ANSYS

Excellence in Engineering Simulation

ADVANTAGE

SPECIAL ISSUE | 2019

FOCUS ON

AEROSPACE & DEFENSE

Implementing Digital Engineering to Thrive

By **Paolo Colombo**
Global Industry Director
Aerospace & Defense, ANSYS

The aerospace and defense (A&D) industry is at a pivotal crossroads with rising operating costs, an exponential number of new technologies and a growing skills gap.

Strategic documents such as "Flightpath 2050" by the EU commission and "Destination 2025" by the U.S. Federal Aviation Administration assert the need for breakthrough technologies to improve fuel efficiency and reduce emissions. Geopolitics is driving an increase in defense spending as nations seek to maintain their technological edge. A new space race has begun with emerging nations and disruptors challenging the status quo. In an era of fewer new aircraft programs, companies are seeking to optimize maintenance, repair and overhaul (MRO) and sustainment operations. And with an eye to the future, next-generation autonomous and highly connected urban air mobility solutions are beginning to emerge.

It is therefore no surprise that Accenture research found that 90% of aerospace and defense companies believe they have entered an era of exponential change [1].

All these factors present the industry with a mind-boggling level of complexity that must be delivered without compromising the industry's incredible record on safety. In the face of this increasingly challenging and competitive environment, the industry must digitally transform to deliver the unprecedented level of innovation needed.

Indeed, "97% of aerospace and defense executives say they are willing to digitally reinvent their business and industry" [2]. However, "just 7% of A&D companies have fully integrated digital threads that impact the strategy and/or work of multiple teams" [3].

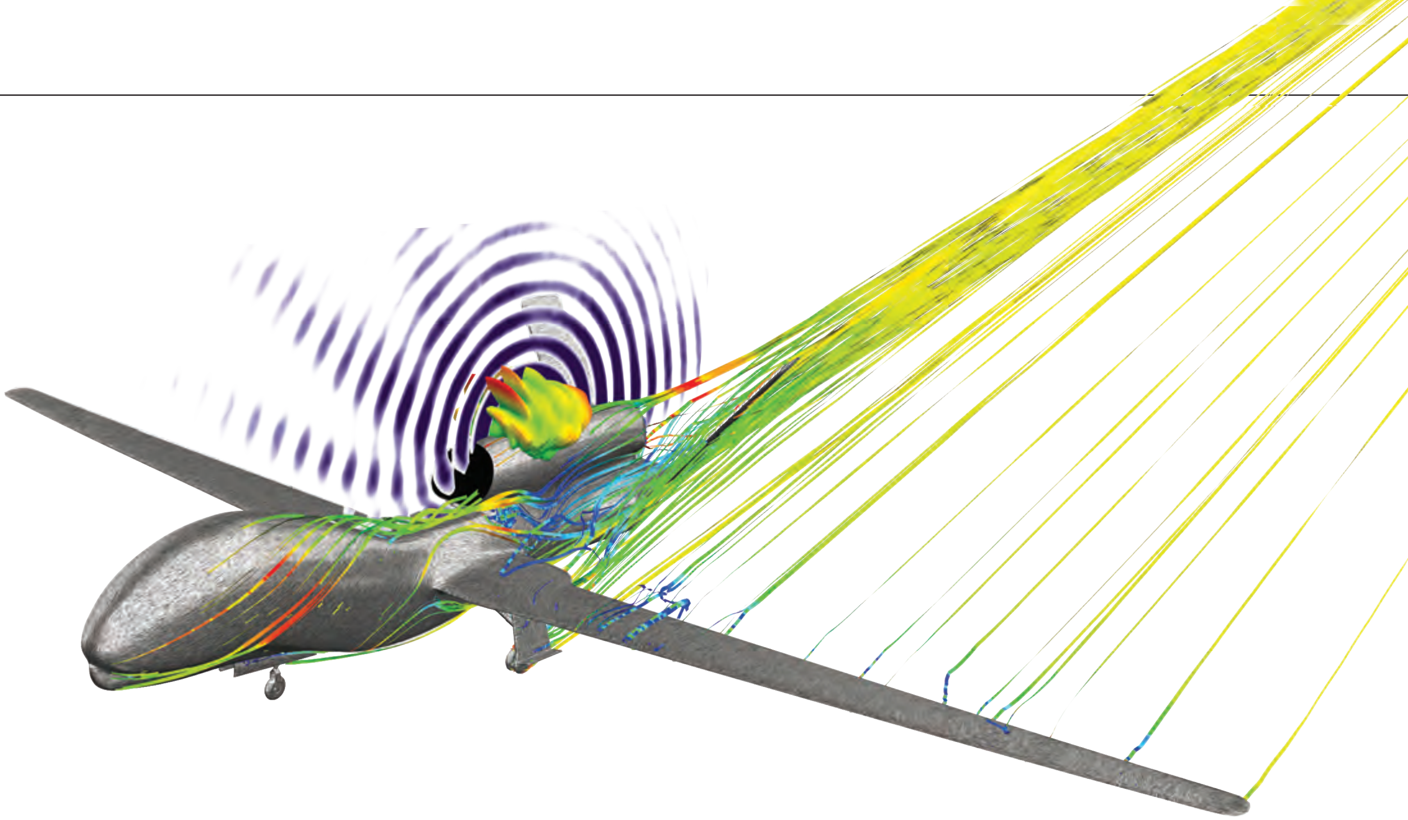
> ***"The only way to stay competitive is to embrace the exponential innovation rate and the changes that accompany it."***

This is a gap that simulation can help companies overcome. ANSYS is uniquely positioned to help accelerate digital transformation through its comprehensive multidisciplinary simulation solutions, integrated and open platform, ecosystem, and skilled workforce. Building on a 50-year history of delivering customer success, ANSYS solutions allow the creation of a digital thread from program and product concept through development, manufacturing, testing, production, training, sustainment and acquisition that delivers innovative technology faster and at substantially lower cost. We call this pervasive simulation.

This special edition of *ANSYS Advantage* shows how companies, from innovative startups to the established giants, apply pervasive engineering simulation solutions so they can succeed in their key business initiatives and thrive in the market.

Avio Aero (a GE Aviation business) demonstrates the impact of digitalization of engineering processes by revealing how it applies the concept of the "digital thread" to follow designs from their earliest ideation through real-world operation. A digital thread is a closed-loop process that feeds operating data back to engineers to accelerate development, increase staff productivity and improve product quality. Learn how Avio Aero uses digital threads on page 2.

The unpredictable cost of fuel and the ambitious emissions and noise reduction targets set by the Clean Sky and CLEEN initiatives are driving the demand for more fuel-efficient and environmentally friendly aircraft. The industry is seeking revolutionary propulsion systems, lightweighting methods and improved aerodynamics.



MagniX (page 8) reveals how the company applied simulation to reach its goals.

Emerging trends in urban air mobility, commercial drones and persistent connectivity are transforming the aerospace industry. The aircraft of the future will be more autonomous, connected and electric. They will require configurations and propulsion systems that are radically different from past versions, with little design precedent. Engineering simulation is the only way to explore these revolutionary design spaces and rapidly innovate with less cost and risk. The success stories of Embraer and Optisys are included on pages 22 and 26.

To capitalize on increasing global defense spending, defense companies must digitally transform to deliver new, advanced warfighter technologies as quickly as possible. Raytheon (page 38) and Kontron (page 34) accomplished this by leveraging the power of multiphysics.

With fewer new aircraft programs, rising operational costs and increasing scrutiny of the efficiency of defense program sustainment, A&D companies are focused on optimizing MRO operations. The prevalence of sensors, connectivity and analytics is enabling the digital transformation of these operations, leading to improved efficiency and direct cost savings through predictive maintenance and analysis of failure during operation. Learn how Lufthansa Technik (page 42) can extend the time before overhauling (TBO) of the engines they maintain, and how the U.S. Air Force (page 46) saves millions of dollars by analyzing operational failures.

"The aerospace and defense industry is at a pivotal crossroads."

The A&D industry also must explore revolutionary ideas in areas where there is no sound experience, while maintaining the highest standard of safety that the industry requires. Vector Space (page 52) and Hindustan Aeronautics Limited (page 49) use simulation to dramatically accelerate their testing and certification phases, reducing the number of expensive and time-consuming physical tests while rapidly gaining experience of the behavior of their complex new systems.

The only way to stay competitive is to embrace the exponential innovation rate and the changes that accompany it, including the increasing complexity of the products being designed. Digitalization of engineering is one way companies can cope with this change. As the global leader in simulation, ANSYS helps A&D companies by deploying simulation-based digital transformation to the most critical operational and technological initiatives within the industry.

References

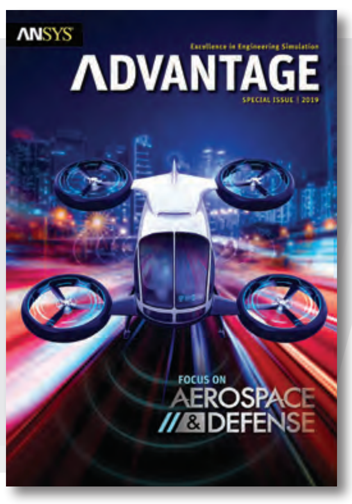
[1] Accenture, Accelerating Through Digital Turbulence: Technology Vision for Aerospace and Defense 2017
[2] Accenture, Seizing the Digital Opportunity in Aerospace & Defense 2018
[3] Accenture, The Digital Thread Imperative 2017

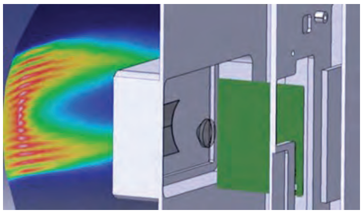
Table of Contents

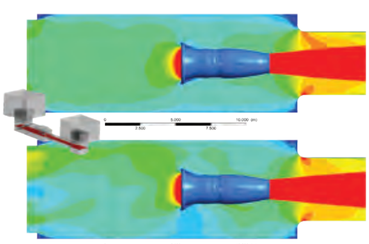
Focus on Aerospace and Defense

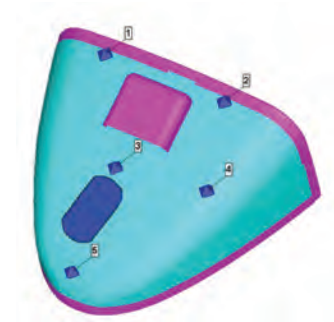
ABOUT THE COVER

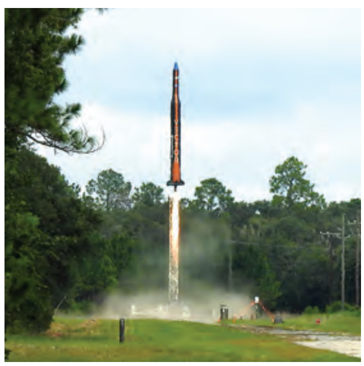
The only way aerospace and defense companies can stay competitive is to embrace the exponential innovation rate and the changes that accompany it that include autonomy, electrification and next-generation design. Digitalization of engineering is one way companies can cope with this change.











Join the simulation conversation
ansys.com/Social@ANSYS

Welcome to *ANSYS Advantage*! We hope you enjoy this issue containing articles by ANSYS customers, staff and partners.

The Editorial Staff, *ANSYS Advantage*
ansys-advantage@ansys.com

Executive & Managing Editor
Chris Reeves

Editorial Advisers
Amy Pietzak, Tom Smithyman

Editorial Contributor
ANSYS Customer Excellence North America

Senior Editor
Tim Palucka

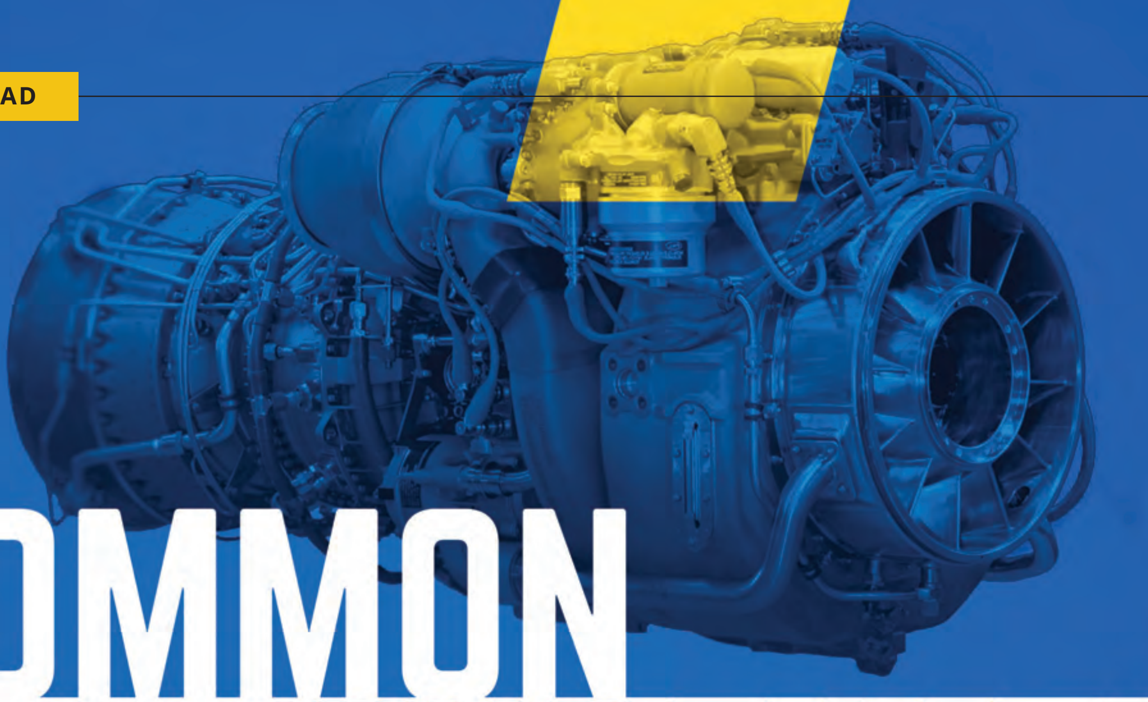
Editors
Erik Ferguson, Kara Gremillion, Mark Ravenstahl, Walter Scott, Terri Sota, Scott Nyberg

Art Director
Ron Santillo

Designer
Dan Hart Design

ANSYS, Inc.
Southpointe
2600 ANSYS Drive
Canonsburg, PA
15317
USA

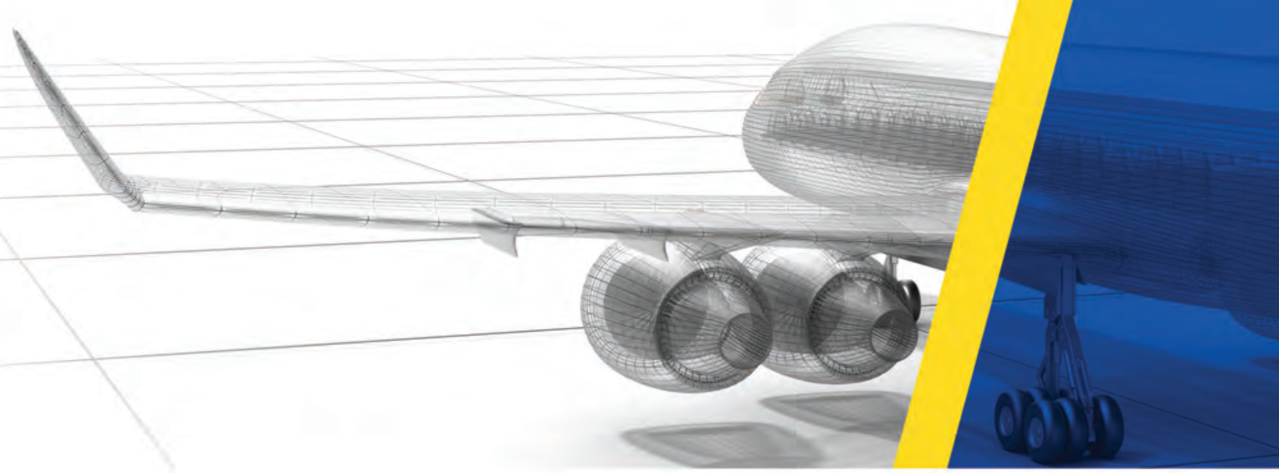
Subscribe at ansys.com/magazine



COMMON THREAD

Aerospace leader GE Aviation is pioneering an innovative concept: creating a "digital thread" that follows designs from their earliest ideation through real-world operation. By centralizing all data related to a specific design, the company is not only accelerating the pace of development and increasing staff productivity, but also significantly and consistently improving product quality. Even more exciting, soon digital twins will create a closed-loop process that feeds operating data back to engineers.

By Luca Bedon, Senior Engineering Section Manager
Avio Aero – a GE Aviation business, Turin, Italy



LUCA BEDON

> ***Pressured by new environmental and safety regulations, rising fuel costs and consumer price concerns, commercial airlines are demanding highly innovative product solutions — delivered faster than ever.***

Designing systems and components for commercial jet engines has always been a difficult task, characterized by engineering complexity, strict industry regulation and zero tolerance for product failures. Today, aerospace engineering is even more challenging.

Pressured by new environmental and safety regulations, rising fuel costs, and consumer price concerns, commercial airlines are demanding highly innovative product solutions — delivered faster than ever. In recent years, the number of days until delivery mandated by aerospace customers has decreased by an order of magnitude as jet manufacturers struggle to keep pace with market demand.

Avio Aero — a GE Aviation business and a global leader in manufacturing jet engine systems and components — realizes that meeting these growing demands can only be achieved by identifying and applying best-in-class engineering technologies. A user of engineering simulation for over 20 years, the business has recently increased the impact of this technology by training more people and expanding its applications beyond the engineering function.

With support from the Italian government's National Industry 4.0 program — aimed at maintaining the competitiveness of technology leaders like Avio Aero — today the company is at the leading edge of digitalization, pioneering new ways to gather, analyze and apply engineering data. The majority of the product development engineers in Turin, Italy, and in all the company's other sites are trained to use simulation. This creates a sense of shared ownership and collaboration that can lead to dramatic innovations.

This commitment to innovation positions the company for continued leadership, even as the business environment grows more and more challenging.

Digital Thread: A Cutting-Edge Concept

GE Aviation has pioneered an innovative concept called the "digital thread" — a common set of engineering and product performance data that is expanded daily and shared by all key stakeholders in the business.

What led GE Aviation to embrace this idea? The company recognized that, by making its engines more digital and more connected over time, it was generating and gathering a huge volume of performance data. In fact, data generated and collected from today's fleet of smart engines is growing exponentially compared to the traditional designs before 2010, in the "no digital" era. An extensive use of analytics, combined with physical models enabled by advanced simulation capabilities, would allow GE Aviation to get meaningful insights that could be employed to improve product performance and reliability, profitability, and customer-oriented solutions — optimized according to how engines actually operate.

Engineering simulation data plays a central role in the digital thread strategy at Avio Aero. Simulations of jet engine components and systems are numerically large — encompassing multiple physics, complex reactions and transient forces. Simulation was making a significant contribution to the speed, cost and quality of the company's product development processes, but Avio Aero recognized that the benefits of simulation would be amplified if all simulation data were collected and made accessible to all stakeholders.

It means that every future design benefits from the lessons of the past.

Today, for each product design, information is gathered at the earliest stages of ideation — and that data follows the design throughout its lifecycle, as the component is verified, tested, redesigned and released to the manufacturing function. Any design rework is simplified because all existing information related to that design is immediately available and unambiguously identified by the same part number. Costly and time-consuming repetitive handoffs have been eliminated. Anyone, anywhere in the business can see at a glance where each design stands and easily contribute to the product's ultimate success.

Increasing Data Availability and Access

Avio Aero calls this process "creating a single source of the truth," and the benefits cannot be overstated. Increased information access means that every single product design moves more quickly and cost-effectively through the development cycle, eliminating unnecessary redundancies and streamlining incremental improvements to that design.

But, equally important, it means that every future design benefits from the lessons of the past. Engineers conducting a new simulation can easily see if a similar study has already been carried out. They can start with accurate product geometries and operating parameters, based on what has worked — or not worked — in the past. This gives Avio Aero a critical competitive advantage as it meets tighter and tighter product delivery deadlines.

Closing the Loop via Digital Twins

The result of Avio Aero's digitized product development process is a virtual prototype that has been produced through collaborative engineering and is now ready for physical testing. Any physical test results are collected as part of the digital thread, impacting any rework on that product, but also becoming part of the company's general knowledge base.

What's next on the horizon is even more exciting. The next step is the creation of the product's digital twin, developed by partnering with the customer and placing sensors on an actual working product. When this is achieved, Avio Aero will be able to collect real-world operating data in near–real time. By applying the same physical conditions to its virtual prototype, Avio Aero can see the effects of long-term operation. This will enable the business to predict failures, schedule maintenance, order repair parts and otherwise improve each working product's performance over time.

Digital twins will also close the loop on the digital thread — creating, for the first time, a view of a product design's entire lifecycle, from earliest ideation through real-world operation. The insights gathered across this lifecycle will be available and accessible to every stakeholder within Avio Aero, impacting future designs and forming the foundation for high product performance for years to come.

TURNING SPECIALISTS INTO STRATEGISTS

Identifying and applying advanced technology, including simulation, has been critical in Avio Aero's move to digitalize its engineering efforts. But equally important has been the cultural change needed to support this initiative.

"Twenty years ago, everyone in the engineering function was a specialist, with a narrowly defined role," says Luca Bedon, Senior Engineering Section Manager. "For example, someone would learn to run a CFD simulation, and that's all they would do, all day. They didn't have a view toward the ultimate success of the product — because they didn't see what happened after they completed their isolated task."

According to Bedon, today the engineering team at Avio Aero has a completely different mindset. "We completely redefined the role of what we called 'specialists,' shaping a different organization based on a system mindset and showing everyone that they can contribute to the product's success," he explains. "We've trained half the team in simulation, so anyone can pick up a project and work on it. We've eliminated handoffs, increased ownership and given everyone visibility into the end-to-end product lifecycle.

"That has created a strategic perspective and a feeling that every employee is contributing to the shared success of Avio Aero," Bedon adds. "That's a big cultural change, but one that our employees have really embraced. They enjoy their work and believe they really are playing a key role in our top-level business strategy."

ANSYS: A Strategic Partner

An ANSYS customer for over 20 years, Avio Aero has relied heavily on ANSYS to help implement its vision of the digital thread. Since ANSYS is the acknowledged leader in simulation technology, it only makes sense for Avio Aero to leverage its advanced solutions as it creates a next-generation digital architecture.

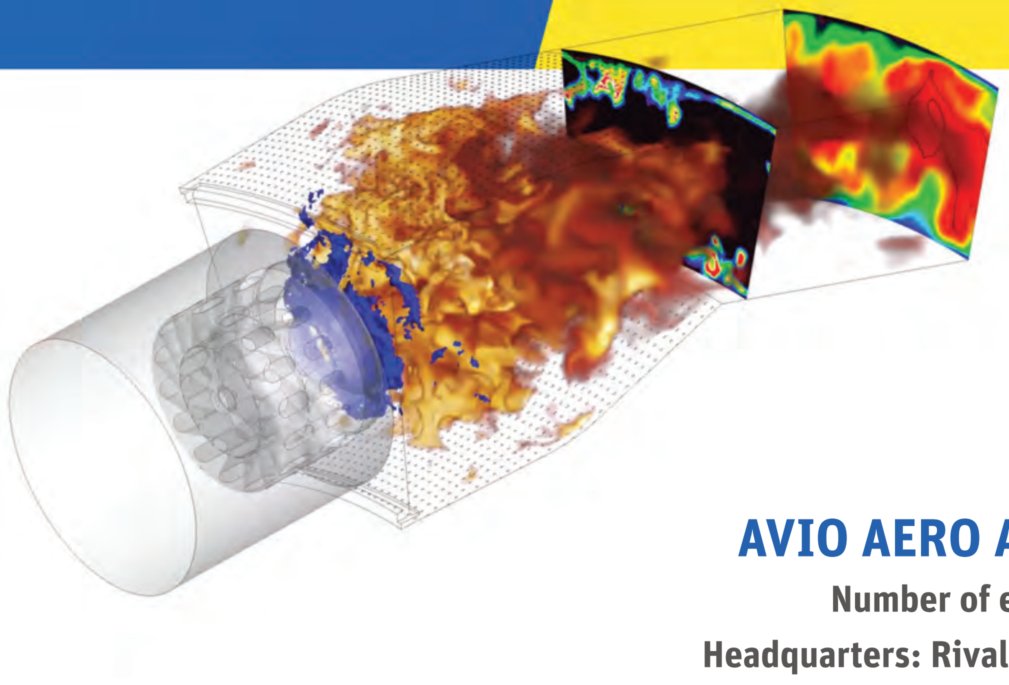
ANSYS has not only provided best-in-class simulation solutions that cross multiple physics and engineering functions, but it offers a unified platform that supports easy collaboration. ANSYS experts consulted with Avio Aero on the best ways to integrate ANSYS solutions with the company's data architecture, as well as its suite of in-house and third-party tools.

Avio Aero defined its vision of how engineers would work together in the future, and ANSYS helped the company achieve that vision. Over time, Avio Aero's relationship with ANSYS has evolved into a true strategic partnership.

Digitalization Takes Off

To meet growing customer demands, new environmental standards and stricter regulatory protocols, GE Aviation must support the development of the most innovative, high-tech jet engine ever produced. Realizing this goal means employing the most innovative, high-tech product development strategy. This rationale led GE Aviation to embrace the concept of an end-to-end digital thread that collects and leverages insights at every stage of the product lifecycle.

Not every company makes products as complex as jet engine systems, or competes in an industry as demanding as the global aerospace business. But every engineering team can benefit from the concept of the digital thread — a single source of data and a shared version of the truth for every product design. Making a commitment to gathering and leveraging simulation data speeds the development process, maximizes staff productivity, minimizes rework and ultimately improves product quality. This concept is taking off — and with good reason.



AVIO AERO AT A GLANCE

Number of employees: 4,800

Headquarters: Rivalta di Torino, Italy

Avio Aero
A GE Aviation Business

Engineering the Fully Electric Airplane

By ANSYS Advantage Staff

Electric cars have gradually found their way from our imaginations to our roadways in recent years. Initially starting with limited range, electric cars now offer ranges comparable to internal combustion-powered cars. Now, all-electric aircraft are on the horizon. Engineers at magniX employ multiphysics simulation to develop powerful electric motors for propeller planes that could revolutionize the short-haul and middle-mile flight industry, making it more economical and convenient to take a 30-minute flight rather than a 2½-hour drive and a 1½-hour flight instead of an 8-hour drive.

While electrification is a powerful driving force in most industries, aircraft propulsion has not been one of them — until now. In order to carry hundreds of people thousands of miles, large jet-powered planes are the only solution. However, the aerospace industry has benefited from the electrification initiative. Some components of aircraft have been made more electric in recent years — power generation management, passenger comfort, air pressurization, air conditioning and flight control, for instance — but electric propulsion aircraft have not emerged because there has not been an electric propulsion system powerful enough and light enough to power an aircraft.

Now, an entrepreneurial propulsion company called magniX, with locations in Redmond, Washington, and Gold Coast, Australia, is revolutionizing the aviation industry. Its goal is to enhance global prosperity through connecting communities by providing clean, low-cost, electric-powered air transportation. magniX is designing electric motors to power propeller planes capable of carrying from 8 to 20 people on flights of 650 miles or less. These direct flights will avoid major airport and connect people and communities that are currently just a little too far away, with low-cost, efficient air connections.

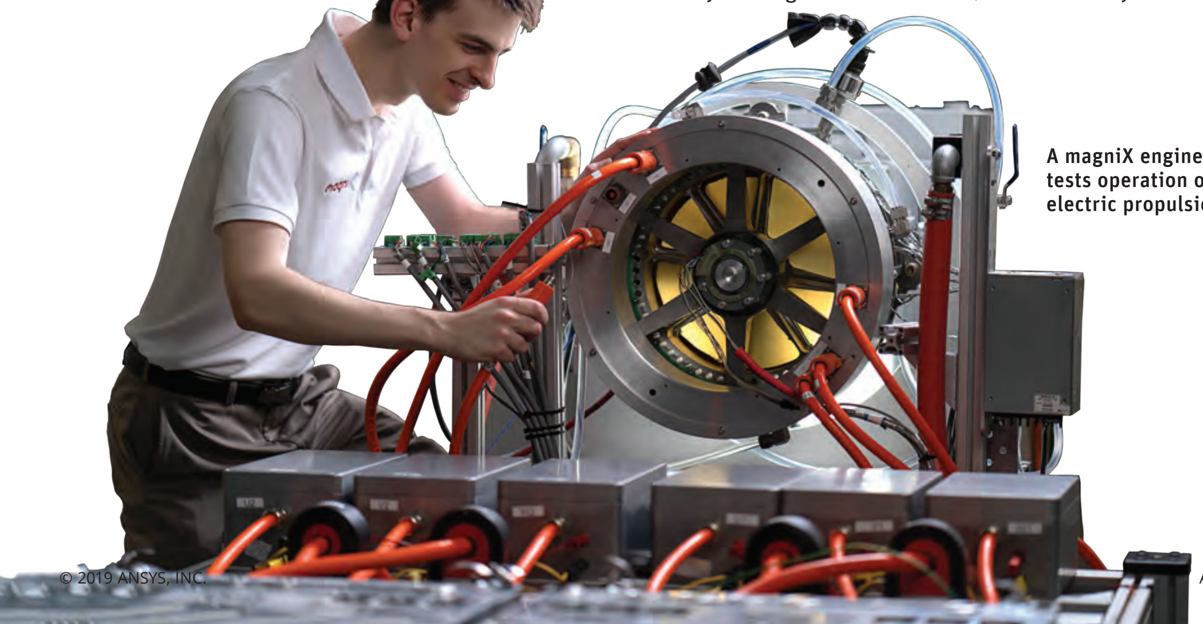
With plans to begin test flights on a variety of aircraft later this year, magniX engineers are using ANSYS structural, electromagnetic and thermal simulation solutions to design and test the robust, reliable electric motors needed to ensure aircraft safety and reliability. Because many of the regulatory aviation commissions worldwide that certify aircraft for commercial use hold ANSYS simulation data in high regard, using ANSYS solutions could help speed magniX electric-powered airplanes to the marketplace.

> **“magniX’s goal is to enhance global prosperity through connecting communities by providing clean, low-cost, electric-powered air transportation.”**

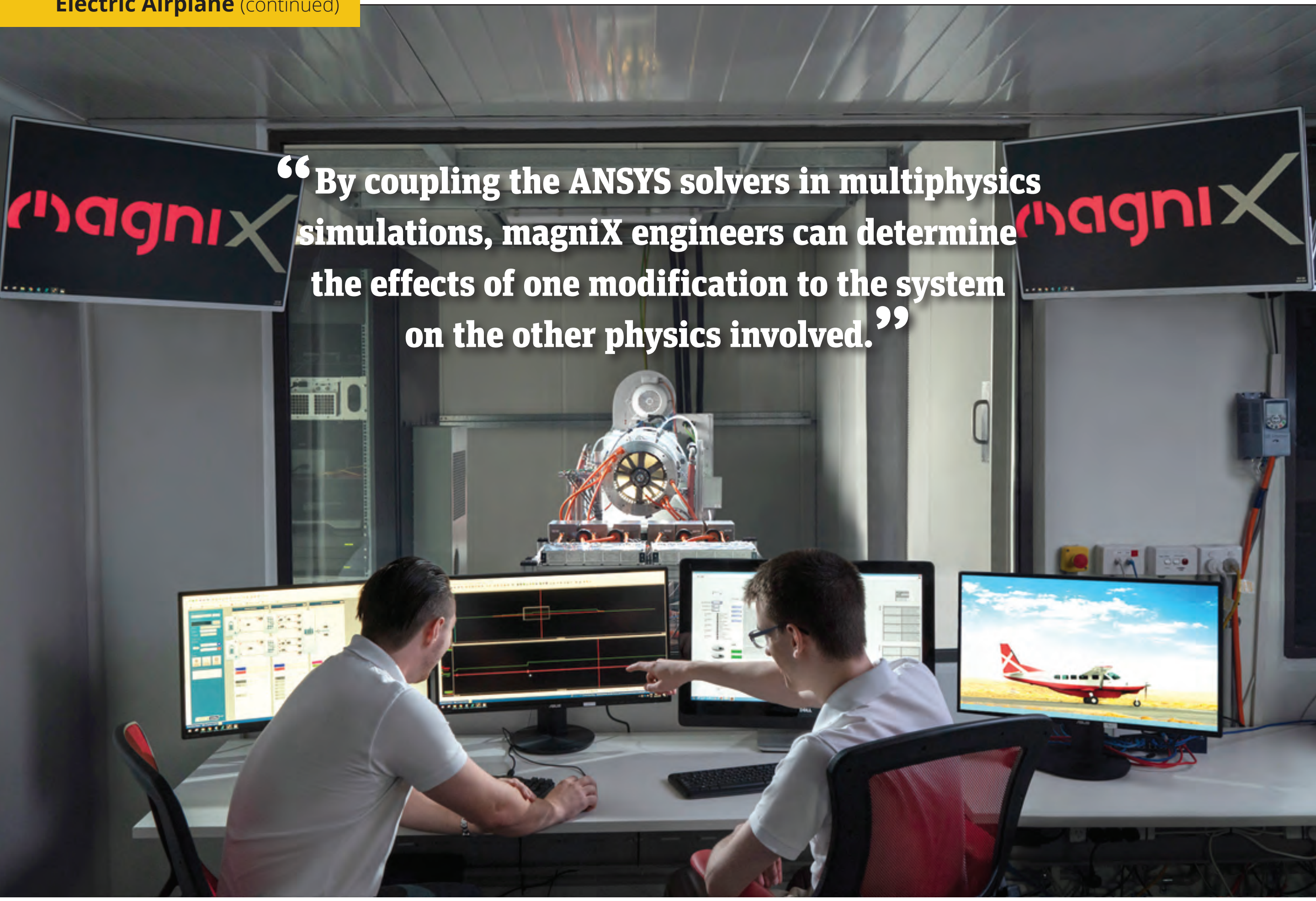
The Case for Short-Haul Electric Planes

According to the FAA’s National Plan of Integrated Airport Systems (2019–2023) report, the United States has over 19,000 airports. Major airlines fly to about 500 of them; if you include smaller airlines and chartered flights, this number increases to about 5,000. That leaves approximately 14,000 airports that could accommodate small, electric-powered planes conveniently and at low cost. The number of airports worldwide is greater than 40,000, so the opportunity is immense.

In 2018, approximately 5% of scheduled airline flights worldwide were 100 miles or less. Because turbine and piston engines are very inefficient, for this 100-mile flight a turbine or piston aircraft will consume about $400 in fuel and emit CO_2 and other greenhouse gases into the atmosphere as combustion byproducts. With electric motors working at 95% efficiency, and electricity costing a fraction of fuel, an electrically



A magniX engineer tests operation of electric propulsion



> “By coupling the ANSYS solvers in multiphysics simulations, magniX engineers can determine the effects of one modification to the system on the other physics involved.”

magniX engineers reviewing results of electric propulsion testing

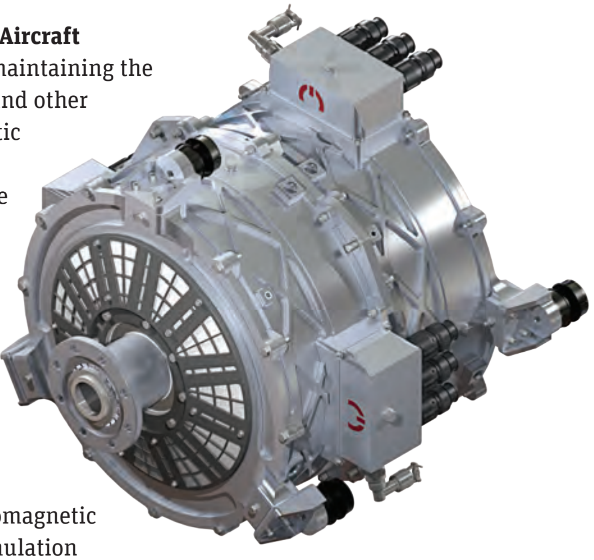
propelled plane could make that same trip using $12 worth of electricity while producing no tailpipe pollutants at all.

Finally, electric-powered planes will be quieter, eliminating some of the noise pollution we all experience.

Engineering Challenges of an Electrically Propelled Aircraft

Like anything in an aircraft, reducing weight while maintaining the mechanical strength and performance of the motor and other components is critical. Optimizing the electromagnetic properties of the motor to provide the most power possible in a small, lightweight package is of extreme importance too.

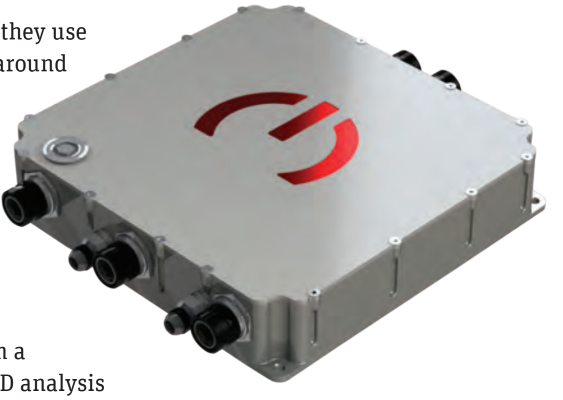
To meet these design challenges, magniX engineers use ANSYS Mechanical, ANSYS Fluent and ANSYS Maxwell to perform multiphysics simulations to optimize structural integrity, fluid flow and the electromagnetic properties of their innovative electric motors.



magni500 motor provides 560 kW of power output and 2,814 Nm torque at 1,900 rpm

Multiphysics Simulation of Electric Motors

magniX engineers use Maxwell to analyze the electromagnetic behavior of the motor and optimize it for weight. Simulation data from the electromagnetic analyses, such as losses and internal forces, are shared with Mechanical and Fluent to perform thermal and structural multiphysics simulations. Using Mechanical, they analyze the structural components of motors to ensure that they are robust and lightweight given all loading conditions. Finally, they use Fluent to study both air and coolant flow in and around the motor to understand how the motor will behave thermally in service.



By coupling the ANSYS solvers in multiphysics simulations, magniX engineers can determine the effects of one modification to the system — such as a change in the electromagnetic design — on the other physics involved, such as the mechanical and thermal properties. For instance, the resulting losses from a Maxwell simulation are exported to Fluent for CFD analysis to determine the thermal behavior of the motor under different operating conditions. The thermal loads from this analysis may then be exported to the Mechanical solver. Given the combined thermal and structural loads on the motor, engineers can determine maximum stresses and displacements, and then study the design to see what areas may need optimization. After deciding what area to focus on to improve the design, they modify the inputs to the relevant ANSYS solver and run another multiphysics iteration.

“When faced with many possible designs, the ability to rule out those that will not work well can be done quickly using simulation.”

Case Study: Eliminating the Gear Box

One advantage of the magniX electric motor is the ability to simplify the overall propulsion system by directly driving the propeller without the need for an intermediate gearbox between the motor shaft output and the propeller. Typically, for fuel-powered small airplanes, a motor turning at 10,000 to 20,000 rpm is connected to a propeller turning at only 1,900 rpm. A heavy mechanical gearbox is usually needed to step down the speed of the shaft to match the speed of the propeller, just as the transmission in an automobile adapts the output of the internal combustion engine to the speed of the wheels. This gear box adds weight, complexity and more maintenance to the overall system.

The magniX motor creates its power while turning at 1,900 rpm, thus matching the propeller and eliminating the need for a gearbox. To accomplish this, engineers had to ensure that the speed of the motor shaft is equal to the speed of the propellers. Therefore, the motor had to be designed to withstand not just the torque and thrust loading but structural and vibration loads coming from the propeller. magniX engineers used Mechanical extensively to design and optimize the mechanical structure of the motor for strength, stiffness and weight.

Choosing ANSYS Simulations

In searching for a simulation solution, magniX knew that ANSYS technology was already used by many aerospace companies. Starting with a proven tool to solve the challenges of a revolutionary technology — electrically propelled airplanes — eliminates some of the risk. The fact that ANSYS also has multiphysics simulation capabilities, so data from electromagnetic, fluid and structural solvers can be shared seamlessly in one simulation environment, also made ANSYS solutions a good choice.

The company applies simulation to shorten the development timeline by ruling out options. When faced with many possible designs, the ability to rule out those that will not work well can be done quickly using simulation. Engineers can then focus on a smaller group of options that have the best potential. Without simulation they would need to build every motor, every inverter and every component of that motor or inverter.

Electric Machine Design Methodology: A Revolutionary Approach
ansys.com/electric-machine-design

Seeking a Material Advantage

The aerospace and defense industry leverages a wide range of cutting-edge technologies to tackle environmental, safety, cost and many other challenges. A critical area that applies to all these challenges is that of materials, where making an informed decision could mean the difference between project success or failure.

By **Stephen Warde**, Vice President of Marketing – Materials, ANSYS

Getting materials decisions right is always important. But it is more fundamental for some products than for others. In aerospace and defense, engineers often need to push the boundaries of technical feasibility, while guaranteeing safety and reliability. Meeting environmental and cost imperatives for lighter aircraft while maintaining structural integrity demands much wider use of composite materials. Pushing the performance of aero engines means higher operating temperatures for greater fuel efficiency, placing more demands on metal alloys that already operate in an environment that exceeds their melting points. No organization wants to get left behind in the use of new material technologies: for example, applying additive manufacturing to enable on-demand production of parts, or investigating new Kevlar replacements in body armor.

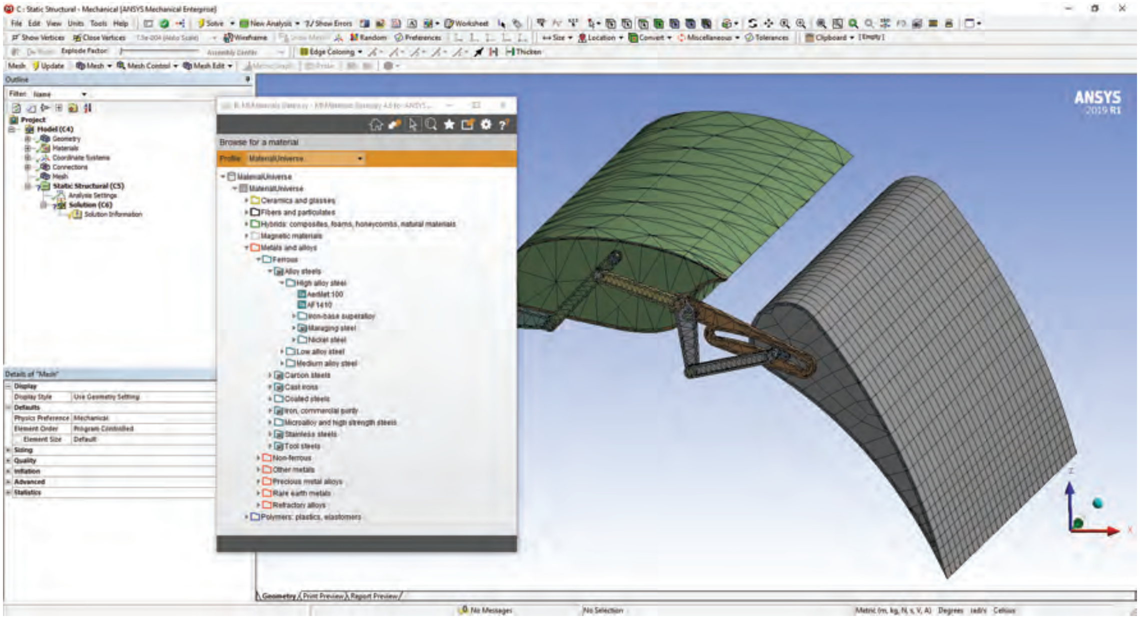
ANSYS acquired Granta Design — based in Cambridge UK — the leader in materials information technology. Granta has close collaborations with a number of aerospace and defense leaders, which can lead to multimillion-dollar benefits.

THE INFORMATION CHALLENGE

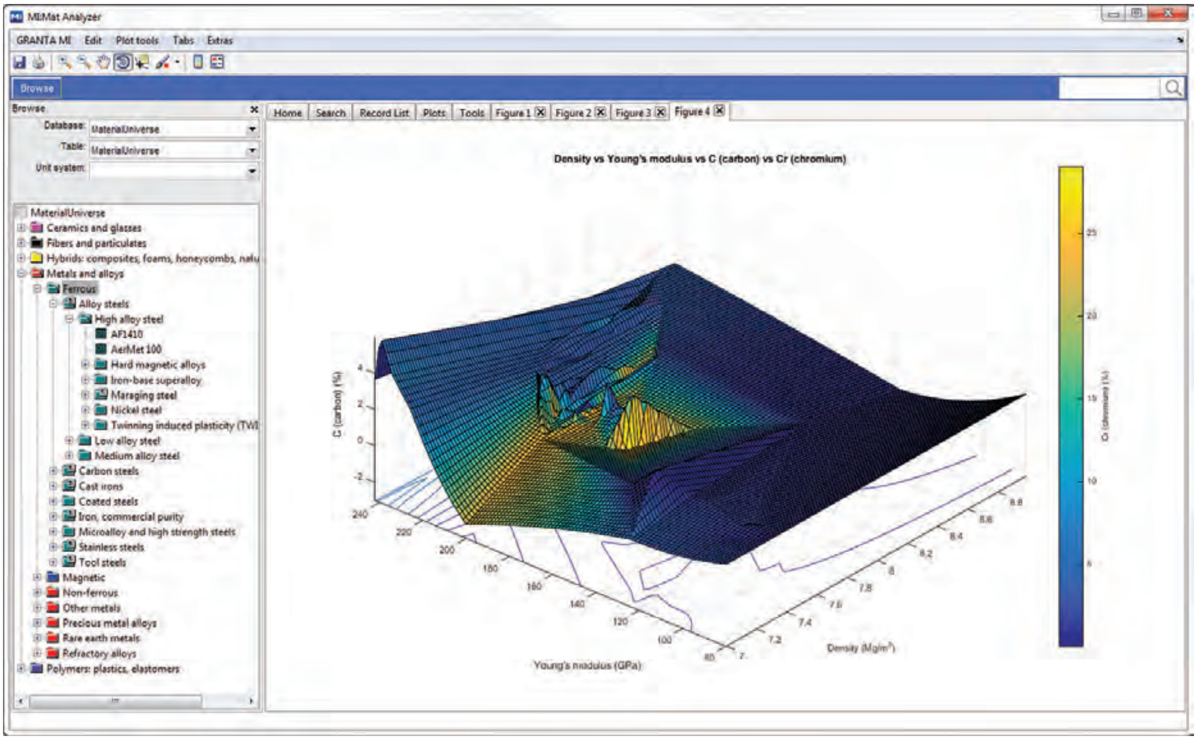
Making good decisions requires good information, and materials are no exception. In the examples above, physical property data and test results are central. Composite systems must be qualified for each new application. An aircraft program can require hundreds of thousands of coupon tests, which all need to be captured, analyzed and retained as a coherent data set for certification purposes. For alloys in an aero engine, engineers must keep track of the latest data describing the relationships between mechanical properties and temperature. Materials innovation requires understanding that only comes from effectively combining experimental and simulation data on the relationships between properties, structure and processes.

Much of this data is complex. For example, to adequately describe a metal for the purposes of design or simulation in aerospace requires a series of multidimensional mathematical models characterizing its physical behavior across the full range of operating conditions. There are authoritative sources of such data, like the Metallic Materials Properties Development and Standardization (MMPDS) alloys handbook, but now

"A leading aero engine manufacturer certified benefits of £6.9 million per year (approx. $10 million) through a materials information management project facilitated by GRANTA MI."



Materials data in a GRANTA MI database can be accessed from within ANSYS Mechanical.



Analysis of materials engineering data in GRANTA MI

engineers need to access this data in an easy-to-use digital format. And, for a new or modified material system, or one being used in a new application, the "design allowable" data must be generated anew via in-house or outsourced testing and analysis. Similarly, ongoing tests ensure quality and enable study of materials in-process and in-service. This generates a vast body of test results, analysis, quality assurance data and research information, all of which provide vital intellectual property (IP) from which aerospace and defense enterprises must extract maximum value.

TRACEABILITY FROM TEST TO DESIGN

Historically, many organizations failed this test. Today, many enterprises still do not have systematic programs to manage and apply materials information. As a result, they duplicate tests, waste time searching for data, or put simulation and design work at risk due to inaccurate or inconsistent inputs.

The good news is that this situation is changing, and fast. This is partly in response to the work of the Material Data Management Consortium (MDMC), a project founded by NASA, ASM International and Granta in 2002. Today's members include Honeywell Aerospace, GE Aviation, Rolls-Royce, UTC, Los Alamos National Laboratory and Northrop Grumman. The collaboration has defined best practices in managing enterprise materials information and focuses on the process whereby materials test results are captured, processed, analyzed to generate design data and deployed for design. This must all be achieved while ensuring appropriate access control and traceability: allowing a design decision to be tracked back to the information used to make it, and the data and analyses that underlie that information.

Success is partly about having the right information technology (IT). The MDMC advised Granta on the development of its GRANTA MI software, which enables user organizations to create a robust corporate materials information system. It is also about having the right people and processes in place and ensuring that the IT integrates smoothly with these workflows.

THE BIGGER INFORMATION PICTURE

There is also a bigger picture, beyond materials engineering and its connection to design. Any effort to manage materials information in an enterprise must account for the way in which materials are described within that organization. This is often in terms of specifications or standards that define the physical properties and processing requirements that must be met, rather than a specific purchasable grade of a material. Specifications are often defined in unstructured documents and connect engineering materials with process data, surface treatment requirements and related chemical substances — posing a difficult information challenge.

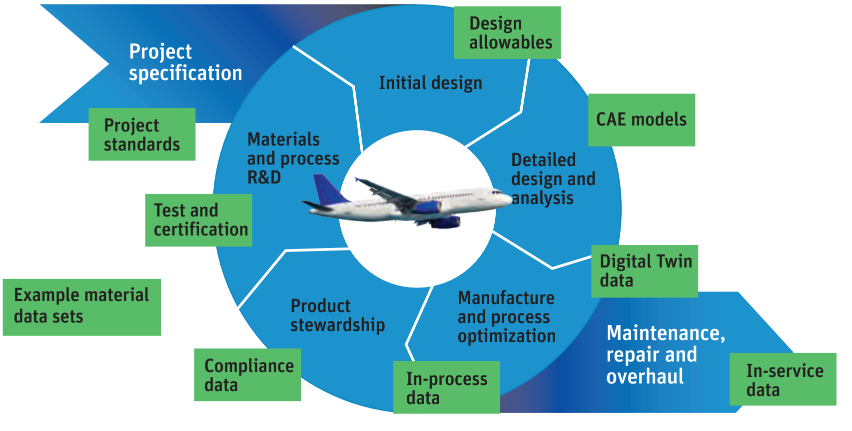
> ***“GRANTA MI data structures deal with the complexities of specialist materials data, while retaining flexibility.”***

One real-world example is restricted substance regulatory compliance. For a product with a long lifespan, such as an aircraft, manufacturers want to ensure future compliance with ever-changing regulations, such as the European Union’s REACH directive, which controls the use of chemicals that may harm the environment or human health. If a new chemical is added to the at-risk list, manufacturers want to understand which of their products, materials or specifications could be impacted. That requires systematic management and linking of information about each of these factors throughout the product lifecycle.

THE GRANTA MI ADVANTAGE

GRANTA MI provides this control and linkage. User organizations store all materials and process information in one system. GRANTA MI data structures deal with the complexities of specialist materials data, while retaining flexibility — for example, so they can be configured to support a developing additive manufacturing project. Critically, integration technologies enable seamless exchange of data with other engineering software (CAD and CAE tools, PLM systems) ensuring that the materials information system does not itself become an isolated silo. One such integration enables data in GRANTA MI to be accessed from directly within ANSYS Workbench. Different aspects of the organization’s varied materials and process data can be connected with each other and compared with the best available reference information, which is also stored in the database — the MMPDS aerospace alloy handbook data, for example, or Granta’s unique database of restricted substances and related regulations.

Substantial benefits accrue, as described by customers at Granta seminars and webinars. A leading aero engine manufacturer certified benefits of £6.9 million per year (approx. $10 million) in efficiencies and more effective use of materials IP through a materials information management project facilitated by GRANTA MI. The world’s largest aerospace company described a project on restricted substance risk assessment. A query about which specifications used an at-risk chemical, which previously took a team of 11 people 14 hours to fulfill, was completed in 20 minutes. Perhaps more importantly, it discovered impacts that the initial search had missed. A tier-1 supplier of systems and equipment in the aerospace and defense markets spoke about saving time in communicating between the materials lab and the design office, supporting a move from certifying one new engine every 10 years, to three engines every two years. The leading supplier of products for the space industry in Europe captured inspection data on the performance of materials and shared it to save time and improve consistency.



Product development process for an aerospace project and the various types of materials data required throughout that process

CONCLUSION

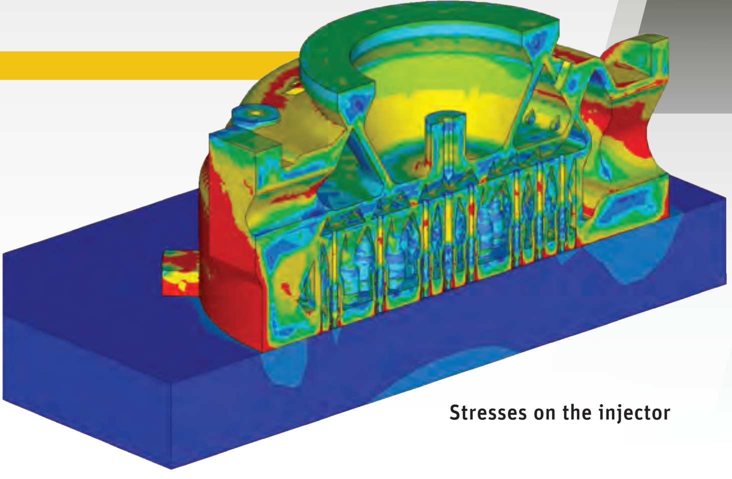
Materials matter, and the newest addition to the ANSYS portfolio is helping aerospace and defense enterprises to get critical decisions right, ensuring accuracy and traceability for design and simulation. Not only will the combination of ANSYS and Granta make it easier for simulation analysts to find the materials input data that they need, it will also enhance the connection between experiment and simulation — making it easier to compare data, and to validate and calibrate tests and analyses. This will help tomorrow’s enterprises to realize the promise of simulation: dramatically reducing the number, and thus cost, of physical tests — gaining a material advantage.

Material Intelligence
ansys.com/materials

Qualifying Additive Manufactured Rocket Parts with Simulation

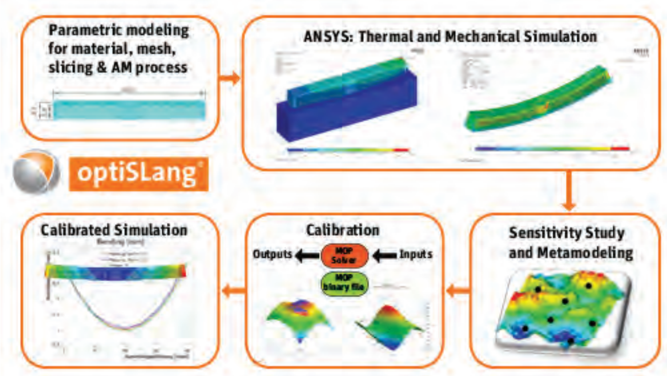
As the aerospace industry moves to implement additive manufacturing, it must validate that components will survive in an environment where a single failure in a launch vehicle could force termination of a mission. When introducing a new production technology, because many parts must be produced and verified until target quality can be achieved, the traditional trial-and-error validation process is very time-consuming and expensive. ArianeGroup used ANSYS and Dynardo software to create a simulation-based workflow that predicts part quality and has the potential to significantly reduce the process time required by the traditional method.

By **Dieter Hummel**
Thermomechanics Engineer
ArianeGroup GmbH
Ottobrunn, Germany, and
Roger Schlegel
Director of Consulting
Dynardo GmbH
Weimar, Germany



Stresses on the injector

Avoiding mission failure is the number one requirement for a launch vehicle. Each failure sacrifices the launch cost of about $150 million and the loss of a satellite that might cost hundreds of millions of dollars and take years to rebuild. Between April 2003 and December 2017, ArianeGroup's Ariane 5 heavy-lift launch vehicle successfully delivered 82 consecutive payloads into geostationary transfer orbit (GTO) or low Earth orbit (LEO) without a single failure. ArianeGroup is currently developing the next-generation Ariane 6 launch vehicle with similar performance to the Ariane 5 but with lower manufacturing costs and launch prices. Metal additive manufacturing is being used in the Ariane 6 to reduce manufacturing cost and lead time, and to decrease part weight and the space required to accommodate it.



Workflow uses ANSYS Mechanical and ANSYS optiSLang to calibrate simulation models.

In the company's liquid propulsion engineering cluster, one department focuses on combustion devices, a generic name for all engine components that handle hot gases, such as gas generators, power units and main thrust combustion chambers. ArianeGroup qualified the first parts for additive manufacturing using an expensive trial-and-error process that involved building prototypes and testing them to determine their performance. The thermomechanics team within the combustion device department has recently developed an automated workflow using ANSYS Mechanical to simulate the additive manufacturing process. During the development process for new components, engineers identify risks during the printing process by leveraging simulation to predict temperature, stress and strain evolution. ANSYS optiSLang allows the team to automate the process and calibrate the model to optimize manufacturing process parameters at a fraction of the cost of the current hardware trial-and-error method.

Previous Validation Process

The powder bed metal additive manufacturing process works by placing a thin layer of metal powder on a build plate. A laser sweeps the build plate to selectively melt tiny sections of the powder to form one layer of the part. As each section cools, it contracts, but the solid underlying layers resist these contractions, generating residual stresses. These residual stresses can generate distortions in the finished part (plastic strain) and, in the worst case, cracks that often cannot be detected with inspection because they are hidden by other sections of the part. Combustion devices are critical to the success of the mission, so switching to a new manufacturing process requires proving that the new process is free of cracks and other defects.

Before approving additive manufacturing parts for inclusion in the Ariane 6, ArianeGroup engineers must understand the process, determine the effects of key process parameters on part quality, and develop a manufacturing process that reliably allows them to meet final quality requirements, including the variability of each process parameter.

Simulating the Additive Manufacturing Process

To develop a workflow to increase the speed and reduce the cost of validation, ArianeGroup and Dynardo engineers first created a model of a relatively simple part. They simulated the additive manufacturing process with ANSYS Mechanical finite element analysis software and developed an ANSYS Parametric Design Language (APDL) script that mimics the metal additive manufacturing process by slicing the entire structure into individual layers. The elements of the printed layer are then activated with the EALIVE command, which

Ariane 6 rocket

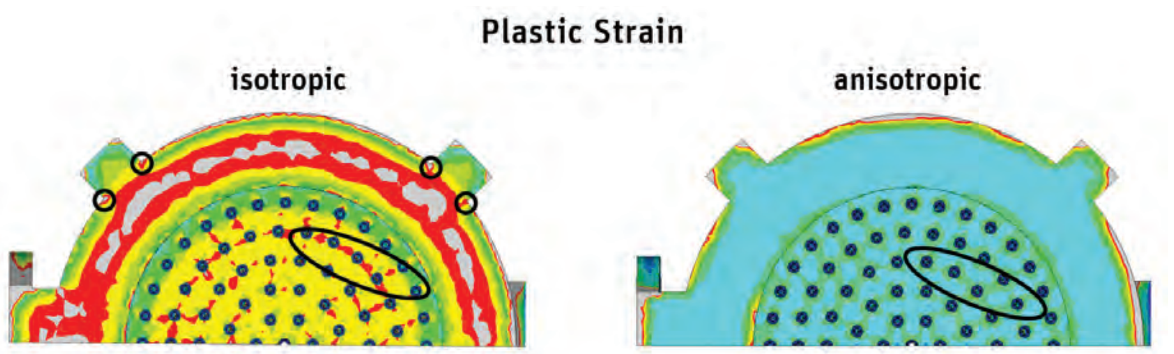
Additive Manufacturing Simulation Made Easier

Recently, ANSYS has released ANSYS Additive Suite, which reduces the need for APDL script development by users, supports the parameterization of the models and optimizes solver settings. Learn more about these capabilities in the article "Ensuring Additive Manufacturing Success."

sets their temperature at the melting temperature of the material used to produce the part. Different variations of this script either activate the entire layer at once, activate rectangular elements on a layer in a step-wise fashion, or sequentially activate angular swathes across the layer. The elements are then allowed to naturally cool, and the residual stresses are tracked in each element. Another layer of elements is then activated in the model in the same way as the preceding layer. The script simulates the complete process of building the part and tracks the residual stresses and deformation of each element.

a complete layer, one rectangular element at a time of various sizes, or an angular swatch across the layer), the time until melting of the next partial layer and the time until placement of the next powder layer.

Measurement of the manufactured material revealed anisotropic deformation and strength behavior, so engineers used Dynardo's multiPlas, a custom anisotropic multisurface elastoplastic material model in ANSYS Mechanical, to match this anisotropic behavior, and incorporated it into the additive manufacturing model. Comparing isotropic and anisotropic elastoplastic material models, the team determined that the lower yield and ultimate strength



Comparison between isotropic and anisotropic elastoplastic material models. Anisotropy has a major impact on plastic strain forecast.

Calibrating the Simulation Model

To prove the quality of the simulation model, test structures were produced and the model calibrated to measured deformation and residual stresses. In the calibration process, the variation space of the material parameter, the process parameter and the discretization parameter is scanned by a design of experiment (DoE). From this, a metamodel of optimal prognosis (MOP) is generated by optiSLang. This metamodel shows how process variability affects the results. The MOP is then used to calibrate the simulation model parameters to match the results of physical measurements on the part. Important parameters used in the calibration were the element size on the x, y and z axes, the laser path (activating

in the normal direction (between 80 percent and 90 percent of the strength in the in-plane direction) has a very important effect on the evolution of plastic strains. Employing this anisotropic material model, the finite element model was calibrated to predict the physical build to a high level of accuracy.

Once the process parameter at the test structure was calibrated, the simulation workflow was ready to forecast deformation, stresses and cracks of the part to be qualified. ArianeGroup and Dynardo engineers simulated the process of building a more complex part,

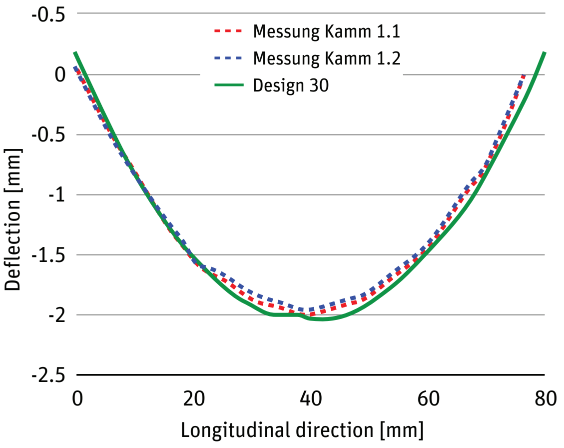
ANSYS optiSLang
ansys.com/optislang

an injector for a development prototype. The finite element model had 1,065,000 nodes and 620,000 quadratic volume elements. It required 7 hours for thermal analysis and 32 hours for mechanical analysis on a personal computer with 4 central processing units. The forecast using anisotropic material models was an excellent match to the measurements of the printed injector.

Optimizing the Part Geometry and Manufacturing Process

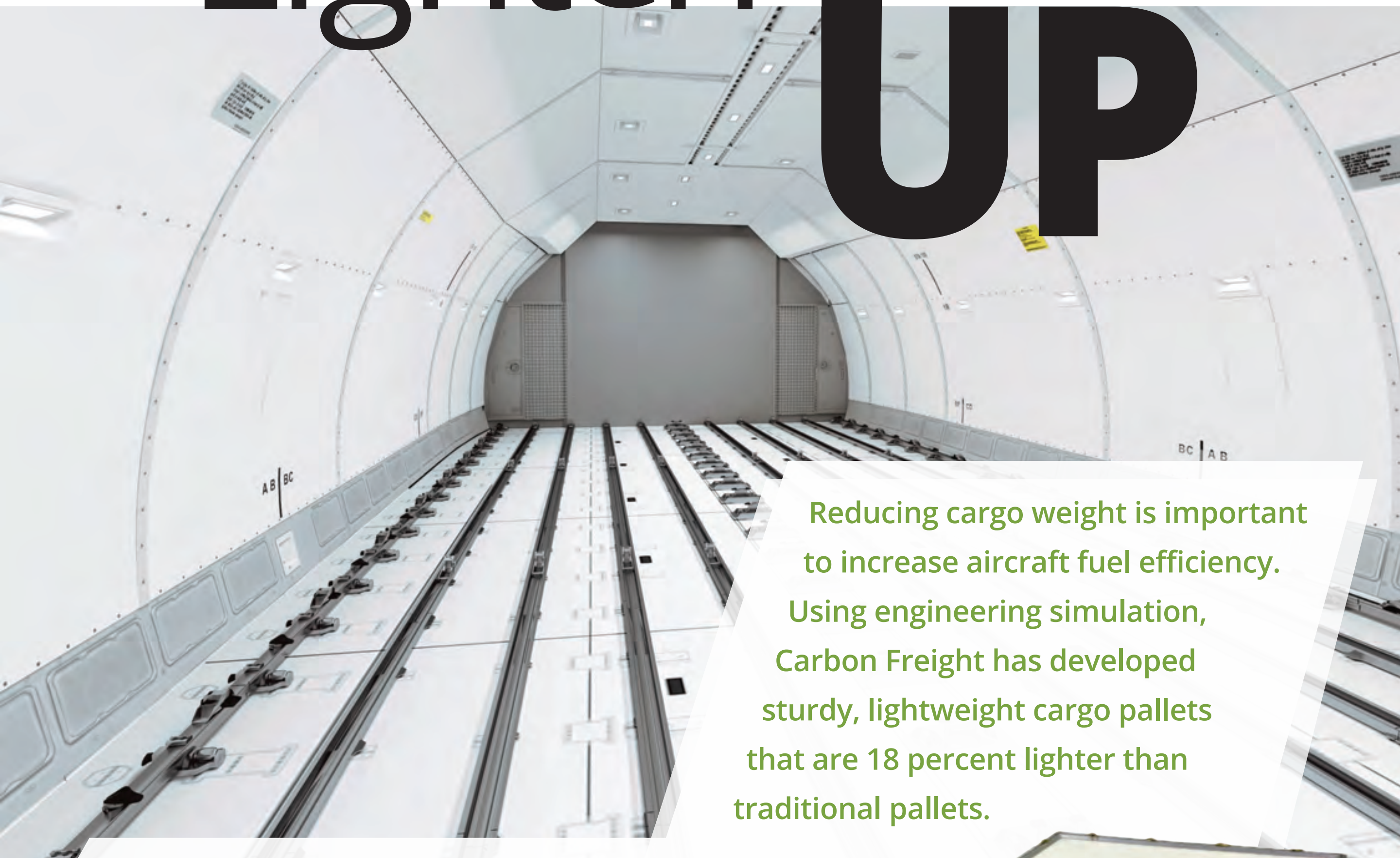
Next, engineers extended the workflow to investigate the effect of part geometry variation and key additive manufacturing process parameter variations on residual stress, plastic strain and distortion of the finished part. They created a fully automated workflow that identifies the sensitivity of part quality to each design and process parameter incorporated into the DoE used to build the MOP. The workflow can optimize the part geometry and the additive manufacturing process at the same time.

The exceptionally high cost of a failure in the extremely competitive aerospace industry makes it essential to perform a thorough validation process before adopting new technologies. In the past, this has meant a long trial-and-error process to validate new manufacturing processes. Simulation can be combined with a much smaller volume of physical testing to provide fast qualification and insertion of new technologies without sacrificing mission safety. For example, this new workflow drastically reduces the time required to validate a new part, potentially making it possible to optimize the part geometry and additive manufacturing process with only two builds, one to validate the simulation model and the second to validate the optimized part design and process. ArianeGroup engineers are planning to use this process to reduce the time and cost required to validate parts for the new Ariane 6 launch vehicle.



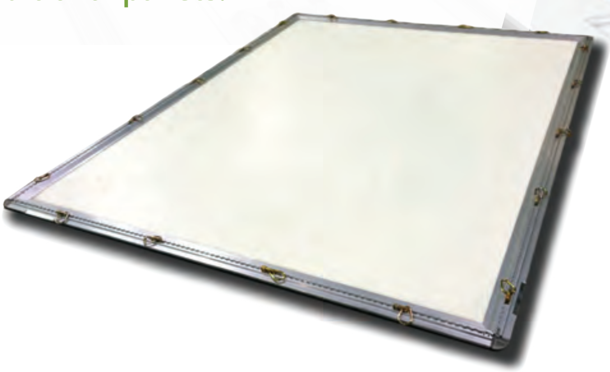
Deformation predicted by calibrated simulation model closely matches physical measurements.

Lighten UP



Reducing cargo weight is important to increase aircraft fuel efficiency. Using engineering simulation, Carbon Freight has developed sturdy, lightweight cargo pallets that are 18 percent lighter than traditional pallets.

Lightweighting is one of the most important trends in the aerospace industry today, as jet manufacturers and their suppliers work to reduce the overall weight of planes and improve their fuel efficiency. But little attention has been paid to reducing the weight of the cargo carried by planes every day.



Carbon Freight's pallet

Carbon Freight, a startup based in Pittsburgh, U.S.A., is attacking this issue with flexible, lightweight cargo pallets that are 18 percent lighter than traditional pallets. "There hasn't been much innovation in the air cargo industry, certainly not compared to the aerospace leaders' focus on new materials and production processes that reduce weight," notes CEO Glenn Philen. "Since cargo can represent a significant percentage of a fully loaded jet's weight, it only makes sense to look at historic cargo storage and transportation product designs — which have been in use for decades — and ask how we can adapt them for the challenges of today."

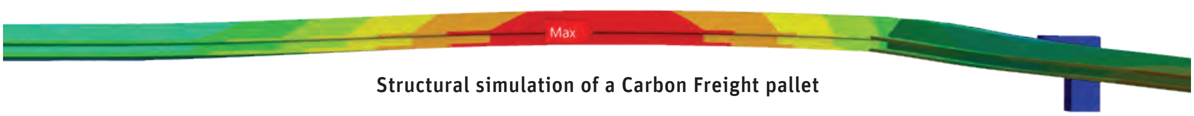
Measuring 8 feet by 10.5 feet, freight cargo pallets have typically been constructed of aluminum. By integrating composites into the materials mix, Carbon Freight has been able to achieve a significant reduction in overall weight. This weight reduction allows a typical cargo plane to carry up to 1,365 pounds in additional freight, and it enables passenger flights to carry more people by reducing cargo load.

"Simulation has helped us model and understand our pallet structures to improve their overall strength and flexibility, while minimizing their potential for damage."

While Carbon Freight's innovative design decreases weight, at the same time it actually increases a pallet's strength and durability significantly, compared with existing lightweight options. "Durability is a key characteristic for cargo pallets, because they need to fit together as closely as possible in the hold of an aircraft in order to optimize all available space," explains Philen. "But they also take a lot of abuse, and they need to have some give. We've found that composite pallets initially present some durability challenges, but there are actually opportunities for increased durability over other options. They actually deliver a lot of positive performance characteristics that go beyond lower weight."

The close proximity of pallets to one another, coupled with constant movement and handling, have created some engineering challenges for the Carbon Freight team. Says Philen, "We not only have to consider the loading stresses on our products created by the cargo, but also a wide range of contact stresses that occur as pallets are lifted, transported and packed together. There is a diverse set of complex forces that our design team needs to consider in order to deliver the best product durability over time."

Carbon Freight's product development team has relied heavily on engineering simulation to understand and manage these diverse physical stresses. "We've been able to test different material thicknesses and fiber orientations without the time and expense of creating physical prototypes. When we do get to the physical testing stage, we're really happy with the accuracy of our simulations," noted Philen. Simulation has also been able to help Carbon Freight manage one of its biggest business challenges: securing regulatory approvals from the Federal Aviation Administration and other organizations. "One of the reasons that traditional aluminum pallets are so entrenched is that it's difficult to secure approvals for a new product design," Philen points out. "Everything that goes into an aircraft must be stringently tested and proven to be safe. As passengers, we want and need that high degree of confidence. But the numerous approvals present challenges that a startup like Carbon Freight has to overcome to compete in the global aerospace industry. Established companies have an advantage in navigating the approval process."



Structural simulation of a Carbon Freight pallet

By visually demonstrating how its pallets will perform under everyday stresses — and verifying their safe performance over time — engineering simulation has helped Carbon Freight progress through the regulatory approvals process. According to Philen, "Simulation via ANSYS has saved 50 percent in development time and hundreds of thousands of dollars in physical testing." The company is on track to launch its pallets to the global marketplace in early 2017.

Despite the fact that simulation has helped reduce product weight by 18 percent, Carbon Freight executives recognize that there will be challenges involved in breaking into the global market. "Composite materials are more expensive than aluminum, which means a higher price point for our pallets. However, the new lightweight design of our products has the potential to save significant fuel costs and add revenues over their lifetime. We're offering passenger airlines and freight carriers a very attractive value proposition, and we believe Carbon Freight has a bright future ahead," concludes Philen.

Simulation of 3-D Composites
ansys.com/composites

The Carbon Freight team

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

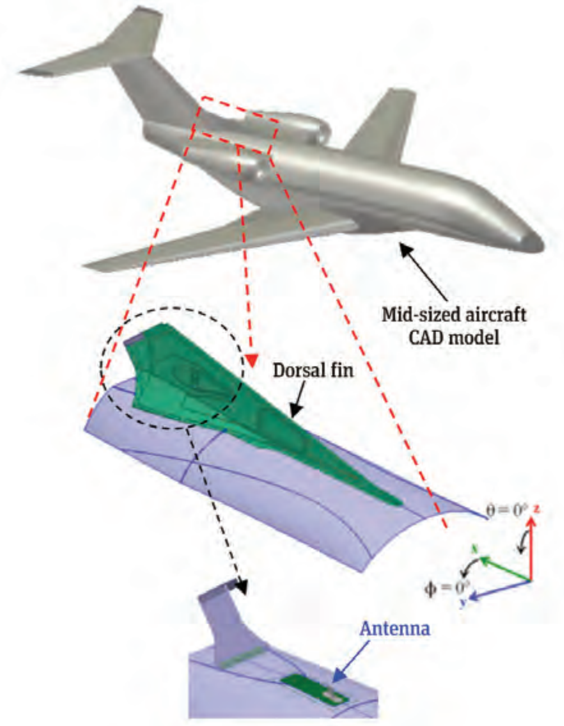
Inside Story

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

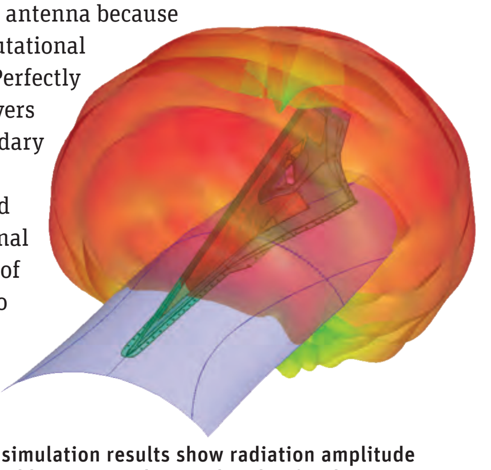
They built a physical prototype of a composite dorsal fin sheltering an existing antenna. They excited the antenna and measured the resulting radiation pattern in an anechoic chamber, which enables accurate measurement of antenna radiation by eliminating reflections of electromagnetic waves as well as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

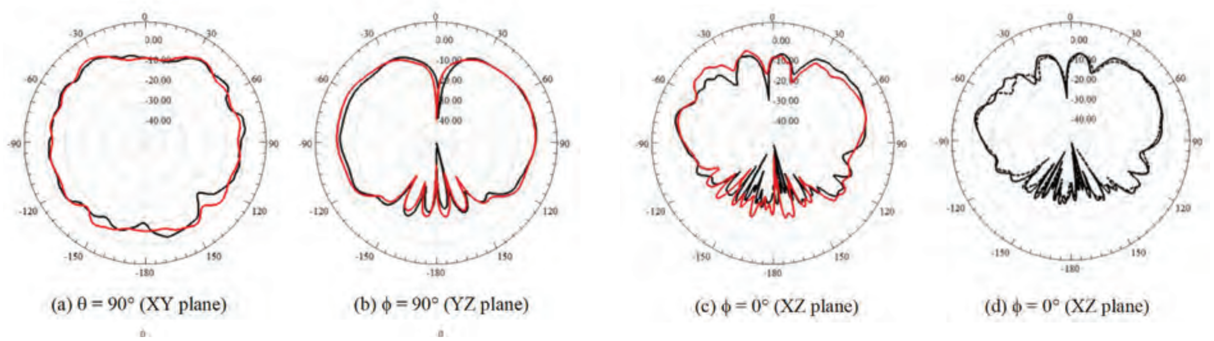
“Engineers discovered that the *position of the antenna* with respect to the composite and the thickness of the *composite structure* had the greatest impact on antenna performance.”

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.

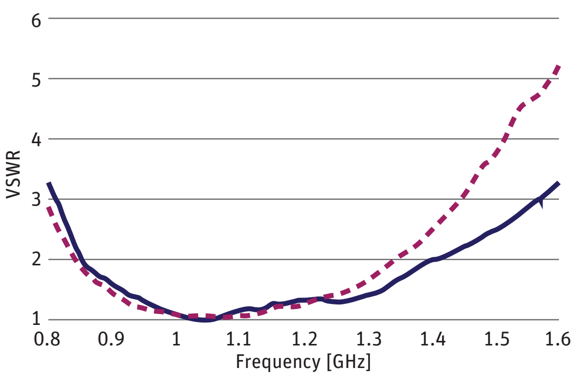
ANSYS HFSS computed the full electromagnetic field pattern inside the structure and calculated all modes and all ports simultaneously for the 3-D field solution. The simulation results correlated well with physical testing, validating both the measured material properties and the HFSS simulation model. 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.



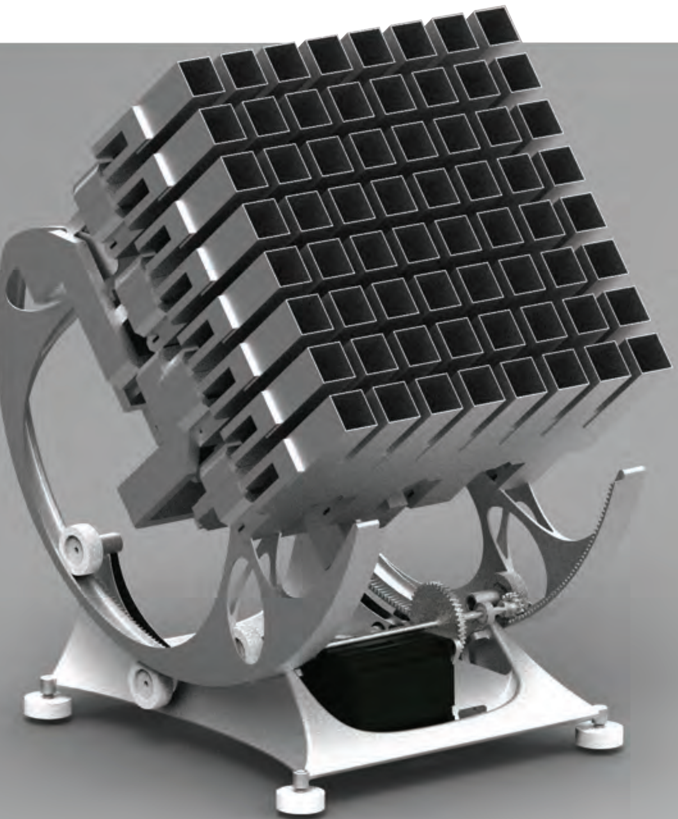
Comparison of simulated (red and dashed line) and measured (black) radiation patterns show close agreement.



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

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.



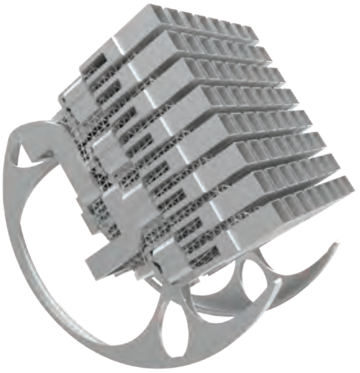
Tuning in to Antenna Design

By **Michael Hollenbeck**
Chief Technology Officer
Optisys, LLC, Utah, U.S.A.

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.

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



Array model

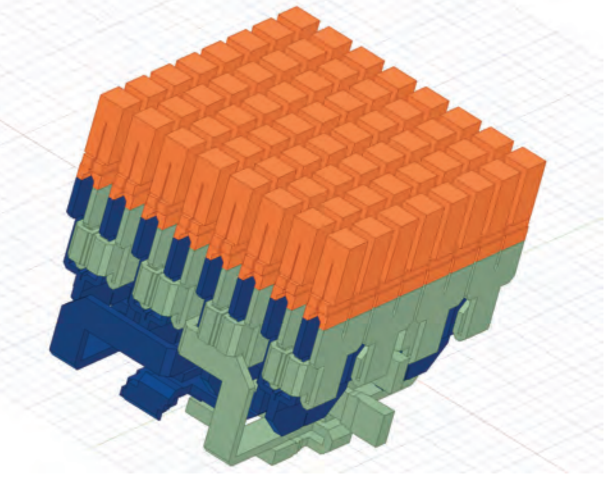
> **"Using engineering simulation with Rescale's big compute platform provided Optisys with massive efficiency gains and the ability to reduce design cycles from months to weeks."**

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.

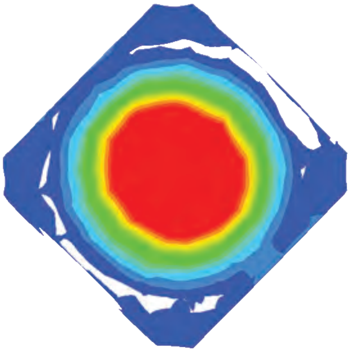
Revolutionizing Antenna Design

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.



ANSYS HFSS model of radiating elements

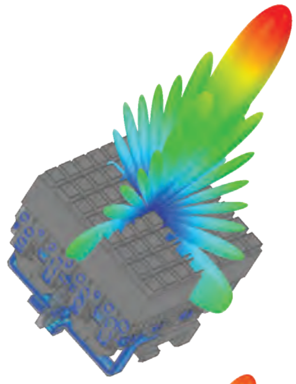


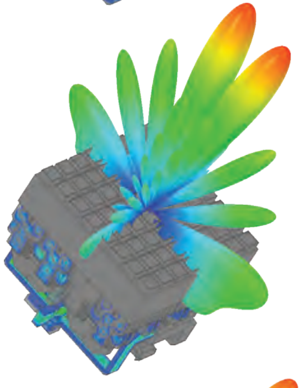
E-field inside antenna horn

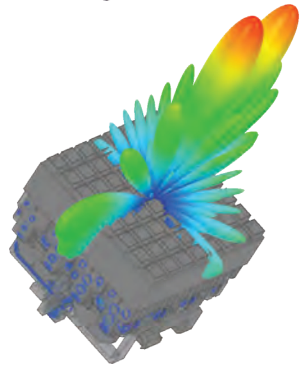
Optimizing the RF Design

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.

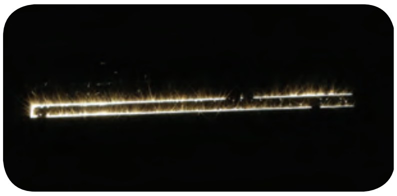
Cloud Computing for the Startup

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."

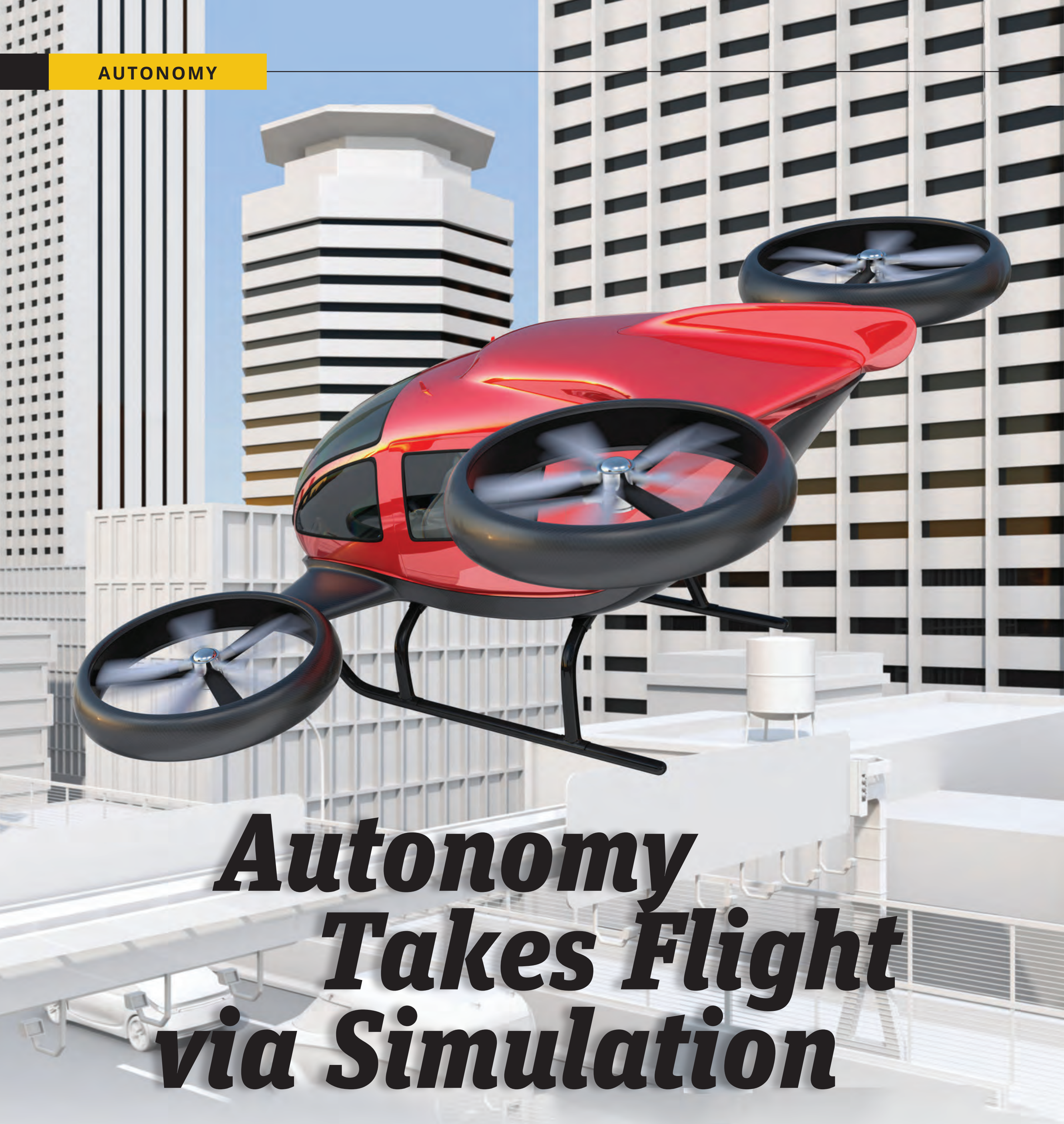
The design of the XSITA array showcases the level of integration that can be achieved with 3-D printing when engineers leverage ANSYS HFSS to optimize complex RF designs and the power of virtually unlimited scaling available on Rescale's cloud HPC platform. The success of startups like Optisys depends 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



Autonomy Takes Flight via Simulation

While self-driving cars are already a reality, the aerospace industry has been slower to develop fully autonomous systems for aircraft. There are a number of reasons, including the high cost and long time frames involved in testing and verifying the software and systems that deliver autonomy. However, closed-loop capabilities from ANSYS are now helping aerospace leaders develop and verify systems for vertical takeoff and landing (VTOL) vehicles — the first step toward the launch of truly autonomous aircraft.

By **Bernard Dion**, Chief Technical Officer – Systems, and
Nicolas Dalmasso, Chief Technologist – Optics, ANSYS

The commercial drone — or unmanned aerial vehicle — market is growing at 14% annually because a remote-piloted craft is simpler, safer and less expensive — and can be smaller — than a piloted craft for many functions. In addition to the well-publicized potential of drones for military applications and package delivery, unmanned aerial vehicles (UAVs) also represent a simpler, more affordable solution for inspecting bridges, monitoring power lines, checking the conditions in agricultural fields, spraying crops and performing other industrial tasks.

In addition, the urban air mobility (UAM) market has huge potential, as crowded airspace and traffic congestion create a demand for small aircraft that can lift off and land in confined spaces.

The vertical takeoff and landing (VTOL) aircraft segment is the subject of increasing attention and investment today — and with good reason. Aerospace leaders, including Airbus, Rolls-Royce and Bell, are developing product solutions, hoping to capitalize on a market opportunity that Booz Allen estimates to exceed $500 billion. As many of these aircraft can carry two or four passengers, eliminating a pilot via autonomy increases the payload capacity by 25% to 50% — creating a significant cost advantage.

However, there are significant engineering challenges involved in making VTOL aircraft fully autonomous. They need to safely handle every possible scenario, without intervention from a human operator. They must navigate the difficult transition from vertical to horizontal flight under every conceivable weather condition. And they must accurately sense the physical environment around them, so they can reliably distinguish a harmless visual phenomenon like a light reflection from a potential

This ANSYS simulation of a drone in an urban virtual environment includes physical factors such as the effects of wind on flight dynamics, and accounts for optical phenomena such as the reflection of sunlight on glass buildings.

hazard such as a flock of birds. Finally, in the event that any component fails, it is essential that software systems protect system integrity and functional safety as needed.

Engineering an autonomous VTOL aircraft is a complex proposition, bringing together physics, electronics, optics, embedded systems and control software. Engineers need to accomplish these tasks with a high degree of confidence:

- **Model and test millions of operating scenarios**, including the animation of both the VTOL aircraft and its surroundings
- **Develop and test sensors** that observe the vehicle's surroundings and deliver appropriate output signals
- **Define software algorithms and embedded systems** that consider inputs, make decisions and drive actuator behavior in response
- **Ensure the functional safety** of the aircraft at the system level, by identifying and addressing all potential failure modes

Given the complexity of these tasks, and the drive to commercialize autonomous VTOL vehicles quickly, simulation-driven product development is the only answer. ANSYS software makes it possible to simulate VTOL aircraft at both the component and the system level, while ensuring tight control, functional safety and compliance with all relevant regulatory standards.

ANSYS provides the first complete simulation environment that includes virtual world models and operating scenarios, simulation of vehicle dynamics, physically accurate sensor models, embedded software development tools and functional safety analysis. In addition, the ANSYS VRXPERIENCE virtual-reality platform helps optimize the flight experience for human passengers. One of the keys to widespread adoption of autonomous vehicles is overcoming users' fears about their safety and comfort. By recreating the user experience in a virtual environment, simulation can help ensure a positive experience that makes autonomous flight an attractive proposition for consumers.

By capitalizing on these integrated capabilities, the developers of VTOL and other autonomous aircraft can dramatically reduce the time and cost involved in launching safe, reliable designs to capture this market opportunity.

Flight Simulation: Understanding the Physics

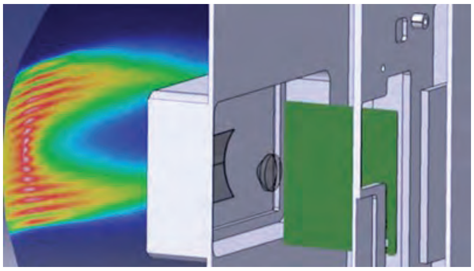
Known for its flagship physics-based modeling solutions, ANSYS allows aerospace engineers to simulate VTOL aircraft during virtual test runs — including flight dynamics and wind effects. Engineers can use traditional simulation capabilities already proven in the global aerospace industry to optimize the aerodynamics involved in flight as they model VTOL designs under real-world conditions.

Because of their unique functionality, VTOL vehicles present additional engineering challenges. To accurately model the complex fluid dynamics involved in vertical takeoffs and landings, ANSYS Fluent delivers custom capabilities that are unmatched in the industry.

To establish reliability across years of use and thousands of flight miles, ANSYS supports very detailed simulation of specific physical environments. Via a closed-loop process that brings other ANSYS software into play, engineers can consider all the interactions of the autonomous craft with its environment, including any physical forces and obstacles, across millions of operating scenarios.

Results obtained via the ANSYS closed-loop flight simulation process give engineers a much deeper understanding of how to engineer the vehicle to ensure its compliance with both safety regulations and customer expectations. Based on realistic operating conditions, the ANSYS simulated autonomous vehicle makes the same reliable decisions as the future real-world connected vehicle.

Vertical takeoff of a drone in an urban environment. Since vertical takeoff is driven by the output of camera sensors installed on the drone, it is crucial that these sensors are simulated and tested for reliable performance.



ANSYS SPEOS enables engineers to simulate the optical images that are gathered by cameras and lidar systems mounted on the VTOL vehicle — critical in ensuring that the craft can accurately sense and respond to its physical surroundings.

Optical Sensors: Obtaining a Clear View

In addition, specialized ANSYS software enables the simulation of all the optical sensors integrated into a VTOL aircraft. Autonomous vehicles require an increasing number of optical sensors, including cameras for visible and infrared detection, as well as lidar systems for a 360-degree, three-dimensional view of the operating environment.

ANSYS SPEOS optical simulation software validates the performance of the optical sensors through physics-based simulation that accurately represents their real-world performance. SPEOS enables engineers to perform a detailed physics simulation of optical cameras and lidar — taking optical lenses, imagers, mechanics, sensors, materials and light properties into account in both visible and non-visible (IR) wavelengths, as well as merging images obtained by multiple cameras.

SPEOS also simulates in-vehicle installation via reduced-order modeling (ROM) of the cameras and lidar as integrated into actual operating scenarios. These simulations accurately replicate the images that are gathered, so that sensors can be engineered to identify complex optical factors such as sun glare and reflections.

ANSYS HFSS can be used in a similar manner for evaluating and verifying the performance of radar sensors, as well as other antenna systems mounted on a VTOL aircraft.

Embedded Software: Ensuring Tight Control

After input has been gathered from sensors, the VTOL vehicle must now be programmed to take the right actions in response. This is the role of embedded software, which applies machine learning and control logic to determine a flight plan and execute it by driving the craft's actuators. This control loop is executed repeatedly, in cyclic fashion, so that the vehicle can respond to constant environmental changes.

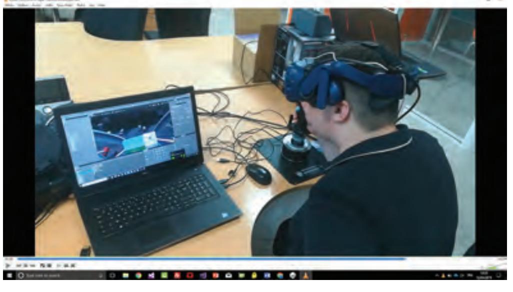
In order to design and generate code for the control logic, ANSYS has developed a comprehensive solution capable of automatically generating code from software models for autonomous vehicles. The ANSYS SCADE Suite KCG code generator has been qualified to meet the most stringent aerospace standards and ensure the safe operation of VTOL aircraft under every operating condition.

Because the SCADE solution is part of the integrated ANSYS development platform for VTOL vehicles, it is possible to verify by closed-loop simulation of the flight scenarios that any changes in the control software perform as expected and do not create any regression. By using SCADE to generate a control architecture and underlying code, software developers can drastically reduce the time and cost of validating and certifying their embedded systems.

Functional Safety: Bringing It All Together

The final step in engineering a VTOL aircraft is ensuring that all components work together in a safe, reliable manner when brought together as a system. All failure modes must be identified, and appropriate responses must be defined. Functional safety analysis acts as the "cockpit" for the entire engineering process, ensuring that the system-level design is safe and meets all relevant aerospace industry standards.

ANSYS medini analyze addresses functional safety, and has been proven in many automotive and aerospace applications. While there is not a specific aerospace standard developed yet for VTOL vehicles, medini analyze meets standard ARP 4761, which requires that aeronautics safety engineers evaluate and assess the safety of aircraft systems by identifying relevant hazards and failure modes for all electronic components. In addition, the emerging SOTIF standard that is currently created for autonomous cars can be used as a basis to assess the safety of such complex systems, including sensors and AI-based perception.



The ANSYS VRXPERIENCE platform enables engineers to test the impact of a specific control law — developed with the SCADE software suite — on the real-world human experience. The simulation user is fully immersed in a highly accurate virtual reality environment, and can experience a complete VTOL flight scenario long before the real aircraft exists.

While many product developers implement functional safety analysis as a separate, manual activity, the integrated ANSYS simulation platform brings this mission-critical task into the closed-loop process. By considering functional safety as part of the system architecture, reliable performance and industry certification are built into the aircraft design at an early stage.

VTOL Autonomy: An Achievable Goal

Autonomous vertical takeoff and landing aircraft have enormous market potential, but engineering them is a practical challenge that still needs to be overcome. Bringing together physics, electronics, optics, embedded software controls and functional safety, VTOL aircraft represent one of the most complex product designs today — and, because their performance is absolutely mission-critical, there can be no shortcuts.

Simulation provides the only practical answer, replacing years of physical testing and hours of flight time with affordable, low-risk, system-level modeling. By placing their VTOL designs into a highly detailed, three-dimensional simulated environment, engineers can verify their safe performance, including sensors, software and other highly sophisticated components. They can recreate millions of real-world operating scenarios without investing in prototypes or physical tests.

By leveraging the integrated autonomous vehicle development platform from ANSYS, engineering teams can quickly and economically simulate any VTOL vehicle, with any combination of sensors, with any control system, in any operating scenario. This allows them to significantly reduce the time and financial investments needed to achieve both performance and safety goals for these advanced product systems.

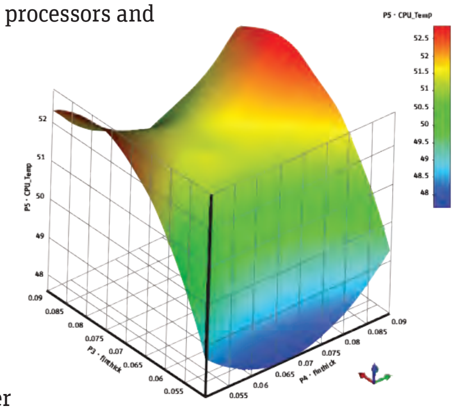
Ruggedized Systems: COOL and CONNECTED

To meet demanding military specifications for mobile and interconnected surveillance, communication and operational devices, Kontron uses sophisticated thermal simulation to balance size, weight, power and cooling (SWAP-C) trade-offs for "ruggedized" modular chassis that support customized solutions for mission-critical operations.

By **Simon Parrett**, Conceptual/Structural/Thermal Engineer, Kontron, Poway, U.S.A.

Today's military vehicles depend on state-of-the-art visualization, imaging and networking technologies to improve situational awareness and enable military leaders to make the best possible decisions. Vehicles such as Humvees, armored mine-resistant ambush protected vehicles (MRAPs) and unmanned aerial vehicles (UAVs) increasingly rely on advanced electronics, such as processors and circuitry, in compact systems to support their missions.

To satisfy the military's demand for these electronic systems that can be adapted to a range of uses, defense contractors must meet a host of requirements and specifications. The devices placed on vehicles, such as battlefield sensor systems, military GPS and next-generation communications equipment, must be able to communicate and interact in extreme physical environments where they might be exposed to severe electromagnetic conditions. Military standards require that these devices withstand specified extremes of temperature, vibration, shock, salt spray, sand and chemical exposure. Size, weight, power and cooling (SWAP-C) requirements demand that the electronic systems that power these devices be small enough that they do not hinder mobility.



Parametric optimization of enclosure cooling fins

The approach that has proven most effective is to contain the electronic system functionality in a chassis that has been precertified for "ruggedized" operation. Using this chassis, designers can ensure that the system is maintained in a sealed and temperature-controlled environment. To design these ruggedized systems, Kontron, a global leader in embedded computer technology and an IoT leader, uses sophisticated computational

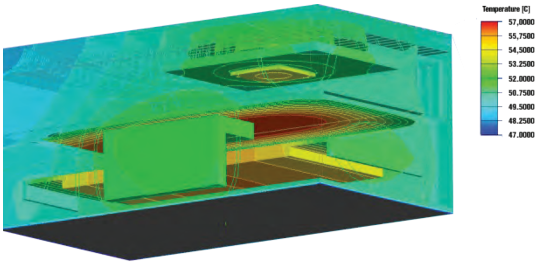
> **"*Defense contractors* must meet a host of requirements and specifications to satisfy the military's demand for *flexible electronic* systems."**

fluid dynamics (CFD) analysis to accurately manage thermal reliability for components and ultimately the complete integrated system. The chassis they provide enables original equipment manufacturers to build customized solutions for mission-critical applications.

Ruggedized Systems

Kontron's COBALT line of computing platforms uses a modular approach to deliver a rugged, sealed computing system with a specialized carrier board and configurable front panel that can be integrated into the electronics bay of a Humvee, MRAP-type vehicle or UAV. The box-level system provides processing power to enable third-party developers to maintain flexibility, compatibility and interoperability for many types of rugged applications. Using standard interfaces reduces long-term costs and makes it easy to upgrade, replace and reuse capabilities across systems. Hundreds of these systems can be fitted onto a single aircraft or ground vehicle.

To develop a truly flexible system, Kontron must take many variables into account and identify trade-offs. Surveillance applications, for example, require high I/O and fast processing speeds. They also require low signal bandwidth for communications efficiency, and reliable wireless communication to send information back to data centers. For these applications, customers want a chassis that can ensure that powerful processors or other components do not impair the radio signal. Power consumption and thermal management are also important; the heat from a processor can impede the performance of other components, and thermal cycling stresses as the processor heats and cools, especially in conditions such as extreme desert heat or the cold of high altitudes, can cause fatigue in components and the chassis. As systems become more complex and are required to incorporate more capabilities, managing SWAP-C requirements is even more critical, and design priorities depend upon the size of the vehicle, the nature of the applications, and the missions for which the vehicles are employed.



System-level thermal trade-off analysis, used to build the Excel product thermal configurator

CFD Analysis for Thermal Management and Reliability

To develop these chassis, designers of the COBALT product line have adopted a "five-gate" process of sign-off procedures, from loose specification (Gate 1) through various iterations, to a finished product (Gate 5). Typically, they introduce ANSYS analysis at Gate 1 to anticipate problems and trade-offs early in the design phase, leading to more complex products in a shorter design frame. The team uses ANSYS DesignModeler to import geometries, ANSYS Icepak to determine temperatures, ANSYS DesignXplorer for design exploration, and ANSYS HPC for faster results. ANSYS Workbench provides the common environment to integrate the simulation process.

The Kontron design team uses CFD analysis to evaluate and optimize chassis thermal performance. Some key activities are:

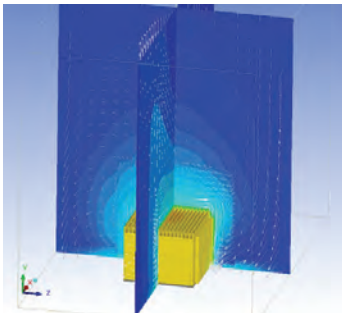
- Designing the enclosure to draw as much heat as possible from the circuit board and processor. The team uses ANSYS Icepak to streamline CFD analysis to design finned surfaces and heat sinks, and arrive at an optimal design.
- Determining placement of electronic components and subsystems within the chassis and balancing

Conceptual CAD rendering of the Kontron COBALT (computer brick alternative)

the trade-offs necessary to meet SWAP-C requirements. For example, engineers analyze the power dissipated by an expansion board and its effect on the temperature of a nearby processor.

- Reviewing internal thermal conduction paths from high-power components to ensure that there are efficient paths to the enclosure walls.
- Exploring external environmental factors in situations where the full system will be deployed. If the system chassis is deployed in a UAV, for example, the cooler temperatures and thinner air in high altitudes will affect thermal management. Another factor might be the location of the chassis in the vehicle. If additional chassis are located nearby, heat and radiation exchange need to be considered.

Besides the early focus on optimal design for SWAP-C considerations, Kontron designers are also concerned about longevity. When the chassis is added to a ground vehicle or plane, it's expected to last three to five years, plus another two years with maintenance. The mean time between failures (MTBF) is very important to their customers.



Initial natural convection cooling assessment

Evaluating Design Trade-Offs

Recently, the design team introduced a new gate, Gate Zero, wherein they talk to customers and work with product managers to get new ideas for their products. This enables the team to create "what-if" scenarios even before they write the specifications. To test the Gate Zero concept, Kontron engineers modeled a sample heatsink using rough designs in Icepak and tested various configurations to determine what trade-offs would be required.

In the past, they would analyze thermal problems by running an initial analysis, trying some manual design variations, and after seven or eight design iterations that included physical mockups, perform a final analysis and publish their results. Using DesignXplorer to drive Icepak, the team was able to exceed those limitations, identifying 240 potential design variations to test. The software then used mathematical models to narrow down the list to just 70 essential variations for further study. By running 70 intelligent design iterations over a weekend, engineers were able to evaluate 10x more design variables than was possible with the old methodology in the same amount of time. The designers were presented with three optimal design candidates to choose from.

From the large design space that was explored using simulation and driven by DesignXplorer, the Kontron team developed a chassis configuration tool with an Excel® interface that their sales team can use in customer meetings to rapidly design a chassis customized to client requirements.

Starting with a baseline configuration with the desired maximum ambient temperature, application engineers add design variables, such as CPU max power or electronic expansion trays; operating parameters, such as the orientation and position of the device; and the altitude where it will be used. The spreadsheet shows the power consumption of each component in the box and how their interaction affects the temperature within the box. They can also plot out remediation options, such as extending the size of the heat sinks, to calculate their effect on the temperature. The spreadsheet can also be used to factor in the cost of changes, for example, the cost of adding a heatsink based on the number of fins and their thickness. Using the inputs and relationships they have learned using ANSYS software enables them to better inform their customers so that they can find the best configuration together.

With the ability to increase virtual tests by a full order of magnitude in less time, Kontron can avoid potential problems, adapt to their customers' needs, and provide rugged, reliable systems for the connected army of the present and the future.

ANSYS Icepak
ansys.com/icepak


creo simulation live
powered by ANSYS
CREO SIMULATION LIVE
Real-time feedback as you design
www.ptc.com/csl
What if your 3D CAD software could provide design feedback in real time?
With Creo Simulation Live, powered by ANSYS, you can deliver fast, easy simulation within your 3D CAD environment. The result? Design feedback in real time to guide your design decisions.
ptc
ANSYS


NEWS FROM ANSYS
Sign me up to receive updates and offers from ANSYS and its partners.
I can unsubscribe at any time.
ansys.com/optin
ANSYS

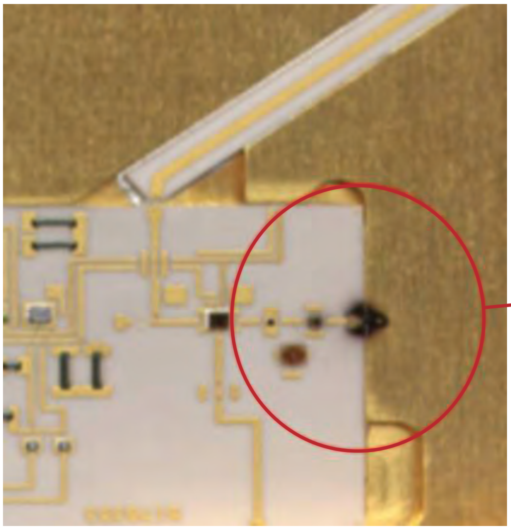
HOT WIRE

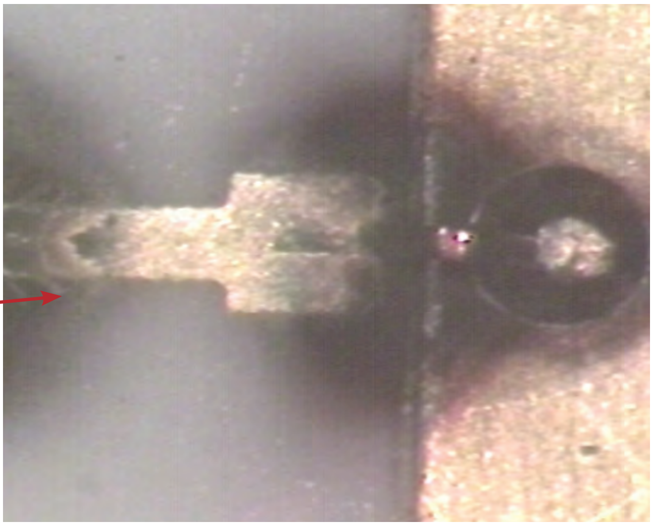
Multiphysics simulation helps to achieve robust electronics design for high-power antennas and microwave components.

By **Amedeo Larussi**
Senior Principal Electrical Engineer
Raytheon Corporation
Goleta, U.S.A.

The aerospace and defense industry is charged with delivering advanced electronics systems faster and at a lower cost than ever before. Antenna and microwave design engineers must balance competing requirements for reduced size, high power delivery, rock-bottom cost and excellent reliability. The result is that antennas and microwave components operate at higher power levels and higher frequencies while being contained in smaller form factors. The inevitable outcome is increased risk that temperatures will greatly impact product performance. Traditionally, electrical design and thermal design are the responsibility of two different groups, each operating

> **“Antennas and microwave components operate at higher power levels and higher frequencies while being contained in smaller form factors.”**





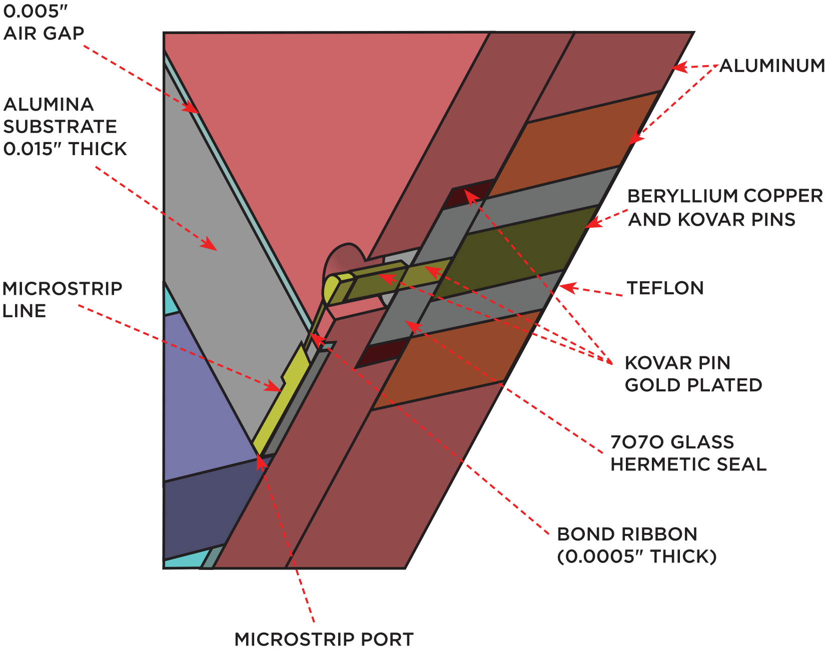
Photos (normal left, magnified right) show damage to the microwave junction.

with their own separate requirements and analysis tools — and with only limited cross-group interaction. This common failure to more fully account for design dependencies has, in some documented cases, resulted in serious product malfunctions.

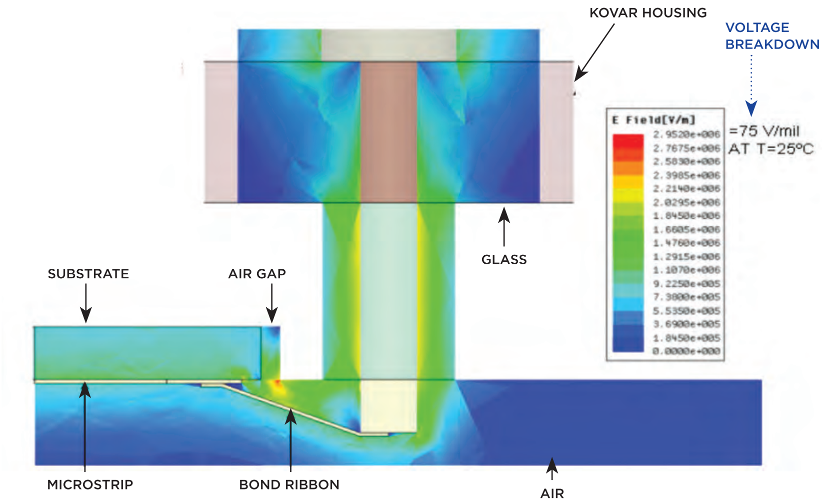
For example, the heat generated by microwave components can increase the dielectric loss tangent of some materials; the consequence is more heat production and the potential for a runaway reaction. In extreme cases, product failure could prevent a mission from being accomplished or even cause loss of life. Combining electrical, thermal and structural simulations often provides unprecedented insight toward preventing failures and improving product performance. Raytheon Corporation — a technology and innovation leader specializing in defense, security and civil markets throughout the world — uses comprehensive robust electronic design solutions to improve the reliability of its products, reduce time to market, and control engineering and manufacturing costs.

Multiphysics Simulation — A Brief History

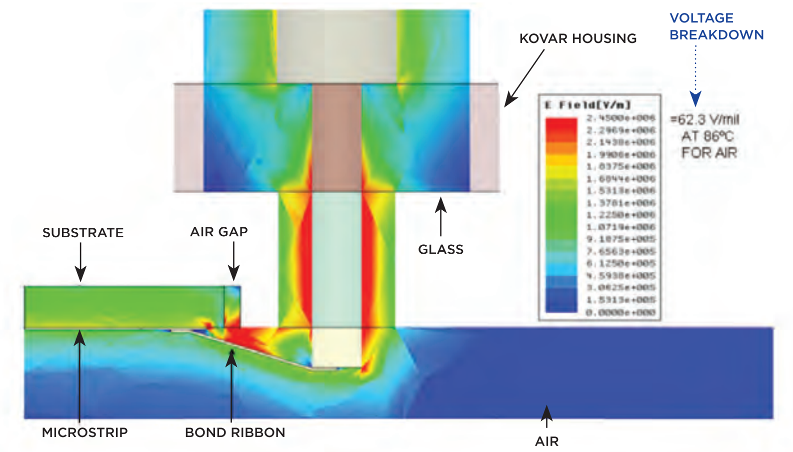
Engineers have long been interested in combining high-frequency electromagnetic simulation with thermal analysis, but before the turn of the millennium, there was no efficient way of doing so. About 2002, Raytheon management encouraged investigation into the potential for coupled simulation capabilities. This led to the selection of ANSYS HFSS to enable coupling between electromagnetics and thermal analysis. Raytheon engineers began using the tools extensively to design microwave systems with excellent results. In 2007, the group needed to add vibration and fluid dynamics capabilities to the coupled



ANSYS HFSS model of microwave junction



Electrical field analysis at 25 C



Electrical field analysis at 86 C

“Raytheon engineers took advantage of integration capabilities in ANSYS Workbench to capture electromagnetic and thermal interdependencies.”

analysis toolkit. With HFSS integrated into the broader ANSYS simulation portfolio (for example, ANSYS Mechanical and ANSYS Fluent), it was easy and intuitive to perform multiphysics simulations within ANSYS Workbench.

Voltage Breakdown at Microwave Junction

In an example from a recent project, a high-power signal is received by the antenna plane. The effective received radiation signal flows to a microwave feed circuit. Although both the electrical and thermal groups signed off on the design, a voltage breakdown occurred at a microwave junction, where a co-axial pin connects to a microstrip trace at the frequency of interest. Shortly after power was turned on, excessive heat destroyed the connector. To address this, Raytheon engineers modeled the components in HFSS. This software accurately models microwave components, such as tuning screws and probes, to a fine level of detail. HFSS employs the finite element method, using small unstructured mesh elements when needed, along with large elements when small elements are not needed, to reduce processing time without sacrificing accuracy. Adaptive meshing refines the mesh automatically in regions in which field accuracy needs to be improved.

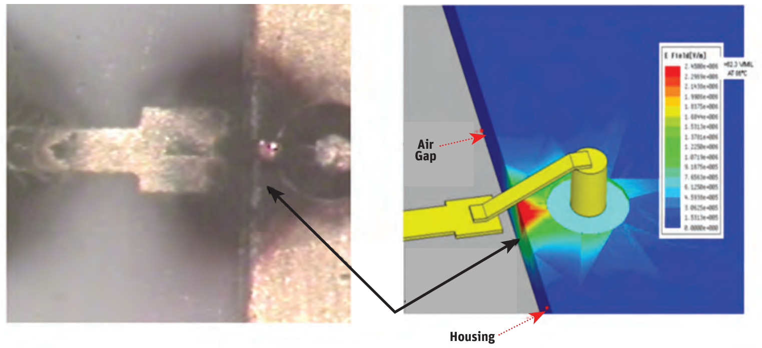
Raytheon engineers imported initial design geometry from a computer-aided design (CAD) file. They defined the electrical properties of the materials, such as permittivity, dielectric loss tangent and bulk electrical conductivity for the Kovar® housing, alumina substrate, Teflon® insulator, and beryllium, copper and Kovar pins. Engineers then defined boundary conditions that specify field behavior on the surfaces of the solution domain and object interfaces. They defined ports at which energy enters and exits the model. HFSS computed the full electromagnetic field pattern inside the structure, calculating all modes and ports simultaneously for the 3-D field solution. (The dielectric properties of the materials are temperature dependent.) The HFSS electrical field analysis at 25 C showed that the electrical field in the area in which the failure occurred does not exceed 1.5×10^6 volts per meter (V/m), as compared to the 2.952×10^6 V/m value for voltage breakdown in air.

Coupling Electrical and Thermal Simulation

The real-life situation is more complex because ambient temperature affects the dielectric properties of the materials, and the dielectric properties of the materials affect the heat that is generated by microwave components. Raytheon engineers took advantage of the integration built into ANSYS Workbench between HFSS and ANSYS Mechanical to capture these interdependencies. The HFSS model was coupled to ANSYS Mechanical to perform a transient thermal simulation. Boundary conditions for natural convection cooling were added on the bottom face. The temperature distribution was used to perform a static structural analysis.

Engineers employed ANSYS Workbench coupling to apply temperature fields (determined by physical measurements) to ANSYS Mechanical to calculate the thermal stresses associated with these temperatures. The structural simulation showed high stresses and deformation up to 22 µm in the inner connector. Thermal analysis indicated that temperatures actually reached 86 C on the bond ribbon and the pin near the point where they connect, which translated into a lower breakdown voltage. Raytheon engineers re-analyzed the components at 86 C using the dielectric properties at the higher temperature and discovered that the electrical fields in the area where the failure occurred exceeded the 2.45×10^6 value for voltage breakdown in air at this temperature.

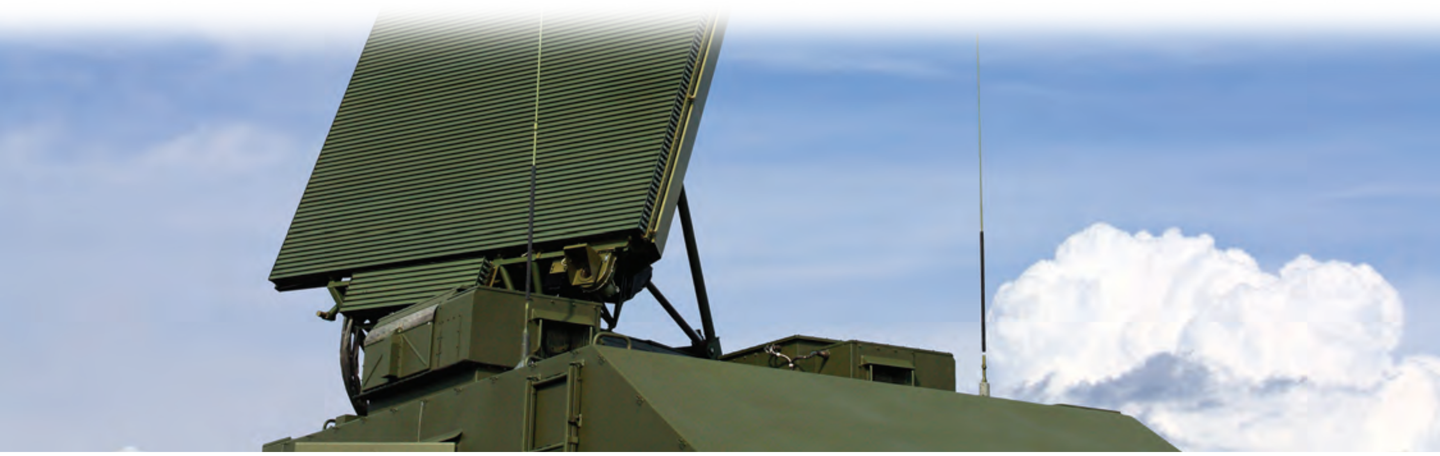
The simulation results helped Raytheon engineers understand how the failure occurred, and they corrected the design to eliminate future failures. The team solved the electromagnetic model at the initial temperature, sent the electromagnetic loss to the thermal simulation to determine the impact of the losses on temperature, sent the temperatures back to the electromagnetic model to calculate losses on the new temperatures, and continued to iterate until steady-state temperature changes were reached. After a few more changes to the materials used in the product, the simulation showed that the design worked perfectly, and this was confirmed by physical testing.

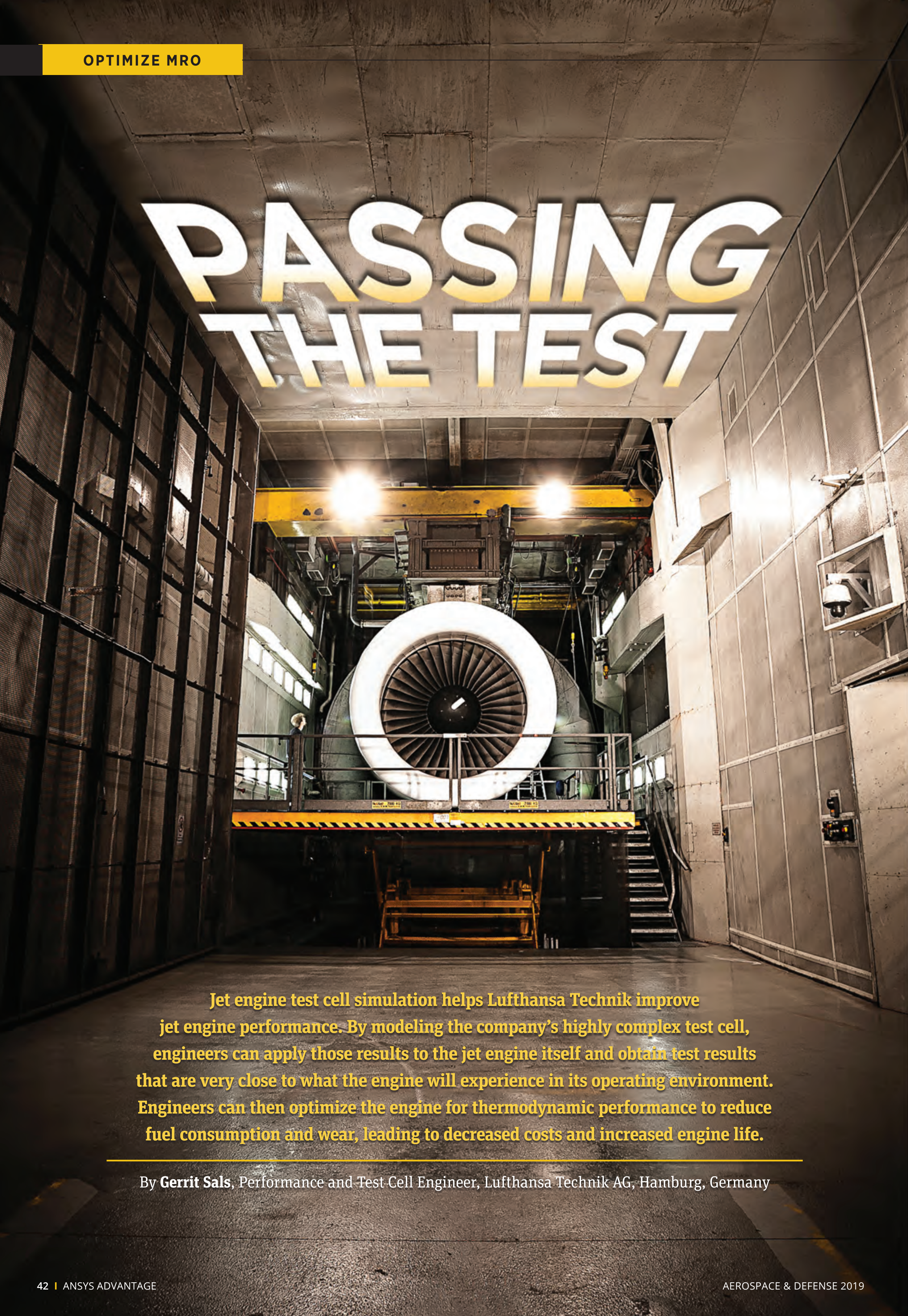


Multiphysics analysis accurately predicts voltage breakdown damage. Physical damage on left and simulation on right. Fields are plotted on the right.

> **“The simulation showed that the design worked perfectly; this was confirmed by physical testing.”**

Robust Electronic System Design Practices for Aerospace and Defense Products
ansys.com/83wire raytheon-webinar



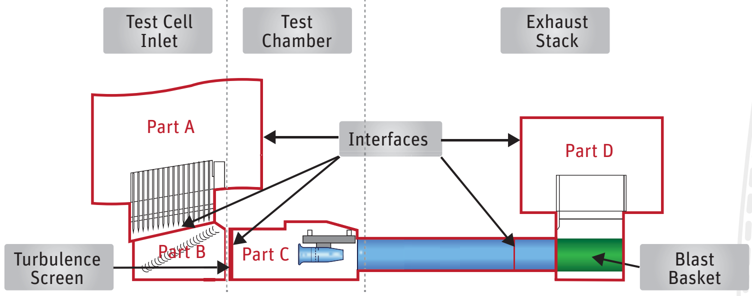


PASSING THE TEST

Jet engine test cell simulation helps Lufthansa Technik improve jet engine performance. By modeling the company's highly complex test cell, engineers can apply those results to the jet engine itself and obtain test results that are very close to what the engine will experience in its operating environment. Engineers can then optimize the engine for thermodynamic performance to reduce fuel consumption and wear, leading to decreased costs and increased engine life.

By **Gerrit Sals**, Performance and Test Cell Engineer, Lufthansa Technik AG, Hamburg, Germany

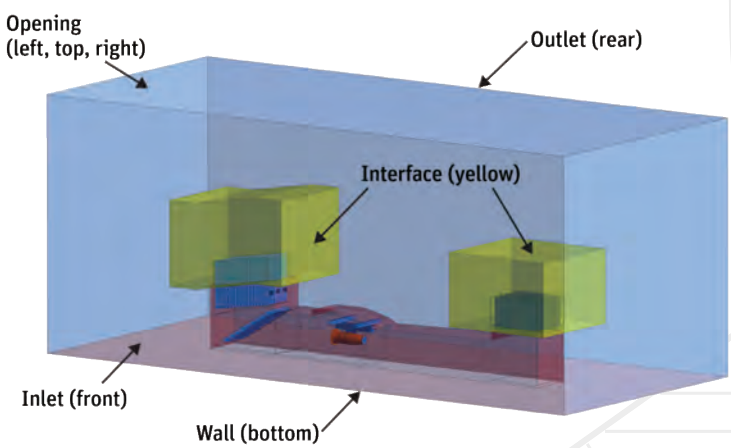
Overhauling a typical commercial jet aircraft engine might cost about $2 million as an expert team inspects and services or replaces up to 40,000 parts. Such an overhaul could be necessary each time the engine flies between 2,000 and 10,000 flights. Overhauls can vary greatly in their work scope, which describes the engine components that are to be serviced or replaced. The work scope is vital because it largely determines the overhaul cost and the performance of the overhauled engine. Lufthansa Technik is improving the engine overhaul process by simulating individual engines at a very detailed level to quantify the relationship between the condition of specific components and the operating behavior of the engine. The insight gained from these simulations allows the team to develop a customized work scope in close consultation with the customer. This work scope might allow engineers to increase the thermodynamic engine performance, which reduces fuel consumption and wear, thereby decreasing future maintenance costs. The understanding acquired from simulation also makes it possible to obtain maximum use from thermodynamically as well as economically critical parts, for example, by operating expensive turbine blades for longer periods.



The test cell was partitioned into five models joined with interfaces to enable simulation of the complex model.

Until recently, these simulations were based solely on the engine operating in the air or on the runway, in contrast to jet engine diagnosis and acceptance testing, which is performed in test cells where operating conditions can be significantly different. Lufthansa Technik engineers have long wanted to simulate engines as if they were operating on the company's jet engine test cell. This would require modeling the test cell so the results could be used in modeling the engine. However, test cells are challenging to simulate due to the size and complexity of the geometry, the large range of length and velocity scales present, and flow Mach numbers ranging from near zero to transonic.

Lufthansa Technik engineers have recently overcome these challenges by simulating one of the company's test cells and validating the results against physical testing measurements. Once the team is able to use the test cell simulation results as input to the engine simulation, engineers will be able to better understand the results of diagnostic testing in the test cells, and will also be better able to predict the effects of different overhaul work procedures on acceptance testing. The result should be improvements in engine performance and more accurate overhaul work scoping with resulting cost reductions.



Outer boundary conditions

Optimizing the Overhaul Process

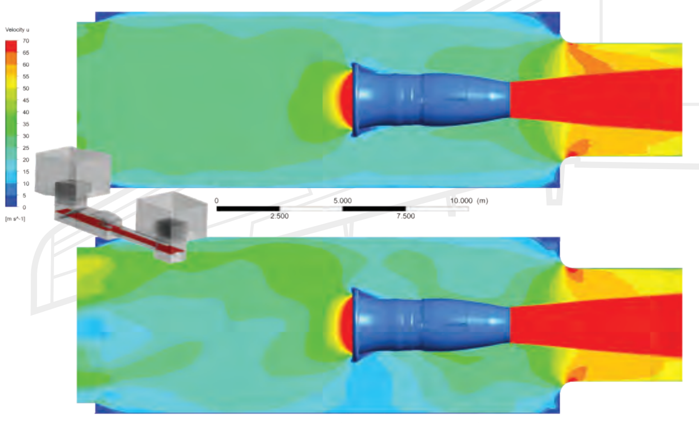
Lufthansa Technik AG is one of the world's leading providers of aircraft maintenance, repair and overhaul services. To improve engine efficiency while avoiding unnecessary work during engine overhauls, detailed knowledge of the internal interactions in the engine is essential. Lufthansa Technik constantly monitors important components so they can be replaced as a function of their condition. Further efficiency improvement can be achieved by precisely determining how the condition of individual components will affect the engine behavior as a whole. By establishing this link between component condition and the operating behavior of the engine, it is possible to target critical components to address during overhaul.

Lufthansa Technik engineers perform three levels of simulation to determine a cause-and-effect link between component condition and engine operating behavior. The highest level is the overall engine level, in which general engine parameters such as thrust, fuel consumption and exhaust gas temperature (EGT) are determined using commercially available thermodynamic cycle analysis software. The second level is a flow simulation of the entire engine based on the multiple mean-line approach. The third level consists of detailed ANSYS CFX computational fluid dynamics (CFD) simulations of sections of the engine.

> **"The understanding acquired from *simulation* makes it possible to obtain *maximum engine* life."**

Recently, Lufthansa Technik engineers set out to further improve this process by simulating the company's test rig to obtain boundary conditions for engine simulations. Internal boundary conditions are derived from the cycle analysis in 95 percent of the cases, which in turn is based on test-cell data. Employing data obtained from a 3-D flow field of the test cell helps the engineers simulate behavior under specific conditions, such as considering the inlet flow of the fan to determine the effects of humidity, rain and crosswinds. This, in turn, enables them to better predict the relationship between component condition and performance on the test cell. Because of the complexity of the test cell geometry, it was split into five models with interfaces between them so the adjoining models provide boundary conditions for each other.

By partitioning the test cell, engineers reduced the model complexity and size, and enabled a modular approach whereby different simulation configurations can easily be constructed by assembling individual components. The CFX flexible general grid interface (GGI) enables such a modular approach. Part A contains the inlet to the test cell and inlet splitters; Part B includes turning vanes; Part C comprises the test chamber, turbulence screen, thrust stand, engine and augmenter tube; and Part D contains the exhaust stack and outlet splitters. The area surrounding the test stands was modeled separately and called the Environment. In addition, the turbulence screen and blast basket were each incorporated into the simulation as subdomains.



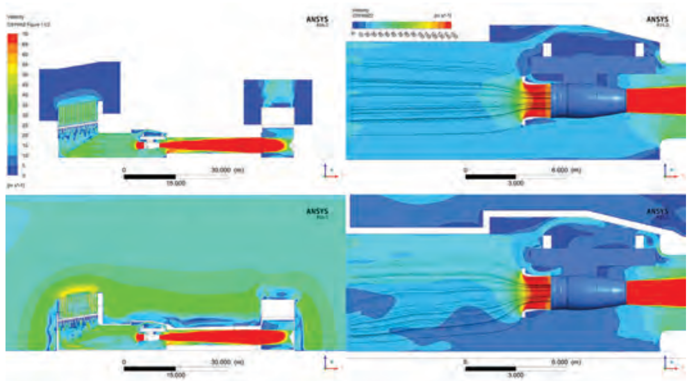
Axial velocity inside test chamber for static conditions (top) and crosswind (bottom)

Modeling the Test Cell

Engineers generated each mesh segment individually using ANSYS ICEM CFD Hexa capabilities, part of ANSYS meshing. Creating the mesh was the biggest challenge in this simulation process. Lufthansa Technik engineers used the mesh diagnostic and repair tools to maintain high levels of mesh quality throughout the mesh generation process. The mesh structure for Parts A, B, D and the Environment was generated as hexahedral H-grids because a hex mesh provides the best trade-off between accuracy and resource requirements. Additionally, small changes can be performed easily. On the other hand, Part C was meshed as a structured hexahedral O-grid for maximum accuracy in this critical section of the model. The interfaces reduced computational time by making it unnecessary to propagate the structured hexahedral O-grid through the turning vane geometry in Part B.

The air enters the test cell through the inlet, where it accelerates when passing through the flow splitters. The turning vanes deflect the vertical flow without significant acceleration. Downstream, the flow passes through the turbulence screen, which leads to a drop in total pressure along with more uniform air flow. The engine then adds energy to the air flow, increasing the temperature, velocity and total pressure behind the engine. This in turn leads to an acceleration of the air bypassing the engine, which is called the ejector effect. The exhaust gas then leaves the test cell through the augmenter tube, blast basket and exhaust stack.

Engineers simulated the test under two different sets of environmental conditions, which were used as boundary conditions. The first assumed no air movement at the inlet and outlet of the test cell, and the second assumed a 20 m/s crosswind at the inlet and outlet. While different wind directions and speeds are not used in testing, adjustments were made to the CFD model to account for crosswinds, and simulation was used to evaluate those adjustments. The external boundary conditions, which are needed only during the crosswind simulation, include an inlet in front, an outlet at the rear, and openings in the left, top and right of the model. The model's internal outlet boundary (engine inlet) is dependent on the model's internal inlet boundary (engine outlet). The mass flow of these boundaries is coupled through functions based on the static pressure and total temperature at the engine's exhaust nozzle. The functions were derived using thermodynamic cycle analysis. This setup increases the accuracy of the model as the engine changes its operating point according to the test cell flow conditions.

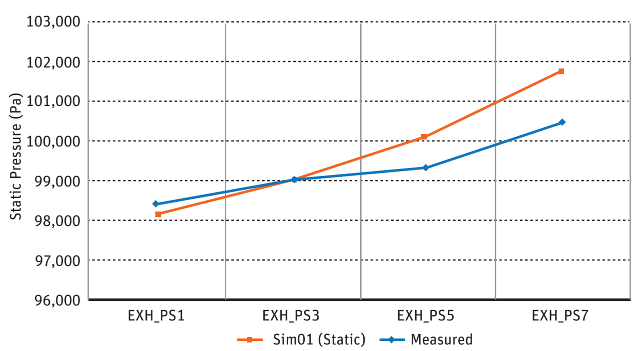


Fluid flow in the test cell predicted by simulation for static conditions (top) and crosswind (bottom). This enables engineers to better understand the test cell under real-life conditions to aid jet engine overhaul.

Validating the Simulation

To better understand the test cell results, all that is needed from the test cell simulation is to determine the boundary conditions at the engine inlet and outlet. However, Lufthansa Technik engineers wanted to validate the complete model — including its ability to predict pressures and velocities at any point in the solution domain — so that this information could also be used in evaluating proposed changes to the test cell. The test cell model was validated by comparing simulation results and test cell measurements of static pressure at various points inside the augmenter tube. The deviation between the simulation and test results was very good (from –0.05 percent to –1.33 percent at four different points). However, Lufthansa Technik engineers are working on further improvements in accuracy by refining the mesh in the area of the blast basket and further downstream.

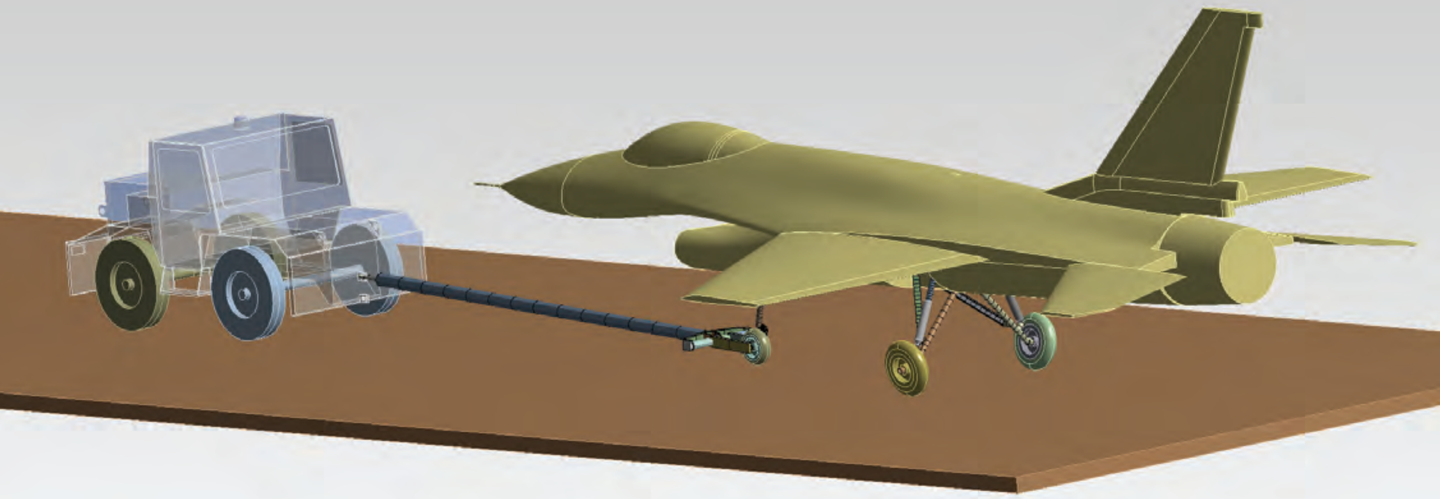
The test cell model will soon be used to provide boundary conditions for engine simulations used as part of the work scoping process for engine overhauls. Accurate engine-in-test-cell simulation will help engineers further improve the performance of overhauled engines and refine the work scoping process with the potential for significant cost savings. For example, the customer may specify that the overhauled engine must provide a certain EGT on the test cell. Lufthansa Technik engineers will be able to better evaluate the impact of different possible work scopes on the EGT as measured on the test stand. In addition, the test cell model will be used to improve the test cell design and evaluate the impact of different sensor placements in specific tests.



Comparison of simulated and measured pressure inside the augmenter tube shows acceptable agreement.

Using simulation, Lufthansa Technik will not only improve jet engine performance for customers but fine-tune internal processes to reduce costs. Simulation accuracy reduces risk and makes the company more competitive.

Efficient and High-Performance Flow Path Development
ansys.com/flowpath

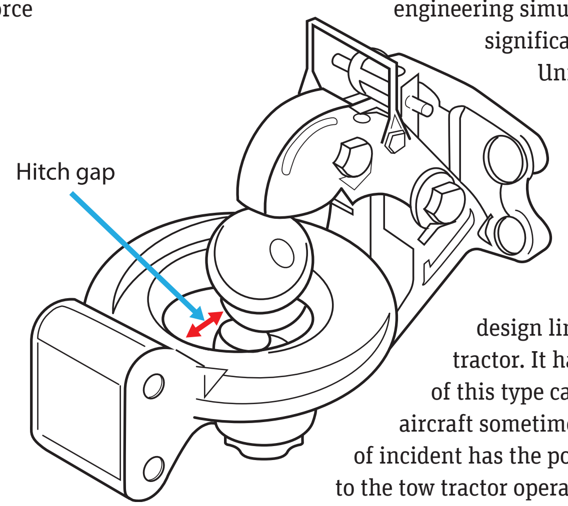


Hitting the Brakes

United States Air Force jets were being damaged when the tow tractor that transports them around bases came to a sudden stop. An Air Force engineering team used ANSYS Mechanical to determine the cause of the problem and devise a simple solution to this multimillion-dollar problem.

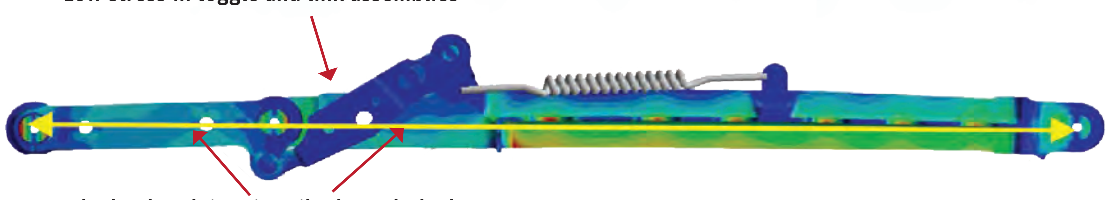
By **Andrew Clark** and **Jared Butterfield**, Lead Structural Analysis Engineers, United States Air Force Hill AFB, U.S.A.

Because affordability is one of the key mantras of the U.S. Department of Defense, and engineering for sustainability initiatives (to optimize operational availability of assets while controlling costs) is growing in importance, engineering simulation is playing an increasingly significant role. This is certainly the case at the United States Air Force (USAF). Before a fighter jet can take off to perform its mission, it must be towed from the maintenance shed to the hangar, from the hangar to the taxiway, etc. USAF lightweight jets experienced mechanical damage after impact loads from a tow bar connection exceeded design limits during a sudden stop by the tow tractor. It has been estimated that a single failure of this type can cost upwards of a million dollars. The aircraft sometimes overhangs the tow tractor, so this type of incident has the potential to cause death or serious injury to the tow tractor operator, not to mention damage to and loss of



> “Fifteen separate transient ***dynamic analyses*** were completed to simulate the ***various combinations*** of factors.”

operational capability for the aircraft. Engineers were puzzled because the drag-brace assembly — the landing component that originally failed in these accidents — should have been designed to withstand known tow-bar loads. Physical testing of the aircraft was of limited use in determining the cause of the problem because an actual aircraft could not be risked in a test. The USAF team solved the problem by simulating a wide range of braking incidents to determine the conditions under which the drag-brace assembly could fail so they can be avoided in the future.



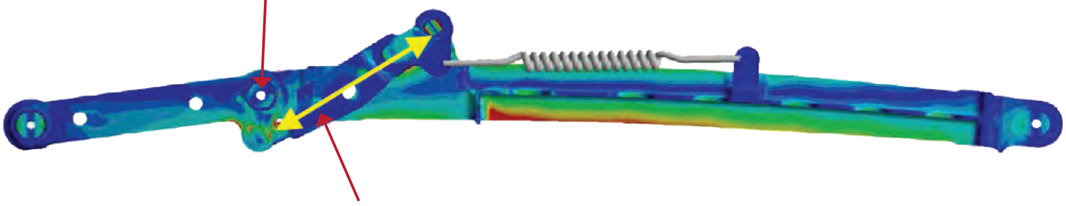
Initially, the upper drag brace bends, resulting in column instability.

Simulation Helps Determine Root Cause

The USAF team first performed finite element analysis (FEA) with ANSYS Mechanical on the drag-brace assembly to determine whether or not it was strong enough to withstand the towing limit loads in the design specification. Engineers created a model of the drag-brace assembly and performed a static structural analysis that showed that the assembly is even stronger than the design specification. The actual drag-brace assembly was placed in a test fixture and loaded in accordance with the FEA simulation. The test results agreed with the structural simulation and demonstrated that the assembly indeed exceeded the design specification. Simulation and testing further defined the sequence of events that occurs during failure. First the upper drag brace bends, resulting in column instability. Next, the primary load path changes to a secondary and weaker load path involving the smaller downlock link assembly. This secondary path load overcomes the downlock link lug, causing the drag brace assembly to fail catastrophically.

Next, engineers performed a multibody simulation using the ANSYS Mechanical Rigid Body Dynamics add-on module for ANSYS Workbench to quantify the loads imparted to the drag-brace assembly when the tow tractor driver hit the brakes. They modeled the towing assembly using CAD software, then imported the geometry into ANSYS Workbench and created a finite-element model using line, shell and solid elements. Material properties including modulus of elasticity, Poisson’s ratio and lumped mass or density was incorporated into the model to account for stiffness and inertial effects. Spring stiffness and damping properties were defined for the nose and main landing gear struts. These properties were applied as user-defined joints to the struts as a function of position and velocity. The tow bar was attached to the tow vehicle with a translational joint using constraint equations that simulated various sizes of hitch gap — the distance between the tow vehicle pintle hook and the tow bar ring. The tow bar connects to the drag brace assembly in the landing gear to tow the aircraft; the hitch gap is the play or slack in this connection. The stiffness of the tires of the fighter jet and tow tractor were included in the model using information provided

Multibody Dynamics: Rigid and Flexible Methods
ansys.com/multibody



by the tire manufacturers. Engineers used time-history velocity data acquired from physical testing as an input to the simulation to increase the accuracy of the load response. Velocity and braking frictional forces were idealized as linear over time.

Parametric Study

Engineers recognized that variable impact loads could occur with different tow tractors, at different speeds, with various braking forces, under diverse operating conditions, etc. Some or all of these variables could have a major impact on the loading of the drag-brace assembly. They accounted for this uncertainty by parameterizing variables that they suspected might play a major role in the series of accidents, including tow-tractor weight, velocity, acceleration time, stopping time and hitch gap. Fifteen separate transient dynamic analyses were completed to simulate the various combinations of factors defined during the testing phase of the contract. The results from these fifteen simulations were compared against test data to validate the model.

Engineers concluded that the shape of the braking model depends upon the tow operator. This in turn affects the load response and causes significant variation from event to event. In spite of this, they determined that the maximum compressive force that develops from the impact event was highly dependent on the hitch gap. A larger hitch gap generated higher compressive forces. The simulation showed that when the hitch gap exceeds a half inch, the collision between the tow bar and tow vehicle can generate compressive loads in excess of the drag-brace assembly's ultimate load. Further simulation iterations showed that decreasing the hitch gap reduced loads significantly across all analysis and test conditions. Engineers also determined that the weight of the tow truck had a significant effect, with heavier tow trucks generating greater loads on the drag brace assembly.

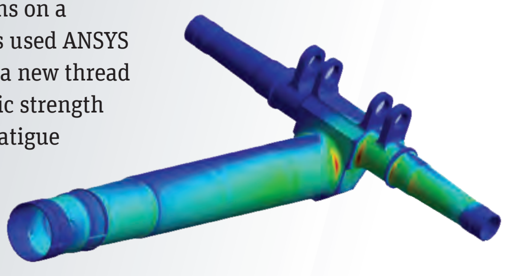
Controlling this gap was determined to be a simple and effective solution in maintaining towing loads below the allowable limit. The Air Force recommended new procedures that limit the hitch gap and mandate that only tow tractors less than a specified weight could be used to tow smaller jets. These new procedures will improve safety and eliminate damage to the nose landing gear of these expensive aircraft during towing operations.

This application provides a typical example of how the USAF is using engineering simulation to determine the root cause of performance issues so they can be quickly and efficiently resolved to save money and improve operational readiness.

$3.6 Million Saved in Nose Landing Gear Piston Simulation

In another case, replacement of nose landing gear pistons on a Boeing 707 variant was a major expense. USAF engineers used ANSYS Mechanical for structural and fatigue analysis to identify a new thread repair method that extends the life of these parts. The static strength margin of safety was verified through simulation, and the fatigue life was verified through digital fatigue analysis.

Savings are estimated at $2.3 million in avoidance of new procurements and $1.3 million in reduction in repair expenses in the first year of implementation alone.

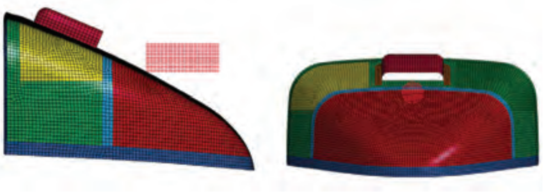


TO THE TEST

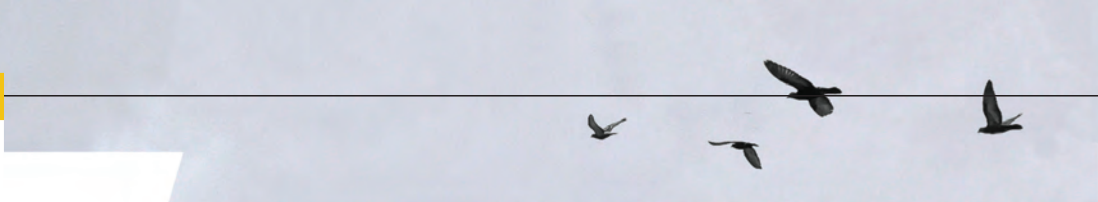
In the past, the only way to determine whether composite aircraft components could withstand bird strikes was with time-consuming physical tests. Now, Hindustan Aeronautics Limited engineers use simulation to get the design right the first time. Bird strike simulation saves the company design time and thousands of dollars per test of composite helicopter components.

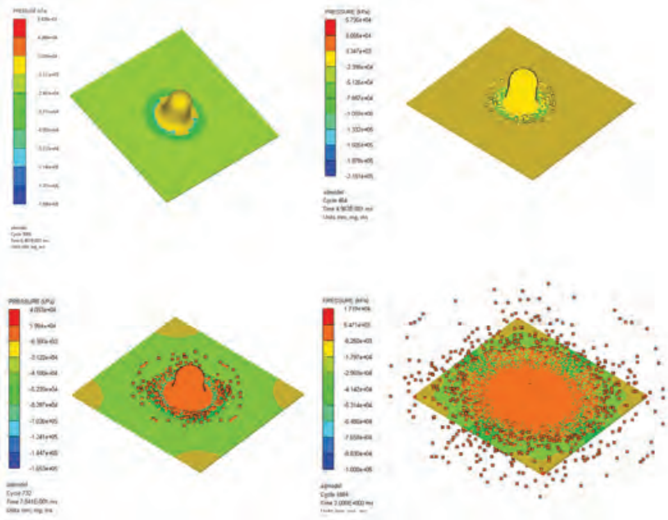
By **Vijaykumar Rayavarapu**,
R&D Manager, Hindustan Aeronautics Limited
Bangalore, India

In 2014, four U.S. Air Force personnel were killed when their HH-60G Pave Hawk helicopter crashed during a training mission in Norfolk, England. The U.S. accident investigation board found that the accident was caused by geese flying through the aircraft's windshield, knocking the pilot and co-pilot unconscious. They were unable to react when another bird struck the helicopter's nose and disabled the craft's stabilization system. The result was an uncontrolled roll to the ground, destruction of a US$40 million helicopter and loss of life. This is not an isolated incident. According to the United States Department of Agriculture's Animal and Plant Health Inspection Service (APHIS), bird strikes to civilian and military helicopters have resulted in 11 human deaths and 61 injuries since 1990. [1]



SPH bird model with Lagrange model of cowling





Simplified simulation of bird model into flat plate

In an effort to protect crew and passengers from the dangers of bird strikes, regulatory authorities, including the Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA), have issued regulations regarding the ability of helicopters to survive bird strikes. For example, the FAA's 14 CFR 29.631 regulation now demands that category A rotorcraft (the highest certification standard, which requires, among other things, assurance of continued flight in the event of failure) be capable of continued safe flight and landing after bird impact. Bird strike certification has been a time-consuming and expensive process because the only way to determine whether a component could survive a bird strike was physical testing. Tests usually needed to be repeated several times because components often failed and replacements were required for each new design. Hindustan Aeronautics Limited (HAL) has substantially reduced the time and cost of certification by using ANSYS Composite PrepPost and ANSYS Autodyn to accurately simulate bird strikes. Simulation makes it possible to efficiently determine a suitable design so that only one test is required per component.

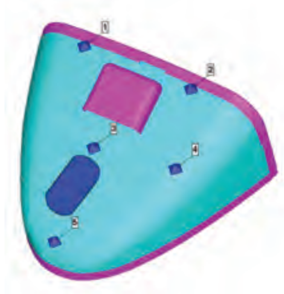
Simulation Challenge

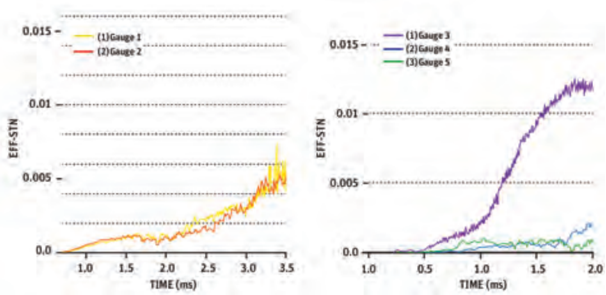
The components that require certification on modern helicopters, such as cowling, horizontal stabilizers and end plates, are typically made of fiber-reinforced composites. Cowling refers to detachable panels covering those areas to which access must be provided, such as the engine, transmission and other vital systems. Bird strike simulations are challenging because they are of short duration, cause large material deformation, and involve interactions between bodies with rapidly changing surfaces. The difficulty is increased by the need to model composite materials that include numerous layers, each with its own material, footprint, thickness and orientation.

As a first step to determine the validity of the model used, HAL simulated a simplified case that could easily be done experimentally. The results of physical testing were correlated with the calculations, which confirmed the viability of models used with the aircraft. The bird strike simulation consisted of an idealized geometry striking a flat plate. The bird was modeled as a cylinder with flat ends, and as a cylinder with hemispherical ends. A bird undergoing impact at high velocity behaves as a highly deformable projectile with a yield stress much lower than the sustained stress. Based on this, and also because the density of flesh is close to the density of water, it is possible to approximate the bird as a lump of water hitting the target. The analysis was carried out with the Autodyn solver using the smoothed particle hydrodynamics (SPH) method to avoid numerical difficulties associated with extensive mesh distortion. The results correlated well with the analysis of shock pressures calculated using hydrodynamic theory.

Defining Composite Geometry

Realistically simulating certification tests requires modeling complex composite structures. HAL imported the geometry of a cowling into the ANSYS Workbench environment. The cowling comprises a Kevlar® fiber skin and a honeycomb core. ANSYS Composite PrepPost was used to define the number of layers and the shape, thickness and orientation of each layer. Compression tests

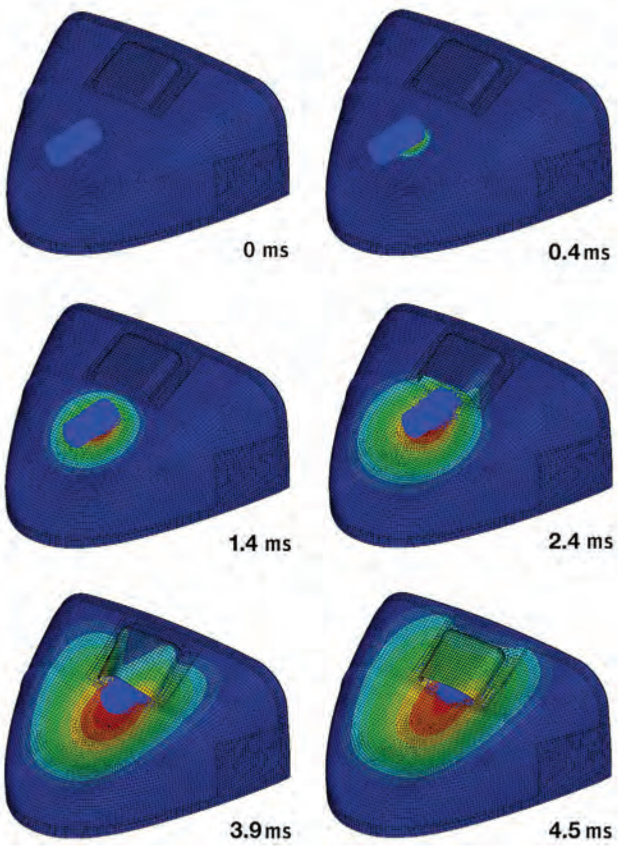




Effective strain plot predicted by simulation on square specimens were performed according to ASTM standards to determine the properties of the core. The composite definitions were then transferred to the finite element model and the solver input file. The material properties for each composite layer were defined with a constitutive material model inside ANSYS Composite PrepPost, with appropriate damage initiation criteria and damage evolution. Further preprocessing was done in ANSYS Explicit STR. The composite definitions from ANSYS Composite PrepPost were seamlessly transferred to Autodyn through ANSYS Workbench.

A key advantage of ANSYS Autodyn explicit solver is its ability to combine Lagrange, Euler, arbitrary Lagrange-Euler (ALE) and SPH methods in a single problem to produce results with the highest accuracy possible within a reasonable computational time. In this case, the SPH bird model was used to model the bird, while the Lagrange model, with its high computational speed, was used to represent the cowling structure. The model was set up to match the test conditions of a bird strike test conducted at a research facility, including the application of aerodynamic loading to the cowling. Virtual strain gauges were defined within Autodyn at the same positions on the cowling as those used in the physical test.

> **"*Bird strikes* to civilian and military helicopters *have resulted* in 11 human deaths and 61 *injuries* since 1990."**



Cowling deformation at various time intervals

Correlation with Physical Testing

Within each element, the Lagrange solver captured the material location of the discretized model and followed its deformation as forces were applied. The solution time was under one hour for a simulation time of 4,000 microseconds. The simulation accurately predicted the basic parameters of the test as well as the damage location and failure size.

The failure mode at different time intervals also matched well with the test results. At the early stages of impact, the mechanical response of the composite structure is controlled by the fiber–matrix interface. At the intermediate stages of impact, when the shock wave reaches the face-sheet–core interface, a negative pressure region begins to develop on the back of the face sheet, giving rise to tensile failures of fibers in this region. At later stages of impact, a substantially larger region of outer face sheet is subjected to negative pressures, causing it to fail structurally. Meanwhile, high strains are observed in the cowling surrounding the top of the projectile.

The correlation study provided a high level of confidence in the ability of the simulation to predict dynamic responses and structural failures subjected to high-energy bird impacts. With the model validated, HAL now uses it to design new exterior structural components that can pass bird strike certification tests the first time. In obtaining EASA certification for a civilian version of the HAL Dhruv Advanced Light Helicopter, simulation eliminated the need for one or two additional tests that were nearly always required in the past, saving time and thousands of dollars in testing for each component that was certified.

References

[1] Keirn, G. Helicopters and Bird Strikes; Results from First Analysis Available Online. blogs.usda.gov/2013/06/06/helicopters-and-bird-strikes-results-from-first-analysis-available-online (12/17/2015).

Impact
ansys.com/impact

AIMING HIGH

By **Eric Besnard**
Chief Technical Officer
Vice President of Engineering
and Co-Founder, Vector
Tucson, U.S.A.

MICROSATELLITES represent a new opportunity to provide connectivity for the Internet of Things, as well as to capture images and data from space, at a relatively low cost — but the challenge is getting them into orbit in a timely and cost-effective manner. By making satellite launches both routine and affordable, startup Vector is opening up the space race to a new generation of small and midsized businesses that can deploy entire swarms of tiny satellites. With its risk-taking engineering strategy, Vector is poised to disrupt the satellite industry, one launch at a time.

Once the domain of large companies and oversized technology, the satellite industry is evolving in exciting ways today in response to a huge, and growing, market for satellite capabilities. The growing Internet of Things (IoT) demands new levels of global connectivity, autonomous vehicles require GPS positioning data, and concern about climate change means that weather conditions on Earth must be continuously monitored.

A new generation of microsatellites — some measuring only 10 centimeters across — has emerged to answer this need, providing uninterrupted connectivity and information capture more affordably than previous technology. These tiny, lightweight satellites are ideally suited to meeting a number of urgent market needs. Deployed in swarms, they provide a powerful solution by enabling communication and supporting data capture and exchange around the world.

While it's relatively inexpensive to manufacture these small satellites, the final frontier is sending them into orbit affordably. The prohibitive cost of traditional launch technology — as well as long wait lists for a launch date — are currently keeping small and midsized businesses from entering the growing microsatellite market. While these businesses can manufacture thousands of tiny satellites, they cannot afford to wait years to launch them.

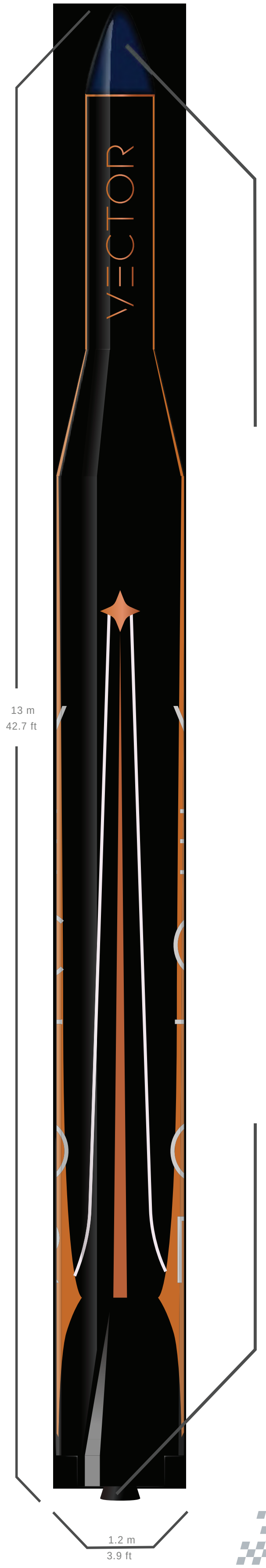
A New Industry Segment Takes Off

Recognizing this market need, Vector was founded in 2016 to design, engineer and manufacture rockets capable of sending customers' microsatellites into orbit. The executive team includes a co-founder of SpaceX, as well as a number of experts who have worked at NASA, Virgin Galactic and other aerospace leaders. The Vector team also brings together a wide range of experience in software and high-technology, engineering, rocket science and business management.

Small to midsized businesses must wait for an opportunity to "hitchhike" on a larger launch mission as a secondary or tertiary payload. Vector is aiming to change that by offering dedicated, frequent, reliable launches. With no competition in the microsatellite launch category — defined as payloads of 60 kilograms or less — Vector sees a unique opportunity to create and then dominate this new industry segment.

Firing Up Innovation

The key to success for the Vector team is quick development and commercialization of the complex technology systems needed to accomplish this goal. Both the launch system and the rocket push the boundaries of physical performance, because significant stresses are placed on every system and subsystem involved. Components in the rocket must withstand speeds in excess of Mach 6, along with temperature variations ranging from –160 C to 3,000 C. All electronics must be miniaturized to keep the rocket small and lightweight, increasing the technical complexity.



While NASA and other large aerospace concerns have generous budgets devoted to research and development, Vector was funded with just $21 million in venture capital. In order to sustain itself and support its future profitability, Vector must keep its team small, minimize development costs and get its products to market as soon as possible. This means implementing a number of new-generation engineering practices.

Engineering simulation represents a critical way for Vector to dramatically cut the time and financial investments required to develop its launch systems. By using a unified set of multiphysics simulation tools acquired via the ANSYS Startup Program, Vector developers can design products in a virtual space, exploring a range of engineering problems across the launch system.

For example, fluids simulation software enables the Vector team to study the rocket engine's internal flows, which are associated with propellants, reacting gases in the combustion chamber and heat loads on the hot chamber walls. Mechanical simulations reveal how the rocket will respond to the huge environmental changes it will have to endure, including extremely high structural, mechanical and thermal stresses.

The combined rocket–launcher system has an enormous degree of numerical complexity. Simulation supports Vector's engineering team as it seeks to bring all those pieces together successfully. Using design exploration, product developers can change parameters very quickly and see how the entire system will respond.

This greatly accelerates the iterative design process and allows the Vector team to arrive rapidly at a rocket and launcher that have a high degree of robustness — before the construction of a physical prototype, which can take months.

Vector and ANSYS
ansys.com/vector

> “Engineering ***simulation*** represents a critical way for Vector to dramatically ***cut the time*** and financial investments required to ***develop*** its launch systems.”

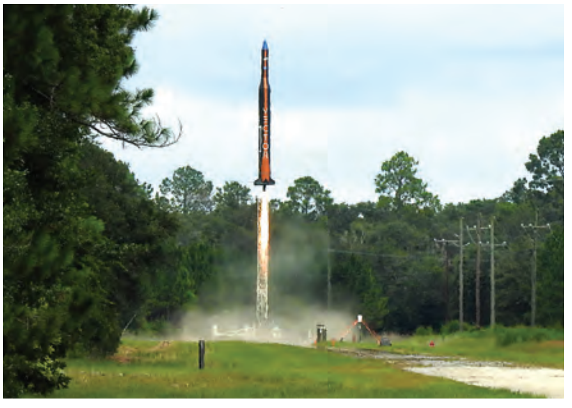
Fail Fast, Fail Often and Fix It

While Vector’s product development team does try to minimize the cost of physical testing, the company also has a unique risk-taking spirit, probably because many of its executive team members have experience in Silicon Valley and the software industry.

Just as software and consumer electronics companies are not afraid to launch imperfect products — then gradually announce new releases with additional features — Vector is willing to test early product prototypes, knowing that the designs are not yet perfect. The Vector engineering team knows that these early rocket designs may not perform flawlessly, but there is much to be learned from failures — and those lessons can actually accelerate the ongoing product development effort. By combining simulation and physical testing, the Vector development team can work quickly to capture the market opportunity, while also making the best use of the limited private funds that are typical of a startup business.

Vector is currently working with the Federal Aviation Administration (FAA) for licensing orbital launches, and in the meantime the company is conducting low-altitude launches, which have a less stringent approval process. Based on these tests, the engineering team is learning about stresses during launch, failure modes, materials strength and other key design issues.

This agile engineering approach distinguishes Vector from traditional aerospace companies, which follow a “waterfall” process in which they design rockets and other systems over the course of years — then build and test prototypes only after years of design work. In addition to being time-intensive, this process consumes large amounts of capital, but it is a necessity because large companies, working under the scrutiny of shareholders and board members, are usually risk averse. They cannot have a spectacular failure, with its accompanying media attention. Vector, on the other hand, embraces the testing that may result in a spectacular failure if it will reveal important engineering insights and inform future design iterations.



Blue Skies Ahead

In its engineering and business philosophy, Vector brings together the best of both worlds: the risk-taking nature of a startup company combined with deep aerospace industry experience and technical depth. That combination should help propel Vector toward its goal of a first orbital launch in 2018.

With two low-altitude test launches on the books, Vector is making steady progress toward redefining the global satellite industry. The company's long-term goal is to schedule 100 launches annually for customers — which means engineering and building 100 rockets per year. Just as the company is applying advanced rocket and launch technologies to invent a new market category, Vector is embracing new-generation engineering practices and tools, including digital design exploration through simulation, to arrive at its ultimate destination faster.

VECTOR AT A GLANCE
Founded: 2016
Number of employees: 100
Headquarters: Tucson, Arizona

PROPELLING STARTUP SUCCESS

Today, engineering simulation software is used by the world's leading engineering teams to design and verify products quickly and cost-effectively, in a risk-free virtual space. Because the cost of licensing simulation software might be prohibitive for startup ventures like Vector, the ANSYS Startup Program was created to help eligible startup companies around the globe bring their innovative product ideas to market. These entrepreneurial businesses can compete more effectively by leveraging the advanced capabilities of ANSYS software, while also benefiting from the world-class engineering processes and workflows that ANSYS has developed over the course of 40-plus years.

"Our ability to access ANSYS software has been a key factor in establishing credibility and securing funding, as well as supporting our engineering success to date," notes Eric Besnard of Vector. "We have very complicated problems to model, and our engineering staff consists of a relatively young team of graduate students and recent graduates. With training and support from ANSYS, we are now conducting incredibly complex design explorations and engineering at the same level as much larger aerospace companies. That is helping us move forward quickly, with a very high degree of confidence in our designs."

For more information on the ANSYS Startup Program, visit ansys.com/startups.

ABOUT ERIC BESNARD

Dr. Eric Besnard is a well-known expert in aerospace system design and rocket and spacecraft propulsion, as well as launch vehicles. He has been involved in liquid propulsion research and launch vehicle technology development funded by NASA and the Air Force, including the development of innovative launch vehicle flights and technologies such as the first known aerospike and LOX/methane rocket engine flight tests. In addition to his work with Vector, Besnard is on the faculty of the Mechanical and Aerospace Engineering Department at California State University, Long Beach.

ANSYS, Inc.
Southpointe
2600 ANSYS Drive
Canonsburg, PA U.S.A. 15317

Send address corrections to
AdvantageAddressChange@ansys.com