation-based design, making it easier to use and comprehend. In turn, easier use makes it possible for a broader base of users to employ simulation-based design techniques as a primary means of design and verification to help engineers design superior products in less time and at lower costs.

Three Drivers of Simulation-based Design

What's changed to enable the trend toward more simulation-based design? First, the economy has changed. Engineers are all now faced with the need to get more work done with fewer resources, and get it done faster. To the extent that we can, we need to reduce the costs involved in physical prototyping. The impact can be dramatically shorter product development times and significantly lower cost.

Second, independent software vendors (ISVs) are developing integrated simulation tools. ISVs are now fully engaged in creating and selling tools that are integrated, making it easier to design, model, and comprehend results. These new tools help users create a single digital model, giving engineers the ability to create, simulate and modify their product ideas in a fast and very creative digital loop.

Last, hardware technology is making what was impossible, possible. Not too many years ago engineers needed a multimillion dollar supercomputer to just get a simple model to run. Even then, the performance was such that the results probably came back after you had to make your design decisions.

Today, a $5,000 to $8,000 workstation with two Intel Xeon E5-2600 product family processors offers you the opportunity to create, test and modify ideas right at your desk in a high-speed innovation ring. The result is you explore more digital ideas in less time; you shorten your development time and you reduce your prototyping cost.

Simulation-Based Design Improves Speed and Accuracy

Simulation-based design is not that simple. I wish it were, but as we have heard before, with every problem comes an opportunity. This new opportunity is being seized by resellers and consultants such as Computer Aided Technology, Inc. (CATI), a SolidWorks partner located near Chicago.

CATI has quietly been staffing up with experts to help users exploit simulation-based design tools. More importantly, CATI does not create your designs for you; instead they help you design your products faster and with higher fidelity. They help you increase your knowledge base and comfort level with simulation-based design through a series of hands-on training and support engagements. This process not only helps you get your immediate product to market faster; it also helps make your company more competitive. You now possess the tools and the knowledge necessary to employ simulation-based design workflows, while your competition may not.

Back to the Competitive Advantage

Integrated engineering design suites from companies such as Autodesk, SolidWorks, Siemens PLM Sotware, and others are making simulation-based design easier and faster to do, even for smaller engineering groups. On the hardware side, workstations based on the new Intel Xeon processor E-2600 makes it possible to get complex results back faster.

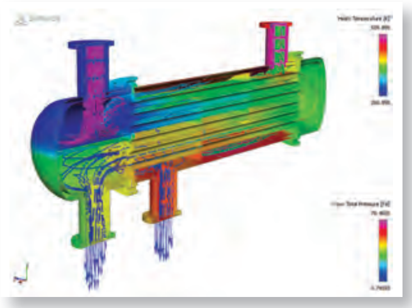
Because of the speed and accuracy of simulations run on these workstations, simulation-based design creates a strategic advantage for your company, whether it's a large enterprise or small design group. It can help you win more business. Engineering groups will have a significant advantage versus other small- and medium-sized groups who may not possess the knowledge or the tools to do simulation based design. DE

INFO → **Intel Corp:** intel.com/go/workstation

Editor's Picks

by Anthony J. Lockwood

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



Direct Modeling and CFD Partner

SpaceClaim Engineer integrated with PumpLinx and Simerics MP.

SpaceClaim and Simerics have announced the integration between SpaceClaim Engineer 3D direct modeler and Simerics's PumpLinx and Simerics MP CFD (computational fluid dynamics) analysis systems.

Simerics MP is a general-purpose physics system that solves CFD problems using multi-physics modules such as cavitation, fluid flow, heat transfer, mixing/reaction, and turbulence. PumpLinx is a customizable 3D tool for simulating and designing pumps, motors, and other fluid devices.

The coupling gives you a full multi-physics CFD design and testing solution without a huge price tag and even fewer hassles.

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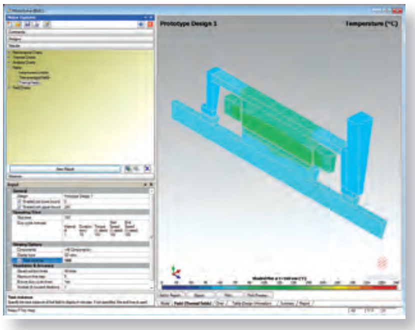

Analyze Switched Reluctance Machines

Thermal analyses also enhanced in MotorSolve v4 electric machine design suite.

Infolytica announced MotorSolve Thermal, an add-on module for the MotorSolve toolset, earlier this year. Now the company has announced version 4 of MotorSolve, which introduces a key new analysis module called MotorSolve SRM (switched reluctance machine).

MotorSolve SRM has a template-based user interface. Using it, you can do things like edit rotor and stator geometries. You can also fill in all your specs and constraints, such as the number of rotor and stator poles, the outer diameter, firing angles, coil geometry, and lamination material.

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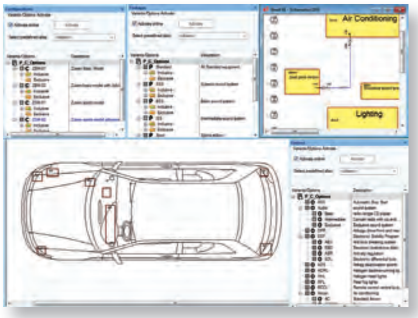

Electrical and Fluid CAD System Configured for Industries

Zuken says its new E³.series Industry Editions electrical design suites are engineered to meet the needs of key industries.

Wiring is a big part of what Zuken does, and they've just come out with a new version of their E³.series software for electrical wiring, control systems, and fluid (hydraulic/pneumatic) engineering that sounds like it can take a lot of pain out of your day-to-day workflow.

What Zuken has done is taken its years of experience working with major players in the aerospace, automotive, machinery, power, railway, and systems engineering worlds and used it to develop what it calls E³.series Industry Editions.

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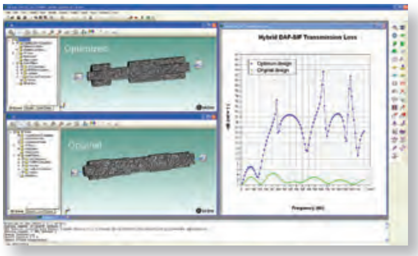

Full Frequency Noise and Vibration Simulation

ESI adds optimization module to VA One 2012 noise and vibration simulation solution.

The 2012 version of VA One from ESI Group adds a fully integrated design optimization module. This module is for people with tough balancing acts, such as balancing design and mass in a car's interior sound package to meet performance goals. ESI says it's quick and easy to use.

Other enhancements in VA One 2012 include a new adaptive integration scheme that's said to make the BEM solvers return faster solutions. New functionality lets you edit the attributes of multiple SEA subsystems quickly, reducing the time required to build and modify SEA models.

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How to Configure the Ultimate Engineering Workstation

Why you need overclocking, SSD caching and dedicated rendering.

Most engineering applications, like SolidWorks, Autodesk Revit, or Autodesk Inventor, are frequency bound (meaning they predominantly use only one processing core), so their ideal hardware platform is a workstation with fewer cores but higher frequency. However, if your workflow also includes rendering and simulation (which use multiple cores simultaneously), you'll need the maximum number of cores to run at peak performance. For most workflows, a quad core Intel® Core™ i7 processor is optimal, especially if it's overclocked like those found in XTREME edition workstations from BOXX.

Overclocking Matters

While brand name computer manufacturers focus most of their attention on mass produced, general use PCs, BOXX offers professional grade workstations custom configured and overclocked for 3D visualization. And with the ability to achieve 4.5 GHz, overclocked 3DBOXX XTREME workstations hold a decided advantage over competitors' top-of-the-line models, which can only manage 3.7 GHz— the speed threshold since 2006.

"It's the frequency plateau," says Tim Lawrence, BOXX Technologies' VP of Engineering. "Improvements to architecture have helped somewhat, but not enough. With processor speeds remaining virtually stagnant for six years, overclocking is the only way to significantly increase core speed and thus, performance."

Faster processes result in an accelerated workflow, greater efficiency, higher productivity, and a better overall user experience.

And if you're concerned about the effects of overclocking on a processor, rest assured knowing BOXX has shipped overclocked systems since 2008 and with thousands of systems in the field, the company has not experienced a processor failure rate any different from that of standard processor systems. And like all BOXX systems, XTREME systems are backed by a three-year warranty.

Critical Components

3DBOXX 4050 XTREME and 4920 XTREME performance is enhanced by the option of Intel® Smart Response Technology, whereby the system automatically learns which files users access frequently and copies them from the hard drive to the solid state drives. The next time the files are requested, they're loaded from the SSDs, rather than the slower hard drive. The result is faster booting, faster application loading, and accelerated performance.

In regard to system memory, you'll need at least 8 to 10 GB. With this amount, if your workstation is responsive and executes tasks quickly, you've made the right choice. If not, you may need to increase your RAM (in many instances) to as much as 16GB.

Although an NVIDIA Quadro 600 card is serviceable, BOXX recommends the NVIDIA Quadro 2000 as an ideal mid-range graphics card for most engineering workflows.

Because rendering is a key aspect of engineering workflows, engineers should consider off-loading it to a dedicated rendering system like BOXX renderPRO. Available with Intel® Xeon® E5-2600 series processors, renderPRO features up to 16 processing cores. It enables users to deliver complex projects within budget and on schedule by drastically reducing rendering time.

Increasing Productivity and Profit

The key to increasing productivity and profit is to accomplish more in less time. Faster turnaround means fewer employee hours invested and more time for new projects and clients. So when you configure the ultimate engineering workstation, consider solutions you won't find anywhere else delivering performance you can't get anywhere else—overclocked 3DBOXX XTREME workstations. DE

INFO ➔ **BOXX Technologies:**
www.boxxtech.com/solutions/solutions.asp

Highly Recommended

For engineering workflows, BOXX recommends the following workstations:

3DBOXX 4050 XTREME is a liquid-cooled workstation, powered by an overclocked quad core, Intel® Core™ i7 processor running at 4.5 GHz. Available with up to two GPUs (NVIDIA Maximus™ technology) and support for solid state drive (SSD) caching for increased storage performance, 4050 XTREME is the industry's fastest single socket workstation for engineering and product design applications.

3DBOXX 4920 XTREME, another liquid-cooled BOXX workstation, includes an overclocked, six core, Intel® Core™ i7 processor also capable of speeds up to 4.5 GHz. 4920 XTREME is available with up to four GPUs (NVIDIA Maximus™ technology), and support for solid state drive caching for increased storage performance.

What it Means to Optimize Design

BY JAMIE J. GOOCH

Our New Year's resolution is to help you implement an optimized design process. But what exactly does that mean? When it comes to upfront design engineering, it depends on who you ask.

From its broadest definition, optimization is simply a process to make something as close to perfect as possible. That's the definition we have decided to use, because optimizing the upfront design process spans all of the technologies used by engineers—from product concept until it's ready for manufacture. If simulation, analysis, prototyping, testing or the computing infrastructure that makes desktop engineering possible is not optimized, then the design process is not as close to perfect as it can be.

It takes more than technology to optimize design. It requires a shi˜ in the engineering mindset.

Simulation Comes First

From a simulation and analysis perspective, optimization is achieved by moving simulation to the very front of the design process. Rather than simulating a design to verify it after the fact, optimization calls for simulation to be used first so that it can guide the actual shape and components of your designs. The software is driven by near-universal goals such as using only as much material as needed, reducing weight and ensuring structural integrity vs. expected stresses and loads. Simulation-driven design is optimized design when it allows engineers to reduce the design cycle by quickly determining the best possible design concept.

But it doesn't stop there. After designs are created based on the concepts, simulation is used to optimize the next stage of the design process as well. Everything from minor tweaks to new materials can be simulated quickly, again and again, to ensure they don't just meet design requirements, but are the best possible way to meet them. The ability to quickly create multiple iterations of a design is a critical ingredient in an optimized design process.

Moving On Up

Because simulation-driven design enables the best concept to be identified so early in the design process, it moves other aspects further forward as well.

Virtual testing can be done before a prototype is built. With the ever-increasing use of embedded software, the ability to test early and often is critical.

Prototypes can be quickly created with 3D printers to keep up with the latest iterations. Simulation-led design is also driving additive manufacturing technologies as engineers discover the optimal design might not be feasible to manufacture by any means other than additive manufacturing.

Upfront simulation also helps ensure problems are discovered and corrected before they ever see a test bench. Instead of simulation verifying a design, testing verifies the simulation.

Making it Possible

The ever-increasing speed and availability of computing processing power is the technical enabler of simulation-led design. From multi-core CPUs and GPUs to high-speed interconnects to on-demand access to computing resources via public and private clouds, simulation-led design would be mired in bottlenecks without it.

But it takes more than technology to optimize the design cycle. Perhaps the highest hurdle of them all is a shift in the engineering mindset that simulation-led design requires. That cultural shift is getting a boost from the forces of a struggling economy, global competition and an always connected society—all of which are combining to erase the silos between engineering disciplines and drive costs and time from the design cycle.

As you assess your engineering group's technologies and culture as the year comes to an end, we hope you'll consider the article topics in this issue to be your engineering New Year's resolutions: Understand optimization, stop over-engineering, let simulation drive design, prototype and manufacture rapidly, verify optimization and enable it with the best hardware and software technologies. **DE**

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

An *Optimization* Overview

Optimization technology has advanced rapidly over the last decade, and engineers face a bewildering variety of tools and methods.

By Tony Abbey

While it is tempting to view optimization as a black box—press the button and the "Answer to Life, the Universe and Everything" emerges—sadly, that doesn't happen often. To understand optimization, we must first ask ourselves some basic questions about our goals, our designs and our constraints.

What are we trying to achieve with an optimization?

This is defined by the objective function, and is traditionally weight minimization. It can be many other things, however, such as maximizing strength. Innovative optimization solutions can be found by thinking about the objective function "out of the box."

Until recently, methods used one unique objective. Allowing multiple objectives is now common—for example, we can evaluate the effect of minimizing weight and at the same time maximizing strength. We don't often get one unique solution; instead, a set of trade-offs is found, all of which are "best in class." The trade-offs are shown in a way that can be investigated to help the user make a decision. The user chooses a compromise between weight and strength margin.

How do we define what we want optimized?

The set of parameters that define the optimization task are called design variables. We will see examples across a wide range of optimization types. But for now, imagine a 2D shell model, such as a storage tank, plating in a girder bridge, etc. Each different plate thickness will be defined by a design variable. For the tank, it may be a single design variable; for the bridge, it may be the separate flange, and shear web thicknesses define two design variables. We may allow more thickness variation and increase the design variable count.

What restrictions do we want to put on the structure?

Restrictions are defined as optimization constraints (not to be confused with structural constraints). There are two types: *response* constraints, preventing the structure from violating stress limits, displacement values, frequencies, etc., and *gage* constraints, limiting the model's physical parameters such as wall thickness and beam cross-sectional area.

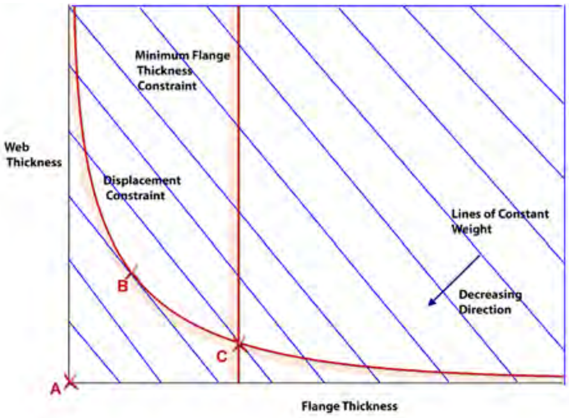

FIGURE 1: Design space.

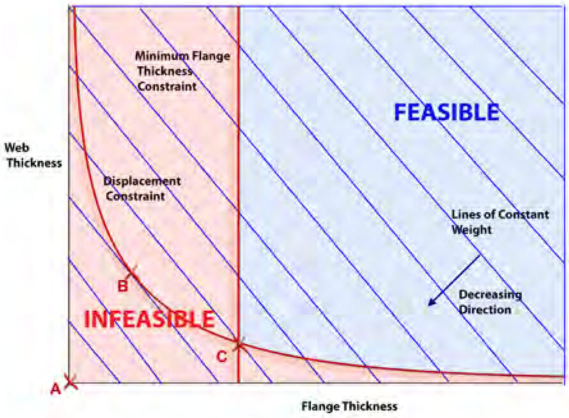

FIGURE 2: Design space showing feasible and infeasible regions.

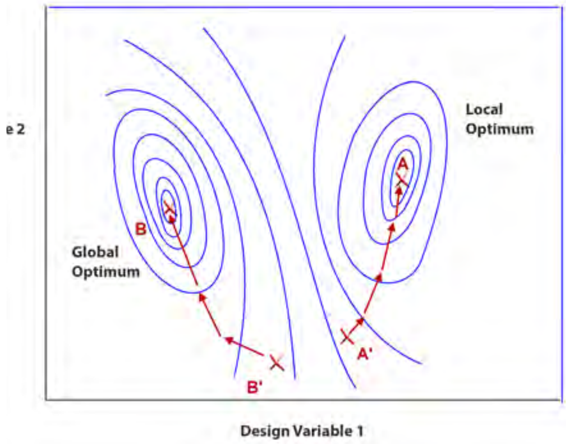

FIGURE 3: Global and local optima.

Constraints can be upper- or lower-bound, a wall thickness defined between upper and lower design limits. Displacement may be limited to a maximum and minimum value. A small tolerance is sneaked in here—it is expensive to trap exact values.

Optimizers hate equality constraints, such as displacement or stress forced to match specific values. It provides a big numerical challenge, so another small tolerance is sneaked in.

After all these questions, we may have a bridge structural model, optimized to minimize the weight. The bridge maximum stresses must not exceed a limiting level, and the center deflection must be below an upper limit. The two design variables are flange and web thickness, defined by the property associated with the relevant elements.

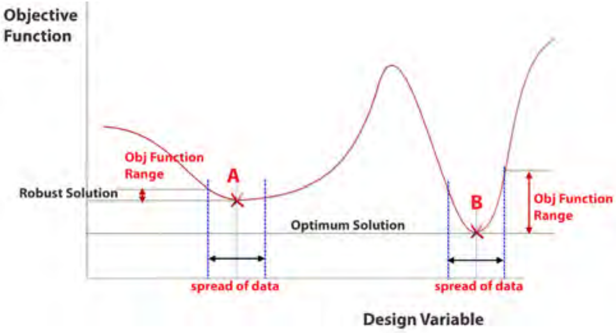

FIGURE 4: Robust design vs. optimum design.

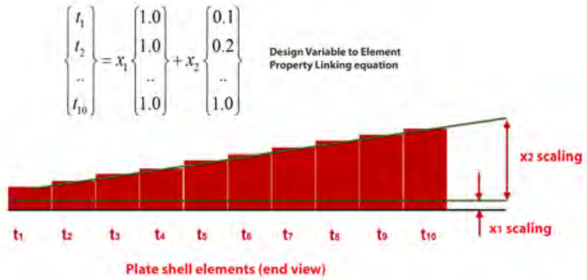

FIGURE 5: Design variable linking.

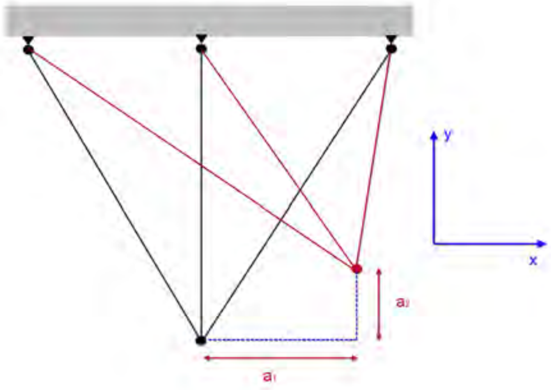

FIGURE 6: Three-bar truss showing shape variables.

Design Space

Design space is shown schematically in Fig. 1 for the bridge. The design variables form the axes, and lines of constant weight are plotted. Without constraints, we have a silly optimum zero weight at A. Adding a displacement constraint gives us a practical design, and the optimum is B. A minimum constraint on flange thickness moves us to a heavier solution, C. Designs that are outside the constraints are feasible; those violating one or more constraints are infeasible, as shown in Fig. 2.

The bridge objective function is linear with a constant gradient. That makes searching for the optimum easy by following the gradient until finding a constraint and sliding down it until we can't go any further. That forms the basis of an important class of methods, *gradient methods*. These are very powerful when used in internal optimization engines embedded within an finite element (FE) solver. The gradients can be solved analytically rather than numerically, saving computational resource and optimization steps. Each optimization step means a reanalysis. Typical gradient methods may need 10 to 20 steps.

A big drawback of gradient methods is that we cannot be sure of a global optimum. Fig. 3 shows an optimum at A, given a start at A'. If we start at B', then we find B, which is the best or global optimum.

Gradient methods can have multiple starting points, but there is still no guarantee of a global optimum—and the cost increases.

A powerful range of methods, taking very different approaches, has been introduced into optimization and are better suited to finding a global optimum. These methods are typically found in external optimization tools, which drive FEA and potentially other parallel multi-disciplinary simulations. The list includes:

- Genetic algorithms use survival of the fittest, reproduction and mutation simulations to evolve an optimum design. The design variables are codified, usually via binary numbers, in a gene-like representation. Radical designs can evolve from this method. Limited sets of gage sizes are well handled—often a problem for gradient methods.
- Neural networks use a simulation of the brain's neural paths. The system is trained on a set of analyses and learns what constitutes a "good" solution. Again, radical designs can be produced; gage sets are ideal and even invalid analyses will be recognized.
- Design of experiments (DOE) uses an initial scattershot approach across design space. This can intelligently evolve into a set of solution points that characterize design space, and this "curve fit" is used to find a global optimum.

The downside of these methods is that huge numbers of FEA solutions are needed, often in the thousands. However, with increasing computing power, many structural models are now viable. They can provide radical solutions, but the "thought process" is not easily traceable, unlike gradient methods.

Keeping 'Optimum' in Perspective

Much early work focused on mathematical search methods using well-defined benchmark problems, and to some extent concentrated on getting the best "optimum" solution to high significant figures. To put that in perspective, "good" FEA may give us stress results to around 5% accuracy!

Modern approaches now include searching to improve the robustness of an optimum solution, as well as the raw "best value." Fig. 4 shows the basis of the method. Design A is the "best," as it minimizes the objective. However, it is unpredictable with small variations in input parameters—remember, we struggle to simulate the real world, and may also in fact end up violating a constraint such as stress or displacement.

We also need to keep an intuitive feel for the robustness of an optimization analysis. One trap is to miss some of the loading cases applied. Unfortunately, the resultant "optimized" structure is very likely to fail when the full load set is applied, as it has been carefully designed to ignore it. Similarly, any poor assumptions or idealizations in the baseline FEA model may well be exaggerated. It is worth spending additional time debugging this model before going onto an optimization study.

Topology optimization is probably the most radical, "free spirit" approach, and is often used in conceptual design. At the other end of the scale, *sizing optimization* is tuning a fixed layout, and may be used as a final pass in an optimization process.

How FEA Carries out Optimization Analysis

The various approaches to optimization found in FEA are basically defined by the way the design variables are used. The earliest method used the simplest parameters available to control the FEA model's physical properties, including:

- shell thickness;
- rod or beam area;
- beam second moments of area; and
- composite ply angles and thicknesses.

Sizing Optimization

The design variables are limited to the idealization parameters of bars, beams, shells, etc.—1D and 2D elements. This type of optimization is called *sizing optimization*, sizing the property parameters. This method is widely used in aerospace, maritime and anywhere the 1D and 2D idealization dominates.

The linking of design variables to property parameters can be a simple direct relationship, or a more complex combination of many parameters. Fig. 5 shows linking shell thicknesses for a tapering skin.

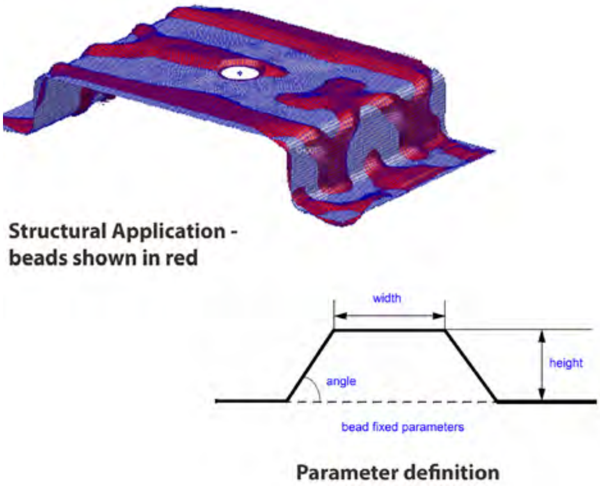

FIGURE 7: Bead definition and application.

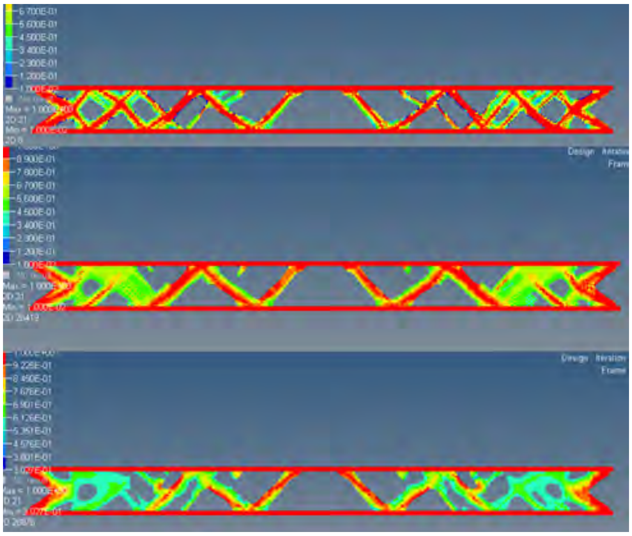

FIGURE 8: Topology variations in a beam structure, plotted as relative material stiffness.

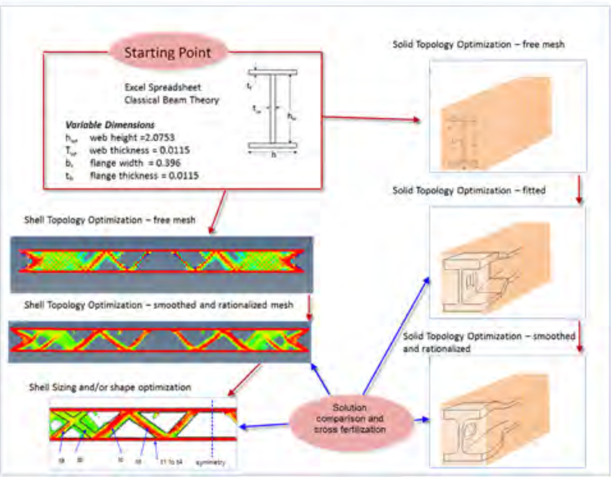

FIGURE 9: Comprehensive workflow to study project optimization.

Shape Optimization

Shape optimization controls the nodal positions of 1D, 2D and 3D structural meshes. Until recently, the FE models kept the same mesh, but the mesh could be distorted. Fig.6 shows a simple 1D example. The two design variables a_1 and a_2 are the node position in x and y.

If we have a more general mesh with many nodes, however, the definition of design variables becomes at first tedious—and then rapidly impossible. Simplification schemes such as giving linear control over edges through nodal position linking can be used.

An alternative approach introduces an "auxiliary model." The parent mesh is distorted in arbitrary, but "natural" ways by applying loading or using mode shapes. The load case on the auxiliary model has no meaning other than to give "pretty shapes." These shapes are then combined and scaled in the optimization to give the final structural mesh shape. Some dexterity is required to set up sensible auxiliary analyses.

Thankfully, recent advances in shape optimization allow morphed variants of the mesh, either directly from the original mesh or via parent geometry morphing.

Another innovation uses a restrictive movement of nodes in shell-type structures to give a beading or swaging effect. Fig. 7 shows nodes allowed to move a fixed amount in a fixed direction. The result is a very useable tool to represent thin panel stiffening, with simple user input defining the design variables.

Shape optimization usability is greatly increased by a new approach. Instead of minimizing weight as the *objective function*, a *weight reduction target* is set at, say, 40%, and the objective is to achieve a *homogeneous distribution* of stress or energy. This can be coupled with automatic perturbation of edge nodes (2D) or surface nodes (3D) and automatic remeshing.

The remeshing operation blurs the original definition of shape optimization. It also has the benefit of avoiding a drawback of shape optimization: excessive element distortion.

Topology Optimization

An alternative to directly controlling size or shape parameters via design variables is to provide a fixed 2D or 3D design space filled with elements. The elements can be "removed" to evolve the structural configuration.

A traditional FE model requires a full mesh of nodes and elements so that the stiffness matrix remains a constant size. Element removal is "faked" by reducing effectiveness. Typically, Young's Modulus and density is reduced, so that a resultant structural configuration of, say, steel is surrounded by mathematical chewing gum. Typical results are shown in Fig. 8, with various parameters controlling the width of members and the sharpness of the material transition.

Topology optimization has also been transformed by replacing traditional weight minimization with maximizing stress or strain energy "smoothness."

The final technology improvement has been to take the "LEGO Brick" mesh results (formed by elements removed in a mesh) and fit usable geometry through the surface nodes. Likely improvements over the next few years include automatic parameterization to increase the relevance to real design and manufacturing geometry.

The Science and Art of Optimization

Engineers are faced with a wide range of optimization methods, including shape, sizing and topology. The underlying technology can vary from gradient methods to neural networks. Some methods have very synergistic technologies—shape and gradient or topology and GA. However, it is up to the user to look carefully at the guidance and recommendations in supporting documentation. The full list of technologies can run to 20 or 30 different algorithms. Some external optimizers have strong automatic selection strategies to link the right technology with a method.

The decisions taken in setting up an optimization problem will strongly influence the optimum found; there is no single right answer. The best we can hope for is to use a combination of engineering judgment, good FE modeling and innovative use of optimization software to come up with a design solution that is often a best compromise. The software by itself cannot achieve that. Multi-objective methods can go some way to assisting us down the path, but common sense is still required to avoid making the problem overly complex.

Fig. 9 shows a schematic that moves progressively through logical stages of optimization of a beam, comparing a 2D shell idealization and a full 3D solid idealization.

We are moving from the conceptual design phase, using classical calculations to get into the right ballpark and then opening the design up to more radical solutions with topology optimization, before finally enforcing more discipline on the design via sizing optimization. The last stage provides a manufacturable design and formal structural sign-off.

Alternatively, it can be argued that the use of the spreadsheet and 2D topology of a defined configuration is too restrictive, and more radical designs are sought. Then a 3D topology optimization with GA technology may be the best approach.

The optimum, like beauty, is in the eye of the beholder. **DE**

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Make **Good** Products **Great** with Outside Expertise

Altair ProductDesign improves the creation process for highly engineered products.

BY PAMELA J. WATERMAN

Technology no longer just marches on; it sprints, cuts back, jukes and spins by with incredible speed. The pace of technological innovation makes it tough to tackle. The difficulties keeping up are exacerbated for design engineers who are charged with mastering new hardware, software and processes in order to create the latest high-tech product designs faster and more affordably than ever before.

Whether your next project shows up on the desk with half the parts already specified, or you're staring at a blank screen and a specification document, final success depends on many factors. One of these is your company's ability to match design engineering tasks to the skills of your own staff.

Are you at the point where a new project is pushing the limits of your in-house expertise? Do you require specialized talent for a short period? Or do you have a sense that fresh ideas are just what you need right now? Working with experts who specialize in areas where your team needs help not only speeds up the development cycle, but can offer a whole new objective vision—and inspire improvements you may not have considered.

One such expert is Altair ProductDesign, an international company that has spent almost 30 years crafting and expanding a distinct approach to consulting. As a division of Altair Engineering, Altair ProductDesign comprises more than 40 offices around the world, a fact that offers the first clue that its approach is hardly business as usual.

Optimized aluminum bus-frame of fuel-efficient transit bus.
Image courtesy Altair ProductDesign.

Enlist Engineering Expertise

In the global economy, the need to differentiate a product drives every aspect of its design. Part count, manufacturing approaches, assembly requirements, material properties, and costs must be constantly reviewed and evaluated. The more complex the product is, the harder it can be, especially under time-to-market pressures. The ideal product includes innovation at every step, and Altair ProductDesign offers this through its simulation-based design optimization process.

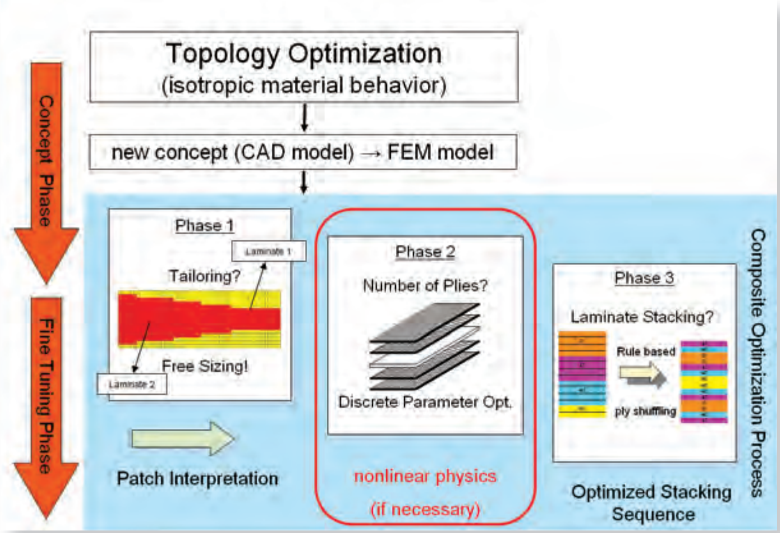
Altair Engineering itself started in the mid-1980s as a mechanical engineering consulting company, with both aerospace and automotive clients. Within a year, the company had an on-site office at General Motors, and soon after started design optimization projects on the classic Corvette and the Ford 150 suspension (looking ahead to the 1996 model).

"The automotive and aerospace industries in particular embraced simulation because they needed to reduce the amount of physical testing required to home in on an optimum design," says Royston Jones, president of Altair ProductDesign. "Gradually, simulation became a tool not just for verification, but to actually lead the design process."

By 2008, the division was up to 500 members and had established its first on-site Optimization Center for Airbus in Toulouse, France, supporting all Airbus European efforts.

Early on, Altair recognized the key factors for successful and innovative product development centered on optimizing performance and weight.

"Allowing intelligent simulation technology to inform the early stages of product development is a cornerstone of our simulation-driven design philosophy," Jones notes. "As companies seek to minimize the material use and weight of their products, combining simulation technology with our



Sample two-phase optimization topology process for use of composites in a structural design process, based on Altair OptiStruct software. ***Image courtesy Altair ProductDesign.***

Online Resource for Product Weight Reduction

Reducing product weight has so many advantages, it's no wonder that design groups are paying more attention to tools for doing so. Launched in January 2012, AltairEnlighten.com serves as a software-independent online resource for anyone in the industry wanting to learn more about advances in this area. Article and blog topics include material substitution (composites, advanced metallics, joining technology), optimization methods and processes, and new advancements (nanotechnology, additive manufacturing, biomimicry).

Peter Roberts, marketing manager for Altair ProductDesign, says it was important to the company to establish a real community beyond just automotive and aerospace.

"The whole simulation-driven design philosophy really is something being applied across industries," he says. "From packaging companies to electronics to heavy vehicles like cranes, I think it's really picking up a huge amount of momentum, not just in those industries that are perhaps more traditionally looking at weight. The amount of material that is used to make products is becoming more and more of an issue for them. They're always looking to get production costs down, and this optimization- and simulation-driven design philosophy is really a fantastic way to achieve those goals."—PJW

own knowledge and creativity helps our clients meet their product performance, fuel efficiency and emissions goals."

Working with existing simulation packages inspired the development of Altair's first software product, HyperMesh, later followed by products such as OptiStruct to form the beginnings of HyperWorks, Altair's full CAE software suite. The suite now comprises more than 15 products for modeling, visualization, analysis and optimization.

Altair OptiStruct is a finite-element-based package with an internal solver that uses a gradient-based topology approach to developing lightweight, structurally efficient designs that clearly take manufacturability issues into account. Advanced capabilities include optimizing laminate composite ply-up sequences, incorporating multi-disciplinary responses (such as buckling or heat transfer), and dealing with multi-body dynamic systems. The last task is handled via the company's own Equivalent Static Load Method (ESLM).

For critical projects demanding high-performance design, Altair HyperStudy applies the concepts of design optimization to an even broader range of tasks, from product weight reduction and design of experiments to multidisciplinary studies and stochastic investigations of reliability/robustness factors. HyperStudy is a solver-neutral optimization package with direct interfaces to dozens of popular solvers.

Optimization No Longer Optional

It's clear that the primary factors driving today's high-end product designs are outside the control of design engineers. Jones says that since 2008, the waves of financial crises coupled with other factors (such as recent European emission standards) have pushed optimization efforts to the forefront for the automotive industry. Very often, the crux of the design lies with its weight, so Altair ProductDesign consultants specialize in innovative structural-design solutions that minimize weight while maintaining performance requirements.

Working at the component level, the design optimization team may first evaluate the roles of a dozen high-mass components that together comprise the majority of a vehicle's weight—a front door or seat pedestal, for example. They would then zero in on several critical parts with potential for improvement. Usually, a component's material (steel or aluminum) and production process (stamping) are pre-defined, so the Altair ProductDesign experts set up dozens to hundreds of optimization runs, varying the geometry parameters of CAD designs subjected to stress analyses. Visualized results can point designers to optimized organic geometries quite different from those based on right angles or traditional symmetry.

More recently, in the continuing search to reduce weights,

Altair ProductDesign is partnering with Edison2 to design the suspension system and other aspects of the next generation of the 110-mpg design that won $5 million in the 2010 Progressive Automotive X PRIZE competition. *Image courtesy Altair ProductDesign*.

material properties are being added to the optimization mix. Designers would like to expand the use of composites beyond non-load-bearing and non-safety-related components such as interior linings. For example, Altair ProductDesign helped Volkswagen Group Research investigate a load-bearing composite B-pillar (the industry term for the vertical structural member generally at the vehicle mid-point).

The simulation sets included a high number of design variables such as geometry, number of layers and composite fiber orientation; load cases were a static roof crush, a seat-belt anchorage test and a standard side-impact. Allowing for nonlinear (deformation) behavior required two stages of optimization, working first on the load analysis of a linear structure to define geometry, then evaluating nonlinear behavior to define the requisite manufacturing process. Having this development approach in place now allows the Volkswagen research group to methodically evaluate structures that were previously impossible to simulate.

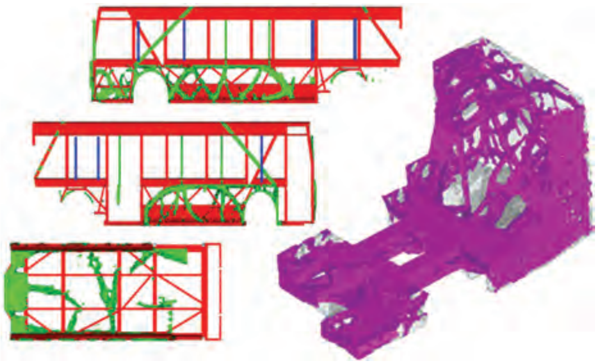
Lightweight, low-cost design requirements also drive Altair ProductDesign's partnership with Edison2 in Lynchburg, VA, to assist in the design of the new Very Light Car 4.0 (VLC 4.0). This vehicle will be the next generation of the fuel-efficient (110 mpg) design that won $5 million in the Mainstream Class at the 2010 Progressive Automotive X PRIZE competition. Whereas the original vehicle operated with a one-cylinder internal combustion engine, the new version will be all-electric and carry four passengers.

Altair ProductDesign will conduct a three-phase engineering study, targeting suspension sensitivity, impact strategy and structural optimizations.

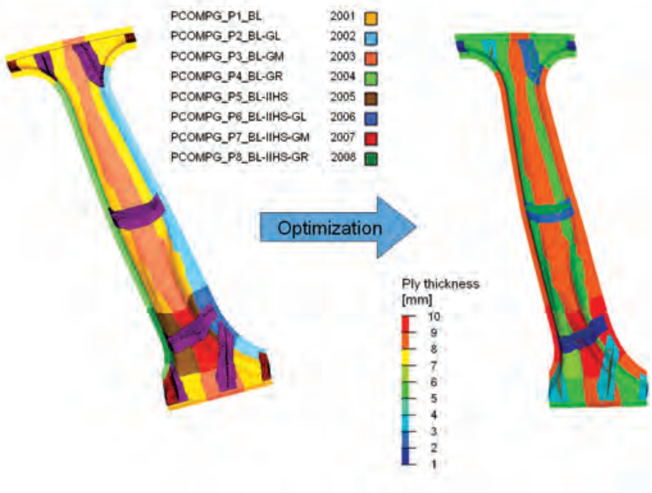
"Our engineers will focus on using optimization in the beginning of the design process to anticipate structural loading requirements with a minimum mass structure," reports Mike Heskitt, chief operating officer for the consultant group. Heskitt adds that Altair's HyperWorks simulation suite will be used to validate Edison2's novel suspension concept (supporting more in-wheel suspension travel). For more on the Edison2 project, see page 32.

Applying Lessons Learned

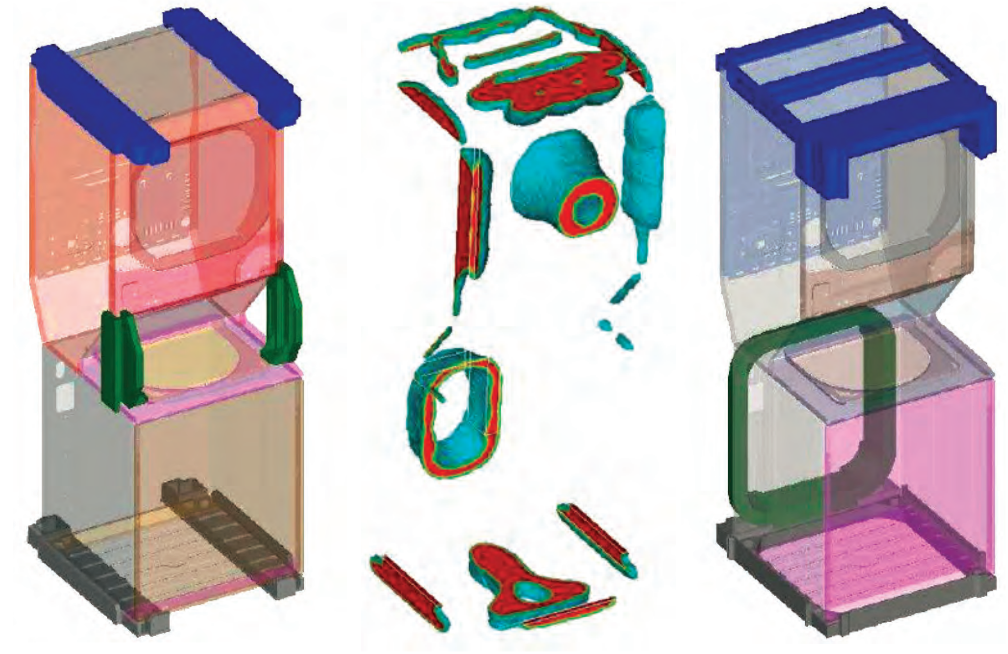
While Altair has its roots in the automotive and aerospace industries, optimization expertise isn't just needed for highly engineered, complex products. Altair ProductDesign is now



Altair ProductDesign consultants used a simulation-driven approach (including use of Altair HyperWorks software) to develop a bus frame with optimized placement of structural material. The resulting vehicle has a frame that is 30% lighter than conventional vehicles, and has twice the standard fuel efficiency. *Image courtesy Altair ProductDesign.*



Various designs and manufacturing processes for an optimized composite-material automotive B-pillar (the mid-frame, vertical load-bearing support between windows). The program was developed by Altair ProductDesign for Volkswagen Group Research, to define a general process for designing, analyzing and validating possible composite parts through simulation. *Image courtesy Altair ProductDesign.*



Design process to improve packaging materials/layout for a combination washer-dryer, performed by AltairProductDesign, a division of Altair Engineering. *Image courtesy Altair ProductDesign.*

applying optimization solutions to many different engineering problems.

For example, another of Altair ProductDesign's customers is Mabe, an international white goods manufacturing company based in Mexico City whose products include a high-end combination washer-dryer. The unit requires packaging that minimizes transport damage while avoiding unnecessary sections that would add material costs and shipping weight. The consulting team was challenged to produce an optimized product-packaging design process based on three goals:

1. derive the best packaging before the product itself was available for physical testing;
2. take into account a variety of loading scenarios; and
3. be flexible enough to work on a variety of future products.

The consulting team used Altair HyperMesh to create a finite element analysis (FEA) model of both the washer-dryer's structural components and packaging elements such as laminated paper, corrugated board and polystyrene foam. After conducting simplified performance tests on the packaging, Altair ProductDesign engineers subjected the virtual washer-dryer to the same loads as in physical testing. Using the "onion peel" feature of HyperWorks' post-processor, HyperView, the group could see internal components and determine the amount of energy absorption shared between the unit and the packaging components.

Because the different packaging materials serve different purposes, it made sense to perform separate topology optimizations on each, maximizing energy transfer, and then translate the results back into the CAD designs. Final results included such improvements as reducing peak reaction forces by 22% through the use of an optimized laminated paper corner-post.

Close Partnerships Pay Off

The philosophy of the Altair ProductDesign operations makes its worldwide consulting partnerships collaborative at a close and practical level, with certain core competencies at each office.

"We'll send one of our engineers to the local customer's office, or we'll take one of the local people and put them in the office where we have the expertise," says Jones. "I want to emphasize how important it is to have that ongoing dialogue with the client, and actually see the eyes of the client."

With regard to the formal Optimization Centers his division runs, Jones says there are more than 10, with long-established groups at aerospace and automotive companies such as Boeing and Daimler, and new ones at other blue-chip original equipment manufacturers either quietly operating or about to begin in the next few months.

"We've waited a long time to realize this vision of simulation-driven design," he adds. "I'd say particularly over the last year, it's really gathering momentum. Undoubtedly, simulation-driven design is where it will go in the future." DE

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

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➜ **Altair ProductDesign:** AltairPD.com

➜ **Edison2:** Edison2.com

➜ **Mabe:** Mabe.com.mx

➜ **Volkswagen Group Research:** VolkswagenAG.com

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Find the Best Design

Too much of a good thing is a not-so-good thing. Optimization is here to help.

BY ALICIA KIM

It seems impossible to get through a day without hearing the word "optimization." We want to maximize the profit, minimize the weight, minimize the cost; the list goes on. Of course, we all know how to optimize a mathematical function: Take the first derivative, equate it to zero, take the second derivative… If only real problems were that simple.

There is no denying that engineering problems are becoming increasingly more complex and multidisciplinary. A typical approach to these problems is to create a potential solution based on innovation, intuition and creativity. We analyze the solution to investigate its performance and improve the design by modifying it with our intuition and creativity. We continue to iterate and "optimize,"—unfortunately, not until the "derivatives" are zero, but when a production deadline is reached.

Optimization can lead to solutions that are completely outside the box …

Time is too often the critical deciding factor. To reduce this critical dependency and improve productivity, computational tools have been introduced—drafting, virtual modeling, analysis and simulation, rapid prototyping and 3D printing. These tools not only speed up the various design stages, they can carry out complex calculations and manufacturing that are otherwise not feasible. However, none of these tools can create new designs. The quality of a design remains primarily dependent on human creativity and intuition. This is why optimization is a truly revolutionary engineering tool: It can now "create" unintuitive designs that we have never thought of before.

There are optimization methods for all stages of design. High-fidelity topology optimization methods determine, from a block of material, the optimum geometrical shape that is readily manufacturable with modern technology (such as additive manufacturing). Starting from a set of random designs, optimization can select and modify the candidate designs to find the best configuration. Multidisciplinary design optimization can also consider highly coupled systems.

The best news for the engineering community is that optimization finds the solution where either the derivative is zero or it cannot be improved further. Whether we use the gradients to guide design to the optimum solution, use natural evolution to modify toward the best genes, or follow ants to find the food, we know we have found the design with the best performance. This provides an unprecedented competitive advantage to industry.

Of course, engineering optimization is also an intense research field that continues to address new challenges. For example, there is an explosion of research to build in redundancy into optimization by accounting for real-life uncertainties (termed robust and reliability optimization). With this technology, we can now look forward to avoiding over-engineered designs with blind reserve factors, and consider the specific uncertainties in design more intelligently.

Challenges to Overcome

However, we know from the "No Free Lunch" theorem (NFL doesn't just stand for National Football League!) that life is never that rosy. Why isn't everyone using optimization already? Well, we need to appreciate that optimization is simply a tool that provides the solution to the given problem. A correct definition of a problem can take several iterations, so it is unlikely that the first solution will be the final design.

In addition, optimization relies on the simulation to find the optimum. Two limitations arise:

1. The optimum solution is only as good as the simulation. In other words, unreliable simulation leads to a non-optimum design.
2. Some complex simulations can take days or weeks, even with the latest computer technology. Thus, iterative applications of these simulations in optimization can take too long.

Perhaps the most interesting challenge lies in the revolutionary nature of optimization. It can lead to solutions that are completely "outside the box" that no one has ever seen or thought of before. Too often, a reaction to such a solution is "no, it can't be right" and it is dismissed. Sure, it may not be right for the reasons outlined above, but it certainly deserves careful attention. Indeed, it is not uncommon for optimized structures to offer a 40% weight savings for those who have taken the brave step of embracing this approach.

Accepting an unintuitive design from optimization may take the courage to boldly go where no man has gone before, but the returns can be truly game changing. **DE**

Alicia Kim *is a Senior Lecturer at the University of Bath, UK, and is currently based in Los Alamos National Laboratory on sabbatical.*

The Twin Forces of Optimization & Inspiration

Material reduction and shape exploration go hand in hand.

By Kenneth W Ong

Peter Macapia, founder and director of labDORA, began using solidThinking Inspire for structural engineering. Eventually he shifted to using the optimal shapes the software proposed as inspiration for new architectural environments.

In Paris, after his lecture on the range of architectural modeling programs available, Dr. Peter Macapia, architect, artist, founder and director of labDORA, was confronted by a testy audience member who asked, "So, is design just about running a program and pushing buttons?" Macapia replied, "Not if you're a creative thinker."

Several years later, when he discovered Altair Engineering's solidThinking Inspire, Macapia would remember that awkward exchange. For shape optimization, Inspire does simplify the operations so that users can obtain the answers they seek with a few inputs, followed by a mouse click or two. Is that what design has become?

Software-driven optimization is a natural evolution to software-driven simulation, powered by finite element analysis (FEA) programs. Simon Pereira, senior product manager at simulation software maker ANSYS, mapped out the anticipated trajectory of ANSYS users' technology adoption in the pursuit of robust design.

"It starts with single physics, moves to multiphysics, then what-if scenarios, design exploration, optimization, and ultimately robust design with probabilistic algorithms," he says. "Most of our customers are halfway up this ladder [in what-if scenarios and design exploration]. We're pushing them to go a little higher."

The push is evident in the digital optimization tools that have sprung up in the last few years: Altair Engineering's solidThinking Inspire and OptiStruct; Autodesk's Inventor Optimization; Siemens PLM Software's NX Toplogy and NX Shape Optimization; RBF Morph with ANSYS Fluent; and Within Technologies' Enhance software, to name but a few.

In some cases, optimization leads to possibilities that the designers might not have intuitively created. Modern hardware and software can subdivide a geometric model into millions of micro-elements (known as meshes in analysis programs) and compute the best alternative for each. Consequently, software-driven optimization can reveal structural weaknesses, potential failures, and opportunities that a designer cannot spot from sight alone. But that doesn't mean designers can now sit back and take a nap. Making sense of the optimized shape proposed by the software still falls on their shoulders.

Putting Designs on a Diet

Topology optimization—identifying the best possible shape for your project—is often driven by the need to reduce material or weight. There are clear advantages to shaving off excess weight from your product. A lighter vehicle or aircraft, for example, gives you better fuel economy. In large-volume manufacturing, a lighter, smaller personal computer requires less material to build and package, and costs less to ship. But optimization possibilities have to be balanced against the stresses and loads anticipated. Shave off too much material from the wrong part of the structure of a car, and you'll end up with a vehicle that won't survive even a low-impact crash.

Many optimization tools are built on top of robust analysis tools. In fact, the input they often require—material type, load, pressure, fixed points in the geometry, and so on—are nearly identical to the variables used in analysis programs.

Where optimization programs differ from analysis programs is the type of results they offer. Instead of displaying stress distribution, displacement and deformation, they display the best (or optimal) shape for counteracting the anticipated loads and stresses.

Light Enough for Edison

In addition to developing engineering software, Altair also operates Altair ProductDesign, a thriving product design consultancy, headed by Mike Heskitt as COO (see page 26 for more information on the company). His division has been recruited to help design the next generation Very Light Car (VLC) by Edison2, a company specializing in workable, sustainable transportation solutions.

Edison2 had set its sight on a prize—the Progressive Insurance Automotive X PRIZE, to be precise. In 2010, Edison2 grabbed the $5 million prize for Mainstream VLC. The company's electric VLC is now on the market. It's continuing its pursuit with the development of the next-generation VLC.

"[Edison2] investigated what really drives the efficiency of a vehicle. It came down to two fundamental things: weight and aerodynamics," says Heskitt. Now, while keeping most of the design parameters that made its first VLC a success, the company wants to further refine the next version. "We're helping [Edison2] with their safety strategy, and with the weight—by putting materials at the right place and choosing the right materials. We're also helping them with improving the ride and handling of the car," Heskitt explains.

For topology optimization, Altair is using primarily OptiStruct to identify the optimal load paths in the structure. From there, a design concept will be developed for further refinement. Altair would also be using RADIOSS for crash simulation and safety verification.

"We can routinely reduce the mass of a mature design anywhere from 10% to 15%, but applying the process this early in the concept stages can yield even greater benefits," Heskitt says.

Jumpstarting Design with Optimization

Siemens PLM Software provides a host of simulation tools that are tightly integrated with its design modeling program NX. In releasing NX 8.5, the company adopted a similar strategy for its optimization tools.

"The advantage of this integration is that designers and design engineers can directly access these capabilities within their familiar design environment to jumpstart the concept development process," says Ravi Shankar, director for Simulation Product Marketing at Siemens PLM Software.

For example, the NX Topology Optimization module guides the user through a step-by-step process to dramatically reduce the weight of a heavy part (such as a bracket), starting from a very rough shape. The output from the optimization process is reference geometry that the designer can use to design the part, while taking manufacturability and other criteria into consideration. The module allows the user to optimize the part for a longer life by eliminating areas of stress concentration.

"Data flows seamlessly from the design environment into these optimization modules, so the user can concentrate on making better product decisions rather than wasting time moving files or data around between different applications," Shankar says.

Automatic Morphing Leads Optimal Shape

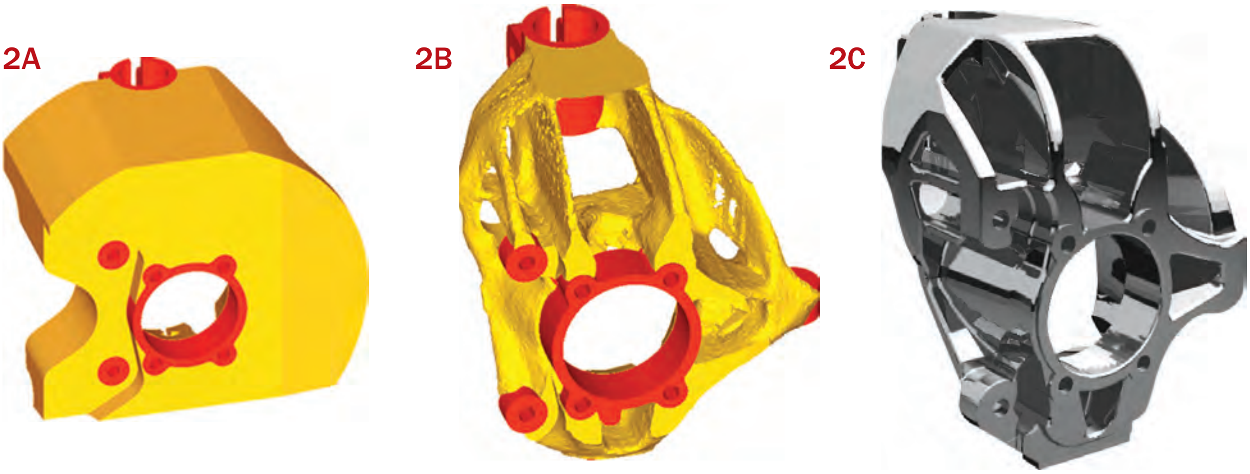
Gilles Eggenspieler, a senior product manager at ANSYS, says he believes the key to shape optimization is mesh-morphing.

"A mesh morpher is a tool capable of performing mesh modifications in order to achieve arbitrary shape changes and related volume smoothing without changing the mesh topology," he wrote in his presentation of RBF-Morph, an add-on module to ANSYS Fluent. RBF-Morph was developed by an ANSYS partner.

"The software doesn't predefine the optimum function. The user defines it: uniform velocity, maximum temperature, maximum power, minimum resistance ..." Eggenspieler wrote. "Then the user defines the sections to morph. The rest is automatic."

In defining morphing possibilities, the user may place certain constraints. For instance, if your objective is to seek minimum resistance, and the design submitted for morphing is a typical four-door passenger car, the software may propose a flattened block as the best shape (in theory, that would produce the least resistance). Therefore, to preserve the shape of the vehicle, you may place constraints around its windshield, hood and passenger compartments.

In a typical analysis workflow, you run a simulation, study the results, modify the geometry, re-mesh, then re-solve the design, and it goes on for several rounds until you get the optimal shape. In software capable of automatic morphing like RBF-Morph, the solver has the ability to take the results from the initial analysis, then try out various morphing strategies to achieve the optimal function he or she desires. In doing so, the software starts with various experimental approximations, until it identifies the right direction. The



The evolution of a bracket optimized in OptiStruct. 2A shows the original design; 2B shows software-proposed optimized shape; 2C shows final result based from optimization results.

advantage with this method is, you no longer need to manually oversee the iterative process.

Bio-inspired Optimization

London-based Within Technologies takes optimization a step further by creating optimized designs that are ready to build using additive manufacturing (AM). The Within Enhance software specializes in optimizing parts by using variable-density lattice structures and surfaces. The company describes the algorithm in its software as "bio-inspired." In optimization, the software mimics the way objects are designed by nature (such as bones)—using denser lattice structures where heavier load is expected, and more porous structures where lighter load is expected or flexibility is required.

"Our works in certain spaces, including aerospace, motorsport, medical and footwear, all gain advantages from using additive manufacturing to achieve extremely light-weighted results of around 30%," says Katherine Prescott, executive assistant, Within Technologies. She adds that in the majority of cases, traditional manufacturing methods cannot produce the optimal shape desired, so Within relies on AM to produce them.

"Our software allows users to import material settings at the start, so the part is optimized taking into account the material properties the part will be built in, as well as the design rules of additive manufacturing," Prescott explains. "We also utilize advanced 3D printer parameter settings—for example, in our medical structure—to allow complex structures to be built at a resolution that wouldn't be possible otherwise. With Within Software, you can use optimization to produce the final design; it's unlike other software, which generates a model for inspiration, which then needs to be revalidated."

Number Crunching in the Cloud

"In Inventor Simulation, you can say, 'I want to minimize the mass of my design, while keeping a certain safety factor and the stress level within a certain range,'" says Bankim Charegaonkar, a product manager at Autodesk. "But when we took a look at it, we realized it might be intimidating for some people. So we came up with a new environment, called Inventor Optimization—really, just a subset of the functionalities in Inventor Simulation."

The new optimization tab reduces the steps to a mere four icons. You have the option to define which aspects of the design can be treated as variable (for example, you may specify that the height and width of the part can vary within 30% of the current values). With Inventor Optimization, the number crunching takes place in the cloud, a remote server accessible from the Internet (the company has adopted the same approach to powering its simulation and visualization products); therefore, your local CPUs remain unencumbered by the process.

"We keep it simple. We set it up so it only optimizes by reducing the weight of the part, and it only uses the safety factor as guidance," says Charegaonkar. "That should be helpful because you know, from general rules, what the required safety factor is for your product in the industry."

A Tool for Discovery and Inspiration

Altair's Heskitt recalls many instances where he felt, based on his professional training and experience, he knew exactly what the optimal shape for a certain project should be, only to be surprised by the dramatically different solution proposed by the software.

"Sometimes the result is obvious and it reinforces your assumption," he says. "But many times, when we put in the loads for our structures, we got results we didn't expect. After

The optimization of a camera's mounting arm, completed in Siemens PLM Software's NX 8.5 with Topology Optimization.

investigating why the results are the way they are, we usually gain far deeper understanding of the project."

For one reason or another, all of Macapia's ideas about building seem to emanate from structure. He once considered writing a topology-optimization program of his own from scratch, or developing a plug-in to his favorite surfacing program, Rhino—all because he wanted to integrate structural analysis into design. When he stumbled on Altair's solidThinking Inspire (called Morphogenesis Form Generation at the time), he decided it was the right program—not only for his research but also for his classroom at SCIARC/Pratt Institute, where he serves as adjunct assistant professor of architecture.

"I can use [Inspire] to solve structural problems, to find structural fitness, and I have. That's really important, of course," says Macapia. "But what's more interesting is, you can reinvent structural systems … Architects can build buildings, but the art of architecture is about rethinking what a building is."

A software like Inspire, Macapia says, gives him "responsibilities as well as creativity" because he can think about both "structural optimization and structural innovation." He likes to experiment by applying different load conditions to his structural concepts, and varying the loads to see what new optimized shapes the software might propose.

"You see interesting patterns, so you can follow up on those," he says. "It's really about the potential for imagination."

Don't Put Blind Faith in Software

"Once you get the optimization results back from the software, you still need to understand what the results are telling you," notes Autodesk's Charegaonkar. "You still need to make a design decision based on what the safety factor is. Do I change the diameter, leave the chamfer or the fillet in, or change the thickness of the part? You need to decide what the acceptable tradeoff is."

Altair's Heskitt agrees. "To take full advantage of optimization, you have to spend time and effort to define your environment carefully," he says. "You do need to understand the loads and constraints pretty well. If you leave out some fundamental loads, your optimization will be missing out on something important."

Even if you have confidence in the software, you are still responsible for reshaping software-proposed shapes into consumer-acceptable products. The software doesn't make aesthetic judgments when considering geometric alternatives, but consumers do when they purchase something. You may be able to obtain a mathematically optimal shape with the simple push of a button in a software menu. But good design is so much more than mathematics. **DE**

Kenneth Wong *is* Desktop Engineering's *senior editor and resident blogger. He believes the optimal time to write articles is after his morning espresso drink. Email him at kennethwong@deskeng.com or share your thoughts on this article at deskeng.com/facebook.*

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➜ **RBF-Morph:** RBF-Morph.com

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

➜ **Within Technologies:** Within-Lab.com

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

Lower the Cost of Test System Development and Ownership

National Instruments' hardware-in-the-loop platform increases testing flexibility.

National Instruments transforms the way engineers and scientists around the world design, prototype, and deploy systems for test, control and embedded design. More than 30,000 companies around the world use National Instruments tools to simplify development, increase productivity, and dramatically reduce time to market.

The diverging challenges of faster time to market, greater reliability, and increasing product complexity necessitate a hardware-in-the-loop (HIL) test platform that provides:

- Efficiency in development and maintenance
- Scalability to meet diverse and rapidly changing requirements
- Innovation to deliver the latest advances in technology to your applications

The NI HIL platform provides these necessities for success through a truly open hardware and software platform; the greatest variety, value, and availability of products; industry-leading real-time multicore and FPGA technology; global services, support, and partner expertise; and a test platform that you can use from requirements definition to manufacturing test.

Modular Solutions and Graphical Programming

National Instruments modular hardware and graphical software tools can help decrease the cost and increase the flexibility of hardware-in-the-loop test systems by incorporating a flexible, high-performance, real-time system; a highly flexible and reliable user-programmable FPGA; and modular, measurement hardware. With NI LabVIEW system design software, you can implement your HIL system using graphical programming. It provides hundreds of analysis and control functions so you can build powerful monitoring and control applications.

Increase Quality and Efficiency With Test Component Reuse

Implement system-level tests that you can reuse throughout the entire embedded software development process.

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Committed to Engineers and Scientists

National Instruments makes a positive impact by doing what it does best — applying engineering expertise toward critical societal issues and equipping engineers with tools that accelerate innovation and discovery. NI's graphical system design approach provides an integrated software and hardware platform that simplifies development of any system that needs measurement and control.

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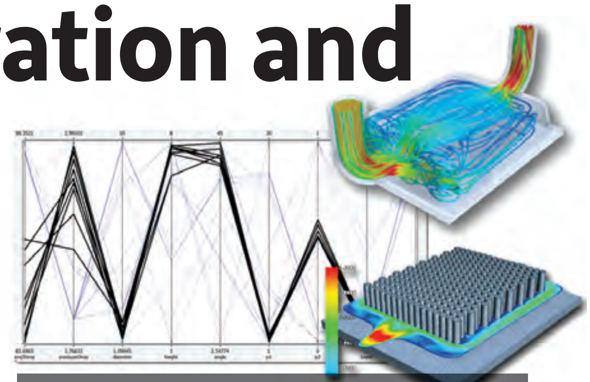
Breaking Down the Barriers of Design Exploration and Optimization

Bringing high-fidelity engineering simulation into the design loop.



Optimate+ add-on module for STAR-CCM+

As organizations realize the value of design optimization studies to gain competitive advantage, it is a natural desire to have the process driven by the most accurate simulations possible. Otherwise, there is a significant risk that the design space established will be a false "virtual design space" that does not correspond to the "actual design space," leading to designs that do not meet expectations when they are put to the test in the real world, thus the need to bring high-fidelity CAE simulations into the automated design loop.

Traditionally, however, there have been several significant challenges that have kept high-end CAE technology from being implemented within design optimization: commercial licensing, accuracy, robustness, efficiency, and coupling with optimization technology.

Power Token Licensing

One of the most common barriers to using high-fidelity CAE simulation is the cost of traditional CAE licensing. The use of high performance computing and parallel optimization algorithms are a practical must-have for automated design studies. Historically this would have meant purchasing many expensive software licenses.

But with the new Power Token license system, engineers have full access to affordable license tokens that provide the flexibility to minimize the cost of their optimization process for each individual project.

Accuracy, Robustness and Efficiency

Accuracy, robustness and efficiency are fundamental requirements for point evaluations in a design study. A simulation code must be valid for the entire design space, otherwise the optimization algorithm will be lost. It is akin to the old adage "garbage in – garbage out." An invalid design space, whether due to code crashes or inaccuracy, will lead to an invalid design optimization result. CD-adapco employs an army of software developers and physics modeling experts from around the globe with a singular purpose: to make STAR-CCM+ the most accurate, robust, and efficient CAE software on the market.

State-of-the-art Optimization Technology

Finally, the simulation software must be coupled with design optimization technology such as with STAR-CCM+ and the SHERPA algorithm from Red Cedar Technology. The Optimate+ add-on for STAR-CCM+ gives engineers direct access to the most powerful and effortless optimization algorithm on the market.

CD-adapco
www.cd-adapco.com

For more information visit:
www.cd-adapco.com

CD-adapco

CD-adapco is the world's largest independent CFD-focused CAE provider. Our singular purpose is to inspire innovation with our customers while reducing their costs through the application of engineering simulation. A key to achieving this purpose is providing access to advanced physics models during conceptual and preliminary design phases, and innovative licensing models for design exploration and optimization.

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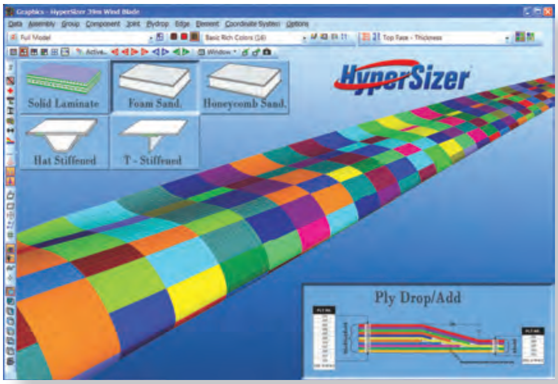
Phone: (+1) 631 549 2300

Optimization Leader /// HyperSizer Software

Is Your Optimization Process Robust Enough?

HyperSizer® from Collier Research ensures integrity from early design to manufacturing.



Whether you are designing and/or manufacturing composite or metallic aircraft, spacecraft, trains, buses or even wind blades, your goal is very clear: Using your materials of choice, create the lightest-weight product at the lowest-possible cost while meeting every strength, performance and safety target in your particular industry. While the word "optimization" is often used these days to describe how such challenges are met, how can you make sure you've arrived at what is truly the best solution?

HyperSizer®, from Collier Research Corporation, was the very first engineering software commercialized by NASA. Born (and still used extensively) in the space agency's zero-failure-tolerance environment, HyperSizer is also employed in Tier 1 and 2 commercial aircraft, UAVs, shipbuilding, and wind turbine blades.

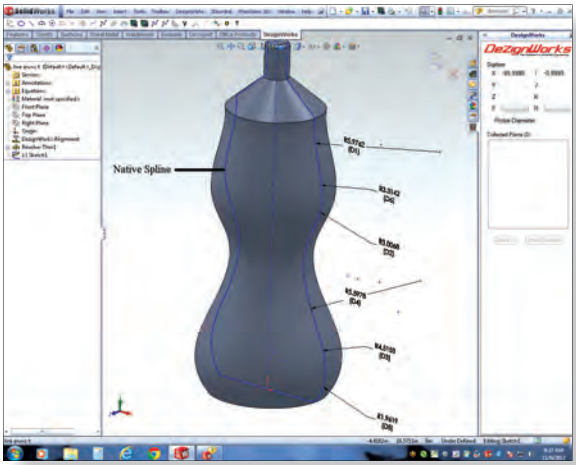
The software works in a continuous feedback loop with finite element analysis (FEA) to automatically search for composites or metallic solutions that minimize weight while maximizing manufacturability. A typical result of this kind of robust optimization process is a weight reduction of from 20 to 40%, which can have significant impact on manufacturing costs as well as promoting fuel efficiency and achievement of energy targets.

In composites, HyperSizer surveys thousands, and even millions, of design-candidates, evaluating them in a ply-by-ply and even finite element-by-element manner. This quantifies, with great accuracy, the tradeoffs between weight, material system and how the product will be manufactured. Such ongoing reality checks support engineers' creativity, allowing them to more fully explore the entire design space while providing a "real-world" analysis of the consequences of proposed design changes.

Working out-of-the-box with industry-accepted CAD, FEA and composites tools, HyperSizer serves as the integrated analysis hub, automating all data transfer from start to finish. As the materials used by many industries become increasingly complex, HyperSizer can improve both the efficiency and the integrity of the product development process.

Breaking New Ground in Reverse Engineering and CAD

DezignWorks so˜ ware optimizes design by working with freeform shapes and reverse-engineered data directly in CAD environments.



Creative Dezign Concepts is the developer of the DezignWorks family of products and is a high-level partner to SolidWorks, Autodesk Inventor and PTC. Its area of expertise has always been in feature-based reverse engineering, but they have recently announced a new CAD add-in tool to help the creative engineer or industrial designer as well.

The company has recently introduced a product called "DezignWorks Toolz," which features a revolutionary new patent-pending technology that analyzes splines and then creates lines and arcs with options to fully constrain or add relationships. This gives the designer the ability to sketch a freefrom shape and turn that geometry into a dimension-able shape that is drawing and manufacturing friendly.

DezignWorks Toolz has been developed and tested in SolidWorks, but Creative Dezign Concepts has plans to incorporate this technology into Autodesk Inventor as well as other platforms.

Accelerate Reverse Engineering

Creative Dezign Concepts originally made its mark in feature-based reverse engineering software. The company's DezignWorks RE packages allow an engineer to reverse engineer a physical part into an editable, native CAD model directly in SolidWorks, Inventor or PTC products. This is accomplished by having a fully integrated module plug-in that utilizes the existing CAD interface and leverages users' knowledge of the 3D modeling package. This tight integration makes it extremely easy for an experienced CAD user to usually be up and productive making models within a few hours.

Jim Watson, president of Creative Dezign Concepts says, "adding this new curve-fitting technology will further extend the advantage of our industry leading DezignWorks Reverse Engineering software, because traditionally when digitizing freeform shapes such as splines, they could only be pushed or pulled. DezignWorks Toolz technology now integrated into DezignWorks RE, allows the user to make engineering changes easily that conform to manufacturing design best practices."

CREATIVE DEZIGN CONCEPTS

Creative Dezign Concepts

Published by Creative Dezign Concepts, the DezignWorks family of software products supports SolidWorks, Autodesk Inventor, and PTC. Engineers and designers use DezignWorks and their CAD software to optimize their original designs as well as capture data from existing parts directly within their respective design environments. This level of integration allows users to maintain associativity so they can design better products faster and more accurately, speeding time to market.

For more information visit:
www.dezignworks.net

Creative Dezign Concepts
116 Morlake Drive, Suite 104, Mooresville, NC 28117

Optimization Leader /// ESTECO

Se˜ ing Optimization Forward

Start from the design concept to be one step ahead.

Engineering design in the current challenging environment calls for improvements of product performance with minimization of costs and shorter time to market. Process complexity grows as the whole design team concurs to improve all product performance metrics of interest, and handle opposing objectives, like increasing efficiency and durability while reducing weight and cost.

Efficient companies have successfully embraced multi-objective and multi-disciplinary design optimization techniques to face such challenges and gain competitive advantage. However, organizations that want to exploit their innovation assets and take product development to the next level should intervene in the earliest steps of the design process. Evaluating the feasibility of certain configurations before competitors is becoming the next big challenge to cope with in the manufacturing of complex products.

This advanced design optimization scenario demands a powerful platform that can streamline the whole process into a single environment, and assess and optimize product performance against conflicting targets at the early product concept stage.

ESTECO's state-of-the-art platform, modeFRONTIER, allows individual users, whole departments and even entire geographically-dispersed companies to create a single, integrated environment for all of their modeling and analysis tools. Design of experiments (DOE) techniques are readily available to demonstrate how interconnected factors behave without having to directly test all possible values, saving simulation time. A complete collection of innovative algorithms allows the software to act as an agent which controls the analysis process, and steers the design of the product towards achieving user-defined criteria. In addition, when it comes to integrate sources of uncertainty (e.g. manufacturing tolerances) in the simulation process, the platform enables the designer to identify a robust set of best possible solutions, while reducing the risk linked to variability. Sophisticated statistical and graphical tools combined with response surfaces, or performance maps, included in the comprehensive post-processing set, make modeFRONTIER an invaluable tool in helping companies achieve optimal designs faster, while manufacturing better-performing products.

ESTECO

ESTECO is a technology provider of numerical optimization and modeling solutions. We are specialized in research and development of engineering software solutions for the optimization and integration of all stages of the design simulation process. Our technology is applied to inspire decision making in several industrial sectors for designing new and perfecting existing products.

For more information visit:
www.esteco.com

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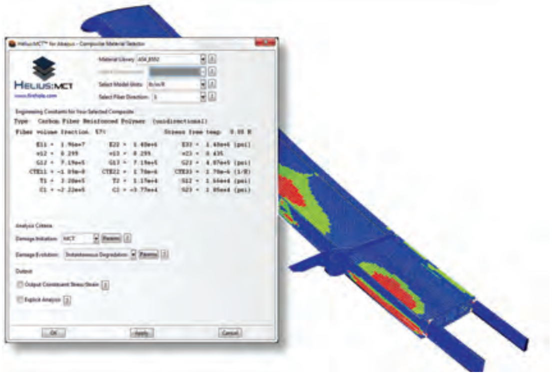
AREA Science Park, Padriciano 99, 34149 TRIESTE (ITALY)

Realizing Composite Possibilities



Firehole delivers solutions for composite optimization challenges.

Companies looking to optimize their designs for weight, corrosion, fatigue, manufacturability, etc. are looking to composite materials. No longer exclusive to aerospace, these materials provide unmeasured opportunities for nearly every industry. However, limited analysis capabilities can prohibit realization of the benefits these materials provide. Opportunities can be lost when engineers are forced to work with inadequate material data, crippling conservative assumptions, analysis uncertainty and costly build and test cycles.

Breaking Barriers

Firehole saw that analysis capability had not kept pace with the opportunities these materials offered and has spent the last decade working to close that gap. Their focus has been to identify barriers to optimization with composites and break them down. These include everything from access to reliable material data to accurate simulation methods for various design objectives. As a result, they have produced a suite of products designed to empower anyone looking to excel with composites. A couple of examples:

For early-phase design work, Firehole offers Helius:CompositePro. Those new to composites will find it provides an ample toolset to enable exploration of what-if scenarios. For composite veterans, it provides the fundamental calculations necessary to rapidly pursue optimal properties and performance.

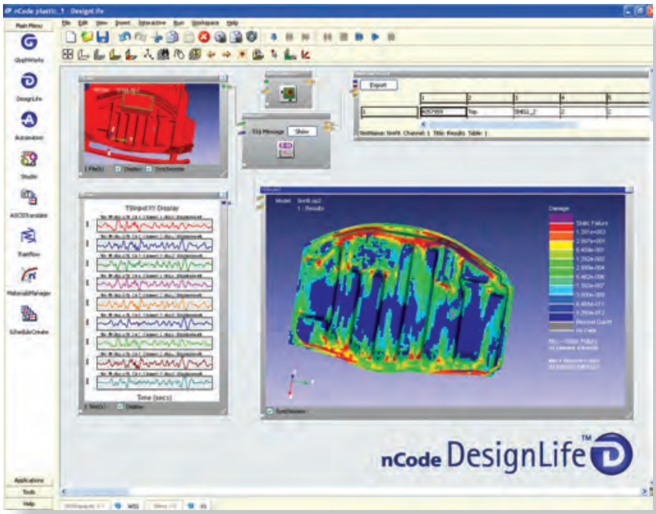
Their flagship product, Helius:MCT, enables advanced finite element analysis of composite materials. Developed as a plug-in to the most commonly used FEA platforms, it provides composites-specific technologies designed to significantly improve accuracy and efficiency of composite simulation. This allows design teams to optimize multiple steps of their design cycle—from material selection and performance improvements to reducing time and money invested in testing.

Active Leadership

Firehole Composites has established themselves as leaders in their field. Recognized for their dedication and expertise, they are actively engaged with subject matter experts and industry leaders in providing the next generation of composite analysis solutions.

Optimization Leader /// HBM-nCode

Meet the Challenge of Change with nCode



Achieve new standards through finite element based analysis.

Advanced technologies developed over the past decade have enabled automotive engineers to design products to meet current and future fuel economy standards. As new fuel economy standards have been set, automakers must now meet a federal Corporate Average Fuel Economy (CAFE) of 54.5 mpg by 2025. This means that engineers are now faced with one of the biggest engineering challenges in decades, a 5 percent increase in fuel economy per year. These new fuel economy demands require automakers to reshape their engineering process without compromising the reliability and durability of their designs.

New materials such as ultra-high-strength steels are being used in body structures, as are aluminum and magnesium alloys for structural components. The use of lightweight material such as composites also presents significant benefits for some automotive components. However, the fatigue of composites has its particular challenges due to the typically inhomogeneous and anisotropic nature of its materials.

Maximize Successful Tests

Up-front design tools such as nCode DesignLife™ can be used in order to maximize the likelihood of successful physical testing and reduce product development time. With this finite element based tool, fatigue and durability may be calculated from FEA results for both metals and composites. Using material parameters based on coupon tests, calculated stresses from simulation are combined together with specific fatigue properties to predict the fatigue lives of the whole component under loading conditions.

As new materials and increasingly radical solutions are required in more engineering applications, the need to simulate and optimize designs using tools such as nCode DesignLife will increase prior to physical prototyping.

nCode n' ...an HBM brand

For more information visit:
www.ncode.com/optimized

HBM-nCode

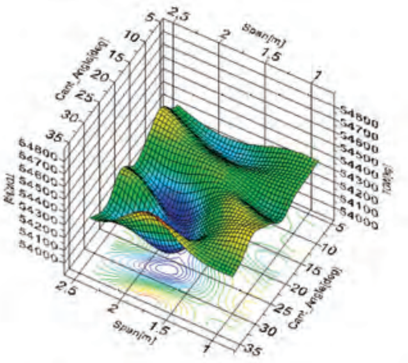
With over 30 years of expertise in durability and data analysis solutions, nCode enables customers to understand product performance, accelerate product development and improve design. The power and scalability of nCode software is a direct result of its expertise and in-depth experience in a broad range of industries.

Sales, Training, and Support

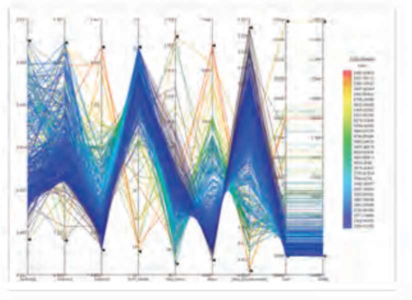
HBM-nCode sales and support is available through local offices in Europe, North America and Asia.

Contact: info@hbmncode.com to reach an office near you.

Top Brands Secure Competitive Edge



Optimus from Noesis Solutions helps manufacturers design benchmark products.



Premium manufacturers rely on high quality and clear differentiation to ensure their new products excel in today's competitive market. They must do this in a lean environment with intense pressure to reduce time to market and development costs. Noesis Solutions' flagship product Optimus empowers companies to design benchmark products "right first time."

A Solution for Today's Lean Staffed Engineering Design Teams

As the pioneer of the market, Noesis Solutions recognized the critical need for a solution to the ever leaner and demanding design environment. Optimus today helps numerous leading companies in engineering-intensive industries worldwide.

For example, at the 2012 Optimus World Conference, Audi, BMW, Snecma, Thales Alenia Space, Tyco Electronics, and Volkswagen, among others, presented how they use Optimus to stay ahead of competition.

Combining Faster Development with Superior Design Performance?

On average, Optimus users achieve 10% or more design performance improvements while reporting design time savings averaging over 30%. The automated Optimus process frees users from repetitive manual model changes and data processing, while efficiently identifying design space regions containing leading candidate designs. These product designs meet a combination of objectives set by multiple (often competing) performance targets as well as design constraints imposed by manufacturing realities and stringent regulatory and standardization requirements.

Implementation is a key ingredient of success, and Optimus' unique customization capability coupled with an exceptionally skilled technical support team enable tailoring, when needed, to match the user's design process, software, and IT. Ease and speed of use are often cited as major factors in the adoption of Optimus, along with a wide range of capabilities including:

- Process integration and automation
- Integration with the majority of CAE and mathematical modeling software
- Design of experiments (DOE)
- Surrogate modeling (or meta, approx imation or response surface modeling)
- Single and multiple objective optimization
- Statistical data mining and analysis
- Robust design

Design for real

Optimus®

For more information visit:

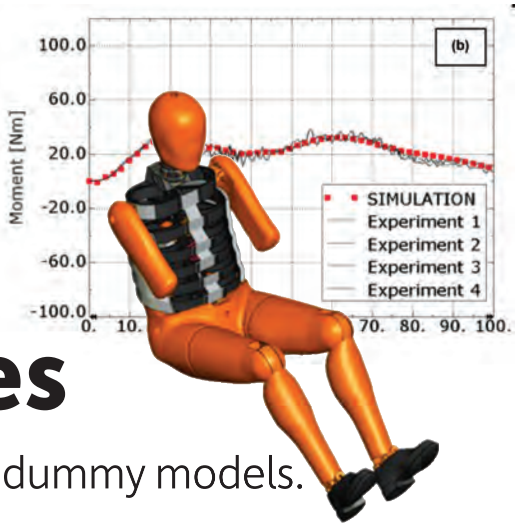
www.noesissolutions.com

Noesis Solutions

Noesis Solutions is an engineering innovation partner. Its process integration and design optimization (PIDO) solution Optimus focuses on resolving manufacturers' toughest multidisciplinary engineering challenges. Optimus automates the traditional "trial-and-error" simulation based design process, and with powerful optimization algorithms efficiently directs the simulation campaign toward the best designs.

Noesis Solutions
35 E. Main Street, Suite 300, Carmel, IN 46032

Discovering Optimal Material Parameters and Design Alternatives



Leveraging Isight to develop realistic crash dummy models.

To develop passive vehicle safety systems, leading automotive manufacturers employ physical crash dummies as well as their virtual counterparts. Using accurate digital dummy models provides time and cost savings by reducing reliance on physical testing.

The Abaqus WorldSID 50th percentile (WorldSID50) virtual crash-test dummy model comprises approximately 260,000 elements and more than 20 different materials. Developing this model required evaluations of hundreds of model parameters to achieve good correlation with test data under different loading conditions and rates. Isight, from SIMULIA, played a critical role in the development of the WorldSID50 model. By providing leading technology for process integration, automation and design optimization, Isight enabled users to create simulation process flows (sim-flows) in order to automate the exploration of hundreds of design alternatives to help identify optimal material and performance parameters.

SIMULIA development engineers leveraged Isight to construct a material optimization sim-flow using Prony terms as design variables, which allowed for the estimation of frequency, amplitude, phase and damping. Several Abaqus simulations, representing various loading rates both in tension and compression, were used within the same Isight optimization sim-flow for calibration. Simulation responses were then reconciled with the test data using Isight's Data Matching component.

By automatically fitting material model coefficients to experimental data, engineers succeeded in creating a linear viscoelastic material model to represent the physical dummy's rubber-like components. This produced a configurable virtual dummy that can faithfully replicate the behaviors of rubber-like compounds, super-elastic alloys (Nitinol), foams, plastics and vinyl.

As the Dassault Systèmes brand for Realistic Simulation, SIMULIA delivers a scalable portfolio of realistic simulation applications, including Abaqus for Finite Element Analysis (FEA) and multiphysics simulation; Isight for design exploration and optimization; and Simulation Lifecycle Management for managing simulation data, processes and intellectual property. SIMULIA applications are an integral part of Dassault Systèmes **3D**EXPERIENCE platform, which accelerates innovation and reduces product development costs for world-leading manufacturing and research organizations worldwide.

For more details on identifying optimal material properties and design alternatives, read the case study at: http://goo.gl/f1Qua.

Innovation Through Optimization

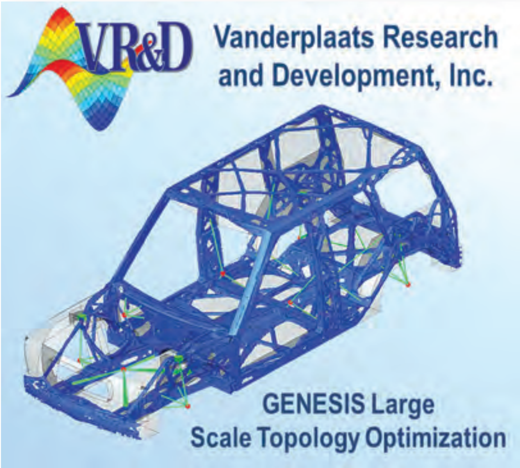
Get on the innovation fast track with VR&D's so˜ ware.

VR&D's optimization software allows engineers and designers to optimize their designs quickly by automatically changing specified design parameters. By using VR&D software, users gain insight into their analyses. This "fast track" to engineering intuition regularly leads to innovation through optimization.

VR&D was founded in 1984 by Dr. Garret Vanderplaats, who is recognized world-wide as one of the original creators of numerical optimization techniques. His original CONMIN (1972) and ADS (1984) software codes are still in use today by some companies to add optimization to their products. VR&D software and their third-party CAE partners all utilize his premier DOT and BIGDOT optimizers for the latest advances in optimization technology. VR&D develops robust, state-of-the-art FEA and design optimization software that enhances the product development process and is used world-wide by aerospace, automotive, other commercial and government institutions, and universities.

Multidiscipline Design Optimization Software

VisualDOC is general-purpose, graphics based, multidiscipline design optimization software that allows the user to add optimization to almost any design task. Design study and optimization options include: DOE, Gradient and Non-gradient, Response surface, Probabilistic and Robust optimization, Post-processing visualization tools etc. The graphical user interface couples with one or more analysis programs to generate the design study system.



Structural Analysis and Optimization Software

GENESIS was designed from the start to be a fully integrated analysis and optimization program based on the latest research by Vanderplaats. Analysis capabilities include: Statics, Normal Modes, Heat Transfer, and Dynamic Response. Optimization includes topology, topometry, topography, sizing, shape, and freeform optimization.

Design Studio is a pre- and post-processor graphical interface enabling users to display FEMs and easily create GENESIS design data. One of the newest plug-in features seamlessly couples large-scale GENESIS structural optimization with LS-DYNA nonlinear analyses via the Equivalent Static Loads (ESL) method.

For more information visit:

www.vrand.com

Email us at: info@vrand.com

VR&D

VR&D exists for the development of optimization technologies for industrial applications. The company goal has always been to provide the best software and have the best staff of experts in the optimization world. This allows their clients to produce better products in less time and at lower cost than ever before.

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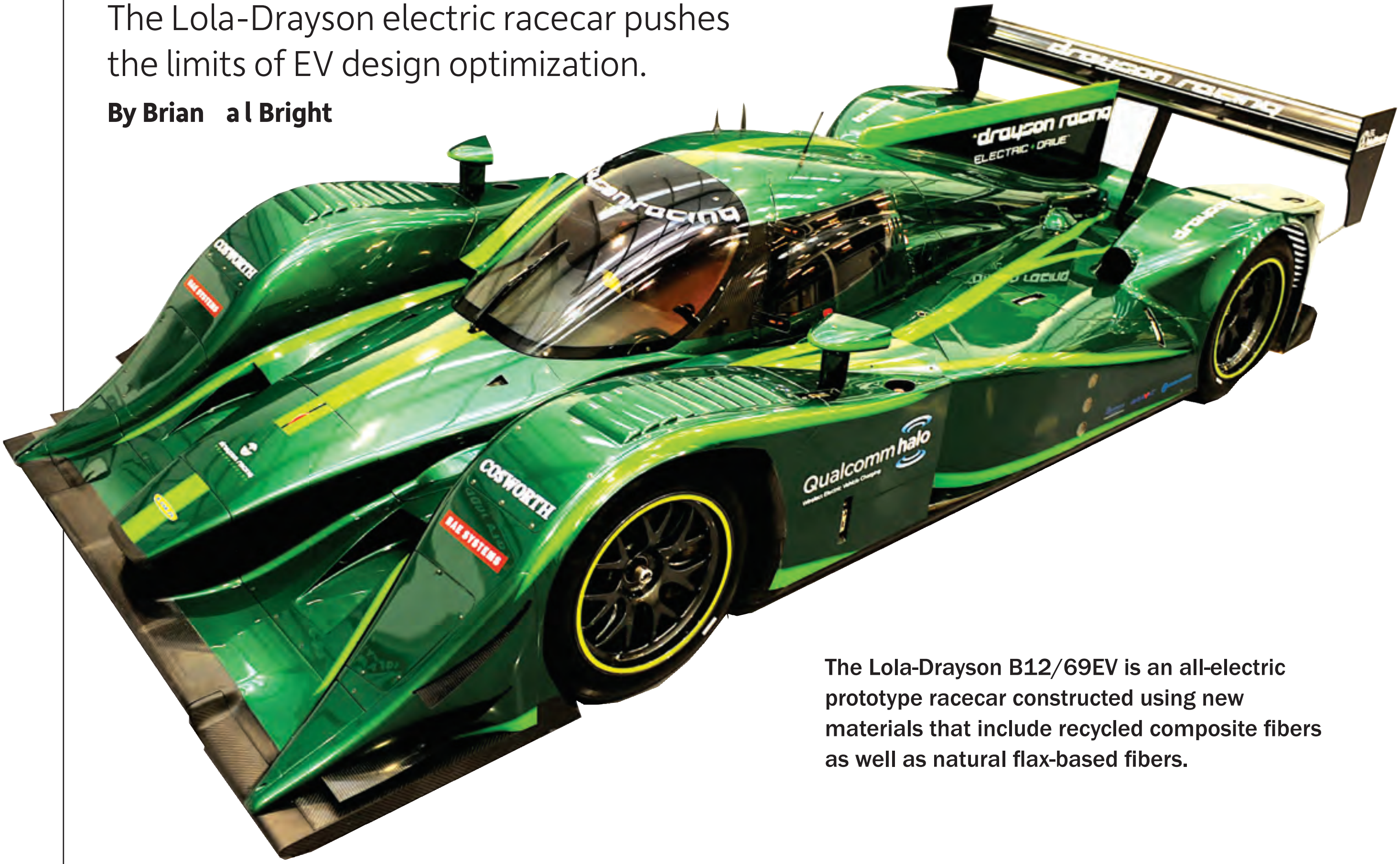
Sustainable Speed

The Lola-Drayson electric racecar pushes the limits of EV design optimization.

By Brian a l Bright



The Lola-Drayson B12/69EV is an all-electric prototype racecar constructed using new materials that include recycled composite fibers as well as natural flax-based fibers.

Starting next year, the Fédération Internationale de l'Automobile (FIA) will launch its "Formula E" championship racing series focused exclusively on electric vehicles. This convergence of motorsport and sustainability would have seemed unlikely just a few years ago.

One of the companies pushing the envelope when it comes to electric vehicle (EV) racing design has been UK-based Drayson Racing Technologies. Last year, Drayson and the Lola Group unveiled the Lola-Drayson B12/69EV, an all-electric prototype racecar built on a first-of-its-kind powertrain—and constructed, in part, using new types of composite materials developed from both natural fibers and from recycled carbon fibers.

It's also fast, with top speeds of 200 mph and the ability to go from 0 to 60 mph in 3 seconds, or 0 to 100 mph in 5.1 seconds. Range, however, is limited. Under the Formula E race format, the electric cars will run four 15-minute heats interrupted by 30-minute recharging periods.

The design of the vehicle not only involved optimizing the usual Formula vehicle design elements of speed, power and aerodynamics, but also sustainability—both in the function of the electric motor and in the incorporation of sustainable materials within the structure.

Focus on Sustainability

What Drayson and Lola are doing is expanding the limits of EV design in ways that could have ramifications for the larger EV market.

"Our intention all along has been to push the boundaries of EV drivetrain design and provide feedback to the manufacturers so that ultimately, they are able to develop smaller motors that deliver more power," says Graham Moore, chief engineer at Drayson Racing Technologies. "It is still very much an ongoing project, and is by no means finished yet, so there is still much to learn. Every day, we are acquiring knowledge about how the drivetrain performs in different conditions."

Lola and Drayson weren't starting from scratch, having already experimented with "green" racecar technology in the Lola B10/60 prototype car (with a flex fuel Judd V10 engine) in the American Le Mans Series and the Intercontinental Le Mans Cup. Since then, however, the team has been focused on developing an all-electric vehicle based on the original Lola Coupe Le Mans Prototype One (LMP1).

"The key focus was really on sustainability," says Dr. James Meredith of the Warwick Manufacturing Group (WMG) department at the University of Warwick. Meredith's group researched and developed the flax-based and recycled composite materials used in the car "that comes not just from the powertrain, but everything that goes in and around the car, particularly the materials that go into it."

The final design of the vehicle marked the convergence of the R&D work done at Warwick on the composite materials, along with Drayson's powertrain design and Lola Group's revamped chassis. According to Drayson Racing, the initial project involved six months of intensive development, starting in July 2011. The fully assembled prototype was launched at the Low Carbon Vehicle Conference in January 2012.

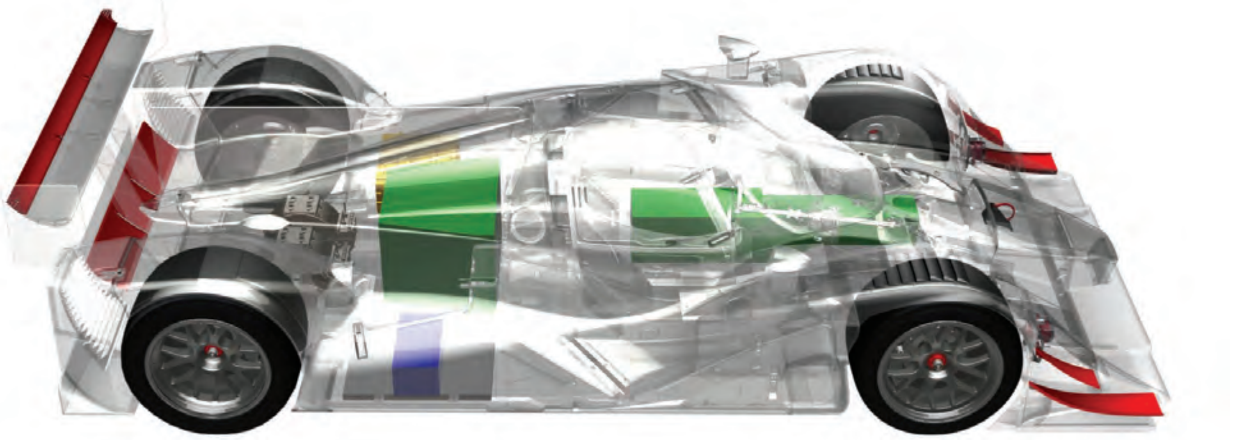
Innovative Battery Technology, Drivetrain Design

The Drayson team worked with UK-based software consultant Desktop Engineering (DTE) to convert the existing vehicle design (which was powered by a 5.5-liter bio-fueled Judd engine) to a pure electric drivetrain. DTE recommended using Dassault Systémes CATIA PLM Express for the process, which Drayson has credited with reducing the overall number of man-hours required for the redesign.

Drayson used the CATIA CAD package, along with the AeroLap simulation tool, to set the performance targets for the vehicle, which were based on what the team already knew about the LMP1 chassis in its original configuration. AeroLap (from Ansible Design) is a tool designed to analyze the performance of racecars over a defined path.

"Once we had our target lap performance, we knew what the power output of the drivetrain, motor sizes, inverters and batteries needed to be, and the physical/power limitations that would influence the design," Moore says.

For Drayson, one major challenge was fitting the drivetrain to the existing vehicle design, balancing performance with optimizing the weight of the vehicle.



Engineers designed the electric drivetrain in parallel with the packing and cooling systems.

"We had to look at different options and motors to end up with what is now a neat design and layout, which optimizes the space and manages the vehicle-to-weight ratios," Moore says. The car weighs approximately 2,200 lbs.—or about 220 lbs. more than the original LMP1.

The electric drivetrain had to be able to support the chassis loads endured during a race, as well as during collisions. Drayson used the CATIA solution and extensive finite element analysis (FEA) so that the drivetrain could be designed in parallel with the packaging and cooling systems in a relatively short period of time.

The vehicle is powered completely by electricity stored in advanced lithium nanophosphate battery cells made by A123 Systems, and used for the first time on the Lola-Drayson EV. The cells drive the four axial flux Oxford YASA motors via inverters supplied by Rhinehart. The motors—which generate more than 850 peak hp—power the rear wheels only.

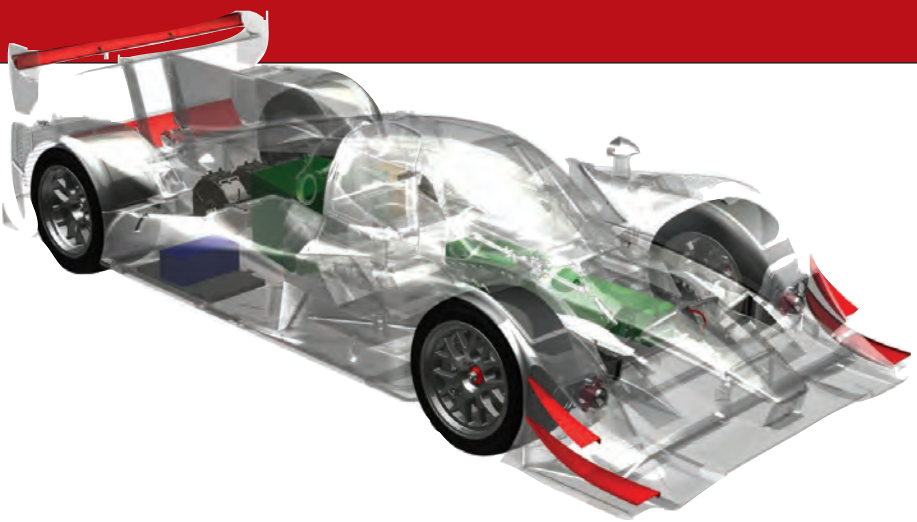
YASA also developed a new position sensor that allows two of the lightweight motors to be stacked together, which then provide 3,000Nm of torque to the wheels. Charging occurs through a HaloIPT wireless induction system (the car can be recharged when parked on a charging pad).

Cooling the motors was also a significant task, given the power-to-weight ratio of the motors. Drayson used CATIA to determine the optimal layout without significantly increasing weight or affecting strength and safety. The company is using dual water and air circuits to cool the systems.

Structural Batteries Incorporated into Chassis

According to Lola Group, the structure of the EV from the rear bulkhead forward is identical to the original LMP1, with most of the changes occurring under the rear bodywork.

Lola leveraged its own in-house CAD, FEA and computational fluid dynamics (CFD) capabilities in the revamped design. The company uses CATIA software on CAD/CAM workstations and a CFD suite that includes ANSYS Fluent, BETA CAE's ANSA, Optimal Solutions'



Sculptor, and Intelligent Light's FieldView for post-processing and visualization.

In addition, the company has its own 50% scale moving ground plane wind tunnel, proprietary simulation software, and a seven-post test rig for full-size vehicles.

Lola's wind tunnel capabilities assisted in the development of a key vehicle element: moveable aerodynamic surfaces on the front wheel screen flaps, rear panel, and on the rear wing. Drivers can control the position of these surfaces using electric actuators to boost downforce or reduce drag while operating the vehicle. Once the drivers have mastered controlling the active aerodynamics, the companies expect a drag reduction of up to 30%.

The rear wing is also home to another innovation: "structural batteries" developed by BAE Systems that power the onboard electronics. These batteries combine nickel-based battery chemistry with a carbon-fiber composite structure that can be formed into any shape and used as part of the actual chassis of the vehicle. This not only helps optimize weight reduction, it can also increase energy storage capacity in later versions of the car (currently, the BAE technology cannot provide enough power to run the motors).

Recycled and Natural Composites

Creating a truly "green" vehicle meant incorporating sustainable materials as well. The recycled composites used in the vehicle emerged from research and development conducted with the WMG at the University of Warwick, Umeco, and ELG Carbon Fibre. By recycling carbon fibers, companies can reduce landfill costs, reduce the environmental impact of the fibers (which do not decompose naturally), and reduce carbon composite scrap levels that ELG estimates at levels of up to 40%, depending on the industry.

For the Lola-Drayson vehicle, carbon fibers from out-of-life MTM49 epoxy prepreg were reclaimed by ELG and re-impregnated with Umeco's MTM49 toughened epoxy resin.

WMG, Lola and Umeco performed extensive physical testing to determine the mechanical and impact properties of the material, comparing them against virgin prepregs.

"We did a lot of pulling, squashing and bending," Meredith says. "We made test cones and put them on a drop rig, and smashed them into the ground to analyze their specific energy absorption."

Those tests showed minimal loss of strength and similar fiber stiffness. There was no computer simulation or modeling during that phase, because as Meredith says, the team was trying to "establish and obtain the values to determine the key performance of the materials under different circumstances."

The flax-reinforced composite development also came out of the Umeco/WMG partnership, this time in conjunction with Composites Evolution. WMG worked with the Engineering and Physical Sciences Research Council and Warwick Innovative Manufacturing Research Center (WIMRC) on the testing, while Composites Evolution provided the woven flax material, which Umeco again impregnated with its MTM28 and MTM49 epoxy resins.

The advantage of flax fibers: They have similar mechanical properties to glass fibers, but at a lower weight and with less environmental impact. They also have good vibration damping and insulating characteristics.

"They require essentially no energy to produce, they are very easy to work with, they're non-toxic, and they are biodegradable," Meredith says. "They can also be burned for energy with no theoretical CO_2 gain."

Initially, the recycled bodywork parts will be non-structural (sidepods, damper hatches, etc.), but the company hopes to expand their use after further refinement and testing. Drayson is waiting to see how these parts perform during actual races, and will continue to gather data and work with the Warwick group to refine the materials.

"[The new composites] haven't been used in safety critical areas, so it is early to predict," Moore says. "Our understanding of how they will perform is very much a work in progress."

Design Tweaks Continue

The B12/69EV completed its first track run at the Goodwood Festival of Speed earlier this year, placing 11th overall and setting a festival record (53.91 seconds) for an electric vehicle on a hillclimb.

Drayson and Lola have continued to work on the vehicle's design. They perform tests on the battery technologies and active aerodynamics as they prepare for the first Formula E events next year. As far as the recycled composites, Meredith says WMG is looking at ways to better utilize short fibers and the longer fibers that come from out-of-life components, which he describes as a "tangled mess."

Now that some baseline information about the properties of the material exists, Meredith says the team can begin to use modeling to develop more complex objects (at WMG, the researchers use SolidWorks, CATIA, and Genesis FEA from VR&D).

"We've been able to set a benchmark for what was possible," Meredith says. "Now we are thinking about how we might improve in the future." **DE**

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

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→ **Composites Evolution:** CompositesEvolution.com

→ **Dassault Systèmes:** 3DS.com

→ **Desktop Engineering:** DTE.co.uk

→ **Drayson Racing Technologies:** DraysonRacingTechnologies.com

→ **ELG Carbon Fibre:** ELGCF.com

→ **Intelligent Light:** iLight.com

→ **Lola Group:** LolaCars.com

→ **Optimal Solutions:** GoSculptor.com

→ **Umeco:** Umeco.com

→ **VR&D:** VRand.com

→ **WMG at the University of Warwick:** www2.warwick.ac.uk/fac/sci/wmg

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Simulation-Driven Design Drives Innovation

BY PETER BARTHOLOMEW

Editor's Note: The topics addressed in this article are treated in greater detail in the recent NAFEMS publication, "The State of Current Practice in Engineering Design Optimization." Those with a desire to increase their involvement are encouraged to become members of the newly formed NAFEMS Working Group on Optimization.

This should be the decade where design optimization finally emerges from the province of university research and specialist groups within the aeronautics and automotive industries to take its place in the mainstream of engineering product design. Industrial-strength commercial software is now available in the marketplace, and is becoming increasingly accessible to designers as the trend to incorporate engineering analysis into CAD products gathers momentum.

It requires a paradigm shift involving changed processes, new tools and new skill sets.

As a concept, design optimization is as old as that of stress analysis. In 1687, Galileo published work on the optimum strength design of a variable depth cantilever.

By the time of the Second World War, optimization played a key role in establishing the principles used for the design of compression structures in aircraft.

The state of the art was to change totally during the 1960s, with the increasingly widespread availability of the digital computer. The structural design optimization problem could be formulated as a combination of numerical optimization methods that were being developed under the name of Mathematical Programming to support the Operations Research community and the emerging finite-element method.

By 1980, Christian Petiau was able to report a decade of optimization applications at Dassault built around the use of Elfini.

With such strong foundations, it is interesting that the area has had to wait so long to take its place as a major driver for innovation in product design, with the potential to impact both time and quality and, ultimately, the financial viability of companies.

As an organization, NAFEMS makes every effort to remain in touch with the needs of its 1,000 or so corporate members worldwide, and in one EU collaborative project, 110 European organizations operating within eight industry sectors provided prioritized requirements for engineering analysis. At that time (2005), optimization ranked 41st in importance out of the 74 topics identified; with validation and verification ranking highest, along with the development of high fidelity methods for the capture of increasingly complex structural behavior.

However, a different balance of priority was to emerge two years later from the AutoSim project. Integration had become a major driver, and both process automation and multidisciplinary design optimization were seen as key elements for the delivery of new products. The goal of the project was to achieve an 18-month product development cycle with upfront simulation, driving design from analysis.

This shift from simulation as a product validation tool to part of upfront design provides fresh impetus to product optimization. It requires a paradigm shift involving changed processes, new tools and, even more critically, new mental behaviors and the acquisition of new skill sets for engineers.

Whereas analysis takes a pre-existing product or concept and predicts performance, optimization reverses the process. Given a set of performance metrics defined by requirements, it establishes the best form for the design and determines optimal values for the defining parameters. To work well, it is essential that the analysis itself is accurate and that the geometric features of the model are sufficiently flexible in their definition.

Both the closer working of designers and analysts within a team and the democratization of simulation, allowing approved simulation processes to be made available to designers within CAD systems and integrated within process automation systems, are factors that are making it possible to apply design optimization techniques at the point in the process where substantial design freedom still exists. **DE**

Peter Bartholomew *chairs the NAFEMS CAD/CAE Integration Working Group, and has been active within NAFEMS since its inception. Send e-mail about this article to DE-Editors@deskeng.com.*

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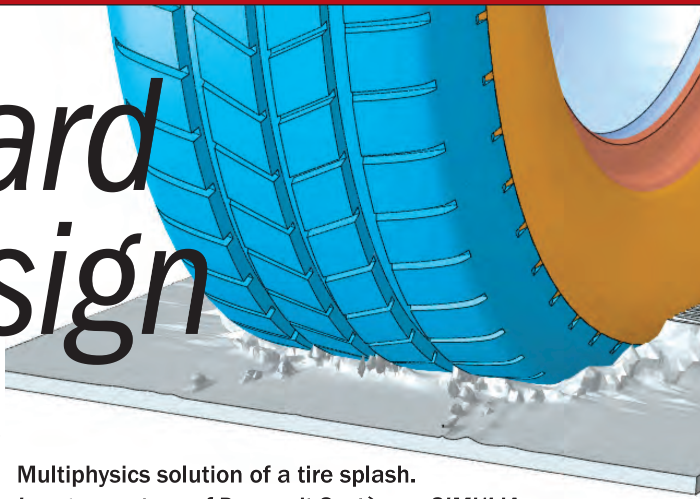
Driving Toward Optimal Design



Multiphysics solution of a tire splash.
Image courtesy of Dassault Systèmes SIMULIA.

Finite element analysis plays a pivotal role.

By VInce Ad Ams

In the first years of the last century, Thomas Edison optimistically commented on his numerous prototypes for an electric storage battery: "Well, at least we know 8,000 things that don't work." Contemporary estimates put the actual number of prototypes around 50,000 over a 9-year period.

More recently, James Dyson advertised that he built more than 5,000 failed prototypes before perfecting his dual cyclone bagless vacuum cleaner. Try to imagine the look on your manager's face if your project plans included that many prototypes. Unless your name was on the building, it probably wouldn't have gone over well.

However, engineers know the more iterations they can try in the time permitted, the faster they'll get to an acceptable design—and the more likely they'll approach an optimized design. It is this challenge that drove the pioneers of industrial finite element analysis (FEA), and the first practitioners to the craft. It remains the vision today.

To fully appreciate the value of FEA-based optimization to your organization, some understanding of how today's technology got to where it is and how it can best affect the design process is warranted.

FEA: Then and Now

Pioneers in structural mechanics, such as Stephen Timoshenko, Walther Ritz and Lord Rayleigh, paved the way for a breakthrough in predictive stress/strain by Richard Courant in 1943. Courant proposed the concept of triangular segments as a basis shape for more complex structures. He leveraged the research of those who came before him to interrogate possibilities and find the deformed structure with minimal distributed energy. The birth and growth of computing in the 1940s and 1950s allowed application of this basic concept to real-world problems in the aerospace industry.

Commercial FEA, along with the name "Finite Element," was born in the 1960s with the development of ANSYS, MSC/NASTRAN and MARC. It was still a specialist technology, employed primarily in the automotive, aerospace, defense and nuclear industries. Shared computing centers were often required to get manageable throughput. But by the 1980s, CAD put computers in the hands of engineers in all industries—and access to FEA followed shortly.

The early design analysts were challenged with model size limitations of a few thousand nodes. They were challenged to make every element count, thanks to the manual methods of node/element creation and the compute power ceilings.

In the 1990s, solid modeling for CAD took hold for good, and CAD-based meshing evolved with the rapidly increasing power of desktop computers. The geometry-centric workflows we now take for granted started to take shape. The potential for design analysis and optimization became a reality. In 1994, Altair's OptiStruct topology optimization ushered in a new way of leveraging FEA by allowing engineers to explore possibly counterintuitive geometries by specifying loads, failure conditions and the allowable design space or physical envelope a part can occupy.

Growth of FEA in Product Design

To truly understand the role of simulation in the design process, let's first take a step back and examine the process itself.

The design process is not a linear process. It often wanders through a sequence of decisions and adjustments. A misstep that isn't caught fast enough can throw the project down an unproductive path. Periodic affirmation that the design is on the right track, much like GPS in your car, can help avoid costly detours.

Calculations, prototypes and analysis provide this guidance to engineers. Because too few real-world geometries can be simplified to hand calculations, they have limited value. Similarly, the very nature of most physical prototypes require that many, if not most, design decisions be made prior to fabrication. The end result is usually an expensive guess that, if deemed sufficient, will rarely be optimized. Fast, affordable FEA can bridge the gap between simplistic hand-calcs and expensive physical prototypes, while offering a vehicle to rapid exploration of variations and improvements.

CAD integration was the catalyst for making FEA a "virtual prototype" tool. Design integrated analysis allows us to explore more prototypes in significantly less time, even if they are simply minor variations. The net result is that we can linearize the design process so that explorations of variants never stray too far from the right path.

Even without detailed loading, material properties or failure criteria, choices can be examined for being overly conservative, dangerously marginal or worth evaluating further. Each feature, parameter or decision can then be optimized on the fly, so the chances of the first acceptable design being closer to the optimal one are greatly increased. Five thousand to 8,000 prototypes, *virtual prototypes*, aren't unrealistic in this scenario.

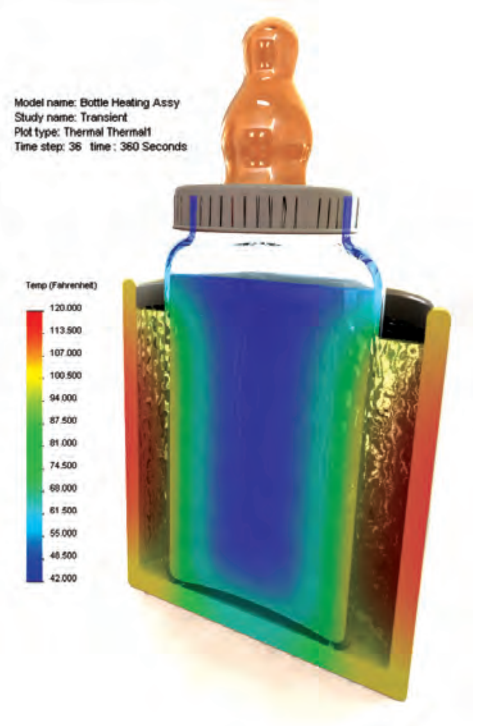
Impact Still Small

With all this potential, why is the use of FEA still limited to a small percentage of engineers at most companies? In a presentation offered at the 2008 NAFEMS Regional Summit in Hampton, VA, Dr. Dennis Nagy, a longtime FE industry expert, estimated that companies were only using 10% to 15% of "already purchased CAE capability." He said he believes these companies can realize increased value from deeper and improved utilization of existing CAE without any further investment.˜

The reasons for this underutilization are certainly more cultural than technological. A leading factor is that too few managers have mandated or allowed a process change that leverages simulation. FEA can't drive a design if it is only used to validate finished concepts. Furthermore, without a process change, it is likely that the design being validated digitally is the one that would have been validated physically. Awareness of this fact artificially devalues the simulation process.

At the user level, designers still haven't learned to properly phrase their questions to a simulation. "Will it work?" isn't specific enough for today's FEA. Unfortunately, engineers new to this flood of detail about a design aren't prepared to recognize what the results are telling them—either about the design or the quality of the simulation. More training on input properties and failure mechanisms will allow them to make more decisions and delve deeper into an optimal configuration. A doctorate in applied mechanics isn't required—but a working knowledge of the materials being specified, and the applicable failure modes of a product are necessary.

The tools an engineer needs are probably available on his or her PC today. Learning how they apply to the decision-making process should be the first priority before looking to add new or deeper levels of simulation.



Temperature distribution in a baby bottle, presented with photorealistic CAD in SolidWorks Simulation. ***Image courtesy of Dassault Systèmes SolidWorks.***

FEA Trends

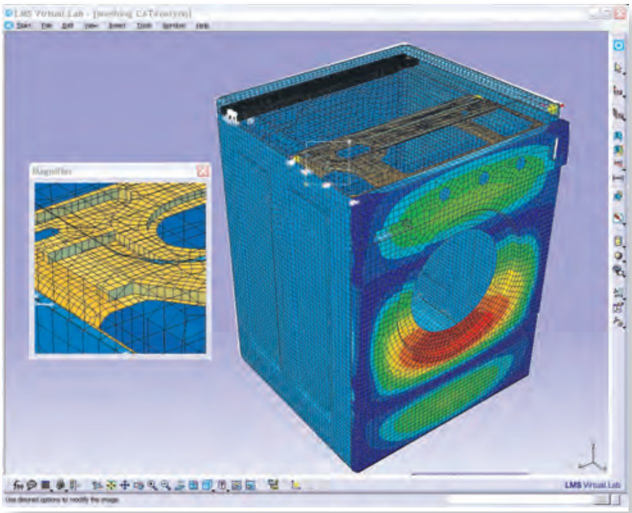
One sure sign of a maturing technology is that the trends today sound much like the trends of 5 years ago. That isn't to minimize the importance of the development work being done in the industry. The growth plan for design analysis is significant and potentially game-changing. In the end, it may turn into a race to see who completes it first.

A look at top FEA developers shows three general areas of focus:

1 Add more realism to the analysis. At its heart, an FEA solver is truly a general-purpose calculator. Triangles and nodes respond to forces and constraints. The solver doesn't know if it is simulating a child's toy or a wind turbine. This puts the responsibility on the user for making sure the mesh, properties, loads and restraints act like the product under study. They must also interpret the results in light of what that product might actually do. To grow the value of simulation to generalist engineers, software developers are attempting to break down longstanding barriers so that simulation truly feels more like design.

Examples of this include multiphysics (MP) and multi-domain simulation. Instead of sequentially solving a deformation scenario, then a fluids scenario—traditionally different governing physics—engineers are beginning to see coupled fluid-structure interaction shifting to the mainstream. Other MP applications include simultaneous solving of thermal, electro-magnetic, acoustic, fluids and other phenomena with structural responses, much like a product or system would experience in real operation. We can expect this to be refined over several more years, since gains in computing speed need to match improvements in user interface and solving algorithms to truly deliver on the promise.

Whereas MP solutions typically compute multiple responses in the same or similar mesh space, multi-domain simulation simultaneously links varied technologies to create a true virtual product. The most common and mature example of this is flexible, strain computing bodies in an otherwise rigid multibody dynamics (MBD) analysis. Highly transient 1D hydraulic, pneumatic and mechatronic systems are now being coupled to



Sound radiating from a clothes dryer. *Image courtesy of LMS International.*

MBD and computational fluid dynamics (CFD) solvers.

Finally, developers are growing vertical applications for disciplines such as turbo-machinery, airframes and composites, so that industry knowledge is tightly coupled with the solving application. This allows engineers to focus more on the real problem than the analysis itself.

2 Tighter integration with CAD and geometry. An interesting dynamic in the industry is that the simulation companies that started in the FEA business and those that grew from the CAD world seem to be growing toward the same vision: a blurred line between CAD and CAE. Dr. Paul Kurowski, author of numerous books and articles on design analysis and president of Design Generator Inc., sees this direction as the natural evolution of both disciplines: "Engineers with an awareness of the needs and value of simulation will make better design choices from the start."

To this end, meshing tools are becoming more tolerant of sub-optimal geometry. They even recognize features like holes and anticipate a more appropriate mesh. Parametric geometry changes will morph an existing mesh where possible. Intelligent decisions about element type (beam, shell, solid), are being made based on an analysis of geometry without remodeling—and when required, the software can facilitate the reduction of solids to true analytical geometry. CAD-based part-part contact is considered mainstream functionality, so engineers can focus solely on assembly interactions.

The development effort in this arena will be ongoing for several more years. It is less constrained by computational efficiency as by the creativity of the software companies and the cultural acceptance of the user community. They must work together to realize the best combination of capabilities.

3 Improved speed. Speed is always on the table for FEA developers. One of the biggest factors is computer speed—which is out of the FEA developer's control. However, making better use of both the available CPU power and the operator's time is. To that end, we'll continue to see improvements in solving algorithms and mesh technology that provide better results with fewer nodes. Additionally, multi-core computers and high-performance distributed solving will be leveraged for rapid turnaround of traditional and newer MP scenarios.

The speed of the total process is being addressed as well, through automation and simulation data management (SDM). Automation will allow repetitive tasks to be scripted and parameterized. This direction has been pursued for more than a decade, and has caught on in certain industries, but it's not widespread. However, SDM is an idea whose time has come now that product data management (PDM) and product lifecycle management (PLM) have taken root. Most players in the FEA software industry have some strategy for SDM, and it may help pave the way for the real benefits of automation down the road.

Where is Optimization on this Road Map?

At first glance, a look at leading developers suggests only incremental improvements in optimization technology going into 2013. That's not because the value of optimization has diminished, but that optimization technology is ahead of the factors needed to make it successful. These include MP/multi-domain simulation, design integration, speed and cultural acceptance.

Also remember that manually iterating (such as the work of Edison and Dyson), is still optimization—and it's more consistent with the way designers have always worked. When the barriers being addressed by the three long-term growth trends come down, and engineering organizations begin to rely more on simulation for design excellence and competitive advantage, automated optimization will truly come of age. **DE**

Vince Adams, *currently an account manager for LMS, is a long-time simulation educator, consultant and speaker. He has authored three books on FEA and numerous magazine articles. Send e-mail about this article to DE-Editors@deskeng.com.*

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→ **LMS International:** LMSintl.com

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Make Digital Designs Physical

Tim Caffrey (left) and Terry Wohlers (above)

The industry is using AM technology to optimize material use and product weight, and to manufacture complex parts.

BY TIM CAFFREY AND TERRY WOHLERS

Our first resolution for 2013 is to use the terms *3D printing* and *additive manufacturing (AM)* interchangeably. Many from the scientific and technical communities prefer AM, especially for industrial systems. About everyone else, including bloggers, the investment community and the mainstream press, prefer 3D printing. There's no going back to the old definition of 3D printing, which once meant an AM process that jetted material through an inkjet print head.

In a perfect world, manufacturing processes would use 100% of raw materials in finished products. As we head into 2013, we still don't live in a perfect world, but AM can get us closer. AM processes yield near net shape products with relatively little waste.

One glaring exception, however, is the recyclability—or lack thereof—of polyamide powders used in powder bed fusion processes. Currently, more than a third of the unused powder in a build cannot be reused. In 2013, we'd like to see process and material improvements that make unsintered nylon powder 100% recyclable, build after build after build.

AM provides design freedom, liberated from the shackles of 20th-century manufacturing.

Also, material used to support parts as they are built also becomes waste. Optimizing the support material helps, but they still have an impact on cost, build time and the amount of scrap.

Shedding Weight

One of the most common New Year's resolutions is to go on a diet. There are ways for AM parts to shed some weight, too, yet still maintain their strength and functionality. Topology optimization software uses algorithms to produce a design that satisfies strength and stiffness requirements while minimizing the amount of material used. Mathematics decides where to put the material.

"TopOp" often results in an organic form that mimics the shapes found in the natural world. And, with AM's inherent ability to build any shape or geometric feature that can be modeled digitally, TopOp is an ideal "dietary supplement."

Lattice and mesh structures are another great way to drop a few pounds. Software, such as Within Enhance, netfabb's Selective Space Structures, and 3D Systems' Conformal Lattice Structures, reduces a part's weight by transforming solid areas into surface skins with interior volumes composed of lattices with open spaces, while maintaining requisite strength and stiffness.

What's so great about weight loss? A "ton" of things. Less raw material is consumed, and that saves money. The strength-to-weight ratio of parts is optimized. The build is faster because less material needs to be processed. Plus, lighter weight parts reduce fuel consumption and transportation costs.

Complexity Is Simple

Topology optimization and lattice structures are great theoretical concepts. And that's what they were—theoretical—until AM came along. Conventional manufacturing can't produce convoluted features or encapsulated lattices, at least not affordably.

Herein lies AM's ultimate optimization advantage. Designers are no longer constrained by design-to-manufacture issues like undercuts in molded parts or multiple setups in CNC machined parts. Almost anything a designer can create using design software can be manufactured by AM.

As we enter 2013, our educational systems must catch up to this new reality. Curricula should not only add 3D printing to manufacturing process options, they should also teach students that AM processes provide design freedom, liberated from the shackles of 20th-century manufacturing.

AM offers the opportunity to reduce material use and waste, optimize the strength-to-weight ratio, and provide radically new designs. It is our hope that engineers and designers, young and old, will embrace this new way of thinking—and explore what could become the most important and popular method of manufacturing in the future. **DE**

Tim Caffrey *is associate consultant at Wohlers Associates.* **Terry Wohlers** *is principal consultant and president of the consulting firm. Send e-mail about this article to DE-Editors@deskeng.com.*

Perfect Partners

Designing for manufacturability has already taken a back seat to optimized design in many industries, thanks to additive manufacturing.

BY JAMIE J. GOOCH

Additive manufacturing (AM) can optimize prototyping by allowing multiple physical iterations of a design to be quickly created and evaluated. However, the technology really shines when it's used to create optimized end-use parts that would not be economically feasible to manufacture via traditional means. It's a win-win situation when an optimal design can be realized with rapid manufacturing.

Jeff DeGrange, vice president of Direct Digital Manufacturing for Stratasys, has first-hand knowledge of end-use 3D printed parts. He worked at Boeing for more than 20 years, including a tenure leading the company's advanced manufacturing efforts. He was the principal engineer involved in getting laser-sintered parts certified for use on F-18 fighter jets and later was the manager overseeing the use of AM on Boeing's 787 Dreamliner.

"Even back in the late '80s and early '90s Boeing was using stereolithography," he recalls. "We had one machine. I remember its serial number was 007. I called it the James Bond machine. It was used to make models for low-speed wind tunnels."

Fast forward to today and end-use AM has spread well beyond aerospace. It's especially found its niche in medical, jewelry, and specialty automotive industries, and it continues to spread into all corners of aerospace—from NASA rovers to unmanned aerial vehicles (UAV) to corporate jet interiors.

"There are a number of different things causing the growth of the technology in end-use parts," says DeGrange. "Additive manufacturing now has a broader array of materials, the machines are getting bigger and faster, and the price points are coming down on those machines."

Design Optimization Meets Rapid Manufacturing

We may be able to add optimization strategies to that list of growth factors. The use of optimization software could help engineers realize AM is the perfect partner for building optimized design concepts for lighter weight products that meet strength requirements while using less materials.

"With additive manufacturing, imagine an I-beam that is not all solid—it could be made out of trusses. It doesn't necessarily need to be solid," DeGrange says. "It could be a lattice structure that bridges the beam to distribute the weight of the load. That would use less material and energy to manufacture, if it could be manufactured—and it can with direct digital manufacturing."

AM can enable manufacturability without compromise in many situations, what DeGrange calls "low-volume, high-product mix" environments.

One such environment is the racing industry, which creates many of its customized parts. For example, Joe Gibbs Racing (JGR) recently used Stratasys' Fortus system to manufacture a filter housing that is mounted in line with the driver's air conditioning to help clean the air blown into the driver's helmet.

"The complex design of the part makes it ideal for an FDM (Fused Deposition Modeling) application," said Brian Levy, a JGR design engineer, in a case study published by Stratasys. "If we tried to machine the part, we would be forced to sacrifice some of its performance to satisfy machining constraints."

F1 Roll Hoop Design

An F1 racecar's rear roll hoop is a structure that protects the driver's head in the cockpit, serves as air intake for the car, plus includes camera mounts and pick-up points.

The heavy component at such a high point on the car is not ideal. 3T RPD's goal was to get the weight of this component down to 1 kilo (2.2 lbs.), which would drop 1 to 2 kilos. Because of the weight constraints of F1 cars, ballast is commonly used to balance the car and meet minimum weight. By reducing the weight of the roll hoop, engineers can put the saved weight lower down in the car design, thereby improving the overall performance of the vehicle.

3T RPD teamed up with Within Technologies to create a new design for the roll hoop. Using Within Enhance software, which has an optimization process linked to an internal finite element analysis (FEA) process, the team created a lightweight design, which incorporated thin walls and internal features. They were also able to minimize the number of support structures that usually accompany metal AM processes. *— Susan Smith*

Leptron's RDASS 4 remotely powered helicopter.

Faster Time to Market

In addition to greater flexibility when it comes to manufacturability, designs intended for AM can also help optimize the manufacturing process by saving time and money.

We can see one example of this in Leptron's use of AM to develop components for its 5-lb. remotely powered helicopter, the RDASS 4. Design variations are needed for the specialized applications of the company's different customers.

According to the company, injection molding would have cost $250,000 and taken six months to build tooling for the RDASS 4's fuselage components. Design changes would have required more time and expense to modify the tooling. Using Stratasys' Dimension 3D printer, the RDASS core components can be printed in 48 hours, and smaller components are printed in 6 hours. According to the company, it cost $100,000 to 3D print the parts needed for prototypes and eight production UAVs.

"We made approximately 200 design changes during the course of the project," said John Oakley, chief executive officer of Leptron, in a case study published by Stratasys. "It would not have been possible for a company of our size to design and build this product using conventional manufacturing methods."

Material Challenges

While many AM materials—from Stratasys' FDM and Objet's PolyJet materials, to sintering materials from EOS, Arcam, and others—are used in manufacturing, it's only the tip of the iceberg. DeGrange says one factor is still holding back more mainstream adoption: a lack of understanding of AM material properties.

"We need to teach this, and not just at select universities, to explain that additive manufacturing is not just for prototyping," he says. "It really needs to start in the education system."

Beyond academia, Stratasys is compiling material test reports that come from accredited third-party sources to show how the company's materials stand up vs. heat, cold, gasoline, flames, etc.

Both Arcam and Stratasys are also working with Oak Ridge National Laboratory to advance AM materials' acceptance by manufacturers, and to develop new materials.

"One goal is a thermal plastic that has the same strength as aluminum," DeGrange says. "You could do complex shapes and parts for automobiles to minimize weight for improved fuel efficiency. You could optimize parts with complex geometries to enhance crash worthiness by putting materials where they're needed to channel forces away from drivers and passengers."

To meet mainstream adoption goals, the industry needs a broader array of materials and material pricing needs to drop, DeGrange says. But with the industry and government working to meet those challenges, realizing the full promise of optimized design using AM doesn't seem out of reach. DE

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

INFO → **3D Systems:** 3Dsystems.com

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→ **EOS:** EOS.info

→ **Objet:** objet.com

→ **Stratasys:** Stratasys.com

→ **Within Technologies:** Within-Lab.com

A Rapid Advantage

3D printing optimizes aerodynamic eÿ ciency in complex racecar shapes.

BY SUSAN SMITH

Formula 1 car racing is both a driving competition and an engineering competition. That's is how James Allison, technical director at Renault Lotus F1 Team in the UK, describes it. The people involved are often referred to as "constructors" rather than teams because they have to build critical parts of their own car. They have to design it, too.

What separates the competition is the aerodynamic efficiency of each car. The Lotus F1 Team, for example, has 500 or so people on the technical side—and nearly 100 of them are only working on aerodynamics. Their wind tunnel program runs more or less 24/7 yearly. Over the course of a year, they test tens of thousands of new ideas.

Each of those ideas is tested on a 60% scale model of the full-sized car.

"We make tens of thousands of new parts of that model each year, searching for improved aerodynamic performance," Allison says. "And those parts are all one-offs—prototypes, so we need a production system that is capable of keeping up with an insatiable demand for this wind tunnel and the people who are thinking up, designing them and wanting them tested.

"We need a manufacturing system that's capable of handling that sort of throughput, where each component is a one-off and complex in its shape," he adds. "It's all flowing, 3D aerodynamic-detailed shape, so no straight lines, no easy angles. Everything is made to get the most of out of the air, not to be manufacturable. That's the perfect environment for what 3D printing can bring."

When the early rapid prototyping machines came on the market, the Lotus team was able to print complex shapes out of liquid using early stereolithography (STL) polymer liquids. In 1998, the Renault F1 Team and 3D Systems became partners, when Renault began using the SLA 5000 System to develop prototypes of components with a size-fit test function. This led to expanding the use of solid imaging technology to manufacturing of wind tunnel models, and the direct manufacturing of production parts for testing and racing.

The team has expanded from STL to selective laser sintering (SLS) machines, and a wide range of materials that allow them to put all these components into the wind tunnel model at a rate that keeps up with the optimization of the car.

Out of the Tunnel

As the technology has matured, they have begun to use it more away from wind tunnels and in the car itself.

"When we make our gearboxes, they are thin wall titanium investment casting, and we make the investment casting using a lost wax process, which is done on our SLS machines," Allison says. "We send these parts off to the casters, where they get used as the patterns for the gearbox casings on the car. There are quite a few cast metal pieces that are used in the car, and we do all pattern work on our machines."

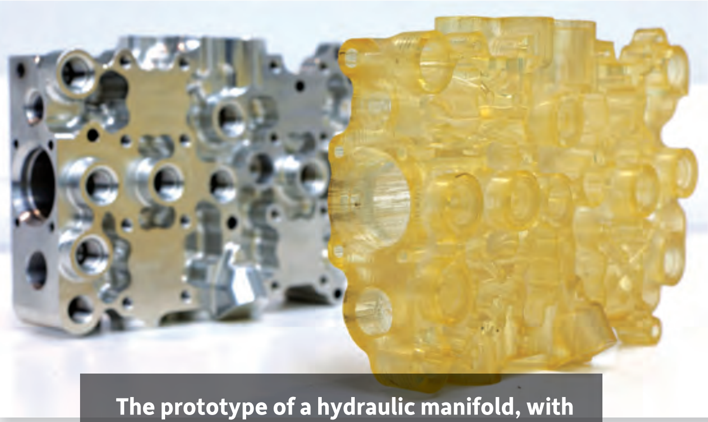
Allison says there are also a large number of components that go on the car itself, as well as anything that requires a very complex, dark shape "where we need to get cooling air from the outside of the car to the inside of the car."

"We can just print off the relevant serpentine duct and have it fit the car and go racing with it, because the materials are now light, stiff, tough and good enough to survive in the environment of the circuit," he says. "It has transformed F1. Now we cannot imagine how to do without it."

Allison explains that all the parts they make are one-off prototypes, which are actually functional. The finished component is made of material you can use; it can take significant loads and withstand reasonable temperatures.

"And they can work beautifully in our environment to

About 80% of the surface of the model used in wind tunnel testing is made via 3D printing.



The prototype of a hydraulic manifold, with the final aluminum component in the background (example of size fit test prototype).

allow us to find more down force every day with our car," he says. "They are prototypes, but they are also working prototypes: They do their job, they get crushed up and we make another 100 the next day."

The majority of the actual racecar is built with carbon fiber, but within it are a number of detailed components that are provided by additive manufacturing technology, such as lots of little trays for holding electrical equipment, and cooling ducts to take air from one part of the car to another part of the car. Certain aerodynamic components on the outside of the car redirect air rather than have a great amount of force on them themselves.

The gear box case and the other significant investment castings on the car are only manufacturable with the accuracy and time scales because the team is able to print the pattern work for those directly on their machines at the factory.

Tens of Thousands of Components Each Year

Allison said that they produce approximately 100 components a day. There are about 40 wind tunnel experiments daily. Each experiment isn't just a single component because normally, you're fitting something to the left-hand side of the car and the right-hand side of the car. This means for every new idea, you're fitting at least two components. But over the course of the year, those 40 tests a day gradually turn into improvements.

The manufacture of these tens of thousands of components a year can result in finding improvements in the aerodynamic efficiency of the car on the order of 12%, Allison says. This equates to 1% per month—which doesn't sound like a lot, but the yearly average is worth over a second a lap.

"If you're a fan of the sport, you'll know that in qualifying the cars, they are normally separated by the less than a tenth of a second, so one second is worth about 10 places at the start of a race, so it's a big deal," Allison says. "A championship-winning car typically has an advantage of two-tenths of a second or so over competitors. This effort is critical to the future of the team, and good aerodynamic judgments are our lifeblood."

He stresses that this could not be accomplished without a manufacturing system "that was capable of realizing all our ideas and testing them in the tunnel. A good idea might yield a quarter of a percent of improvement, so maybe four a month, one per week—out of 350 things you did that week, you might get one thing that was good. The challenge to find an incremental improvement to a design that has already had thousands of hours lavished on it is real."

The Lotus F1 team has critical requirements in terms of engineering materials that can withstand real loads and temperatures, and they also offer input to 3D Systems as to what they need in terms of strength and stiffness. **DE**

Contributing Editor **Susan Smith** *has been immersed in the tech industry for more than 17 years. Send e-mail about this article to DE-Editors@deskeng.com.*

INFO ➜ 3D Systems: 3DSystems.com

➜ Renault Lotus F1 Team: LotusF1Team.com

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Optimize Testing

Integrate testing into the design process, early and o˜ en, to continuously verify design decisions.

BY BARBARA G. GOODE

My sister watched as our friend Bob, an experienced electrician, installed a ceiling fan in the mudroom at our dad's house. "BLEEP poor design on the fan," she texted me. "It took him forever to install."

When it came time to buy another ceiling fixture—this time a heat lamp—I decided to search online. I found a promising one and looked at the reviews. According to one buyer, though, the unit allowed insufficient space between the heat plate and the cap. That flaw caused a lack of airflow, which triggered the unit to overheat just after a few minutes of operation.

Think about what adjustments to your environment would enable streamlining of testing.

Others complained that the installation process was needlessly difficult: One said the design made it hard to get screws into the holes because the fan blades were in the way. Another added some ideas about how the manufacturer might solve the problem. Too bad the company didn't get their input in time to adjust their design.

Continuous Testing

This experience exemplifies the importance of integrating testing into the design process. The feedback indicates testing would have produced helpful insight at least two points: during operation assessment and installation review.

Writing for the Project Management Tips blog (pmtips.net), Brad Egeland asserts that any project without sufficient allocation of testing throughout is doomed. He says that testing must happen continuously, both formally and informally—as part of development, in the phase designated for testing, and both before and after deployment.

Approaching test this way may be very different from the way we are accustomed to thinking about it: Testing is critical and must be integral to design—not the last step before deployment that is afforded whatever time happens to be left.

While Egeland's blog is written with IT projects in mind, the principles apply to product design. You can see what I mean by considering his recap of the importance of testing from Jason Charvat's book, *Project Management Nation*. He writes that with a poorly tested solution, support and maintenance costs will escalate, and reliability will suffer. He also notes that while testers sometimes try to destroy a solution during the test phase, tests are better conducted under realistic conditions. He recommends deciding which tests are necessary and at what points, and advises setting sensible ground rules for testing, such as:

- Use real data and real operators.
- Test as developers build so errors can be corrected quickly.
- Involve people who understand design and user specifications.
- Determine what the test includes—and what it does not.
- Involve users who know how the system will be used.
- Test to see that interfacing the new solution to the current infrastructure has no unexpected consequences.
- Schedule time for repetition of unsatisfactory test results.

This is not a comprehensive recipe for success of course; you know the scope and particulars of your project and how these ideas might apply. But it may be a useful springboard, as will the many tools now available to help you integrate test effectively, collaboratively, and efficiently.

Changing Mindset

In a presentation delivered at Automotive Testing Expo North America 2012, Brad McCully, general manager Product Testing Services for Advanced Technology Services Inc. reviewed the top challenges in product testing. He concluded by noting that testing professionals are starting to think differently about how work gets done. "It's time to start changing to a more productive environment in order to compete in the new marketplace," he said.

It's time to think about what adjustments to your environment would enable streamlining of testing—so that your products, systems, or services can compete for ever more educated and discerning customers. As for me, although the fixture I found online had all the right specs, I've decided to go for one that will elicit less cursing from Bob. **DE**

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A Quality Partnership

National Instruments and IBM marry embedded system design and testing to optimize quality management.

BY PETER VARHOL

More than 2 million lines of code were required to successfully guide NASA's Rover Curiosity to a safe landing on Mars, but Curiosity doesn't have to contend with airbags, turn signals or streaming audio from mobile phones like the Chevy Volt does. When the Volt was released, General Motors compared its development to a rocket program. The car had 10 million lines of software code and 100 electronic controllers—and that's on the model that is now two years old.

General Motors' 33,000 sq.-ft. Global Battery Systems Lab includes 160 test channels and 42 thermal chambers that duplicate extreme real-world driving patterns, hot and cold temperatures and calendar life. ***Photo by John F. Martin for General Motors.***

Engineers are creating increasingly complex products, and as a result, automobiles, aircraft, medical devices, consumer electronics and more depend on software driving the hardware components. Shorter design cycle—like the Volt's record-setting 29 months from the ground up—leave no time to waste. On the other hand, the increased complexity of embedded systems requires more testing than ever before. Design engineers need a solution to tie together design and testing of embedded systems, and they may have an answer in National Instruments' partnership with IBM.

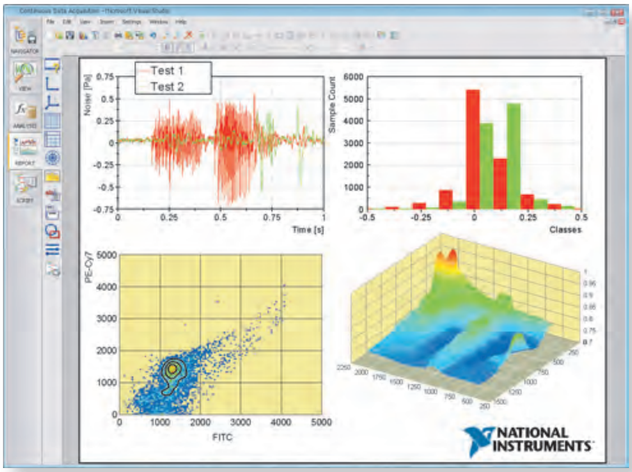
General Motors Battery Lab engineers prepare batteries for testing in the thermal chamber at the GM Tech Center in Warren, MI, in 2008. ***Photo by John F. Martin for General Motors.***

IBM's Rational software, which GM used to design and test the Volt, is being integrated with National Instruments' LabVIEW, VeriStand and TestStand testing environments. The goal is to provide an end-to-end quality management and collaborative real-time testing solution that will increase productivity and quality while reducing time to market. In short, the companies hope to optimize upfront design and testing of embedded systems.

Linking Design and Testing

National Instruments has several technologies that are used to implement test and validation applications for these complex hardware/software systems.

NI LabVIEW is a graphical programming environment



NI DIAdem is a tool for engineering data management, analysis, and reporting that allows engineers to produce information they can make decisions with faster.

with tight integration to I/O hardware and support for IP developed in other languages such as C. Using drag-and-drop graphical icons, engineers can quickly create intelligent test programs tailored to their specific application needs.

NI VeriStand is a software environment for configuring real-time testing applications, such as hardware-in-the-loop simulations or test cell control and monitoring. Out of the box, VeriStand helps teams configure a multicore-ready, real-time engine to execute tasks such as real-time stimulus generation; analog, digital and communication bus interfaces; deterministic model execution; and event alarming and alarm response routines.

NI DIAdem is a test data analysis and reporting tool. It can be used to quickly locate, load, visualize, analyze and report measurement data collected during data acquisition or generated during simulations. Reporting is vital for the team as a whole; it keeps stakeholders informed on what has been implemented, and whether those features meet requirements.

NI TestStand is a test management software tool that helps develop automated test and validation systems. TestStand can be used to develop, execute and deploy test system software. In addition, teams can develop test sequences that integrate code modules written in any test programming language.

As a result of their collaboration with National Instruments, IBM's Rational Quality Manager, which creates and maintains relationships among product design artifacts (such as requirements and embedded software) and product test artifacts (such as stimulus profiles and test programs). It also provides views for insightful decision-making through the lifecycle. Its ability to identify and close gaps in coverage helps improve product quality and the efficiency with which this quality is achieved, especially in an environment where product requirements are changing.

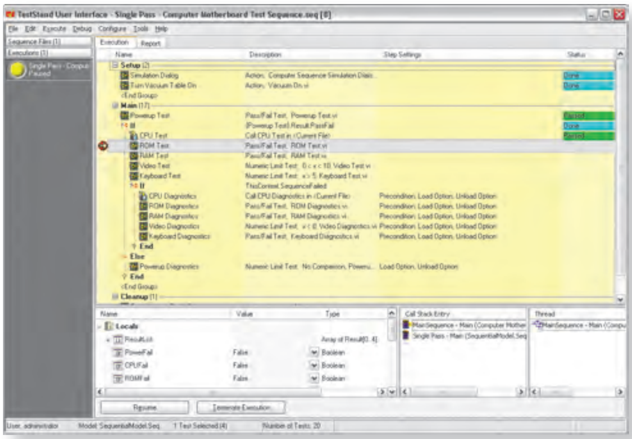
Collaboration Across Silos

Collaboration breaks down the walls between quality management silos, which allows software bugs to be fixed quickly and cost-effectively before a product is deployed. IBM estimates the cost of fixing a software bug post-release can be 100 times higher than if you discover it early in the design process.

To catch those bugs early, information on design and software changes and their impact has to be communicated across the team. Engineers often work in distributed teams, sometimes around the world. It's not always possible to get the entire team in the same room, or even on the phone at the same time. Teams building regulated systems have to keep up with changing standards, and sometimes even completely new regulations. No matter what the product, teams are constantly dealing with new versions of software, electronic systems and new technologies in general.

Collaboration is probably the most important part of any quality product development effort today. No one person can keep all of the project details in his or her head, so a project knowledge repository is essential. And because many people contribute to that repository, they have to maintain lines of communication so that all team members are fully informed about status, changes, and results.

IBM's Rational Quality Manager brings collaborative features to product validation efforts implemented using National Instruments tools. Rational Quality Manager enables the capturing of threaded discussions directly on an asset like a test case, providing the ability for teams to have a common understanding of the state of individual aspects of the project. Link previews and selected feeds give team members insight into development status, without overwhelming them with too much information. Further, teams collaborate among themselves (and with their stakeholders) using web-based reviews and approvals.



NI TestStand automates the execution and results collection of test applications created in any programming environment.

Tackling Traceability

Collaboration is most useful when it's automated. Team members can't manually track requirements through specifications, development and tests, to successful product delivery. That's why automatic traceability across project assets is necessary. National Instruments' testing tools, combined with Rational Quality Manager, automates both collaborative activities and asset traceability.

Most development efforts go through several distinct, high-level phases, such as requirements, design, implementation, test and delivery. At each transition point, it is possible to lose information. Knowledge about requirements can be lost when moving to design, and knowledge of design can be lost during implementation.

Traceability works by providing links from requirements and similar business needs statements to downstream development artifacts, including specifications, code, tests and defects. These links let the project team immediately understand the relationship between requirements and the actual product being built. They provide a direct information connection between product lifecycle phases that is often lacking.

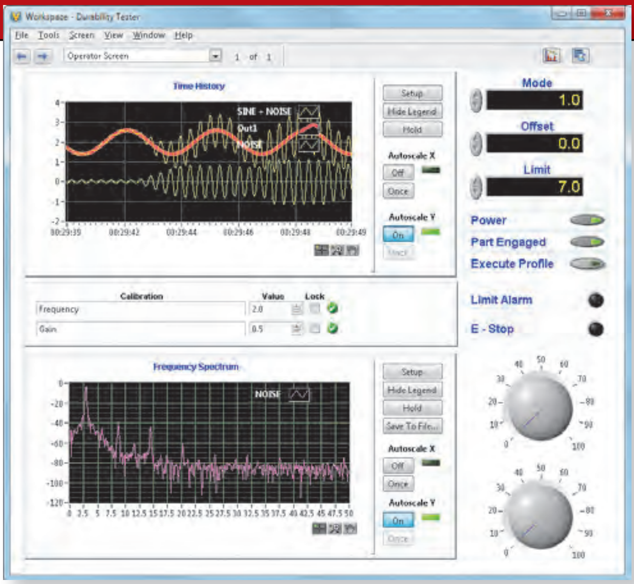
The IBM and National Instruments partnership promises bi-directional traceability across the entire development cycle. Links run both ways, downstream and upstream. The value with upstream linking is that it becomes possible to tell when a requirement has been satisfied. If requirements are linked to system tests, and tests are linked to defects, then team members can tell when requirements have been satisfied. This traceability also enables requirements and test engineers alike to easily perform impact analysis to determine the effects of changing a requirement or updating a test component. Upstream traceability allows developers at all stages to understand how their changes impact other aspects of the project and plan accordingly or eliminate the change altogether.

Traceability helps to ensure that teams build what was intended. This isn't as absurd as it sounds, because the loss of information at each phase in the lifecycle means that it is possible to lose sight of some of the original needs. Also, and more importantly, requirements are apt to change during the course of a project.

A Moving Target

With traceability, teams can quickly and easily identify downstream code changes that might have to change in response to requirement changes. And requirements often change during projects. Whether the intended target market is adjusted, or inaccurate or vague requirements are fine-tuned, the era of frozen requirements and long-lead product development efforts is long past.

Product design teams building products that use a combination of hardware and software need to be cognizant of how requirements changes can affect downstream assets.



NI VeriStand allows test engineers to configure real-time test applications that require stimulus generation, data logging, and/or simulation model execution.

This is an essential part of product teams becoming more agile and responsive to user and market needs during the development lifecycle.

The pressures on engineers surrounding complex designs are high, and still growing. In some cases, there are safety implications. Software failures could result in injury or death if the product has the ability to do harm. Defects or failures may also cost the company a good deal of money in recalls and lost business. The company's reputation is also likely to be harmed, often severely, with poor quality products.

But as complex as today's products are, they're only going to become more complicated. Some luxury cars are already estimated to use 100 million lines of code. And it's not just automotive and aerospace engineers who have to work with embedded software because it is making its way into more and more products that were once strictly mechanical.

The National Instruments/IBM partnership provides design engineers with a collaborative, end-to-end quality management and real-time testing solution to ensure embedded software doesn't derail the design process. It can help reduce time to resolve defects and facilitate improved test component reuse. The partnership could help optimize the embedded system design and test process by improving quality and reducing time to market. **DE**

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Right Test, Right Time

Move testing further up into your design process.

BY DEBBIE SNIDERMAN

Simulation is great for an optimized design process, but where do different types of testing methods fit into an efficient design cycle? How can testing be integrated into a lean design cycle without holding things up? Where can test results still provide value without forcing designers to start all over?

Intertek's environmental chambers are used to prepare products before testing to meet requirements outlined in standards or test plans. *Image courtesy of Intertek.*

The Right Tests

Through simulated "real-life" conditions, accelerated stress testing will provide the data necessary to evaluate recent or proposed product changes. Accelerated stress testing can save both time and money for various applications without making the setup and test execution complex.

There are a large range of tests, up to a dozen types depending on how you break them down. According to Alexander Porter, senior chief engineer of Programs, Performance and Durability at Intertek, what is important is the goal of the information you want to gather, not the test method.

"Rather than focus on the test or the equipment, start with the information," he suggests. "What is the key piece needed to move a product forward? Then choose a task and choose the equipment."

Porter says thermal and vibration are the two main stressors typically tested. Vibrations are a key source of damage in almost every application. But, vibrations are not the same in every environment. There is no one-size-fits-all test for vibration. At Intertek, a variety of single-axis electro-dynamic machines and three types of 6-axis vibration machines create appropriate vibration spectrums. If testing doesn't activate the right frequencies, you can miss significant failure modes.

Thermal testing is a little easier to do. It usually involves an environmental chamber with radiant heat sources such as light banks and environmental controls. Combined temperature and vibration testing cover most of the failure modes.

Another test is for contaminants, which Porter says is very important for computer modeling.

"One thing that is difficult or impossible to quantify is the effect of dust, salt, water spray or other contaminant sources on a product," he says. "If you don't test it in a lab, you won't discover it until it's in the field. Individually, these tests may not precipitate a failure, but they are usually a catalyst that precipitates failure faster when combined with temperature or vibration."

The Right Time

"The best time for temperature, vibration, electrical, and contaminant testing is on the very first prototype," Porter continues. "If the goal is to optimize the design, first brainstorm the potential sources of damage, then determine which of those sources will likely include vibration, temperature, contaminants, actuation, and voltage. We choose which to use and build a HALT (highly accelerated life test) style test or a FM (failure mode) verification test from those results."

If components or subsystems are available early, or if it is a carryover product, Intertek can take a current production model and modify it on the bench.

"The earlier a part is available for testing the better, so they (design engineers) can iterate faster," he explains.

The primary goal of accelerated testing early in development is to help companies identify what information they need and what test will produce that information in the shortest time. Porter says most companies know what challenge they're facing but not what test they want. They think they want a test because they've always done it.

"It's important to drill past this to decide what assumptions they're trying to validate or decision they're trying to make. Don't just blindly test," he cautions.

There are two opportunities for product failure during the design phase, from either flaws in the design or lack of design margin. The goal of highly accelerated life testing is to increase the thermal and vibration margins of a design. It does so by *stimulating* failures, not simulating them.

HALT can shorten the time to market and reduce development costs compared to traditional qualification and design verification testing. Marginal designs may not be observable until a sufficient number of units are in the field. With increased volumes come increasing variations. HALT helps discover marginal systems, and can be used in the design stage before failures occur in the field during customer use and it is too late to redesign.

Why Run HALT During Design

"There's no doubt when you're trying to get things done as fast as you can, simulation before you have prototypes in hand is a good way to start identifying problems," says Neill Doertenbach, senior applications engineer at Qualmark Corporation. "But in real life, by identifying areas where testing will be most valuable and targeting specific tests on sub-assemblies, the first units built, or on critical functions, we can quickly find out if there are design flaws."

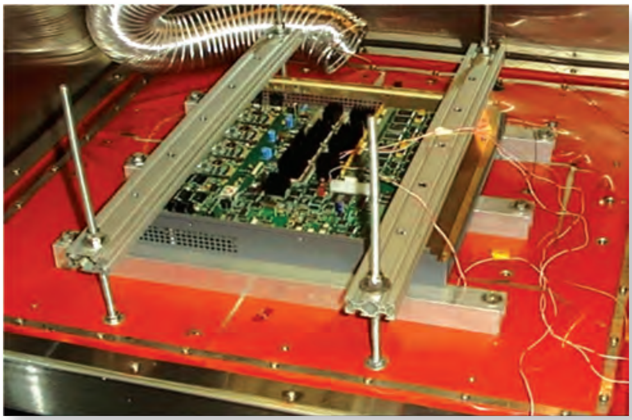
Qualmark, a manufacturer of accelerated reliability test equipment, primarily focuses on HALT testing to force failure modes to occur and to find the weakest parts in the design.

While HALT can test full assemblies or units nearing the end of production to help designers account for variations in component materials and manufacturing processes, it is also useful for pieces of the assembly early on during the prediction stage.

"The concept of taking a product or design and pushing it beyond spec until you find a failure is a step you take in the design phase," says Tom Peters, director of the Qualmark Center of Excellence. "You can take the limits that you learn from HALT and use them to screen variance in supply or vendors. The one cliche we have found to be true: In theory, theory and practice are the same. In practice, they're not."

"HALT finds the low-hanging fruit, the subset of failure modes that are often the ones you don't know about and that didn't come out of the simulation," Doertenbach says. "When ramping stresses to a high level, failures that occur from environment stresses wouldn't come out of predictions that are based on component behaviors."

During typical HALT testing, products are tested with independent and then combined stresses until forcing a failure.



A product fixed to a table with liquid nitrogen ducting in place and ready for Qualmark HALT testing. *Image courtesy of Qualmark.*

It's an exploratory discovery process to find a weakness and understand the cause of the failure. Doertenbach says about a third of failure modes typically don't show up until the final combined stress environment.

Peters says new or small companies that turn designs frequently find value in finding failures early to prevent them from becoming warranty issues. Companies that test to spec without HALT don't know if their design is robust.

"HALT doesn't give an indication of when a product will fail, unless it is tied in to accelerated life testing (ALT) or reliability growth testing (RGT)," Peters says. "If you do HALT first, then you get ALT and RGT with a more mature product. HALT speeds the standard reliability tests and ALT, and makes them less expensive because you fail fewer units. Those are expensive places to find design problems. Those tests should be a demonstration of reliability, not a troubleshooting process."

By doing HALT first, companies can get results from ALT faster, because they're not being delayed by failures that shouldn't have been in there in the first place, says Peters. It also allows companies to make more accurate life predictions and plan for warranty expenses.

"Consumers today expect much higher reliability and better products without failures," he says. "Traditional reliability and testing to spec can't get a design to the reliability levels needed. We have to use a method that finds the failures that you don't know about." **DE**

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Computers Drive Engineering Innovation

BY PETER VARHOL

Rarely is a professional as knowledgeable about his tools as the design engineer is of the computational power needed to bring designs to the light of day. The PC-based workstation has allowed mainstream engineers to shed the drafting table and become part of the automated workforce for all aspects of their jobs.

Engineers can design, simulate, analyze, test and refine without leaving their workstations. In some cases, the design may not even require physical testing before manufacture. The quality of the products is higher than ever, and both the cost of development and time to market have decreased—sometimes dramatically.

Multiple revolutions have made the shi˜ to the modern, multi-functional workstation possible.

Three Revolutions

Multiple revolutions in computing have made the shift to the modern, multi-functional workstation possible:

1. The processing power revolution. This covers several facets, including faster overall processing subsystems, multi-core processors and compute clusters. The latest industry-standard processing systems from Intel and AMD incorporate multiple levels of fast cache, and memory and processor busses two to three orders of magnitude faster than those of 20 years ago.

Multi-core processors enable many computations to execute in parallel, adding a significant performance boost. For some calculations, the performance improvement can be almost doubled with a doubling of cores. Multi-core processors are already paying off, but there is still significant room for performance growth.

Compute clusters add to computing power by adding more cores, and frequently, more powerful cores. Unlike the Crays or mainframes of the past, these utilize industry-standard processors and the same analysis and simulation software that can be run, albeit more slowly, on the deskside workstation.

2. The graphics revolution. Faster graphics processors and higher-resolution monitors have made it possible for engineers to render very high-resolution designs within seconds or minutes, rather than hours. We have so much inexpensive GPU processing power that we can turn some of it into fast numerical computation engines to help with analysis and simulation.

3. The software revolution. None of these innovations would have been possible without advances in software development and delivery. In particular, the entire engineering software industry has refocused on writing parallel code for multi-core processors and clusters.

But that's only part of it. New development tools have made it possible to more easily turn GPUs into computational rocket engines. Free and open source software utilities give engineering professionals the ability to work with designs without having to wait for purchase approvals.

Still More for the Future

Theses revolutions are continuing in the cloud, and on tablets and other devices. The cloud provides computing power on demand, letting you rent thousands of cores for a few hours for a big job. You can provide your own application software and data in virtual machines, or you can turn to cloud vendors that partner with MATLAB, ANSYS or other engineering software vendors to deliver both hardware and software when you need it.

Tablets and smartphones let you harness that power from your desk, at the client site, or from home, giving you the flexibility to maximize your creativity and make the best use of your time. It won't be too long before engineers use an entire array of computers and devices in the pursuit of the best new products for their markets. **DE**

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

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SPOTLIGHT

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

Optimize Workstations for *Faster Simulations*

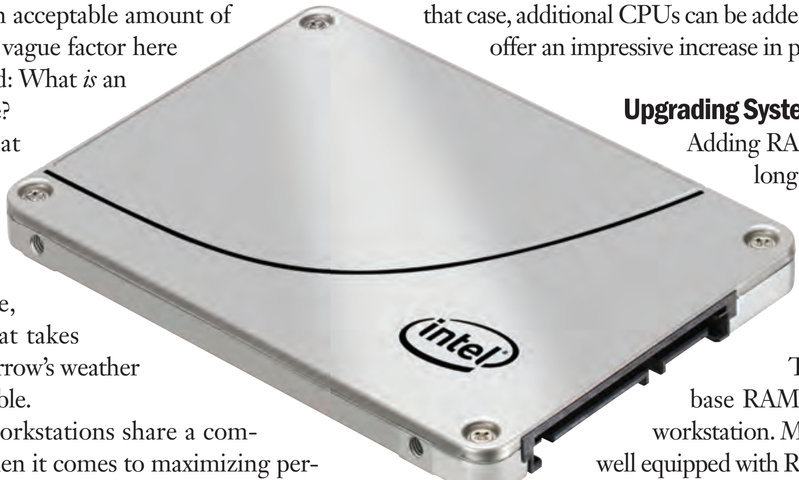
Nearly every workstation can benefit f om upgrades and enhancements when it comes to maximizing performance for simulations.

By Frank J. Ohlh Ors T

The old adage "time is money" proves to be sage advice for anyone in the realm of engineering. Nowhere is this truer than with complex simulations, where reducing time to completion by a few hours, if not minutes, can have noticeable effects on the final outcome.

Take, for example, complex engineering scenarios such as flow simulations, molecular dynamics and weather modeling—each of which requires significant computational power to process a simulation in an acceptable amount of time. However, there is a vague factor here that needs to be addressed: What *is* an acceptable amount of time?

That is a question that is not always easily answered, yet there are some common-sense rules that could be applied. For example, a weather simulation that takes two days to process tomorrow's weather would be far from acceptable.



Nevertheless, most workstations share a common set of challenges when it comes to maximizing performance for simulations. Those challenges are directly dictated by the hardware integrated and the software used for any given simulation. For most simulation chores, it all comes down to the performance of CPUs, GPUs, RAM and storage. Each of those elements has a dramatic effect of the efficiency of the workstation, and how well it performs in most any given situation. Let's take a look at each of these elements and where maximum performance can be garnered.

CPUs Take the Lead

Arguably, the most important element of any workstation is the CPU, which has a direct impact on overall performance. In most cases, the CPU is also the most difficult component to upgrade, because the motherboard, BIOS and several other elements are designed to work with specific CPUs. What's more, CPU upgrades tend to be expensive endeavors—especially when moving from one generation of a CPU to another. In most cases, it makes more financial sense to just purchase a new workstation, instead of dealing with the hassles of a CPU upgrade, which may deliver disappointing results.

There is, however, one exception to the upgrade rule here. Many workstations are designed to support multiple CPUs, but are usually ordered with only a single CPU socket occupied. In that case, additional CPUs can be added economically and still offer an impressive increase in performance.

Upgrading System Memory

Adding RAM to a workstation has long been one of the easiest ways to increase performance. But in the realm of simulations, there may be some caveats to consider.

Take, for example, the base RAM already installed in a workstation. Most workstations come well equipped with RAM, meaning that adding more may not make much of a difference in performance. Other concerns include how much RAM the OS allows access to, and how much RAM the simulation application can effectively use.

For example, 32-bit operating systems, in most cases, are limited to accessing no more than 2.5GB of RAM. The same can be said of many 32-bit applications. In those cases, going beyond 2.5GB of RAM offers less return on performance. There are a few exceptions here, such as utilities that can access above that 2.5GB limit to create RAM drives or caches—but once again, the software has to support access to those options to make it a worthwhile investment.

If you are not limited by software factors or bit levels, though, the rule becomes "the more RAM, the better." Still, there are some limitations to be considered, and those center around system design and concerns around diminishing returns.

When choosing to add more RAM, the most important element to look at is how the OS and the simulation application will use that memory. The questions become "how much memory can the simulation consume?" and "how will the OS allocate the memory?" Ideally, the simulation software will use as much RAM as it is presented with, and leverages that RAM efficiently. The best place for that information comes directly from the software vendor.

One other consideration is RAM speed; some workstations can support different types of RAM, with different MHz ratings. For example, some systems may support 1,600 MHz DDR3 ECC dual in-line memory modules (DIMM), but have shipped with slower RAM, such as DDR3 1,333 MHz, allowing an upgrade to faster RAM for enhanced performance.

The true speed of RAM is dictated by motherboard design. Simply plugging in faster RAM does not equate to enhanced performance. Rather, the supporting hardware must be able to leverage the faster speeds.

Improve Disk Drive Performance with SSDs

Most workstations are designed to balance capacity against performance—at least when it comes to disk drive storage. Because engineering files and workloads can have massive file sizes, workstations are normally equipped with large-capacity hard drives, which by design may offer less performance than smaller-capacity drives.

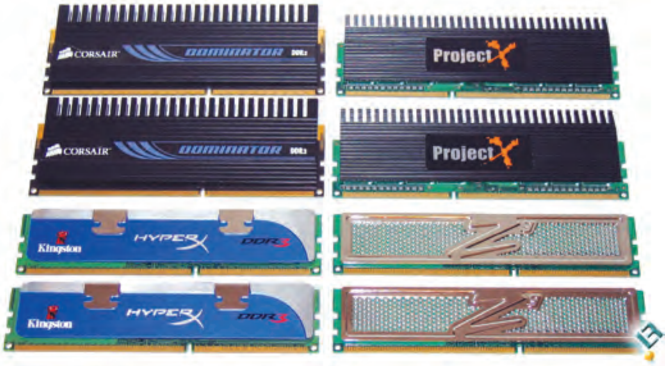
Recent improvements in drive technology, namely in the form of solid-state drives (SSDs), have all but eliminated the size vs. performance barriers. SSDs come in large capacities and offer many benefits over traditional spindle-based hard drives.

SSDs can eliminate the bottleneck created by traditional platter-based drives, and thoroughly optimize system performance. High-performance workstations, especially those used for CAD, simulation or graphics design, are normally equipped with the highest-performance CPU that makes sense relative to budget.

Nevertheless, disk IO performance can be just as important in daily usage to reduce the amount of time that is required to complete a job. Because time is literally money for most workstation users, getting the current job finished and on to the next article of work is essential.

Traditionally, performance workstations have used small computer system interface (SCSI) drives with very high rotational speeds (15,000 rpm) to overcome the issue of disk IO latency. Combining the best-performing drives in a redundant array of independent disks (RAID) 1—or for more performance, a RAID 0 Stripe—creates an effective, albeit pricey solution to the performance challenges inherent with traditional mechanical drives.

SSDs are not hampered by mechanic latency, making that an irrelevant benchmark to show the performance differences between SSDs and traditional drives. Performance is better judged with IOs per second, and SSDs trump physical drives in that category.



Adding more RAM is one of the easiest ways to increase performance.

That performance advantage is compounded even further when SSDs are utilized in a RAID. Generally, RAID 1 or 0 are the norm for workstation use, though in some cases RAID 5 or other configurations may be warranted.

SSDs adding capacity via RAID does not increase latency. If anything, performance is improved as more drives are added—thanks to striping and mirroring technologies that are normally performance-hobbled by physical drives, which do not suffer mechanical latency issues when SSDs are used.

As SSDs continue to fall in price, the technology makes sense for those looking to maximize simulation performance, where large disk writes and reads are the norm.

Graphics Cards

Nothing affects the visual performance of a simulation more than a graphics card. While a lot of number crunching and data movement goes on behind the scenes during a simulation, it is the visual representation of the simulation that has the lasting impact on the observer. Whether it is a simulation of flow, perspective or stress points isn't really the important part here; it all comes down to how quickly, smoothly and accurate the representation of that simulated event is.

Workstation graphics cards aren't exactly cheap, and prove to be a significant investment when upgrading a workstation. However, understanding the value of that investment is a little more complex—it is entirely possible to overinvest in graphics card technologies.

The trick is to correlate needed performance against overall graphics card capabilities, which can be determined with the help of the simulation software vendor. Most simulation software vendors offer recommendations on graphics hardware, and actually do a pretty good job of correlating simulation performance to a given hardware platform.

That said, with some experimentation and in-depth understanding of graphics cards or GPUs, users may be able to pick better performing products than what is suggested by the vendor. It all comes down to what to look for in a graphics card.

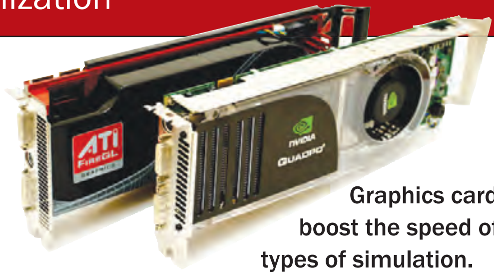
Once again, the simulation software used dictates the best choice. For example, software that depends upon 3D capabilities or other advanced imaging needs may dictate what type of card to choose. Luckily, there is a multitude on the market.

Simply put, a GPU manages how your computer graphics process and display. Thanks to parallel processing, it's typically more efficient than a CPU on software that is designed to take advantage of it. The GPUs that are best optimized for professional graphics-intensive applications, such as design visualization and analysis, are found in workstation-caliber AMD FirePro and NVIDIA Quadro graphics cards.

Professional 2D cards can manage some 3D processing, but are not optimized for regular 3D applications. They generally aren't well suited for engineering. For professional-level simulation work, a Quadro or FirePro 3D add-in card is probably a must. Each of these product lines includes approximately half-a-dozen models that fall into four product categories, such as entry-level, mid-range, high-end and ultra-high-end. (*Desktop Engineering* will review a number of graphics cards in an upcoming issue.)

There are always exceptions, but most buyers will want to match the performance and capabilities of the GPU with the rest of the system—that is, an entry-caliber card for an entry-caliber workstation. Achieving good balance, where each component hits a performance level that is supported by the rest of the system, is the best way to maximize ROI for your workstation purchase and optimize your productivity.

One thing to remember is that GPUs are not solely for just graphics performance; there is a growing trend to use GPUs for general-purpose computing as well. General-purpose computing on GPUs (GPGPU) technology is still evolving, but many of the applications that show the most promise are the ones of most interest to engineers and other workstation users: computational fluid dynamics (CFD) and finite element analysis (FEA). Simulation software developers are porting code to harness GPUs to deliver speed increases. As you might expect, CPU manufacturers are not prepared to relinquish ground to GPGPUs. Intel, for instance, has released its Many Integrated Core (Intel MIC) architecture, which combines multiple cores on a single chip for highly parallel processing using common programming tools and methods. **DE**



Graphics cards can boost the speed of many types of simulation.

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Recipe for Rendering

Many ingredients optimize rendering.

BY MARK CLARKSON

Setting up a machine for rendering is easier than ever. If you're producing your models in, say, 3ds Max or SolidWorks, and you can run the applications themselves, you can almost certainly run their renderers.

That being said, to optimize rendering means to do it as quickly as possible. The need for speed throws a few new ingredients into the mix. In addition to upgrading your workstation, you may want to connect workstations together on a local-area network, or access a cloud of processor cores. The options get a bit more complicated as you go.

LAN Rendering

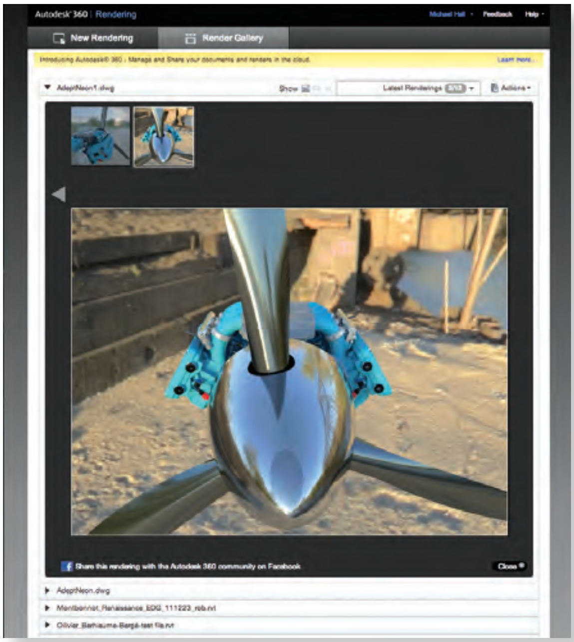
If you're part of an engineering team, there are probably other computers nearby, and they can help you render. Most rendering software makes some provision for rendering across a local network, usually by sending different individual render jobs to different machines. This approach works best for animations or other sequences of images; it's no help if you want to accelerate the rendering of a single, high-resolution image.

There are other ways of distributing the load. The mental ray renderer, for example, supports distributed bucket rendering (DBR), which breaks images down into smaller chunks and distributes those chunks among the processors on the network.

"You can install 3ds max on five machines," says Autodesk's Kelly Michels, "load up mental ray, add the other machines to the render and, when you render, all those machines act as one big processor. If you have 20 processors on the network, they all act as one processor."

Of course, some people might object to you soaking up their machine cycles while they're trying to work. You can set up batch jobs to run renders overnight, but this doesn't help you if you just want faster feedback from your rendering application.

If you do enough rendering to justify it, you can build your own render farm: a networked collection of machines just waiting to run your next render job. If that sounds imposing, companies such as BOXX Technologies, Appro (recently acquired by Cray) and Ciara Technologies build preconfigured render farms that make it easy to get up and running quickly. (See "Create Computer Clusters for Small Engineering Teams," in *DE's* June 2012 issue for more information on clusters and render farms.)



Another option is to let someone else build and maintain a render farm for you, on the cloud.

An Out-of-This-World Option

The cloud, says Autodesk's Rob Hoffman, promises on-demand rendering power: "You can spool up from one to 1,000 machines at a whim, for as long as you require. Once the project is over, all those machines go away. There's no capital expense lingering after the fact."

A local render would be competing for your compute processes, but with a cloud render, your computer isn't affected in any way. You can get on with your work.

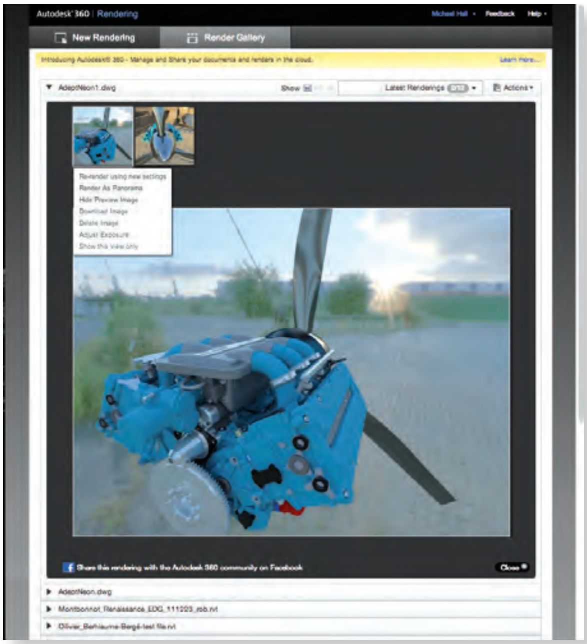
The big problem cloud rendering is that it's not quite ready for prime time.

"Everybody's really on the cusp," Hoffman admits. "There are some cloud rendering options available, but nothing is really in place for the bulk of the standardized rendering solutions."

Autodesk does offer a cloud rendering solution, 360 Rendering, available for newer versions of Revit and AutoCAD. The cloud is just another rendering option within the software, giving you access to lots of processor cores. But cloud rendering isn't currently available for the rest of Autodesk's desktop offerings. Autodesk won't comment, but I don't expect that to last.

There are also commercial render farms like Render Rocket that sell time by the core hour, but they tend to be geared toward the media and entertainment industries. Whether they'll work for you depends on your software and business considerations.

"It's not a matter of if [cloud rendering] is going to take off," says Hoffman. "It's a matter of when. Everybody's eyeing the cloud as a potential savior. This is going to give people the ability to have the rendering power of a Pixar or a Weta, but not have the cost of implementing a rendering farm like that."



While rendering in the cloud with Autodesk 360, your local machine is freed up to do other tasks.

Graphics Processing Units (GPUs)

Aside from the cloud, another big change in rendering technology is the rise of the graphics processing unit (GPU). Developed to take on some of the heavy lifting of displaying graphics on the screen, GPUs can run in parallel. Modern graphics cards can have a lot of them. Dozens. Hundreds.

NVIDIA's new K5000 cards, for example, boast a startling 1,536 processor cores. That's a lot of raw processing power on a card. Coupled with plenty of memory—say, 16GB of GDDR5 high-performance, high-bandwidth RAM—it makes for a fast, powerful parallel computer.

This development is especially good news to those of us who produce 3D renderings.

"Rendering applications are one of the few applications that actually scale with the number of cores," notes Edwin Braun, CEO of cebas Visual Technology.

Consider ray tracing. Computationally, ray tracing involves tracing the paths of rays of light as they bounce through the scene. These rays are independent and calculated in parallel—perfect for a massively parallel computer like the modern GPU-based card. The more cores you have, the faster you can calculate the scene.

Software is the Missing Link

Many software applications use GPU-based rendering, either by itself or in conjunction with CPU-based rendering. But many of them don't. I have started to feel frustrated by applications that don't leverage the processors on my Quadro.

If you do use a GPU with software that takes advantage of it, your CPU and system memory may be freed up during renders, but your graphics card is now busy running simulations and rendering futuristic products. Regular tasks like scrolling a page or even moving the cursor can slow down or grind to a halt.

To counteract that, your killer render machine might very well end up, not just with multiple graphics cards, but with multiple kinds of graphics cards—one for crunching numbers and one for actually displaying information on the screen. NVIDIA's Maximus workstations, for example, pack Quadro cards for OpenGL graphics, and Tesla cards for compute unified device architecture (CUDA)-powered simulation and rendering tasks, as well as powerful system CPUs and plenty of RAM to go around.

Not to be outdone on the parallel processing front, Intel just released its Xeon Phi coprocessor. It uses the company's Many Integrated Core (MIC) architecture to cram 50 x86 cores onto a PCI-connected card, each of which supports four threads. Phi is designed to work with Intel's Xeon E5 family of server and workstation CPUs. According to Intel, Phi is easier to deploy than NVIDIA's CUDA or AMD's OpenCL-based technologies because it uses common x86 software. The initial Phi model, available widely next month, is expected to be used mostly on advanced supercomputers before the technology trickles down to high-end workstations.

As computing power increases and cloud options become more readily available, software makers are responding by updating their software to take advantage of those extra cores, right out of the box. As those updates accelerate, one of the bottlenecks of the design cycle—rendering complex products—will be eliminated. **DE**

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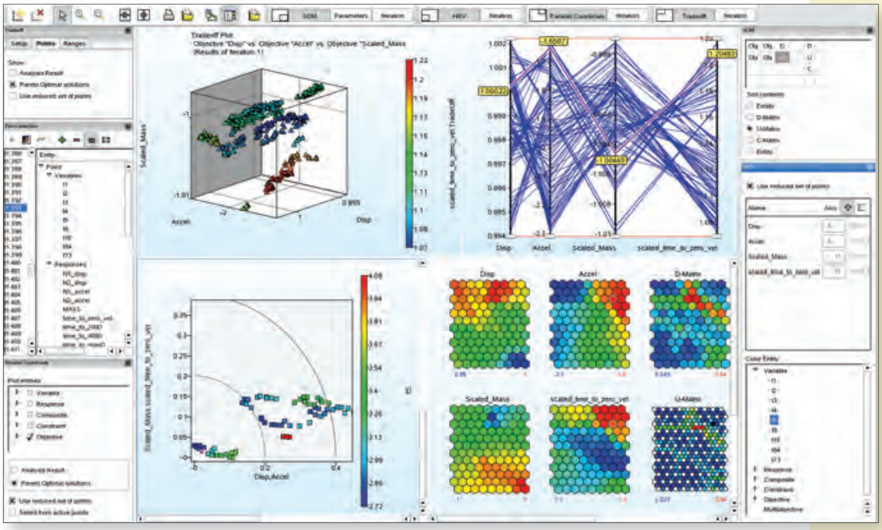

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