

SIMULIA

COMMUNITY NEWS

#13 May 2016

JOURNEY TO THE 3DEXPERIENCE PLATFORM

**COVER
STORY**

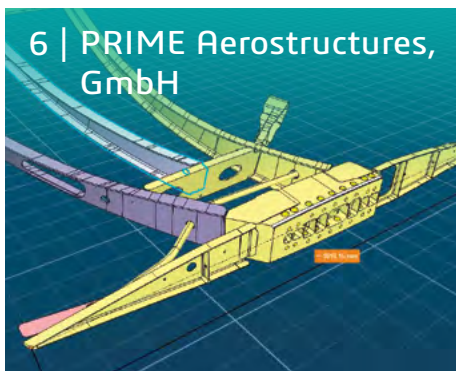
PRIME Aerostructures GmbH

 **DASSAULT
SYSTEMES** | The **3DEXPERIENCE®** Company

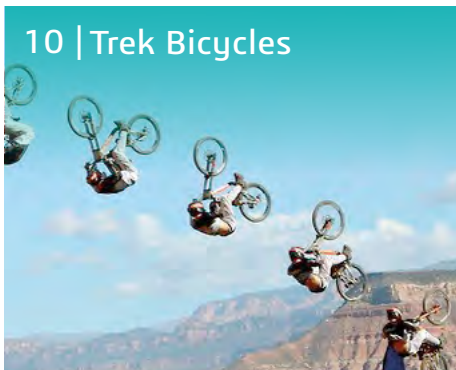
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SIMULATION-BASED SCIENCE POWERS INNOVATION

Whether I am speaking with a customer or just watching the latest online video about a new direction in design and manufacturing, I am always amazed at the vast range of innovative products being developed in every industry; at the same time I am proud. Let me explain.

The fundamental forces that drive us to innovate have not changed much since the beginning of mankind. There are the basic needs and desires: to eat, to protect our families, and to provide them with a healthy environment to grow. What has changed is that as the population increases, we are faced with an increasing set of constraints on the world's resources. How do we continue to innovate within these constraints? The answer is simple: Science! Innovation requires natural curiosity and determination to better understand science; we can then translate this knowledge into improved mathematical models that can be used by designers, engineers, and researchers.

As the person responsible for SIMULIA R&D, I believe that to be successful at innovation, the tools must:

1. have a strong scientific foundation;
2. provide you with the ability to explore designs automatically and quickly through realistic virtual testing;
3. reveal an understanding of the behavior that is beyond the obvious and expected; and
4. be technically robust so you can rely on them and be confident in your results.

Providing best-in-class tools to help you create innovative products is something we have been working on for decades. However, bringing everything together requires a radically new approach. Over the past couple of years, we in Dassault Systèmes have taken the game changing step to create such an environment through the **3DEXPERIENCE** platform. At SIMULIA, we continue our focus on creating the best simulation tools to guide you through the confluence of science and simulation. These tools are the combination of new applications working seamlessly with the well-established products that you are comfortable with and have confidence in.

We are excited that our customers will be able to showcase their innovations driven by science and simulation, at the upcoming Science in the Age of Experience conference in Boston. This forum provides our international community with an opportunity to meet other innovators as well as Dassault Systèmes partners and domain experts. For more about this combined SIMULIA and BIOVIA event, please see the article featuring SIMULIA's Chief Technology Officer and BIOVIA's Chief Strategy Officer on page 4 of this issue of SCN.

Whether or not you attend Science in the Age of Experience, you can read about the work that some of our customers will be presenting there: Silvestre Pinho's research at Imperial College London (page 22) reveals how his team is leveraging a multiphysics molecular dynamics Finite Element Method for the design of composite and graphene-based materials. On page 10, you can read how Trek Bicycle uses simulation to predict the performance of bicycles.

And you won't want to miss our cover story, the second in a three-part series on PRIME Aerostructures' journey from our traditional SLM product to managing all their simulation processes and data on the **3DEXPERIENCE** platform.

So why am I proud? I am proud because as an engineer and a leader in Dassault Systèmes R&D, we are building tools that have helped—and will help—all of you to be innovators. We look forward to supporting you as you continue to leverage the virtual world to improve the real world.

*COLIN MERCER,
Vice President, SIMULIA R&D*

SIMULATION FROM NANOSCALE TO MACRO—AND THE HUGE SHIFT COMING IN THE WAY WE DESIGN EVERYTHING

The convergence of SIMULIA and BIOVIA at this year's "Science in the Age of Experience" event in Boston reflects a deliberate decision on the part of Dassault Systèmes to highlight the profound changes that are coming in the way we all look at the relationships between simulation, design and manufacturing.

BIOVIA's focus is on biological, chemical and materials modeling and simulation, particularly on the nano and molecular level (with tools for collaborative discovery plus laboratory and manufacturing process management as well). SIMULIA's strengths include deep materials modeling, simulation and optimization capabilities from which product performance, quality and reliability can be predicted on a meso- to macro-scale.

The ability to create unique materials—designed at the molecular level to produce specific results in a final product—is the enticing promise of a workflow that combines the power of BIOVIA and SIMULIA under the **3DEXPERIENCE** umbrella.

Why has the potential of such powerful, complementary technologies working together taken on an even deeper meaning now? Because there are events taking place outside the world of software development that are beginning to have a profound effect on how we all think inside that world.

In the words of Bruce Engelmann, Chief Technology Officer for SIMULIA, "We have arrived at a critical moment where something momentous is happening outside the software realm—in the world of manufacturing—that is affecting the way we'll all be looking at simulation and design going forward."

ADDITIVE MANUFACTURING CAUSES A SHIFT IN THINKING ABOUT ALL DESIGN

That "something" is the achievement of industrial additive manufacturing (AM). The technology (which is also known as 3D printing) has been around for a while. But AM is no longer just for prototyping: it can now produce finished, certified end-parts.

While AM is not expected to replace all conventional manufacturing processes, it can certainly complement some of them in ways that optimize supply chain efficiencies. It also offers a previously unheard of level of design freedom that lets engineers think outside the box in highly creative ways. You can greatly reduce part count, lightweight with internal lattice structures, print electronics inside a product, customize everything from patient-specific medical devices to personalized consumer goods—and more.

"Additive manufacturing is going to fundamentally change the way people design things," says Engelmann. "When you design for AM, simulation and design have to be done at the same time; they can't be sequential."

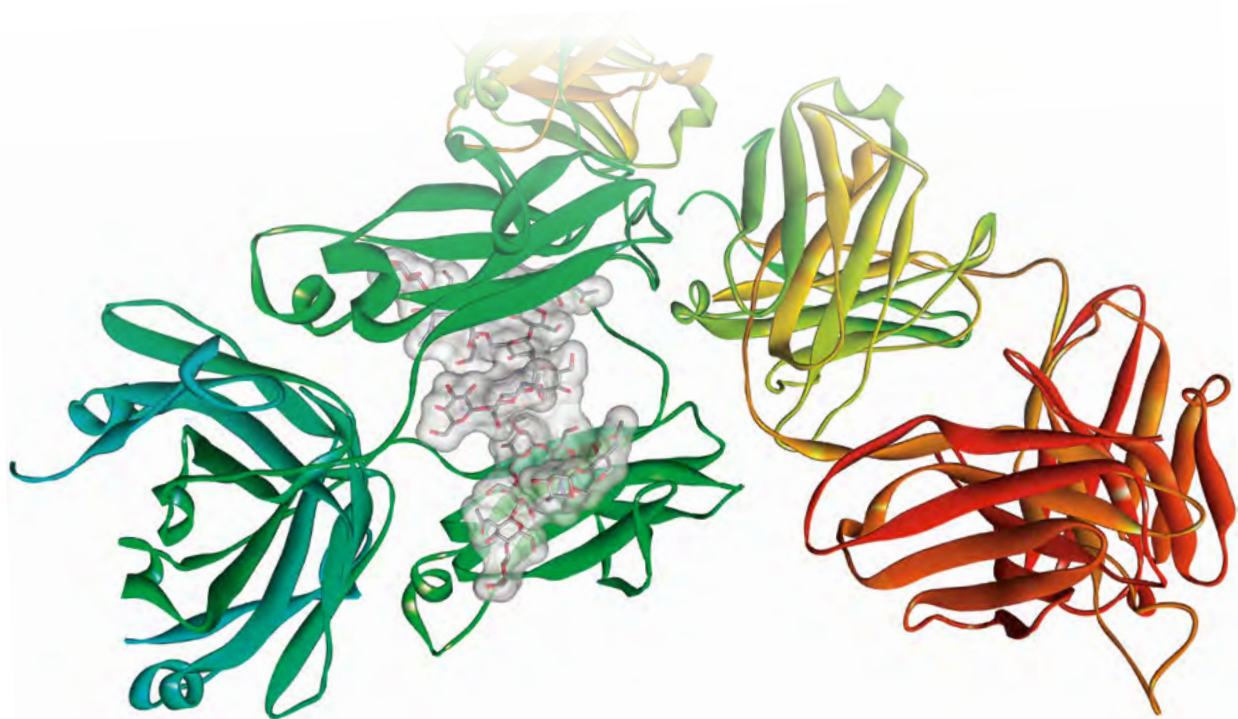
Now as our community of users is well aware, the benefits of putting design and simulation together have been apparent for some time—no matter what your final manufacturing method is going to be. Says Engelmann, "Our customers are seeing that the whole process of product development is enhanced when you integrate simulation with design. And optimization is the pinnacle of that, where you are literally running simulations underneath as you are designing the part. As you iterate on your design and move around your parameters, you're doing so based on results of an optimization that's happening underneath."

Engelmann points out that, despite the availability of advanced simulation tools, some people have up until now been able to "get by" applying them sequentially. But he sees the growing impact of what could be called "additive manufacturing thought" affecting the way everyone thinks about all design. "The design envelope is no longer considered to be a static concept," he says. "Of course human input is still needed for surfaces, and for fixed points like bolt holes, but everything else within the design space is now available for software tools to suggest an optimal design."

NEW CAPABILITIES IN CATIA DELIVER OPTIMIZED DESIGNS READY FOR MANUFACTURING

Not surprisingly, Dassault Systèmes has risen to meet the challenge of this new freedom-of-design mindset. We understand that, no matter what technology is used to manufacture it, a finished product still has to perform to the final customer's complete satisfaction.





To achieve that goal, every creative, organic part shape design (perhaps created with SIMULIA's Tosca and/or fe-safe tools) needs to be translated back into the geometry of a CAD file. Why? Because CAD data still drives everything from higher-level simulations (drop-testing, crash, etc.) to manufacturing—no matter whether you are using plastic injection molding or a metal AM machine.

Since our customers look to Dassault Systèmes to provide leadership in CAD reconstruction capabilities, our best CATIA and SIMULIA teams have spent the last year building it right into our CAD application for the designer and are in the process of making it available across multiple industry applications.

WIDENING THE DESIGN ENVELOPE

It's important to keep in mind, as the design envelope widens in such exciting ways, that it extends in both directions: outward towards the macro, finished product but also downward into the micro level of molecules from which that product is made. At the same time that our control over the end result is enhanced, new windows are also opening into pre-design considerations of materials choice. Predicting material behavior has only become more critical as processes like additive manufacturing—which melts and combines materials in novel ways, often at very high temperatures—enter the production picture.

So here's where BIOVIA enriches that picture.

THE BIOVIA AND SIMULIA CONVERGENCE

"We often describe our everyday experiences through a macro world lens," says Reza Sadeghi, Chief Strategy Officer of BIOVIA. "However, there is a hidden, micro world that supports these life experiences. Scientific developments are now enabling us to harness our macro and micro worlds concurrently."

In the past, new materials used to take decades from discovery to commercial viability—and those materials were typically found in nature. "But the demand for faster innovation and

better performing products exceeded the performance envelope for available materials," says Sadeghi. "Science responded by developing engineered materials for which quantum structure and characteristics could be synthesized to meet multifunctional performance objectives at the macro scale."

BIOVIA enables such materials engineering by helping users design and select specific molecules, biologics and materials and refine their application with modeling, simulation and predictive analytics to produce smart coatings, lighter stronger composites, and eco-sustainable polymers. "We are fast approaching the point of using material as a variable, not a constraint," says Sadeghi.

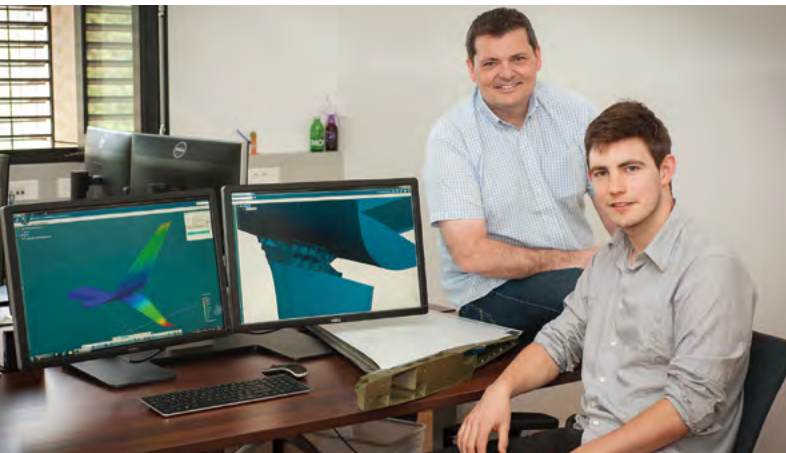
He notes that designing and engineering products takes the skills, talents, and brainpower of many specialists—all of whom need to communicate effectively to ensure that everyone is working from the same information towards the same goals. "The **3DEXPERIENCE** platform ensures that everyone involved is working from a single version of truth," he says. "There's traceability for how products evolve, from concept to scientific discovery and all the way through manufacturing."

"The convergence of the BIOVIA and SIMULIA brands, catalyzed by the **3DEXPERIENCE** platform, seamlessly fuses science-driven materials and engineering capabilities with virtual product engineering and performance simulation in terms of data, protocols, methods, models and knowledge. This convergence finally bridges the abyss between the macro and micro worlds, enabling the realization of atom-to-product design and optimization."

For More Information
www.3ds.com

TAKING THE HIGH ROAD

PRIME Aerostructures goes to the Cloud to prepare their engineers for on-premise installation of the **3DEXPERIENCE** platform



Roland Zeillinger (left) and Andres Belles Meseguer (right) with the Ventral Strake on the desk.

When we first spoke with Roland Zeillinger, president and CEO of PRIME Aerostructures GmbH [see the previous issue of SCN], his company was enjoying the benefits of a move to simulation lifecycle management founded on ENOVIA. His team of 12 engineers was employing new capabilities for data traceability, templates and task automation in their aerospace and automotive design work—all of which were helping them better serve their customers.

But Zeillinger was still looking for more: an ideal world with a single, front-end webpage where he'd have access to every app he needed. "Your one-stop shop," was how he described his goal, "Where you can just go right in there and do all your work." He began thinking about upgrading to the full **3DEXPERIENCE** platform. Three months later, here's his company's progress report:

Of course as everyone who works in the digital realm knows, even in the best of all worlds data migration can present challenges. PRIME Aerostructures was on version R2013x and wanted to migrate to R2015x. As they began the process, Zeillinger and his CATIA/ENOVIA value-added reseller (VAR), Guenther Mueller of EBM, found there were some issues with data reading and visualization between versions that needed to be considered.

But as EBM worked on those IT issues for him, Zeillinger decided to think further ahead, attending a couple of webinars on the newest version of the **3DEXPERIENCE** platform—R2016x. "I saw all the new capabilities in R2016x and realized we could get all the 'latest and greatest' simulation tools there," he says. "As my company primarily works on the simulation side, I began thinking 'why don't we just move directly to the latest version?'" He decided to push ahead with that goal.

And here's where Zeillinger made another decision that began paying off immediately for his team: While EBM tackled the on-premise migration, PRIME Aerostructures began exploring the latest version of the **3DEXPERIENCE** on the Cloud. "To make sure we were not losing a lot of time in terms of how we work, we decided to move ahead with 2016X in the On-Cloud version," he says. "This move brings with it a paradigm shift in our way of working, so while we waited for our on-premise installation to be finalized, we could go ahead and try out all the Roles and familiarize ourselves with what's available on the Platform right now."

TRYING OUT DIFFERENT ROLES ON THE PLATFORM

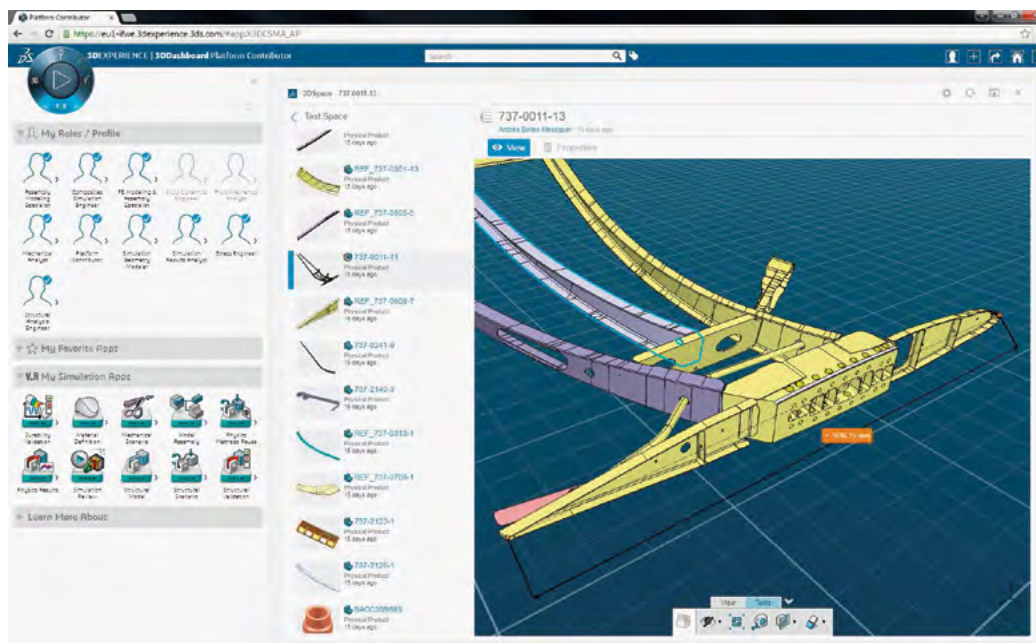
The 'Roles' Zeillinger is referring to are groups of related applications available in **3DEXPERIENCE** that streamline the user's access to only those specific applications most appropriate to their workflow needs. Roles are tailored to every possible discipline in a company—from design, engineering and simulation, to manufacturing, sales, marketing, finance, procurement and management. The role of Stress Engineer, for example, delivers mechanical, thermal, and durability simulation capabilities for product design with simulation-based guidance for all designers. The role of Structural Analysis Engineer provides a broad environment to conduct structural static, thermal and dynamic response simulation of parts and assemblies. The Mechanical Analyst role provides expert tools needed to perform advanced simulations. And the Composite Simulation Engineer role covers composite layups defined with the CATIA Composite Design (CEG) tool in advanced simulations of composite parts.

By allowing his designers and engineers to get used to all the available roles in advance, Zeillinger could 'hit the ground running' when their on-premise installation went live.

"We started by focusing on our two main groups, the engineers and the analysts," says Zeillinger, "comparing the available analysis tools to the functionalities in the engineering roles. For example, we look at Stress Engineer, or Structural Analysis Engineer, on one side—and then on the other side we have the expert Mechanical Analyst role."

"The pricing is something to consider as well; the On-Cloud version lets you know exactly what you are paying for, and what you get for what you are paying."

—Roland Zeillinger, president and CEO of PRIME Aerostructures GmbH



Screenshot of 3DSpace App in the **3DEXPERIENCE** platform running in the Internet browser. Image courtesy of FACC Operations GmbH.

"For us as a customer of Dassault Systèmes it's important to really know how far we can go with one role, and where we do need to use a different one," he says. "This knowledge is not only for us, it's also because we ourselves are a VAR and are introducing **3DEXPERIENCE** to some of our customers.

"We are a fairly small company and not all of our engineers need a Mechanical Analyst role; maybe the Fluid Dynamics Engineer role is sufficient—these are all things we need to find out." For his CATIA staff, there are some simulation roles that could be helpful—and vice versa, Zeillinger notes. "The Assembly Modeling Specialist role, or the Simulation Geometry Modeler, are interesting, not just for the analyst, but for the designer as well. Our designers find that these modeling capabilities provide an easy and fast way to create geometries without having to parameterize everything. And in the case of the Composites Simulation Engineer role, this contains many SIMULIA tools but much of it is actually on the CATIA side for designing surfaces and plies," he says.

Wearing their other "hat" as a VAR, PRIME Aerostructures is making a point to completely familiarize themselves with all the capabilities that come with every **3DEXPERIENCE** Role so they can best tailor their end-customers' workflows to the needs of their individual businesses. "Our own experience with the **3DEXPERIENCE** platform in turn helps us support each Dassault Systèmes user, along with the dedicated sales and technical teams, so that their transition to the **3DEXPERIENCE** platform is both targeted and efficient," says Zeillinger.

INTUITIVE LEARNING WHILE DOING

Reactions from PRIME Aerostructures staff to trying out the roles themselves On Cloud have been positive. "My experience with the **3DEXPERIENCE** platform is that it's very intuitive," says associate Andres Meseguer. "When you find the role you need you can locate the tool you're looking for pretty easily.

Once you know where the tools are you can do a lot of things very quickly. The graphics are very modern and nice looking."

Adds Zeillinger, "It's very easy to work on **3DEXPERIENCE** without a lot of training. When you want to de-feature something or merge surfaces, for example, it's very clear what to do with the functionalities within a specific Role."

This ease of transition to the Platform is an important benefit of the **3DEXPERIENCE**; the ways in which the user is empowered by simulation are customized to the Role they are using.

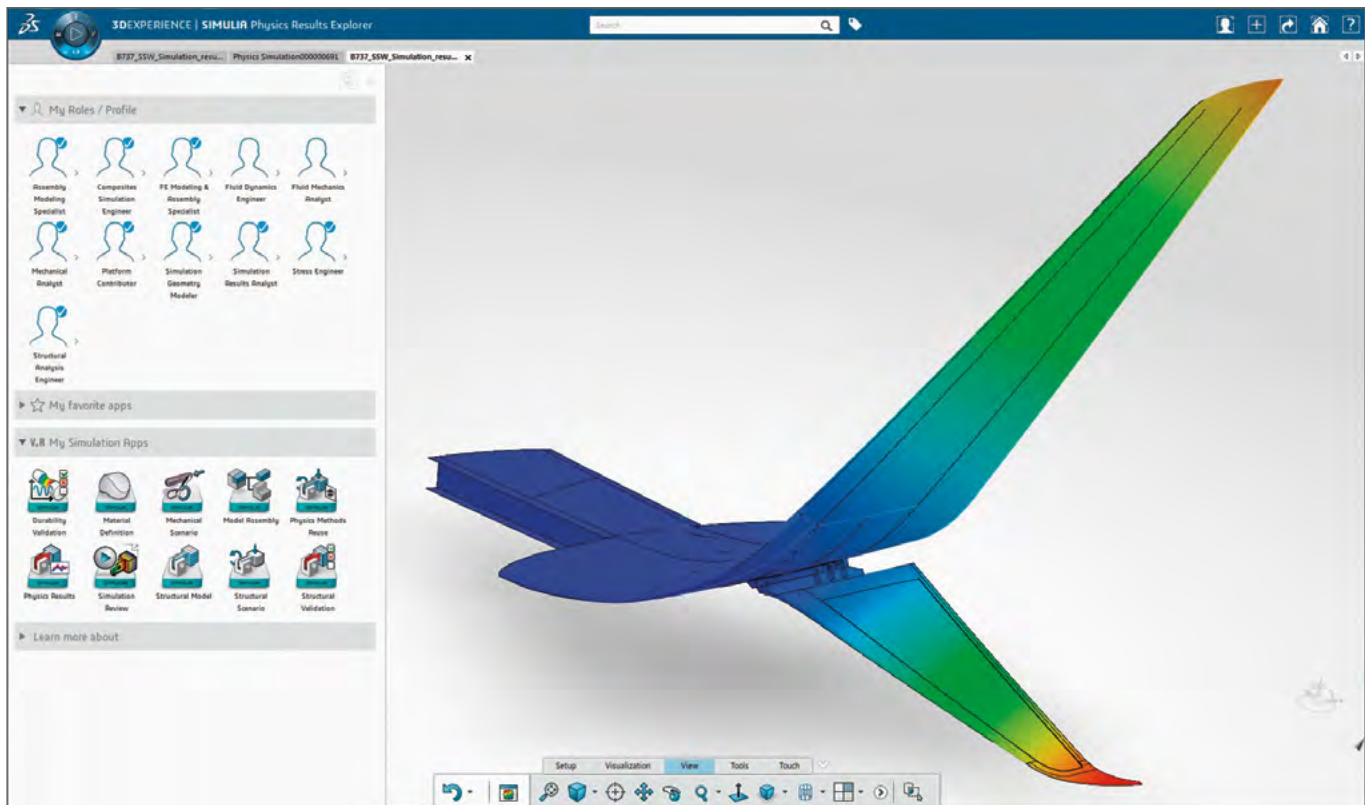
"For example, in Stress Engineer there is essentially a 'wizard' that tells you how to proceed," says Meseguer. "You don't have to give the command 'make model'—the model is created automatically. You don't have to be an expert in finite elements; you can produce a nice model with contact, parts, etcetera—and calculate from there."

The 'wizard' that Meseguer is referring to streamlines the interface for the non-expert user, guiding them through tasks that an expert would take for granted. For the expert, of course, a complete FEA framework is available, allowing them to pick and choose exactly what they want to do to solve a task. This kind of "democratization" of simulation capabilities is extremely powerful. It allows all levels of users to carry out their respective tasks themselves, yet be understood clearly by their colleagues, and collaborate from different vantage points, because everyone's results are based on the same robust solvers.

TAKING IT TO THE REAL WORLD

As the PRIME Aerostructures team gets further up the learning curve on R2016x via the Cloud, they are trying out their new **3DEXPERIENCE** capabilities on actual projects. "We're already doing a lot of things On Cloud," says Zeillinger. "We have simple models we use for quick checkups, but we are also

Case Study



Screenshot of Physics Results Explorer App in the **3DEXPERIENCE** platform showing results from the B737 Split Scimitar Winglet. Image courtesy of FACC Operations GmbH.

using existing projects internally, rerunning them On Cloud to see how it all works. We can evaluate previous issues we've had, pre- and post-CAE, and determine how they might come out in the new Platform. We're definitely not just playing with stick models, we're using real live examples."

The goal for PRIME Aerostructures remains an on-premise installation but, at press time, they had just made a decision to go for a new operating system and a new server as well. "We've decided we want more memory and power in our database server," says Zeillinger. "And it was cheaper to buy a new one rather than upgrade the old one."

This may mean starting a clean installation from scratch, which is what the company did when they first migrated to ENOVIA (as detailed in the previous article). "We are considering two options right now," says Zeillinger. "There's direct data migration or, like we did last time, we simply export everything from the older version and import it all back into the new one."

So the journey for PRIME Aerostructures is not yet over but, in the meantime, Zeillinger points out, "We're giving our engineers plenty of time to learn **3DEXPERIENCE** On Cloud to get all our processes done. When our on-premise installation is finished, we'll have already defined our roles, methods and workflows and know exactly what we need to purchase."

While Zeillinger is committed to having R2016x on-premise for his own firm, he points out that an option for some other

companies may be to go directly to the Cloud and skip an on-premise installation. "Speaking as a VAR now, I would have to say that, particularly if you have just occasional simulation needs and you don't have your own IT or database people, On Cloud is very easy to handle," he says. "The pricing is something to consider as well; the On-Cloud version lets you know exactly what you are paying for, and what you get for what you are paying."

"But even if a company has decided to go for an on-premise version, it's very good to get to know the tools ahead of time with the On-Cloud version in parallel," he emphasizes. "You let your IT guys figure out all the on-premise details, but meanwhile your engineers can be working with the Cloud to figure out any issues or changes in process they need to make to be fully functional when your on-premise installation is complete. I think that's a good thing."

How will PRIME Aerostructure's final on-premise migration to R2016x be accomplished? And will the engineers' On-Cloud experience enable them to be fully functional on the Platform when that happens? Stay tuned for the final installment of their journey in the next issue of SIMULIA Community News...

For More Information
www.primeaero.at

3D PRINTING IN AEROSPACE: EXTENDING THE FRONTIER OF THE POSSIBLE

Additive manufacturing, or 3D printing, is often associated with rapid prototyping applications, where there are no functional or load-bearing requirements on the printed parts. However, the situation is rapidly changing. AM technologies have matured significantly in recent years, and industrial-grade materials are now being used in many AM processes to produce parts for production applications in the aerospace, automotive, and many other industries.

SIMULIA is addressing the key AM challenges by collaborating with Stratasys, a leading manufacturer of 3D printers for more than 25 years, to develop a new end-to-end simulation and optimization process including everything from upstream material design to downstream manufacturing processes to ensure that the part performs as desired in a production environment.

3D PRINTING IN AEROSPACE: EXTENDING THE FRONTIER OF THE POSSIBLE

Innovation in aerospace is accelerating, advancing frontiers at the component and product levels in manufacturing operations, along supply chains and, in some cases, even at the model level. Parts can now be created with complex geometries and shapes that in many cases are impossible to create without 3D printing. Low aerospace volumes make 3D printing an attractive, less costly alternative that can even replace conventional CNC machining and other tooling processes for smaller-scale parts and finished assemblies. Aerospace innovators are embracing 3D printing beyond prototyping and are aggressively pursuing new applications for the technology.

DRIVING DOWN COST AND WEIGHT, SAFELY

Innovative aerospace manufacturers want to drive down the cost and weight of aircraft, improving economy and design aesthetics and adhere to stringent FAA regulatory and compliance standards. 3D printing technology can produce durable, stable end-use parts—bypassing the traditional production line altogether. The Production Series of 3D production systems—the Stratasys® line of larger, top-of-the-line 3D printers—uses a range of materials, including high-performance thermoplastics, to create parts with predictable mechanical, chemical and thermal properties.

Boeing, for example, uses 3D printing while manufacturing aircraft for multiple airlines. Although the plane itself is essentially the same from one order to the next, the interiors vary. As a result, a particular air duct may bend to the right instead of upward. So ordering a custom \$40,000 tool made overseas to create just 25 of these parts is extravagant and time-consuming. Boeing overcomes these problems by 3D printing the custom end-use parts and installing them directly on the aircraft.



Shown prepped for test flight, this UAS by SelectTech Geospatial with all-FDM airframe was the first such craft to take off and land on its own power.



NASA outfitted the Mars rovers with 70 3D-printed parts.

Many other leading aerospace manufacturers are also using 3D printing to fabricate jigs and fixtures, production tooling and final end-use parts. Production parts for instrumentation (Kelly Manufacturing), air ducts (Taylor Deal) and wingspans (Aurora) are airborne today in commercial, military aircraft and UAVs.

Have you embraced 3D printing to help you accelerate innovation? The pattern of adoption and outcomes from implementation are clear: 3D printing accelerates change in aerospace manufacturing, and companies small and large should embrace and learn to leverage this technology.

Learn more about Stratasys and 3D printing in Aerospace and other industries at www.stratasys.com.

For More Information
www.stratasys.com



Photo by Malcolm McIlwain

TREK BICYCLES TAKES SIMULATION TO THE EXTREME

With the power duo of SIMULIA Abaqus and True-Load, Trek models the toughest riding scenarios to push performance to the next level

Whether you're an avid mountain biker or a road-riding enthusiast, the challenge is to go farther, climb higher, land that perfect jump, and pedal faster—all in the spirit of nailing that next level of performance.

The engineering team at Trek Bicycles embraces the same mantra, not just on the bike trail, but in research and development with simulation. What started out as a casual jaunt into simulation territory to analyze the occasional composite structure evolved into a rigorous exercise across all their bike programs—once Trek engineers got a taste for how the methodology raises the bar on design optimization.

For a culture steeped in hard-driving performance, it wasn't much of a stretch for Trek's design engineers to extend their passion for biking to the immersive 3D experience of simulation.

"Lighter, stiffer, faster, and better ride quality are common goals," says Jay Maas, analysis engineer, who joined Trek in 2010 as a dedicated specialist to help expand the simulation efforts and who cycles nearly every day. "We couldn't have stayed ahead of the competition without pushing our analyses to the next level."

PUTTING SIMULATION TO THE TEST

With its 1,600 worldwide employees, 1.6 million bikes sold each year, and claim as North America's largest manufacturer of carbon bikes, it's fair to say Trek is making good strides in lapping the competition.

The bike manufacturer took its first spin with simulation in 2009, complementing its use of the Dassault Systèmes CATIA 3D design and engineering applications with the Abaqus finite element analysis (FEA) application from SIMULIA. Trek's initial use of the tools was primarily limited to simulating laboratory testing to help predict bicycle stiffness performance characteristics such as sprinting, climbing, and cornering.

"Using simulation to predict that weight and stiffness ahead of time reduced the number of make-and-break cycles necessary to get where we needed to be."

—Jay Maas, Analysis Engineer, Trek

By predicting stiffness values in the virtual world, they could better balance the need to put physical bike gear through its paces in order to meet performance targets.

"We'd previously been doing more design iterations and expending significant resources to get the bike weight and stiffness to a target we were happy with," Maas recalls. "Using simulation to predict that weight and stiffness ahead of time reduced the number of make-and-break cycles necessary to get where we needed to be."

Fresh off those early successes, and with Maas and another specialist onboard to champion simulation, Trek engineers across various bike programs were ready to branch out to other types of analyses. Maas was a perfect candidate to grow the simulation campaign, having done similar work in the aerospace industry for 12 years.

Even better, Maas' simulation knowledge dovetailed with his passion for all things bike-related. "It was a perfect fit doing everything I love about engineering and using Abaqus to design a product that I love, which is bikes," he says.



This Abaqus model of a Trek full-suspension mountain bike depicts solid and shell elements linked with constraints and connectors, a welded butted aluminum frame, and a magnesium rocker link.

The accessible user interface of Abaqus combined with its integration of implicit and explicit capabilities in a single tool-set made it easy for Maas to encourage the extended engineering team to apply FEA to other initiatives, from cross-country to downhill bicycles. Trek maintains many different mountain bike platforms and each platform has multiple frame sizes, adding up to a host of configurations. "We have many dozens of bikes with many load cases each running through the analysis group in a given year," Maas says. "It is a really large quantity of work."

Once the team began embracing FEA, the engineers became interested in applying the tools to address other questions beyond the standard test cases in the lab. One item of interest was understanding more about what happens to bikes when they are being ridden in the field, especially by Trek's professional racers, who specialize in gravity-defying stunts like front flips across a 72-foot canyon or barreling down the side of a mountain at 60+ miles per hour. During these extreme events, the professional racers' bikes can experience some extreme loading conditions.

"These athletes push the bikes well past the average consumer and are hyper-sensitive to variations in stiffness and where that stiffness is within the bike," Maas explains. "They also push for faster, lighter, and better ride quality so they can excel and win races which, in turn, pushes us to design faster and lighter bikes without compromising strength, durability, and ride quality."

TAKING IT TO THE EXTREME

It was about this time that the Trek team crossed paths with Wolf Star Technologies, a SIMULIA partner that offers True-Load, a complementary solution that could leverage Trek's existing FEA models to identify the optimum locations on which to place strain gauges on the physical bikes—and then back-calculate loading. Wolf Star president Tim Hunter developed and refined the technology over his decades of work at a major motorcycle company. Once strains are collected, the data is read into True-Load to calculate load-time histories that are guaranteed to match the measured strain to within 2% at every point in time. This enables the Trek team to accurately quantify the loads created in the field and then compare that load to current laboratory tests.

"Jay realized the need to capture true loading of his bike frames in order to drive realistic simulation that matched the real world," says Hunter. "True-Load was a tool that could provide a clean, complete solution to meet those needs."

The Trek team is blessed with a private trail system—236 acres of pristine single track that serves as an outdoor laboratory—perfect for testing extreme riding conditions. The team picked two of the most extreme trails within their system to test drive its Abaqus/True-Load simulation combination for the bike's load cases: The first was Deer Hunter (see Figure 1), a large drop capable of fully compressing the rear suspension and the second was Mojo, a jump also capable of fully compressing the rear suspension, but which allowed the rider to rotate the bike.

The team employed a miniature on-board data acquisition system (DAS), which was small enough so it didn't hinder the rider, and outfitted a Session 29er bike with 12 strain gauges, three tri-axial accelerometers, one linear potentiometer, one Hall Effect sensor, a custom-designed wire harness and carriage system, and an on-board battery (see Figure 2). They also used high-speed cameras and Go Pro video to capture the event.

Using True-Load and Abaqus, the team set up a linear static model in which the boundary conditions and unit load cases mirrored the field-collected data from the bicycle frame (see Figure 3). The material model and mesh also reflected exact strain-gauge placement and orientation—all critical fine-tuning that wouldn't have been possible without Abaqus and True-Load, Maas says.

Strain data is extracted from the event file for when the bicycle is in a quasi-steady state and when the suspension is fully compressed. This also corresponds to the peak loading during the event. This strain data is used within True-Load/Post-Test

Case Study



Figure 1. (Left) The Abaqus/True Load simulation used two extreme events to test drive the bike's load cases: Deer Hunter (shown above: a bike and rider poised to drop from a raised platform down to the ground) capable of fully compressing the rear suspension, and Mojo, a jump that did the same but also allowed the rider to rotate the bike. Figure 2. (Right) Strain gauges attached onto a bike frame.

where unit loads are scaled throughout time to minimize errors between the FEA strains and the measured strains. The resulting loads created a near perfect match between simulated strain and measured strain.

As part of the True-Load/Post Test process, an HTML report is output to showcase error reporting, load amplification curves, and strain history plots. Wolf Star's True-Load QSE tool came into play to perform additional post processing to obtain external (reaction forces) and internal loads (loads from free body diagram cuts).



Figure 3. Abaqus/True Load model.

The analysis work confirmed that loads produced by the professional riders can exceed those generated in normal use. Trek engineers also learned that the load share in the rear end of the bike is different for each bike model.

The exercise now gives them a process to determine real-world loads for other bikes going forward. By understanding the load distribution in the rear end of the bike and how professional riders can cause different types of stresses, the engineering team can make specific design changes that better address those performance needs for all types of riders.

Trek's professional riders won't be the sole beneficiaries of the company's expanded simulation capabilities. Maas says this initial True-Load project has once again sparked interest across Trek's engineers, many of whom are now ready to race ahead with their own simulations on different bike platforms.

Says Maas, "We race to make bikes better. It's what drives our development and we will continue to keep the engineering groups informed about all these capabilities so we can cross-pollinate our tools and methods and let everyone take advantage of them. We believe this will make bikes better for all riders."

For More Information
www.trekbikes.com

INTRODUCING THE 3DEXPERIENCE LAB

Simulate the change you wish to see in the world

It is a shadowy evening in the year 1879. While most were relaxing by dim candlelight a devoted inventor, Thomas Edison, leapt for joy. After the trial and error of over 1,000 failed attempts he finally created a light bulb that wouldn't blow up, or burn out within minutes. Through his commitment, Edison created positive change for society—increasing nighttime productivity, providing safer home and work environments, and paving the way for future inventions like radios, televisions, and ultimately smart phones.

Flash forward to the present...Dassault Systèmes has launched the **3DEXPERIENCE** Lab to support those innovators who also wish to change the world, or simply just make it a better place to live. We embrace the social enterprise and draw upon our long history of engineering in the virtual world to empower those with new perspectives on innovation. The **3DEXPERIENCE** Lab brings a new framework of openness, merging collective intelligence with a cross-collaborative approach to foster entrepreneurship and bring new experiences to life, as well as to strengthen society's future of creation.

Dassault Systèmes recognizes that together we can face the countless challenges in our world ranging from unsustainable energy consumption to natural disasters to affordable healthcare. Entrepreneurs, makers and innovators everywhere are invited to apply for **3DEXPERIENCE** Lab support under the six themes: City, Life, Lifestyle, Internet of Things, Ideation and Fablab. Our goal is to build a community of intelligent, creative and passionate people, focused on positively impacting society, through disruptive, groundbreaking projects.

As an integral part of the **3DEXPERIENCE** Lab, SIMULIA's realistic simulation technology is already driving innovation. One example is a project called 'Organ Twins.' With an estimated annual number of deaths due to medical errors in the hundreds of thousands worldwide, a medical startup, Biomodex, is leveraging realistic simulation technology to modernize the way the medical profession gains knowledge and experience. Biomodex uses 3D printing to fabricate life-like human organs that respond as a real organ would. They can be used by medical students and doctors to learn and practice surgical procedures before proceeding with a live operation. This project has the potential to improve the lives of billions of people around the globe!

"You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete."

– Buckminster Fuller – 20th century inventor & visionary



Another visionary **3DEXPERIENCE** Lab project is the Living Heart Project. This translational initiative unites leaders from cardiovascular research, education, industry, regulatory agencies, and practicing cardiologists on a shared mission to use **3DEXPERIENCE** simulation technology to develop highly accurate personalized digital human heart models. The Living Heart Project moved from theory to reality after signing a five-year collaborative research agreement with the United States Food and Drug Administration (FDA) and launching the first commercial heart model in May 2015.

To learn more about the **3DEXPERIENCE** Lab or to begin your groundbreaking, disruptive project with us today, visit <http://3dexperiencelab.3ds.com>

CONSIDERING TOPOLOGY OPTIMIZATION FOR ADDITIVE MANUFACTURING APPLICATIONS

Sakya Tripathy, SIMULIA Additive Manufacturing Senior Technical Consultant

Additive Manufacturing (AM), known by the more popular moniker of 3D Printing, is giving designers freedom like never before to dream, innovate, and realize their concepts. Iconic companies in the aerospace, automotive, and life sciences industries have embraced this paradigm shift in manufacturing while others are following suit. Jet engine nozzles with complex ducts, light-weighted brackets in airplanes, porous medical implant surfaces for osseointegration, latticed parts for race cars—among many others—have moved beyond functional prototypes to in-service usage. This adoption is being aided, in no small measure, by the rapid advances in simulation technology for multiphysics optimization and predictive analytics. With design no longer constrained by the subtractive manufacturing restrictions, a part designer can answer relevant questions. What is the functional objective of the part? Can we design a part with the same functional characteristics but use less material? Can we obtain the cost-savings from optimized additive parts? These parts are becoming increasingly complex, organic and lighter, while meeting their performance requirements.

A key simulation technology being leveraged in the shortened design cycle for AM is Topology Optimization, a non-parametric optimization technique that identifies and removes areas of a design space not contributing to the stiffness of the part or to the force flow in it. This method determines an optimum material distribution in a defined design area while accounting for existing constraints to the design space: boundary conditions, fixations and pre-tensions, and loads. With reduced manufacturing constraints, more organic structures with 'holes' and 'openings' are now possible with Tosca Structure, a robust general purpose tool for non-linear topology optimization.

As shown in Figure 1, Tosca Structure can be used to create organic designs that use less material while satisfying all the functional requirements and constraints. We start with a larger design space (the gray area) and based on iterative non-linear

finite element analyses using Abaqus, the locations of design space where the material is required is computed as shown in the right frame. In addition, Tosca can also be used with other 3rd-party FEA solvers.

Now, Tosca already accounts for constraints used in conventional manufacturing such as casting and injection molding. So, are there any special considerations before using Tosca for AM? Let's review with an illustrative circuit box (shown in Figure 2) for space vehicles and satellites. A typical launch vehicle hosts dozens of these boxes and with the estimates for sending a single 1lb to space close to \$10,000, costs can add up. Hence, light-weighting these enclosures can be a good design objective. In collaboration with Stratasys, we conducted a topology optimization design study with the intent of printing these new concepts with the Fused Deposition Modeling (FDM) process.

It is very likely that an AM part will co-exist in an assembly with traditionally manufactured parts. Such regions or interfacial areas can be frozen (including pre-stresses) in Tosca and removed from the design space. Next, it is important to set a minimum member size for the optimization to account for the print resolution. For instance, for FDM processes, the member size should be larger than the bead size so that the optimized surfaces can be realized in the real print. Now, for a metal printing process, the minimum member size can be much smaller. However, choosing a conservative limit can help avoid any manufacturing related defects (voids or cracks). Taking the above into account, we conducted a design study with multiple volume reduction constraints on the original design volume and settled on the optimization results that offered a 30% reduction while proving most suitable for print, from a time, quality and material-cost perspective. Another critical point to note is that most AM processes require support structures either to prop the layers, anchor the part or provide heat-conduction paths during the printing process. These supports add to the cost of material and print overhead. While a non-trivial task, employing ways to minimize the use of support structures by reducing the overhang angles, build orientations optimization, and the use of parametric or non-parametric simulations to optimize support placement, will ensure that you realize the cost benefits from topology optimization.

With the optimized shape obtained and a final simulation conducted to functionally validate the new design, it is time to print the part. However, the optimized results will often contain sharp edges, disjoint islands of material and highly tessellated facets. A smoothing step helps, but the obtained STL output will require cleanup for a 3D printer to handle and produce a desirable part. Moreover, we have lost the associativity with the original design. CAD reconstruction

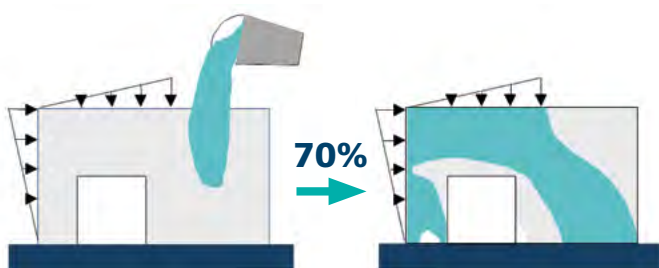


Figure 1. The general goal of topology optimization is the distribution of material in a given design space. For the basic optimization task, the target volume is the constraint. For a given volume (target volume or target weight) the maximum stiffness has to be achieved.

OPTIMIZATION STRATEGY FOR ADDITIVE MANUFACTURING

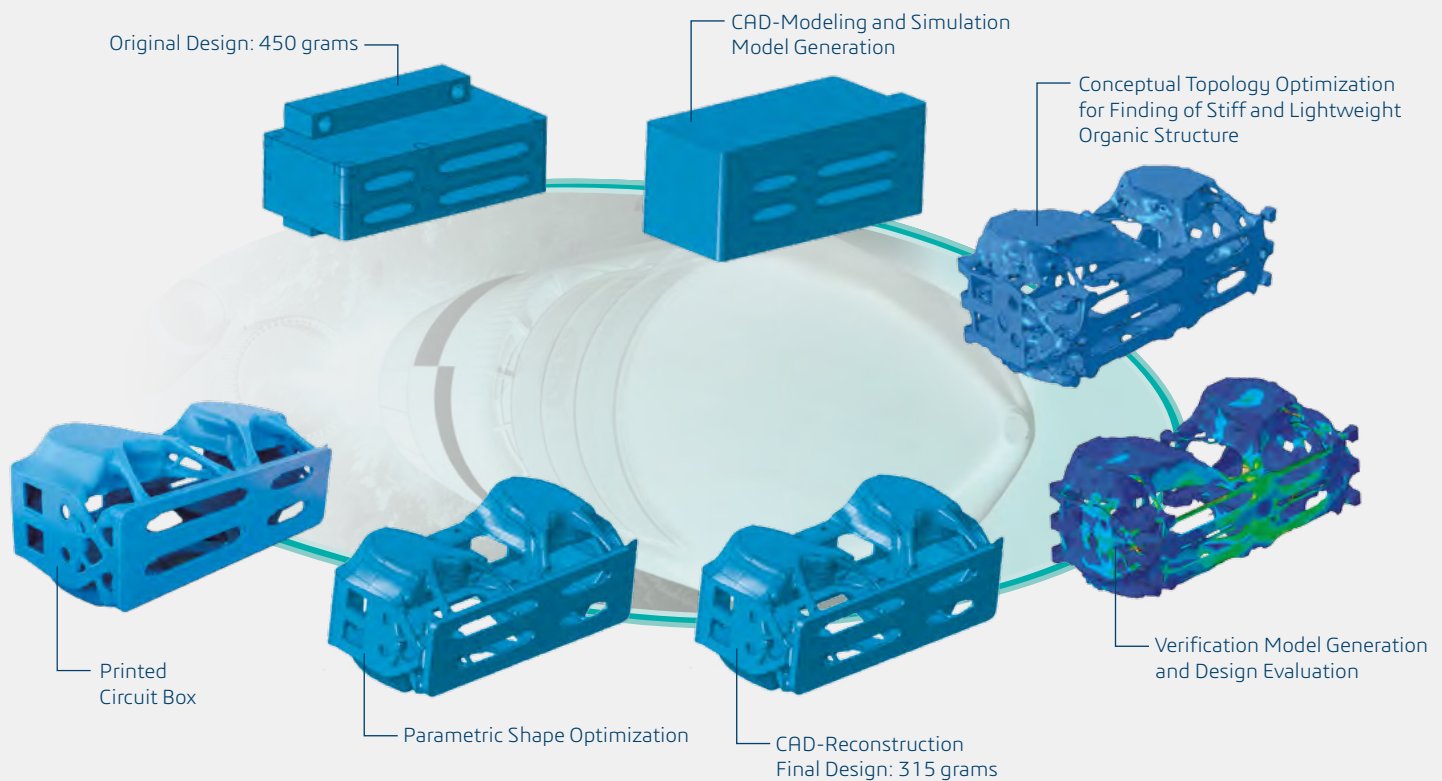


Figure 2. Topology optimization for a 3D printed circuit box. Rocket payload image credit NASA.

addresses these concerns but it is a highly time-consuming manual process, often a bottleneck to wider adoption of optimization technology. In the latest release of Tosca, we've taken a significant step to addressing this issue. Here, using subdivision surfaces, a technique originally developed in the animation industry, Tosca outputs are transferred via points and face inputs in to a CAD environment such as CATIA, no longer requiring the use of STL files. This step drastically simplifies the reconstruction process, providing significant cost benefits as advanced surface modification tools in the CAD environment (shown in Figure 3) can be used to create organic shapes with vastly simplified facet information (reduced file size), true geometric features and parameters which lend themselves well to further parametric shape optimization studies. We are now print ready!

Additive Manufacturing is propelling the next manufacturing revolution with topology optimization at the core of enabling designers to harness the freedom from design constraints. Our powerful tools of non-linear and non-parametric topology optimization through Tosca are well-suited for this shift and we continue to improve our offerings to enable your requirements. Another key area for additive manufacturing is the use of lattice structures. Stay tuned for a future article to learn more on what we have to offer in this area or follow the authors' LinkedIn blogs.

For More Information
www.3ds.com/simulia

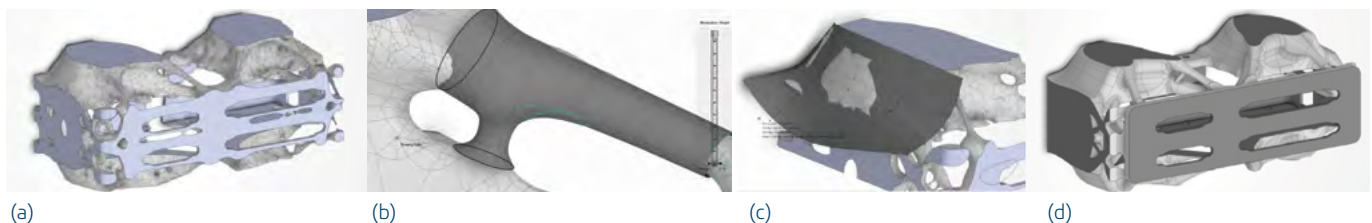


Figure 3. (a) Tosca Outputs (Raw) in CATIA Imagine and Shape; (b) Using tube drawing to sketch sections on raw solid to create surfaces joined at T-junctions; (c) Mesh grid drawing on raw solid allows for fast creation of subdivision surfaces; (d) Final circuit box CAD.

HOW TO DEVELOP A CUSTOM METHOD FOR GEAR DESIGN IN THE 3DEXPERIENCE PLATFORM

The 3DEXPERIENCE platform provides the right set of tools required for fast and sustainable innovations, to both the design engineers and the simulation specialists. The applications for physics simulations available on the platform for both design engineers and specialists share the same Abaqus solver. The platform allows the specialists to democratize simulation to a large user base through tighter CAD-CAE integrations and analysis templates for replicating best practices. One of these methods for democratizing simulations, known as the Custom Method, is discussed here in the context of gear design.

The Custom Method allows the simulation expert to create an action-assisted panel for solving a particular analysis. By using this customized panel, a design engineer (non-expert) can

evaluate a design quickly without getting into the nitty-gritty of the finite element analysis methods. The Custom Method configures the actions, commands, and the assistant content displayed in the simulation status panel. The actions in the simulation status panel are selectable. Upon the selection of an action, the assistant content of the panel updates to show the associated help text (if any) and commands. This makes the simulation status panel integral to the Custom Method. Note that a Custom Method applies only to options available in the Structural Scenario Creation app. Users access a Custom Method via the Physics Methods Reuse app.

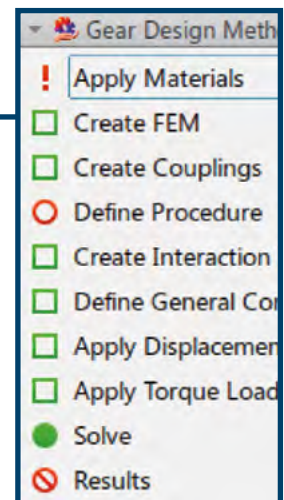
There are three simple steps for developing a Custom Method. These steps are discussed below with the gear design example.

STEP 1: CAPTURE THE WORKFLOW

Normally, a simulation methods developer will decide the actions required for a particular analysis workflow. In this example, for carrying out a static structural stress analysis between two gears, the required actions are apply materials, create mesh (FEM), create couplings, define an analysis procedure, create interaction properties, define general contact, apply displacement boundary conditions, apply torque loads, solve and review the results. The simulation status panel needs to have all these actions as shown in the picture on the right.

STEP 2: DEFINE THE CUSTOM METHOD

In this step, a methods developer will create a method file in XML format. The XML file needs to have all the commands for the actions discussed above required for this workflow. For example, the commands required for creating the “Apply Materials” and “Define Procedure” actions are shown below. Note that the “Create Coupling” action is not available in the structural scenario creation app, so to access this action, users need to switch to the modeling app which is outside of the Custom Method.



```
</Action>
<Action name="Apply Materials" type="ManageMaterials"
id="ID_MyMaterials_1">
  <Assistant>
    <Elem>
      <Text>Apply a Material.</Text>
    </Elem>
  </Assistant>
</Action>
```

Apply Materials

```
</Action>
<Action name="Create Procedure" id="ID_MyProcedure">
  <Commands>
    <CommandHeader headerId="SMAExsStaticStressHdr">
    </CommandHeader>
  </Commands>
  <Assistant>
    <Elem>
      <Text>Create a static stress analysis step.</Text>
    </Elem>
  </Assistant>
</Action>
```

Define Procedure

STEP 3: DEPLOY THE CUSTOM METHOD

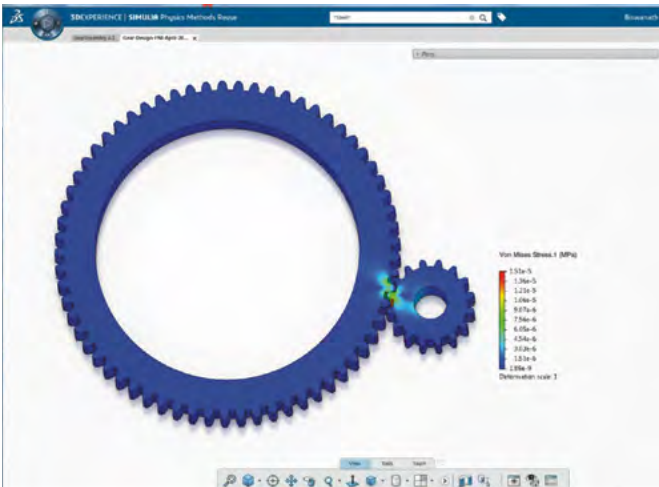
Users can deploy a Custom Method in two ways.

1. Deploying the Custom Method Using the Direct Approach:
First create an index file with the following command lines. The index file accesses the previously defined Custom Method (GearDesign.xml) file stored in the "**D:\users\fni\CustomsMethod**" folder.

```
<?xml version="1.0" encoding="UTF-8" ?>
<Index>
  <Method name="Structural"
    description="Gear Design Method"
    file="D:\users\fni\CustomsMethod\
    GearDesign.xml">
  </Method>
</Index>
```

Save the index file with the name "SMAMPaMethodIndex.xml" and store it in [install directory]\win_b64\reffiles\SimulationProducts\.

2. Deploying the Custom Method Using the Dataset Approach:
First create a VPM document by uploading the Custom Method file as a VPM document, and then access the VPM document using the Dataset app and resource table option.



With the completion of the third step, the gear design Custom Method is ready to be deployed using the Physics Method Reuse app. Open the CAD model first before launching the Physics Method Reuse app. Upon launching the app, you will notice an action panel on the right side of the screen as shown in the picture. Now, you are ready to solve this structural analysis problem with just a few clicks.

For More Information
www.3ds.com/simulia

WANT MORE TRAINING ON 3DEXPERIENCE?

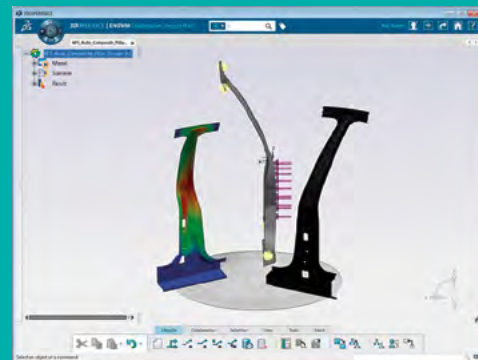
Visit the all-new SIMULIA Learning Community and explore the power of the **3DEXPERIENCE** platform. The Learning Community has a variety of training and introductory materials to help you accelerate and improve product performance, reliability and safety.

Our latest eSeminar featuring the **3DEXPERIENCE** platform, Design and Optimization of Composite Structures on the **3DEXPERIENCE** platform, will help you explore how SIMULIA apps on the platform can be used to optimize all aspects of composite design, from initial sizing through to manufacturing processes.

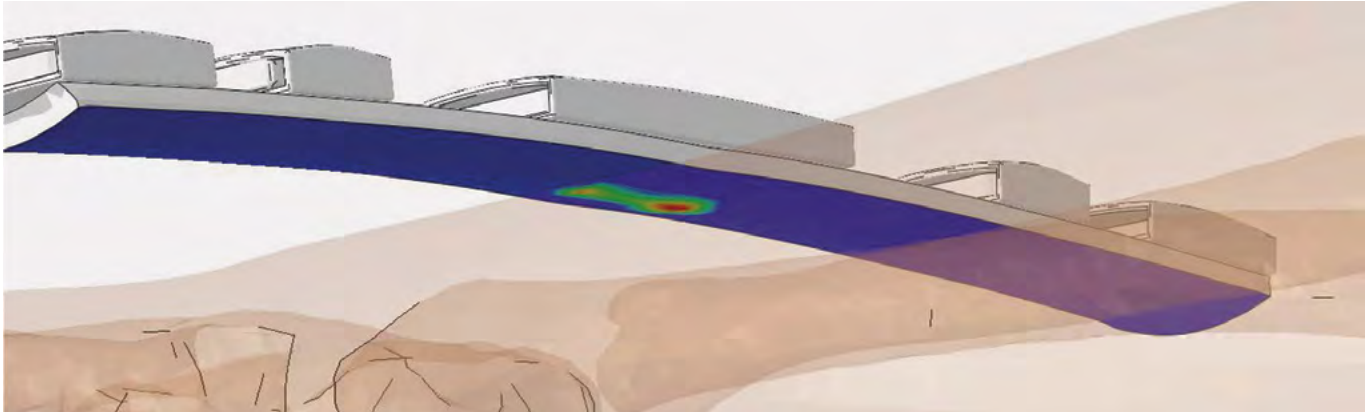
Using the example of an automotive B-Pillar, the eSeminar aims to show how the **3DEXPERIENCE** platform provides the basis for all stakeholders involved in the design and production of composite components to collaborate in order to ensure the final design meets all key requirements. A consistent and shared data model, with the 3D design at its core, provides the necessary integration to ensure all key requirements are managed in the same environment, providing essential decision support during design optimization and trade-off studies.

The Learning Community also features tips and tricks on structural physics, process apps and more. Learn more at www.3ds.com/slc.

For upcoming eSeminars on the **3DEXPERIENCE** platform, please visit us at <http://www.3ds.com/events/all-eseminars/?brand=simulia/k/3DEXPERIENCE+Simulation+2+Democratization>



CST ELECTROMAGNETIC CO-DESIGN DELIVERS COMPREHENSIVE SOLUTIONS



Electromagnetism is a driving force of progress in modern societies. All kinds of miracles happen once you put the plug into the outlet, or for that matter, hit the ON-switch. As we all know, it is not magical at all, but the result of precise engineering science. The foundations are the equations James Clerk Maxwell published 150 years ago which describe all electromagnetic phenomena. Although the equations can be noted down in very compact form, their application is—at almost all times—cumbersome. The solution is numerical simulation.

We at CST—Computer Simulation Technology AG, today take pride in delivering the most comprehensive solution for electromagnetic field simulation in the market. With a solver set that spans from statics to optical frequencies, and involves various simulation methods, CST STUDIO SUITE® enables access to a wide range of electro-magnetic applications through a single, user-friendly interface. With a customer base including market leaders in industries as diverse as telecommunications, defense, automotive, electronics and healthcare, CST STUDIO SUITE is an indispensable tool in many R&D departments to meet specifications and deadlines predictably and efficiently. It is very likely that you own, use or benefit from devices and/or tools designed with CST software.

Besides classical Microwave & RF applications such as antennas or filters, the ability to simulate and optimize entire electromagnetic systems has become increasingly important. This system view could include such aspects as the performance of an antenna installed in its operation environment, or the radiation safety of a patient in a High Field MRI coil, taking also into account the effect of heat transfer through the blood flow. Generally, the prediction of EMC/EMI compliance of the final product in a virtual prototyping state is a challenging application for electromagnetic simulation software that we help our customers overcome.

Electromagnetics is not an isolated effect. In the real world, electromagnetic fields can be coupled more or less strongly to other domains of physics, structural mechanics and

thermodynamics in particular. We can define different Co-design methodologies based on the required exchange or physical quantities:

- In Collaborative Design, structural and EM teams work more or less independently. The designed product will have to comply with respective requirements.
- Concurrent Design requires a tighter communication and data exchange flow. Changes in one discipline might directly affect the performance of the device in the other.
- Multidisciplinary optimization requires access to all employed simulation methods consecutively, and can be organized on simulation management platforms.
- Finally, there is the full Multiphysics Co-simulation. If we look at induction heating for example: changes in temperature immediately affect the electric conductivity of the material and may lead to structural displacement. This requires the involved solvers to have direct and mutual access to the structure, mesh and field data in order to succeed.

In May 2015, we forged a partnership with Dassault Systèmes to integrate CST® 3D electromagnetic simulation technology into Dassault Systèmes' **3DEXPERIENCE** platform. This will enable customers to create and analyze electromagnetic behavioral models that simulate device function in a wide range of frequencies. This capability enhances the **3DEXPERIENCE** platform's simulation applications for solving multiphysics challenges in several areas including hybrid vehicle drivetrains and wearable electronics.

Since then, we have demonstrated workflows for Collaborative Design and Co-Simulation. We will continue to enhance all aspects of these Co-design methodologies in order to deliver the most versatile solution to the market.

For More Information
www.cst.com

MANUFACTURERS ADVANCE PRODUCT DESIGN WITH THE HELP OF HPC SYSTEMS FROM SGI

Manufacturers are under increasing pressure to reduce costs and increase quality throughout the entire product design cycle. The use of virtual prototyping software like Abaqus® from the SIMULIA brand of Dassault Systèmes and high-performance computing systems from SGI®, allows manufacturers to validate the structural integrity of a design before committing to making expensive physical prototypes.

SGI aids manufacturers to maximize engineering productivity and speed up the time-to-market, offering a highly flexible framework of HPC servers, software, storage and services ideally suited for CAE workloads from multiple disciplines. In addition, SGI has a long history of proven domain knowledge and key CAE application expertise. All of these capabilities are supported by our strong technical relationship with SIMULIA.

To that end, SGI has, in partnership with SIMULIA, published the SGI® Technology Guide for Users of Abaqus®. This SGI guide is intended to help customers make knowledgeable choices in regards to selecting HPC hardware to optimally run Abaqus software.



The guide reviews the performance of Abaqus executed on three types of SGI platforms: the SGI® Rackable® cluster, the SGI® ICE™ XA cluster and the SGI® UV™ 3000 Shared Memory Parallel (SMP) platform. In addition to presenting performance results on these three supercomputing platforms, it discusses the benefits of using multicore Intel® processors, the trade-offs of different network topologies, NVIDIA® compute GPU device performance and the use of SGI® MPI PerfBoost. Also included are sizing guidelines and recommendations for HPC platforms running Abaqus.

The Abaqus models selected for this guide are included with each Abaqus release. Using common datasets provides a way to characterize system performance on various platforms to allow general performance comparisons.

For More Information

To download the free SGI Tech Guide, please visit www.sgi.com/abaqus

GRANTA HELPS PREPARE, MANAGE AND USE MATERIALS DATA FOR CAE

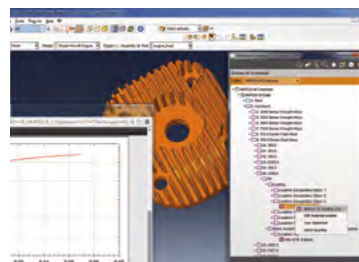
Materials information management is vitally important throughout the simulation lifecycle, and plays a crucial role in successful, fast and accurate computer aided engineering (CAE). Granta Design has developed software tools to enhance the capture, management and use of materials data for CAE, helping you get the most from investments in simulation.

GRANTA MI™ is the leading system for materials information management in engineering enterprises, enabling you to capture, control, analyze, and securely share data on materials and processes with the engineers (including simulation analysts) who need it. GRANTA MI:Materials Gateway™ provides direct access to proprietary data stored in GRANTA MI, complemented by access to a comprehensive library of materials reference information.

Through the MI:Materials Gateway window within Abaqus/CAE®, developed in collaboration with SIMULIA, you can search and browse available materials, view datasheets, and choose and import models directly to your CAE environment with full traceability information and without risk of error due to data transfer.

Granta collaborates with customers to continually improve MI:Materials Gateway. Version 4 incorporates performance and user experience enhancements, making it faster and

easier to find materials and import CAE data. Users benefit from additional workflow options that make importing CAE data more flexible and powerful. An example is improved handling of parameterized functional data, whereby users can specify parameter values (e.g., temperature) at which data should be provided. The preview mode allows a material model to be viewed before import, with the possibility of editing properties, filling missing data, and adding comments. Once imported, users can be notified by email of subsequent changes to the material record in the GRANTA MI database, and consider whether to update their simulations.



GRANTA MI:Materials Gateway™ for Abaqus/CAE®. Through the MI:Materials Gateway window you can search and browse for materials datasheets, inspect materials properties, choose an applicable materials model, and then apply the data directly to your CAE model.

GRANTA MI:Data Analysis Apps™ help prepare materials data for input to simulation. Users can analyze data in their company's GRANTA MI system—for example, to derive simulation data from test results, and model-fitting. Apps can be written in collaboration with Granta or by your MATLAB® or Python™ programmers using the MI:Scripting Toolkit. Thus you can make best use of company data and ensure calculations are accurate, consistent, and repeatable.

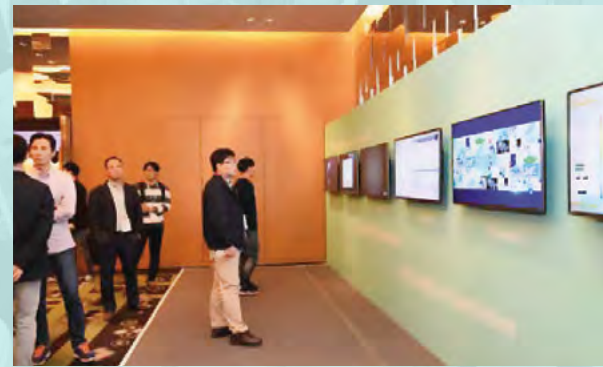
For More Information

www.grantadesign.com

Regional User Group Meetings

MEETING SEASON IS FAST APPROACHING

The SIMULIA Regional User Group Meetings are designed to benefit those who make SIMULIA a success—you, our users! Each fall, SIMULIA provides a place for industry and academia to come together and learn about the latest simulation technology and methods that can accelerate and improve product innovation. Last year, more than 3,500 users attended these meetings in all areas of the globe. We will announce dates, locations and agendas for 2016 soon. Because these are local meetings, we are able to tailor content toward trends and marketing conditions where you are, and present information in native languages. Don't miss the chance to share your experiences and increase your profile in the simulation community. Learn more at www.3ds.com/rums.





MODELING MOLECULES

Imperial College researcher employs Abaqus to simulate the behavior of graphene and other carbon-based structures for use in strong, lightweight materials

The Nobel Prize in physics was awarded to Andre Geim and Konstantin Novoselov in 2010 for their work in the isolation and understanding of graphene, a two-dimensional honeycomb-like structure of carbon just one atom thick. Although the material was first theorized nearly one century ago, the term “graphene” was only coined in 1987 to describe the structure of recently discovered carbon nanotubes, as well as Buckminsterfullerene, a.k.a. buckyballs. But it wasn’t until 2004 that Geim and Novoselov were first able to isolate individual crystals of graphene, using a micro-mechanical cleavage process now known as the “Scotch tape” technique.

Graphene is an amazing material. Found in everything from pencil leads to human DNA, it is 100 times as strong as steel by weight but far more elastic. According to Geim and Novoselov, a theoretical one-meter square hammock made of graphene would be strong enough to support a napping house cat, yet would weigh less than one of the cat’s whiskers and be nearly invisible. Graphene is more electrically conductive than copper, dissipates heat ten times faster, and is virtually impermeable to gases, giving it broad potential for use in semiconductors, fuel cells and batteries, gas sensing equipment, solar panels—and especially composite materials.

It’s this last possibility that brings Silvestre Pinho to work every day.

STUDIES IN SIMULATION

Professor Silvestre Pinho is a member of the engineering faculty at London’s Imperial College department of aeronautics. He and his team of postdoctoral researchers and Ph.D. students use Abaqus finite element analysis (FEA) tools from SIMULIA to study the structural design and simulation of graphene, carbon fiber reinforced plastic (CFRP), and similar materials. Their goal? To improve the strength, fracture response, and damage tolerance of composite materials through the use of engineered microstructures. Their work could be described as building a stronger house by engineering the internal structure of each brick, or making cars safer by designing chassis and body parts from the molecular level up.

In fact, this last application is one likely outcome of the team’s studies. Some current real-world examples of where these new materials could be used include aircraft fuselage, race-car bodies, and the blades of wind turbines or helicopters. And once the manufacturing processes for these microstructure-reinforced composites become commonplace and production costs come down, Pinho envisions them being used in a wide variety of everyday products.

“Carbon fiber is already used today in electric vehicles, but one limitation is fracture toughness,” he says. “Anywhere

you have a large structural component, there are geometric discontinuities—the intersection of an aircraft fuselage with an engine cowl, for instance, or the window frame in a passenger vehicle—that present areas prone to failure in the event of a crash or overload.”

AN EARLY ABAQUS USER

Pinho studied at the University of Porto in Portugal, earning his undergraduate degree in mechanical engineering. It was there that he first began using Abaqus finite element analysis (FEA) in his work. Two years later, he moved to Imperial College in London to pursue a Ph.D. on the simulation of mechanical response in composite materials. Just before completing his doctorate, however, he received an offer to stay on at the college as an academic, and has been there ever since. “I used a different FEA software while doing my doctorate on composite crash behaviors, but went back to Abaqus once my first research project was funded,” he says. “I’ve been using it exclusively for the past five years.”

Pinho says he became an engineer because he was good at math and physics, and felt that path offered him a nice balance between theoretical science and the real world. But when news of Geim and Novoselov’s discovery came out, he got to thinking about some practical uses for the new graphene material. “I thought that within the next decade or so, people should be able to manufacture interesting things with it,” he says. “That in turn created an immediate need for simulation and analysis of its properties, something I knew Abaqus could help me with. Based on that, we spent the next several years developing the molecular-dynamics code needed to simulate graphene and other carbon-based structures within the Abaqus finite element framework.”

PLUGGING INTO THE RIGHT LEVEL OF SIMULATION

His project involves far more than simulation of a few carbon atoms. Pinho is studying the mechanical response of “very large sandwich structures subject to a very localized load that could lead to failure in that very localized place.” This would mean events such as bird strike in a carbon-fiber aircraft wing, or hail damage in a solar array. He says representing three-dimensional structures such as these requires a coarse model at the macro level, inside of which sits a concentration of micro-sized detail at the place where the damage will occur.

“There are many different numerical formulations that help with these types of problems, and Abaqus has several of them implemented by default,” Pinho explains. “One of the more useful ones is the ability to have different length and time scales in your analysis. For instance you can, in-effect, zoom

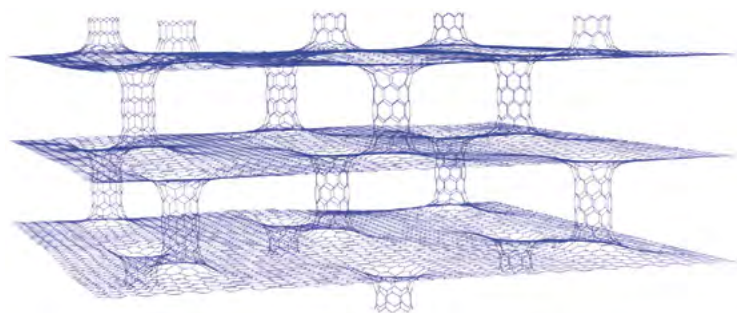
in on the crash zone with Abaqus/Explicit, which provides a very high level of discernment, and then as you move farther away you would use Abaqus/Standard, employing much larger three-dimensional constructs but at lower resolution.”

Because the user interface in Abaqus is very “plug-in friendly,” Pinho and his team have been able to develop their own subroutines that complement and expand the software’s native capabilities. “The interfaces in Abaqus that support user subroutines are particularly well-organized, well-structured, and offer quite a lot of freedom,” he says. “It’s very powerful, and is a key feature for us.”

“SHAKING HANDS” BETWEEN MESHES

Another challenge is accurate representation of the “handshake regions” between the different meshes used to simulate the microstructures within carbon composite materials, which in effect links small-scale models with larger ones. For this reason, Pinho and his students have experimented with different mesh superposition techniques in Abaqus, allowing them to develop schemes that have greatly reduced the computational time needed to perform such complex analyses, while still maintaining excellent accuracy in their models.

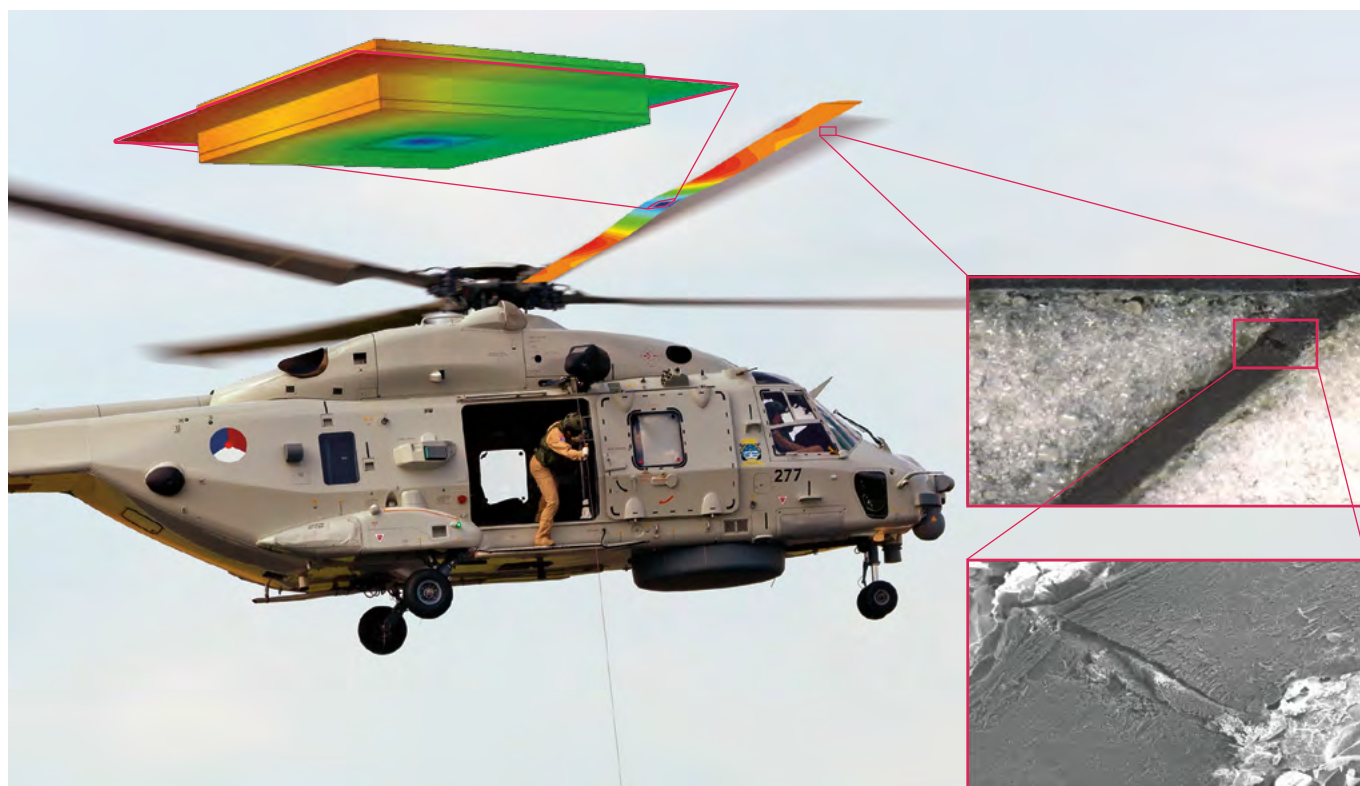
“The ability to create handshake regions between meshes was quite important to our work,” Pinho says. “Without it, it would be far more difficult to perform simulation of large structures simultaneously with the underlying material’s microstructure.”



A theoretical representation how graphene’s brittle nature can be toughened up—here, multiple layers of graphene are interconnected using carbon nanotubes to create a robust three-dimensional structure

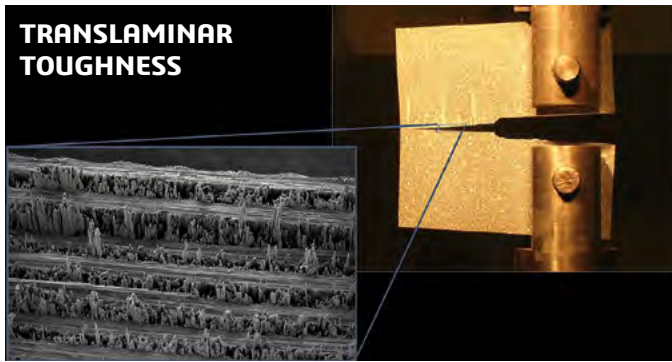
HELPING DEVELOP NEW CAPABILITIES IN ABAQUS

Pinho has collaborated with SIMULIA throughout this complex work, and has even influenced the Abaqus software development path to some extent. “There was one case where SIMULIA had just released a new phantom-node method, but I along with other researchers wanted to implement our own criteria for failure initiation inside the new method,” he says. “SIMULIA invited me to submit my own interface design, which was subsequently approved and released to me in beta version within a very short time frame. This allowed me to explore different failure possibilities much more quickly than would otherwise have been possible.”

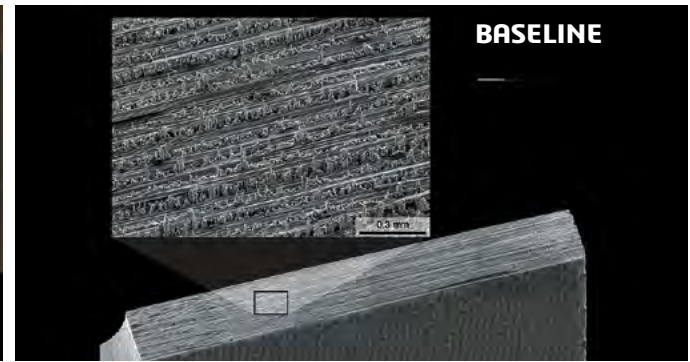


Low velocity impact on a large helicopter blade whose profile consists of a pin-reinforced composite sandwich structure. This real world example of carbon fiber use shows how failure of large composite structures begins at the microscopic level.

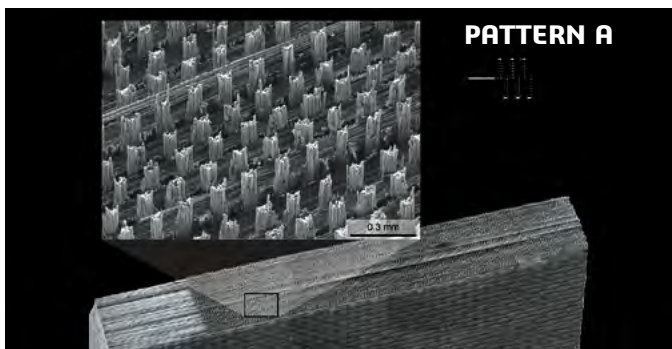
Academic Case Study



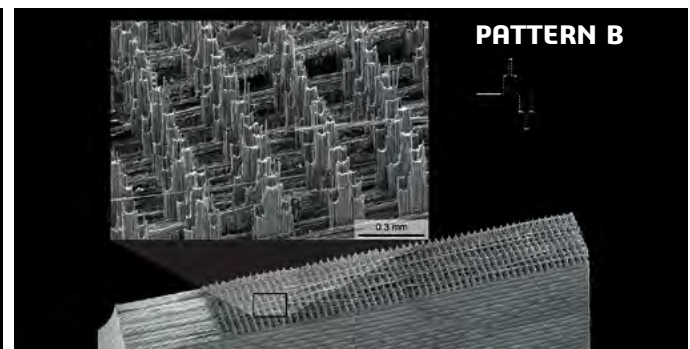
Measuring translamellar fracture toughness requires a device (right) that rips apart a test sample (middle), leading to a controlled fracture of the carbon fibers (left).



An electron microscopy cross section of the standard carbon fiber material used as the baseline for Pinho's microstructure testing. Note the random fracture pattern of the individual fibers.



Pattern A illustrates the effect of translamellar fracture of an engineered carbon fiber microstructure. Note the regular and predictable fiber pullout, creating a much tougher material.



The skyscraper-like Pattern B promotes fracture across several scales, further increasing the material's translamellar toughness and notched strength. As manufacturing techniques are further refined, ever more complex structures can be developed, leading to ultra-strong, tough, and lightweight materials.

While the majority of Pinho's current work with Abaqus is devoted to micro-structural modifications of carbon-fiber-reinforced composites, this work has led to several valuable lessons which are useful for nano-structural design using graphene. The physics and mechanical interactions at graphene's molecular level are admittedly quite different from those of a carbon-fiber aircraft component, but Pinho says a fundamental understanding of each is critical to increasing fracture toughness in carbon-based materials.

"Everything we've learned about numerical methods within Abaqus, and the knowledge of how the different features of the finite elements code are organized, allows us to understand how we could express the equations that come from the interaction of individual atoms in a way that can be formally equivalent to the equations Abaqus expects to solve," he says. "Knowing that we could do all these things within the finite element framework of Abaqus itself has been quite important to our work. It's a very powerful tool."

TOUGHENING UP MICROSTRUCTURES

With a material ten times stronger than steel, crash-proofing would seem to be unnecessary, but graphene and to a lesser extent carbon fiber have an Achilles heel: they're brittle. For two-dimensional graphene, breaking the van der Waals bonds

between the graphene crystals is fairly easy to do, the atomic equivalent of poking your finger through a pile of paper. And carbon fiber composites are known for their propensity towards delamination and impact cracking.

In both cases, Pinho seeks to manipulate the structures of those materials at the micro or even nano level. He cites one theoretical possibility where two graphene sheets might be connected by a series of carbon nanotubes, greatly increasing its crack resistance. A more real-world example is one where Pinho and his colleagues were able to construct polymeric microstructures in carbon fiber composite material, increasing its energy dissipation capability.

"Basically, we modify the microstructure of each individual ply before the material is cured and the end result is a material with 560% percent the fracture toughness of the baseline carbon-fiber material. We've demonstrated it can be done; the next step is how to do so on an industrial scale. I imagine that within the next few decades, we will hopefully have the ability to design nanoscale structures, and tailor them to produce whatever mechanical properties we want them to have."

For More Information

<http://wwwf.imperial.ac.uk/aeronautics/research/pinholab/>

SIMULIA Spotlight: John Draper

John Draper is the founder and director of SIMULIA's fe-safe, which became part of the Dassault Systèmes portfolio in 2013. He is a recognized authority in the fatigue design and life assessment industry and has been a regular presenter at software conferences around the world. Before he retires, he will be sharing some of his accumulated wisdom with attendees of this month's Science in the Age of Experience conference in Boston. SIMULIA Community News spoke with him recently:

SCN: How did you come to work in fatigue?

John Draper: I've always been interested in aircraft and during an apprenticeship with an aircraft company I worked with the 'fatigue design' team. The topic seemed very interesting because you need to know so much about what was happening to the whole aircraft, not just the part you were working on. I created the role of trying to develop improved methods, and I wrote a simple fatigue life computer program in the early 1970s. The most valuable part of my education was a two-year post-graduate course in advanced engineering at the College of Aeronautics at Cranfield, because it combined theory with practical design projects.

SCN: You are a recognized authority in the fatigue industry. What qualities does an engineer need to develop in order to become an expert in their field?

DRAPER: I don't think anyone is really an expert because the more you learn the more you realize there is more to learn. I've spent my career in the single field of metal fatigue, in both aircraft and rail, and for the past 30 years mainly focused on software development and training courses for many industries. This wide range of experience has been very helpful. And being prepared to question what is being done and being open to new methodology.

SCN: How many years had your company, Safe Technology, been attending SIMULIA SCCs before being acquired by Dassault Systèmes and how does your joining DS enrich the experience and power of simulation software?

DRAPER: I think we attended an Abaqus conference in 1998 when it was HKS, and we made presentations at the 1999 Abaqus conference. So this was 15 years before we were acquired by Dassault Systèmes. HKS made an early decision to sell fe-safe as a product. This was very important in helping us establish fe-safe, and it certainly enhanced our credibility.

In recent years the market for simulation software has grown and it is embracing design engineers as well as technical specialists. Users want to carry out an analysis without running a sequence of programs—they want the user interface to do that and make it seamless. And for many components, although the designer calculates stresses, temperatures, vibration modes and other things, the ultimate goal is to assess the fatigue strength. fe-safe adds this capability to the DS simulation portfolio.



SCN: You mentioned that the accuracy of fatigue life predictions has been transformed since the 50's. How and why?

DRAPER: For over a century fatigue assessment was a simple calculation using engineering stresses, with empirical factors to try and get a reasonable life estimate. These factors were often very difficult to estimate and were often derived from experience of past designs. So you never knew when you would step outside their range of validity. Modern fatigue analysis really started to develop in the 1950s, although you can trace some key ideas back to the early 1900s. The focus has been to try and replace empirical correction factors with something more scientific. fe-safe doesn't request any correction factors.

SCN: What are your plans for after retirement?

DRAPER: Many! I've always been an active hill-walker with a bit of mountaineering. I do some cycling. Twice I've helped sail a small boat round the north coast of Scotland and I plan to do another sailing trip in September this year. I have a little MG sports car and I'm slowly building a replica of a 1930s Jaguar two-seater. I enjoy concerts, art museums and the theatre. I have three children and three grandchildren. I have a backlog of CD's to play and books to read...

SCN: Do you have any advice for young engineers about the future of the profession, or how to develop an individual career path?

DRAPER: I think engineering is one of the most exciting and satisfying professions. It's changing so rapidly, in part because of computing power. There is so much innovation and so many opportunities to contribute to this innovation. I don't like giving advice but a good start is to find an area of engineering that gives real interest, read as much about the subject as possible, be committed, be open to new ideas and keep questioning things.

TRAINING SPOTLIGHT: MULTIBODY SIMULATION

From initial concept designs through to production and redesigns, multibody simulation (MBS) is used to help engineers fully comprehend and optimize systems, vastly reduce the need for physical prototyping, shorten time to market and improve product quality and lifespan. In essence, multibody simulation enables manufacturers to gain a competitive edge by offering the ability to create high quality products in a time and materially efficient manner, thus reducing overall costs in design, production and maintenance.

SIMPACK

Simpack is a general purpose multibody simulation software used for the dynamic analysis of any mechanical or mechatronic system. It enables engineers to generate and solve virtual nonlinear 3D models in order to predict and visualize motion, coupling forces and stresses. Simpack offers a large variety of high-end modeling elements tailor-made to the automotive, engine, HiL/SiL, power transmission, railway, and wind energy industrial sectors, but can be applied to any branch of mechanical engineering. Simpack simulation software is particularly well-suited to high frequency transient analyses, even into the acoustic range.

SIMPACK TRAINING OFFER

SIMULIA offers a variety of Simpack courses designed to teach the user how to efficiently set up and solve multibody models and take advantage of Simpack's high-end features.

Simpack Basics (3 day class)

This course is for users who are just beginning to work with Simpack. You don't need to be a multi-body simulation expert—this training goes over all the basics. Even if you already have some Simpack experience, it's worth taking part as a refresher or to learn new functionalities.

Simpack Flexible Bodies (1½ day class)

The Flexible Bodies training class explains how to import finite element models in Simpack, optimize calculation time and postprocess the results, including stress calculation and export to fatigue software like SIMULIA fe-safe. This allows you to take structural elasticity into consideration. The course also explains SIMBEAM, Simpack's built-in finite element tool designed for linear and nonlinear 3D beam structures.

Simpack Automotive (1 day class)

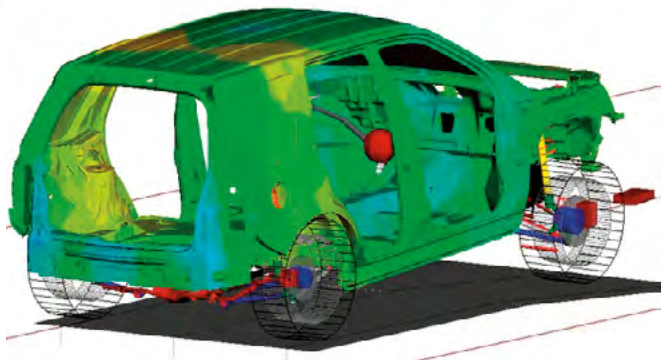
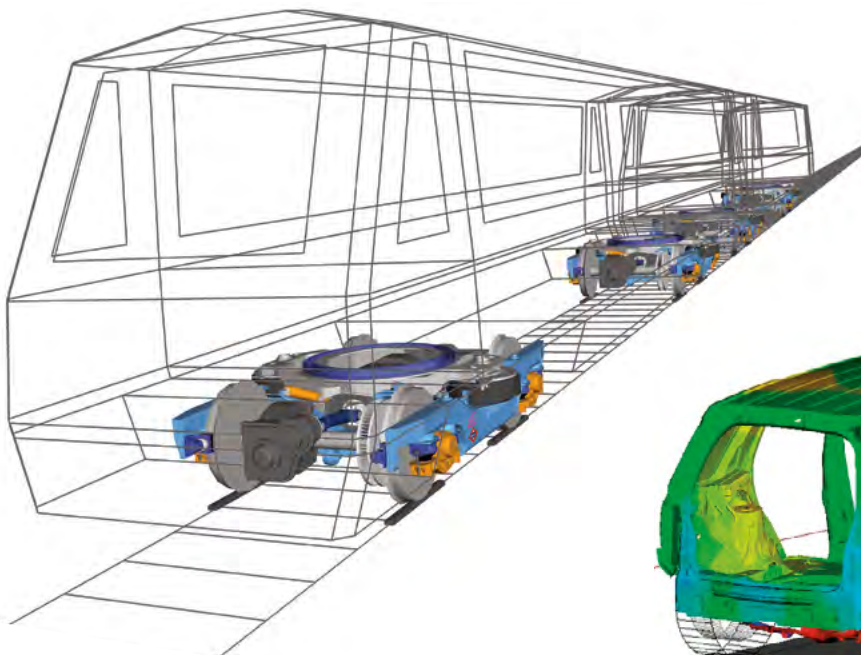
The Simpack Automotive training course explains how to set up vehicle models using Simpack's automotive database, how to add user models to the database, and introduces Simpack's automotive elements (tires, roads, steering controllers, and more).

Simpack Rail (2 day class)

This class explains how to model the contact between rail and wheel, to set up entire rail-vehicle models, and the most important analysis types, like derailment, stability, and comfort. It also introduces rail-vehicle specific elements such as track, irregularities, wheel and rail profile, and suspension elements.

For More Information

www.3ds.com/products-services/simulia/services/training-courses/schedule-registration/



BOB JOHNSON: A TRULY ONE OF A KIND ABAQUS USER

Long-term Abaqus user Bob Johnson has started his own consultancy, REAL FEA, after a career as a mechanical engineer, NAFEMS instructor, and technical editor of Benchmark magazine. He is recognized as one of the leading individuals in the engineering analysis community in the UK. Johnson has also demonstrated his creative genius recreationally, in some very unique ways.

SIMULIA Community News: At what point in your life did you know you wanted to become a mechanical engineer?

JOHNSON: I always wanted to be an inventor. I didn't realize that would equate to being a mechanical engineer, or any sort of engineer for that matter. I just wanted to invent. I was passionate about creating and seeing gears turning, cams going, valves lifting, and that sort of thing.

SCN: When were you first introduced to simulation?

JOHNSON: While working towards my third degree, I took elasticity and loved it. I coded my own FEA system, as well as the finite element force method back in the early 80s. I was meshing completely by hand. To be able to predict what was going to work before you even made it is what fascinated me. It was like being able to see the future.

SCN: What do you think about working with Abaqus FEA software?

JOHNSON: I use whatever software my clients have, yet I'm a massive fan of the Abaqus system because it's reliable, robust, and trustworthy and that's a colossal thing. I honestly wouldn't have a business without a code like that. I've been using it since around 1993 and I think what's great for me is its rigor, the solid foundation that it's from and, again, its dependability.

SCN: What do you think about how the visualization of results has changed over time?

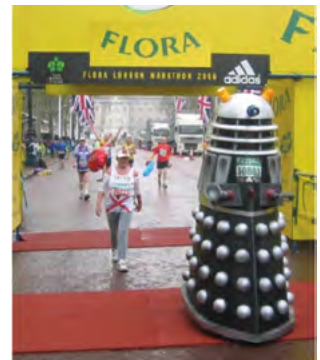
JOHNSON: I am a great fan of rigorously analyzing results. The potential for something like Abaqus is absolutely enormous. I find the code can do so much more these days and people are making very complicated models, but common sense has gone to the background a bit. I believe in, what I call, the "dinosaur methods" of working on something simple: first a 2D model, then a 3D model with two kinds of symmetry, then maybe your main production model, then perhaps a half-model. It's a staged approach.

SCN: Tell us about your hobby of running and how you've blended that with your passion as an inventor.

JOHNSON: I have been running ever since I was a little kid, for about 50 years. More recently, I have been participating in marathons wearing "fancy dress." I've run the London marathon as Dalek of the Dr. Who television series. That



(Left) Bob Johnson's ostrich costume, created by hand and worn during the 2015 London Marathon, weighed 21 lbs. (Right) Johnson's 31-lb. "Dalek" costume from the "Dr. Who" television series, worn during a previous marathon.



costume took roughly six months to make and weighed over 30 lbs. with no wheels. I had to carry that thing 26 miles and never come out of it! I also ran a marathon in an ostrich costume that I had made which weighed about 21 lbs. That was quite a heavy outfit to carry around. The ostrich idea had been in my head for five years and came to life after my brother no longer could run with me.

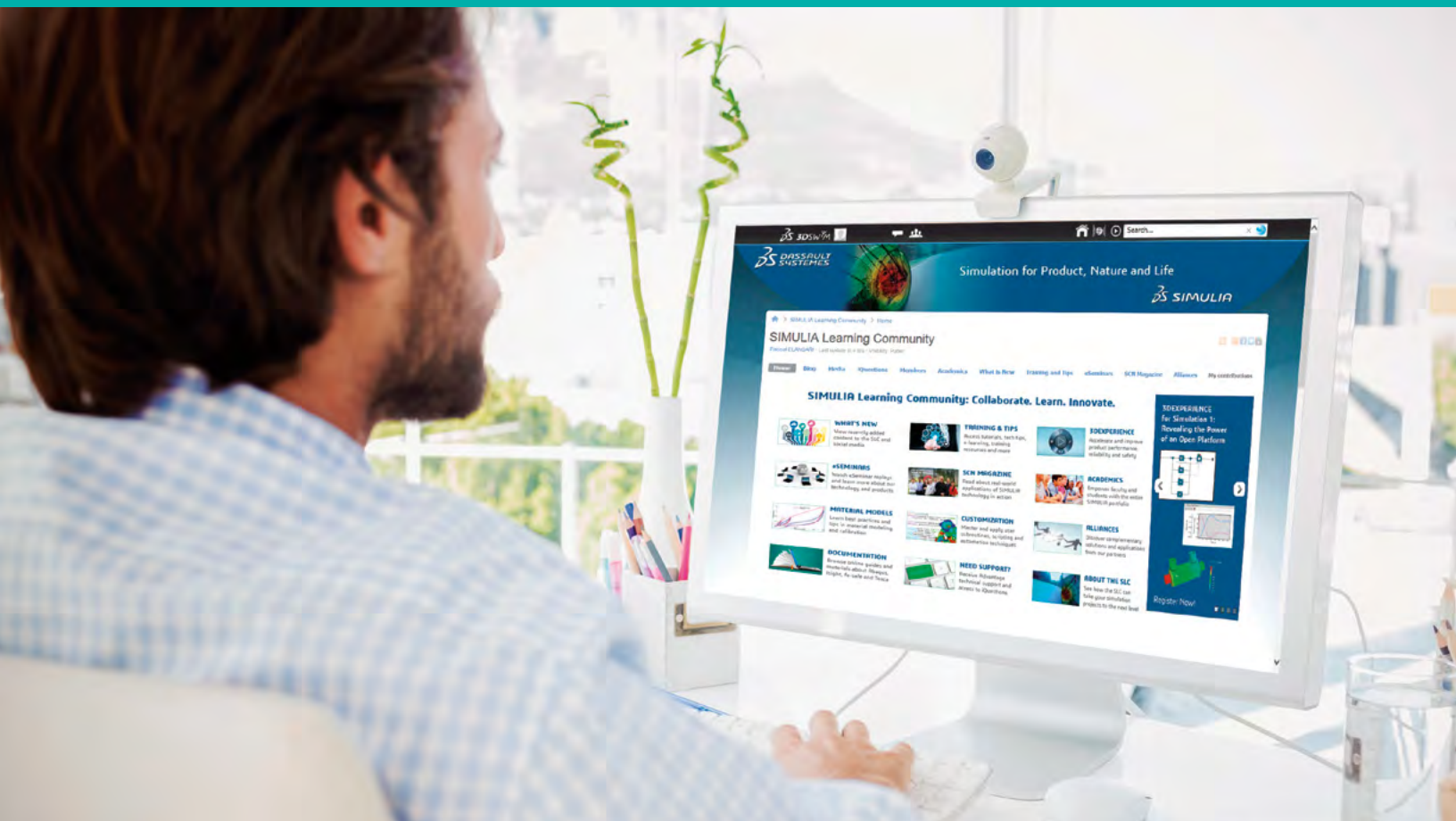
SCN: Have you received any accolades for your creative efforts?

JOHNSON: The Guinness Book of World Records caught wind of my ostrich costume and were eager to include me in their book. Normally you have to submit an application to be in the book nine to ten months in advance. Nevertheless, when they saw it, they were amazed by the fact that it was over 20 lbs.—and basically made a new classification for me. They called it "the fastest marathon as a three-dimensional bird."



(Left) A large-scale, porous structure built by Johnson that was featured in Benchmark magazine and has been put on display by SIMULIA. (Right) A smaller version of the model.

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