# SIMULIA COMMUNITY NEWS

#10 May 2015

## SIMULATION POWERS INNOVATION

COMPETING WITH CONFIDENCE IN A CROWDED MARKETPLACE

## COVER STORY

iXent, GmbH

DASSAULT SYSTEMES | The 3DEXPERIENCE® Company




# In this **Issue**

May 2015



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## STAYING AHEAD OF THE GAME

For those of you attending our 2015 SIMULIA Community Conference in Berlin, I welcome you, and I hope to meet you in person at the event. I always look forward to hearing about the various ways our customers use SIMULIA's applications. For those of you reading this new issue of SIMULIA Community News in your office, home or elsewhere, I greet you, too! I hope you have had a strong start to 2015.

We challenge you to seize the opportunity in front of you and to power transformation at your own company. Even if you don't consider yourself an innovator, you are! Your work will continue to increase in value as more powerful tools become available and the scope of what you are able to do widens. In this issue, as well as at our conference, we will expand on this theme and show you how many of our customers are already benefiting from these advancements.

In the Product Update section, you will read how the capabilities in our R2015x release are designed to support the work you do now and the growing needs of your business in the future. We hope you find these improvements will continue to add to the value of our products. Harmonizing Product, Nature and Life continues to be a focus for SIMULIA as we prepare to release the first-ever commercially available multiphysics human heart model. The Living Heart Project is the first milestone in this effort to develop detailed biomechanical models of important subsystems. Look for more news about this in the weeks and months ahead.

As our portfolio continues to grow, we see more of our customers harnessing the power of the products. Our cover story highlights the benefits of leveraging experience and technology. Read how iXent's advanced composites work using Tosca helped contribute to the Oracle Team USA's win of the America's Cup in 2010 and 2013. We also have two articles showcasing our latest SIMPACK acquisition: Clemson University and the Rosetta space probe mission to comet 67P/Churyumov–Gerasimenko.

At SIMULIA, we challenge ourselves to continually meet and exceed the demands of your business and the need to stay at the forefront of current trends in the market. The promise of simulation-powered innovation is the acceleration of product to marketplace and the reduction of cost and materials. This is a win-win for you and for us. This drives our delivery of software now and will in the years to come.

Happy simulating!

***Sumanth Kumar***
*VP, SIMULIA Growth*

# ENHANCE THE VALUE OF YOUR SIMULATION TOOLS

## The latest **3D**EXPERIENCE platform update offers important productivity benefits to the SIMULIA user community

As a member of the SIMULIA user community, you can take genuine pride in the fact that the continuously enhanced capabilities of Abaqus, Isight, fe-safe and Tosca are a direct result of the input and feedback you give us over the years. The SIMULIA portfolio wouldn't be where it is today—the best-in-class suite of simulation technologies for the specialist—without you.

Dassault Systèmes has always understood this fundamental user/developer relationship of mutually beneficial scientific inquiry and technical collaboration. And DS has been working rigorously in recent years to extend the reach of SIMULIA's advanced simulation capabilities into the Enterprise with industry-specific offerings now available across a vast range of engineering disciplines.

In aerospace and defense, for example, Isight is at the core of the Winning Program industry solution experience that performs trade studies to develop complex physical platforms capable of meeting competing customer requirements. Co-Design to Target is based on Abaqus analyses of parts and small assemblies in the detailed design phase. Likewise, Abaqus is used to perform analyses of large assemblies to support physical testing for certification in the Test to Perform program.

SIMULIA capabilities are similarly threaded throughout the Energy, Process & Utilities industry experience in applications that help design sustainable wind turbines, manage simulation data in power plants, and integrate oil & gas reservoir simulations with geomechanics to increase recovery and improve safety. (There's much more: To view the full roster of industry solution experiences please visit www.3ds.com/products-services/simulia/capabilities)

Now DS is amplifying the power of this collective knowledge for existing SIMULIA users at the simulation-department level by offering you robust, tangible benefits on the **3D**EXPERIENCE® platform that deepen the support for, and extend the value of, your own established tools. Your Abaqus, Isight, fe-safe and Tosca capabilities (and any other software you use as well) will continue to be your go-to, workhorse resources. But you now have the option to do much, much more with them by accessing them on the powerful **3D**EXPERIENCE platform.

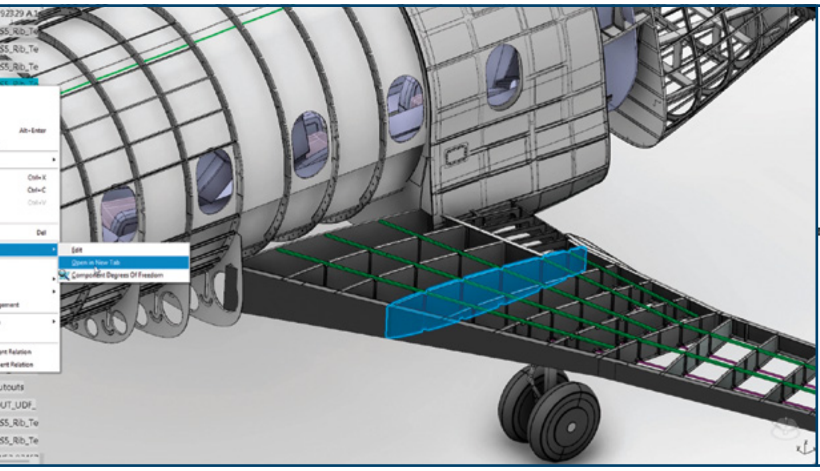
You may have heard about the latest release of **3D**EXPERIENCE R2015x earlier this year. You might be wondering how it could apply to your own work. Here are just a few ways you can build additional value into your simulation results using the 3DX platform:

- **Direct CAD Modeling Capabilities for geometry repair and changes**

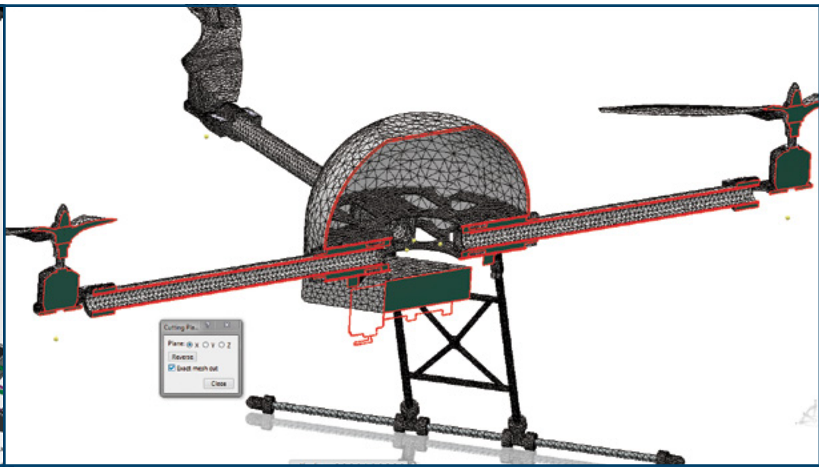
  **Benefit**:
  - Easy product design change based on CAD morphing allowing fast design-analysis loops for experts in preliminary design who don't know CAD systems

- **Rules-based Meshing and Collaborative Batch-Modeling**

  **Benefits**:
  - Generate high-quality meshes with significant reduction in meshing and modelling time



Better than associativity, simulation tasks are performed directly on the design geometry for parts, sub-assemblies, and complete vehicle assemblies. Simulation methods and model building tasks can be automated, recorded, and re-used to simplify model building for even the largest assemblies.



For the analyst, R2015x offers advanced finite element simulation techniques to understand and validate complex engineering problems using best-in-class Abaqus simulation technology provided within a collaborative enterprise environment built to maximize the value of simulation activities.

- Mesh quality guided by mesh rules independent of the experience level of the user
- Storage and easy retrieval for playback of best practises (meshing rules and modelling techniques)
- Collaborative tools to build large-scale models leveraging multiple teams and locations
  - Distribution of CAE tasks between users with single source of the truth
- Less time spent looking for geometry, part assembly information, and connection data

- **Simulation Process Capture and and Re-use**

  **Benefits**:
  - Capture of processes and best practises for re-use
    - Extend to non-expert users
  - Design space exploration
    - Process composer and results analytics provide powerful tools to drive innovation through simulation

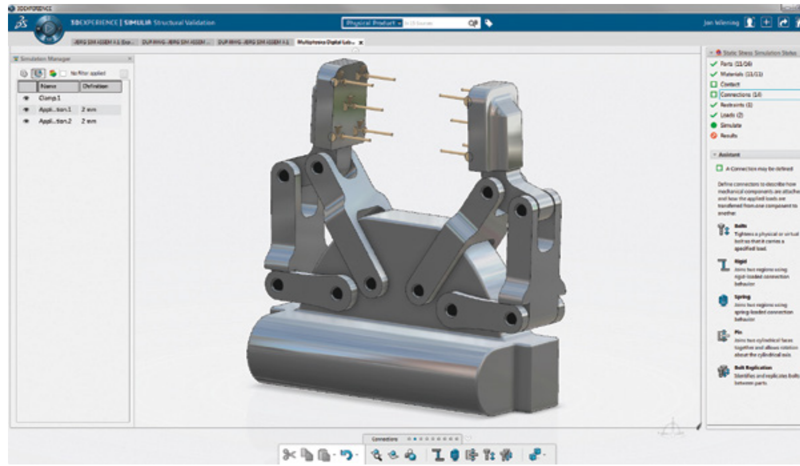
- **Big Data Analysis via Results Analytics to assimilate simulation data**
- **Flexibility to change simulation processes as needed, enabling products to be brought to market faster**

All these capabilities in R2015x are designed to support the work you do now—and add more value to the work that is increasingly being asked of you going forward.

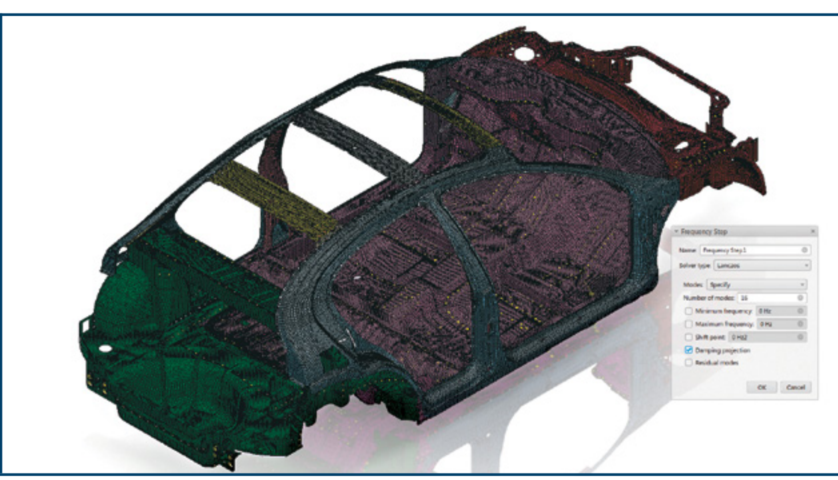
You well know that optimization and collaboration are keys to the digital experience of today. Of course experts and analysts will always have to apply their unique expertise to the most complex problems—but they may now need to share, consult and collaborate in new ways. Larger teams are increasingly required for today's more complex design and engineering challenges in order to arrive at optimized, time-and-cost-effective solutions that are innovative enough to capture your customers' imaginations—and their business. **3D**EXPERIENCE R2015x supports both your existing work as well as this expanded opportunity to leverage the power of simulation.

Your needs in any industry will, of course, vary with your role. Being introduced in R2015x is a user interface through which you can select capabilities appropriate for your role in a project directly from the 3D Compass. Examples of roles include stress analysis engineer, project manager, or process planner. All your choices can be customized to your toolbar.

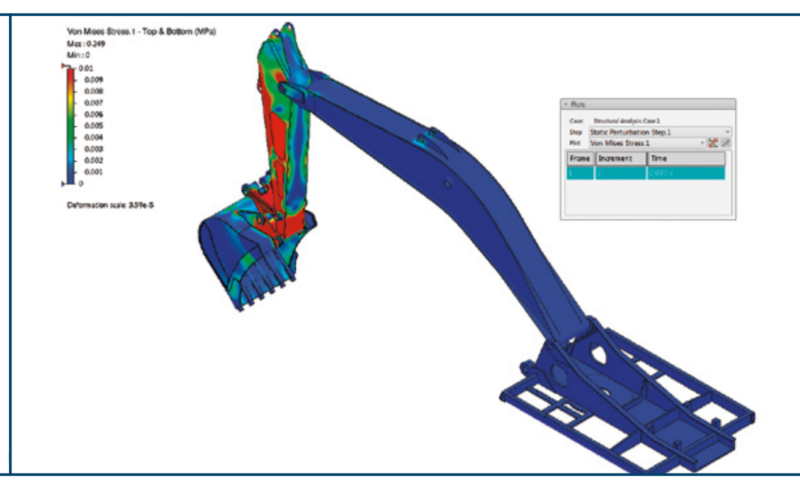
Want to learn more? Consider attending the Early Bird session at the 2015 SCC in Berlin, ask your sales representative, and/or read about it here: www.3ds.com/how-to-buy/contact-sales



Design engineers can use R2015x technology to perform routine strength and deflection calculations under static loading conditions directly from the design geometry using an active assistant and an intuitive interface to estimate product life and guide design modifications.



State-of-the-art simulation based on well-known Abaqus technology deployed in a comfortable connected interface is available to validate noise and vibration requirements of complex products subject to structural dynamic loading using advanced techniques with high accuracy.



The **3D**EXPERIENCE R2015x release provides powerful finite element based simulation techniques for structural analysis engineers responsible for assembly performance to assess the structural integrity of products subject to a wide range of loading conditions and guide design decisions.

# SIMULATION POWERS INNOVATION

## Competing with confidence in a crowded marketplace

There is little doubt that the simulation world is changing. At the 2014 SIMULIA Community Conference, we even called this change a revolution! Such a wonderful word does capture the excitement that pervades the simulation industry today even if you may think that it is too strong a word to use in our familiar world.

So what's really going on?

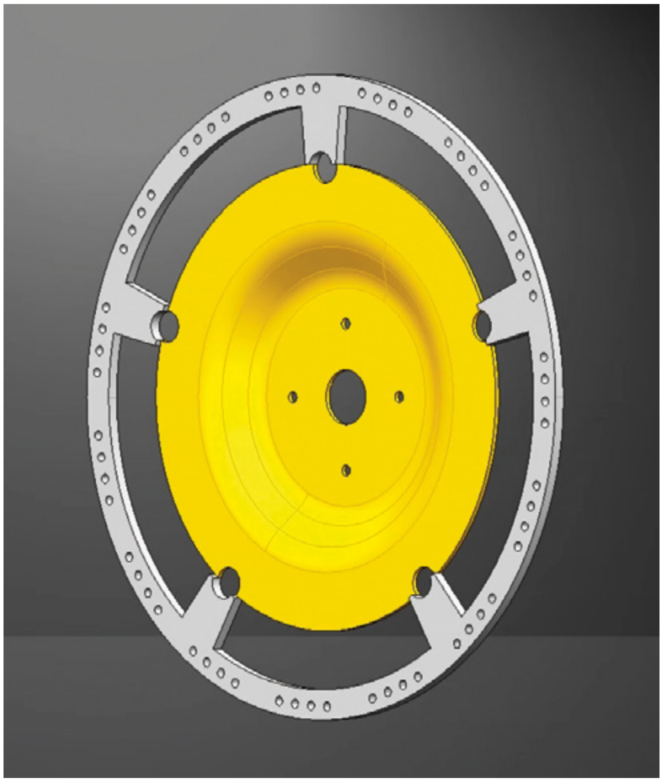
Historically, the simulation industry has been focused on the process and end result of the "solve" part of simulation. At SIMULIA, our history from the beginning has been a very strong focus on technology related to the mechanics, functionality, usability, and performance needed to "solve" your most challenging and important industrial simulation problems. We have focused on solver performance and scalability, on features for state-of-the-art mechanics and material modeling, on assemblies and contact problems, on fracture, on multiphysics co-simulation, and on many other areas of deep technical need in FEA.

Let's be clear: This technology focus at SIMULIA is continuing and will continue. It is our heritage, our belief, and our mantra that users need as much technology as they can get their hands on. And we are responding with the widest, most scalable, most easily accessible technical portfolio in the business through our Power of the Portfolio established product line delivered with the simple Extended Packaging strategy. With the Power of the Portfolio and Extended Packaging, users today get immediate access to Abaqus for FEA, Tosca for non-parametric optimization, Isight for parametric optimization and process capture, and fe-safe for durability and fatigue simulation, all through a shared token pool that provides efficiency, flexibility, scalability, and is economical. With the Power of the Portfolio, we are offering more technology today than ever before.

But our industry is changing. Today, simulation users need even more than just technology. We need a way to capture and leverage the knowledge we gain through simulation throughout our companies, to communicate its value more fully and more widely, and to bring simulation to bear on a much wider array of problems facing industry today. The issue for most companies in their hyper-competitive environments is not simply how to "solve," but how to "innovate." Simulation plays a very large role in innovation. Unlike prototype testing, simulation is available anywhere, anytime, 24/7/365. Through captured workflows developed by specialists, but deployed to non-specialist users, anyone now has access to the value of simulation and its benefits. And of course, testing often provides a simple pass/fail result.

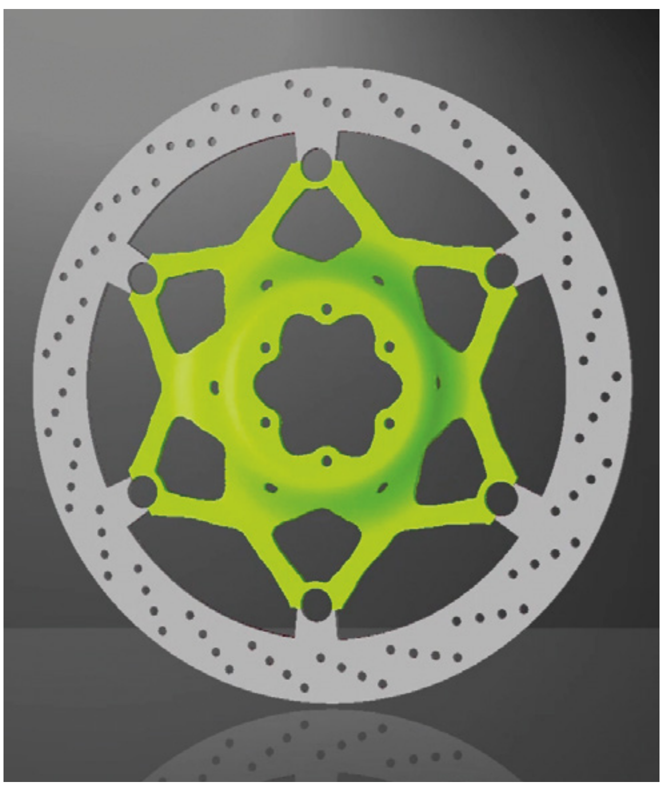
Simulation, on the other hand, can tell you why your product passed or failed. It can tell you how close you are to failing. It can highlight ways to improve your product design, and can drive learning, understanding, and the entire design process. And with process capture and automation, simulation allows you to explore your design spaces in ways impossible to imagine. We now have many, many examples of customers using our technology to identify design points that could never have been identified before.

So the industry is going through a revolution: from "solve" to "innovate." When we have fully made this transition, simulation activities will be the core of what companies do. Analysts will become essential for not only reducing costs and design time, but reducing risk. They will allow their companies to compete with confidence in their crowded marketplace, to develop innovative products that benefit society, and to fully utilize the promise of computing and the virtual world. Those who don't make this transition will fall behind.

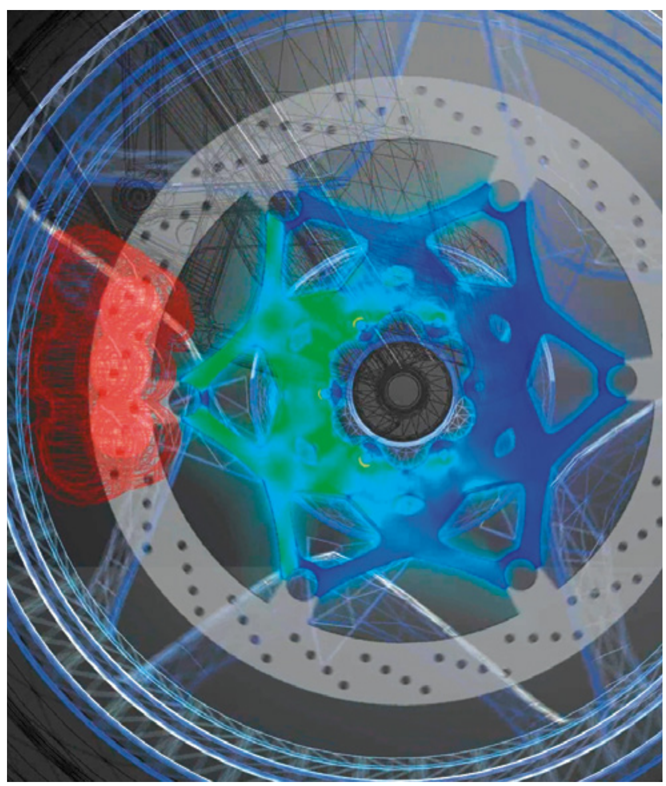


The initial design concept.

Innovation at work - an intermediate design state during optimization.



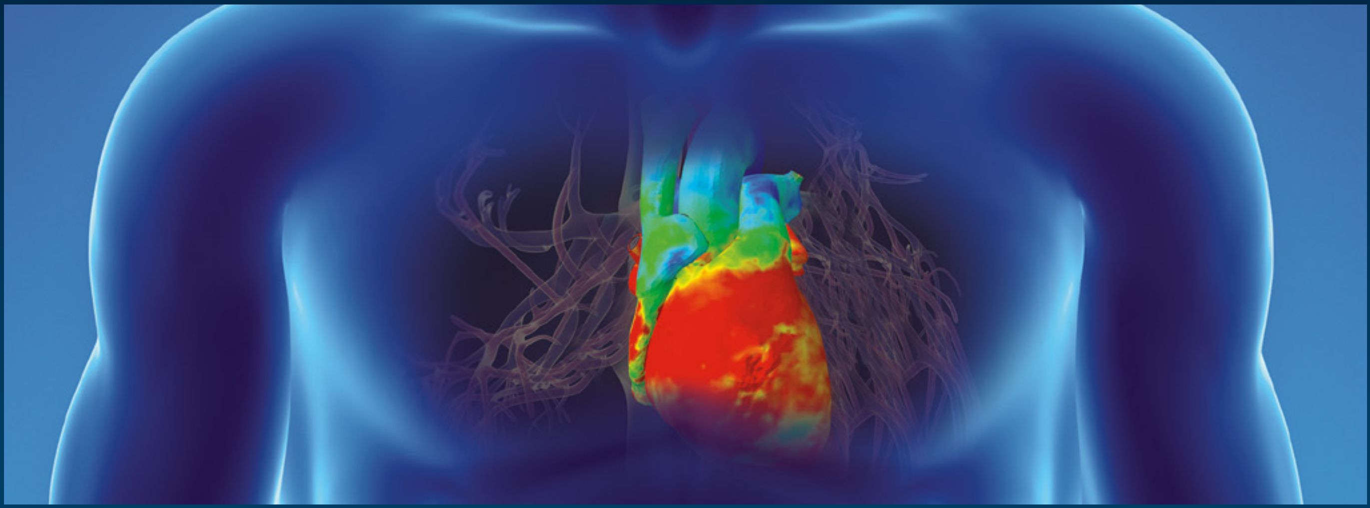
The final design optimized for weight.



Performance validation of the final design.

## For More Information

www.3ds.com/simulia



# SIMULATION COMES ALIVE

## Design and engineering come out of the lab and into the real world

Since the time of Imhotep and the Egyptian pyramids, engineers have been hard at work inventing and improving the devices that make our lives easier, more enriched and productive, while doing their best to minimize any negative impact on our world. However, the bounds of human understanding and available technology have long forced us to reduce the complexity of the real world into idealized and disparate representations, and as a result, our products have sometimes been sub-optimal. As we enter the 21st century and the age of experience, it is now possible to overcome these limitations and include a realistic representation of the world in which our products will function...in other words, to harmonize product, nature, and life.

At SIMULIA, we have been working for more than five years on technology to help our customers embrace this holistic approach, with a particular focus on the people who use, wear, or even host these products in their bodies. The first milestone was the Living Heart Project, launched in 2014 to a warm reception for its ground-breaking vision, unique crowdsourcing collaboration methodology, and rapid pace of development. This May, we release the first ever commercially available multiphysics human heart model. This model will allow medical researchers and device engineers to study healthy and diseased cardiac function, as well improve implanted device performance and reliability.

While the cardiovascular system keeps us alive and healthy, the musculoskeletal system allows us to experience our world and interact with the products we create. With guidance from experts across industry and academia, we have developed detailed biomechanical models of important subsystems including arms, legs, shoulders, hands, and feet that can determine the balance of internal forces generated during daily activities such as walking, lifting, and manipulating objects. Combined with material models for flesh, skin, bone, and other biological materials, we can start creating a truly realistic virtual human environment. Using these models, product designers can understand how people actually experience everyday objects such as running shoes, toothpaste tubes, tennis rackets, car seats, and so on....and then design new products that perform better, and are safer and more fun to use.

"These are exciting developments for engineers who want to go beyond developing products in isolation," says Victor Oancea, Principal Scientist, SIMULIA CTO Office. "Unlike their real counterparts, virtual human models can be interrogated while they experience a product and provide unprecedented levels of feedback for design exploration and performance optimization." The product roadmap does not end with a virtual environment to test new medical devices and procedures. Tools are under development to allow researchers and clinicians to be more precise in diagnosis and treatment, directly improving health while reducing time, inconvenience, and expense. Going beyond medicine, engineers can learn from nature to understand the body as an optimized multiphysics and multiscale system, and accelerate the development of the biologically inspired products and technologies of tomorrow that will adapt to our lives.

Where does all this lead? With the launch of the heart model and the emergence of the **3D**EXPERIENCE platform, we usher in an era where products will not just be tested before they are built, but will actually be used in the virtual world. The possibilities are limitless. Working together, we can take design and engineering out of the laboratory and into the real world... as they were always intended.

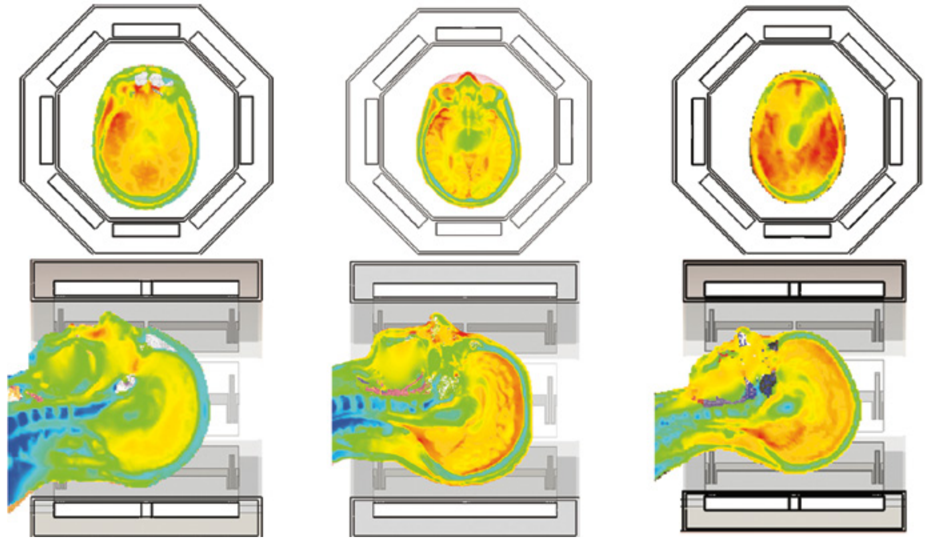
**For More Information**
www.3ds.com/heart

# CST – COMPUTER SIMULATION TECHNOLOGY AND SIMULIA ENTER INTO A NEW STRATEGIC PARTNERSHIP

Dassault Systèmes Simulia Corp. and CST–Computer Simulation Technology are embarking on a new strategic partnership. CST is an electromagnetic simulation software company founded in Darmstadt, Germany in 1992. CST has a balanced presence across the globe with offices in EMEA (Germany, France, UK, Italy, Poland, others), Americas (Massachusetts, California, and Brazil), and Asia (Korea, Singapore, China, India, and Taiwan).

Currently, CST is very strong in the high frequency electromagnetics market (antennas, Electromagnetic Environmental Effects (E3), passive components, emissions, signal integrity, MRI safety, etc.), as well as in the low frequency market (sensors, switchgear, transformers, motors, generators, and other machinery).

The partnership with SIMULIA will focus on interoperability between our respective products as well as new electromagnetics applications on the **3D**EXPERIENCE platform, which can be coupled with other physics.



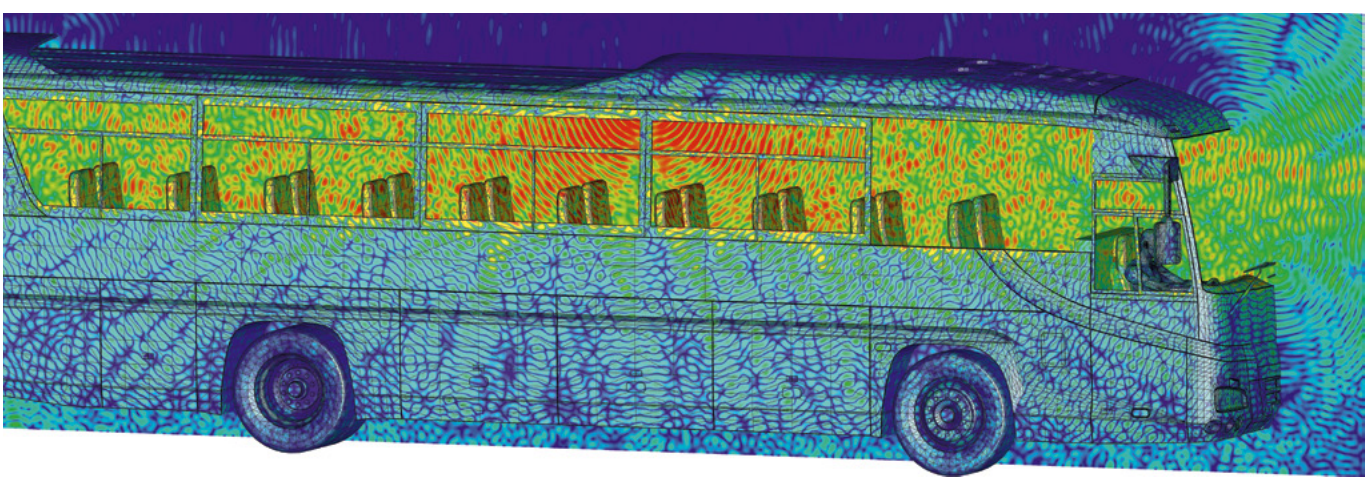
10 g averaged SAR distributions in three different models in the same head coil, in transverse (top) and sagittal (bottom) planes. Images Courtesy of Erwin L. Hahn Institut, Essen, Germany

As the market trends toward wireless, interconnected smart products, this partnership will enable a more complete solution for our customers. CST provides the most comprehensive and technologically advanced solutions in the electromagnetics space. They have many 'first-to-market' claims: Finite Integration Technique, Perfect Boundary Approximation, Thin Sheet Technique, and Complete Technology for 3D EM. CST and SIMULIA are both market leaders and are well aligned from a technical and cultural perspective. We will be able to leverage existing technologies to deliver new solutions in the growing low frequency electro-mechanical market.

CST is a Premier Sponsor at the SIMULIA Community Conference in Berlin, Germany (May 19-21). They will be presenting their solutions in the Integrated Solutions speaking track. For further information on our partnership, please contact SIMULIA Alliances.

### For More Information

www.cst.com



Wi-Fi coverage simulation: Electric field from a Wi-Fi antenna at 2.45 GHz inside a bus, simulated with the transient solver.

# SMOOTHER SAILING WITH SIMULIA

## Advanced engineering company iXent employs the power of the SIMULIA portfolio to optimize and lightweight a key composites component for a world-champion racing boat

A two-sailor team quickly rotates the "coffee grinder" that powers the gear driving a winch (lower right).

The graceful swoop of a racing sailboat through ocean waters is a compelling sight. There's the slice of streamlined bow through the waves, the dramatic shift of massive sails, the side-to-side rush of the crew as the boom swings and the boat comes about—and the flurry of "coffee grinder" teams frantically winding the winches to drive the rope lines that fine-tune the whole performance.

The manpower that makes those winches work is impressive: Two sailors, facing each other, grab and turn a pair of handles together at breakneck speed. The rotational force they generate is transferred through a gear to a large winch controlling a variety of running-rigging lines. These lines—halyards, downhauls, sheets, etc.—are either tightened or released by a whole series of deck-top winches that change the position of the sails and boom. A recreational sailboat employs lighter, one-handed winches, but it's a different story on a racing boat, where up to six two-person teams must supply the manual energy that drives all the vessel's key working components.

"The more aggressively you sail these racing boats the higher the loads on the winch-gear structure get," says Thomas Hahn, founding partner of iXent, a German technology consulting and engineering services company that specializes in applied lightweight engineering of composite materials. He should know: Hahn and co-founder Christoph Erbelding helped design components for the U.S.'s Oracle Team USA sailboats that won two America's Cup championships.

### WHY TWO AERONAUTICAL ENGINEERS DESIGNED A YACHT WINCH

Although now known for their sailboat expertise, Hahn and Erbelding originally trained as aeronautical engineers—and then went on to spend years in the automotive industry. It was their Munich location (close to Audi, BMW and Mercedes), and iXent's extensive (and still ongoing) advanced automotive composites work, that led to their being chosen to join the Oracle Team USA "technical competence" team in 2004 by BMW, a sponsor of the America's Cup. iXent's profile in high-tech yacht racing evolved rapidly from there as Oracle Team USA went on to win both the 2010 and 2013 Cups; they are currently working with the 2017 team.

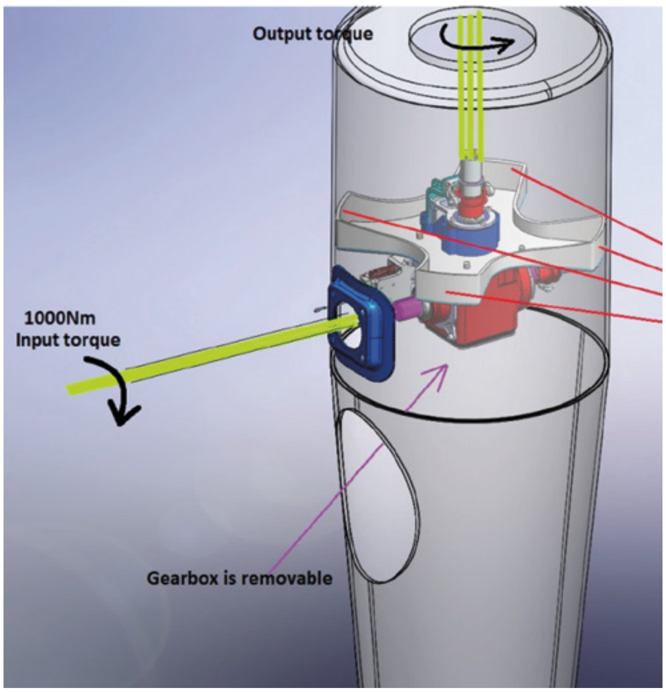
Of course the yachting world is a vast one, with hundreds of races held around the globe in a wide variety of classes based on length, hull type, rigging, etc. A key race for owner-drivers of the larger boats (the Maxis, above 72 feet long), the Rolex Maxi Worlds, has been held at the Costa Smeralda Yacht Club in Porto Cervo, Italy, every September for 35 years. A "Mini-Maxi" competition for "smaller" maxi boats was added in 2010. Regardless of length, the Maxis are all known for pushing the boundaries of design and technological innovation.

The owner of one Mini-Maxi, the Alegre 3 (24 meters), became a client of iXent when a colleague they'd worked with on the 2010 Oracle team, winch specialist Jon Williams of Stay In Phase Ltd., recommended iXent's capabilities. The Alegre team was looking to fine-tune design and weight to help overcome the second-place finishes they'd had to settle for in the previous two years at Porto Cervo.

> "We see the whole simulation package as a big help. If you don't use it you will be left behind. These digital tools definitely support us in making our experience-based decisions."
>
> –Thomas Hahn, founding partner of iXent

Every area on the boat was open to review, leading to some significant developments. The ramp deck was made into a continuous surface from cockpit floor to foredeck, creating an unbroken load path that increased the stiffness. The keel fin was bolted to a keel tower internally to further maximize stiffness and produce the biggest possible righting moment.

To accommodate the increased loads on the rigging due to all that added stiffness, Williams asked iXent to reimagine the winch design—making it more robust while taking out as much weight as possible. The primary winches needed to be placed in the optimal location for the trimmers, on pods which incorporated the winch gears into vertical shafts for maximum rigidity.




Winch gear (red) and support (grey and white) inside shaft. Winch (not shown) is at top.

An initial design space for a winch gear support plate optimization exercise. Designs that stay with such a flat, circular shape can be susceptible to warping under the high stresses of competitive sailing.

## SIMULATION LEADS TO TOUGHER, LIGHTER DESIGNS

iXent focused on the support plate that holds everything in place inside each winch shaft. Many other gear-support designs Hahn had seen were just flat, circular plates highly susceptible to bending and twisting under excess stress. "The plate has to be really, really strong," he says. "I've seen this in reality: a weak support starts bending and wiggling around. If the support deflects, the whole drivetrain locks up and you can't move your mainsail."

So how to go about designing the optimum winch-gear support for the Alegre? While iXent applied its own extensive industry knowledge, and several proprietary techniques they'd rather not discuss, Hahn is happy to name some of the simulation tools his group depended on to guide much of their innovation: from the SIMULIA portfolio, Tosca Structure (for non-parametric topology optimization); Isight (for process automation and parametric optimization); and Abaqus (for finite element analysis). Their primary CAD tool was Dassault Systèmes' CATIA.

"We see the whole simulation package as a big help," says Hahn. "The simulation process chain we have here basically covers everything from conception up to detailing. Our customers know we are using cutting-edge technology. If you don't use it you will be left behind. These digital tools definitely support us in making our experience-based decisions."

That experience dictated that the plate be made from composite materials. "You always push for your designs to be as light as possible because these boats have to really fly nowadays and, in the case of Alegre, the class rule limits your maximum weight," says Hahn. "So with any component, if you can design something lighter with composites, you should do it. Even just leaving off a few grams, multiplied over several parts, can add up to a significant weight difference."

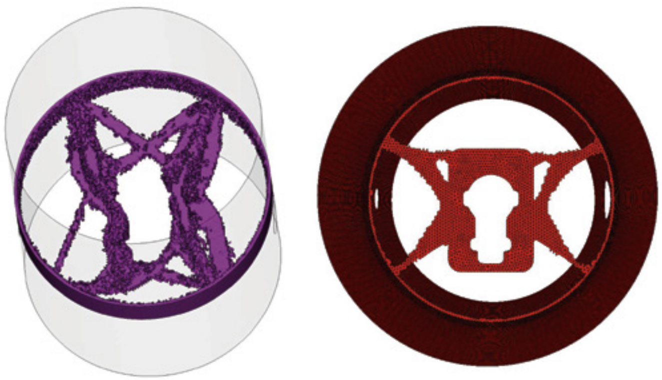
Tackling the durability challenge required additional assessment of just what sort of loads the winches would experience during a racing event. "Six crew members on three winches can produce up to 1200 newton meters when they're sheeting in a mainsheet sail—that's like generating a load greater than the weight of three mid-sized cars," says Hahn. "Another way of looking at it is that 1200 Nm is about three times the torque moment of modern three-liter diesel engines, which are known for their optimal torque production."

## TOSCA FUELS IMAGINATION, INNOVATION—AND "THE BATMAN"

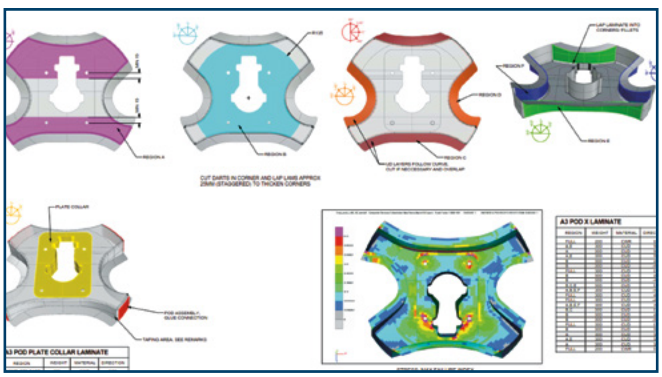
With load estimates in hand, the team was ready to perform a non-parametric analysis of the problem using Tosca. "We like to think differently about every design problem we take on," says Hahn. "We say, 'Let's think innovatively about it'—and this is why we use Tosca. You define a structure which is essentially a black box at the beginning. You add in your anticipated load cases—top, bottom, up to as many as ten.

"Even as an experienced engineer, I can't fully imagine what the optimum structure is in terms of where I can save weight and where I have to add material in. But Tosca automatically runs through all the possibilities to give you a meshed, almost Rorschach-like pattern that identifies the most efficient structure."

Because the initial Tosca result bore a strong resemblance to the Bat Signal projected into the sky to call the Caped Crusader to the rescue, the team affectionately dubbed the new winch support design "The Batman."



(Left) iXent's first Tosca iteration of the sailboat gear support and (Right) the final output.



(Top) Final drawings for the Batman winch-gear support plate design. Note phalanges along outer edges (upper right image) that provide additional stiffness. (Bottom) A finished Batman composites component.

Next the team rebuilt their Tosca geometry in CATIA, refining it further into a 3D CAD representation. They then used the pre-processor ANSA (from Beta CAE) to extract an executable file into Abaqus, setting up a system of torques and moments that represented the envelope of loads the part would see during operation.

## ISIGHT AND ABAQUS OPTIMIZE COMPOSITES DESIGN

Finally the team employed Isight to automatically drive a series of Abaqus FEA analyses toward an optimized composite laminate design that had the least possible weight but satisfied all the required boundary conditions. "You can't do this degree of optimization by hand," says Hahn. "You might have intuition, but it's really amazing how these tools squeeze out the last bit of weight savings from your laminates."

Interestingly enough, Tosca can also contribute to a determination of composite orientation later on in the production process, Hahn notes. "Tosca basically creates a truss/bridge type of structure that uses the least amount of material to minimize bending. Of course, composites work in much the same way: Their fiber orientation is strongest along the length of the fiber, in either compression or tension. So why not use Tosca to design a composite laminate, because the principles are the same."

The final Batman design achieved a weight savings of around 17% compared to a typical such component in a racing yacht. And—coincidentally or not—the Alegre, with its newly optimized winch gear supports, won the Mini-Max competition in 2014.

## WINNING TAKES A TEAM

Hahn is a busy man, and was pleasantly surprised to hear of the win some months after it happened. "I don't think you win by being strong in just one field," says Hahn. "You win by having the best total 'package'—very good sailors, very good shore support and, of course, good design. In this case our client really likes the final Batman solution, which is both light and strong.  If you go at every part on your boat with those goals surely you would end up with the optimum design package."

That winning attitude helps iXent bring their Tosca expertise to bear on a variety of weight reduction challenges faced by their automotive and manufacturing-automation clients as well. "While the Batman example is a nice demonstration of what is possible, we also use Tosca for much bigger structures, like topologies on larger parts of cars as well as boats," says Hahn.  "You can use Tosca for almost any structure when you are not clear what the most efficient shape looks like; Tosca sparks your imagination and gets you out of your design rut."

### For More Information

www.ixent.de

# TEXAS A&M UNIVERSITY USES ABAQUS TO SIMULATE SELF-FOLDING STRUCTURES

## The Shape Memory Alloy Research Team (SMART) analyses Shape memory alloy (SMA)-based self-folding structures

Figure 1. Examples of paper models created via origami principles.

Origami has inspired the design of engineering structures for decades. The endless variety of shapes that can be obtained by folding a planar sheet makes origami of great interest to engineers and scientists. For instance, Figure 1 shows a small spectrum of the countless shapes obtained by folding a piece of paper.

The fundamental principles of origami are universal, which has led to applications ranging from nano-scale devices to large deployable space structures. In recent years, engineers have become interested in the use of active materials, those that transform various forms of energy into mechanical work, to exert the folds in these structures. Active materials allow engineers to make self-folding structures, which are capable of executing folding and unfolding processes without being manipulated by external loads. This is valuable for many applications including remotely-operated systems (space and underwater), small scale devices, and self-assembling systems.

In this work, the focus is on the simulation of shape memory alloy (SMA)-based self-folding structures. SMAs are active materials that undergo solid-to-solid phase transformations induced by appropriate temperature and/or stress changes during which they can generate or recover seemingly permanent strains. These characteristics allow them to have several existing and potential applications in diverse fields such as aerospace, biomedical, and others. SMAs can provide a significant amount of strain (up to 10%) under large stress (hundreds of MPa), a characteristic of great utility in morphing structures.

The ***Shape Memory Alloy Research Team*** (SMART) at Texas A&M University (http://smart.tamu.edu/), led by Drs. Dimitris Lagoudas and Darren Hartl, has years of expertise in constitutive modeling of SMAs and structural analysis of SMA-based structures. An Abaqus user-material subroutine (UMAT) developed by the SMART team members of the world-renowned Texas A&M SMA constitutive model, which has evolved over the years, provides for the state-of-the-art simulation of SMA structures in finite element analysis.

Two challenges arise in the modeling of SMA-based morphing structures: the account for large rotations that arise during morphing (e.g., folding from one configuration to another), and the numerical implementation of evolution equations of variables that account for the inelastic phenomena in SMAs (e.g., martensite volume fraction and transformation strain). To account for large rotations, Abaqus provides the NLGEOM option for most types of analysis steps which provides for proper rotation of variables such as stress and strain and allows for accurate simulation of structures experiencing large rotations. Such a rotation is applied automatically for stress and strain once NLGEOM is active in the considered analysis step; however, non-scalar quantities stored as solution dependent variables in the UMAT (e.g., transformation strain tensor) have to be rotated in the UMAT code itself. To this end, Abaqus provides the rigid body rotation increment matrix DROT as an available input in the UMAT and the built-in utility subroutine ROTSIG that allows for rotation of a tensor. For shell elements where the coordinate system of the material point rotates with the structure, it is not necessary to rotate variables inside the UMAT (DROT is simply an identity matrix) and just activating NLGEOM in the analysis step suffices for the consideration of large rotations.

For the evaluation of the non-linear thermomechanically-coupled SMA constitutive equations in the UMAT, an elastic predictor/ transformation corrector framework is used. The first step in the UMAT is to rotate the non-scalar solution dependent variables using the ROTSIG utility subroutine. Then, the martensite volume fraction and transformation strain are assumed to be unchanged from the previous global iteration and the elastic prediction is performed. Analogous to classical rate-independent plasticity, a transformation surface (dependent on stress, temperature, and martensite volume fraction) is evaluated to determine if the SMA is transforming. Unlike classical plasticity, however, the SMA model has two transformation surfaces that need to be checked; one for transformation from austenite to martensite (transformation strain may be generated during this transformation) and from martensite to austenite (existing transformation strain is recovered during this transformation). If transformation is found to not occur (transformation surfaces having non-positive values), the current value of stress is provided as output. When transformation is found to occur, a return mapping algorithm is used to correct stress, transformation strain, and martensite volume fraction to ensure that the transformation surface value goes to zero (or in practice close to zero within a given tolerance). Proper tangent matrices of stress with respect to strain and temperature (DDSDDE and DDSDDT in the UMAT, respectively) have been derived and are implemented in the UMAT to ensure fast global convergence of the solution. For more information about the SMA constitutive model and its numerical implementation, the reader is referred to: Lagoudas, D., et al. (2012). Constitutive model for the numerical analysis of phase transformation in polycrystalline shape memory alloys. International Journal of Plasticity, 32, 155-183.

The team exploring origami-inspired SMA structures at Texas A&M is led by professors Darren Hartl (Aerospace), Dimitris Lagoudas (Aerospace), Richard Malak (Mechanical), Ergun Akleman (Visualization Architecture), Nancy Amato (Computer Science), and Daniel McAdams (Mechanical). They consider a self-folding composite laminate that has three layers. The two outer layers are composed of pre-strained thermally activated SMA wires in an orthogonal mesh pattern while the inner layer of the laminate is composed of a thermally insulating and compliant elastomer. When either side of the laminate is heated in a line-like region up to a certain SMA transformation temperature, the SMA wires begin recovering the pre-strains and contract, generating a fold at the heated line in the direction of the side being heated.

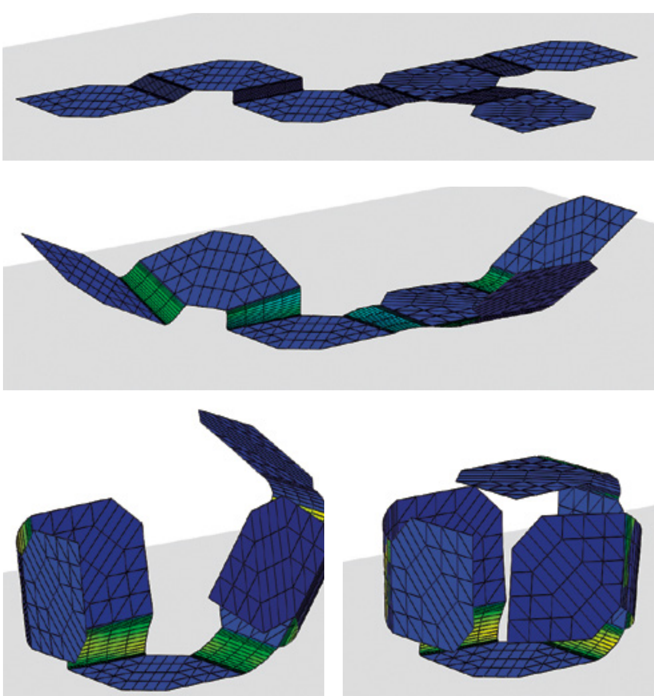


Figure 2. Finite element analysis results considering the thermally induced morphing of an SMA-based laminate sheet shaped to self-fold into a cube. The contour plot indicates local phase transformation progress, a state variable provided by the SMA UMAT.

"Without the capabilities provided by Abaqus, I cannot imagine tackling such a complex structural analysis problem. From the underlying hysteretic material behavior to local instabilities to self-contact, we truly aim to test the limits of the software as we explore this exciting new area."

– Darren Hartl, Ph.D. , Texas A&M University

The generation of the sheet geometry and fold patterns is a challenge that involves multiple disciplines. Such a challenge has been addressed by the collaboration between engineering and architecture/visualization. Dr. Ergun Akleman, professor in the Visualization department at Texas A&M University, is part of the team that works on the study of SMA-based self-folding sheets.

Dr. Akleman and his research group have developed several algorithms and programs to provide engineers with appropriate geometries and fold patterns for origami design. In addition of generating the sheet geometry and fold patterns, Drs. Akleman, Hartl, Lagoudas and their students have developed Python scripts and .inp files to import such sheets into Abaqus for analysis. The .inp files contain the information of the mesh, which can be subsequently refined or modified in Abaqus if desired, as well as element and node sets corresponding to the fold heating regions for convenient element and node selections during the application of boundary conditions.

One of the works includes an algorithm for unfolding and folding of polyhedra. Figure 2 shows an Abaqus finite element simulation of a self-folding cube which geometry was generated using such algorithm (the sheet is modeled with Abaqus S4, S4R, and S3 elements, a composite section is used). The contour plot shows martensite volume fraction (a state variable in the aforementioned SMA UMAT) which ranges from 1 (100% pre-strained martensite) to 0 (100% austenite, a phase in which all the transformation strain in the SMA has been recovered).

The non-linear hysteretic behavior of SMAs as well as structural instabilities such as local buckling at certain regions of the self-folding sheets during the folding/unfolding maneuvers add more difficulty to the execution of these studies. Abaqus

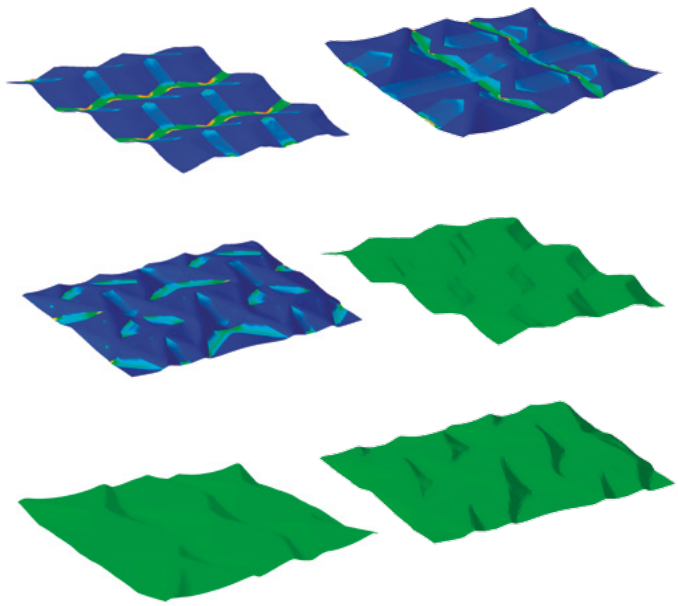


Figure 3. Martensite volume fraction contour plots and shaded shape deformation plots from Abaqus after analysis are presented.

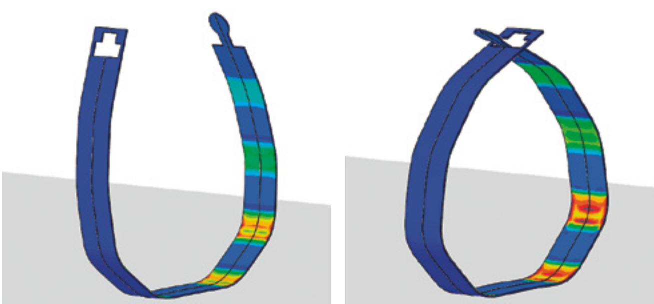


Figure 4. Maneuver towards folding a ring-shaped structure with a tab and slot connector. When the sheet is cooled the tab slides into the thin slot region and the two ring ends connect. Contour plot indicates local phase transformation progress.

features such as geometrically non-linear simulation, contact, and implicit dynamic analysis procedures, along the with UMATs developed by Texas A&M researchers, made this kind of simulations possible. Most of the Abaqus finite element simulations of SMA origami structures at Texas A&M have been performed by Edwin Peraza Hernandez, a Ph.D. student in Aerospace Engineering.

In addition to the use of in-house tools, the team has also explored freely available origami design tools, such a Tomohiro Tachi's Freeform Origami (http://www.tsg.ne.jp/TT/software/). A Python-based script for the importation of Freeform Origami crease patterns into Abaqus has been developed. First, the folding pattern is exported from Freeform Origami as a Drawing Exchange Format (.dxf) file. It contains the considered folding pattern in the form of a line drawing. The .dxf file is then imported into Abaqus as a line sketch. Afterwards, the sketch is oriented, scaled, and positioned into a sheet which dimensions are defined by the user. Next, the folding lines are thickened to create heating areas at the location of the folds. Subsequently, the heating areas are classified as mountain or valley folds. The final step entails the discretization of the sheet into finite elements. Material properties and boundary conditions are added after the importation process is finalized. Examples of fold patterns generated by Freeform Origami and imported and analyzed in Abaqus are shown in Figure 3. It should be noted that although the SMA cannot provide sharp folds (as in creased paper) due to stress constraints, it provides significant curvature at the folds such that the obtained foldcore approximates the desired shape as shown in Freeform Origami.

For self-folding structures created with the SMA laminate, it is inefficient to hold permanent heating at the actuated SMA regions to preserve the shape of the folded structure. Connectivity systems have also been proposed to prevent this permanent heating. Various designs for connectivity systems have been explored via finite element analysis in Abaqus. An example is shown in Figure 4 where the connecting maneuver of a self-folding ring with a tab and slot connector is explored. This problem entails non-linear boundary conditions involving normal contact and tangential friction in the interaction at the tab and slot connection. Abaqus and its multiple options for simulation of contact were essential for these simulations.

The experimental validation of the finite element simulations is essential. To this end, Aaron Powledge, Darren Hartl, and Richard Malak used Digital Image Correlation (DIC) techniques to explore the deformation of experimental samples of the SMA-based self-folding sheet. Finite element models have been created in Abaqus for comparison with experimental data and validation of the finite element approach.

For experimental samples, the overall curvature is found by averaging the curvature of multiple points on the sheet, either on the entire sheet or in local sheet regions (to avoid including regions where sheet defects affect the local radius of curvature). Table 1 shows that the radius of curvature predicted by the finite element model is in good agreement with experimental data that was obtained using different approaches.

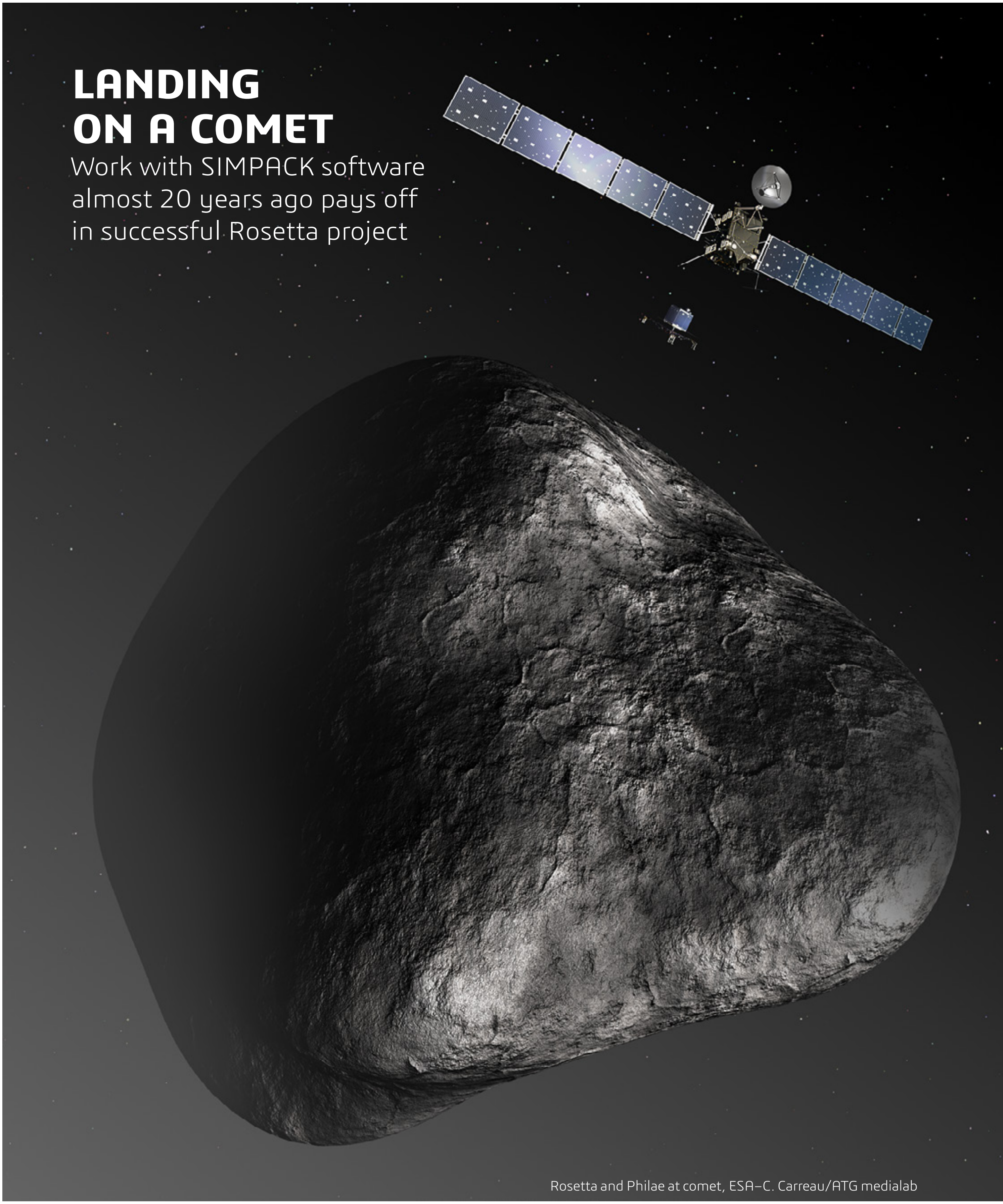
There are multiple other efforts in the simulation of SMA-based self-folding systems, for more information visit http://origami.tamu.edu/. This work is supported by the National Science Foundation and the Air Force Office of Scientific Research under grant EFRI-1240483 and the finite element analysis was performed using a research license granted by Simulia to Texas A&M University.

## For More Information

http://smart.tamu.edu

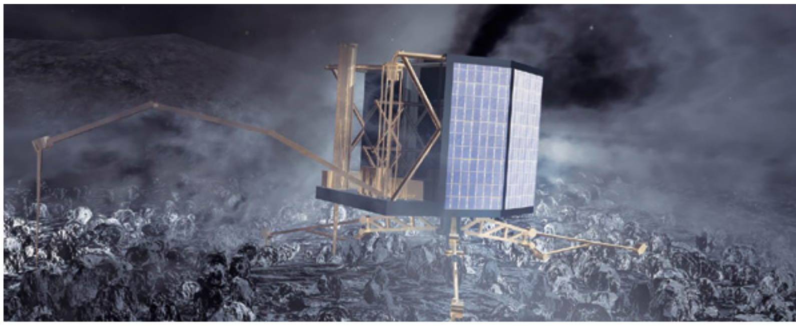
# LANDING ON A COMET

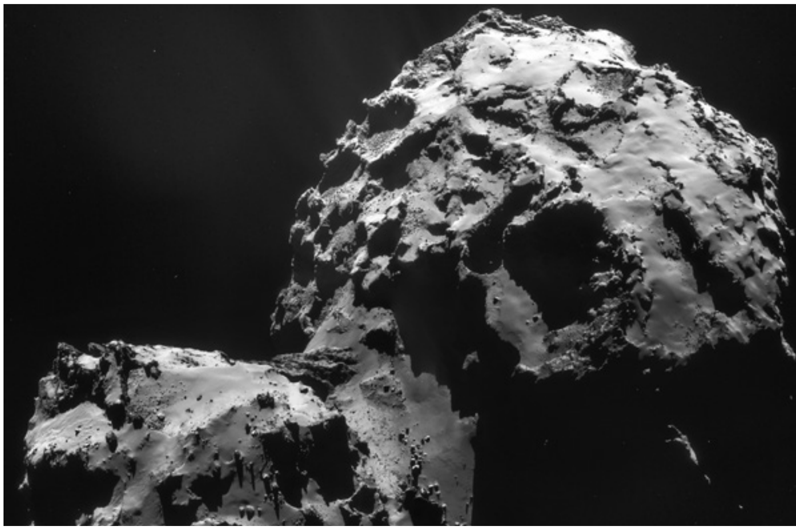
Work with SIMPACK software almost 20 years ago pays off in successful Rosetta project



Rosetta and Philae at comet, ESA–C. Carreau/ATG medialab

Scientists watched with bated breath as the Philae lander left the European Space Agency's Rosetta spacecraft and touched down on the surface of a comet last November after a 10-year, 4-billion-mile journey. Among those glued to their screens was Dr. Martin Hilchenbach, one of the original designers of the lander. He and his team used SIMPACK simulation software (now part of the Dassault Systèmes SIMULIA portfolio), between 1996 and the 2004 takeoff of Rosetta from Earth, to model scenarios for the Philae's landing and guide design changes that helped ensure its survival. A presenter at the 2015 SCC in Berlin, Dr. Hilchenbach answered some questions for SCN earlier this spring:





(Top) The Philae lander at work on Comet 67P/Churyumov-Gerasimenko.
(Bottom) Comet on 10 January 2015 – NavCam.
Copyright ESA/AOES Medialab

### How did you end up on the Rosetta team, designing a vehicle to land on a comet?

**Hilchenbach**: Raised in the industrial part of Germany during the Apollo lunar landings, I studied physics, atomic physics, immunology, laser physics, and photochemistry in Austria and the U.K. I finally achieved a "dream job," in plasma research based on satellite data and instrument hardware development, at the Max-Planck-Institute for Extraterrestrial Physics. Moving to what is now the Max Planck Institute for Solar System Research, I became involved with subsystem development as research scientist for the Rosetta lander, Philae. My first thought when learning of the project was "Great, this has never been done before, it's a new field to explore and, best of all, unlike modeling and data analysis alone, at some point we will know if we got it right!"

### In what ways was your work supported by the use of SIMPACK software?

**Hilchenbach:** The multibody simulation program package SIMPACK was extremely useful, with a robust solver and solid concept, but even more for the capability to easily transfer CAD data and then present the various SIMPACK simulations as 3D "videos" and visualize the advantages and disadvantages of the proposed technical approaches. During the Rosetta development project the software evolved nicely and the interfaces (as well as computer hardware and processing speeds) improved very much. From what I have seen from my colleagues still applying SIMPACK, the overall design has further improved and the interfaces look even better.

The principle that simulation needs to be carried out in close proximity to real hardware and engineering design envelopes is still valid. We tested in an Earth gravity environment to obtain force, joint and other specifications for our models, then just switched the gravity environment from terrestrial to cometary to get a nice, hopefully real, impression of how the actual lander would behave in an environment one cannot really test on Earth.

### Describe your feelings during the actual landing of Philae. How did it compare to your simulations?

**Hilchenbach:** It was very exciting! We were finally seeing the real thing (with a half-hour time delay) after years of simulations. Thanks to the Rosetta orbiter's cameras, we were able to image Philae's free fall—it was like sitting right next to the comet and watching reality unfold. From our simulations I assumed, quite rightly, that Philae would need all three subsystems to work perfectly: the damping mechanism, the hold-down thruster and, most important, the anchoring with the harpoons. After about 20 minutes it became clear that Philae endured the landing in good shape but the harpoon/anchor system did not work and it was hopping across the comet nucleus. The fourth impact, where the lander became wedged in a final resting place, demonstrated that you can secure a lander on a comet without the action of a harpoon/anchor! But the fact that Philae stayed intact, and its pre-programmed activities continued, is testimony to the robustness of the software that we used to finalize its design.

### What are you working on now?

**Hilchenbach:** I am still a staff scientist at Max-Planck and, over the past decade, my focus has been on in-situ analysis of cometary dust as Principal investigator for the COSIMA instrument team of the Rosetta orbiter. But I am keeping an eye on Philae as the comet comes closer to the Sun in May. Over the past few months it's been in a colder environment than it was intended to withstand, but there is a slight chance it will "wake up" and transmit additional data.

### For More Information

www.mpg.de/8323582/wakeup-Rosetta


Figure 1. Clemson University's 7.5 MW test bay showing left to right the drive motor, gearbox, load application unit, and nacelle.

# VIRTUAL TESTING OF FULL-SCALE WIND TURBINE NACELLES

## SIMPACK from SIMULIA is a key tool used by Clemson University to understand and fully utilize monster windpower machines.

The single biggest challenge to studying system-level wind turbine behavior is the stochastic nature of its natural driving force—the wind. Wind profiles corresponding to many of the design load cases are generally rare events, and if you are lucky enough to experience one in the field with a prototype turbine, you'll never see one just like it again.

In consequence, engineers build test benches to allow them to controllably and repeatedly apply full-scale loads to wind turbine components. Wind energy conversion systems have experienced a steady growth in size through their commercialization and use in utility scale power production. But as wind turbine size increases, so too must wind turbine test benches, which have become larger and more complex than ever before and are impressive dynamic systems in their own right.

One such facility is Clemson University's Wind Turbine Drivetrain Testing Facility (WTDTF) at the South Carolina Electric & Gas (SCE&G) Energy Innovation Center (EIC) in North Charleston. The WTDTF houses two wind turbine dynamometer test benches, one rated at 7.5 megawatts (MW) (Figure 1) and the other rated at 15 MW. These test benches are designed to rotate full-scale nacelles while applying non-torque loads (thrust force, vertical force, shear force, pitch moment, and yaw moment). Additionally, the Duke Energy eGRID (electric Grid Research Innovation and Development) center, also located at the EIC, can load the nacelle electrically with an electric grid simulator.

The facilities at the EIC offer testing capabilities for the onshore and offshore wind industry as well as R&D opportunities for students and faculty at Clemson and partner universities. However, these systems are expensive to operate and require a high skill level for safe operation; it's an environment not ideally suited to engineering students or other non-experts.

To help mitigate this situation, Clemson University is constructing a multi-body, real-time wind turbine test-bench simulation laboratory to serve as an intermediary between purely simulation-based analysis and physical testing (Figure 2). The lab consists of two primary pieces of equipment. The first is a duplicate test control computer from RENK Test Systems. The second is a real-time simulation computer from Concurrent Real-Time. This control computer is the human-machine interface to the test rig and is where the test engineer programs the test profile, executes the test, and monitors the behavior of the test bench.

The real-time simulation computer is for running dynamic models of the test benches, which interact with the duplicate test control computer in real-time. The actual simulations are managed by Concurrent's SIMulation Workbench, a complete framework for developing and executing real-time HiL simulations. This tool allows for a SIMPACK multi-body simulation model to be relegated to specific CPU cores, isolating it from other models or processes and ensuring deterministic behavior.

The simulator accepts input signals from the test control computer, simulates the dynamic response of the test bench, and provides feedback to the test control computer. This is essentially a virtual test bench, which offers engineers the ability to evaluate proposed test profiles, troubleshoot unexpected behavior, and train personnel without ever having to use the physical test bench. Additionally, the lab will have controllers, I/O hardware, and data acquisition hardware so that engineers can replicate test-floor configurations in a laboratory setting.

The simulation lab makes the dynamics of the test benches accessible to students and faculty with zero risk compared to using the actual test bench. Practical applications of the simulation lab include test profile development, system troubleshooting, training, and pre-test communication validation.

The laboratory is designed specifically to replicate and study the dynamic behavior of the complete test bench, including both the device under test (DUT) and the test equipment (hardware and software). Many other researchers and manufacturers have studied the dynamic responses of wind turbines. The Clemson lab is focused on understanding the dynamic response of the complete test bench system, including the nacelle.

## MULTI-BODY MODELING WITH SIMPACK

To better understand the dynamic response of the complete test bench, multi-body and dynamic models of the test benches have been created in SIMPACK and Simulink®. The complete test bench includes the DUT in addition to the test equipment. Components modeled in SIMPACK include the drive motor,

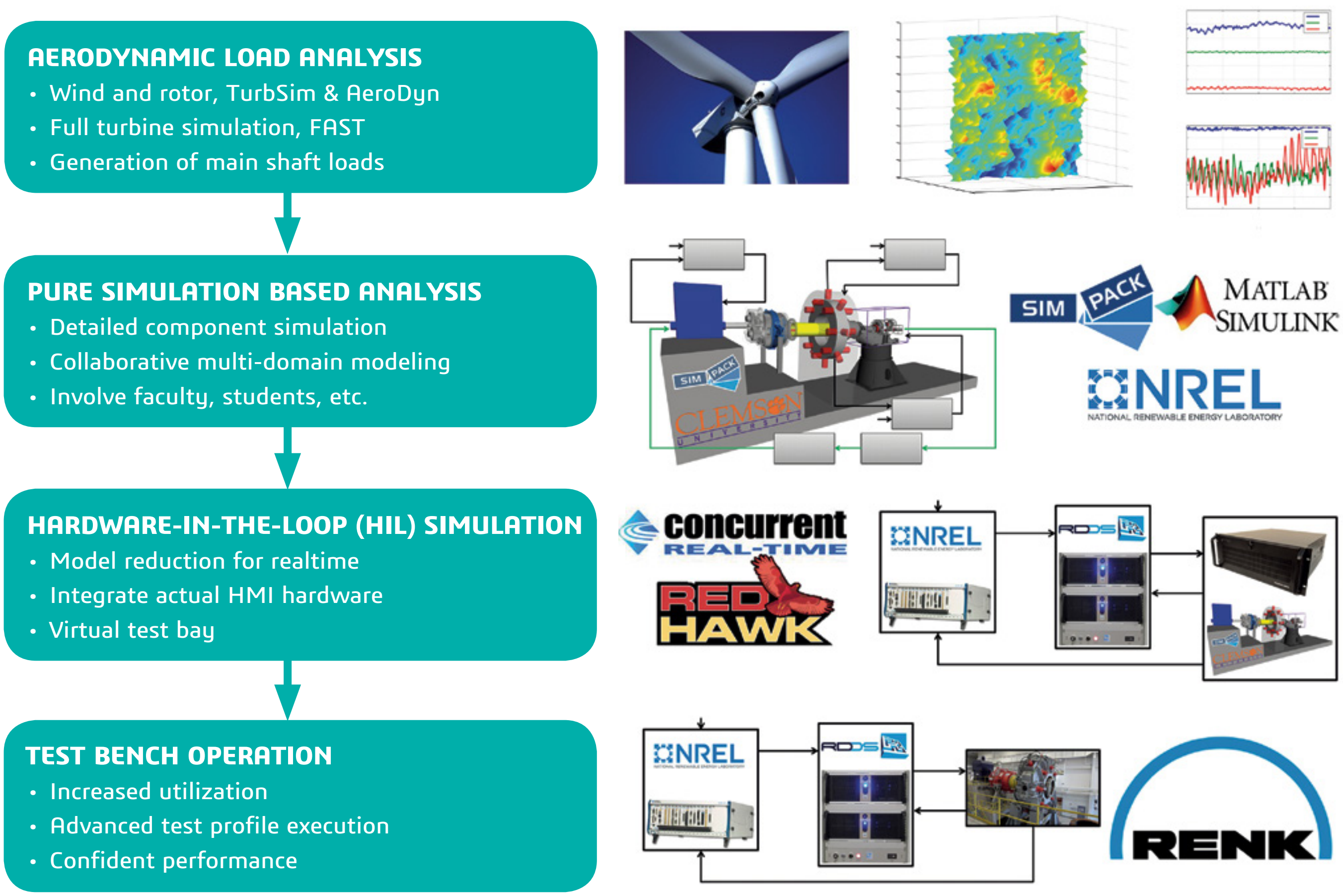



Figure 2. Various modeling and simulation activities are underway including aerodynamic load analysis, pure simulation based analysis, and HiL simulation. All of these activities directly support the physical testing that is carried out on the test benches.

high-speed couplings, 7.5 MW reduction gearbox, low speed shaft, load application unit disk, and nacelle, including main bearing, gearbox, and generator. The dynamic character of the DUT significantly influences the overall system response and therefore must be included in the modeling effort. Clemson University has been working with its first customer, General Electric, to develop representative dynamic models of GE's wind turbine nacelle, also in SIMPACK.

Many of the component models have multiple versions with varying levels of fidelity, allowing the complexity of the overall model to be aligned with specific modeling goals. The system model is divided into naturally occurring subsystems in both SIMPACK and Simulink. Senders, Receivers, and Substructures are used heavily in SIMPACK, making the model easy to reconfigure and work on. Different gearbox model versions all have the same input, output, and support Markers making it easy to reconfigure the model for high and low fidelity simulations.

In addition to multi-body systems, the test benches include hydraulic, electric, and control system models all functioning simultaneously to produce an overall system response.

The governing equations for these various subsystems were developed analytically and coded in Simulink. These models interact with the SIMPACK model using SIMPACK's co-simulation feature or the S-function model export feature. The complete model couples the behavior of the multi-body and non-multi-body systems (as shown in Figure 3).

## SIMULATING A FULL-SCALE MECHANICAL AND ELECTRICAL RESPONSE

The ultimate goal is to replicate a nacelle's response to full-scale mechanical and electrical loads in a controlled and repeatable environment. Replicating such a response requires two hardware-in-the-loop simulations operating simultaneously – one mechanical and one electrical. This is an advanced testing strategy and making it a reality is challenging.

Engineers at eGRID are currently developing dynamic models of the facility's power systems and future goals include coupling the mechanical (WTDTF) and electrical (eGRID) models to form a single, facility-level, dynamic model. The availability of such a model will help to make this testing strategy a reality.

**For More Information**
http://clemsonenergy.com

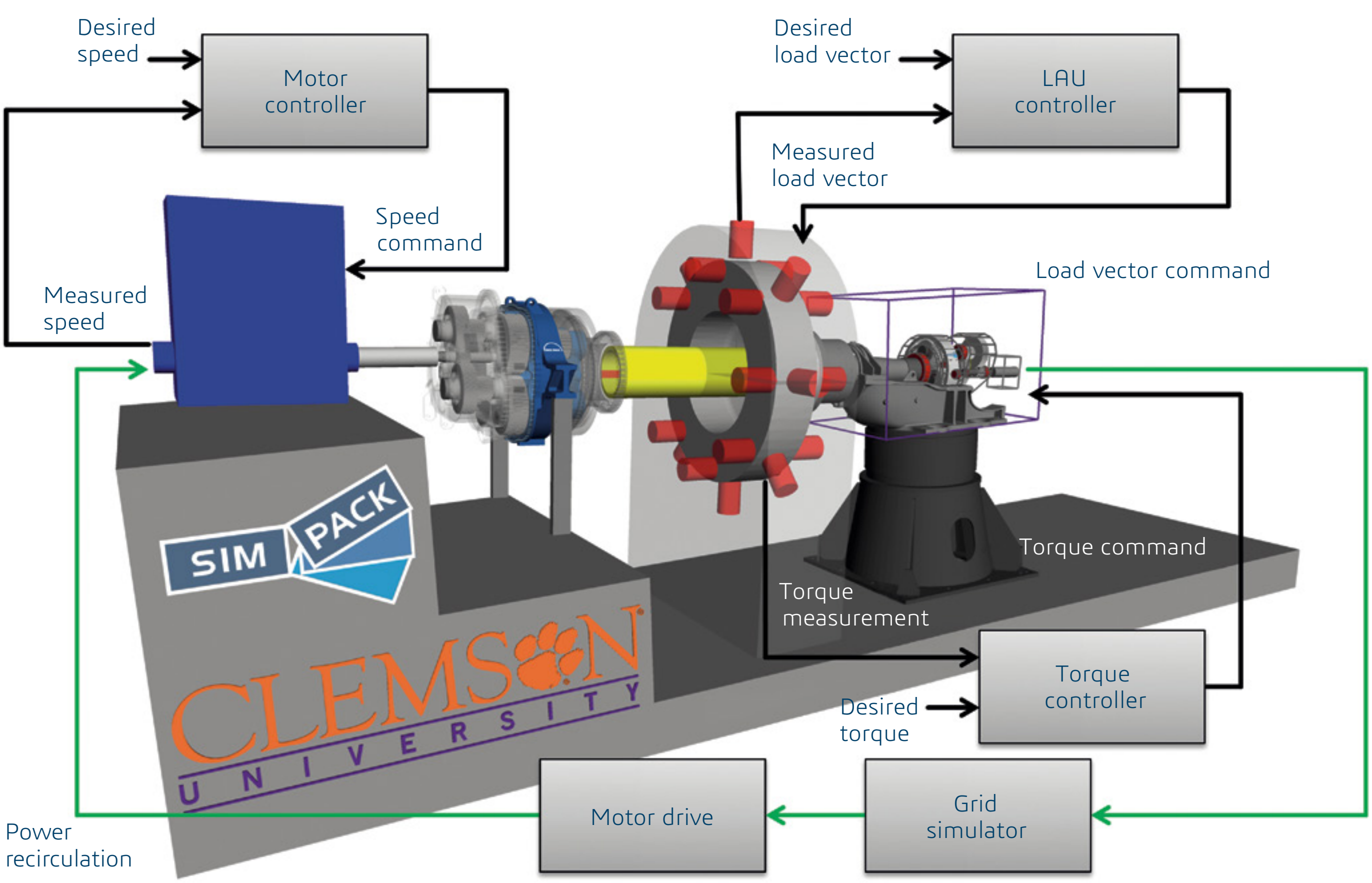


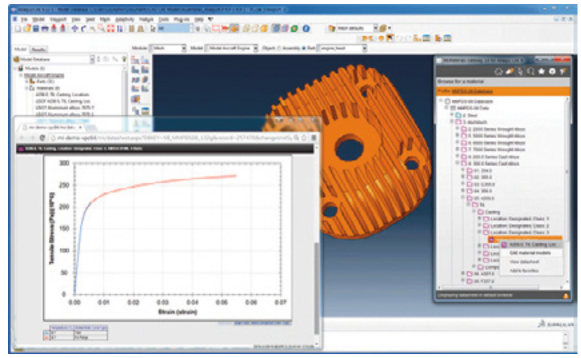

Figure 3. Integrated test rig model showing the multi-body and non-multi-body models and how they interact with one another.

## LATEST GRANTA MI: MATERIALS GATEWAY VERSION 3.0

At this year's SIMULIA Community Conference, Granta is demonstrating Version 3.0 of the GRANTA MI:Materials Gateway™ for Abaqus/CAE®.

Granta provides the leading system for materials information management in engineering enterprises. GRANTA MI™ enables these companies to manage their materials data lifecycle—storing all of their complex proprietary materials data (e.g., property data for metals, composites, and plastics) alongside relevant reference data provided by Granta, and managing this information resource as data changes with on-going research, testing, analysis, or simulation.

GRANTA MI:Materials Gateway for Abaqus/CAE is a proven technology that integrates this systematically-managed materials information with the SIMULIA simulation software. Abaqus/CAE users get direct access to validated CAE materials models from within their familiar simulation environment. They simply open the MI:Materials Gateway window within Abaqus/CAE, search and browse the available materials in their company database, view their datasheets, choose applicable CAE materials models, and then import these models with a single button-click. Full traceability is provided, along with version control and notification, so that users can have confidence in the data they are using. These tasks are quick, interactive, and carry no risk of error during data transfer.



GRANTA MI:Materials Gateway for Abaqus/CAE.

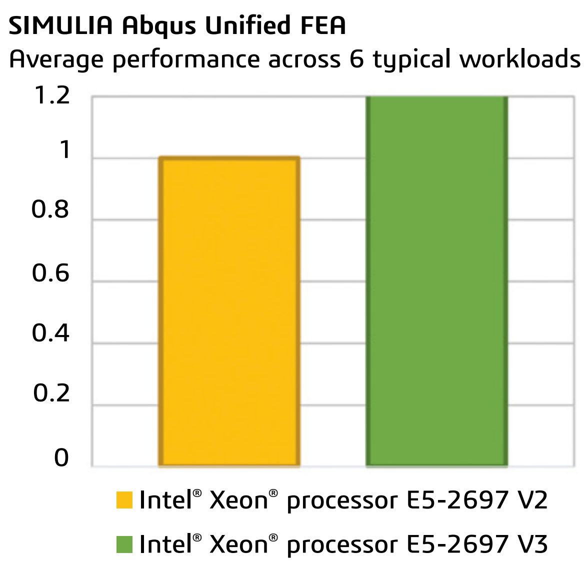
The new GRANTA MI:Materials Gateway Version 3.0 operates with Abaqus 6.14. Optimizing usability has been a key focus for this release—with enhanced performance, familiar operations such as undo/redo use of keyboard shortcuts, and the ability for users to save and re-use combinations of search criteria that reflect their requirements.

## INTEL AND NOR-TECH TEST WORKLOADS ON THE LATEST CLUSTER TECHNOLOGY

Upgrading cluster hardware offers a path to faster and more accurate simulations, which can help engineering and design teams speed up development cycles and gain deeper insight into product behavior. Intel and Dassault Systèmes have optimized Abaqus FEA software code for the latest Intel® Xeon® processor E5 v3 product family and the performance benefits can be substantial.

To provide general guidelines, Intel and Dassault Systèmes measured performance for SIMULIA Abaqus FEA across six standard benchmarks that reflect a variety of design scenarios. The results showed an average performance gain of 22 percent for a system based on the latest Intel Xeon processor E5 v3 product family compared with a system running on previous-generation processors.

Your in-house performance gains will depend on the size and complexity of your design models and the configuration of your existing system. You can quantify the benefits by running your actual workloads on a current generation test cluster. Intel, Dassault Systèmes, and Nor-Tech offer virtual test drives on a two-ten node Windows or Linux cluster based on the Intel Xeon processor E5 v3 product family. It's a relatively simple process that can help you make informed upgrade decisions based on your specific business and computing needs.




"The increased capacity of the new Intel® Xeon® processor E5 v3 enables more efficient execution of larger problems in less time."

–Matt Dunbar, Software Architecture Director, Dassault Systèmes

## CD-adapco™ CELEBRATES 35 YEARS OF CFD INNOVATION

CD-adapco, the largest privately held CFD-focused provider of Computer Aided Engineering software, is celebrating its 35-year anniversary. As the largest independent developer of simulation tools for engineering and design, CD-adapco has grown from a three-person outfit that originated in an attic in 1980 into an international multi-faceted business conglomerate with 34 global offices and revenues approaching $200 million.

In 1980, Steve MacDonald, Bill Wheeler and Marc Whittlesey identified a market for engineers who needed to solve difficult problems involving turbulence, heat transfer and combustion with speed and precision.

"The solution of complex industrial engineering problems requires simulation tools that can cross engineering disciplines," said Steve MacDonald, co-founder, President and CEO of CD-adapco. "From the very beginning, our philosophy was to push the boundaries of our simulations as far away from the area of interest as possible, capturing all of the relevant physics, minimizing approximation, and taking account of all the factors that are likely to influence the performance of a product or design in its working life.

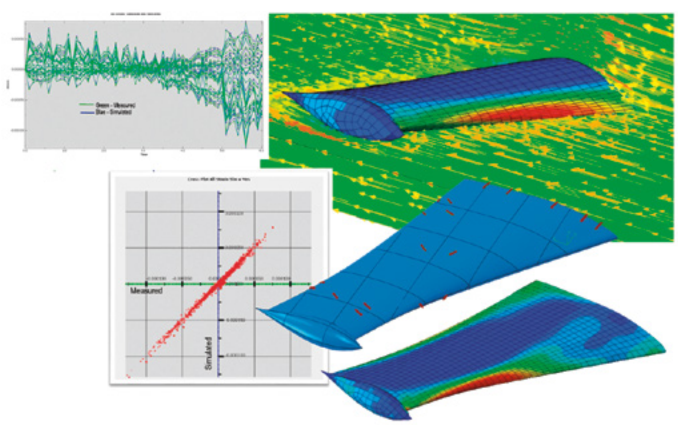
"Fully realizing that vision has taken 35 years of hard work, involving many of the most talented engineers and developers that industry has to offer. I am proud of all we have accomplished."

Thirty-five years later, CD-adapco is setting the industry standard in simulation software development. Led by its flagship tool, STAR-CCM+, CD-adapco remains privately-owned and is the rare high-growth technology company that enjoys sustained growth over many years.

CD-adapco is a Premier Sponsor at the SIMULIA Community Conference in Berlin, Germany (May 19 - 21). They will present their solutions in the Integrated Solutions speaking track.

## WOLF STAR TECHNOLOGIES: A BETTER WAY TO UNDERSTAND STRUCTURAL LOADING

Developing product requires in depth understanding of the loads. With today's FEA pre-processing tools like Abaqus/CAE, high levels of geometric and mesh fidelity can be achieved. In addition, the advanced material modeling and solution capabilities of Abaqus make design iteration quick, efficient and effective. The only missing piece in the equation is accurate knowledge of the structural loading. Traditional methods require the use of expensive of load transducers which usually require structural modification. Modifying components to accept load transducers is expensive and time-consuming. By introducing load transducers often the load paths and structural response are changed. In many situations, the component cannot be operated in its normal configuration. This leaves the value of high-fidelity FEA analysis significantly compromised. Quite simply, if the analyst doesn't understand the loading, the FEA solution is just a guess.




Wolf Star Technologies' True-Load™ software offers an alternative approach to understanding loading. Structures are turned into multi-axial load transducers by strategically locating strain gauges on the components. The placement of the strain gauges is determined by user-specified unit load cases. The unit load cases can be any loading dreamed up by the analyst including point loads, unit displacements, pressure loading, thermal loading, inertia loading and even mode shapes. A correlation matrix is created based on the relationship:

$$[\varepsilon]\ [C] = [F]$$

The example shown illustrates calculating aerodynamic loading on an aircraft wing. The correlation results show maximum error of simulated strain versus measured strain of 4.95% RMS error.


Arek Bedrossian, B. Sc.(Eng), DMS, DipM, is Chief Engineer and head of the Advanced Engineering Group at KW Subsea, part of the Petrofac Group, a major multinational oil & gas services company. Using many software products to support his role, he has also been a longtime user of Abaqus as part of his suite of tools. He is a strong believer in the key role simulation plays today, yet he has words of caution for the next generation of engineers about using those powers.

### How did you learn about Abaqus and when did you start using it?

**Bedrossian**: I first heard of Abaqus when I was working in the UK nuclear industry in the early 80s. Some of the major players were already using the software. After I joined the BP research center it took several years, and the collaboration of another ex-nuclear person who had joined the company after me, before we acquired an Abaqus license. I became an Abaqus user in 1989, by which time I had 10 years of FE experience and was able to maximize the features of the software.

### What is your vision of the ever-more-digital world?

**Bedrossian**: It would be great to see the digital world, as far as engineering simulation is concerned, develop to such an extent that designs and assessments of components are performed on fully automated bases by the codes themselves, without human intervention. But I think this is still far off in the future. Coaching and development of the next generation of engineers to be the future innovators in the use and evolution of simulation software is vitally important.

### How does the next generation of engineers you work with differ from yourself when you were younger? What are the most important things you can teach them?

**Bedrossian**: They've got it easy now, haven't they? When I started my FEA work in 1979 it was a matter of taking graph paper, drawing the model by hand putting down node and element numbers on it, and if I was lucky with the particular package, use some facilities for generating a series of these, and then punching these numbers into a file which would then be transmitted to a mainframe computer for analysis.

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One of the most important things new and future engineers need to be taught is how to be critical of the results obtained from the simulations that they see on their screens, and to perform scoping checks using alternative simplified methods. Most of the young engineers in my team at KW Subsea are also driven by the desire to innovate, through either finding novel ways of applying existing capabilities within their software tools or suggesting improvements in the capabilities.

### What is your favorite thing to do outside of work and why?

**Bedrossian**: I like reading about the history of the late 19th and early 20th century world and thinking laterally to try and make sense of the seemingly unrelated events that took place then, in order to try and understand the present. I like this rather investigative activity because I think it is analogous to applying lateral thinking in the same way as I have done throughout my career in engineering simulation to solve unusual problems. This has relied on understanding the underlying physics of the problem, critical appraisal, thinking creatively and building realistic models that provide the right answers.

### For More Information

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