THE FUTURE OF MANUFACTURING
BETTER MATERIALS—INNOVATIVE SOLUTIONS

COVER STORY
COMPOSITES MANUFACTURING AND SIMULATION CENTER AT PURDUE UNIVERSITY
Welcome Letter
Roger Keene, Vice President, SIMULIA Worldwide Operations

News
Dassault Systèmes Acquires CST, xFlow and Wave6

Product Update
Highlights in R2017X

Cover Story
Interview with Dr. Byron Pipes: Simulating the Additive Manufacturing of Composites

Future Outlook
Reinventing Modern Manufacturing with Simulation and Additive Manufacturing

Strategy
Making the Hard Work of Innovation Easier

Ariens
Cutting the Cost of Lawn Mower Redesign with Abaqus and fe-safe

Alliances
DFR

Digital Product Simulation
Integrating the Design of Physical and Control Systems with Co-simulation

Training Spotlight
Durability

Zollner Electronik AG
Designing the world’s largest robot using SIMULIA’s multibody simulation software

Additive Manufacturing Symposium
Contributors: Parker Group, Ariens, Composites Manufacturing and Simulation Center at Purdue University, DPS North America, Zollner Electronik AG
On the Cover: Byron Pipes, Executive Director of CMSC, John L Bray, Distinguished Professor of Engineering, Director of DMS TR, Director of cdmHUB
Photo by Sarah Parent Photography.
LET SIMULIA GUIDE YOU FROM CONCEPT TO PRODUCTION

It was great to see and talk with so many of you at last fall’s Regional User Meetings. We carry this excitement into 2017 by welcoming CST, XFlow, and Wave6 to our family. The acquisition of these three best-in-class products and teams expands our portfolio to include enhanced capabilities for electromagnetic simulation, computational fluid dynamics, vibro-acoustics, and much more.

For more than 30 years, the continued expansion of our technological solutions has been driven by your desire to push the boundaries in your industries. Today, we are living through a revolution in the manufacturing world with the rapidly increasing use of additive manufacturing for production. Engineers, designers, and the businesses they work for are staying at the forefront of this revolution by leveraging simulation, optimization and other digital tools to transform the industry, shifting it from a design-build-test approach to developing functional parts right the first time.

The collaborative environment and the seamless integration of our technology and applications on the 3DEXPERIENCE® platform are empowering individual users to innovate in ways never dreamed possible! Learn more about how we can help you succeed in this transformation by ensuring that simulation insight guides you all the way from concept, to design and production in our Future Outlook feature article (page 10).

Our cover story for this issue highlights the work of Dr. Byron Pipes, Executive Director of the Composites Manufacturing and Simulation Center at Purdue University (page 8). Dr. Pipes discusses the role of composite-based materials for the future of additive manufacturing, where we are today, and the possibilities for tomorrow. I hope you enjoy reading this interview and seeing how simulation is playing a key role in the development of materials.

Please consider joining us in Chicago, for our second Science in the Age of Experience conference May 15–18, 2017, and see how our customers are imagining the impossible and innovating the invisible. With our sister brands, especially BIOVIA and GEOVIA, we plan to highlight the latest trends and innovations from industry experts, experience new technologies through hands-on training and seminars, and create valuable connections with you! Also join us for the first Additive Manufacturing Symposium and Hackathon and to experience the future of design and manufacturing (page 27).

Our customers are the heart of the conference as well as SIMULIA Community News magazine. We are grateful for your contribution and are excited to highlight Ariens, Digital Product Simulation, and Zollner Electronik AG in this issue—lawnmowers, gantry robots and robotic dragons!

Whether you are looking for inspiration, the latest simulation strategy, news on manufacturing trends, or just something to read while eating lunch, we hope you enjoy the content on our new SIMULIA blog, blogs.3ds.com/simulia. We launched the blog last fall to help you stay better informed on the topics that matter most to you. It is going to be a year of learning and advancements. I look forward to exploring the possibilities with you.

ROGER KEENE,
Vice President, SIMULIA Worldwide Operations
MULTIPHYSICS/MULTISCALE OFFERINGS DEEPEN WITH LATEST ACQUISITIONS

New Dassault Systèmes products from SIMULIA expand capabilities for addressing complex physics within many industries.

Take another look at the SIMULIA portfolio—there’s even more available to you now following Dassault Systèmes’ recent acquisitions of Computer Simulation Technology AG (CST), XFlow and Wave6 technologies. With our broad customer base in mind, we now provide you with a more complete multiphysics/multiscale solution, capable of addressing electromagnetics, computational fluid dynamics and vibro-acoustics. These advanced approaches support some of the most challenging simulation scenarios that arise in whichever industries our customers are working.

As innovative products continue to be imagined with ever-increasing sophistication and complexity, realistic simulation must follow suit with capabilities that predict behaviors accurately so you can optimize product design and development. Our new acquisitions fill-in previous gaps in the portfolio: CST is a leader in electromagnetic (EM) simulation while XFlow has a unique “meshless” technology for simulating highly dynamic flow. Wave6 enables high level noise and vibration simulation.

**CST: ELECTROMAGNETIC EXCELLENCE**

Electromagnetism is a fundamental physics domain so the addition of CST AG, based in Darmstadt, “the City of Science,” Germany, strengthens our offerings in this domain significantly.

CST® solutions span the full spectrum from static and low frequency to microwave and Radio Frequencies (RF), up to optical frequencies and across all length scales. CST STUDIO SUITE® software is already being used by designers and engineers at more than 2,000 leading companies in the high-tech, transportation and mobility, aerospace and defense, healthcare and energy industries to evaluate all kinds of EM effects during every stage of electronic-system design processes. Customers include Airbus Defence and Space, Bosch Group, Frauscher Sensor Technology and Sirona.

**ELECTRONICS EVERYWHERE**

Electronics, electrical devices, and electromechanical products are becoming more pervasive in many industries with the growth of smart, connected products. Increasingly these days we see devices, vehicles, buildings and other items that are “smart”: with electronics, software, sensors and network connectivity that allow them to collect and exchange data.

Important considerations in the development of any electronic product include Electromagnetic Interference (EMI) and Compatibility (EMC)—all of which are critical to proper systems integration and function. EMC standards that have been developed to control emissions from electric and electronic systems must be met. And systems may have to be able to withstand severe hazards in their operating environments, such as lightning strikes and electromagnetic pulses.

Of course electromagnetics phenomena does not occur in isolation. In the real world, electromagnetic fields can be coupled to other domains of physics such as, structural mechanics, and thermodynamics. Depending on the required exchange or physical quantities that are needed, different methodologies can be employed to use CST STUDIO SUITE analyses either independently or between disciplines.

In a full multiphysics co-simulation of 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 to account for all of the interrelated simulation effects. Going forward, such CST STUDIO SUITE capabilities will clearly enhance the 3DEXPERIENCE platform’s simulation solutions for solving broad multiphysics challenges like hybrid vehicle drivetrains and wearable electronics.

**MODULES CUSTOMIZE THE CST EXPERIENCE**

CST provides a complete set of general 3D EM simulation tools, along with several specialized ones for applications such as cable harnesses, PCBs and EM/circuit co-simulation. The CST STUDIO SUITE software includes a number of modules with customized capability sets—all of which are integrated into a common architecture and design environment that provides access to the entire range of solver technology. These include:

- CST MICROWAVE STUDIO® provides for 3D EM simulation of high frequency devices, such as antennas, filters, couplers, and planar and multi-layer structures
- CST EM STUDIO® simulates the static and low frequency behavior of devices, such as actuators, transformers, motors, touch screens, sensors

**CST**
• CST PCB STUDIO integrates easily into Electronic Design Automation (EDA) flows, providing for prediction of Signal Integrity (SI), Power Integrity (PI), and EMC on printed circuit boards (PCB) as well as the generation of SPICE-ready macromodels of electrical interconnect structures
• A unique complementary tool is Antenna Magus, a modern antenna synthesis tool

**XFLOW: A UNIQUE TOOL FOR MODELING HIGHLY DYNAMIC FLUID FLOW**

Dassault Systèmes’ acquisition of XFlow compliments SIMULIA’s existing capabilities in Computational Fluid Dynamics (CFD) in an exceptional way. We have already built up strong applications for steady flow based on the predominant Navier-Stokes approach. XFlow goes beyond these existing technologies to the different Lattice Boltzmann methodology that is preferred by most users for highly dynamic, or unsteady, flow.

Unsteady flow often arises with flow across complex solid geometries, such as the exterior surface of an automobile. A traditional mesh-based approach to these problems is highly dependent on the quality of the mesh—so that engineers have to spend significant time working on mesh discretization. Difficulties can arise when there are changes in the topology of the domain for problems involving the presence of moving parts or fluid-structure interaction. XFlow’s meshless particle-based methods reduce the traditional time-consuming meshing burden, enabling engineers to focus the majority of their efforts on design iteration and optimization.

With XFlow’s discretization approach, surface complexity is not a limiting factor. The underlying lattice can be controlled with a small set of parameters; the lattice is tolerant to the quality of the input geometry and adapts to the presence of moving parts. XFlow’s kinetic solver has been specifically designed to perform very fast with accessible hardware. The solver also features, adaptive wake refinement for proximity to walls, high-fidelity turbulence modeling, thermal analysis, porous-media flow, non-Newtonian flow, a fan model and more.

XFlow supports behavior prediction and improves performance of many different kinds of complex designs subjected to unsteady flow. In addition to aerodynamic flow past a vehicle, these can include aerodynamic noise from aircraft landing gear and lubrication of complex drivetrains. This technology continues to improve automobile fuel economy and emissions, reduce the environmental noise of aircraft, and increase the efficiency of wind turbines, among many industry applications.

**WAVE6—STATE-OF-THE-ART METHODS FOR NOISE AND VIBRATION SIMULATION**

It’s no longer adequate to analyze the mechanical, aerodynamic and thermal performance of your product without also considering noise and vibration performance. This is a core reason behind the acquisition of the Wave6 technology. It provides groundbreaking methods for efficiently and accurately simulating noise and vibration across the entire audible frequency range. The development team has written all of these methods from the ground up. This means that instead of having a collection of disparate solvers, Wave6 solvers are integrated into a single common engine within a common user environment. This enables our users to combine methods in the same model and efficiently analyze noise and vibration problems in ways that are simply not possible in other software packages.

It also offers unique functionality for automatically pipelining and templating advanced noise and vibration analysis processes using high level workflows. This makes advanced noise and vibration analysis methods accessible, automated and easy to use. This state-of-the-art-technology complements and extends the capabilities within Abaqus, Simpack and XFlow. It also fits perfectly with our vision for expanding simulation capabilities within the 3DEXPERIENCE platform.

Wave6 technology is useful for many industries where acoustics and vibration considerations factor into the product experience as well as durability, especially in Transportation & Mobility, Aerospace and Defenses, and Marine and Offshore, among others. By integrating Wave6 into your design process, you can ensure noise and vibration performance is built into your product at the design stage, and reduces the risk of discovering expensive noise and vibration problems late in the design cycle when physical prototypes are made available.

**POWERFUL NEW TOOLS FOR INNOVATION**

Please feel free to ask your SIMULIA representative for more information about how these latest additions to the portfolio might further power innovation for you and your team. And look for these new tools to become integrated onto the 3DEXPERIENCE platform soon.

For More Information
**Product Update**

**FUNCTIONALITY IMPROVEMENTS AND INCREASED INTEGRATION BETWEEN APPLICATIONS**

**3D EXPERIENCE** R2017x marks another strong software release for Dassault Systèmes including SIMULIA. Not only are there a host of functionality improvements in many of our individual products, there is significantly increased integration between applications—that now extends even further into enhanced roles on the 3D EXPERIENCE platform. Such enhancements benefit the individual user as well as strengthen the capabilities of entire organizations to pursue excellence through innovation more effectively than ever before.

One focus of the new release is “democratization,” a buzzword of note in technology these days. The term implies that everyone—from managers to designer engineers to expert analysts—needs to be able to access the simulation data, methods, and tools that are relevant to them so they can optimize their own performance and best contribute to the success of the group as a whole.

What makes such democratization possible? An innovation platform that delivers everything in a single portfolio with a common social user interface and data structure. This provides you and your team with our state-of-the-art simulation technology and fully integrated Simulation Data Science that leverages the value of simulation by anyone, at any time, within your corporate practices.

The 3D EXPERIENCE Simulation portfolio is delivered by User Role. There are 30 Roles in R2017x Simulation delivered on premise and on cloud. Most of them (17) are for Analysts and Specialists, who want to dive deep into the SIMULIA portfolio of our top-of-the line tools (Abaqus, fe-safe, Isight, etc.). But others have been specifically crafted to accommodate users who are not simulation experts—including business leaders/managers, design engineers, part designers and product engineers. Three roles deliver the aforementioned Simulation Data Science functionality. Six are for designers and product engineers. And three are industry specific.

Below is a sample of available roles in R2017X with highlights.

**Decision makers and collaborators**

For Decision Makers in R2017x, there are two enhanced Roles that allow any user to use simulation to empower decision making. First is the Simulation Foundation platform option that allows any platform user to search for, find, and re-run a simulation method from the company library of simulation best-practices. Highlights include a new drag and drop capability for selecting process content on a dashboard and streamline visualization in the results review application. The second is in the Results Data Analyst (RIW) role, which provides trade-off analytics and decision support using Isight technology. Highlights include generation of higher order mathematical models, along with managed traceability and sharing as a functional mockup unit (FMU) with other DS applications.

**CATIA Design Engineers**

SIMULIA has been working very closely with CATIA and has built a new Static Study app that is embedded directly into several CATIA roles in R2017x. In these roles, users can now perform straightforward static linear analysis directly during design. For the part designer who needs FEA beyond the Static Study app, the Stress Engineer role is supported within a guided environment; task-by-task workflows geared for non-experts are an attractive feature here, as are analytics for decision support. Highlights in R2017x include a new workflow and improved user interface for contact modeling, along with fast, linearized contact detection and default meshing enhancements with a new exposed meshing tool for greater precision in defining global and local mesh density. We have also provided an integrated solution in CATIA called Function Driven Generative Designer where topology optimization is built-in to allow simulation to suggest the optimal shape of a design for a given scenario. This role is the entry point for the Dassault Systèmes complete Additive Manufacturing capability.

**Analysts**

Among the 17 new or enhanced roles available here is Mechanical Analyst (SMU), which provides state-of-the-art FEA capabilities, using the well-known Abaqus solver suite, within a collaborative environment where FEA simulation methods and results can be shared, managed, and re-used. Enhancements include improved geometry handling for mid-surface extraction and defeaturing, a new Context Toolbar for surface meshing, bolt-modeling enhancements for multiple bolts, and fastener import from XLM and import of materials from CATIA fasteners. Also new in R2017x is a role that supports using the existing Abaqus/CAE standalone tool in a “Power By” mode on the 3D EXPERIENCE platform. This means that the user can start, work within, manage the work-product of, and execute models from these products using 3D EXPERIENCE, all within the comfortable interface of Abaqus/CAE.

R2017x includes default meshing enhancements with new exposed meshing tool for greater precision in defining global and local mesh density.
Engineers
For product designers and engineers, the Structural Analysis Engineer (DRD) role provides all the tools needed to conduct structural static, frequency, buckling, modal dynamic response, and structural-thermal simulation of product designs within the 3DEXPERIENCE platform. It provides unique capabilities to collaborate, simulate, and impact product development processes throughout the extended enterprise using state-of-the-art Abaqus simulation technology to ensure accuracy of the virtual testing. New functionality includes a toolbar for interactive meshing including improved meshing for holes to better match underlying geometry, scenario-definition enhancements in support of contact modeling, and new display groups options for finer control over model and results visibility.

New Roles for Engineers
3DEXPERIENCE R2017x also includes new roles for Engineers, including a new Plastic Injection Mold Engineer that works hand-in-hand with the enhanced Plastic Injection Part Engineer. These two roles in combination with mold-design capabilities in CATIA provide a complete capability for understanding and designing runner and mold-cooling layouts for parts and molds manufactured using plastic injection technology.

The Living Heart
This showcase of Dassault Systèmes multiphysics capabilities is now available on the 3DEXPERIENCE platform! This realistic, 4-chambered human heart model includes calibrated materials model and accurate physics (electrical, structural, and blood flow) to provide baseline healthy cardiac behavior. Cardiovascular devices such as stents or artificial valves can be placed within the Living Heart to understand the effectiveness of the devices and to make improvements. It’s also possible to introduce disease states and to understand tissue remodeling to then predict longer-term outcomes of various treatment options.

For a complete list of roles with and further explanation of new enhancements, please contact your SIMULIA representative.

2017 RELEASE
Abaqus
- Enhanced Contact and Constraints
- XFEM Contact Improvements for Abaqus/Standard
- Advances in LCP (Linear Complimentary Problem) Equation Solver for Abaqus/Standard
- CZone Enhancements for Abaqus/Explicit
- Enhanced Materials and Elements

Isight
- Updated SIMULIA Execution Engine (SEE) with improved robustness and performance of TomEE
- Component Enhancements for Abaqus, Ansys, MS Office, and Matlab
- Pointer-II performance improvements

Tosca
- Improved fe-safe integration
- New Tosca Python driver integrates Abaqus and Tosca together and offers up to 75% faster runtime performance
- New custom interpolation schemes
- Tosca Fluid improved interfaces for: StarCCM+ 9.02 – 11.04

fe-safe
- Weld Fatigue Enhancements
- Enhancements for Abaqus Users
- Vibration Fatigue Enhancements

For more information, visit the SIMULIA Learning Community to access our latest eSeminar replays for these products: https://swym.3ds.com/#community:73/eSeminars

For More Information
https://www.3ds.com/products-services/simulia/products

Interactive visualization allows analysts to observe dynamic cardiac motion, stresses, strains, and propagation of electrical signals.

Intuitive interface fully integrated with CRD guides the product designer through simulation set-up and solution, even for complex fabricated structures like this door model.
Dr. Byron Pipes is the executive director of the Composites Manufacturing and Simulation Center at Purdue University, as well as John L. Bray Distinguished Professor of engineering. Dr. Pipes has been working with composite materials since 1969, and humorously refers to himself as the “Godfather” of the field. Today, he and his team use both CATIA and SIMULIA’s Abaqus FEA, among other solutions from Dassault Systèmes, to simulate the process of manufacturing composite materials employing additive manufacturing (AM, aka 3D printing).

How did you become involved with composites?

It was an easy decision for me. After receiving my Master’s at Princeton I was offered two different positions at General Dynamics. One of the jobs I was offered was to join a group working with composites and I chose that position for one reason: I saw the most interesting, intellectually exciting group of people I had ever seen working together in a new subject. Prior to my accepting the position, they had been searching for a way to make an airplane from carbon fiber. Everything from the design, engineering, materials development and so on was happening right there in Fort Worth, Texas, and I was eager to join in because I saw such a creative group of people doing such interesting things.

In a world revolving around mathematics and computational numbers, how were you drawn to simulation?

My simulation background dates back to my career in civil engineering where I was a structural engineer. Finite element methods were developed out of the civil engineering profession. I had the background for it, I saw it coming, and I saw what could be done. That being said, the simulation tools available at the time were nowhere near as powerful as they are today. When we looked at creating a complete finite element model of the F-111 airplane, there were roughly 5000 degrees of freedom for the entire model. Today, with cloud computing access to high performance computing, it is not uncommon

"Abaqus is the backbone upon which we’re building the foundation for the simulation of AM with composites. It has wonderful functionality and works extremely well with anisotropic materials."

—Dr. Byron Pipes, executive director, Composites Manufacturing and Simulation Center, Purdue University
to have millions of degrees of freedom in models. That gives you some sense of the computational power of the day and how much more powerful the software has become. Today, not only are simulation tools more sophisticated, but so is our ability as engineers to use them in different ways. For example, much of past manufacturing has been empirically developed. Now we have the power to build the virtual manufacturing system that allows rapid optimization of these complex processes.

**How does your work with composite materials research, education, and development translate into requirements for Additive Manufacturing?**

3D printing is a big subject, so I’ve really focused all of my attention towards a subset of the industry that relates to the printing of carbon fiber-reinforced polymers. Much of AM today is either printing metals or polymers, and not reinforced materials. As soon as you put fiber inside a polymer, you have created a composite. When printing this material, it has all the aspects of a composite material, namely the high degree of anisotropy—materials that have properties that depend on their ‘direction.’ For example, the direction parallel to the grain of a plank of wood is stronger than the direction perpendicular to the grain. In the case of fiber composites, it is the fiber direction that defines the maximum strength.

In these systems, fiber orientation produces its anisotropy in the printed material. This means we have another degree of freedom to consider—and that design isn’t solely defined by the geometry of the product you’re making and the material you’re making it from. Instead, you must control the direction of the material and its strength properties and point them in the direction where the most strength is required.

The 787 aircraft was designed with unidirectional fibers made up in thin layers. We made the airplane by layering fiber layers that are about one tenth of a millimeter thick on top of one another. This gives you the ability to design for the complex stresses that exist in the material itself.

Note that biological materials that we are all made of are themselves highly anisotropic. Nature’s done this for a long time. We’re just now being able to copy nature in real structural materials made of carbon fiber.

**How does Abaqus enable your RM research and adoption?**

Abaqus is the backbone upon which we’re building the foundation for the simulation of AM with composites. It has wonderful functionality and works extremely well with anisotropic materials. We’ve even taken Abaqus beyond structural simulation and used it to simulate flow processes as well. When 3D printing, the composite material goes from liquid to solid as it melts and it cools and we have anisotropy in the flow characteristics of the material as well. Essentially, if you put long fibers in the polymer it will not flow very well in the direction of the fibers.

In addition to Abaqus, what other simulation tools do you and your students use?

We are using the 3DEXPERIENCE platform, although it is relatively new to us. As we become more familiar with it I am sure we will make more use of it, but for now our main tools are CATIA and Abaqus. We are educating our students on utilizing this software and are working to develop something we call the ‘composites design studio.’ We will be able to hire students for 20 hours a week to sit in the studio and use simulation to solve industry problems within the Institute for Advanced Composites Manufacturing Innovation (IACMI).

The beauty of using CATIA and Abaqus is that they talk to one another. CATIA delivers geometric information and Abaqus takes that information and carries out a physics-based simulation. With such complex geometries that we deal with on a daily basis, we need a software like CATIA that is able to reflect the anisotropic properties composites and how they are deposited. From that deposition process we can determine the orientation state of the fibers and the resulting composite physical properties, those properties are then mapped into Abaqus where physics-based analyses are carried out.

Also, IACMI needs a data management and collaboration system to manage its business. For this, the organization will leverage ENOVIA capabilities within the 3DEXPERIENCE platform. You can imagine how complex this management problem is: IACMI has five Technology Areas that are all located in different states with a ton of information flow that must be managed, along with deadlines and other schedules. ENOVIA will also be installed on the cvfHUB at Purdue so that all of our related information and models will be accessible at IACMI headquarters in Tennessee and we will be able to access the information and data being shared by them. The solutions from Dassault Systèmes will provide not only the technology for design and simulation, but efficient and effective communication and collaboration as well.

**Where do you see the additive manufacturing of these composite-based materials headed?**

I’ve recently had the chance to talk to materials suppliers in this field, all of which are sponsors of the IACMI operation. Together we came to the conclusion that the 3D printing of fiber-reinforced polymers will exceed the volume of injection molding of those same materials in a short time. Imagine what that would mean for the future of simulation software. When you design and build a new product, you must have simulation tools with the ability to model the process by which the manufacturing occurs. The 3D printing industry is going to continue to grow and I’m convinced that the roles Dassault Systèmes CATIA and SIMULIA play in supporting its growth will be equally exponential, as they continue to provide the simulation tools of choice for 3D printing of carbon-fiber materials.

For More Information

https://www.purdue.edu/cmsc
Over the past century we have witnessed amazing milestones in manufacturing. The most impactful achievements share one important commonality—they brought greater simplicity and automation to the design and production process. Consider the roll-out of Henry Ford’s moving assembly line in 1914, the launch of the first CAD software in 1954, and the arrival of industrial robots in 1973. Each of these revolutionary developments allowed manufacturers to hit the hypothetical fast-forward button on production, bringing better products to the marketplace more quickly while advancing society technologically.

Today we are witnessing the next mammoth milestone—the widespread adoption of additive-manufacturing technology, popularly known as 3D printing, in production. Invented for rapid-prototyping purposes in the 1980’s, 3D printing had many niche applications that were mostly non-structural, but the technology’s true potential remained untapped for decades. With the advent of highly controlled materials and processes, made possible through advanced software, we are now seeing the proliferation of much more functional engineering applications using layer-wise manufacturing methods.

This adoption of additive manufacturing 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 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? Engineers and designers are empowered to develop parts that are increasingly complex, more organic and lighter—all while meeting their performance requirements while using less time and resources! And process simulation solutions allow us to successfully print these unique designs by providing us with detailed analytics that help us predict potential failures and optimize the printing process parameters so that each part can be printed right the first time.

**CAPTURING INTRICATE DETAILS AT THE PART LEVEL**

Most engineering parts that we traditionally think of are built from solid stock units of material of various regular shapes: blocks, beams, bars, and sheets. This means that they are internally continuous and usually homogenous in nature. A unique capability of additive manufacturing is the ability to manufacture parts with complex and heterogeneously variable internal sub-structures and properties at minimal additional production cost. These include repeating in-fill patterns and customized lattice designs. But designing those complex internal structures is in no way trivial, and has been a focal point in the additive manufacturing community for the past several years. It’s also particularly challenging for simulation. How do you capture intricate details at a part level and still have a computationally efficient model? Driven by representative volume elements (or RVEs) we can transform these detailed internal structures into continuum representations such that we can model them realistically in part-level simulations.

But, why stop there for innovation? Since the underlying variable that drives a topology optimization is the relative density of the material, we can now link it to RVEs and determine variable densities and material distribution in a fixed design space, a shoe insole for example. Users can apply single or multiple loadings, such as a pressure loading profile from a realistic human foot model, to represent static loading for different activity conditions may also be considered. The final outcome is a heat map of material distribution that can guide an infill deposition process. Final reconstructed design.

**Initial design of the shoe sole (top-left). Using a clustering technique the design space was partitioned into multiple zones. A 4th order polynomial was then used with Tosca to determine relative density of each block. The loads applied simulated a walking gait. Multiple loads**
of an averaged human’s weight. Tosca will iterate with this load case to find the maximally stiff structure within a given mass constraint. The optimization yields a continuous field of relative density throughout the component. Amazingly, the optimization results often reveal that the maximum density region does not always correspond to maximum load location. This is the kind of insight that can only be achieved using simulation technology.

**LET SIMULATION BE YOUR GUIDE TO ADDITIVE MANUFACTURING PROCESSES**

The additive-manufacturing machine provider market-space is ever expanding, from global conglomerates to startups, from hardware that handles metals to polymers. The process families can be widely divided into metal powder bed processes, polymer extrusion processes, binder-jetting methods and even advanced welding-like processes. Most AM processes require unique and detailed process analytics, such as temperature and distortion profiles, in order to get a better handle on process robustness and reliability. As this additive manufacturing ecosystem grows ever more complex, the engineering and research communities are looking at simulation as a necessary tool to mature these methods to a state of full-scale production readiness.

To address the community’s needs, we’ve developed an all-purpose simulation framework that gives them the flexibility to simulate parts built from different processes. The framework allows users to specify machine-dependent information (such as tool path, build environment, power input) as inputs in space and time, include support structures from their builds, analyze material behavior—while it computes the solution locally (micro-level) and globally (part-level).

**REIMAGINING METAL POWDER-BED PROCESSES WITH SIMULATION**

Metal powder-bed processes have been a central focus of our solution development and workflow creation efforts because it is a strategic technology for many of our customers who recognize the need to stay ahead of the manufacturing curve. Metal additive manufacturing offers the hope of producing highly customized and light-weighted primary load-bearing structures in Aerospace and Defense. It offers the possibility of osseointegration, the ability of human bone cells to attach to a metal surface, and biologically compatible orthopedic implants in the Life Sciences.

With our simulation solutions, engineers can model metal builds at a variety of scales, looking at melt-pool level effects and metal phase transformations in the research stage, and then full part-level distortion predictions in the production stage. The same model can be used for both studies by simply changing the level of discretization in both mesh size and time increment size, because we’ve decoupled the definition of the process from the definition of the finite element model. Choose the simulation fidelity that is right for your application.

Our vast nonlinear material modeling capabilities in Abaqus are used extensively to simulate complex material effects like a range of plasticity behaviors, viscoelasticity, and even damage and failure. For additive, we’ve made yet another step towards realism by developing a new material-model concept that allows us to traverse a phase diagram and predict the fractions of metal phases as a result of a metal print. This has traditionally been one of the key drivers in AM research: how do I get a handle on the material properties that result from my process? Physically building parts and testing them for their metal phase composition is highly costly. How much of that work can be replaced by a virtual model? How much money and time would you save your organization, and how much would you be able to accelerate ahead of your competition?

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We are ready to help our customers succeed in this transformation by ensuring that simulation insight can guide them all the way from concept to design and production. Please join our existing simulation community in this revolution.
Future Outlook

MASTERING POLYMER EXTRUSION PROCESSES WITH SIMULATION

We live in a world of plastics. Polymer extrusion processes are sure to become a mainstay for medium and even high-volume manufacturing in the future. SIMULIA’s solutions for polymer extrusion processes are enabling engineers to innovate while benefiting from multiple methods under the polymer extrusion umbrella. We can produce models directly from CAD geometry or even use path data to run simulations on a voxel-based mesh of the build volume without the need for any CAD description whatsoever. Material orientations are accounted for automatically by reading the machine tool path. The simulation software automatically enables the progressive addition of material according to the tool path without any requirement on the user’s end to align the finite element mesh with the tool path. It’s critical to note that we’ve decoupled the build description from the finite element mesh and that reduces the preprocessing effort to a great degree. Evolving heat transfer surfaces are automatically updated as material is deposited and elements are activated. This can be done while simulating the actual part together with support structures, providing a complete view of the process physics for realistic build analytics. Similar to material behavior modeling, we are able to simulate not only the process for part-level warpage, but also account for defects such as void generation and interlaminar failure. Simulation tools for predicting delamination and failure within Abaqus have been the mainstay of design in composites airframes for a decade now. The same solutions can be leveraged to look at defects in the layup of reinforced polymers for additive manufacturing processes.

The usage of simulation doesn’t end there. Our regular capabilities for simulation will allow users to virtually study the behavior of the part in action inside assemblies and sub-assemblies with in-service loads (NVH) or extreme events (such as drop or crash).

THE FUTURE FOR SIMULATION AND ADDITIVE MANUFACTURING

The adoption of 3D printing will continue to rise as manufacturers strive for faster and reliable throughput from their machines. As the factories of the futures, become reality, so will the parts that roll out of these machines. We are ready to help our customers succeed in this transformation by ensuring that simulation insight can guide them all the way from concept to design and production. Please join us and our existing simulation community in this revolution.

For More Information
Follow Subham Sett, Director, SIMULIA Strategic Initiatives, on LinkedIn for more information. https://www.linkedin.com/in/subhamsett/
The word “innovation” brings with it the assumption of perpetual improvement—everything can always be made a bit better, faster. If you’re in product design and development, being innovative is just the way you are expected to work these days. Fortunately the use of simulation-enabled design is increasingly becoming the norm, firmly entrenched at the center of the more successful engineering and manufacturing-based businesses.

It’s not just those of us at Dassault Systèmes SIMULIA who are saying this: analysts at CIMdata, Gartner, and others are reporting this same trend. For example, in CIMdata’s recent Simulation & Analysis Market Analysis Report, it states that simulation “must be at the core of the infrastructure for enterprise product engineering platforms” to enable true, repeatable innovation and business decision-making in our hyper-competitive industry environment. (CIMdata 2016 Simulation & Analysis Market Analysis Report, July 2016)

Yet the landscape is ever-changing in product design and development as new materials and technologies become commercially available. Just look at recent strides in advanced composites materials, and the intricacies of designing for industrial additive manufacturing (also known as 3D printing).

Simulation is key here because it offers a way to virtually engineer the multiscale AM process to minimize unwanted effects like stress and distortion in 3D-printed parts. Our topology-optimization tools automatically generate designs for AM that the designer can consider and adapt. We’ve also worked with our sister brand CATIA to develop advanced capabilities in that portfolio specifically geared towards translating those designs into the types of CAD data files required for 3D printing. These tools are available now, both standalone and on the 3DEXPERIENCE platform.

Of course, no matter how a product is manufactured, understanding the material(s) from which it’s made is clearly fundamental. With the addition of BIOVIA to the Dassault Systèmes family, we are working on developing simulation of material behavior on the atomic, molecular, and eventually part and full-product level. Not only will this enable you to understand very detailed phase-transformation effects and fatigue responses in AM, it will help inform the way you build models for advanced materials such as composites—and for many other applications for which it’s desirable to design and/or select materials with customized end-performance as the goal.

And just like you, we never stop innovating. So we’re not sitting on our successes: we’re continuing to broaden our portfolio of offerings to give you even more tools to improve your mastery over product development and maximize your productivity. We now have Simpack for modeling whole systems, and, most recently, CST for electromagnetism, XFlow for CFD and Wave6 for vibro-acoustics.

Add to these the huge potential of molecular-level simulation capabilities in BIOVIA discussed previously, and the power of the connected technology to enable end-to-end solutions of customer workflows and design processes on the 3DEXPERIENCE platform becomes apparent. I hope you enjoy reading about these trends in this edition of SCN!
If you were wealthy enough to afford a lawn in the 17th century, you had scores of scythe-wielding men cut the luxurious green grass of your estate property. Then in 1830, English engineer Edwin Budding invented the first “push” mower—an idea that stemmed from the mechanical challenge of trimming fabric in a cloth mill. Budding designed a series of blades situated around a cylinder that could be moved back and forth with a handle. Lawn care would never be the same.

Around the time when motorization made the automobile possible in the 20th century, the first power-driven lawn mowers roared to life. Mower designs have continued to evolve since then, from ones with improved muffling and lower-emission engines to ride-on and zero-turn versions. The push for ever-better lawn-care equipment continues in this multi-billion dollar industry.

A major American manufacturer of both industrial and personal lawn-care equipment, Ariens Company owns the century-old Gravely® brand that produces a state-of-the-art zero-turn commercial lawn mower. “Zero-turn” allows for 180 degree rotation in a single pass, saving time and providing better maneuverability when cutting.

With the latest upgrade in the Gravely zero-turn due, Ariens engineers were tasked with a list of important challenges. “We needed to make the mower stronger, less expensive to manufacture, and more fuel efficient,” says Mathew Weglarz, lead engineer and structural analyst at the Ariens Company. “Our goal was to design a structure as simply as possible, while maintaining the mower’s ability to perform the task at hand.”

“Now that we use simulation, by the time that we do go to run a physical test of a finished redesign, we are confident that it is going to work.”

—Mathew Weglarz, lead engineer and structural analyst, Ariens Company

CUTTING THE COST OF LAWN MOWER REDESIGN WITH ABAQUS AND FE-SAFE

Ariens reduces part count, improves durability of their next-generation zero-turn machine
Weglarz, a longtime user of SIMULIA’s Abaqus software, proposed the idea to incorporate the SIMULIA portfolio into Ariens’ design process when he began working there two years ago. Prior to Weglarz joining the engineering team, Ariens had only occasionally used SOLIDWORKS Simulation to analyze certain components. With the help of Weglarz and Ariens’ structural analyst and engineer, Aleysha Kobiske, the engineering team at Ariens used a number of SIMULIA tools to drive innovation in the design of their newest Gravely mower.

The team began by examining the current model and finding areas that could be improved upon, such as geometry, material thickness, or maintenance access. All parts of the mower were simulated—everything from the main chassis, frame tubes, and cross and under-bracing brackets, to engine support mounts and seat platforms. The frame, which was comprised of 22 different pieces of steel that were welded together, was where a majority of design changes were made. “A strong structural design is key for noise and vibration control, durability, and overall manufacturing costs,” says Weglarz.

DESIGNING A BETTER FRAME

Part consolidation of the chassis was vital to a successful redesign. First, a number of welds could be eliminated outright. “Now one piece of steel could perform multiple tasks without the need for three or four brackets to be welded to it,” says Weglarz. Then other welds were designed out of the primary load paths so that the parent metal on either side took over the loading and the role of the welds became secondary. “These design changes increased the overall strength of the frame structure considerably,” said Weglarz.

At the end of the redesign process, the new frame had 50% fewer parts (11 total) and cost less to manufacture than its predecessor.

While lightweighting a frame could be viewed as beneficial towards reducing fuel emissions, it was not a stated design objective in this case: When it comes to industrial lawn-care equipment, there is a perceived correlation between weight and quality. “Even though you can probably make a mower out of aluminum or plastic and have it be just as durable as steel, people wouldn’t buy it because it just wouldn’t feel like a commercial machine,” says Weglarz. “Our customers want that durable, powerful feeling.” So while part-count reduction helped lower manufacturing costs for Ariens, weight itself was maintained with the customer in mind.

BUILDING THE MODEL, RUNNING THE SIMULATIONS

SIMULIA’s Abaqus/CAE and fe-safe, along with True-Load from Wolfstar Technologies, were the main software tools used in the redesign process. The engineering team was pleased with how well the different programs worked with one another. “True-Load interfaces seamlessly with Abaqus,” says Kobiske. “It takes the data and writes out a macro to fe-safe. Then all we have to do is go into fe-safe and hit the play macro button and it sets up the entire job.”

Using Abaqus/CAE, the engineers examined the stresses around critical frame welds to predict any areas of potential concern. “The read and write capabilities to and from Abaqus are what makes it so easy to use. You can easily pull out whatever data you need in order to get what you’re looking for,” says Kobiske.

Twelve linear-static load cases were run to account for every load direction coming onto the frame through the wheels. The strain simulation results of the unit loads acting on the frame were then sent into True-Load to determine the precise locations in which to place strain gauges on the structure for field testing. A total of 22 gauges were placed on the mower chassis.

Following field tests on an actual mower, the real-world strain-gauge data was incorporated back into the Abaqus model, improving the accuracy of the simulations for a truly realistic representation of the loads that the mower would encounter when cutting a lawn. With high-fidelity Abaqus models of the current frame in hand, the design team could then make
“But after just one year, management was seeing reduced development time and increased efficiency. They’ve already said that the programs are well-worth what we’ve invested in them.”

—Aleysha Kobiske, structural analyst and engineer, Ariens

Upgrades to the frame that would help them achieve the “less expensive, stronger” mandates of the redesign project.

To further strengthen the chassis, engineers tweaked their designs in critical areas to reduce the amount of strain from the attached engine, transaxles, seat, and deck masses. Mounting points for roll-over protective structures (ROPs) had to be built to strict ISO safety standards. “We needed to ensure that we’d designed a strong, reliable frame to support the roll bar,” says Weglarz.

And how to predict the effects of many years of heavy grass work on a lawn mower frame? By using fe-safe to determine fatigue life of the component.

“We normally run fe-safe once for a design iteration,” says Weglarz. “Each time we make further changes to the design we will run fe-safe again to see the difference the design changes make. The life predictions from fe-safe help us determine areas of concern in the structure that we can address with subsequent adjustments.”

After its first round of design changes, the frame showed favorable structural responses and extended fatigue life.

**SAVING TIME WITH THE SIMULIA PORTFOLIO**

Prior to using simulation software, Ariens engineers had spent much more time and money on field testing. “We would run a machine until it broke, go build another one, and run that one until it broke,” says Weglarz. “Now that we use simulation, by the time that we do go to run a physical test of a finished redesign, we are confident that it is going to work.”

“We use our time much more effectively and we are extremely efficient,” says Kobiske. “We now can simulate hours and hours of testing in just a fraction of that time.”

The new mower underwent final field testing at the Sebring International Raceway in Florida. As a way of saying “thank you” for using the space for testing, Ariens takes care of all of the grass at the race track and surrounding area.

**HELPING UPPER MANAGEMENT APPRECIATE SIMULATION**

When Weglarz initially approached upper management with the proposal to integrate SIMULIA tools into the design process at Ariens, he was met with some skepticism. But the visualization that Abaqus delivers helped bridge the gap, explaining why a design may or may not work—as opposed to the pass/fail results of a physical test.

“There’s so much going on inside of the software, that to try and explain everything that’s happening to a non-technical person is extremely difficult,” says Weglarz. “The visual aids that come with simulation are helpful in illustrating everything we’ve done to validate a design prior to actually building it.”

Although images and animations are helpful in demonstrating the power of simulation, the reductions in cost and time are what truly convinced upper management. “At first the investment in the software packages seemed daunting,” says Weglarz. “But after just one year, management was seeing reduced development time and increased efficiency. They’ve already said that the programs are well-worth what we’ve invested in them.”

Adds Kobiske, “The software clearly pays for itself.”

**PROMOTING COLLABORATION BETWEEN DESIGNERS AND ENGINEERS**

The use of the SIMULIA portfolio also encourages greater communication between the engineers and the product designers at Ariens. Being able to show the design team areas of concern on-screen helped the engineers easily provide advice on how to redesign components.

“We get a STEP file from our designers, look at it, analyze it, and run it through fe-safe. From there we evaluate the structural concerns that surface and talk to the designers about them. They make the necessary changes and give a better design back to us,” says Weglarz.

“We—the engineers—are the structural guys. We don’t know all that goes into the packaging and other aspects that the design team is responsible for. The visual representation of the analyses we do help us work with them to understand both our structural needs as well as their packaging constraints.”

**EXPLORING OTHER CAPABILITIES IN THE SIMULIA PORTFOLIO**

Ariens plans to continue to learn more about the power of the SIMULIA portfolio and implement new tools and strategies into their design process. They are looking to expand beyond Abaqus and fe-safe to produce the next-generation of lawn-care equipment—and it appears their focus is on topology optimization.

“Tosca, and also Isight, are two programs we are definitely interested in adopting,” says Kobiske. “For future generations of mowers we are going to keep improving our designs—making them more fuel efficient and easier to use. We want to continue down this path of product innovation.”

Although next-gen product ideas are confidential at this point, it is safe to say that simulation will be playing a key role in the development of something truly “cutting edge” at Ariens.

For More Information
www.ariens.com
A PARTNERSHIP TO ACCELERATE ANALYSIS OF ELECTRONIC HARDWARE


As a simulation engineer/manager, why should you care? Because eventually the system that you are working on, if not already, will likely incorporate electronic hardware that is the foundation of all technology. And, increasingly, the adoption of these technologies throughout all environments, not just home and office, can result in thermal, mechanical and reliability challenges. To respond to these, DfR Solutions created Sherlock Automated Design Analysis (ADA) software.

Finite element analysis (FEA) is typically the go-to-solution in resolving these challenges, but the electronic hardware development process has some unique challenges not seen in other areas. The first is that electrical engineers control an extensive amount of the hardware design process. Electrical engineers often know little about FEA. Some use electronic design automation (EDA) software that is not compatible with FEA (no .stp outputs, much less .cae or scripting).

This is where the Sherlock software first steps in and provides a powerful pre-processor for Abaqus users. Sherlock can read all EDA output files and translate them into intelligent 3D models mesh-ready for Abaqus. This is not a trivial process since EDA files are flat 2D plot files with almost zero mechanical information at the part level. Sherlock uses a unique combination of powerful parsing code, embedded and global libraries (materials, part, package, laminate, solder), part number translators, and standardized build modules (wire bonds, heat sinks, mount points, etc.) to provide an out-of-the-box solution.

An intuitive user interface, consisting of easy to use fill-in fields and drop-down commands, allows the user complete control over model complexity. Users can start with a simplified model, consisting of bricks on a flat plane, with simulation times under 10 minutes. As knowledge is gained about the product and the user desires to better represent real-world geometry, Sherlock is able to ramp up detail to the point where every feature (ball, trace, via, lead, corner) is represented in high detail. Important aspects of electronic hardware can be captured in Sherlock, including complex daughter card/mother board configurations,
flex and rigid-flex, and even housing. The result is that most users are able to go from raw EDA to a Python script ready for input into Abaqus in under 90 minutes.

The user, whether a beginner from the design team or extensive Abaqus expert, can now perform a range of simulation activities. This is because the Sherlock Python script has not only provided model dimensions, parts, and material properties, but also tied contacts, boundary conditions and environmental loads. Abaqus is now able to do what it does best, performing a wide range of implicit and explicit simulations designed to capture the temperature rise (thermal) and mechanical response (strain, creep, fatigue, displacement) under a range of conditions (temperature cycling, harmonic vibration, sinusoidal vibration, mechanical shock, bending).

Once the Abaqus simulations are complete, we experience the second challenge with electronic design: the sheer number of unique parts and failure modes. The average electronic hardware has between 500 and 5000 parts that could fail. Each part, could have between 1 and 10 different mechanisms that could cause failure. The complexity of it all often results in organizations defaulting to ‘rules-of-the-thumb’ (e.g., temperature rise cannot exceed 20°C, board-level strain cannot exceed 500 μstrain) rather than harvesting the true value of the simulation activity.

Now, Abaqus simulation results (thermal, mechanical, or both) are imported into Sherlock’s rigorously validated damage models. To access this potent capability, the user has to literally do nothing other than import the results from their Abaqus simulation (thermal, mechanical, or both) and leverage Sherlock’s position as one of the most powerful Abaqus post-processors on the market today. Sherlock automatically identifies every part in the model, recognizes it’s technology and packaging, determines the failure modes most relevant to that part, and then makes a prediction for every unique combination of failure mode and electronic part.

The result is a complete life-curve for your technology. True tradeoff analysis (this material is 8% cheaper, but will raise warranty costs by 5%) can now start at the very beginning of product development process. First-pass success can now be assured, driving down time to market (especially true for automotive with their 6-12-week thermal cycle requirements). And minor improvements and modifications can now be validated through software rather than a complicated and costly physical validation testing.

Because of this powerful synergy between Sherlock and Abaqus, we have forged a deep and close relationship with Dassault Systèmes SIMULIA over the last several years. Our partnership goal is to drive deeper integration between the two software tools and to educate the larger technology world of the value of iterative Sherlock-Abaqus analyses during the product development process.

For More Information
www.dfrsolutions.com
Case Study

INTEGRATING THE DESIGN OF PHYSICAL AND CONTROL SYSTEMS WITH CO-SIMULATION

DPS uses Abaqus and CATIA Systems to help optimize the performance of a gantry robot

Automation may be increasingly replacing human labor in many industries, but not even robots can avoid the laws of physics. A robotic gantry crane starts, runs and stops along precisely defined X, Y, and Z coordinate paths, yet the effects of inertia, acceleration, vibration and/or oscillation can still result in performance that is less than ideal.

Simulating this kind of complexity was the aim of a collaboration between global CAD/CAE provider Digital Product Simulation (DPS) and the French mechanical engineering school Supmeca. The school participates in PLACIS (“Collaborative Platform for Systems Engineering”), which is funded by the French National Agency for Research. The PLACIS program supports international Masters of engineering students, teaching systems engineering through a project-based learning approach that often involves industry partners such as DPS.

Christophe Baroux graduated from Supmeca a decade ago and is now technical sales manager for DPS North America. He coordinated a recent academic/industry PLACIS project between DPS and Supmeca and reported the student/engineer team’s findings at Dassault Systèmes’ inaugural Science in the Age of Experience event in Boston last year.

The team’s choice of a gantry crane to demonstrate co-simulation between Dassault Systèmes’ Abaqus and CATIA Systems tools was a good one, Baroux feels. “Co-simulation is a very exciting topic, but still a niche subject with not many applications in the real world yet,” he says. “Gantry robots are used widely in industrial settings, so we felt our example might be of interest to engineers who are interested in optimizing the performance of complex systems in a number of different fields.”

MODELING THE COMPLEXITIES OF MECHATRONICS

Gantry robots (also called Cartesian or linear robots) are employed for machine tending, materials handling, stacking and palletizing—and are highly valued for their positioning accuracy. Tactics that have been used to improve their productivity include reducing the weight of the robot’s end effectors (manipulate-able arms) and/or increasing the speed of operation of the gantry setup. But lighter, flexible robotic arms are more susceptible to swaying while travelling at speed, and they can oscillate for a period of time even after a move is completed. The settling time required for any residual vibration can delay the next step in the operation line, conflicting with the demand for increased productivity.
Case Study

“A gantry robot is not as simple as it looks,” says Baroux. “It’s a complex mechatronics challenge because it involves different mechanical aspects that are controlled by integrated electronic systems that implement algorithms within the hardware. We found that the surest route to optimizing real-world performance of something this multifaceted was to combine the core strengths of the physical modeling capabilities of Abaqus with the logical modeling features of CATIA Systems.”

ADDING SYSTEMS ENGINEERING ONTO CORE FEA CAPABILITIES

DPS’ knowledge of both physical and logical modeling runs deep: already established CAD/CAE services providers and longtime users of Abaqus, they became a Dymola reseller after the software was acquired by Dassault Systèmes in 2006 (and renamed CATIA Systems).

Of course Abaqus is the world’s technology-leading suite of finite element analysis software for modeling, visualization and best-in-class implicit and explicit dynamics of physical product behavior.

CATIA Systems, on the other hand, provides a graphical interface for building “big-picture,” logical models that simulate the behavior of entire systems. The physics of a system are not what is being modeled—the behavior of the system that emerges from the underlying physics is. As an example, you wouldn’t simulate the fluid in a hydraulic system, you would model the power and force transmitted by that fluid. In this way, the function of an entire machine—including its powerplant, hydraulics, electronic controls, mechanical actuators and so forth—can all be simulated at once.

Because such a large, logical model is much less computationally dense than, say, a finely meshed FEA one, it can be run across any timespan desired. “Logical models enable you to study global behavior over whatever time cycle you are interested in,” says Baroux. “Depending on the inertia in the system, and what it is doing, this can vary from seconds to hours to months. With CATIA Systems added to our toolkit we became able to significantly expand the scope of our capabilities.”

“Abaqus is well suited to handle any detailed simulation, and combining it with CATIA Systems’ dynamic visual modeling provides an easy and convenient way to verify and validate the control part.”

—Christophe Baroux, technical sales manager, DPS North America

BROADENED DESIGN ENGINEERING CAPABILITIES BRING IN MORE BUSINESS

As DPS’ design engineering knowhow widened with its toolkit, the company began winning more industrial jobs on such large systems as nuclear power plants—predicting, for example, the clogging of steam pipes over a year or more. They also contributed to Dassault Systèmes’ “Ice Dream” project, which imagined months of towing an iceberg from the Arctic Ocean to provide fresh water to the Canary Islands (DPS’ analysis predicted that more than 60% of the iceberg would survive the trip).

Then, with their expertise established in both FEA and systems modeling, DPS started to investigate bringing those two worlds together with co-simulation. “When the opportunity to participate in the PLACIS project arose, we realized that a mechatronics system like a gantry robot was well suited to demonstrating our logical-physical modeling methodology with Abaqus and CATIA Systems,” says Baroux. “This robot challenge was certainly on a smaller scale than an entire power plant, but it does provide a clear example of how co-simulation can help optimize systems behavior.”

THE GANTRY ROBOT CHALLENGE

The PLACIS project team’s goals were to minimize the vibration of a one-axis gantry robot arm as it moved and to increase the precision of the arm’s positioning. The modeling approach was simplified by the team, who pursued their studies with a wireframe 2D model mainly for simulation runtime reasons. The group created a 2D Abaqus model of the gantry robot, with a 2-meter long arm moving along an 8- by 4-meter horizontal frame. Friction behavior was added to the connection between the arm and the frame and the arm had one translational degree of freedom.

Figure 1. A logical-physical model flow. For the gantry robot project, the physical system modeled with Abaqus includes virtual sensors and actuators in a “Plant” (orange). The sensor data from Abaqus is passed to CATIA Systems (the yellow “Controller”), enabling the controller to compute the actuation needed to drive the physical system towards the desired state. This co-simulation can be repeated in a feedback loop to optimize the performance of the robot.

Figure 2. Displacement of the robot arm when an instantaneous force is applied.
Virtual sensors were positioned to measure the displacement and velocity (the outputs) of the top node of the arm. Then a concentrated force, driven through a virtual actuator (the input), was applied to the same node.

As Figure 2 shows, when the simulation was run, vibration in the arm was clearly visible when an instantaneous force was applied. Now the task was to couple this Abaqus model with a CATIA Systems model to find a good control set that would minimize the arm’s vibration.

The CATIA Systems model was created with two inputs from the Abaqus model—displacement and velocity—and one output: force amplitude. The model was set up using two different controllers (Figure 3)—one that acted only on position and another that acted on both position and velocity—enabling more accurate computation and correction of any errors between the desired and current states of the Abaqus model. Position response was compared with a reference value to compute the right force to apply on the arm, while velocity and force were limited so as to model what might occur in a real-world system.

With the Abaqus and CATIA Systems models established, the co-simulation could be run in a feedback loop of data exchange to tweak the controllers’ parameters until they reached values that would minimize the gantry robot’s vibration as well as increase the positioning accuracy of its arm. This “tweaking” can be accomplished via a PID (Proportional-Integrator-Derivator) technique or, alternatively, by integrating the co-simulation with Isight/SEE to achieve a more robust parameter set. “This is one of the key capabilities of Isight,” says Baroux. “You can integrate your co-simulation in an optimization loop within the Isight environment to automate the tweaking of the controller and reach your desired target.”

As seen in Figures 4 (an early run when the controller was not yet optimized) and 5 (a final run), the end result was much improved control over the gantry robot arm’s behavior.

“This Abaqus-CATIA Systems co-simulation technique is very useful when your control model has an influence on your physical model’s accuracy,” says Baroux. “Abaqus is well suited to handle any detailed simulation, and combining it with CATIA Systems’ dynamic visual modeling provides an easy and convenient way to verify and validate the control part.”

Baroux feels that co-simulation has tremendous potential to enhance the efficiency and accuracy of the overall design process, particularly when modeling large, complex systems. “Our investment in the software has definitely paid off,” he says. “You do need to be rigorous if you want to use this approach because every project includes collaboration between different groups of people. The emergence of innovation platforms like 3DEXPERIENCE is helping democratize the application of systems modeling and co-simulation, making them more accessible to non-analysts.”

For More Information
www.dpsinc-us.com/about-us
TRAINING SPOTLIGHT: DURABILITY

Durability for transportation and mobility

Durability driven by Isight

Shape optimization & durability targets

Introduction to fe-safe

Theory & application of fe-safe/Rubber

Custom fatigue courses
Durability is a requirement for product development across numerous industries. In transportation and mobility, each vehicle system has to meet a different number of miles or years of use under warranty. Testing and simulation both play a vital role in accelerating the design cycle and reducing time to market, while meeting such targets.

Many of us learned about the Goodman diagram in our university experiences, and even calculated fatigue life using an S-N diagram, but that can only take us so far. Modern multiaxial strain-based fatigue analysis is required to drive our designs as they get lighter and challenge the boundaries of previous applications.

To do this, fe-safe combined with advanced FEA can account for:

- Plasticity in metals, and hysteresis effect
- Residual stresses from forming, installation or shot peening
- Mean stress effects
- Surface roughness in steel and cast iron
- Complex variable amplitude and non-proportional loading
- Mission statements and proving ground loads
- Welded joint fatigue and many other features

At this moment, no one can guess the location of “lowest lives” given the complex inputs and interactions of these effects. So we need software to run the calculations all over the model.

**DURABILITY DRIVEN BY ISIGHT**

Let’s take an example from the life sciences: Adding modern multiaxial fatigue to the parametric optimization of a hip implant allows the designer to select the best design candidate from over 200 variants in less than a day when Abaqus and fe-safe are automated in Isight. Compare 12 days’ validation on one single test machine to the 60 days on 40 test machines that would be required if all of those variants were evaluated in the lab.

**SHAPE OPTIMIZATION & DURABILITY TARGETS**

Taking the same hip implant concept further, shape optimization can be used to fine-tune the design. In Tosca Structure, shape optimization can be driven by an objective to minimize damage in the area of lowest life. Along with constraints to keep the mass the same and to allow manufacturing and assembly, this target led to an overall increase in life of almost 5 times over the selected design from the earlier Isight optimization. In this way both optimizers work together, to provide the best solution for patient and designer.

**DURABILITY TRAINING OFFER**

SIMULIA offers a variety of fatigue theory and application courses designed to teach the user how to include durability calculations in the development process for many applications:

**Introduction to fe-safe (2 day)**

In this course you will learn how to set up and run various fatigue analyses using fe-safe. The course includes hands-on workshops using your choice of FEA solution (Abaqus, ANSYS or Nastran). Topics include: Using the fe-safe GUI and group settings, introduction to fatigue theory, loading definitions in fe-safe, algorithms and analysis process, infinite life methods, and diagnostic tools.

**Automating Analysis in fe-safe (1 day)**

This course focuses on the details of automating fe-safe analyses using command line, batch file or macro files and the basics of integrating fe-safe analysis with Isight, Tosca or ANSYS Workbench.

**Theory & Application of fe-safe/Rubber (2 day)**

This course provides hands-on software workshops for using Abaqus and fe-safe/Rubber to run a rubber-fatigue analysis. Topics include rubber material fatigue properties, crack-growth calculations for rubber, variable-amplitude loading, constant loading, multiaxiality and post-processing.

For more information: www.simulia.com/training

**Custom Fatigue Courses**

Lectures are available for custom courses on metal fatigue including stress-based and strain-based fatigue, rainflow cycle counting, fatigue properties, infinite life and high-cycle fatigue, theory of critical distances, PSD fatigue and more:

Request a custom course: www.3ds.com/products-services/simulia/services/training-courses/request-a-training-course.

A wide range of videos about durability, including Developing a Design Process for Durability, can be found in the training section of the SIMULIA Learning Community. (https://swym.3ds.com/#post:38907)

**ABOUT THE SIMULIA LEARNING COMMUNITY**

The SIMULIA Learning Community is the place to find the latest resources for SIMULIA software and to collaborate with other users. The key that unlocks the door of innovative thinking and knowledge building, the SIMULIA Learning Community provides you with the tools you need to expand your knowledge, whenever and wherever.

For More Information

https://www.3ds.com/products-services/simulia/services
Case Study

CREATING A MONSTER WITH SIMPACK
Zollner Electronik AG engineers design the world’s largest robot using SIMULIA’s multibody simulation software

“The software lets us know what works and what doesn’t, without the need for extensive field testing. If a design flaw is found, it also shows us exactly where and why the problem is occurring, making it easier for us to fix.”

—Frank Pfeffer, mechanical engineer, Zollner Electronik AG
Medieval folklore stretches the imagination and sends us to a magical realm unlike any other. From orcs and trolls to elves and giants, human-like species make this unearthly world weirdly compelling. But the one creature of the genre that remains the most iconic—instilling fear, wonder and excitement into everyone—has to be the dragon.

Imagine an “animal” five stories tall, standing above you, its scales seemingly rock solid and teeth razor sharp. You look up at its beautiful 40-foot wingspan in amazement and back down at its enormous feet in terror—knowing this beast, weighing over 10 tons, can squish you like a bug. Its head rests at ground level so it can see your every move—close enough that you can feel the hot steam from every breath it takes. Then it steps forward, lifts its head high, opens its mouth, and unleashes bursts of flames across the sky.

**BRINGING FANTASY TO LIFE**

Such an encounter is something most folklore fans can only dream of. Of course dragons don’t exist, but can one be made? Zollner Electronik AG engineers have proven it is possible by creating the world’s largest, fully-functional mechatronic dragon—coming to life every year at the ancient German folk festival, Further Drachenstich. During the event, the 50-foot fire-breathing beast walks among people who come from all over who come to celebrate in the Bavarian Forest. Called Tradinno—an homage to both tradition and innovation—the 11-ton animatronic robot is scarily real.

Currently listed in the Guinness Book of World Records as the “world’s largest robot” since 2014, Tradinno is powered by a 100kW Diesel engine—where 50 closed-loop controlled axes are moved by carbon fiber laminated (CFK) hydraulic cylinders. At 15.5 m in length, 4.5 m in height and with a 12 m wingspan, Tradinno moves up to 0.5 km/hr and assumes several pre-programmed positions during the show.

Such an impressive machine was obviously extremely challenging to design. The biggest hurdle for the team at Zollner stemmed from Tradinno’s large mass, paired with the high number of degrees of freedom in individual components and the resulting play of varying dynamic forces on them. To support the motion of each component and minimize their individual and combined effects on the entire robot, Simpack from Dassault Systèmes’ SIMULIA was used throughout the design process. Simpack multi-body simulation software enabled the engineers at Zollner to generate and solve 3D models that successfully predicted and visualized motion, coupling forces, and stresses on a flexible mechatronic system.

“Simpack made us confident that our finished design would work,” says Frank Pfeffer, mechanical engineer at Zollner Electronik AG. “Without the tool, it would be near impossible to ensure that the finished dragon would operate as flawlessly as it does.”

**MAKING A DRAGON MOVE**

Over 100 subassemblies (CAD geometries and mass properties) were imported into Simpack via ProSIM. Each component had different functions and subsequently different effects on the overall performance of the machine.

Because of the high number of moving parts and their combined overall weight, getting the robot to walk was an especially difficult task. Zollner engineers realized early on that evaluating contact and friction forces between the four feet...
and the ground was a priority. There were many variables that affected the stresses in the feet while walking, including the influence of wobbling masses such as the motor and hydraulic pumps or the weight of compressed oil within the cylinder.

To identify suitable stiffness and damping values, the team ran a variety of simulations to assess the range of flexibility of the leg subassemblies. They found that by optimizing the trajectory of each individual leg, the force from the impact of stepping on the ground could be reduced.

With the legs functioning as desired, walking and movement tests were then run on the robot as a whole—traversing a flat plane or a slope, moving in an arc, and turning on the spot. Simulating these stepping cycles provided information needed to strengthen the legs to prevent lateral buckling. The team then optimized the location of the components connected to the torso, and the motions of the neck and tail, by evaluating Tradinno’s total center of mass while walking.

Additional tests were done on the wings to find the best possible balance between weight and stability. The engineers also found ways to stabilize the dragon in the rare event of a complete front-leg failure. “It was clearly important to eliminate any potential risk to festival attendees,” says Pfeffer.

For smooth operation of the beast in action the Zollner team used MATLAB’s SIMAT interface in conjunction with Simpack to run closed-loop control tests to ensure that when the operator pressed a button on the controller, the robot would automatically perform the designated function. “Simpack was used to easily implement the geometry of the dragon to SIMAT and to connect it to MATLAB,” explains Pfeffer. “With SIMAT we simulated the control processes to be as realistic as possible—for example the motion of a walking leg. Our aim was to observe the behavior of the dragon’s hydraulics when it was walking and to determine whether or not the individual control circuits would interfere with one another.”

**SIMPACK SIMPLIFIES COMPLEXITY**

Zollner engineers value the simplicity of using Simpack for such complex design projects, where their team needs to work with maximum efficiency to produce high-quality, high-performance mechatronic systems.

“Simpack allows us to easily identify and solve design challenges,” says Pfeffer. “The software lets us know what works and what doesn’t, without the need for extensive field testing. If a design flaw is found, it also shows us exactly where and why the problem is occurring, making it easier for us to fix.”

With the world’s largest robot under their belt, there’s no telling what project the engineers at Zollner will tackle next, but it’s safe to say that Simpack will continue to play a key role in the design process of their next complex mechatronic assignment.

You can see their fire-breathing beast in action for yourself at the annual Further Drachenstich festival every August, or on the event’s website at www.drachenstich.de/index.php/english.

**For More Information**
[https://www.zollner-electronics.com](https://www.zollner-electronics.com)
Additive Manufacturing Symposium

ADDITIVE MANUFACTURING SYMPOSIUM & HACKATHON AT SCIENCE IN THE AGE OF EXPERIENCE

Additive manufacturing has progressed from its roots in prototyping applications to functional end-user production parts progressed at enormous speeds enabling lighter parts and shorter development cycles. Modern 3D design and modeling tools are powerful vehicles for producing generative designs and bridging the gap between as-designed and as-manufactured parts. Additive manufacturing is encompassing new materials, processes and applications every day. However, this fast-developing technology brings with it such challenges as how manufacturing affects design, quality control, process monitoring and supply chain considerations.

We are delighted to host our first ever Additive Manufacturing Symposium and Hackathon at Science in the Age of Experience, May 15-18, Chicago, IL. This Symposium will bring together expert speakers and panelists from different sectors of technology including industry executives, research leaders, independent consultants, software and hardware vendors, product designers/engineers as well as manufacturing engineers/managers. Attendees will have the opportunity to discuss the latest innovations in additive manufacturing and participate in collaborative challenges to address and accelerate the adoption of this technology.

The day is divided into two sessions with keynote talks from industry leaders as well as presentations of latest trends in hardware development in the morning and panel discussions and technical presentations in the afternoon. Speakers at the symposium include: John Vickers, NASA; Troy Hartwig, Kansas City National Security Campus; Tim W. Simpson, Pennsylvania State University; Jack Beuth, Carnegie Mellon University; Lyle Levine, National Institute of Standards; Pieter Volgers, DuPont. On May 15-18, we will host an Additive Manufacturing Hackathon. Participants will explore design and manufacturing challenges through topology and lattice optimization, reconstruction and process simulations.

Come prepared to experience the future of design and manufacturing—all driven by science!

For More Information

JOIN US FOR TRAINING DAY

In addition to the Additive Manufacturing Symposium, SIMULIA will offer six training courses on Monday, May 15. Choose from the following:

Technology Seminars
• Computational Fluid Dynamics (CFD) Solutions inside 3DEXPERIENCE: Introduces users to Computational Fluid Dynamics-based roles available in the 3DEXPERIENCE platform.
• Topology Optimization Using Tosca for Abaqus: Learn how to apply topology optimization techniques to a structural finite element analysis, including setting up design volumes, defining simulation objectives and constraints, and considering manufacturing and structural requirements.

Hands-on Training Courses
• Hands-on with Composites Simulation: Advanced Composite Materials Analysis – Damage and Multiscale: This course aims to introduce users to the capabilities in Abaqus that enable effective modeling of composite materials with special emphasis on the topic of multiscale material modeling and damage.
• Hands-on with Acoustics and Linear Dynamics with Abaqus: Effective Solution of Structural Vibration Problems: Introduces the user to the algorithms and methods used to study linear dynamic problems with Abaqus/Standard.

Application Seminars
• Deep Dive into Simulation on the 3DEXPERIENCE platform: Attendees will leave the course with a complete understanding of the function of the platform, how the platform facilitates collaboration between analysts and others, what technology is available on the platform, how that technology works together, what workflows are enabled by the platform, how to capture, share, and publish those workflows for others, and how simulation on the platform increases the value and reach of simulation activities.
• Analyzing Drivetrains using SIMULIA Simpack Multibody Simulation: Attendees will come away from the course with a firm understanding of the technology and applicability of Simpack for drivetrain analysis and the value of Multibody Simulation as an application area together with FEA and other Dassault Systèmes technologies.

For More Information
https://www.3ds.com/events/science-in-the-age-of-experience/overview
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IF WE SIMULATE DOWN TO THE INFINITELY SMALL, CAN WE HARMONIZE THE INFINITELY BIG?