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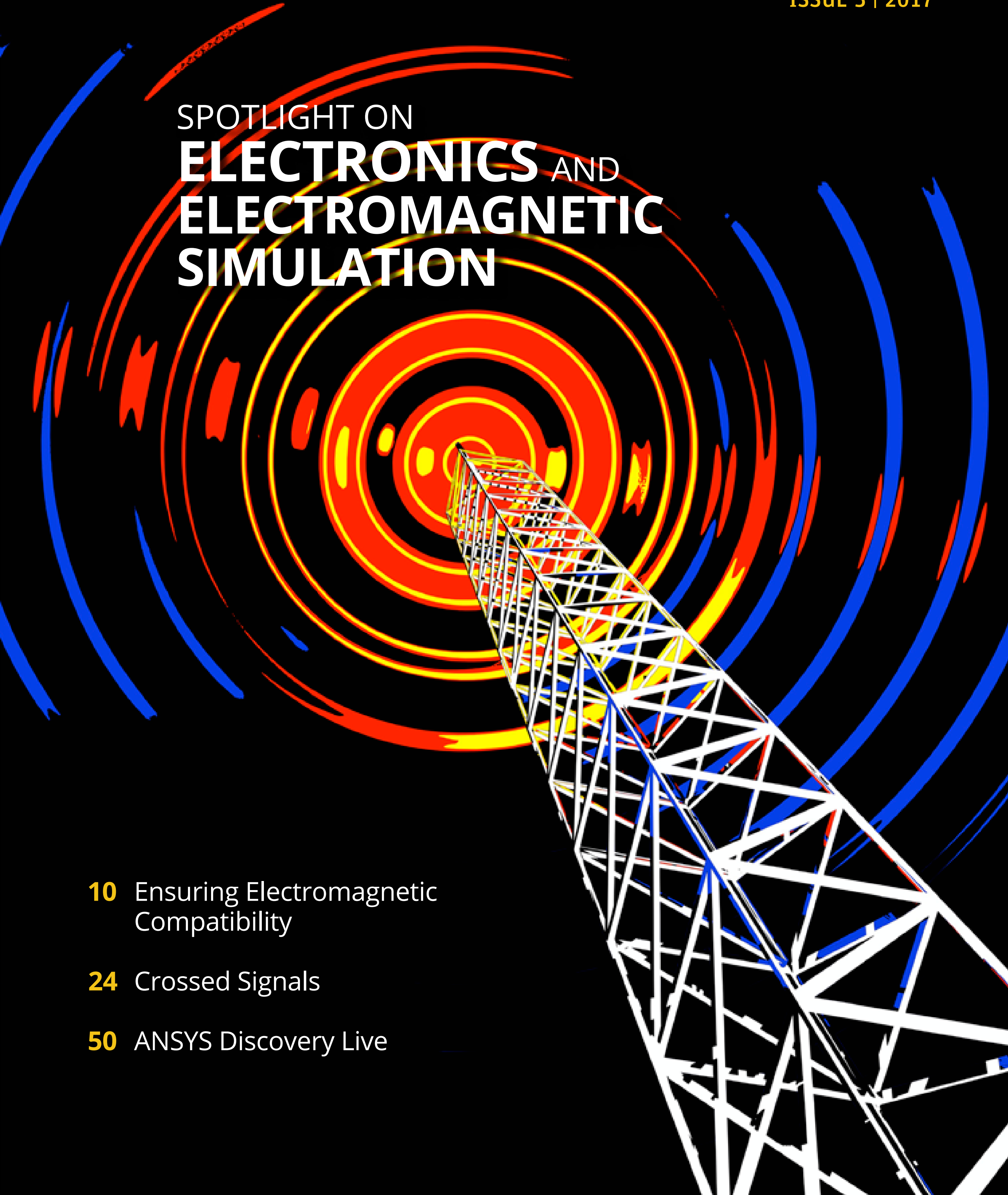
ADVANTAGE

ISSUE 3 | 2017



SPOTLIGHT ON ELECTRONICS AND ELECTROMAGNETIC SIMULATION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Vice President, Research at ANSYS, Inc.
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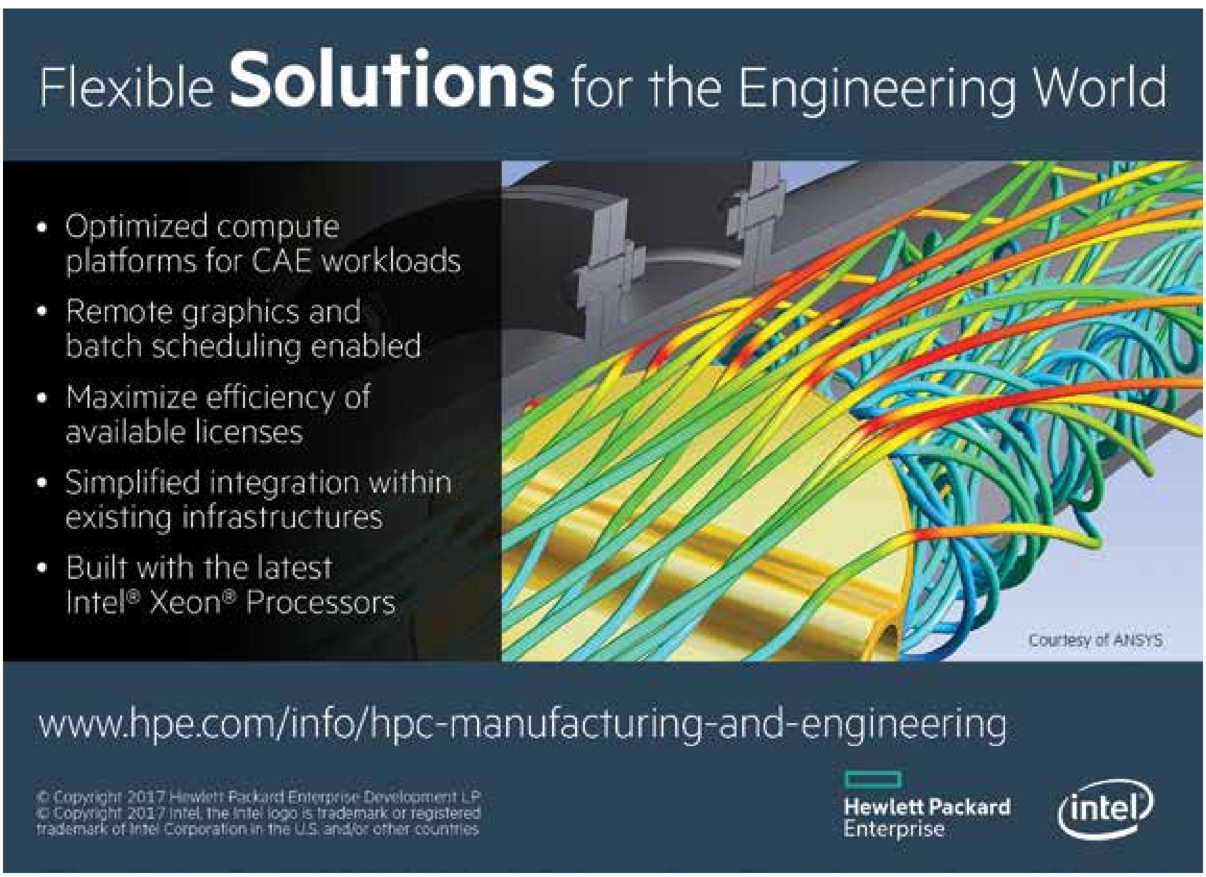
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ENABLING THE FUTURE FOR ELECTRONICS

As electronics become more and more pervasive in our lives and businesses, the complexity of design increases exponentially, requiring advanced electronics simulation to develop the reliable products we can no longer flourish without.

By **Lawrence Williams**, Director of Product Management Electronics, ANSYS

Electronics are everywhere! Of course, the smartphone and computer are pervasive examples in our lives, but there is no shortage of electronics in automobiles, banking, aircraft, retail and countless other applications. With the emergence of the Internet of Things (IoT), even household appliances are now under electronic control and becoming connected. As we benefit from the convenience and productivity that electronics provide, we become increasingly reliant on embedded electronic systems. If those systems were to fail, it would be not only inconvenient, it could become a business problem, a productivity problem and in some cases a personal safety problem. It is increasingly important to produce systems that are robust and reliable. Advanced simulation of electronics enables exploration of designs, not only for the nominal ability to perform, but to perform reliably over the life of the product.

Modern electrical simulation delivers digital prototyping and design exploration for electronics and electro-mechanics. With simulation, engineers can deliver reliable, high-performance and lower-cost products that have been thoroughly scrutinized so that there are no electrical, thermal or structural surprises in production or deployment. The most advanced simulations combine real physics modeling with circuits and systems for high-speed, high-density printed circuit boards and assemblies, antennas and wireless systems, power conversion, and electromechanical devices. The digital prototype can be leveraged to establish virtual compliance with design requirements and provide engineers insight to deliver not only today's products but tomorrow's even more automated, mobile and innovative inventions.

Our Wireless World

5G connectivity promises a faster, more robust mobile computing experience for everyone. These applications have particularly strong design challenges that benefit from simulation. The promise of millimeter-wave technologies will be preceded by extending sub-6 GHz systems to leverage band-aggregation to obtain 5G speeds using existing infrastructure. This requires multiple radios to operate simultaneously, which can lead to crosstalk and thermal issues that can be addressed upfront with simulation. As millimeter-wave technology emerges, engineers will leverage simulation to solve sensitivity to temperature, efficiency and circuit density challenges.

There will be tremendous need for antennas and wireless for 5G and IoT product connectivity. Electromagnetic simulation enables engineers to select, design and integrate antennas for IoT systems and environments. IoT suppliers will require more integrated and programmable subsystems to streamline adoption for system integrators, and making solutions easier to adopt is key. Simulation with automated design flows, accelerates adoption of simulation within organizations.

Transforming Business and Breaking Down Barriers

Advanced simulation is a critical driver for the most pioneering companies. Industry leaders adopt multiphysics simulation to bridge the gap that exists between engineering disciplines, and enable the products to be designed from a true systems perspective. Electronic devices must perform across electrical, thermal and mechanical domains. Electronic systems get hot. They get dropped. They sometimes operate in harsh environments. Multiphysics simulation methods aid businesses in addressing these challenges across high-frequency, high-speed electronics and electromechanical systems. Adopting a multiphysics system engineering approach can make the difference between a nominal design and a truly robust design.

Future Considerations

Future electronic product innovations will require a platform on which engineers can simulate and design entire electrical and electronic products while including all the necessary physics and system effects. This can include the minute details of a complex integrated circuit up to a full product like an automobile. Industry-leading companies rely on simulation, and the most advanced engage with ANSYS to automate processes so that more engineers can leverage the richness of real physics. With a single platform, electrical engineers can deliver a faithful representation of electrical, thermal and structural performance, while sharing models with mechanical engineers for even more rigorous examination.

This issue of *ANSYS Advantage* demonstrates some remarkable advances in electromagnetic field simulation that can help you drive design innovation.

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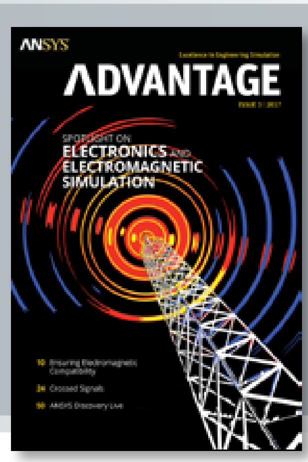
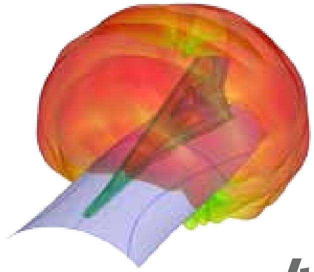
This issue of ANSYS Advantage *demonstrates some remarkable advances in electronic and electromagnetic field simulation that can help drive design innovation.*

Credit: RUSSELL KIGHTLEY/SCIENCE PHOTO LIBRARY





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If you've ever seen a rocket launch, flown on an airplane, driven a car, used a computer, touched a mobile device, crossed a bridge, or put on wearable technology, chances are you've used a product where ANSYS software played a critical role in its creation.

ANSYS is the global leader in engineering simulation. We help the world's most innovative companies deliver radically better products to their customers. By offering the best and broadest portfolio of engineering simulation software, we help them solve the most complex design challenges and engineer products limited only by imagination.

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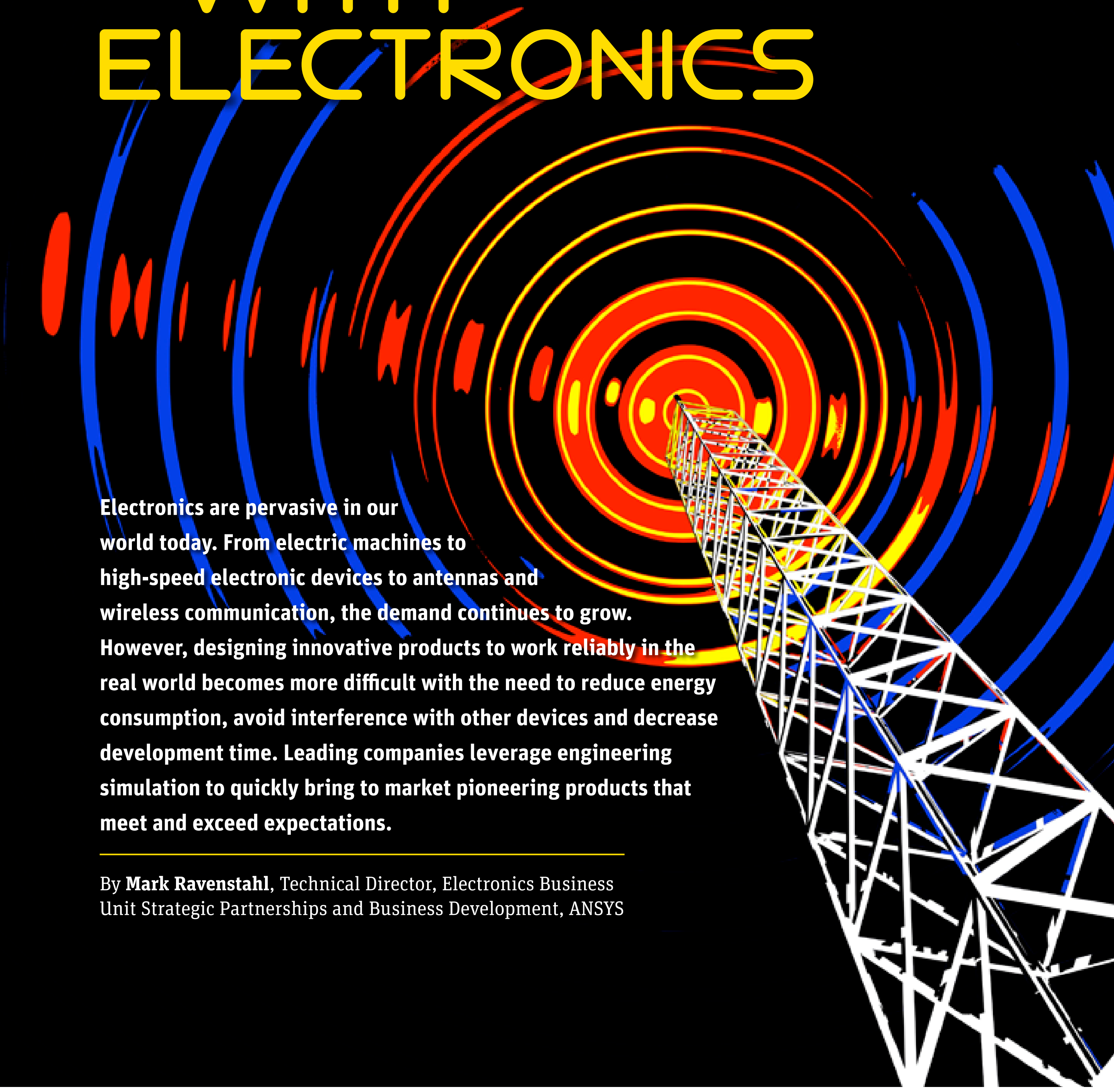
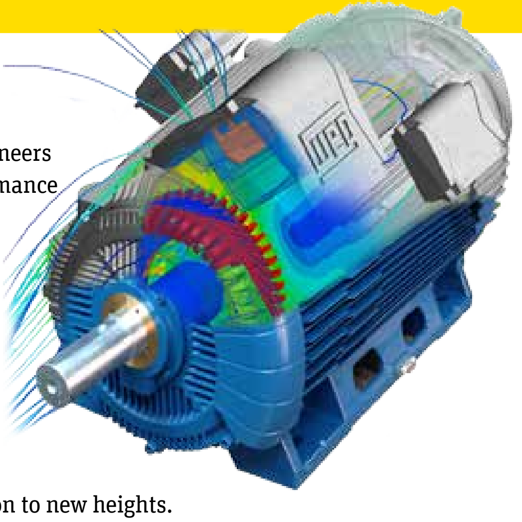
DRIVING INNOVATION WITH ELECTRONICS



Electronics are pervasive in our world today. From electric machines to high-speed electronic devices to antennas and wireless communication, the demand continues to grow. However, designing innovative products to work reliably in the real world becomes more difficult with the need to reduce energy consumption, avoid interference with other devices and decrease development time. Leading companies leverage engineering simulation to quickly bring to market pioneering products that meet and exceed expectations.

By **Mark Ravenstahl**, Technical Director, Electronics Business Unit Strategic Partnerships and Business Development, ANSYS

HIGH-PERFORMANCE ELECTRONICS drive some of the most remarkable innovations in every industry. Trailblazing inventions such as advanced driver assistance systems (ADAS), the Internet of Things (IoT), 5G communications, hybrid propulsion and others require advanced electromagnetic field simulation so that leading organizations can design, optimize and deliver products quickly to market. Engineers need to evaluate the effects of system density as radio frequency (RF) and wireless communications components are integrated into compact packages to meet smaller footprint requirements while improving power efficiency. Electrification of cars, planes and ships requires pushing industrial components such as electric machines and electronics beyond their traditional limits by leveraging new ways of thinking and design.



An electric machine from WEG demonstrates how virtual design leads to real innovation. Using ANSYS simulation, WEG delivered best-in-class energy efficiency, exceptionally low noise and bearing life over 100,000 hours.

With accurate simulation, engineers can predict the detailed performance of their designs and deliver innovative products. ANSYS supports the delivery of cutting-edge products with powerful innovations, including an integrated platform, best-in-class single physics and comprehensive multiphysics to push the envelope of computer simulation to new heights. Our most recent electromagnetic software innovations for electric machines, high-speed electronics and RF/ wireless communications continue to help engineers reach functionality and reliability goals on schedule.

Electric Machine Design

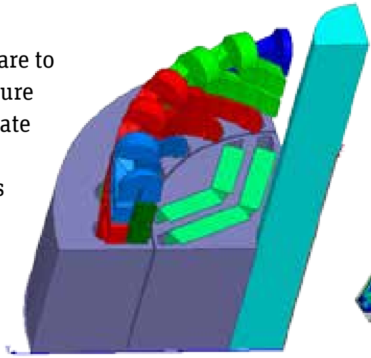
Electric motors account for two-thirds of the world's industrial electricity consumption, which is equivalent to 28 percent of the world's total electricity consumption, according to a study by ABB [1]. That is a massive amount of energy considering that the world devours electrical energy at close to 24,000 terawatt-hours per year [2]. Improving motor efficiency by 1 percent would save the equivalent of 81 million tanker trucks of gasoline each carrying 9,000 gallons of fuel. That's enough eighteen-wheelers to go halfway around the Earth if placed bumper to bumper. Clearly this energy savings is worth exploring. ANSYS simulation software helps electric machine designers optimize their designs and improve energy efficiency.

ANSYS Innovation: Comprehensive Multiphysics Workflow

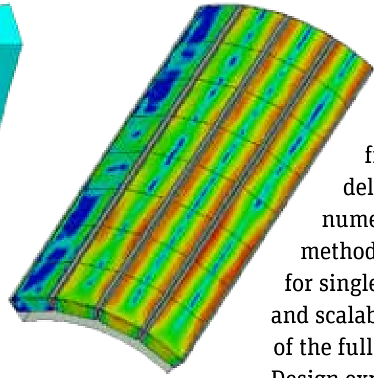
To improve motor efficiency, ANSYS Maxwell software carries out rigorous performance calculations for the machine, including the motion-induced effects caused by linear translational and rotational motion, advanced hysteresis analysis, demagnetization of permanent magnets and other critical electromagnetic machine parameters. Maxwell shares the same CAD source with and can be coupled to ANSYS Mechanical, ANSYS Fluent or ANSYS Icepak through the ANSYS Workbench platform to perform stress, thermal, CFD and acoustic analyses. These multiphysics capabilities are required for a detailed analysis of the full spectrum of factors that influence electric machine efficiency. For example, losses calculated by Maxwell can be used

Robust Electric Machine Design Through Multiphysics
ansys.com/electric-machine

as inputs to CFD software to calculate the temperature distribution and evaluate cooling strategies. Electromagnetic forces and torque calculated in Maxwell can be input to ANSYS Mechanical to analyze deformations and further assess potential vibrations. This depth of multiphysics analysis is unique to the ANSYS platform and can lead to machine designs that significantly decrease power consumption.



End effects



Subdivided magnets

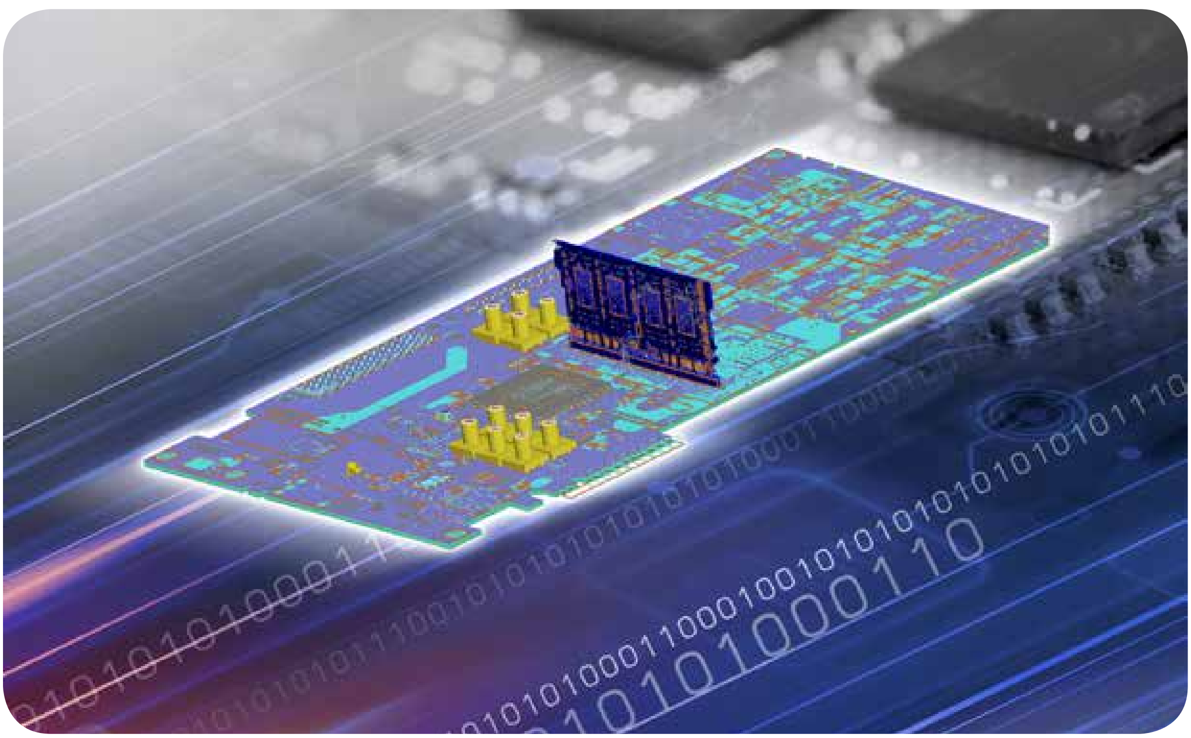
Electric machine 3-D effects have significant impact on end-product performance.

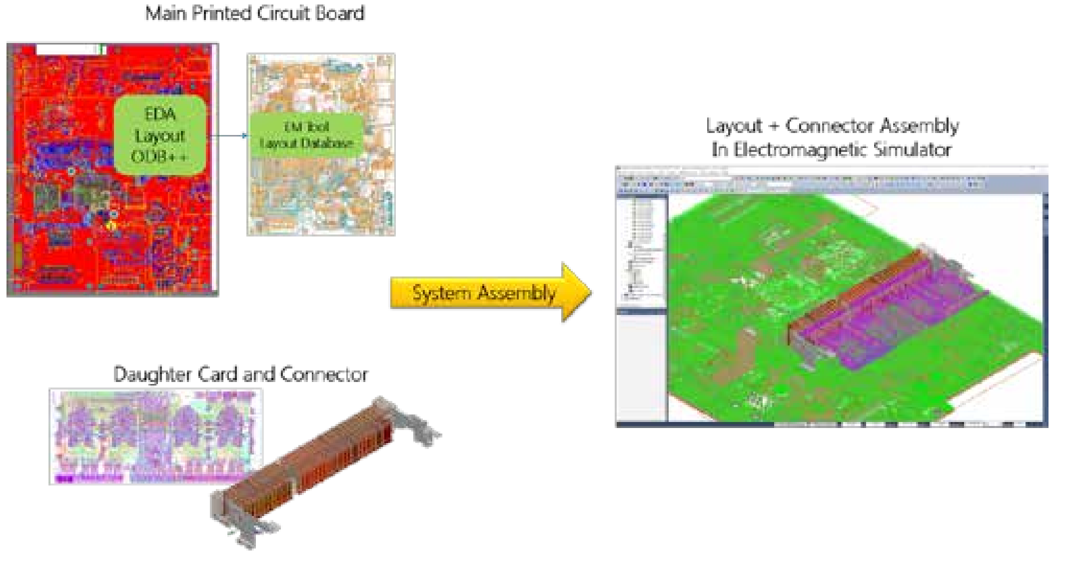
to simulate more and larger models both faster and with higher fidelity. ANSYS software delivers groundbreaking numerical solvers and HPC methods that are optimized for single multicore machines and scalable to take advantage of the full power of a cluster. Design exploration using parametric analysis is highly accelerated when scaled across a cluster. Motor dimensions, drive currents, speed, torque load and any other simulation parameter can be evaluated at numerous design points and solved simultaneously on multiple cores. The new time decomposition

> *“Electrification of cars, planes and ships requires pushing industrial components such as electric machines and electronics beyond their traditional limits by leveraging new ways of thinking and design.”*

ANSYS Innovation: High-Performance Computing
One of the most significant advancements in the field of engineering simulation is high-performance computing (HPC). Organizations are now leveraging tens, hundreds or even thousands of computer nodes

method (TDM) within ANSYS Maxwell takes advantage of modern compute clusters. TDM delivers the computational capacity and speed needed to perform the full transient electromagnetic field simulations required for electric motors, planar magnetics and





Three-dimensional layout with integrated system assembly for a laptop computer that combines a main printed circuit board layout coupled with an edge connector and a daughter card

power transformers. This enables engineers to solve all time steps simultaneously instead of sequentially, while distributing the time steps across multiple cores, networked computers and compute clusters. TDM makes full 3-D simulation possible during the design phase so that details such as winding end effect or subdivided magnets commonly used in electric machines can be explored and considered in a matter of hours. The result is a phenomenal increase in simulation capacity and speed that allows engineering design teams to explore many more options early in the development process to reduce power consumption and meet other specifications.

High-Speed Electronics

Automated electronics design has evolved since the days when IC design was controlled by the capabilities of the lithographic manufacturing process. Once layout and design could be considered together, electronic signaling speeds increased and signal integrity challenged electrical engineers with short signal rise time, transmission line effects and crosstalk. This required electromagnetic modeling. With today's tight packaging densities, fast signaling and high frequencies, tools for layout and electromagnetics must be employed jointly to obtain optimal performance and reliability. Circuit and system analysis is now part of the broader EM assembly solution rather than the driver of it. Transient circuit analysis can be run directly from the layout so electrical engineers can virtually assemble a digital electronic system with IC packages, printed circuit boards, connectors and cables, and then perform analysis of that system to leverage appropriate technology.

ANSYS Innovation: Assembly Modeling, 3-D Components and Automation

Electrical engineers have long used schematic-based design to connect models for printed circuit boards, IC packages and components. This works well for relatively simple designs, but becomes tedious and error-prone for larger, more complex designs. If the engineer misses just one point-to-point connection for a single node, the simulation results will be incorrect. Layout-driven assembly is a superior method because it eliminates the need to create a schematic by assembling actual 3-D models of individual components. The layout-based environment is designed to prepare a model for advanced 3-D electromagnetic simulation by instantly making all electrical connections the moment the component is placed on the board. This streamlines the geometry setup so that the engineer can launch a full electrical circuit simulation from the layout.

ANSYS HFSS: Layout-Driven Assembly in ANSYS Electronics Desktop
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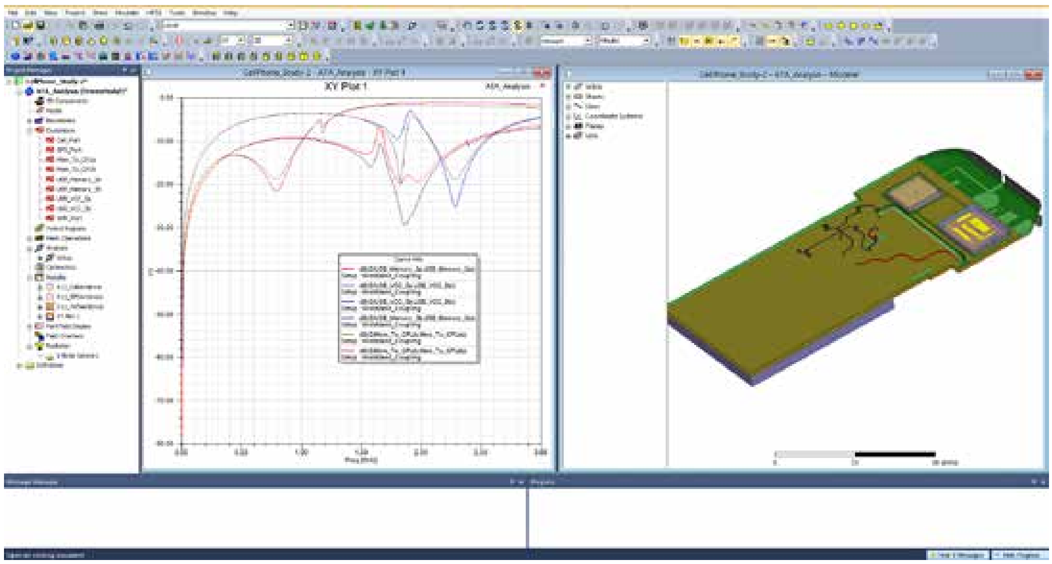
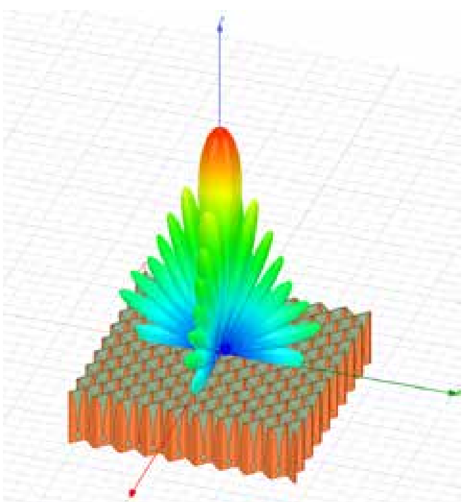


Simulation of a smartphone in ANSYS HFSS. Coupling among antennas and components across the frequency spectrum is shown on the left and the 3-D geometry is shown on the right. HFSS predicts the installed antenna performance, and coupling among antennas and signals on the PCB, across a broad range of frequencies.

RF and Wireless

Antennas are critical for excellent wireless device performance and essential to delivering innovations like the IoT, autonomous driving and more. In our modern wireless world, devices have multiple antennas for various radio services and multiple input, multiple output (MIMO) processing, and must operate in the vicinity of other electronic devices in large, complex electromagnetic environments such as an office, home or automobile. The latest ANSYS product innovations assist industry leaders in designing reliable antennas, no matter what the size or end application.



ANSYS Innovation: Antenna Synthesis and Installed Antenna Performance

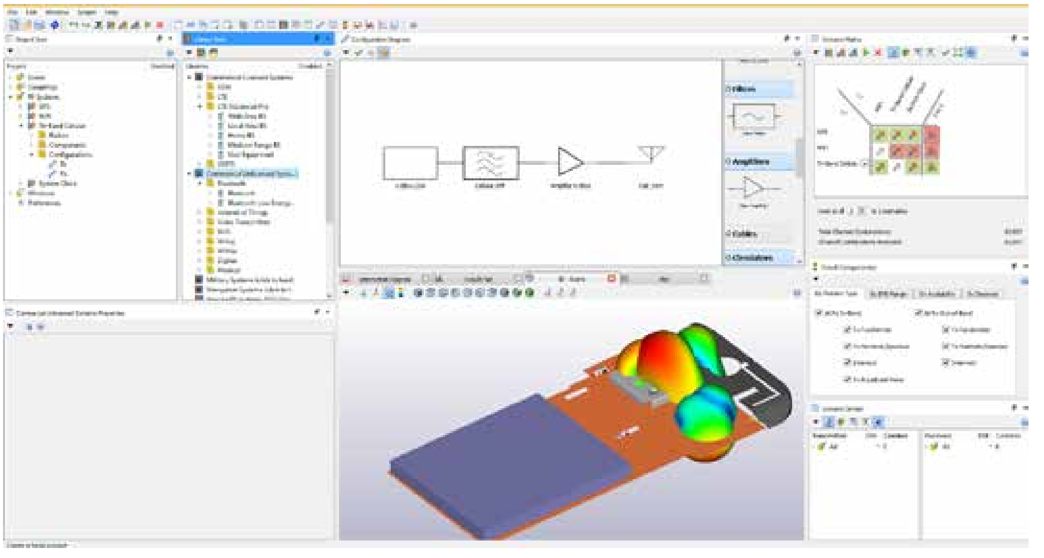
ANSYS HFSS high-frequency electromagnetic software streamlines synthesis, setup and analysis of antenna designs. It allows every engineer, including those without antenna expertise, to create and optimize antenna designs and integration. ANSYS HFSS SBR+, a powerful, shooting and bouncing ray (SBR) electromagnetic field solver option for HFSS, delivers installed performance analysis for antennas mounted to electrically large platforms. Antenna designs created individually in HFSS can be digitally placed on an electrically large platform and rapidly solved as an array using HFSS SBR+. This powerful combination enables analysis of installed performance and antenna placement optimization.

ANSYS Innovation: RF Co-Site Prediction

As the number of wireless devices increases and the spectrum in which they operate remains the same, these communication systems are more likely to interfere with each other and degrade the performance of neighboring systems. The ANSYS RF Option now includes ANSYS EMIT, the industry-leading software for predicting RF co-site and EMI interference of multiple radio transmitters and receivers.

Platform and antenna coupling information from HFSS is automatically transferred to EMIT through a powerful link. Using libraries

Maxwell Time Decomposition Methods Accelerate Simulation of Transient Electromagnetic Fields
ansys.com/time-decomposition



ANSYS EMIT is a unique RF interference tool that can evaluate system performance in complex RF environments. The EMIT desktop shown here includes the HFSS model, radio circuits and a unique scenario matrix in the upper right corner. The red squares in the scenario matrix indicate several RFI issues that must be addressed, while green squares show no problems present.

and behavioral models of radio circuit elements in EMIT, designers can quickly configure RF systems to model their performance under real-world operating conditions. This includes interference from other radios and unintentional emissions from the phone's circuitry. The software provides the tools to diagnose complex issues like intermodulation products.

While simulation was once the sole domain of experts and used mainly for verification, advanced automation features allow more simulation by the product development team up front in the development process to quickly evaluate design changes.

"The ANSYS RF Option now includes ANSYS EMIT, the industry-leading software for predicting RF co-site and EMI interference of multiple radio transmitters and receivers."

The precise path of all interference is revealed in the interaction diagram to help identify causes of problems. Once identified, mitigation measures can be simulated to gauge their effectiveness, ultimately enabling an interference-free design as indicated by the scenario matrix.

Future

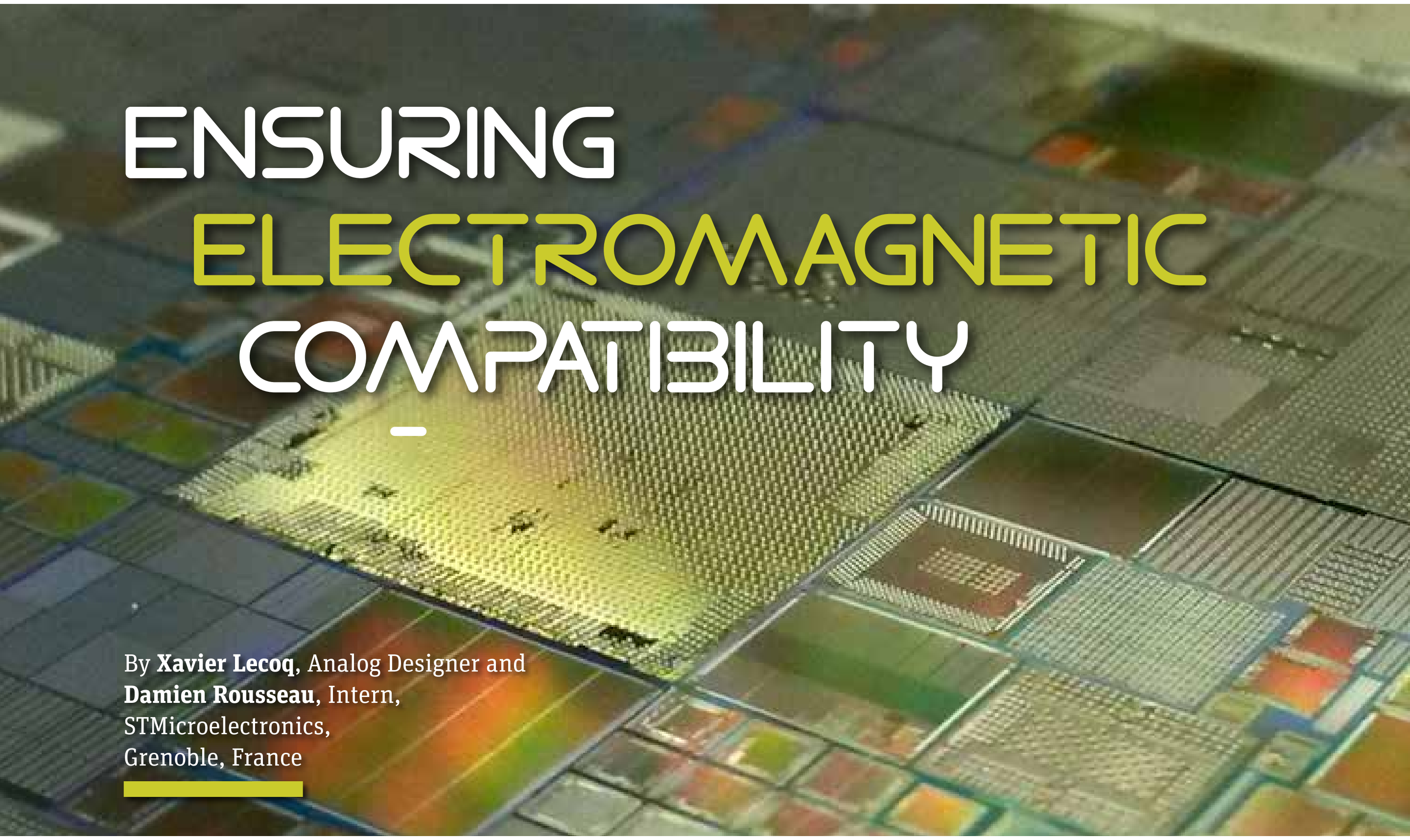
Future electronic product innovations will be far-reaching and apply to a broad array of industries. Delivering these innovations requires a platform on which engineers can simulate and design entire electrical and electronic products while including all the necessary physics and system effects. This could include the minute details of a complex integrated circuit or even a full product, like an automobile.

ANSYS electromagnetics products simulate not only the electromagnetic behavior of a motor, a circuit board or an antenna, but digitally place it in its operating environment so that you can determine real-world performance, even with interference with other arrays. ANSYS delivers products that drive innovation.

References

[1] **ABB, High-efficiency motors:** "Haze Killers," August 2017. abb.com

[2] **Enerdata, Global Energy Statistical Yearbook 2017,** August 2017. yearbook.enerdata.net

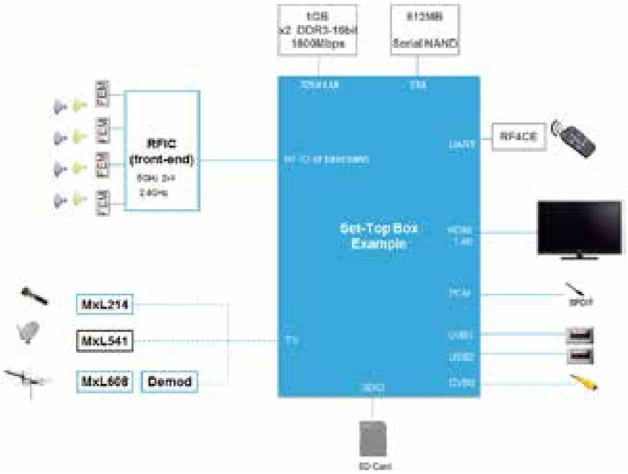


ENSURING ELECTROMAGNETIC COMPATIBILITY

By **Xavier Lecoq**, Analog Designer and **Damien Rousseau**, Intern, STMicroelectronics, Grenoble, France

STMicroelectronics has developed a workflow that combines full-wave frequency domain with circuit simulation to determine electromagnetic interference / electromagnetic compatibility and electromagnetic coexistence issues before physical prototyping. The new approach has been proven to identify and fix, early in the design process, issues that could otherwise delay the product launch by up to four months or 20 percent of the development time.

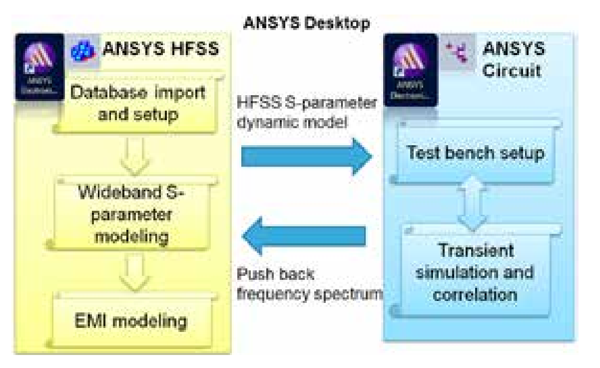
The dramatic proliferation of wireless (Wi-Fi, Bluetooth, ZigBee, etc.) and wired communications channels, combined with higher data rates and increasing package density, has greatly increased the challenges involved in achieving compliance with electromagnetic interference (EMI) / electromagnetic compatibility (EMC) standards that have been developed to avoid interference between coexisting interfaces. Traditionally, these issues are addressed during the design process using an electromagnetic simulator to extract an S-parameter model of individual features that are expected to create difficulties. This approach has limited accuracy because the S-parameter model is usually excited with a generic signal, so electrical and magnetic emissions predicted by full-wave simulation may differ significantly from the actual circuit.



Set-top box used to validate new simulation methodology

"Improved *EM simulation techniques* and large-scale HPC empower engineers to simulate the entire PCB with *full-wave accuracy*."

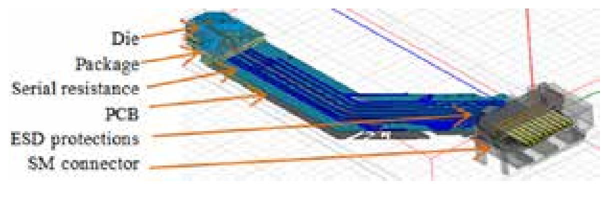
Engineers at STMicroelectronics, a global semiconductor company with innovative semiconductor solutions for autonomous vehicles and the Internet of Things, address this challenge using a workflow based on the ANSYS HFSS 3-D finite element model (FEM) electromagnetic (EM) solver to model the structure and calculate EM fields in the frequency domain. Leveraging the ANSYS Electronics Desktop environment, the resulting S-parameter model is embedded in the circuit model. The HFSS circuit analyzer provides a realistic excitation of the HFSS model to accurately predict the magnetic and electrical emissions of the actual circuit. Simulation results generated using this approach correlate well with experimental measurements, so it can be used with confidence to identify EMI and coexistence problems and evaluate potential mitigation techniques. ANSYS tools make it possible to rapidly deliver robust EMI/EMC-compliant products.



Simulation workflow used to generate realistic excitation for full-wave model

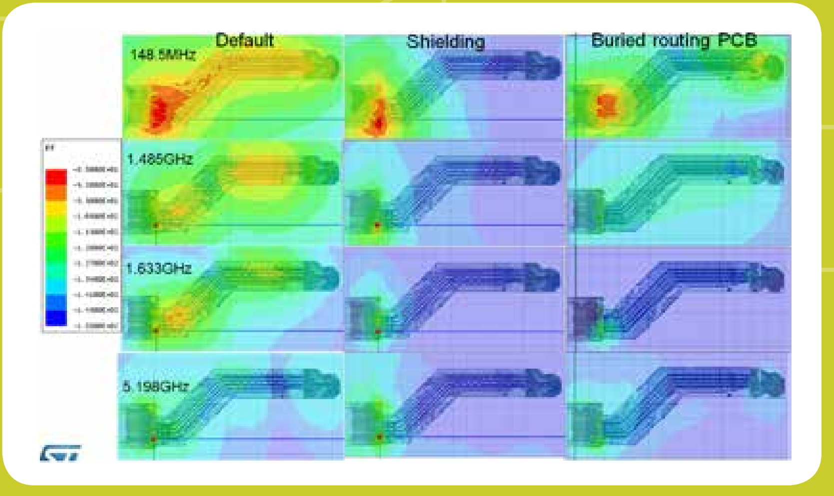
Ensuring EMI/EMC Compliance

No aspect of modern electronics design presents greater difficulties than ensuring the proper coexistence of the many digital interfaces found in today's cutting-edge electronics products, such as mobile phones, set-top boxes and wearables. The challenge is to ensure that each individual interface in a complete system delivers the same level of performance as it would in isolation. Current simulation methods address individual interactions, such as the determination of whether the double data rate synchronous dynamic random-access memory (DDR SDRAM) interferes with the USB3.1. But today's leading-edge products often have so many different features that it is almost impossible to know in advance which have the potential to interact in harmful ways. Too often these problems are discovered during testing, which requires a redesign that delays the product launch as the problems are mitigated using trial-and-error methods.



Full-wave model of communications channel

EMI/EMC and Coexistence Simulation for High-Performance Digital, Mixed-Signal and RF Wireless Products
ansys.com/EMI-EMC



Average H-field with default design, shielding and buried routing

Realistic Excitation of Full-Wave Model

Now, the combination of improved EM simulation techniques and large-scale, high-performance computing (HPC) makes it possible to simulate the entire PCB with full-wave accuracy. The methodology developed by STMicroelectronics engineers goes one step further by performing transient simulation using the full-wave model with realistic excitation patterns. Results of the circuit simulation are back-annotated to the full-wave model to reproduce real-world EM fields. This approach was validated on an existing digital high-speed transmission channel in a set-top box and used to evaluate potential EMI/EMC mitigation methods in the simulation space.

The HFSS S-parameter model was converted to a SPICE-like model and linked inside the HFSS circuit environment. The HFSS model remained at a manageable size by defining the appropriate box type and size around the structure, port types, frequency sweep for wideband S-parameter modeling, mesh settings and convergence criteria. The port excitations were set by drivers in IBIS format using a pseudo-random bit sequence

> **“*ANSYS tools* make it possible to *rapidly deliver* robust *EMI/EMC*-compliant products.”**

(PRBS) to reproduce a real use case. The transient simulation generated eye diagrams and H-fields that correlated very well with physical measurements in the time domain. The next step was to push the excitation back into HFSS to recalculate the EM fields, focusing on the magnetic fields that dominate the electrical fields in this case.

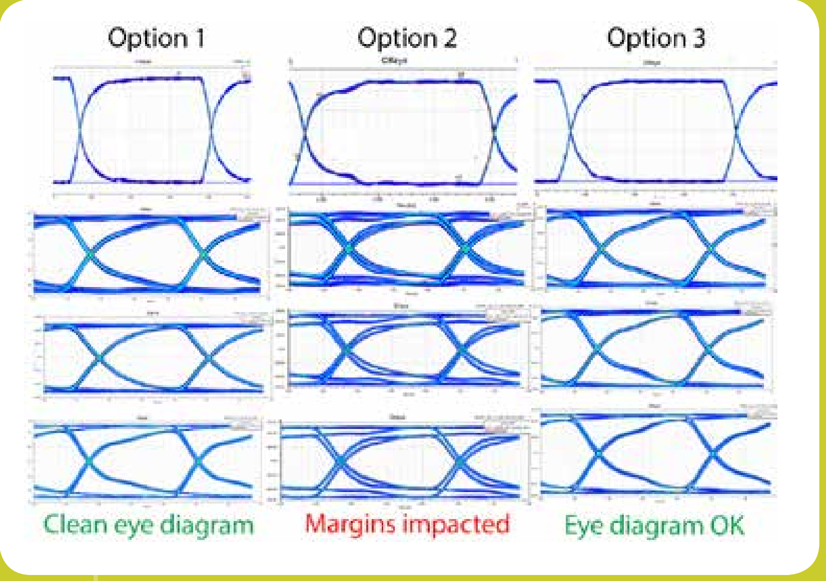
Evaluating Potential Mitigation Methods

STMicroelectronics engineers investigated the use of functional and physical layout techniques to mitigate EMI/EMC risks. Increasing the slew rate from 5 percent to 8 percent of the unit interface (UI) provided an average of 3 dB of mitigation on the clock frequency spectrum, reducing the radiated magnetic field. Engineers also implemented the spread spectrum clock (SSC) method to reduce EMI by up to 10 dB on the third harmonic and 15 dB on the fifth harmonic. They evaluated the effects of

ANSYS HFSS: Layout-Driven Assembly in ANSYS Electronics Desktop
ansys.com/layout-driven

“A new cost-optimized and ***EMC-compliant product*** **can be brought to market and begin generating revenues with much *lower development risk* and shorter design cycle.”**

placing common-mode filters at different locations on various harmonics. The results showed that for this design, common-mode filtering using STMicroelectronics ECMF04-4HSWM10 is more efficient when the filter is placed closer to the source of the signals, in this case the system-on-chip (SOC). EMI radiation is reduced by up to 25 dB on even harmonics of the clock. Engineers also evaluated the impact of 1 mm copper shielding with a 10 mm by 0.6 mm aperture and found that the gain on the average H-field rose from 15 dB to 20 dB, except at the shield resonance frequency of 2.4 GHz to 2.5 GHz, where the gain was only about 6 dB. On the other hand, buried PCB routing increased H-field gain from 5 dB to 15 dB, except at the routing resonance, where the radiation gain was only about 0.66 dB.

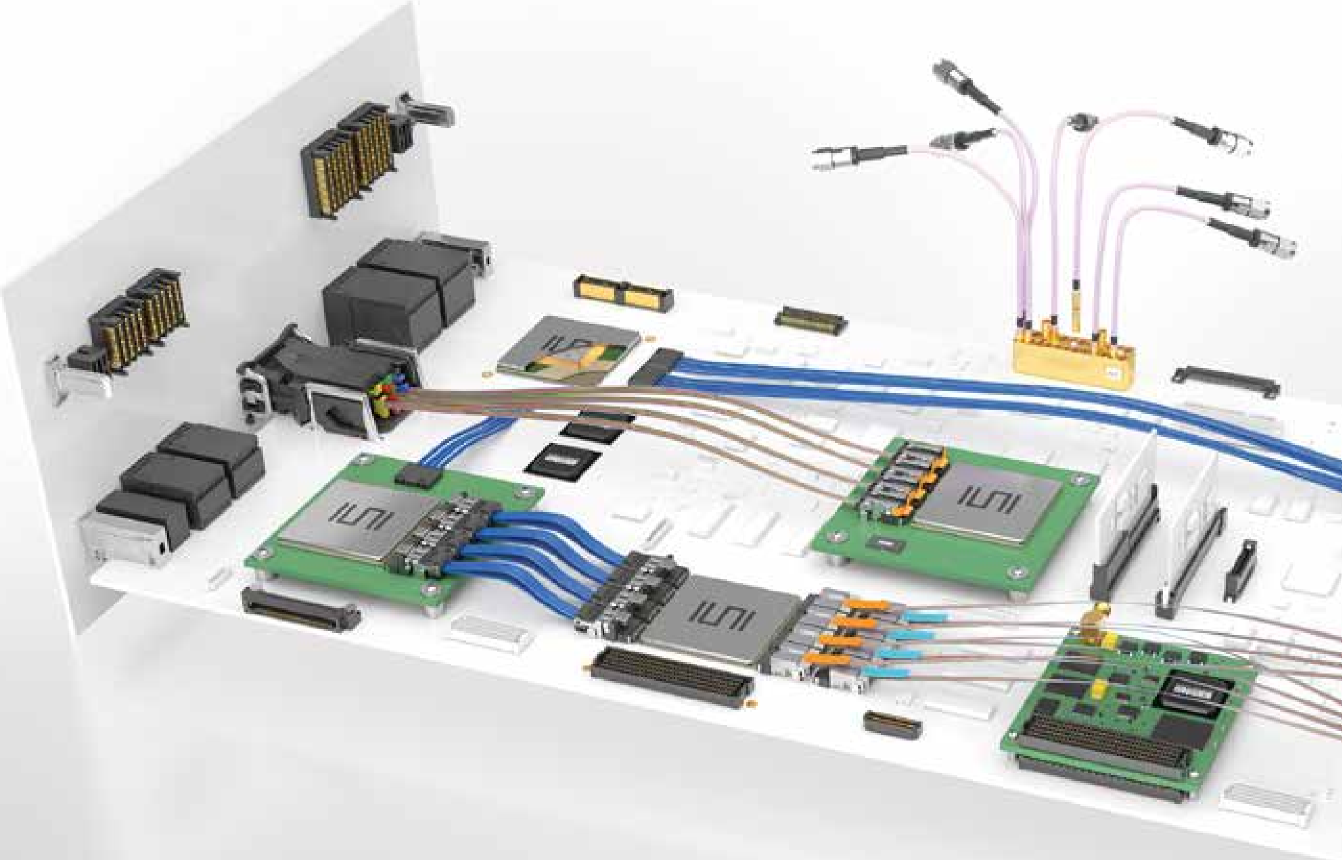


Eye diagrams of the clock with common mode filtering used at three different locations

The growing integration of high-speed digital communications technologies has increased the difficulty of achieving compliance with EMI/EMC standards and EM coexistence. In many new products, ensuring compliance requires a redesign during the prototype phase, which increases engineering and prototyping costs and delays new product introduction with associated revenue losses. The new methodology developed by STMicroelectronics makes it possible to perform full-wave EM simulation with a realistic excitation. The resulting high level of accuracy provides a way to confidently identify EMI/EMC and coexistence problems and evaluate the relative effectiveness of a wide range of mitigation measures long before a prototype is available. A new cost-optimized and EMC-compliant product can be brought to market and begin generating revenues with much lower development risk and shorter design cycle. ∧

Reference
ECMF components by STMicroelectronics
www.st.com/ecmf

Turning Signal Integrity Simulation Inside Out
ansys.com/signal-integrity

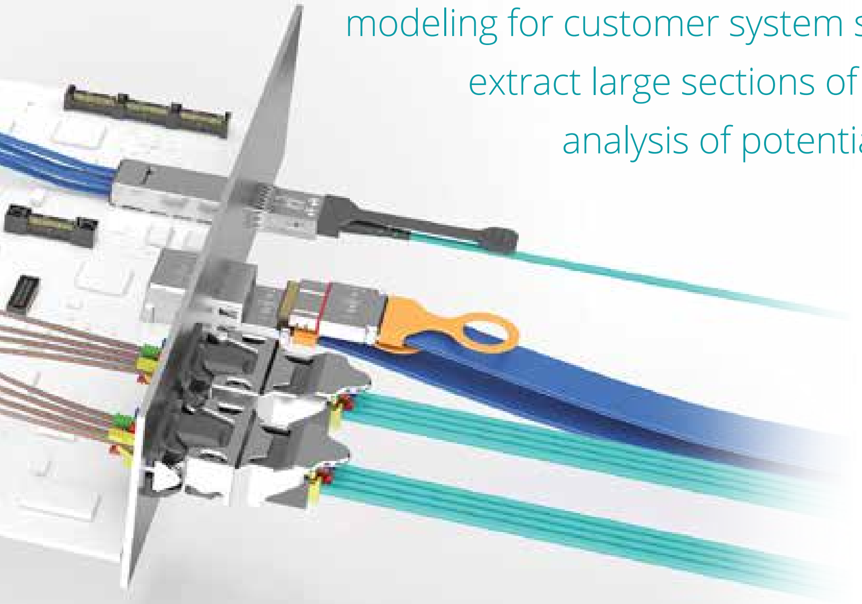


Deep Channel Analysis for High-Speed Interconnect Solutions

Data center servers, storage and networking equipment communicate over copper and optical cable assemblies joined by ever-faster connectors. Samtec leverages a comprehensive suite of simulation software from ANSYS to design and optimize next-generation, high-performance interconnect solutions across the entire signal channel.

By **Scott McMorrow**, CTO, Signal Integrity Group, and
Matt Burns, Product Marketing Manager,
Samtec, Inc., New Albany, USA

"The flexibility of the state-of the-art 3-D full-wave solvers in ANSYS HFSS allows Samtec to target subcomponent and system modeling. Engineers can perform large connector modeling for customer system simulations and extract large sections of packages for deep analysis of potential issues."



Data. Data. Data. Consumers demand real-time access to personal and professional data no matter where they are or what the time of day. Twenty-first–century consumers and workers are untethered, so mobile data is expected. At the end of 2016, global mobile data traffic reached 7.2 exabytes per month (an exabyte is one billion gigabytes). That number will exceed 49 exabytes per month by 2021 [1].

The demands of easily accessible mobile data via cellular and fixed networks (via Wi-Fi and low-power cellular base stations called femtocells) places increasing demand on data centers and backbone networks. Data center equipment — servers, storage, communications and networking — are constantly upgraded to support higher data rates.

Data center equipment OEMs must keep up with demand. Current-generation solutions typically support data rates of 10 Gbps to 15 Gbps. Next-generation solutions will operate at 28 Gbps/56 Gbps and beyond. Routing high-speed signals throughout a system presents many design challenges. While legacy design decisions were made at the component level, engineering 28 Gbps systems requires a deep analysis of the entire channel from IC to IC via packages, PCBs and interconnect solutions. How does Samtec — the service leader in the electronic interconnect industry with full-channel system support from the IC to the board and beyond — support deep analysis throughout the high-speed channel?

Designing a High-Speed Signal Channel

Next-generation, multigigabit-per-second designs require a holistic approach for the signal channel path. Developers cannot focus on just one component, but must analyze and optimize the interaction of all components across the entire channel.

Each component in a channel has design variables that affect the performance of others across the path. Connector variables such as insertion loss, return loss,

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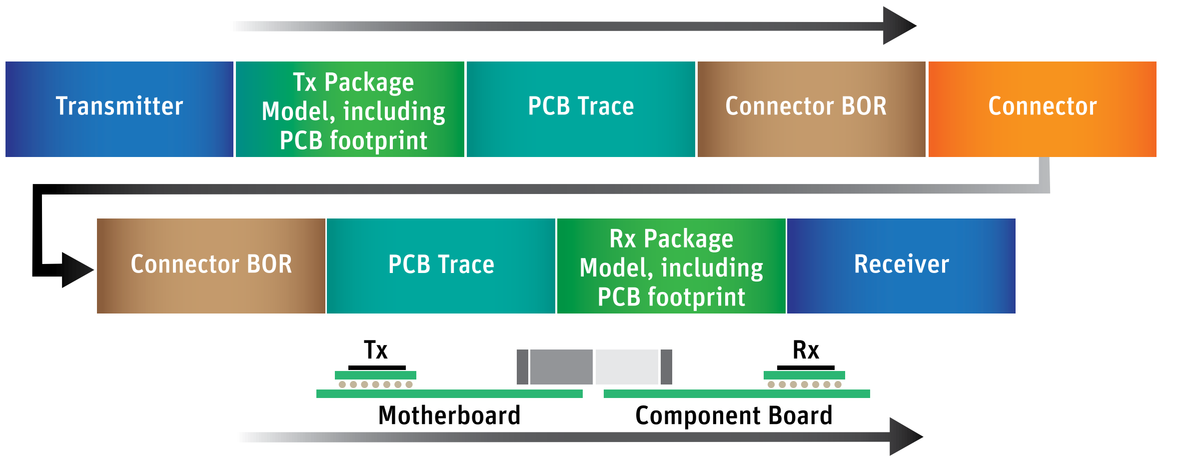


Components that typify a simple, standard 28 Gbps high-speed channel

crosstalk and impedance must be considered. PCB design decisions include placement, routing, material/laminate selection, trace lengths and impedance matching — all of which can enhance or adversely affect the performance of the high-speed serial channel. The breakout region (BOR) of PCB traces from the connector is often overlooked, yet it can break a design.

Designing and optimizing the high-speed channel requires two basic steps. Engineers must model each particular component in the channel. The channel model is created from the concatenation of these component models to form a complete system. The system model can then be simulated, modeled, analyzed and tested at data rates of 28 Gbps and beyond.

Modeling Complex 3-D Components

Channel components, especially connectors and cable assemblies, are complex 3-D mechanical structures that typically are mechanically modeled in industry-standard MCAD tools. Samtec's engineers port the mechanical models into the ANSYS HFSS software tool to analyze and optimize 3-D structures with high-frequency electromagnetic fields.

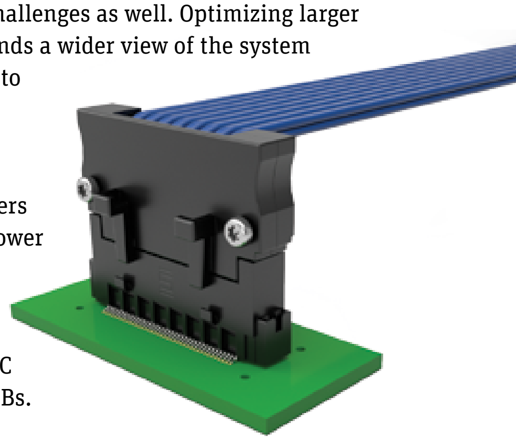
The flexibility of the state-of the-art 3-D full-wave solvers in HFSS allows Samtec to target subcomponent modeling as well. Modeling 3-D structures of PCB traces, cables, RF launches and the complex transitions between PCBs, the package and multichip modules (MCMs) expand channel optimization capabilities.

The accuracy of ANSYS HFSS also enables improved channel optimization. Solver accuracy can reach error levels well below manufacturing tolerance, which allows virtual prototyping. When combined with the speed and capacity of high-performance computing (HPC), Samtec leverages HFSS accuracy to offer predictable correlation to measurements at frequencies up to 70 GHz. Driven by system inputs, Samtec can fine-tune channel variables, like the connector BOR, via placement, trace type, manufacturing variability and other factors to drive accurate analysis and simulation across the channel. In addition, advances in HFSS solver technology for hybrid planar/3-D designs in HFSS 3-D Layout have enabled Samtec engineers to rapidly prototype complex interactions between components and PCBs, compressing the time to solution from weeks to days, and from days to hours.

HFSS 3-D Components
ansys.com/HFSS-3D

Optimizing IC Packages and PCBs

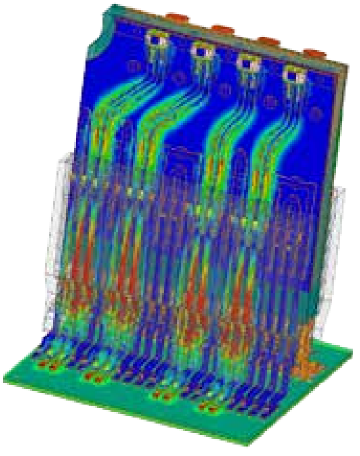
Optimizing the signal channel requires optimizing large integrated circuit (IC) packages and PCBs found within the channel. These components present unique design challenges as well. Optimizing larger structures demands a wider view of the system and, in addition to high-frequency electromagnetic simulation and analysis, engineers must consider power integrity, signal integrity, crosstalk and EMI analysis of IC packages and PCBs.



MCAD 3-D rendering of Samtec MEC5-DV connector and cable assembly

“The company continues to leverage the capability of ANSYS software to shorten product design cycles and expand its capabilities to provide next-generation products to tech industry performance leaders.”

Samtec uses ANSYS SIwave software to model and analyze large planar PCB and IC package high-speed channels and complete power delivery networks (PDNs). Using SIwave, Samtec can design current flow pathways, eliminate current crowding and minimize IR voltage drops virtually in internal connector test boards and customer-specific applications. Samtec can also model resonances, reflections, inter-trace coupling, simultaneous switching noise, power/ground bounce and DC voltage/current distributions, and near- and far-field radiation patterns in connector breakout regions, packages and PCBs. Using what Samtec terms “deep modeling technology,” SIwave models entire buses and packages using S-parameters with hundreds or thousands of ports in hours so that Samtec designers and customers can identify critical signal integrity / power integrity issues without guesswork. Problems that could not be solved five years ago are now readily solved with SIwave running in a high-performance computing (HPC) environment.



ANSYS HFSS-modeled electric field within Samtec MEC5-DV connector and cable assembly

Circuit Simulations Across the Channel

Once the channel has been modeled and characterized electromagnetically with ANSYS HFSS and SIwave, the remaining step is circuit simulation across the channel. Samtec uses ANSYS Nexxim time-domain circuit simulation engines to perform full-channel simulations of a high-speed interconnect.

Industry-standard IBIS-AMI drivers and receivers act as signal transmitters and receivers across the channel signal path. When used in combination with IBIS-AMI, the Nexxim circuit simulator represents the industry’s leading solution for high-speed communication channel design. The ANSYS Nexxim circuit solver combines IBIS-AMI models with the channel performance model to provide SerDes circuit and timing analysis. This approach provides virtual time-domain compliance to the Samtec design team.

ANSYS High-Performance Computing Options

Simulating, analyzing and optimizing the entire high-speed channel signal path across multiple components can be time intensive. Samtec leverages the HPC capabilities of the ANSYS tools to increase problem size and complexity while minimizing time-to-solution. Engineers can increase product performance while reducing the overall design cycle.

Samtec has developed the appropriate IT infrastructure to fully leverage the HPC features from the ANSYS tool suite. Leveraging the HPC capabilities of ANSYS tools is necessary to harness bigger, faster and higher-fidelity simulations. Like many companies, Samtec has engineering and signal-integrity resources located in many places with multicore servers and multiple scalable computing clusters to fully unlock the HPC capabilities of the ANSYS tools across the world.

For ANSYS HFSS and SIwave applications, Samtec leverages highly parallelized clusters running HFSS to achieve full-wave solve times accelerated by 10 times to 100 times. Engineers can perform large connector modeling for customer system simulations and extract large sections of packages with thousands of ports for deep analysis of potential issues.

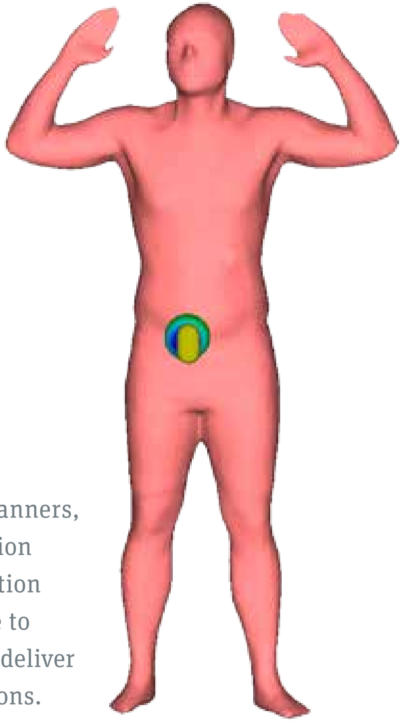
Conclusion

The combination of Samtec’s SI capabilities for 28 Gbps (and faster) channels with ANSYS tools provides data-center equipment OEMs a platform for deep channel analysis. Samtec is currently developing a 112 Gbps connectors, package and interconnect design, using ANSYS software to shorten product design cycles and expand its capabilities to provide next-generation products to tech industry performance leaders.

Reference

[1] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021 White Paper

Enhanced Detection of **Concealed Weapons**

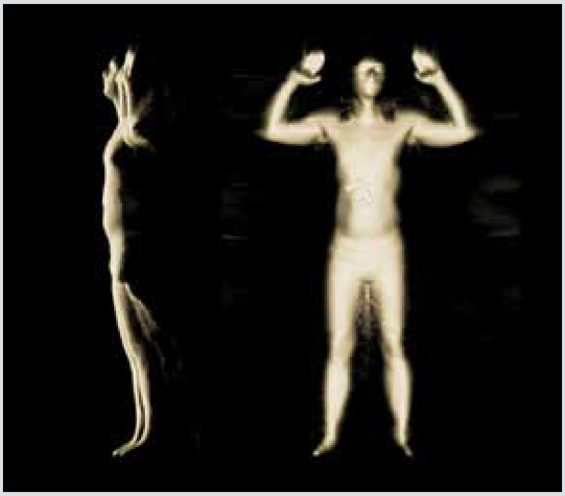


To develop next-generation full-body millimeter-wave airport scanners, Pacific Northwest National Laboratory researchers used simulation models of the electromagnetic systems to reduce design exploration times compared to experimental-based methods. They were able to easily investigate factors required to improve the technology and deliver higher-resolution images for better detection of concealed weapons.

By **Mark Jones**, Senior Research Engineer; **David Sheen**, Technical Team Leader; and **Thomas Hall**, Staff Engineer; Pacific Northwest National Laboratory, Richland, USA

If you have flown within the past five to 10 years, you are familiar with the millimeter-wave (mm-wave) imaging portals that scan passengers for concealed weapons. The scenario is probably familiar to even nonfrequent flyers: You step inside a cylindrical booth, are asked to place your arms over your head, and wait as antenna array masts sweep around the booth to scan for concealed weapons.

Researchers at the Pacific Northwest National Laboratory (PNNL) in the U.S. developed this technology more than a decade ago and have licensed it for commercial use. Now, PNNL is working to optimize the image quality and resolution of next-generation mm-wave imaging systems for enhanced threat detection. Engineers leverage ANSYS software to simulate the antenna performance and ANSYS high-performance computing to explore the design space using realistic 3-D images.



Use of 30 GHz bandwidth and 60-degree beamwidth showed excellent depth resolution and body illumination.

Improving Scanner Performance

An active mm-wave scanner forms an image of the human body by transmitting electromagnetic waves that harmlessly penetrate clothing and reflect off the body, sending signals back to a transceiver; the transceiver then sends the signals to a computer that reconstructs the signals from various positions as the scanner's antenna arrays rotate to create a 3-D holographic image.

PNNL is conducting studies that examine three methods to enhance the capabilities of mm-wave imaging for concealed weapon detection: wide-frequency bandwidth of up to two octaves of bandwidth for high depth resolution; wide antenna beamwidth to increase lateral resolution and improve the capture of

“ANSYS HFSS SBR+ provided simulation results to 3-D mm-wave imaging challenges that enabled rapid development and refinement of antenna designs.”

specular reflections from the imaging target, which improves the visual quality of the image; and circular polarization to reduce artifacts caused by multipath signal propagation.

To understand how these design parameters impact the mm-wave imaging system performance, PNNL engineers simulated the effects of various bandwidths, beamwidths and polarizations on images captured via a virtual scanner modeled using ANSYS HFSS SBR+. The resulting datasets helped them study design requirement trade-offs for enhanced next-generation systems without the need to fabricate and test a full prototype or perform time-consuming measurements.

Before the use of advanced simulation tools, the researchers did not possess the capability to conduct advanced digital design studies for these imaging systems. Instead, the team relied upon simplistic simulations of point scatterers or measurement-based data collected using rectilinear scanners. Although researchers were able to get information from the simulated point scatterer scenarios, they could not obtain images that accurately represent a scanned person in order to determine quality of illumination, clarity and other objectives.

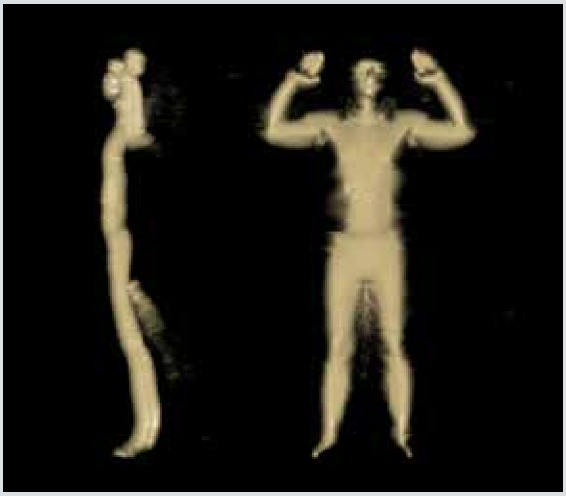
Security Scanner Simulation

Previously, researchers created a physical experiment using a rectilinear laboratory scanner and a mannequin coated with a reflective paint. A transceiver raster-scanned the mannequin and transferred the measurement information to a software package that used an algorithm to mathematically focus the image.

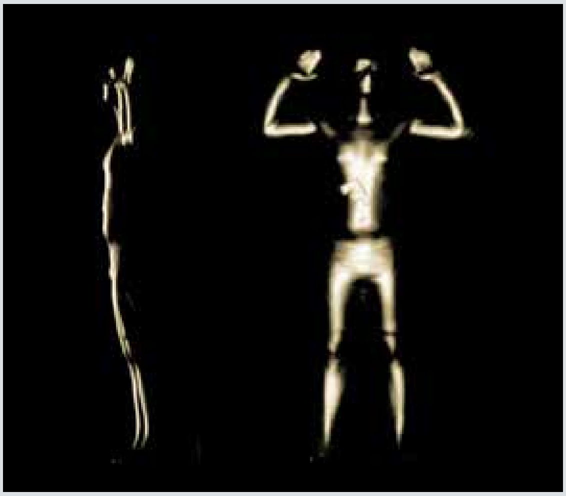
To avoid the need for this type of physical system, the researchers turned to ANSYS HFSS SBR+ to simulate the antennas, define their patterns and simulate the target to be scanned. The simulations were configured to import and determine results based upon the realistic complex geometries required for this application. ANSYS HFSS SBR+ provided simulation results to 3-D mm-wave imaging challenges that enabled rapid development and refinement of antenna designs. Researchers dramatically reduced overall system development time by using high-performance computing to explore and validate designs.

The researchers first raster-scanned a pair of co-located transmit and receive antennas across the aperture defined in the simulation model.

Solve Large-Scale Problems in a Connected World with HFSS SBR
ansys.com/large-scale



Use of 5 GHz bandwidth and 60-degree beamwidth showed impact of reduced depth resolution on image quality.



Use of 30 GHz bandwidth and 20-degree beamwidth revealed impact of reduced body illumination on image quality.

> "This technology will be able to detect concealed weapons with even greater accuracy to increase security while reducing false alarms."

At each location, they performed a frequency sweep and evaluated the complex-valued signal at the receiving antenna. A typical scan used approximately 500 discrete frequency point samples at each antenna position during approximately 10,000 individual simulations. A complete simulation dataset was processed to produce a single fully focused 3-D image.

Airport mm-wave scanner. *Courtesy TSA.*

While the measurement process is semi-automated, simulation offers the advantage of investigating scenarios researchers cannot easily replicate or for which a physical measurement test may be difficult to perform. This removes limitations on design studies which can be performed for a given application.

To accelerate throughput for this large amount of simulation data, researchers ran 10 simulations simultaneously using ANSYS high-performance computing. ANSYS HFSS SBR+ paired with high-performance computing was able to yield realistic simulated image datasets in less than one day.

Better Image Quality

After the simulation model was created and solved using ANSYS HFSS SBR+, the data was manipulated via proprietary mathematical algorithms. Researchers were able to study a number of simulation scenarios to examine the effects of beamwidth, bandwidth and polarization on image quality.

To determine the effect of bandwidth on image quality, the researchers simulated 5 GHz and 30 GHz bandwidths using the same antenna beamwidth in both scenarios. The resulting data was used to study the impact of better depth resolution on image quality when larger bandwidths were used.

The use of extremely wide bandwidths — up to 30 GHz — can result in depth resolution as fine as 5 mm. This wider bandwidth operation may allow for improved detection techniques based upon high-range resolution. Because designing systems for high bandwidths becomes difficult and expensive, simulation allows researchers to evaluate the bandwidth performance to choose the lowest bandwidth that corresponds to the required image quality.

The ANSYS software also helped the researchers explore the effects of antenna beamwidth. To determine how antenna beamwidth would affect imagery, they simulated different beamwidths over a 10 to 40 GHz range. They found that the images constructed from a 60-degree half-power beamwidth offered significantly better illumination of the body than those that used a 20-degree half-power beamwidth. Additionally, a wide antenna beamwidth can allow for operation at a lower center frequency, resulting in less scattering and attenuation from the clothing.

For the third parameter, the researchers studied the effect of polarization on the simulated imagery. Polarization diversity can be used to eliminate artifacts from even-bounce "corner traps" on the body or to highlight features on the body. The images created using cross-circular polarization antenna pairs were brighter and contained fewer artifacts than those using vertical polarization antennas.

With this information in hand, future generations of mm-wave scanning systems can be efficiently designed to produce superior images for use by automated threat detection algorithms. This technology, which is widely deployed at airports and other areas, will be able to detect concealed weapons with even greater accuracy to increase security while reducing false alarms.

How High-Performance Compute Can Accelerate Your Simulation Throughput
ansys.com/throughput

A modern automated warehouse relies on many wireless links to ensure communication and data transfer for proper operation. The antenna patterns show the location of some of the wireless devices in the warehouse. The system must be designed to operate antennas simultaneously without interfering with each other.

Ensuring Antenna Performance in **Complex Wireless Environments**

As wireless systems proliferate in our increasingly connected world, the opportunities for interference and performance degradation expand. The results could range from merely inconvenient with regard to personal entertainment to catastrophic in the case of aircraft or defense equipment. By determining where interference is likely to occur early in the development cycle using specialized simulation software, companies can avoid interference issues, decrease the costs to remediate problems later and reduce risk.

By **Fred German**, Senior Manager Research and Development, ANSYS

This widespread proliferation of wireless systems provides constant mobile communication, navigation and data services that extend across multiple industries and applications, including personal electronics, home automation, telecommunications, automotive, aerospace and defense. With the emergence of exciting new wireless technologies that include fifth-generation wireless systems (5G), the Internet of Things (IoT), autonomous vehicles with advanced driver-assist systems (ADAS), and rapid advances in expanding the application and performance of existing wireless technologies, the business opportunities have become enormous. Simultaneously, the challenges of designing and deploying so many wireless systems in complex environments have increased. Competition demands rapid design, evaluation and deployment of wireless systems that are capable of achieving superior performance in their intended operating environments. These systems must operate in the presence of other nearby wireless systems that have the potential to cause interference and performance degradation. Unintentional sources of radio frequency (RF) interference (RFI) present in the environment also must be considered to achieve a robust system design.

Simulating Wireless Systems

Simulation-driven product development of wireless systems to predict performance in complex environments must begin very early in the conceptual stage of the system design. By necessity, design needs to include the impact of other wireless devices and sources of RF signals in the environment that are not part of the system under design. Failure to design for the intended environment will likely lead to a system that works spectacularly in lab tests, but suffers performance degradation when deployed, leading to costly interference mitigation and possibly failed business strategies.

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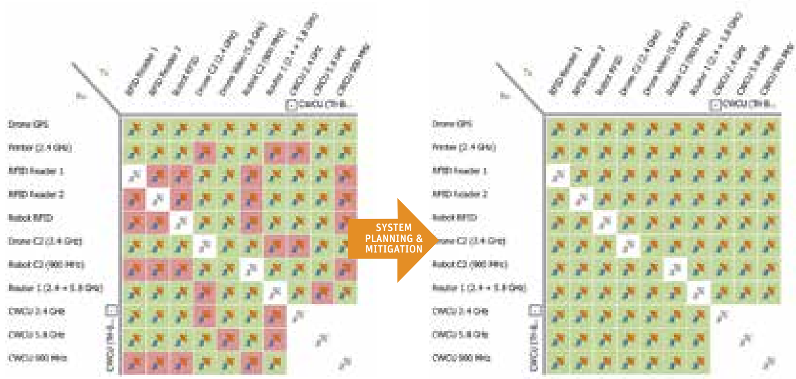
The simulation of wireless systems in complex environments spans multiple computational domains and solution methodologies. It requires a workflow created for design engineers, not just expert analysts. Design productivity and efficiency demands that these methods work together in a seamless engineering workflow that provides the necessary multifidelity model libraries so simulations can begin before complete and detailed device information is available. Simulation should produce results that drive performance requirements and component selection.

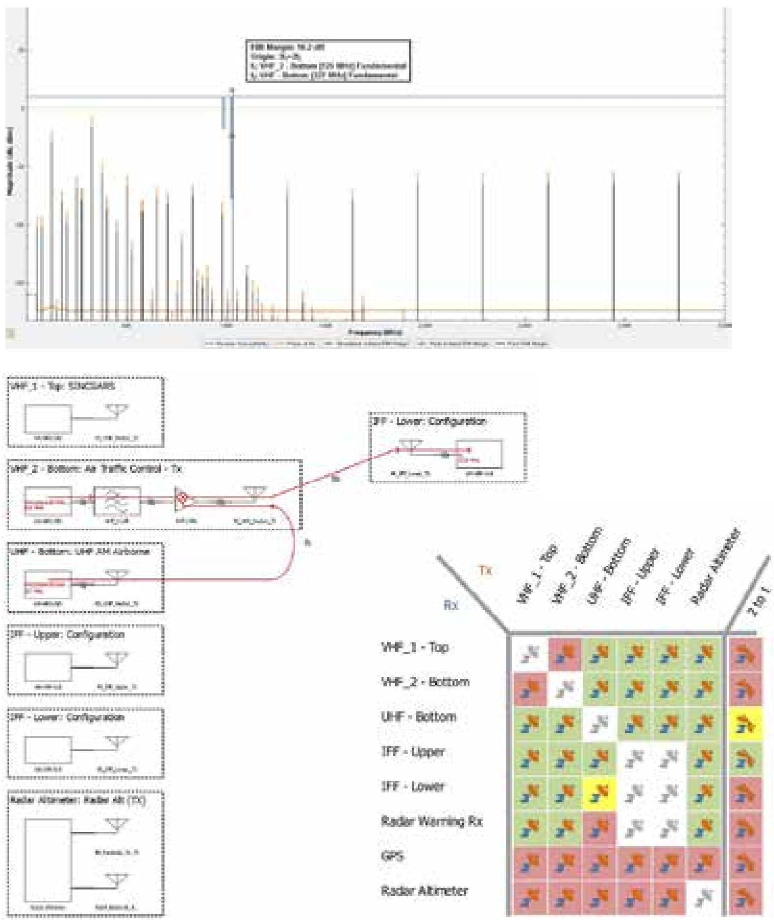


The scenario matrix simulation result view shows a color-coded systems-level summary of potential performance issues. Red squares indicate problematic interference between the affected systems and warrant further attention to mitigate the issue. After implementation of proper frequency planning, interference mitigation and operational procedures, the completely green scenario matrix shows that all systems operate properly in the warehouse environment.

Simulating Complex Environments

ANSYS provides world-class simulation solutions that cover all the required disciplines, including electromagnetic analysis using ANSYS HFSS for antenna design and placement, and circuit and system simulators employing the ANSYS RF Option to predict the performance of wireless sensors when connected to the antennas. ANSYS RF Option now includes ANSYS EMIT, which integrates all the technologies from the electromagnetic and circuit/system worlds to completely simulate the performance of all the wireless systems in complex environments. ANSYS EMIT provides model libraries based on industry standards for many types of wireless systems. Its unique multifidelity modeling approach provides useful simulations capable of driving early design decisions even when only an incomplete set of design and performance parameters is available.

For example, a modern automated warehouse might receive orders and dispatch them via delivery drones. The warehouse relies on numerous radio devices to wirelessly link the different parts of this order and delivery process. Wireless systems in the warehouse include radio frequency identification (RFID) tags and readers for inventory control, wireless links operating in various



Automatic diagnostics, signal traceback and tagged spectrum displays rapidly identify the root cause of wireless system performance issues so mitigation measures can be designed and evaluated.

Predicting Radio Frequency Interference with ANSYS EMIT
ansys.com/emit

unlicensed frequency bands to send and receive commands to the robots and drones, GPS for position information, and Wi-Fi and Bluetooth® connectivity between devices. Additionally, other sources of RF signals, such as handheld radios used for communication between workers in the warehouse, will affect the performance of the wireless links employed to keep the warehouse running. In such a complex wireless environment, there are many opportunities for interference to occur and degrade system performance. Using simulation during the early design of the warehouse's wireless systems can identify and prevent costly downtime before the system has been deployed.

An analyst can leverage ANSYS HFSS and ANSYS RF Option to model the performance of all antennas and wireless devices operating within the warehouse environment before the structure is even built. The top-level results can be summarized in a scenario matrix where each square in the matrix represents the interactions between the wireless systems. A color-coded scheme will identify any performance issues with a red square. Green entries indicate that performance requirements are being achieved. The detailed results from the simulation will drive proper frequency planning, define operational parameters and suggest mitigation measures necessary to ensure proper operation for simultaneous functioning of all wireless systems as evidenced by a completely green scenario matrix.

Avoiding Interference

Another typical challenge for system integration in complex environments is ensuring proper operation of all radio transmitters and receivers on an aircraft, such as a helicopter. All antennas must operate simultaneously without degrading the others' performance.

The integration of multiple RF systems onto an aircraft platform, such as a helicopter, is a common challenge for system integrators who need to ensure that all systems can operate in the crowded environment without interfering with each other. The radiation patterns indicate the positions of the nine antennas on the aircraft.

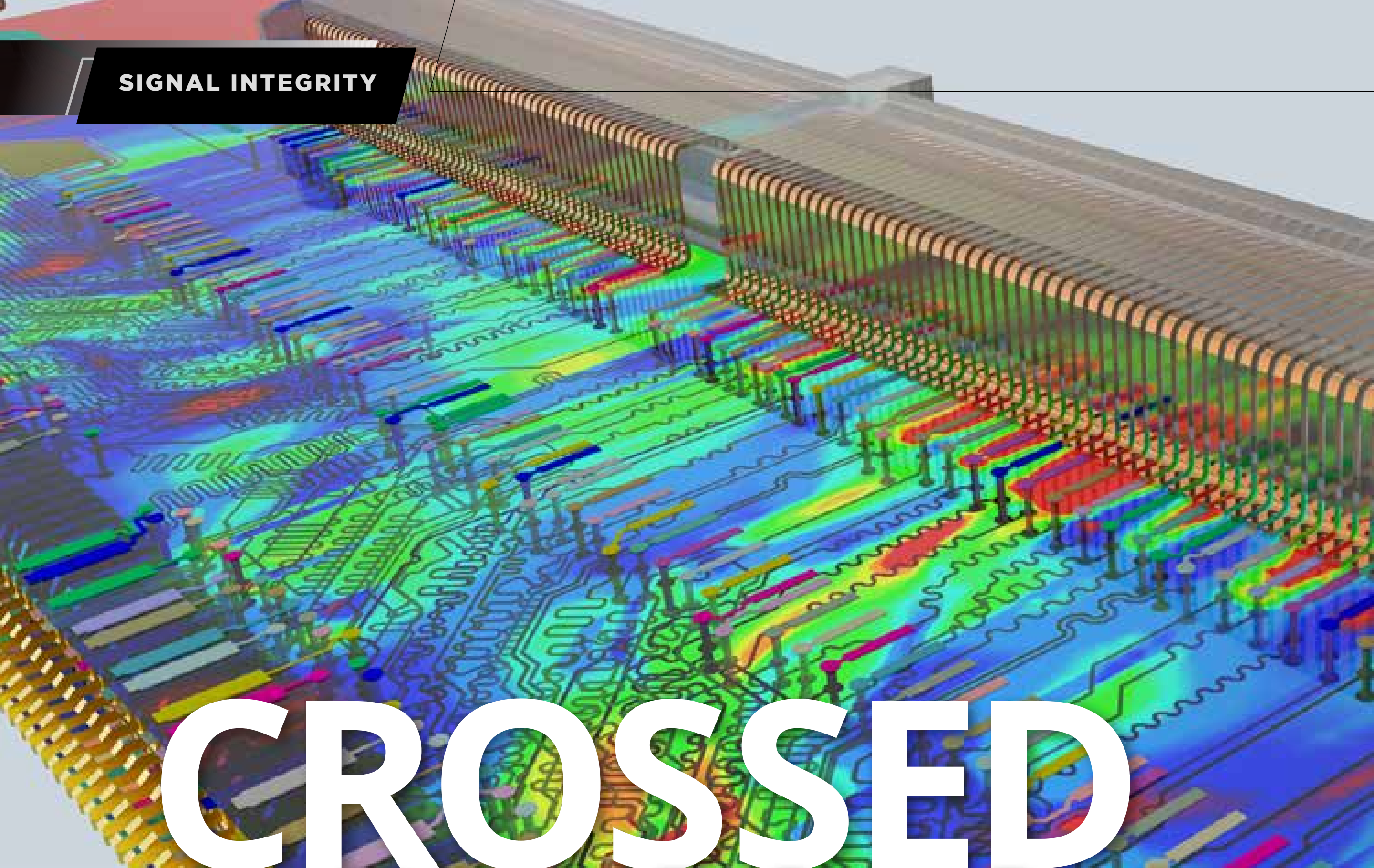
To appreciate the complexity that must be addressed, a typical aircraft environment can have tens of millions (or more) ways that interference, which leads to performance degradation, can occur. The scenario matrix provides a high-level overview to quickly identify problems in systems interactions, but it yields little insight into the root cause of the problem or the paths of the interfering signals. Automated diagnostics and results visualization available in ANSYS EMIT provide designers with the tools needed to rapidly identify problems and design mitigation measures.

For example, if one of the radios on a helicopter suffers from interference caused by simultaneous operation of other co-located transmitters, the diagnostic tool shows the signal traceback display along with interference tags that are placed on the wideband spectral plots. Designers can immediately identify that the issue is caused by a high-order intermodulation product arising from the nonlinearity of a power amplifier that occurs due to coupling between two of the transmitter systems. This sort of interaction can be incredibly difficult to predict and diagnose without automated diagnostics. Relying on test and measurement approaches to identify these problems is a very costly process exacerbated by the need to test the entire environment with all RF equipment operational. Recently, a system integration program manager at a major aerospace contractor estimated achieving a savings of over $1,000,000 by identifying and addressing aircraft RFI issues, similar to the one discussed here, early in the conceptual design phase for a new unmanned platform.

Integrated Workflow

These examples demonstrate the necessity of using simulation to drive wireless system design in complex environments. As the number of wireless devices proliferates, it becomes even more critical to assess the impact of co-located devices on the performance of the system being designed if proper performance is to be expected in installed locations.

Efficient and accurate simulation of wireless system performance in complex environments requires a tightly integrated workflow focused on system designers. It must leverage best-in-class solver technologies across multiple domains and provide automated diagnostics to support the rapid evaluation of design decisions throughout the design and integration of wireless systems.

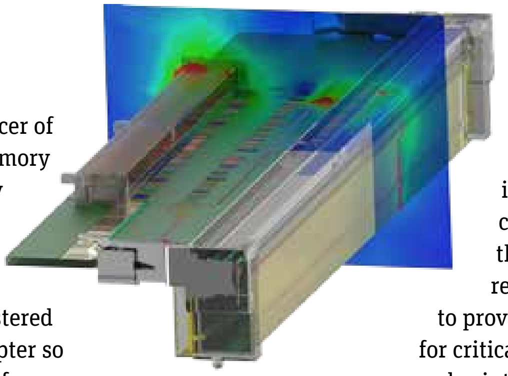


CROSSED SIGNALS

Smart Modular Technologies engineers leverage the ANSYS Electronics Desktop platform to reduce the time required to perform signal integrity analysis of a high-speed printed circuit from days to hours. By using unified electromagnetic, thermal and structural simulation, engineers developed a reliable adapter.

By **Fabio Bauman**, R&D Specialist, Smart Modular Technologies, Atibaia, Brazil

Smart Modular Technologies (SmartM) is a leading producer of dynamic random-access memory (DRAM), flash and hybrid memory technologies. The company needed to develop a SO-DIMM-to-UDIMM (small outline dual in-line memory module to unregistered dual in-line memory module) adapter so that a test platform could be used for two types of modules. When installed, the first version of the adapter did not work, and engineers suspected a signal integrity problem. In the past, diagnosing the specific issue first required engineers to simulate the entire board in a 2.5-D EM simulator that can handle complex layouts, and then transfer the S-parameter result to a 3-D full-wave simulator to provide the high resolution needed for critical integrated circuit (IC) packages and printed circuit boards (PCBs).

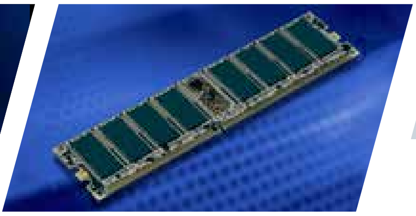


Electrical field on a cross section

Finally, the team would use S-parameter data from the combined simulation with a circuit simulator to run linear network analysis. This approach

"SmartM engineers **reduced the time** to simulate the adapter by deploying the layout-driven **assembly workflow** introduced in **ANSYS Electronics Desktop.**"

SmartM SO-DIMM



SmartM UDIMM

was very time-consuming; the engineering team had to run two or three different software packages and several data export/import steps. This had to be repeated for each design iteration.

SmartM engineers reduced the time to simulate the adapter to hours by working with ANSYS channel partner ESSS to deploy the layout-driven assembly workflow introduced in ANSYS Electronics Desktop in ANSYS 18. The methodology combines several solvers, including ANSYS SIwave for complex PCBs, ANSYS HFSS for connectors and critical layout nets, and a circuit simulator in a unified platform, so that the S-parameter of the full channel can be extracted in an automated way. Simulation revealed crosstalk and impedance mismatches on three signal traces that compromised the eye diagram opening, jitter and bit error rates. SmartM engineers used these simulation results to determine the source of the problems and altered the board design to alleviate issues. They also leveraged ANSYS Icepak and ANSYS Mechanical to validate the board's thermal integrity and its ability to withstand thermal–mechanical stresses.

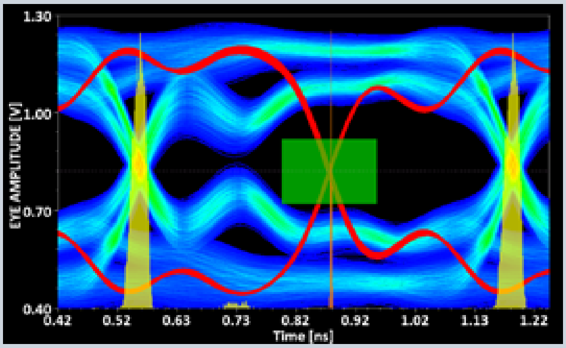
Tough Signal Integrity Problem

With high data rates and low voltage margins, signal integrity has become a pressing issue for printed circuit board designers. In this case, the board passed testing on an automated memory tester, providing a strong suspicion that signal integrity (and not memory) issues were at the root of the problem. The SIwave simulation showed crosstalk and impedance mismatches on several signal and clock traces. Next, engineers checked each byte lane, which showed closed eye diagrams.

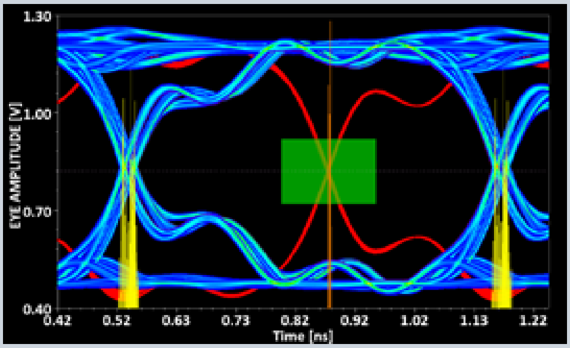
In the original design, the signal and clock layers were close to the PCB core with several split power and ground planes above and below them. SmartM engineers changed the stack-up to avoid problems such as impedance variations where traces cross the power–ground discontinuity. They repositioned the ground planes directly above and below the signal planes to improve the return path. Power was assigned to the top and bottom layers, and slow-speed and power nets were moved to the bottom layer, leaving only the critical memory data nets and clock signals on the internal signal layer. Engineers also experimented with layer thicknesses to optimize the impedance of the signal planes. Some traces were rerouted to avoid crosstalk between traces on the same layer.

Engineers ran impedance and crosstalk simulations again to check the effectiveness of the new design. The margins in the eye diagram were much larger than

Geometry Parameterization in SIwave
ansys.com/parameterization



Eye diagram of original design



The final design achieved a more opened eye, meeting the DDR4 specification.

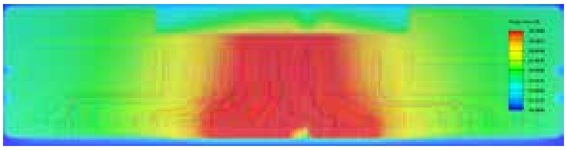
the original design, which indicated that the signal integrity problem had been solved. A DDR4 JEDEC JESD79-4 standard virtual compliance test confirmed that the new design exceeded DDR4 margins.

Thermal Integrity

Engineers then proceeded to analyze the thermal integrity of the new design. They calculated the DC currents, voltage drop and power in the PCB using SIwave, and the results were used to compute Joule heating. This heating is becoming an increasingly important source of thermal loading in PCBs as board sizes are reduced while power consumption stays the same or rises. The automated bi-directional workflow helped the team to export the board trace map and current density predictions to ANSYS Icepak. Icepak calculated the temperatures at every point in the board and automatically transferred this information back to the Electronics Desktop. SIwave updated the electrical properties of the DC solution based on the temperature field, and recalculated the board trace map and current density. The automatic iteration continued until the temperatures converged, indicating a temperature rise of only 12 C in the worst-case scenario.

Structural Durability

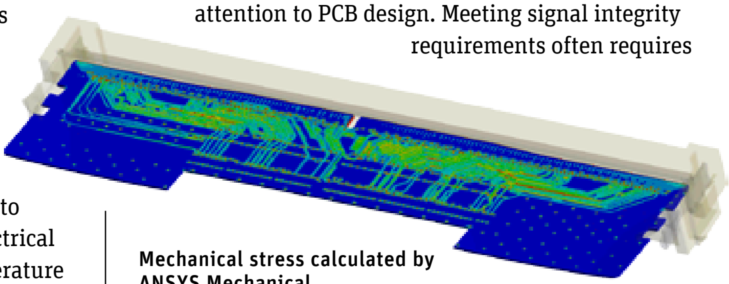
Engineers also considered the durability of the mechanical connection from the PCB to the SO-DIMM connector. They created a structural model using ANSYS SpaceClaim to read the ECAD geometry and



Temperature in the PCB calculated by ANSYS Icepak

convert it into solid geometry layers. They used ANSYS Mechanical to discretize the solid layers into a grid of elements. The details of the ECAD geometry were represented by assigning material properties to each element corresponding to the proportion of metal and dielectric appropriate for that element. The resulting finite element model provided accurate predictions of the stresses, strains and deformation generated by thermal or mechanical loading at any location on the board in a fraction of the time required to solve the fully detailed board geometry. The stress plot calculated by ANSYS Mechanical showed that the connector could perform reliably over its expected life.

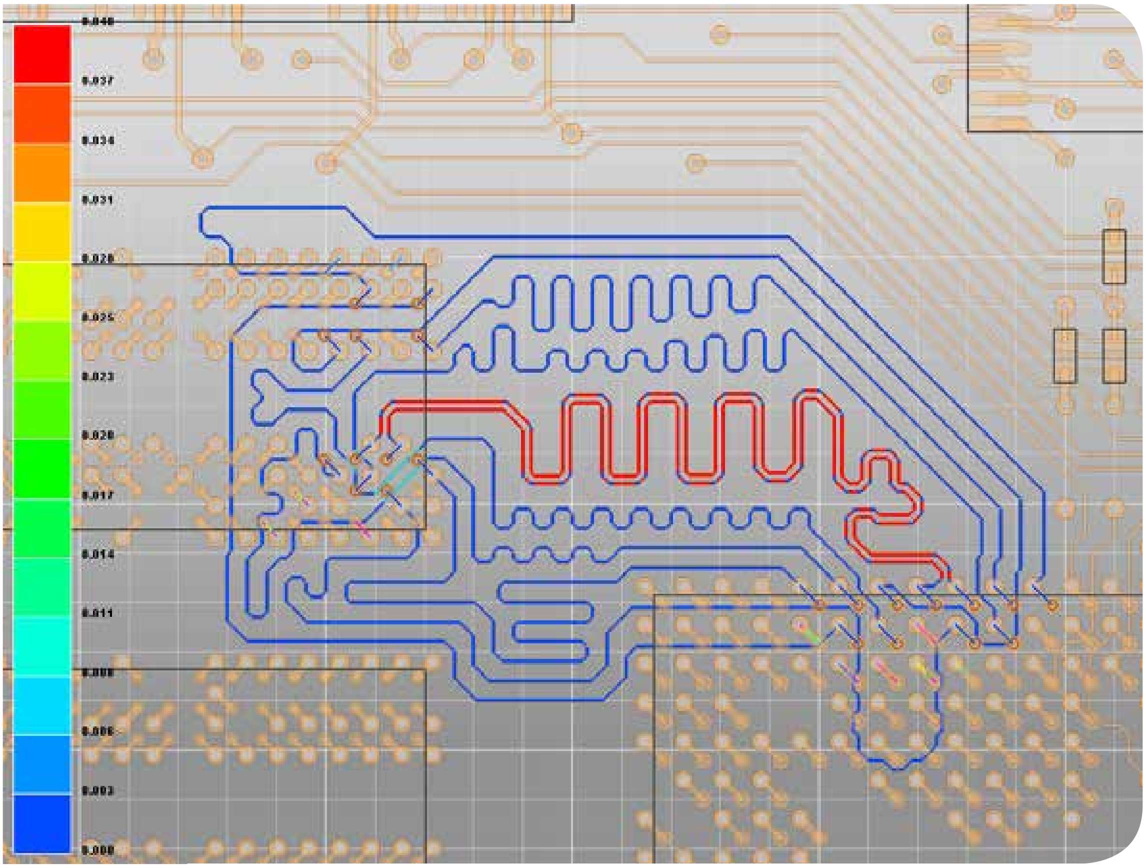
The performance and reliability demands of modern electronic systems require that engineers pay close attention to PCB design. Meeting signal integrity requirements often requires



Mechanical stress calculated by ANSYS Mechanical

a very specific layout that can be extremely difficult to achieve with trial-and-error methods. Electromagnetic, thermal and structural simulation of PCBs provides a much faster approach to meeting today's high-speed interface standards. The integration of a wide range of multiphysics tools makes it possible, for the first time, to simulate the signal integrity, thermal integrity and mechanical integrity of a complete PCB in a time frame that is relevant to the design cycle in the early stages of the product development. In this project, SmartM was able to very quickly develop an internal solution customized to our engineering needs before this adapter hit the market, at 60 percent less cost than an adapter purchased from a supplier. At the same time, SmartM reduced the time and cost required for physical prototyping by 50 percent.

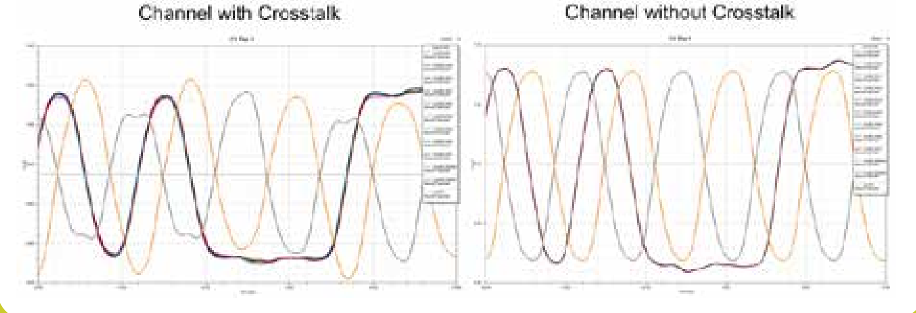
Smart Modular Technologies is supported by ANSYS Elite Channel Partner ESSS.



A VIA RUNS THROUGH IT

By **Stephen P. Zinck**, President, Interconnect Engineering, Inc., North Berwick, USA

Signal integrity has emerged as a major issue in the design of high-speed electronics. While signal crosstalk has been a challenge for electrical engineers for some time, the proliferation of electronics in our lives amplifies the negative consequences of bad design practices. The ANSYS Electronics Desktop, which includes enhancements to ANSYS HFSS and ANSYS SIwave, is an essential tool for engineers looking to address electronic system reliability issues, such as signal integrity, power integrity and EMI/EMC. Interconnect Engineering, Inc. used these simulation tools to analyze a customer case involving a DDR3-800 board. They determined that unexpected crosstalk was originating in the BGA vias, and solved the problem by routing layers closer to the primary side of the PCB.



Waveform results from ANSYS SIwave simulation unexpectedly showed that DQS signals had serious signal integrity issues due to suspected crosstalk.

Before there was mainstream signal integrity (SI) analysis, there was crosstalk. Typical of early designs was a Micro Channel, 10 Mbit/s Ethernet card for the IBM PS/2. The proof of concept prototype was actually a programmable array logic (PAL)-based design that was physically wire-wrapped on an off-the-shelf development board. This board had thousands of little green, blue, yellow and red wire connections and wire-wrap pins that were crowded together, creating a potential crosstalk nightmare. But this design worked because the timing margins were fairly large and the edge-rates were extremely slow. Electronics design and verification engineers abandoned this laborious build-and-test workflow as soon as it was practical to do so.

Today's High-Speed Crosstalk Challenges

Wire-wrap board designs were soon obsolete when crosstalk became a very real concern with the advent of high-speed electronics. The traditional forms of crosstalk still pose problems for today's high-density designs. The use of dual stripline printed circuit boards (PCBs) can cause crosstalk problems, especially since the breakout trace lengths from ball grid arrays (BGAs) can be long enough to cause crosstalk saturation with today's fast edge-rate silicon. Every designer knows the most obvious crosstalk cases to avoid, such as line-to-line spacing on the same layer. Crosstalk occurs in connector systems and device packages, but is also lurking in areas that might surprise some designers.

Customer Analysis Case: DDR3-800

Interconnect Engineering, Inc. was given the task of analyzing a customer's DDR3-800 board, which poses no challenges from a speed or technology perspective. The initial SIwave extraction produced valid, causal and passive S-parameter results that were imported and simulated in the Designer SI DDR3 environment that had been previously constructed. But these simulations also produced results that were unexpected. The waveform results showed that the DQS signals (qualifying signals indicating whether the data is valid) had serious signal integrity issues due to suspected crosstalk. This crosstalk also shifted the edges of the DQS signals such that flight-time variation relative to the rest of the byte-lane group was occurring. When the channel was simulated without exciting the neighboring members of the byte-lane group, the signal integrity and flight-time skew were normalized. Deeper inspection would be required to understand these deleterious effects.

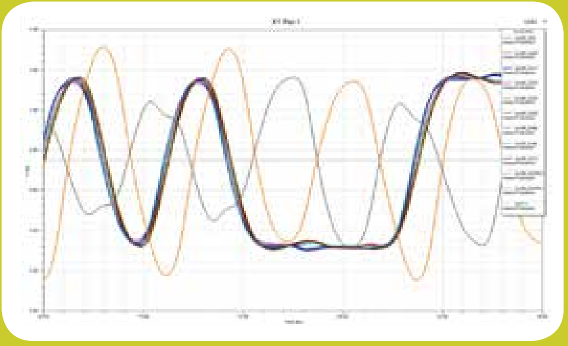
Finding the Source of Crosstalk

ANSYS SIwave contains a new, powerful engine to find sources of crosstalk. With very little setup time required, SIwave presents a whole host of analyses and results to parse. Interconnect Engineering, Inc. used SIwave and discovered that, for this design, the near-end crosstalk result showed anomalous behavior.

The DQS signals highlighted in red had crosstalk effects, but, strangely enough, they did not occur at the destination, which would have pointed to line-to-line spacing violations. The company that had done the layout of the DDR3 interface had taken great precautions to make sure the edge-to-edge crosstalk spacing constraints were much greater than one would have expected, so this was not the cause of the crosstalk.

Engineers then turned to ANSYS HFSS, with its 3-D field-solving capabilities, to solve the crosstalk mystery. The database was imported into HFSS, and, again, causal and passive S-parameters were extracted and imported into the Designer SI circuit simulator for validation. The results showed that the same phenomenon was present using either tool (SIwave or HFSS).

ANSYS Electronics Desktop determined that the customer had routed and constrained their own design with very good crosstalk rules, but simulation showed that, in fact, there was significant crosstalk occurring between signals. The signals in question were not even routed next to each other on the same layer. The source of the crosstalk was not coming from the routing per se; it was coming from adjacent vias in the BGA footprint area. These BGA pins could not be changed as the device was a commercially produced processor.



Designer SI circuit simulator results showed that the same crosstalk phenomenon was present using either ANSYS SIwave or ANSYS HFSS.

So it appeared that this crosstalk was embedded into the design without the designer's knowledge or their ability to change anything to ward off its effects.

Reducing Crosstalk

The PCB stackup the customer used was quite thick with many layers. The layers they used to route the interface happened to be close to the secondary side of the stackup. Interconnect Engineering, Inc. postulated that if BGA footprint via crosstalk was an issue, reducing via parallelism would help the situation. ANSYS Electronics Desktop was again used to change the layers of the routing to more favorable layers that were closer to the primary side of the board to see if this would solve the problem.

One More Tool for the Toolbox

The results are clear: Using layers closer to the primary side will yield less crosstalk for any system, especially for high-speed systems (DDR4, 28Gb/s, 100Gb/s, etc.). Engineers can no longer think about — or simulate — designs in two dimensions; they must adopt a 3-D perspective. BGA footprint vias are not as benign as we would like to think. So one more rule can be added to the designer's toolbox: Utilize routing layers closer to the primary when trying to reduce crosstalk for critical interfaces. The source of the crosstalk was not obvious, but could only be discovered using state-of-the-art simulation tools from ANSYS.

Reduced crosstalk resulting from using layers closer to the primary side

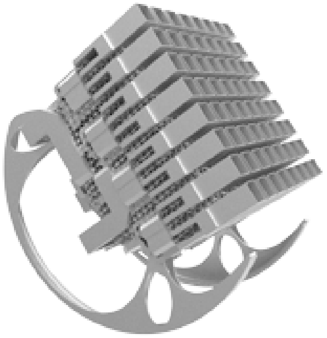
Using the full functionality of the ANSYS Electronics Desktop enabled Interconnect Engineering, Inc. to analyze, diagnose and implement a solution for the customer's crosstalk issue, which would have resulted in at least one costly re-spin to solve the problem. Without ANSYS solutions, they may have never found the true culprit causing the crosstalk. The engineers may have had to resort to slowing down the memory interface in order to be able to ship product with sub-par bandwidth performance. Project schedule, cost and performance all would have suffered. ANSYS Electronics Desktop enabled Interconnect Engineering to ship the best-performing product on time and on budget. Λ

Tuning in to Antenna Design

By **Michael Hollenbeck**,
Chief Technology Officer,
Optisys, LLC, Utah, USA

Using engineering simulation, big compute and 3-D printing, Optisys achieves orders-of-magnitude reduction in antenna size and weight while reducing development time. By leveraging ANSYS electromagnetic and structural simulation tools running on Rescale's big compute platform, this startup's engineers take full advantage of the design freedom offered by 3-D printing to meet radio frequency (RF) performance requirements for an integrated array antenna.

High-frequency antennas are traditionally built by fabricating and assembling dozens to a hundred or more individual components plus hardware to provide the required RF performance and structural integrity. The RF energy propagates from component to component through interfaces, seams and discontinuities, so the RF path length must be increased to compensate for these obstructions. Each component needs mounting surfaces and hardware, which add more unnecessary weight and space. In addition, part material thickness must be suitable to meet design-for-manufacturing constraints, and extra space is needed throughout for assembly clearances.

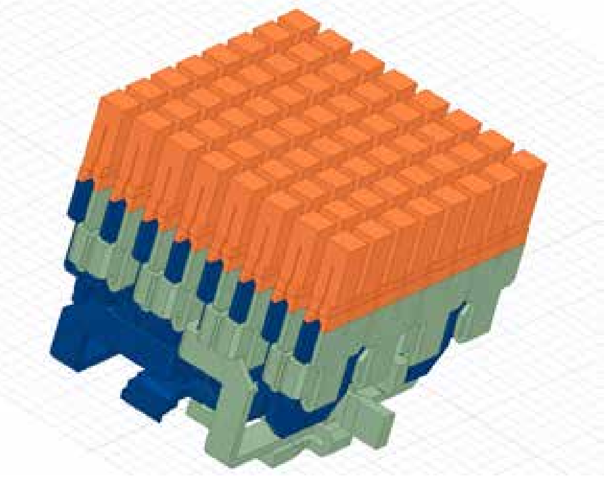


Array model

Advances in metal 3-D printing now make it possible to fabricate antennas and RF components at the scale required for wavelengths in the millimeter range. The entire antenna can be printed in one build as a single component. The elimination of interfaces, seams and discontinuities makes it possible to substantially reduce the length of the RF path, and absence of mounting surfaces and hardware provides further size and weight reductions. Further reductions can be achieved by decreasing material wall

> *“Using engineering simulation with Rescale’s big compute platform provided Optisys with massive efficiency gains and the ability to reduce design cycles from months to weeks.”*

thicknesses. Because assembly clearances are not required, engineers can make further size reductions by packing features tightly into the entire 3-D volume. Optisys engineers used ANSYS simulation software to deliver order-of-magnitude reductions in size, weight and development time for the new 64-element X-band SATCOM integrated array antenna (XSITA). The amount of simulation required to perform such a feat is incredibly compute-intensive, and Optisys does the bulk of simulation on Rescale’s cloud platform for high-performance computing (HPC), minimizing its on-premise IT footprint.

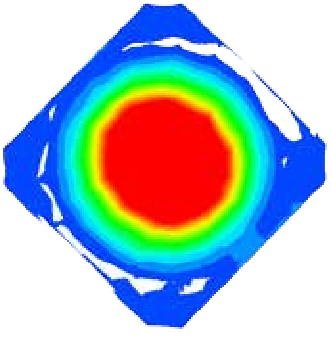


ANSYS HFSS model of radiating elements

Revolutionizing Antenna Design

Three-dimensional printing is revolutionizing high-frequency antenna design by realizing levels of integration and performance far above conventional fabricated antennas. To gain the full potential benefits of 3-D printing and other new manufacturing processes requires engineers to redesign the antennas from scratch. This is a long and laborious task using traditional RF design methods, which involve hand calculating an initial design, building a prototype, testing the prototype and then tuning manually. These steps are repeated over and over until the design meets all specifications, which can take a year or more.

To evaluate a broader range of alternative designs and iterate to an optimized design before building a prototype, Optisys uses simulation. By joining the ANSYS Startup Program, the company gained access to ANSYS HFSS electromagnetic simulation software and ANSYS Mechanical finite element analysis software to evaluate the RF and structural performance of the design. Engineers create simulation models locally and upload them to the Rescale cloud platform where they can run ANSYS software natively and access powerful HPC resources without having to maintain a computing infrastructure. Rescale complies with International Traffic in Arms Regulations (ITAR) so Optisys is able to use the platform even for antennas used in defense and homeland security applications.

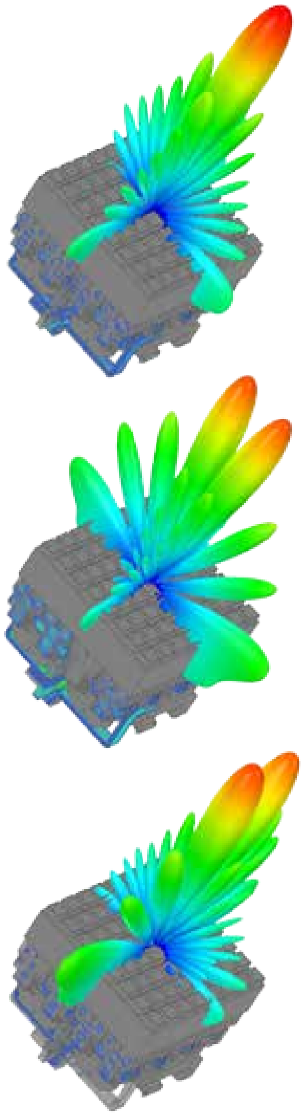


E-field inside antenna horn

Optimizing the RF Design

Optisys engineers parameterized their initial concept design and used HFSS to calculate the S-parameters of each section of the antenna. They used the ANSYS Optimetrics electromagnetic optimizer to evaluate multiple design variables at a time based on the S-parameter results, primarily considering how much of the RF input was transmitted versus

Antenna Design and Platform Integration Analyses Using ANSYS HFSS
ansys.com/antenna-design



Radiation pattern for the antenna array is simulated in ANSYS HFSS for different elevations and rotations.

how much was reflected back. The optimizer stepped through the design space by following gradients toward an optimal design that minimized insertion losses and reflected energy. Engineers frequently generated e-field and surface current plots of the waveguide cavities for the designs generated by the optimizer to visualize performance and determine which areas are most in need of improvement.

The XSITA radiating elements consist of 64 square waveguide elements with chokes formed from the structural supports. Both left-hand circular polarization (LHCP) and right-hand circular polarization (RHCP) are generated, based on a classical 2-port septum design that transforms a single mode input to a circularly polarized output. The LHCP and RHCP networks were designed so that each quadrant of the full radiating element array is broken into four-element by four-element subsets. The polarizer outputs connect to a 16-to-1 corporate feed network that pulls down each quadrant into combiner networks that feed into monopulse comparators. The RHCP and LHCP outputs have separate monopulse comparators for tracking on both polarizations, resulting in eight total output ports. The monopulse comparator for each polarization is nested among the bottom sections of the corporate feed in a compact manner that adds as little extra additional volume as possible.

Due to the high levels of integration, with waveguide spacing approaching 0.020 inch in multiple regions, it is necessary to route the waveguide paths with all components of the model visible, but only simulate a subset of the geometry to improve simulation speed for optimization. HFSS makes it possible to include or exclude geometries from the simulation without removing them from the modeler window. This makes it possible for Optisys engineers to independently design the RHCP and LHCP networks while winding them around each other to minimize 3-D volume and waveguide length.

Designing the Structural Supports

Engineers used ANSYS Mechanical to analyze the lattice support structure to ensure sufficient mechanical strength to allow for reducing the thickness of the RF components to minimize the weight of the antenna. Engineers also designed a printed elevation axis that includes a rocking arm and gears and connects to an external motor.

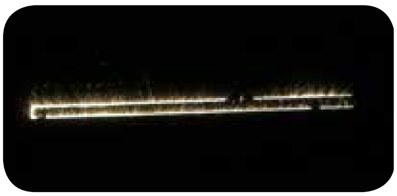
Cloud Computing for the Startup

Startups increasingly employ a cloud-based simulation platform because it is the only viable, cost-effective way to build digital prototypes for new products. Startups occasionally need increased compute capacity and often lack IT staff and/or the capital budget required to purchase, set up and maintain the appropriate hardware infrastructure. ANSYS actively works with cloud hosting partners such as Rescale to provide seamless turnkey access to ANSYS simulation and HPC resources. This approach provides ANSYS customers — from startups to large enterprise organizations — with an HPC cloud solution that is delivered by a partner who is an expert in HPC, remote hosting and data security.

— Wim Slagter, Director of HPC and Cloud Alliances, ANSYS

> *“Optisys engineers used ANSYS simulation software to deliver order-of-magnitude reductions in size, weight and development time for a new array antenna.”*

The design of the XSITA array showcases the level of integration that can be achieved with 3-D printing when engineers leverage ANSYS HFSS to optimize complex RF designs and the power of virtually unlimited scaling available on Rescale’s cloud HPC platform. The success of startups like Optisys depends on delivering innovative solutions to the market faster than well-funded establishments. Using engineering simulation with the ability of Rescale’s big compute platform to parallelize multiple projects provided Optisys with massive efficiency gains and the ability to reduce design cycles from months to weeks. While existing antennas in this space average 50 pounds and contain more than 100 components, the Optisys XSITA is only 8 pounds and consists of a single component. These capabilities allow a startup like Optisys to compete in this new field of 3-D printing, which is expanding exponentially and enabling unprecedented capabilities.



Antenna being built in 3-D printer

3-D printer used to build antenna

Rescale Cloud HPC Simulation Platform
rescale.com/ansys

Antennas are mounted on the exterior of today's airliners.

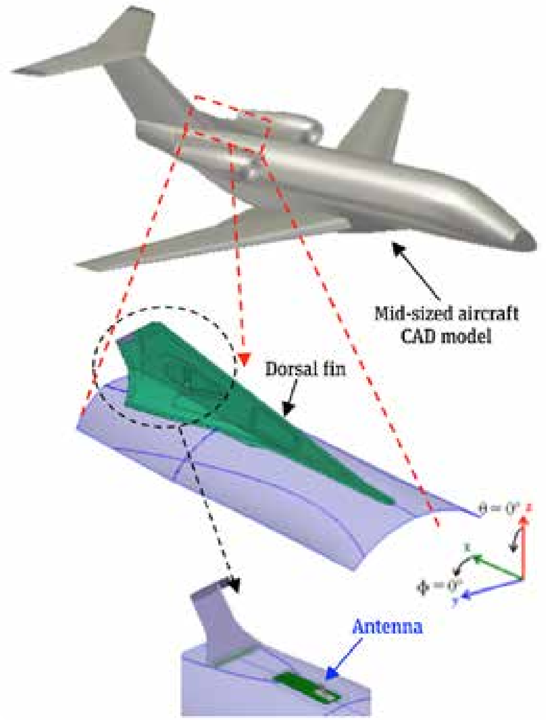
Inside Story

The scores of antennas extending from the surface of today's jet airliners create drag that adds to fuel consumption. Brazilian National Institute of Telecommunications (Inatel) and Embraer engineers have been developing new ways of installing antennas that could save fuel. With ANSYS simulations, engineers can predict the performance of proposed installations without the time and expense of building prototypes.

By **Arismar Cerqueira Sodré Junior**, Associate Professor,
Brazilian National Institute of Telecommunications (Inatel),
Santa Rita do Sapucaí, Brazil; and
Sidney Osses Nunes, Product Development Engineer, Embraer,
São José dos Campos, Brazil

"Placing antennas in their traditional position on the exterior of the *aircraft increases drag*, which intensifies fuel burn at a time when airlines have mandates to be *increasingly energy efficient*."

The number of antennas on commercial aircraft is steadily rising to support new safety, navigational and radar systems and to deliver services, such as Wi-Fi and live TV, to passengers. However, placing these antennas in their traditional position on the exterior of the aircraft increases drag, which increases fuel burn at a time when airlines need to be increasingly energy efficient. To address this challenge, Embraer is working on new installation designs for aircraft antennas. Antennas must still emit the same amount of radiation in every direction, so many design variations must be evaluated. If physical prototypes had to be built and tested for every proposed antenna and position, it would be extremely costly and time-consuming. The Brazilian National Institute of Telecommunications (Inatel) and Embraer are using ANSYS HFSS electromagnetic field simulation software to evaluate the performance of alternative antenna installation designs. HFSS simulation results match closely with physical testing, and therefore greatly reduce the amount of time required to assess design alternatives. The result may be substantial fuel savings in future Embraer aircraft.



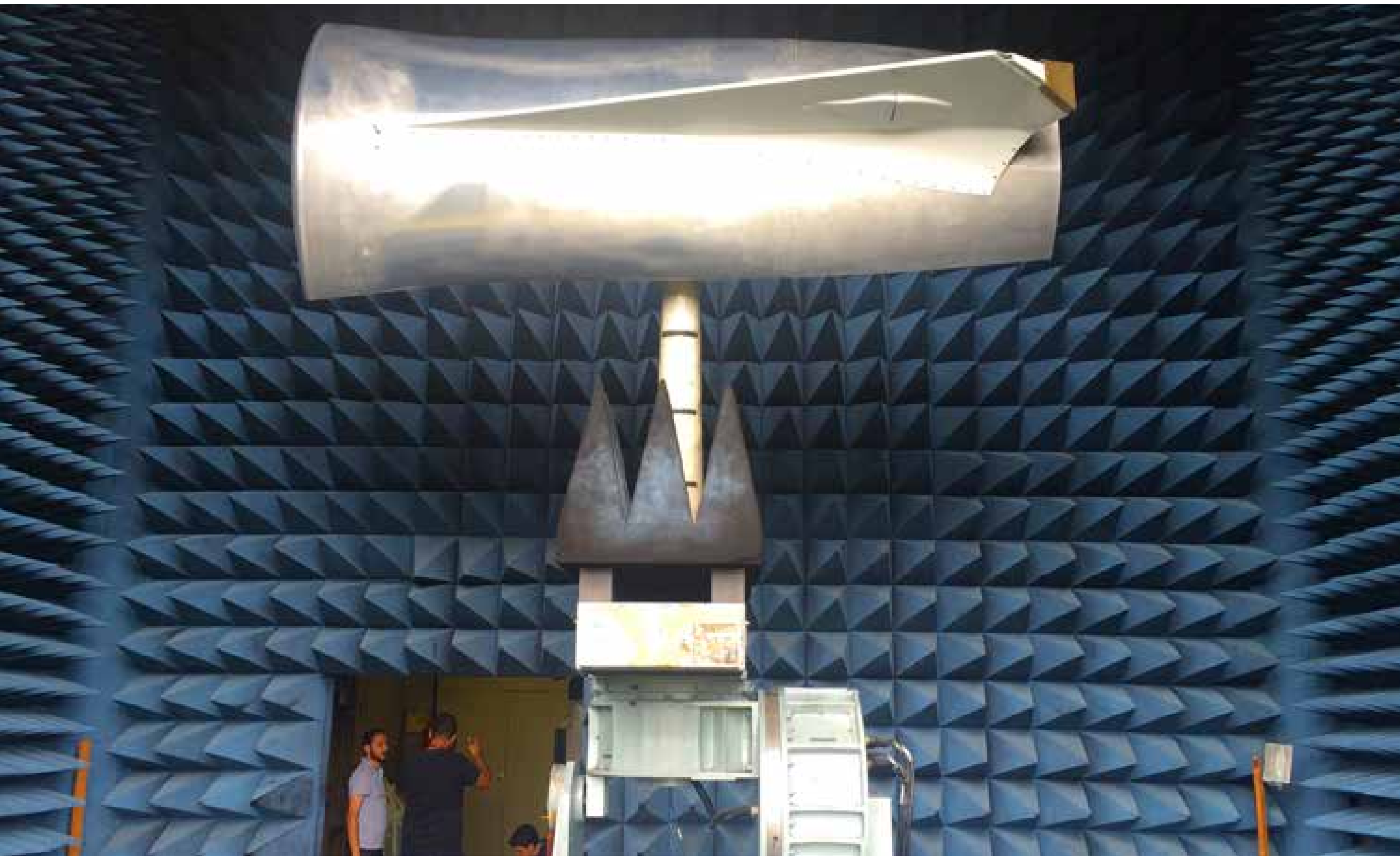
A light jet aircraft and the ANSYS HFSS numerical model of its dorsal fin

Using Actual Antenna Installation for Validation

The latest generation of commercial airliners have up to 100 antennas that are used for air traffic control (ATC), traffic collision avoidance (TCA), instrument landing systems (ILS), distance measuring equipment (DME) and many other applications. In the past, aircraft exterior structures were primarily made of aluminum, which largely blocks electromagnetic radiation, so antennas had to protrude from their surface. Now many aircraft are built from fiber-reinforced composites, giving rise to new electromagnetic challenges for antenna placement and making it more difficult to design antennas into the aircraft fuselage. Besides reducing drag, this approach also can potentially reduce weight by eliminating the protruding structures now required to support antennas.

To simulate proposed antenna installation designs, Inatel and Embraer engineers first needed to determine the electromagnetic properties of the composite in which the antenna would be covered.

Designing Antenna and Electronic Systems for Space and Airborne Applications
ansys.com/airborne-antenna



Prototype of aircraft dorsal fin tested in anechoic chamber

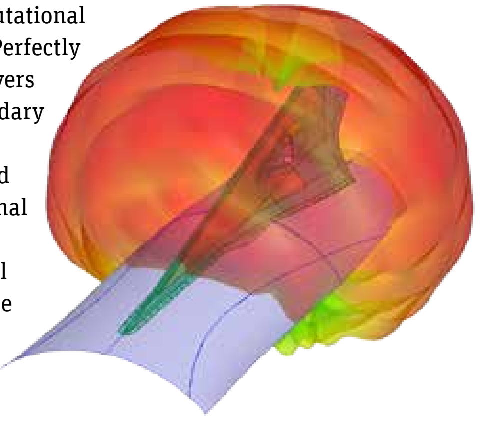
They built a physical prototype of a composite dorsal fin sheltering an existing antenna. They excited the antenna and measured the resulting radiation pattern in an anechoic chamber, which enables accurate measurement of antenna radiation by eliminating reflections of electromagnetic waves as well as waves entering from outside.

Engineers measured electrical permittivity, loss tangent and the radiation pattern of the antenna so that they could use these measurements to define the composite material properties in HFSS. They imported the geometry of the structure and antenna from computer-aided design (CAD) models. The HFSS meshing algorithm generated and adaptively refined the mesh, iteratively adding mesh elements where needed due to localized electromagnetic field behavior. The next step was to define boundary conditions to specify field behavior on the surfaces of the solution domain and on the object interfaces. Ports were defined where energy enters and exits the model. A sine wave signal was used to excite the antenna.

ANSYS HFSS Perfectly Matched Layer Boundary Automation
ansys.com/boundary-automation

Hybrid Solver Technology Saves Time

Inatel and Embraer engineers used the ANSYS HFSS hybrid method, combining a finite element model of the dorsal fin with an integral equation model of the fuselage and antenna. The finite element method was selected for the dorsal fin because the dielectric properties of this structure were critical and the finite element method allows them to be precisely defined. The integration equation or method of moments (MoM) technique within HFSS was used for the rest of the aircraft and antenna because of its computational efficiency. Perfectly matched layers (PML) boundary conditions were applied to the external boundaries of the model to reduce the amount of



ANSYS HFSS simulation results show radiation amplitude field generated by antenna designed within fuselage.

> **“Engineers discovered that the *position of the antenna* with respect to the composite and the thickness of the *composite structure* had the greatest impact on antenna performance.”**

air in the computational domain. PMLs are fictitious complex anisotropic materials that fully absorb the electromagnetic fields impinging upon them. They were placed at the model boundaries to emulate reflection-free radiation.

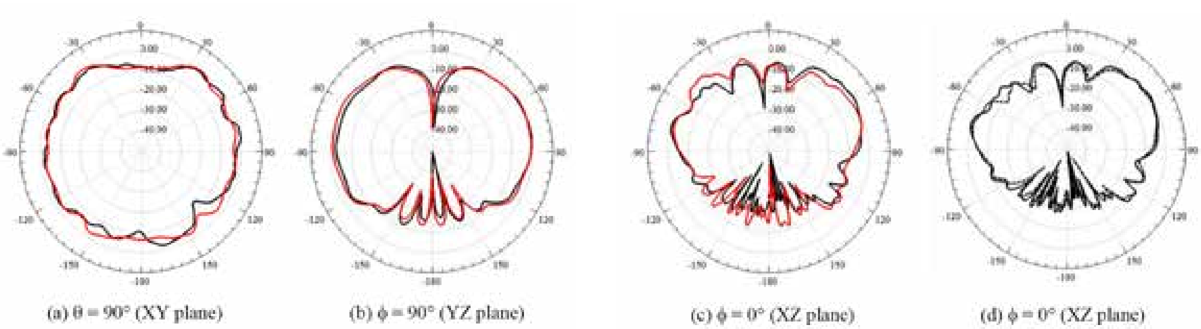
ANSYS HFSS computed the full electromagnetic field pattern inside the structure and calculated all modes and all ports simultaneously for the 3-D field solution. The simulation results correlated well with physical testing, validating both the measured material properties and the HFSS simulation model. Engineers determined that the performance of different fiber-reinforced composites are dependent on frequency. For example, at 100 KHz a significant amount of carbon fiber reinforcement can be used without harming the radiation pattern, but at 10 GHz even a very small amount of carbon fiber presents major design challenges.

Iterating to an Optimized Design

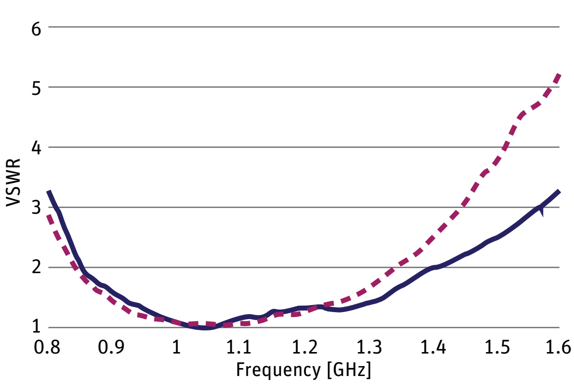
Engineers then evaluated different antenna installation designs with the goal of obtaining an omnidirectional radiation pattern. By changing the dimensions of different design parameters, they discovered that the position of the antenna with respect to the composite structure (in the x and y directions) and the thickness of the composite structure had the greatest impact on antenna performance. Engineers used the parametric design capability in HFSS to evaluate ranges of values for these and other design parameters in batch mode. Next, engineers modeled the complete aircraft structure to determine how it affected the performance of the antenna and made further changes to the design to maintain omnidirectional performance.

Guided by simulation, engineers developed an antenna installation that provides a radiation pattern very close to the desired omnidirectional pattern, nearly matching that of the uncovered antenna. After optimizing the design of the antenna, Inatel and Embraer engineers built a prototype of the optimized design. Physical measurements of the new prototype closely matched the simulation. These new installation designs for antennas have the potential to substantially reduce fuel consumption in next-generation aircraft.

Inatel and Embraer are supported by ANSYS Elite Channel Partner ESSS.



Comparison of simulated (red and dashed line) and measured (black) radiation patterns show close agreement.



Measurements of final antenna design show that it closely matches performance of conventional antenna at frequencies of interest between 1 and 1.2 GHz.

FUEL INJECTION: Breaking Up is Hard to Do

By **Junmei Shi**, Simulation Team Leader, and
Pablo Lopez Aguado, Ph.D. Student,
Delphi Automotive Systems, Bascharage, Luxembourg

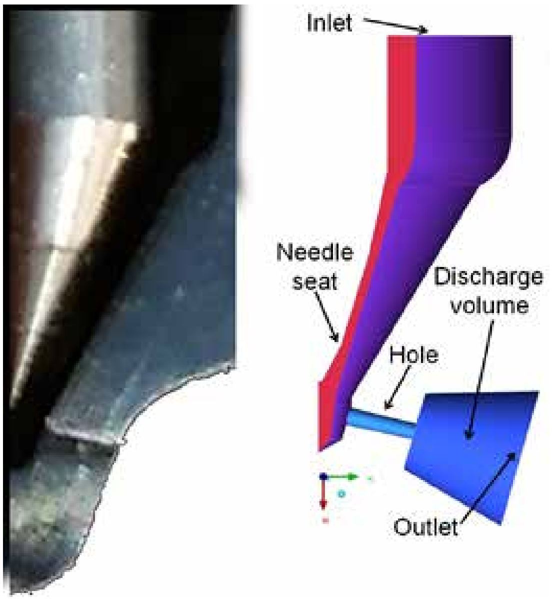
Improving internal combustion engine emissions and fuel economy performance requires better understanding of the process by which the fuel injection nozzle breaks up the liquid fuel and propels atomized droplets into the cylinder. Delphi engineers are using ANSYS computational fluid dynamics (CFD) software to design the fuel injector nozzle geometry to deliver droplets in just the right spray pattern to optimize engine performance.

Improvements in clean internal combustion engine technology require controlling and optimizing the fuel–gas mixing, ignition and combustion processes. Engineers must translate the particular spray requirements of each engine into a detailed nozzle design. One of the big challenges to nozzle development is determining the fundamental physics of the primary breakup process and how this is impacted by nozzle geometry. Physical experiments have limitations in understanding the breakup process because there is no way to effectively measure turbulence and vortex structures inside tiny injection nozzles. Delphi Automotive Systems engineers use ANSYS Fluent CFD large eddy simulation (LES) to characterize the nozzle flow dynamics and breakup process. The nozzle flow and measured spray pattern predicted by simulation closely match experimental results, significantly advancing the fundamental understanding of fluid dynamics useful for optimizing fuel injector nozzle designs.

“Delphi Automotive Systems engineers use *ANSYS Fluent CFD* to characterize the nozzle flow dynamics and *breakup process*.”

Traditional Fuel Injector Nozzle Design Methods

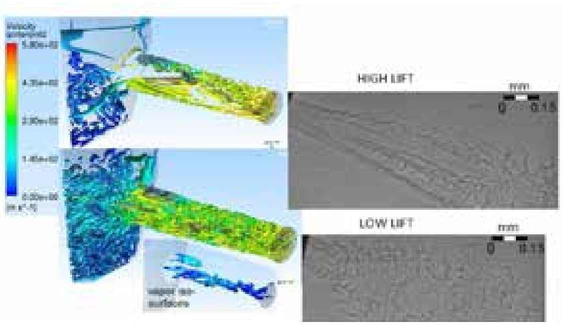
The performance of a fuel injection nozzle in breaking up the liquid fuel into spray droplets and the fuel–air mixing in the engine cylinder have a major impact on fuel economy and emissions. Both primary and secondary breakup phenomena occur simultaneously in the spray formation process. The primary breakup refers to the liquid jet deformation and big ligament formation phenomena. The ligaments further break up into droplets in the secondary breakup process. The primary breakup process involves highly complex multiphase and multiscale fluid dynamics phenomena, including turbulence and cavitation and their interaction inside the nozzle, along with aerodynamic interaction outside of the nozzle. The fuel injection engineering community has been working on this issue for more than 50 years, but have been hampered by lack of effective experimental and numerical diagnostic tools. Optical measurement techniques including phase-contrast X-ray imaging (PCX) and X-ray radiography have been developed for in-nozzle cavitation characterization, but so far there is no effective way to measure field turbulence inside the injection nozzle.



The nozzle flow path

Researchers have also worked with simulation to understand the breakup process. The level set interface tracking technique has been successfully employed with CFD to resolve the liquid–gas interface during droplet formation. But this technique requires direct numerical simulation (DNS) in which the Navier–Stokes equations are numerically solved without any turbulence model to deal with cavitating flows. DNS is still not feasible today since the computer power required is not available. An alternative to the level set technique is the volume of fluid (VOF) technique, which tracks the volume fraction in each cell rather than the interface itself. VOF is effective for in-nozzle flow analysis but is inaccurate for the prediction of jet breakup and droplet formation.

Because of these limitations in measurement and simulation techniques, fuel injector design still largely relies on a parametric optimization of the geometry following the build-and-test method. This process is inefficient and is sensitive to interactions between the many geometric parameters and to inaccuracies in the measurement system.

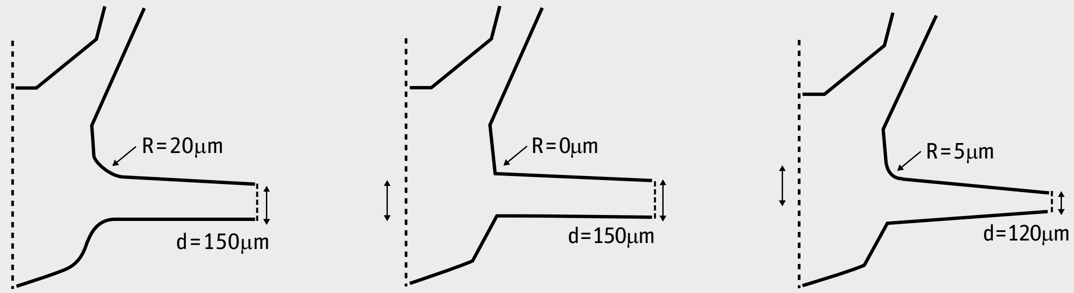


Strong correlation between simulated and measured nozzle spray for round injection hole nozzles at high and low needle valve lifts provides confidence in internal nozzle flow simulation.

LES Enables CFD Simulation of Flow Inside Nozzle

Delphi is working with Wayne State University and Argonne National Laboratory to achieve detailed characterization of the liquid–gas interface structures of the near-nozzle spray in the breakup process. In parallel, Delphi is leveraging the ANSYS Fluent LES turbulence modeling scheme in conjunction with VOF and

Rounded | **Sharp Edge** | **High-Performance Atomization**



Rounded

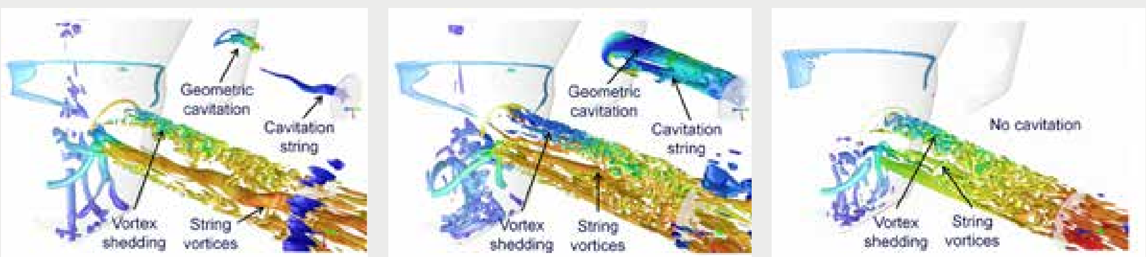
- Near-nozzle spray shows a transitional fluctuation between large-scale regular surface structures and smaller-scale, irregular structures.
- Weaker vortex shedding and cavitation
- String structures survive from time to time all the way to the injection hole outlet.

Sharp Edge

- The jet begins to break up closer to the nozzle hole exit, and the spray pattern is more stable with more fine-scale structures.
- Small-scale vortices accompanied by vortex shedding at the upper lip of the injection hole entrance and strings of vortex pairs rotating in opposite directions accompanied by string cavitation
- The intensity of shed vortices and cavitation are strong enough to break up the string structures inside the injection hole.

High-Performance Atomization

- Moderate, stable spray pattern with small-scale irregular surface structures
- Shed vortices interact with the string vortices, but no cavitation is observed.
- The shed vortices produce pulsating momentum, which leaves the injection hole exit and triggers jet deformation and wavy liquid–gas interface structures.
- Shed vortices also produce pulsating surface vortices, which are enhanced by liquid–gas interfacial interaction between liquid and surrounding gas, triggering droplet formation.



Comparison of LES simulation of the flow inside the nozzle helped engineers to understand how the different nozzle geometries produced contrasting results.

coupled VOF–level set techniques to simultaneously resolve the multiscale vortex dynamics in the nozzle and the liquid–gas interface of the near-nozzle spray during the primary breakup process. In LES, large eddies are resolved directly, while small eddies are modeled. Resolving only the large eddies makes it possible to use a much coarser mesh and larger time steps in LES when compared to DNS. Delphi uses this approach to simulate round- and sharp-edge–hole nozzles as well as its high-performance (HP) atomization hole nozzle, which uses a very high hole taper to increase the nozzle's hydraulic efficiency and the spray momentum rate.

The LES simulation of the flow inside the nozzle helped engineers to understand how the different nozzle geometries produced contrasting results as shown in the chart.

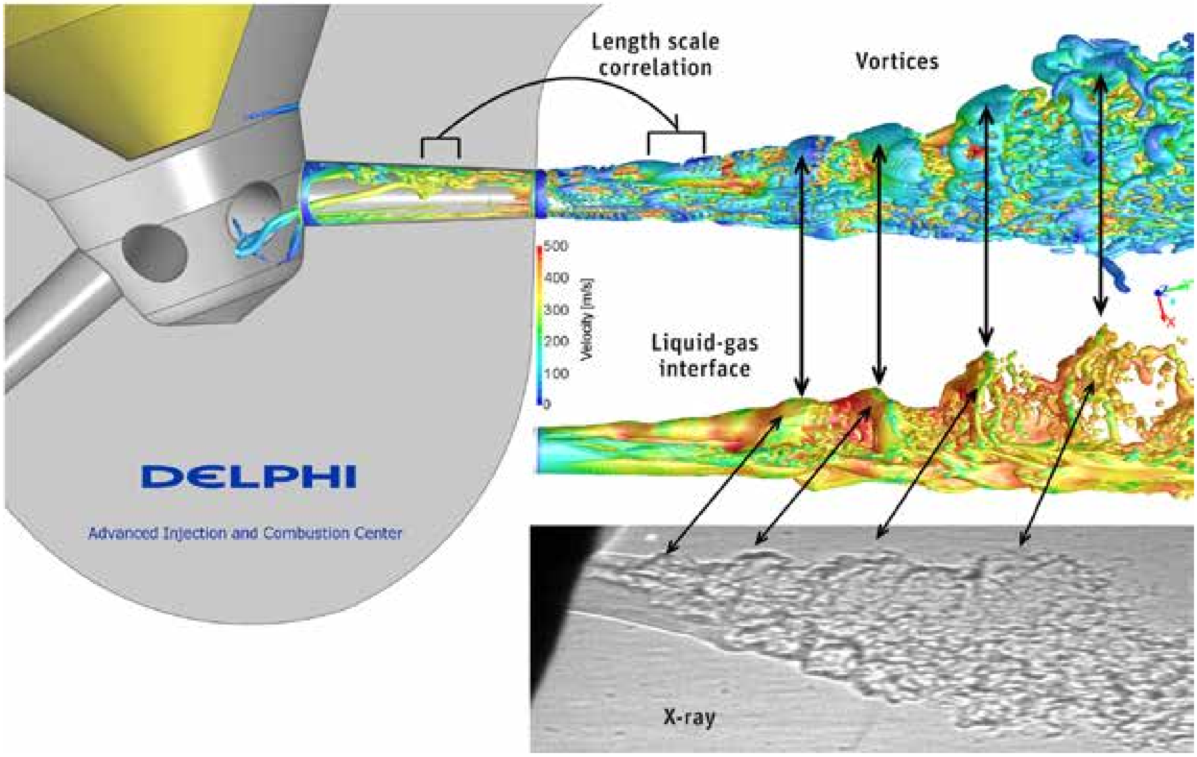
Nozzle Design Migrating to Simulation

For each case, good correlations were found between the predicted and the measured spray patterns, providing a high level of confidence in the accuracy of the flow patterns inside the nozzle. It was discovered that the process of the fluid flow entering the nozzle hole triggers vortex shedding, which further initiates liquid surface deformation and ligament formation in the primary spray breakup. This finding explains the influence of nozzle design parameters such as seat-sac, hole-inlet rounding, taper, needle shape and needle lift on the spray formation, and provides a new understanding of the primary breakup mechanisms in high-pressure fuel injection.

The fuel injection research community has been wrestling for over 50 years with the challenge of understanding the turbulence inside the nozzle and its

“Delphi Automotive Systems engineers use *ANSYS CFD* to characterize the nozzle flow dynamics and breakup process.”

effect on spray simulation. CFD simulation with LES has substantially improved engineers’ understanding of the fundamental physics of the primary breakup process and the impact of the nozzle geometry on spray structure. Delphi engineers are moving forward to incorporate simulation in the design process for fuel injector nozzles in new engine models. Simulation will enable engineers to better understand the complex interaction of geometric parameters within the nozzle, which will allow a shift from a parametric to a knowledge-based optimization process. Fewer samples will be required for testing, and it is expected to reduce the time necessary to develop nozzles, leading to higher-performing engines with greater fuel economy and lower emissions.



Simulated and measured nozzle spray for HP nozzles match well.

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Injector Dynamics Assumptions and Their Impact on Performance
ansys.com/injector

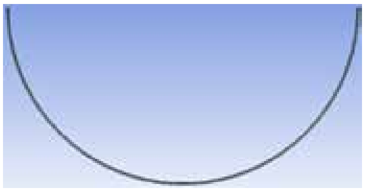
Decreasing Spacecraft Fuel Sloshing

Fuel sloshing in the tank of a spacecraft has the potential to change the center of mass. This affects the carefully calculated maneuvers that accurately direct sensors to specific ground locations. Airbus engineers used fluid–structure interaction simulation to evaluate the ability of a proposed elastomeric membrane to minimize the effect of fuel sloshing on the center of mass in the early stages of developing a spacecraft.

By **Rémi Roumiguié**,
Fluidic Engineer,
Airbus Defence and Space,
Toulouse, France

Typical missions of spacecraft include monitoring the weather and the environment — such as changes in vegetation, atmospheric gases, ocean conditions and ice fields — and performing terrain mapping. Airbus Defence and Space is a recognized leader in this field, providing complete solutions to increase security; boost agricultural performance; maximize oil, gas and mining operations; improve management of natural resources; and protect the environment by monitoring deforestation and carbon emissions.

Attitude control is particularly important because spacecraft are often tasked with observing a specific fixed point on the ground. Their attitude is changed frequently to observe a different location or to point an antenna



Drawing of the membrane at an offset from the lower part of the tank

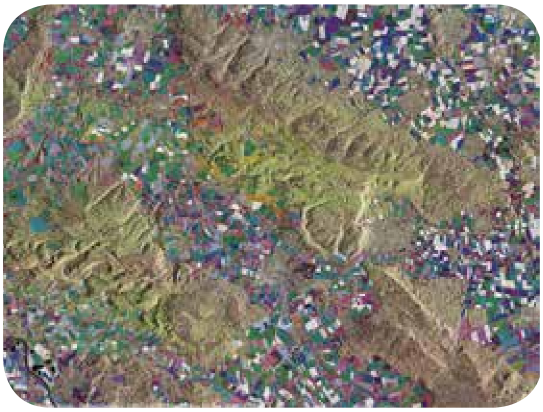
"Spacecraft designers must determine whether remediation is needed to achieve attitude control specification and identify an approach that will meet the specification with the lowest cost and weight penalty."

toward a ground station to transmit the collected data. The attitude control system (ACS) typically relies on control moment gyroscopes and reaction wheels to perform smaller attitude maneuvers using electricity provided by solar arrays. Thrusters fueled by propellant perform larger maneuvers. The algorithm used for the control moment gyroscopes and reaction wheels requires precise knowledge of the center of mass of the spacecraft. But as it begins to move, liquid fuel sloshes around in its tank, changing the center of mass and generating forces on the tank wall that counteract the control moment gyroscope or reaction wheel.

Spacecraft often use remediation measures to reduce sloshing so that the spacecraft can be controlled within the allowable attitude window. One approach is to use physical barriers, such as baffles or compartments, to control sloshing. Another common method is to use an elastomeric membrane to divide the tank into two compartments — one filled with fuel and the other with pressurized gas — to dampen sloshing.

Designers must determine whether remediation is needed to achieve attitude control specifications and, if so, to identify an approach that will meet the specifications with the lowest cost and weight penalty. Physical experiments are almost impossible to use to measure sloshing in zero gravity and would be very expensive. Airbus engineers decided to use simulation early in the design process to evaluate the performance that could be achieved by an elastomeric membrane, because making design changes early is less costly than making them later.

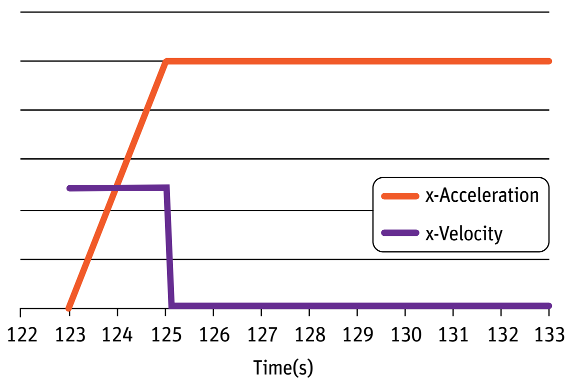
Modeling sloshing under the influence of an elastomeric membrane is complicated because of the complex interactions of both the liquid fuel in the tank and the membrane. Airbus engineers had never modeled these interactions before, and a literature search did not identify any published results that could act as a guide. So the engineers decided to take advantage of the integration of ANSYS multiphysics tools in the ANSYS Workbench environment to perform fluid–structure interaction (FSI) simulations to analyze the behavior of the proposed membrane.



Typical image captured by Airbus spacecraft

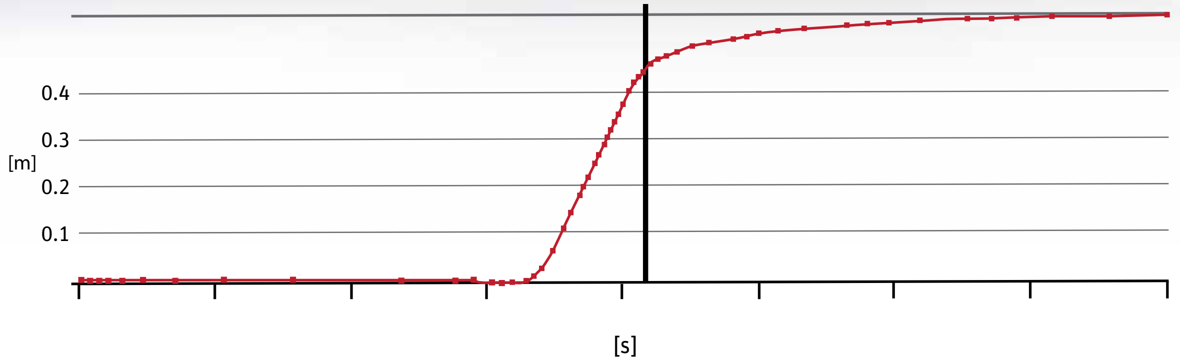
Design Study for a Spacecraft

Airbus engineers needed to perform a design study to calculate the impact of a membrane on the response of a spacecraft under development. They were asked to estimate the changes in the center of mass and the forces exerted by the fuel on the tank walls as the spacecraft made several defined maneuvers. This required simultaneously solving for the effect of the liquid fuel on the membrane and the influence of the membrane on the fluid. The biggest obstacle in



Typical translation profile applied during FSI simulation

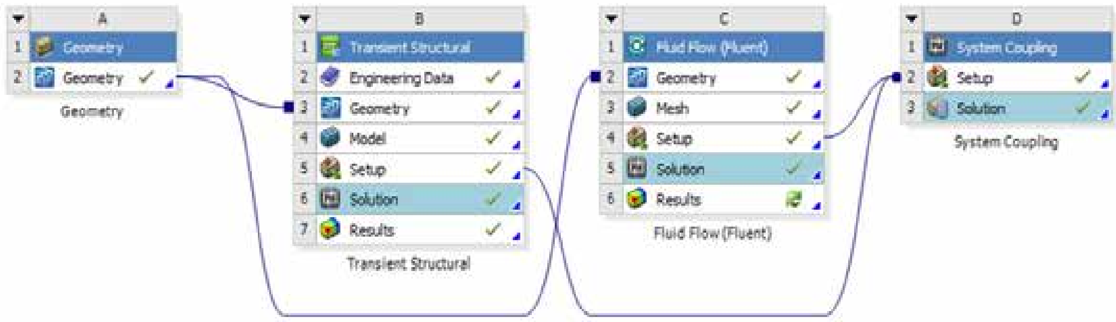
> *"FSI and other multiphysics simulations enable Airbus engineers to make more informed design decisions at a stage in the design process when it is possible to have a substantial impact."*



Displacement of the midpoint of the membrane during the mechanical deformation process

performing FSI simulations is that the computational fluid dynamics (CFD) software used to simulate the fluid and the finite element analysis (FEA) software used to simulate the membrane are often supplied by different vendors and are not designed to work together. The user must find a way to integrate these tools. This may involve writing and validating scripts, and transferring data manually between CFD and FEA software packages for each simulation run. Manual intervention in the simulation process takes time, results in a complex simulation workflow and can sacrifice the accuracy of the overall simulation.

ANSYS software overcomes these difficulties by providing the complete physics required for FSI simulation, including CFD and FEA solvers, integrated in the ANSYS Workbench environment. The output from one software package is coupled as input to the next with a simple drag-and-drop operation, so there is no need for manual data transfer. In this case, Airbus engineers modeled the membrane as a solid offset from the lower part of the tank and created a fluid outlet on the lower tank wall. The unique integration between ANSYS Fluent and ANSYS Mechanical made it possible to use the solid part of the tank walls to contain the fluid domain model and the surfaces to define ANSYS Mechanical solid elements. The tank walls were also included in the ANSYS Mechanical model to impose contact with the

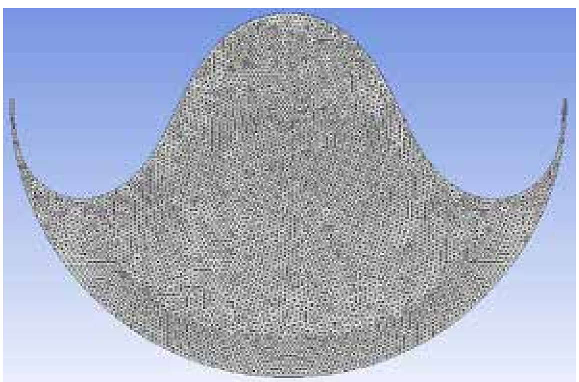


Airbus engineers linked fluid and structural codes by dragging the output of one code to the input of another.

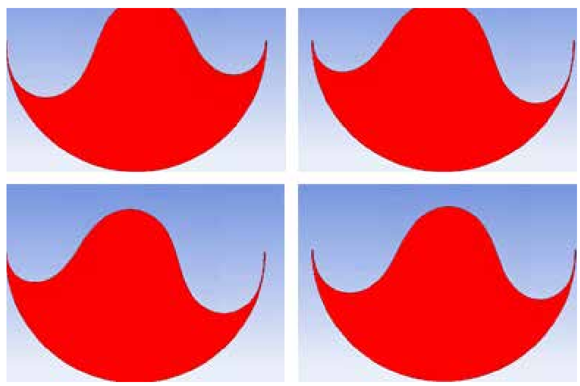
> "ANSYS software provides the complete physics required for FSI simulation, including CFD and FEA solvers integrated in the ANSYS Workbench environment."

membrane. The entire model was only one element thick to reduce computational effort so it was in effect a 2-D simulation.

Filling the tank could have been done with FSI, but instead Airbus engineers used the simpler and less computationally intensive approach of applying mechanical pressure rather than fluid pressure to deform the membrane toward the upper part of the tank. The deformed shape was then applied to the fluid model. A mass flow outlet was added, and the tank was allowed to drain to the desired filling ratio while maintaining equilibrium between the fluid pressure and stress in the membrane. A flow rate profile was used to drain the tank gradually to avoid generating pressure waves.



Stabilized position of membrane after tank drained to partial level



FSI results

Performing Fluid–Structure Interaction Simulation

Once the shape of the membrane and its associated stress field were determined, engineers applied specified translation profiles to the tank. Each profile consisted of an acceleration time history representing a typical spacecraft maneuver. At each time step in the transient FSI simulation, ANSYS Fluent calculated the fluid reaction forces. These forces were seamlessly transferred by ANSYS Workbench to the ANSYS Mechanical solver to load the elastomeric membrane. ANSYS Mechanical then calculated the deflection of the membrane. The updated membrane shape was passed back to ANSYS Fluent, which used it to establish the flow domain for the next simulation time step. The simulation results included the center of mass of the tank and the forces and torques exerted by the fluid on the tank walls at each time step.

Airbus engineers used FSI simulation in the early stages of the design process to model the behavior of the elastomeric membrane subjected to a typical spacecraft maneuver. They also use simulation to evaluate other sloshing remediation methods such as baffles or compartments. The final aim is to determine which solution is the more suitable for tank design.

With ANSYS software, Airbus engineers developed a new capability: They are now able to simulate a tank configuration with an elastomeric membrane. FSI and other multiphysics simulations enable Airbus engineers to make more informed design decisions at a stage in the design process when it is possible to have a substantial impact on the performance, cost and lead time of the finished product.

Mastering Complexity
ansys.com/mastering

ENGINEERING E-MOTORS

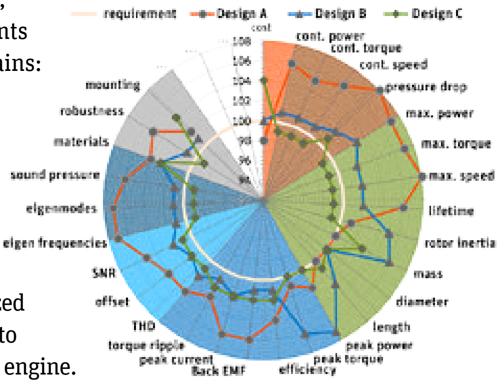
By **Marc Brück**,
Senior Expert
Simulation Technology,
EM-motive GmbH,
Hildesheim, Germany

Creating an optimal custom engine for hybrid and electric vehicles requires that multiple electronic and mechanical components are designed and tested together as a system. Identifying and choosing trade-offs is difficult, but EM-motive GmbH tackled this challenge by developing a multidomain workflow incorporating ANSYS simulation and ANSYS optiSLang optimization software.

When car manufacturer Daimler formed a joint company in 2011 with Bosch, the world's leading automotive supplier, the synergy between the two companies was obvious. The joint company, EM-motive GmbH, combines Daimler's expertise in fuel cells and batteries with Bosch's knowledge of the development and production of electric motors to design and manufacture electric traction motors for electric and hybrid vehicles. Because the motors are designed to be modular, they can be adapted to fit a variety of vehicle classes and meet specifications for many different vehicles. Since 2012, the company has manufactured more than 300,000 e-motors for client companies throughout Europe.

Even with this combined expertise, manufacturing a modular engine is complex and challenging. In addition to the main engineering constraints (cost, mounting space for the motor, cooling and inverter-specific properties), the customer-based requirements for each type of engine cover a wide breadth of individual physical domains:

- **Thermodynamics:** coolant flow rate and temperature, environmental temperatures, as well as winding and magnetic temperatures
- **Structural mechanics:** mounting space, torque, power, speed, tolerances to other parts and forces on bearings
- **Electrical engineering**: voltage, current, inverter-specific properties
- **Efficiency and acoustics:** airborne and structure-borne noise



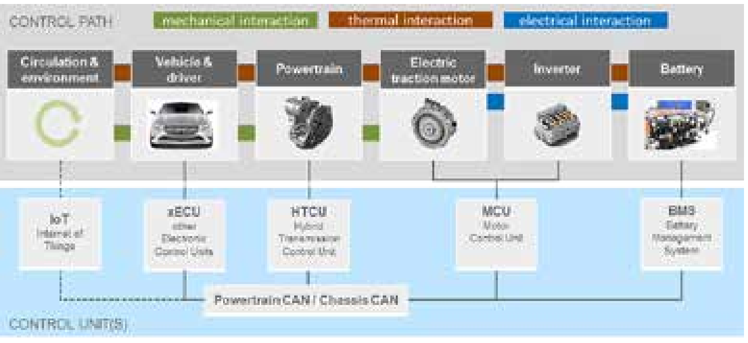
A radar chart illustrates three design concepts and how well they meet customer requirements.

To make the challenge even greater, all of the parameters to be optimized have to be considered simultaneously. Other factors must also be taken into account: noise, vibration and harshness (NVH); safety; and the cost of the engine.

The engineers at EM-motive realized that, in such an interactive environment, a "classic" component development system, where rigid specifications for each component are designed separately and then assembled, was no longer possible. Instead, the company developed a design workflow that incorporated simulation throughout to account for the dynamic interactions between the components, as well as all the necessary parameters to determine optimal solutions and ensure design robustness.

The parametric workflow to support sensitivity analysis, design optimization and design robustness evaluation includes ANSYS simulation software and other software tools, and was built and hosted in ANSYS optiSLang. These workflows help EM-motive to develop electric motors within challenging time and cost requirements, as well as resolve customized design challenges, such as a late-stage customer requirement change for an engine design.

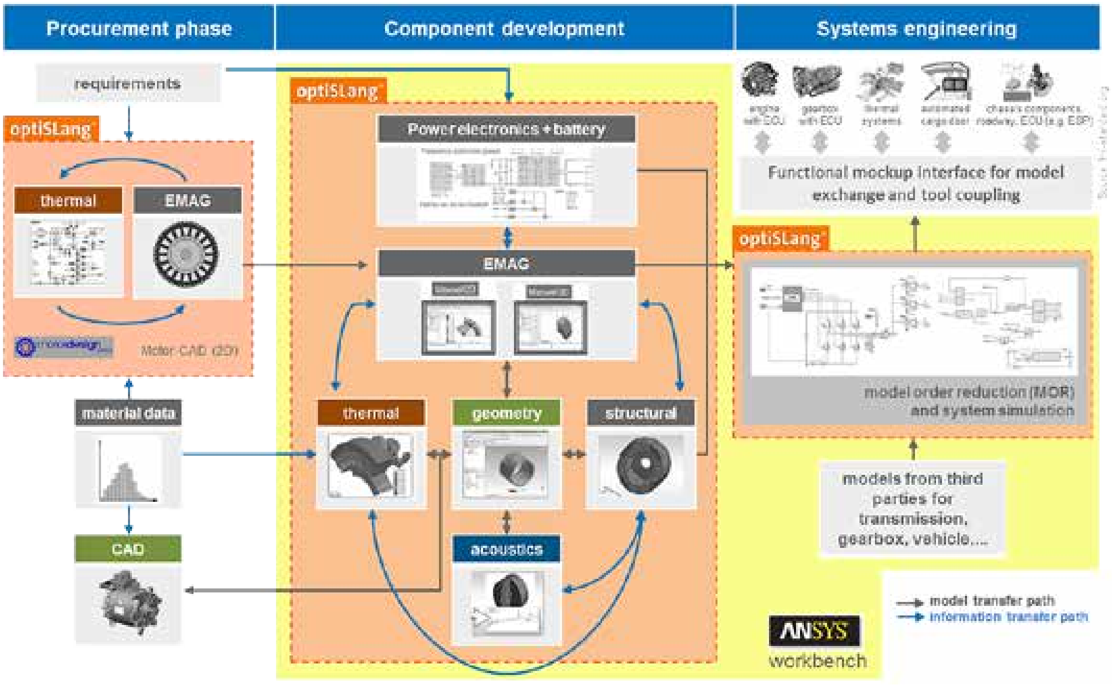
As an example, a customer requested that the maximum speed for a particular engine needed to be increased by 1,000 revolutions per minute (rpm). The centrifugal forces of the accelerated speed, however, would cause the rotor design to fail. The engineers could increase the bridge thickness of the pockets for the magnets that are punched into the rotor lamination to withstand stress caused by the higher centrifugal forces.



The design workflow for an electric motor must comprise all of these internal and external components.

However, this would increase the flux leakage in the rotor itself, causing reduced torque and power. An option to address this reduction is to increase the current in the windings (but only if higher current is available from the battery and electronics system). This solution would intensify losses and reduce efficiency, and was not acceptable to the customer. It was therefore necessary to redesign the entire engine to comply with all requirements.

Fortunately, the EM-motive simulation workflow can be flexibly adapted to analyze the requirements for a specific engine, simulate all the dynamic interactions between the components, and present the customer with a solid understanding of the trade-offs for each design decision. The workflow provides the foundation to determine the best compromise for often contradictory goals.



The three phases of the workflow are iterative as the designs are optimized.

A Workflow for Digital Exploration

During the procurement phase, using ANSYS optiSLang workflow connected to CAD and employing specialized electromagnetic–thermal software, the design engineers have the freedom to explore possible variations and their tolerances to fulfill customer requirements. They can then provide a fast answer so the customer will know if the requirements can be met with available motors or if new motor development is needed.

Through a set of iterative phases in which additional requirements are added, a new motor is designed and optimized using ANSYS simulation software in all the relevant physical domains. A shared interface with the ANSYS Simplorer systems simulator helps them analyze the influence of power electronics on the motor. Because there is a bidirectional interface between ANSYS DesignModeler and the CAD system, engineers can create parameterized models of auxiliary geometries, such as the housing, and integrate them into the system design. The ANSYS tools allow the designers to use the results of one type of simulation as a boundary condition for another. They can then use forces from an electromagnetic simulation with ANSYS Maxwell as initial data for a structural mechanical simulation with ANSYS Mechanical. Using the various ANSYS tools integrated through ANSYS Workbench makes it possible to create a completely coupled simulation of the electromagnetic, mechanical, thermodynamic and acoustic domains.

With these parametric workflows in place, all important physical domain sensitivity studies within the relevant design space, as well as tolerance determination, can be conducted. The engineers can add further optimization loops, but because of the conflicting character of many discipline goals and constraints, and because of the need to quickly check the motor behavior on a systems-simulation level, reduced-order models (ROMs) must be extracted. Using the integrated equivalent circuit extraction (ECE) toolkit within ANSYS Maxwell or ANSYS optiSLang's data-based ROM generation, the team can extract reduced models for an overall system simulation.

> “The company developed a design workflow that incorporated simulation throughout to account for the dynamic interactions between the components.”

Systems Modeling

These reduced-order models can be coupled in ANSYS Simplorer to create a complete system simulation. Again a parametric workflow is built within optiSLang and, optionally, other third-party models can be integrated, such as a transmission model or a complete vehicle model. At this point, the engineers might perform a system optimization loop to analyze the interactions between the components by varying parameters such as those for the controller.

Finally, to make the model interchangeable with additional engine components designed by outside parties, the designers use the industry-standard functional mock-up interface (FMI) to create models of the individual components, called functional mock-up units (FMUs). These FMUs are created with third-party software and can easily be exchanged while maintaining IP confidentiality: Since they contain only standardized inputs and outputs, the product-specific know-how is only accessible to the manufacturer. Another advantage of FMUs is that they can be imported into all current software packages for system simulation and can describe, for example, the behavior of the e-machine as a single component in the simulation landscape of a customer or development partner.

Understanding the Options

The final challenge is to present the optimized designs so that the customer can clearly understand the different design choices and their trade-offs. EM-motive developed a single radar diagram that transforms all performance indicators into dimensionless variables using the requirements as standardization values. It includes all domains and their requirements, further highlighted with a colored pie chart in the background, to clearly represent the domains. All points that are located outside of the 100 percent reference circle meet the design requirements. Interactions between physical domains are also easily depicted in the diagram. If, for example, a design should be revised to improve acoustics, the mostly negative effects on efficiency are plainly shown. The chart provides a comprehensive understanding of the strengths and weakness of each redesign and how it fulfills (or doesn't fulfill) their unique requirements.

Engine design, like many complex processes today, requires a collaborative, systemic approach to be successful. EM-motive's systemic approach to engine design integrates the ANSYS parametric simulation environment and an innovative presentation method to ensure that their automotive manufacturing customers can develop the next generation of hybrid and electric vehicles within challenging time and cost constraints.

This article was adapted from an interview by the editorial team of the CADFEM Journal.

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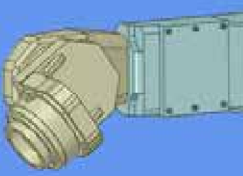
ANSYS DISCOVERY LIVE: *Real-Time Simulation Revolution*



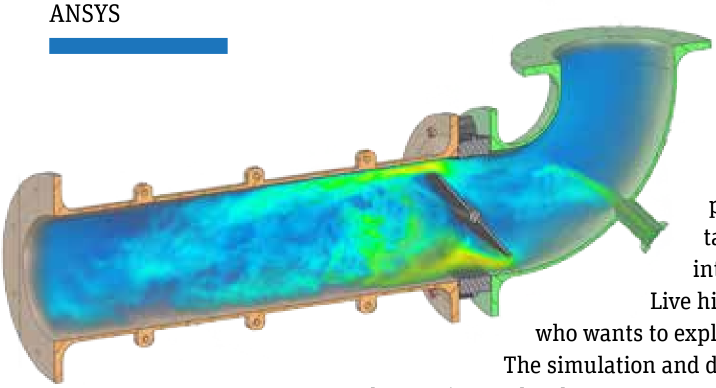
With the revolutionary new ANSYS Discovery Live solution, simulation is no longer a matter of hours or days — it is instantaneous. Engineers can start seeing simulation results in seconds after importing a geometry, with no need for a high-performance computing system. That is because all the computing is handled by the graphics card (GPU), which has thousands of processors running in parallel. Without pausing the simulation, they can change the design and physics and immediately view the results. This interactivity and instant feedback lets engineers experiment with more variables early in the digital exploration stage of the design process, which is vital to developing successful products in a highly competitive market.

By **Justin Hendrickson**, Director, Product Management, ANSYS

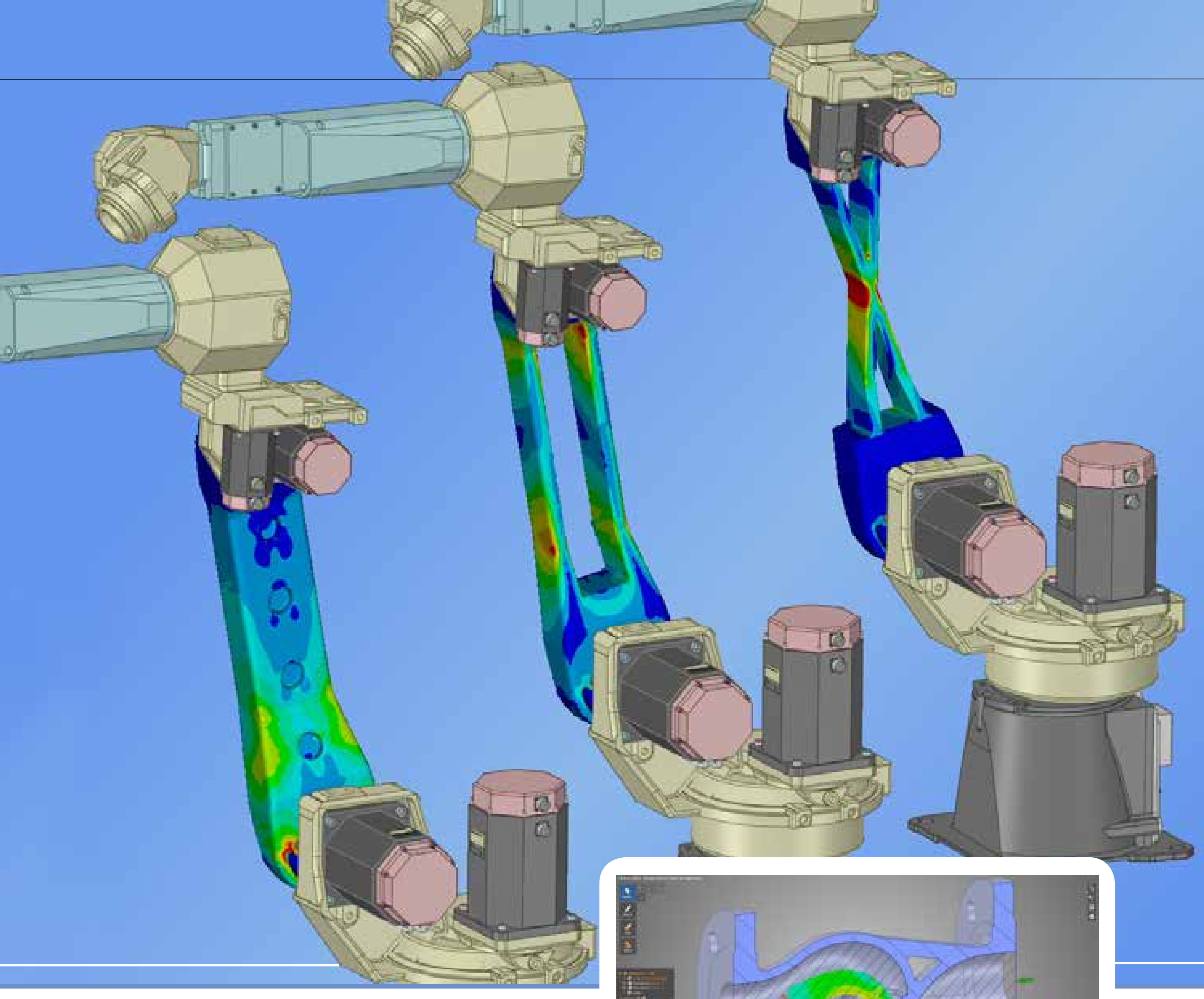
For the first time, engineers can explore design options using interactive physics in real time. A revolutionary simulation solution called ANSYS Discovery Live enables early design exploration and virtual experimentation in fluid, thermal, structural and modal applications. It makes simulation faster and easier than ever by reducing setup, solving and post-processing time to near zero.

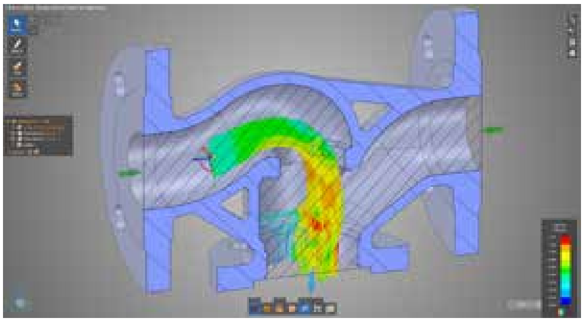
ANSYS Discovery Live is intended for engineers who are not full-time simulation analysts. It enables them to concentrate on product design and physics while the simulation takes care of itself. Ease of use, speed and interactivity are key features that make Discovery Live highly valuable to the non-expert simulation user who wants to explore the possibilities of many design options.

The simulation and design exploration is truly "live": The simulation changes instantly whenever an engineer alters the conditions, without pausing or restarting the process. The effect is the same as experimenting with the design in real time. Engineers can make decisions to switch between physics, modify geometry on the fly and change the way results are displayed, all live.



Engineering insights and trends are instantaneous, regardless of changes to boundary conditions such as flow rates, material types and inlet pressure.





The user can choose the way results are displayed, such as this streamline representation of gas flow through a pipe.

GPUs Make Real-Time Simulation Possible

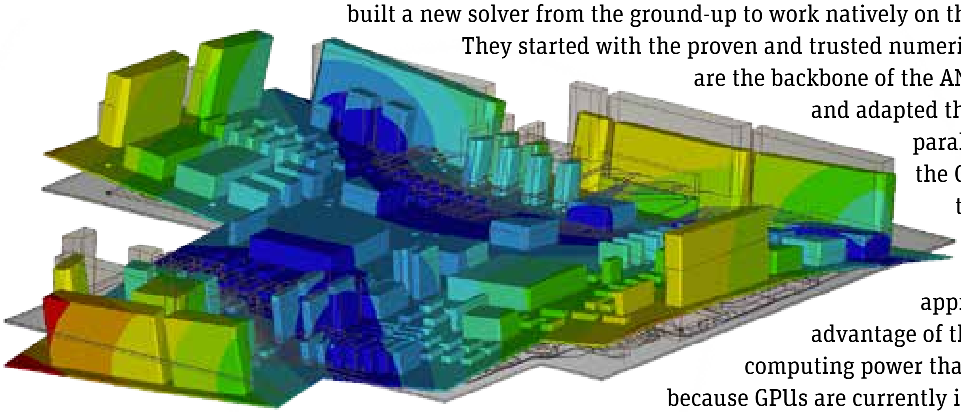
Discovery Live is possible due in part to the dramatic increase in computational power provided by graphical processing units (GPUs), which now exceed the power of central processing units (CPUs). The newest GPUs can approach supercomputing capacities and speeds, so simulations can be completed in seconds instead of hours. GPUs have an order of magnitude more compute power than CPUs. A $500 GPU card today has thousands of processors running in parallel; a similar CPU card has eight. While individual CPU cores are somewhat faster than GPUs, ANSYS decided to take advantage of the overwhelming improvement in compute power — resulting in a thousand-fold speedup in time — to obtain simulation results in seconds instead of minutes, hours or days.

“I was blown away by the speed and ease of use of Discovery. The time to complete an analysis is on the order of minutes as opposed to hours. You will be able to perform your first analysis in less than 15 minutes.”

— **Travis Jacobs,** Founder & Principal, Jacobs Analytics

Writing Software for Massively Parallel Solvers

Software written for CPUs will not run on GPUs automatically. ANSYS engineers built a new solver from the ground-up to work natively on the GPU architecture. They started with the proven and trusted numerical methods that are the backbone of the ANSYS product line and adapted them to the massively parallel architecture of the GPU. This involved the invention of new, proprietary algorithms and approaches that take advantage of the tremendous computing power that GPUs provide. And, because GPUs are currently improving faster than Moore's law predicts (while CPUs are evolving more slowly), basing Discovery Live on GPUs ensures speed and computation improvements for many years to come. Another key was adapting ANSYS SpaceClaim as the platform for Discovery Live. Because Discovery Live includes all of SpaceClaim's tools for creating and modifying geometry, engineers can take any 3-D model and not only simulate it, but also change it, all while the simulation is running. As soon as a modification is made, the result instantly updates, with no re-meshing involved. For simulation to be a driving force in 3-D design, it is critical that a designer be able to make edits to improve a design within the simulation itself.



A 1,300-part modal simulation is solved in 30 seconds.

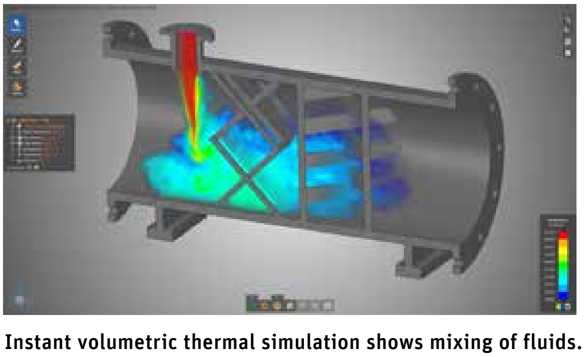
"This is by far the fastest, easiest and most intuitive tool I've seen for CFD. Starting with a parametric model, skipping the mesh and watching it steady up in real time is really something special. Being able to modify the components in real time speeds up iteration intervals in a way I haven't been able to calculate."

— **Waylan Elmenhurst**, Founder and Principal, 4D RD&D

Model Complexity is No Longer a Factor

With Discovery Live, running quick structural simulations of an entire engine block, complete with cooling channels and tens of thousands of faces can be done in a matter of seconds. The user simply has to choose a material; apply a load to, for example, the piston cylinder faces where combustion will take place and generate a lot of force; and see the stresses throughout the entire 3-D volume of the engine in seconds. They can even animate the simulation deformation results with a simple click.

How can a complex engine block with tens of thousands of faces be solved so quickly? The answer is that the complexity of the shape is not a significant factor in solve time. Simulation in Discovery Live depends primarily on the volume of the geometry being solved, not its complexity.



Instant volumetric thermal simulation shows mixing of fluids.

Gaining Flexibility with Little Loss of Accuracy

Discovery Live enables the user to choose higher speed or higher fidelity for a given simulation. In effect, this

Speed of Discovery Live
ansys.com/speed

“I never thought I’d be able to do CFD modeling unless I pursued a higher level engineering degree. I was able to complete structural simulations in Discovery Live after tinkering with it for just a few hours. The intuitive UI made it easy for me to utilize which streamlined my solution process.”

— **Olivia Lim**, Materials/Structures Engineer, Airloom Energy

sets the size of the smallest feature that will be resolved and allows the user to make the trade-off between simulation speed and fidelity.

The interactivity and speed of Discovery Live provides engineers with unprecedented flexibility to explore design options very early in the development process. This flexibility encourages investigation of many more possibilities in a short time, potentially uncovering new or breakthrough ideas that can then be refined and further developed. Discovery Live provides directional solutions — indications that changing a certain parameter or geometric feature moves the design in the desired direction. Once a promising design is identified in Discovery Live, engineers can seamlessly export it to ANSYS Mechanical, ANSYS CFD or ANSYS AIM software to run simulations for high accuracy and higher-fidelity results.

Discovery Live can easily switch between physics — from the external airflow around a vehicle to the mechanical stresses on the same vehicle — in seconds.

Seeing is Believing

With Discovery Live, ANSYS takes simulation in a whole new direction that will enable all engineers to benefit, no matter their level of expertise. The ability to see simulation results almost instantly is a quantum leap in how engineering simulation will be employed in the future. Real-time results that were never before possible, when utilized early in product development, save costs later, when design changes become exceedingly expensive. Better still, leveraging the tool’s interactivity, users can experiment with more design options. Extensive early experimentation can uncover novel designs that may have been missed using traditional processes, resulting in breakthrough products. That is why it’s called ANSYS Discovery Live: For the first time, every engineer will have the power of live experimentation to help them discover and unlock the next big idea.

THE FOUR KEY STRENGTHS OF DISCOVERY LIVE

1) **SPEED.** Simulation is so fast it seems “live.” The computational power of GPUs coupled with an efficient architecture from ANSYS makes this speed possible.

2) **EASE OF USE.** Meshing is eliminated and the software makes all simulation setup decisions so the user can concentrate on the physics and not on the solver.

3) **NEW METHODS.** New simulation methods allow for simulation of dirty CAD geometry or faceted data such as an STL file. These approaches mean that model complexity will not slow down the solve time.

4) **INTERACTIVITY.** Interactive functionality enables engineers to change physics, geometry and result displays on the fly, allowing for exploration of ideas as fast as they occur.

MEANINGFUL RESULTS

The performance of an asphalt plant depends upon the interaction of many different processes. Astec has made substantial improvements in its ability to accurately simulate these different processes, generating large quantities of disparate data whose impact on the design issues at hand is often difficult to understand. Astec brings meaning to this data by combining results from different simulation tools and different design alternatives. Animations, graphs and explanatory text are merged into a single composite image using ANSYS EnSight. This gives the decision-maker everything he or she needs to know to improve product performance.

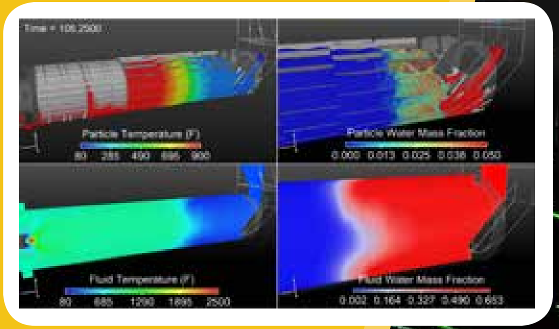
By **Andrew Hobbs**, Chief CFD/DEM Engineer,
Astec, Inc., Chattanooga, USA

Astec Industries continually works to improve the efficiency of aggregate dryers for asphalt production to reduce energy consumption and save energy costs for customers in this growing industry. Direct observation of the dryer drum in operation is difficult, so simulation offers the best opportunity to experiment with new designs. Astec provides a complete line of continuous and batch mix asphalt equipment, including rotating drum aggregate dryers that dry hundreds of tons per hour of wet aggregate rock to ensure that the rock will bind with liquid asphalt. Inside the drum, the aggregate is kept in motion by shaped scoops, called flights, that produce a veil of falling wet material that is heated by products of combustion from the burner. The company's ability to simulate such complex products and processes has vastly increased due to a combination of the wide array of increasingly accurate physical models, the ability to merge simulations of different types of physics to better understand reality, design exploration tools that automate the process of investigating a design space, and high-performance computing (HPC).

After successfully simulating a complex product, the simulation engineer is often left with the challenge of filtering and organizing the results to present the most relevant and meaningful information to the engineers and managers who make design decisions. Astec addresses this challenge by using ANSYS EnSight post-processing software to combine multiple types of results from, for example, different software packages, different physics, different design alternatives and different operating conditions to demonstrate interaction and shed light on the appropriate design issues. Using EnSight, simulation users can combine relevant results into a single image that makes it easy to understand how a product can be improved.

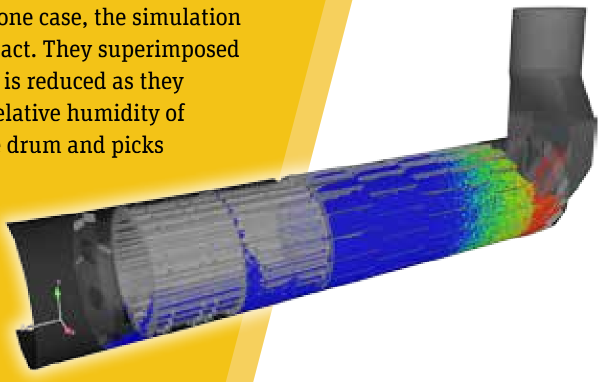
Presenting Results of Aggregate Dryer Simulation

The performance of Astec's aggregate dryers depends upon the operation of the burner that heats air entering the dryer, the flow pattern of the air through the dryer, the temperature and moisture content of the air in various locations of the dryer, and the movement of particles inside the dryer as driven by the flights. Astec uses ANSYS Fluent software to simulate the burner and flow of air through the dryer and EDEM discrete element modeling (DEM) software to visualize particle flow within the dryer. Over the past decade, the company has developed the ability to integrate particle and fluid simulation to deliver substantial increases in accuracy through bidirectional transfer of momentum, mass and heat between the particle and liquid phases. Both simulations generate large volumes of information on the behavior of the particles and gases. When viewed in their raw state, the sheer volume of data often makes it difficult to interpret what can be done to improve the performance of the dryer.



ANSYS EnSight combines aggregate dryer simulation results, including particle temperature (upper left), particle water mass fraction (upper right), gas temperature (lower left) and gas mass fraction (lower right).

So Astec engineers use EnSight to combine the results of the two software packages into graphics that highlight how the effects of fluid flow and particle flow interact to determine the performance of various design alternatives. In one case, the simulation engineers combined two pieces of information for greater impact. They superimposed a plot that shows how the water mass fraction of the particles is reduced as they move through the drum on another plot that shows that the relative humidity of air increases as it moves in the opposite direction through the drum and picks up water vapor evaporated from the particles. Engineers also created a graphic that shows the temperature of the particles throughout the drum superimposed on an image that shows the temperature of the gas in the dryer. These graphics help design engineers understand how the particle and fluid flow physics combine to determine the performance of the dryer and guide design engineers to improvements that could increase performance and reduce energy consumption, such as directing particles toward areas where the gas is hotter and drier to ensure full utilization of all the burner's energy.



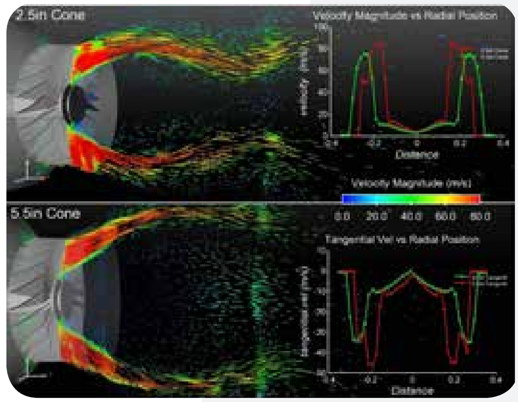
Presenting Burner Simulation Results

The burner that heats the air before it is driven into the dryer also has a big impact on energy efficiency. Astec simulation engineers use ANSYS Fluent CFD software to evaluate the performance of design alternatives. In one case, they used Fluent to compare the flow through the

> *"ANSYS EnSight software enables engineers to assemble the most relevant simulation results into composite images that maximize the insights provided to design decision-makers."*

burner with 5-inch and 2.5-inch cones. The Astec engineer summarized the performance differences by embedding two graphs over the flow analysis results. The first of these graphs compares the velocity magnitude (the combination of the axial, radial and tangential components) across the vertical axis for the two design alternatives; the second shows the maximum tangential velocity across the vertical axis for both options. Strategically positioning the most relevant results together with explanatory text led to a quick and successful design decision.

Aggregate dryers are critical to asphalt plant operation, and improvements in their efficiency translate directly into lower operating costs and reduced emissions over the dryer's operating life. Simulation provides deeper and more accurate understanding of dryers while avoiding the cost and lead time associated with physical testing.



ANSYS EnSight is used to embed charts of velocity versus radial position over flow analysis results.

ANSYS EnSight post-processing software enables simulation engineers to assemble the most relevant simulation results into composite images that maximize the insights provided to design decision-makers. The result is better design decisions that result in high product performance.

Introduction to ANSYS EnSight

ANSYS EnSight post-processor helps engineers make better decisions with their CFD, FEA crash, electromagnetics, DEM, rigid bodies and other simulation data.

This unique post-processing software:

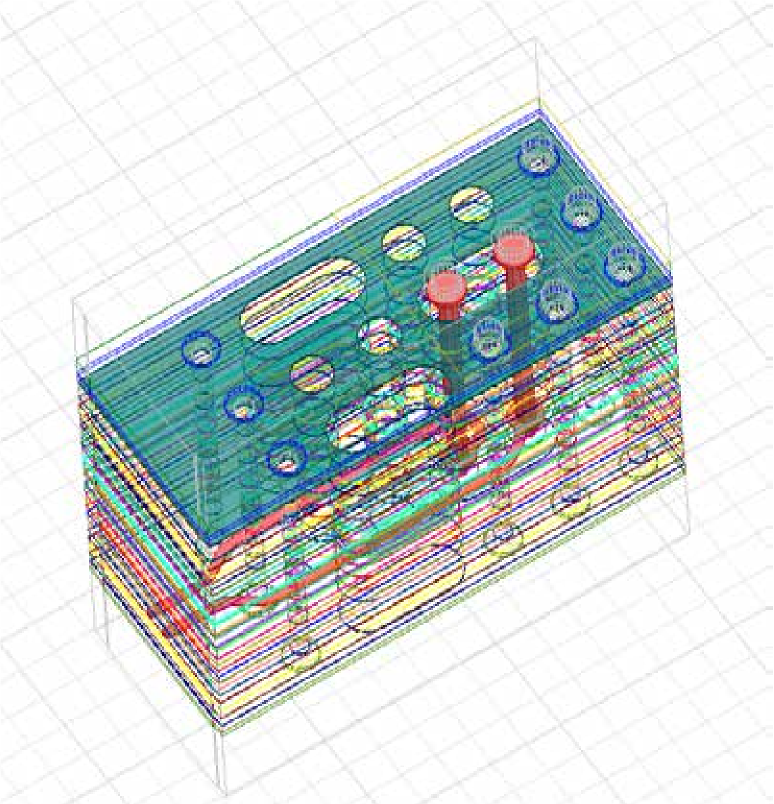
- Delivers extremely high-quality image and animation resolution with photorealistic output
- Reads up to 32 models at the same time so you can compare results from different data sources or solvers

It enables you to:

- Compare results between solvers or multiple runs of the same solver
- Perform fluid–structure interaction and optimization post-processing
- Input movies, photos and test data for assessment with simulation
- Use batch and interactive operations to run explorations during the day while EnSight completes batch post-processing overnight
- Display multiple viewports to provide large overviews and detailed views at the same time, or to study multiple models concurrently. Views can be linked for easy comparison across a number of perspectives
- Obtain efficient analysis and visualization for problems with a billion or more cells

As an optional feature, EnSight can accelerate the visualization and animation of large, complex transient simulations with huge datasets.

Analyze, Visualize and Communicate your Simulation Data with ANSYS EnSight
ansys.com/intro-ensight



GETTING ON BOARD WITH VIAS

By **Rick Rabinovich**,
Signal, Integrity Hardware Architecture,
Ixia, Calabasas, USA

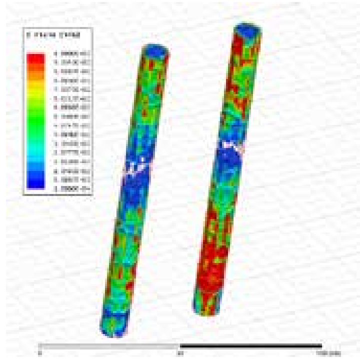
It is not uncommon to have a design fail in the field due to signal integrity issues even though simulation shows it should work perfectly because the as-manufactured product differs from the design definition. To avoid this problem, the signal integrity engineer needs to understand what will actually be delivered and use simulation to verify that the frequency- and time-domain performance will meet the design requirements. Simulation can be used to address the question of how differences between as-designed and as-built vias might degrade time- and frequency-domain performance of printed circuit boards (PCBs).

To reduce complexity to manageable levels, electronic products are nearly always initially designed based on a series of simplifying assumptions, such as that its geometry will match the perfect shapes defined in the CAD system. Of course, the manufacturing process cannot build these perfect shapes, at least not at a price customers are willing to pay, and the product still needs to meet performance requirements. Electronics theory is not much help because it addresses only the perfect world defined in a CAD system. Physical experiments can answer the question, but only at a very high cost and with the lead time required to build the product to varying specifications. Simulation, on the other hand, provides a practical solution by modeling both the perfect world and an unlimited number of more realistic scenarios to determine whether or not performance will meet expectations.

For example, PCB vias that interconnect traces between signal layers are almost always defined in a computer-aided design (CAD) system as solid cylinders. When the PCB is simulated, the simulation model typically matches the design definition. However, in the real world, PCB manufacturers generally build vias by drilling a hole through the PCB and electroplating the hole with copper deposited to a thickness of between 1 and 2 mils. The center of the hole may be empty or it may contain filling paste, copper debris or a combination of all of these. This raises a significant signal integrity concern — does the conflict between the design definition and the manufacturing process have a negative impact on the performance of the product?

The reason that engineers are not usually concerned about whether a via is a solid cylinder or a hollow barrel is the assumption that the skin effect will cause high-frequency current to flow in the outer surface of the conductor regardless of the conductor's geometry. The skin depth equation can be used to quantify the decrease in current density from the surface to the center of the conductor. This equation shows that for a frequency of 500 MHz, 99 percent of the current flows within less than 0.6 mil from the outer surface. This is well below the minimum 1 mil copper plating thickness specified in most board manufacturing processes. Does this mean that a PCB with vias shaped like hollow barrels will provide the same performance as a PCB with vias shaped like solid cylinders?

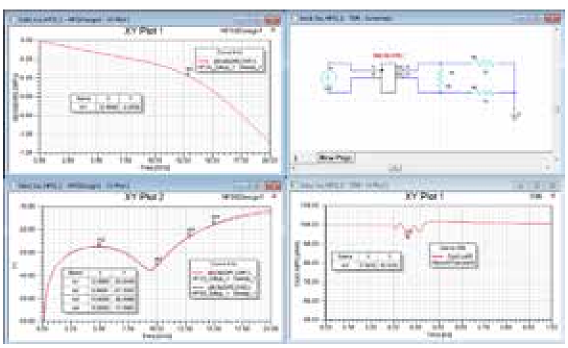
The question is complicated by the fact that PCB manufacturers



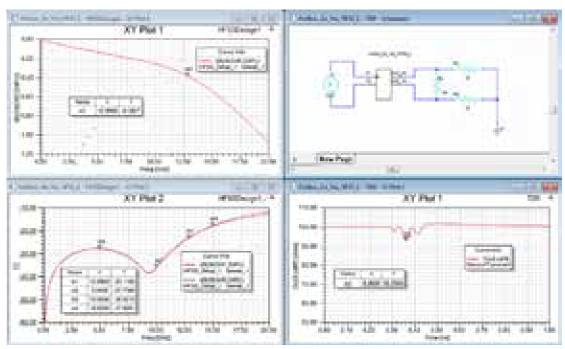
Most of the differential electric field is distributed along the external surface of the via with minimum internal field strength.

frequently cut out a via with a drill bit whose diameter is 1 to 3 mils larger than the specified finished hole size. Then the manufacturer plates the inner walls of the hole with 1 to 2 mils of conductive material, leaving the inside empty or filled with some nonconductive material. Due to imperfections in the plating process, some conductive material plating residue may even remain in the hole. For example, if a 10 mil via is specified, the result will be a barrel with an 11 to 13 mil outside diameter barrel and a 10 mil inside diameter.

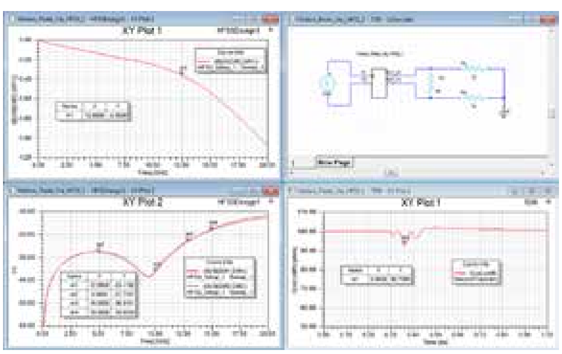
It is logical to assume that a larger-diameter barrel will increase the parasitic capacitance between the barrel and the adjacent power planes due to increased proximity between the outer barrel wall and the adjacent power plane edges. The amount of signal degradation is a function of the via structure and the characteristics of the surrounding area, such as the number and proximity of power planes, so it can't be quantified as a generic number or defined by rule of thumb. An impedance



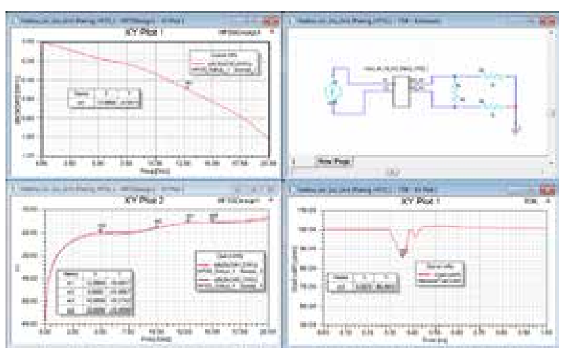
Simulation 1 frequency- and time-domain performance of a solid via



Simulation 2 frequency- and time-domain performance of an air-filled via



Simulation 3 frequency- and time-domain performance of a paste-filled via



Simulation 4 frequency- and time-domain performance of an enlarged-diameter via

"Whether the hole is empty, copper-filled or filled with paste, the frequency- and *time-domain performance* remain the same as long as the outer wall diameter *remains constant*."

degradation will cause increased return losses, which reduce the bandwidth of the channel, increase the rise time and cause closure of the eye.

Ixia engineers used ANSYS HFSS to simulate a PCB with four different via structures:

- **Simulation 1:** 10-mil outer diameter, solid cylinder matching the typical design specification
- **Simulation 2:** 10-mil outer diameter, 8-mil inner diameter barrel filled with air
- **Simulation 3:** 10-mil outer diameter, 8-mil inner diameter barrel filled with paste
- **Simulation 4:** 12-mil outer diameter, 10-mil inner diameter barrel filled with air. This represents the typical as-manufactured via when the design is specified as in simulation 1.

All four simulations were analyzed at 12.89 GHz, the Nyquist frequency of a 25 Gb/s Ethernet differential signal. These examples used a multilayer PCB structure consisting of a differential stripline pair located on layer 26, sandwiched between ground planes on layers 25 and 27. A differential port P1 comprising lumped ports was located between the pads and ground on the top layer of the PCB. The pads were placed on top of the vias (via-in-pad). The second differential port, P2, was a waveport located between the differential striplines in layer 26 and the adjacent ground planes.

	Insertion loss at 12.89 GHz	Return loss at 12.89 GHz	Differential impedance at lowest point
Simulation 1	−0.3835 dB	−23.0445 dB	92.535 ohms
Simulation 2	−0.3827 dB	−23.1192 dB	92.708 ohms
Simulation 3	−0.3630 dB	−23.1192 dB	92.708 ohms
Simulation 4	−0.5073 dB	−15.6847 dB	85.492 ohms

Simulations 1, 2 and 3 deliver similar results in terms of insertion loss, return loss and differential impedance as expected from skin effect theory. Simulation 4 has a higher insertion loss, lower return loss and lower differential impedance.

The simulation results shown in the table indicate that simulations 1, 2 and 3 deliver similar results in terms of insertion loss, return loss and differential impedance as expected from skin effect theory. Simulations 1, 2 and 3 also show similar differential impedance, ranging from 92.535 to 92.708 at their lowest point. On the other hand, simulation 4 has a higher insertion loss, lower return loss and lower differential impedance due to increased parasitic capacitance caused by the decrease in spacing between the barrel walls and the edge of the power planes. These results are especially noteworthy considering that simulation 4 best represents actual manufacturing practices.

In summary, whether the hole is empty, copper-filled or filled with paste, the frequency- and time-domain performance remain the same as long as the outer wall diameter remains constant. This is because 99 percent of the current flows through the outer surface of the barrel due to the skin effect. However, the signal integrity engineer needs to be aware that the common case where the as-built via diameter ends up 1 to 3 mils larger than the diameter specified may result in a significant performance degradation. The signal integrity engineer needs to consult with the PCB manufacturer to understand its manufacturing process. Simulation then can be used to investigate the performance of the as-manufactured design from a signal integrity standpoint before building the board.

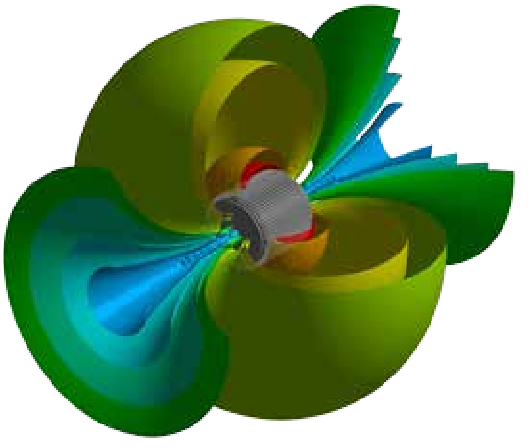
ANSYS HFSS Features
ansys.com/hfss

Simulation in the News

ANSYS 18.2 ENHANCES SIMULATION SPEED AND ACCURACY

Market Insider, August 2017

This latest release brings increased levels of accuracy, speed and ease of use — spurring more engineers to use simulation across every stage of the product lifecycle to more efficiently and economically design cutting-edge products. Highlights include advanced visualization and modeling for better antenna design; increased speed for more robust electronics design; new acoustics and topology optimization; faster, more detailed and accurate CFD models; integrating systems and failure analysis; and topology optimization and transient CFD for design engineers.



ANSYS ACQUIRES COMPUTATIONAL ENGINEERING INTERNATIONAL

Digital Engineering, July 2017

ANSYS has acquired Computational Engineering International, Inc. (CEI), developer of a suite of products that helps engineers and scientists analyze, visualize and communicate simulation data.

> *"By bringing CEI's leading visualization tools into the ANSYS portfolio, customers will be able to make better engineering and business decisions, leading to even more amazing products in the future."*
>
> — Mark Hindsbo
> Vice President and General Manager, ANSYS

SYNOPSYS, ANSYS INTEGRATE PRODUCTS

EET India, June 2017

By partnering, the companies will enable customers to accelerate the next generation of high-performance computing, mobile and automotive products. The partnership will tightly integrate ANSYS' power integrity and reliability signoff technologies with Synopsys' physical implementation solution for in-design usage.

HOW MANUFACTURERS ARE DRIVING AUTOMOTIVE INNOVATION

Auto Tech Review, July 2017

Automotive systems are far more complex than ever and must meet government standards that regulate fuel efficiency and emissions. In addition, manufacturers face market demand for new technologies and innovations, like electric and hybrid cars as well as autonomous vehicles. In this environment, engineering simulation is indispensable.

ANSYS SELF-HEAT, POWER INTEGRITY AND ELECTROMIGRATION SOLUTIONS ENABLED ON SAMSUNG'S LATEST FINFET TECHNOLOGY

CNC Times, May 2017

Certification of self-heat for 10 nm chip technologies and enablement of electromigration (EM) and voltage drop (IR) for the latest 7LPP/8LPP technologies reduces customers' design risk while providing robustness and reliability to their high-performance computing, mobile and automotive applications.

THE FUTURE IS 8.8 BILLION MILES AWAY

ANSYS.com, July 2017

Self-driving cars may be the future of transportation, but the underlying technologies will require an estimated 8.8 billion miles of road tests before they are ready. These road tests would require more than 26,000 years, so simulation is required to deliver autonomous vehicles safely to market in a reasonable time.

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KRONO-SAFE, ANSYS PARTNER TO ACCELERATE AVIONICS SOFTWARE DEVELOPMENT

Avionics, June 2017

To build safer airplanes while optimizing fleet maintenance and cost, new aerospace computers must be built to handle both traditional safety-critical control and command applications, as well as modern maintenance and monitoring capabilities. KRONO-SAFE's integrated real-time operating system platform, ASTERIOS®, with ANSYS' embedded software, ANSYS SCADE Suite, provides aerospace customers with a real-time integration flow suitable for safety-critical avionics multirate applications on single or multicore platforms.

STRATEGIC VALUE OF HIGH-PERFORMANCE COMPUTING FOR INNOVATION

Open Access Government, August 2017

Wim Slagter of ANSYS highlights the importance of a sustained investment in high-performance computing (HPC). With HPC, engineers and researchers can explore highly detailed simulation models that provide valuable insight into product behavior.

> *"HPC is without doubt a key enabler of scientific and industrial innovation today."*
>
> — Wim Slagter
> Director HPC & Cloud Alliances, ANSYS

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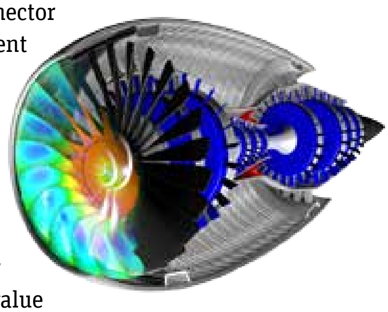
ANSYS BRINGING SIMULATION TO THINGWORX'S IOT AND DIGITAL TWINS

Engineering.com, May 2017

The development of a connector between the ANSYS platform and the ThingWorx® Industrial Internet of Things (IoT) platform from PTC will enable customers to transform raw data into new forms of actionable intelligence. The connector will integrate intelligent digital simulation models with products as they exist and operate in the real world. This will open up new opportunities for companies to create value by optimizing operations and maintenance, and then integrating them into their product development processes.



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ANSYS, SAUDI ARAMCO AND KAUST SHATTER SUPERCOMPUTING RECORD

Trade Arabia, July 2017

Saudi Aramco, King Abdullah University of Science and Technology (KAUST) and ANSYS have set a new supercomputing milestone by scaling ANSYS Fluent to nearly 200,000 processor cores. High computing speed enables organizations to make critical and cost-effective decisions faster and increase the overall efficiency of oil and gas production facilities.

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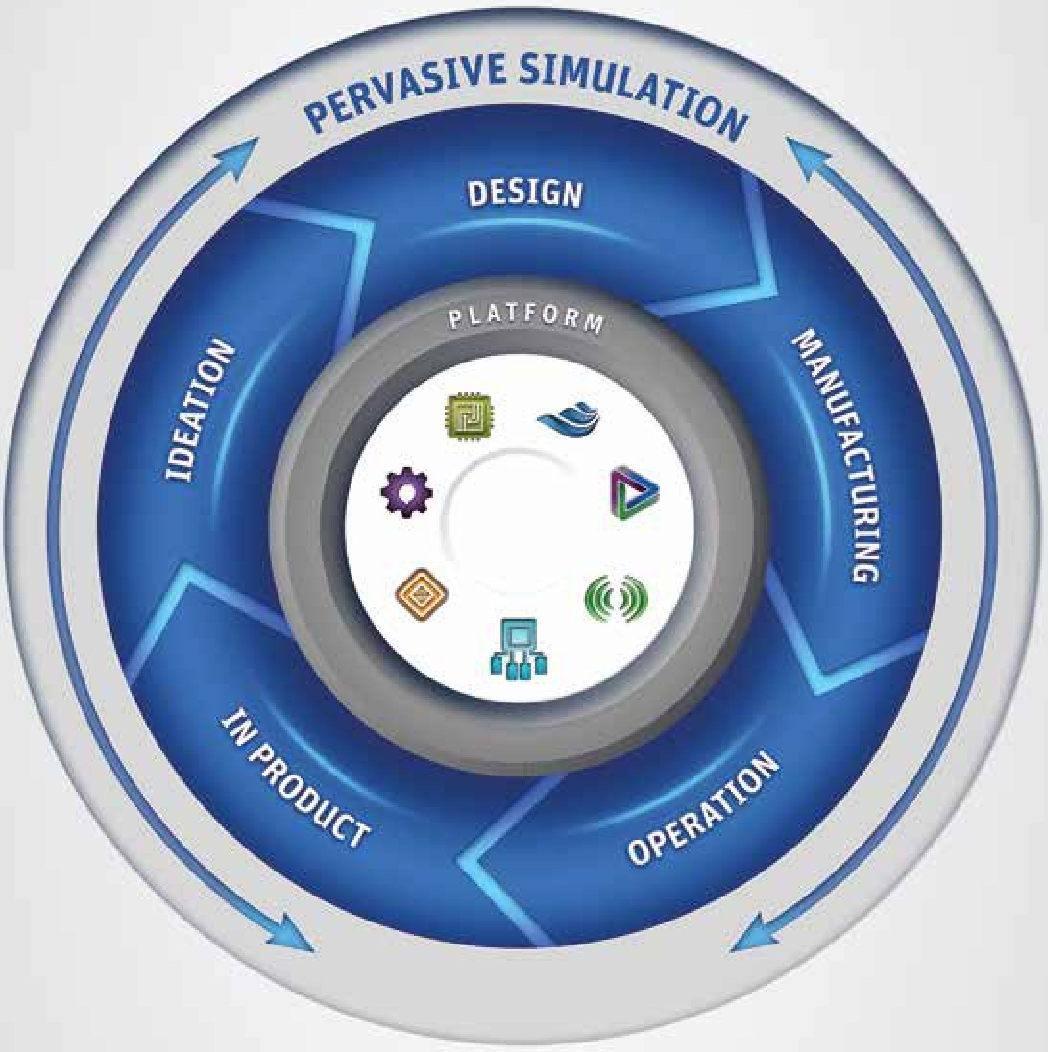
Simulate. Iterate. Innovate.



ANSYS

Product development is transforming. Engineering simulation is evolving with it. With ANSYS, pervasive engineering simulation extends across the product development process — from ideation to design to manufacturing to operations.

Learn more at ansys.com/pervasive