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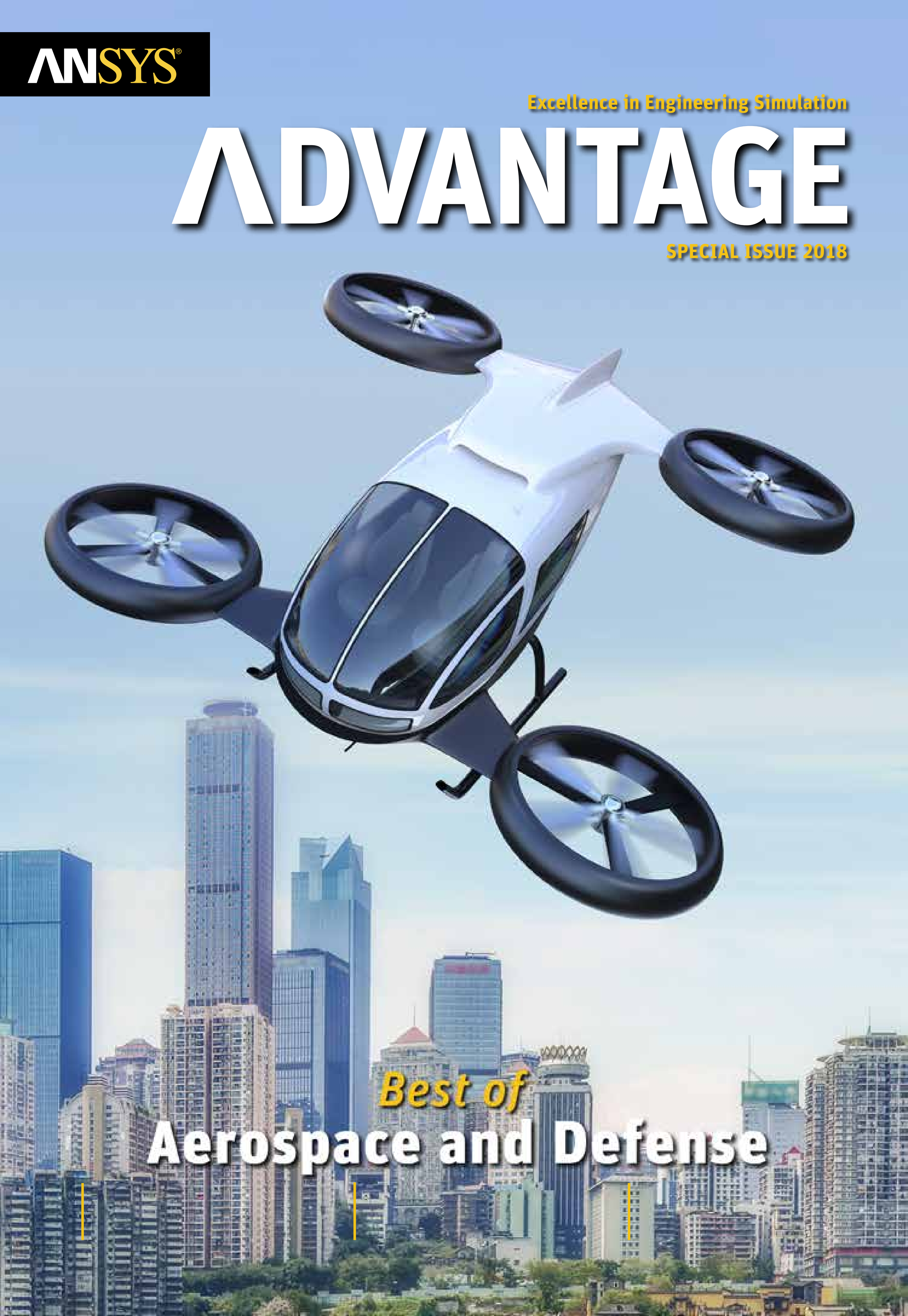

Best of Aerospace and Defense

THE VIEW FROM ABOVE AND BEYOND

By **Paolo Colombo**
Global Industry Director
Aerospace and Defense
ANSYS

Aerospace and defense companies have much in common: the complexity of products they produce, the harsh environments in which these products operate, and an overriding focus on safety and reliability. However, the commercial aircraft, space and defense sectors each face unique technical challenges and market trends. In this special issue of *ANSYS Advantage* focused on aerospace and defense, we explore how these trends drive technology innovation along with how leading companies leverage pervasive simulation to get products to market faster and increase market share.

COMMERCIAL AVIATION

The commercial aviation segment faces constant pressure to reduce both cost and time to design, produce and maintain aircraft. Simultaneously, regulatory agencies demand improvements in fuel economy, emissions and noise control. In response, commercial aviation companies, along with academic engineers who perform research in this field, are making significant investments to improve performance of engines and the entire aircraft. For example, the University of Nottingham's Institute for Aerospace Technology brings together more than 400 researchers working on 70 projects that explore more electric and green aircraft. To reduce the drag effect of antennas that protrude from the surface of an aircraft and save fuel, Inatel and Embraer embed antennas into the plane's composite structures. This effort incorporates aerodynamics, but also includes a true muliphysics exploration that involves mechanical and electromagnetic phenomena analysis to ensure that the antennas can transmit and receive signals through the composite shell without sacrificing communications efficiency.

Weight reduction using new materials and production methods is another way to achieve aircraft efficiency. Carbon Freight, a Pittsburgh startup, designed cargo pallets that are 18 percent lighter than traditional aluminum pallets by employing composite simulation to guarantee durability and performance. Through simulation and additive manufacturing, Optisys reduced large multipiece RF antenna assemblies into a single compact part. This decreased the volume of the assembly by a factor of 100, reduced its weight from pounds to ounces, cut product development time and saved the company greater than 50 percent per system in costs. Such reduction in volume and weight is especially important for space applications and drones.

Competition to capture the growing number of air travelers also means an increased focus on passenger comfort. Aircraft climate control experts at Tianjin and Purdue universities employed systems-level simulation and detailed thermal analysis to improve performance of an entire environmental control system.

The aerospace giant Airbus employs simulation to manage and integrate the increasingly complex, distributed smart systems that comprise the modern jet aircraft. Hindustan Aeronautics and many others save money and time by incorporating simulation and automatic coding into the regulatory certification process.

Pervasive simulation unleashes the power of simulation throughout the product lifecycle, not just during the design phase. As part of maintenance, repair and overhaul (MRO) support services, Lufthansa Technik AG simulates the wear and tear of aircraft components, particularly in jet engines, to prolong service intervals and to create new ways to repair used parts.

DEFENSE

While striving to deliver a technological edge in the least amount of time, many defense organizations and their suppliers operate on the principle of "design for affordability," which focuses on simplifying systems, standardizing components across a platform and using COTS (commercial off-the-shelf) components without sacrificing quality and durability. Governments today invest in a modern warfare environment that includes initiatives like C4ISR (command, control, communications, computers, intelligence, surveillance and reconnaissance), autonomous systems, hypersonic weapons and stealth fighters. These systems are highly dependent on electronics that must perform in harsh environments and tough conditions. Simulation helps engineers understand how failure can occur and how to prevent it. As an example, Kontron uses sophisticated thermal simulation to balance size, weight, power and cooling trade-offs to meet demanding military specifications for mobile and interconnected surveillance, communication and operational devices.

Engineering for sustainability and optimizing operational availability of assets is critical for the defense community. The United States Air Force used simulation to solve a multimillion-dollar issue that occurred when towing aircraft from the maintenance shed to the hangar to the taxiway. Finite element analysis also helped to improve the design of a maintenance trainer for a tracked combat vehicle.

SPACE

After several decades of relative dormancy, the space industry is again a vibrant and growing segment. Previously, well-established incumbents like government agencies and their prime contractors focused on a small number of government and defense contracts, resulting in little incentive to innovate. Now this paradigm has been disrupted by a diverse collection of new entrants and startups. The new space industry is market-driven and supported by private investors interested in rapid technology development for the masses by driving down costs and delivering profitable returns.

New players like Vector leverage simulation to design smaller rockets for more frequent launches, all to make deploying microsatellites routine and affordable. This pushes existing players to modify their design approach to include much more virtual testing, in addition to physical test rigs. Airbus DS performs fluid–structure interaction simulations to solve the problem of fuel sloshing and investigates the effectiveness of a proposed elastomeric membrane in a spacecraft's fuel tank. Innovative companies like World View Enterprises design special vehicles to bring payload up to 95,000 feet and keep it there for weeks or months, reducing cost and deployment time by eliminating the need for a launcher.

Explore this special issue to discover the many ways that simulation is helping to revolutionize the aerospace and defense field. We hope to tell your story next.

ANSYS ADVANTAGE

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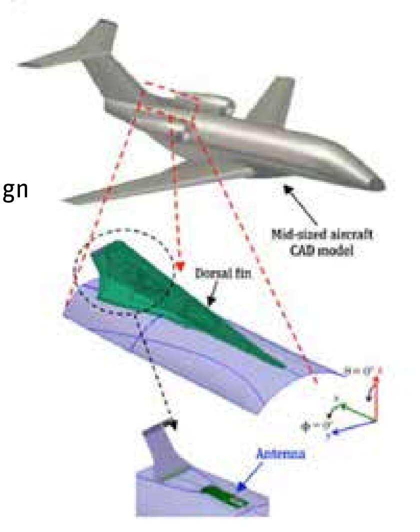
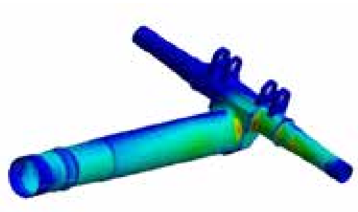


DEFENSE



SPACE

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If you've ever seen a rocket launch, flown on an airplane, driven a car, used a computer, touched a mobile device, crossed a bridge, or put on wearable technology, chances are you've used a product where ANSYS software played a critical role in its creation. ANSYS is the global leader in engineering simulation. We help the world's most innovative companies deliver radically better products to their customers. By offering the best and broadest portfolio of engineering simulation software, we help them solve the mostcomplex design challenges and engineer products limited only by imagination. ANSYS, Inc. does not guarantee or warrant accuracy or completeness of the material contained in this publication.

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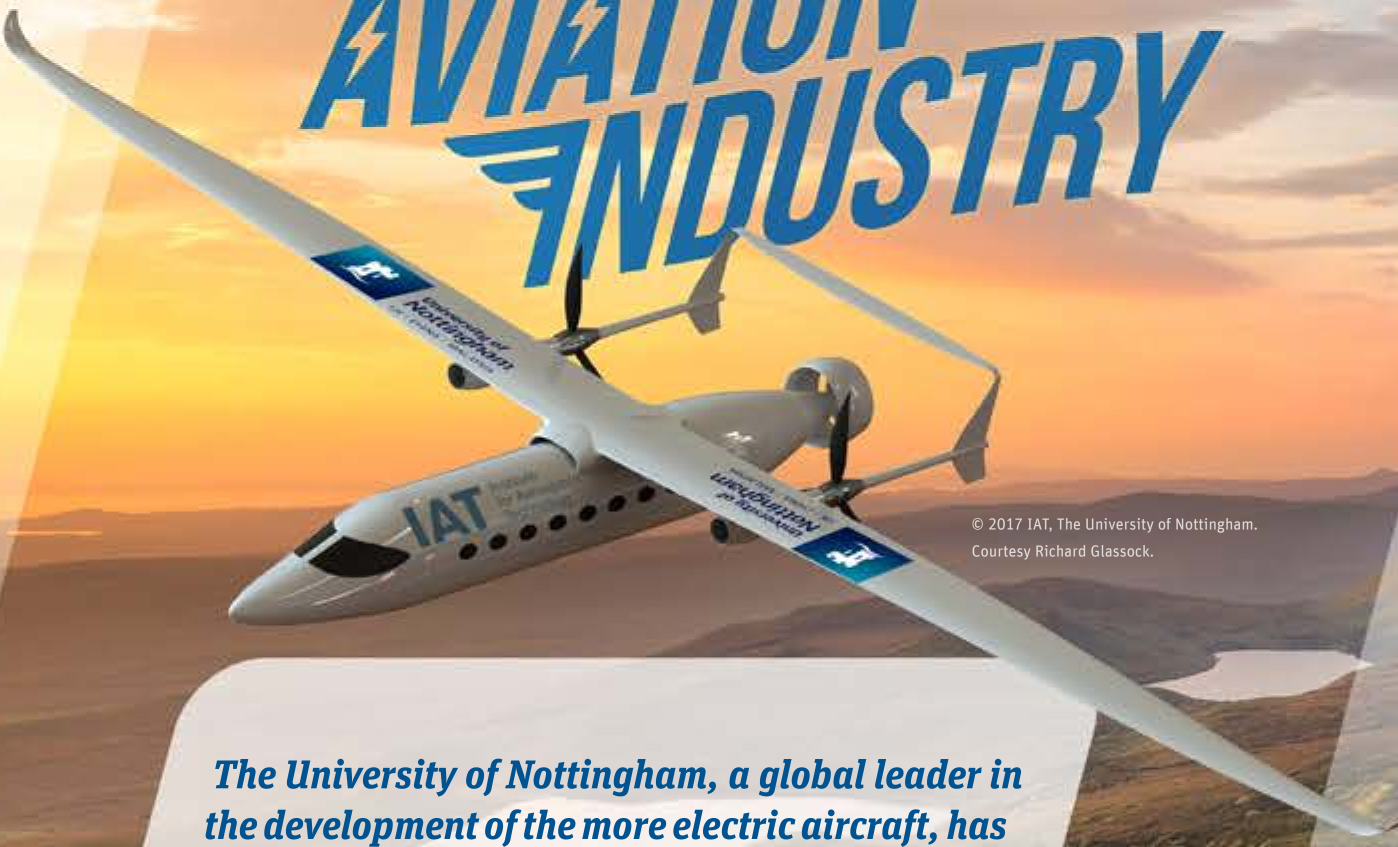
ELECTRIFYING THE AVIATION INDUSTRY



© 2017 IAT, The University of Nottingham.
Courtesy Richard Glassock.

The University of Nottingham, a global leader in the development of the more electric aircraft, has assembled the world's largest research group in power electronics and controls for aviation. As the former director of the University's Institute for Aerospace Technology, Hervé Morvan has a unique perspective on the engineering and business challenges involved in achieving this vision. Recently, Dimensions *spoke with Morvan about the ongoing efforts to electrify traditional aircraft designs for lower environmental impact and greater energy efficiency.*

DIMENSIONS: Tell me about the Institute for Aerospace Technology, which has emerged as a world leader in advanced aviation technologies. Why has the University of Nottingham invested so heavily in this focus area?

HERVÉ MORVAN: The Institute for Aerospace Technology, or the IAT, was founded in 2009 because the university recognized that it had developed a critical mass in aerospace research. The goal was to consolidate all these efforts and bring them together under a single umbrella so the university could accelerate its progress. Today we have more than 400 researchers working on more than 70 projects, with a research investment of more than US$80 million.

We also benefit from a broad interest and great dynamism in aerospace in the United Kingdom today. The U.K. already has the world's second largest aerospace sector, and global demand for air travel is accelerating. It is estimated that, by 2030, there will be around 27,000 new large commercial airliners in the skies. Air travel is projected to grow from 3.4 billion passengers in 2015 to more than 16 billion by 2050. The European Commission, industry and the British government provide funding to our program and other initiatives that will help the nation capitalize on this opportunity — as well as meet the more stringent environmental regulations for aircraft that are so critical to achieving global sustainability and in-service efficiency. As just one example, we have 14 projects, worth €38 million (approx. US$43.5 million) that are directly tied to meeting the goals of Europe's Clean Sky 2 initiative, which spans 24 countries and focuses specifically on reducing CO_2 and other gas emissions, as well as the noise levels associated with aircraft. We also host national facilities for the Aerospace Technology Institute (ATI), the U.K. aerospace research agency.

DIMENSIONS: In addition to government support, do you also collaborate with industry?

HM: We collaborate with industry all the time; this is core to us. We cannot be taken seriously as a global research center if we do not partner with industry to understand business needs, and transfer innovative technologies and knowledge to aircraft manufacturers.

We are working at a technology readiness level (TRL) in the mid range, or a 4–6 level. This means we can verify our ideas in our laboratories, but also support the testing and validation of critical system functionalities in a realistic and industry-relevant environment. We can help our partners conduct all research activities up to the pre-test flight demonstration. This means we can make a significant contribution to those businesses that collaborate with the IAT.

We are fortunate to partner with a number of international aviation leaders — including Rolls-Royce, GE Aviation, Airbus, Boeing, BAE Systems, Bombardier and GKN — as well as small- and medium-sized enterprises that support the aerospace industry, e.g., Romax. These collaborators help us ensure that our work boosts innovation for real-world problems, and that our solutions have significant practical relevance.

DEVELOPING A MORE ELECTRIC AIRCRAFT MEANS REPLACING MANY OF THE TRADITIONAL SYSTEMS WITH SMARTER, MORE CONNECTED, MORE DIGITAL — AND, OF COURSE, MORE ELECTRIC — TECHNOLOGY.

More electric aircraft is a key initiative in the aerospace and defense industry. The aim is to create more-efficient and safer aircraft by converting hydraulic systems to electric and electromechanical ones, thus bringing simpler, lighter and more-reliable technologies on board.

To accomplish this, we must have roots in fundamental engineering science and academe, but also the capability and desire to work at the TRL 4–6 level and, in some cases, even at TRL 7. For example, we aid the formulation of novel models and explore emerging methods such as smoothed particle hydrodynamics (SPH). But we also support design project work with Rolls-Royce and host national test facilities that enable us to achieve validation and demonstrations on aero-engine modules.

Recently, we were awarded a Clean Sky 2 Core Partnership with Rolls-Royce, based on simulation via ANSYS software, that allows us to consolidate a number of our models and numerical methods developed by my team over the past 10 years (time flies!) for industrial applications. This core partnership was awarded based on our track record in the field, but also because we have the capability to conduct this work in-house, at relevant scales — including the ATI-funded test bench onto which a Rolls-Royce engine module can be mounted so that we can collect data for demonstration purposes.

DIMENSIONS: Certainly one of the most exciting areas of aerospace engineering today is the development of a "more electric aircraft." What exactly does that mean — and how is the IAT helping to make it a reality?

HM: Developing a more electric aircraft means replacing many of the traditional systems of the aircraft with smarter, more connected, more digital — and, of course, more electric — technology. One of the main challenges is eliminating or reducing reliance on some of the oldest and most widely accepted components, such as gas turbines, as direct drives or propulsors. They are replaced with, or used in conjunction with, cleaner and higher-performing alternatives. Another challenge is developing larger generators and integrating the whole system.

Of course, the problem is that no one fully knows what such an architecture will eventually look like. We have to throw out a lot of what we know and imagine new engineering solutions that include a broader spectrum of physical phenomena. This is where research institutions like the IAT can play a role. Many industries are pressed for resources. They have 10 years' worth of customer orders to fulfill and require heavy financial investments to support their current development efforts. They also have products to maintain and a booming sector to run and support. This means they need partners to help them invest in and investigate some of these new ideas in a collaborative context. By bringing together 400 experts in diverse technology areas, the IAT can act as a think tank, but also be a delivery vehicle that focuses on innovations that might not be commercialized for years, yet are crucial to the future of the aerospace industry. And then there are the certification challenges of these new solutions … maybe for another interview!

DIMENSIONS: What are some of the biggest engineering challenges that must be solved in order to realize the vision of the more electric aircraft?

HM: The single greatest engineering problem is generating and storing

enough energy to support long-haul flight. An enormous amount of energy is needed not just during extremely high power-consumption events like takeoffs, but to propel the aircraft over hundreds or thousands of miles.

We all know conventional jet fuel has its financial and environmental drawbacks, but it has a high energy yield compared to its weight — about 12 kilowatts per kilogram for Jet A fuel. In contrast, current electric battery technologies generate less than one kilowatt of energy per kilogram of weight. That's simply not a practical answer, because batteries could never support the new energy needs created by their own massive weight. In addition, the materials currently used to manufacture electrical systems might not survive the harsh operating conditions required. And then, there are also integration issues and strict certification guidelines about what can and cannot be done on board an aircraft, as well as reliability and redundancy issues to address. The design framework also has to evolve.

As a short-term solution, we are working to develop new hybrid systems that combine gas turbines to generate electricity with storage systems on board the aircraft that distribute energy to power electrical fans. This is just one example. We are also looking at electromechanical coupling of conventional mechanical systems with more electric components. Such coupling requires a multiphysics simulation approach, to look at thermal management and other challenging issues. These systems will at least allow the turbines to be switched off sometimes to lessen their environmental impact. But in the long term, we need to engineer well-integrated propulsion systems, lightweight battery technologies and more efficient energy storage mechanisms that may, one day, enable the progressive replacement of gas turbines. We are already seeing the creation of new electric battery technologies that can support short flights, so that is encouraging, even if they are not yet sufficient for commercial flight.

Some of the other engineering challenges we are addressing at the IAT include reducing the weight of many aircraft components — for example, landing gear is extremely heavy — as well as exploring new fuselage materials and manufacturing methods for building planes. Today's aircraft are extremely complex systems, and we need to look at every aspect in order to one day achieve the vision of the more electric aircraft. The issue is not simply replacing technologies, but rethinking what a whole system might look like, including an aircraft using the new technologies. Tomorrow's aircraft is unlikely to be a tube, wing and pods, for example. It is also going to be far more electric and digitally enabled and operated.

DIMENSIONS: The aerospace industry is known for its long development and lead times, even for conventional planes. How is the IAT working to accelerate its development cycle for the aircraft of the future?

HM: While the Institute for Aerospace Technology does have some full-scale physical testing facilities, more and more of our development work is accomplished via engineering simulation. Obviously, this saves us significant time and money versus building and testing multiple physical models of aircraft. The industry is naturally looking at this too, and the concepts of "high value design," "whole system design" and "fail fast" simulations are becoming more and more prominent. Digital design and reduced testing are very appealing and are the focus of significant attention in the industry. Here, we can work with and learn from the startup industry and institutions such as the Digital Catapult in the U.K., for example.

Simulation enables IAT researchers to take risks, limit the impact of compromises and redundancies, and ask what-if questions. When you are replacing a foundational technology like a gas turbine or conventional propulsion system with something completely new, you're asking, "How might this work?" You need the freedom to ask bold questions and come up with bold answers. The majority of those solutions may not work out in the long term, and simulation gives researchers at the IAT the opportunity to study and discard many proposed innovations quickly and limit expensive testing down the line, and across multiple physics as well — while focusing on those few ideas that hold more promise. It provides our team with a high degree of creative freedom, which is a necessity when you're essentially trying to reinvent an entire industry.

DIMENSIONS: Looking ahead, when do you think we will see the first all-electric aircraft? And what's the key to achieving that vision?

HM: We are never going to achieve the all-electric aircraft with the technologies we have in place today; it is simply not physically possible yet. It is one thing to engineer a relatively small electric car that has to travel hundreds of miles, but it's quite another thing to move an aircraft weighing tons across thousands of miles using electric propulsion — achieving not only the required energy and power levels, but also the needed reliability level. Someone is going to have to arrive at revolutionary new power-generation and storage technologies before that can happen. And then we will also need to reimagine the infrastructure necessary to support aircraft that are more or all electric. We can already see future, relevant steps on the horizon with projects like the Airbus–Rolls-Royce–Siemens collaboration in E-FanX, and the very vibrant and potentially disruptive electric flying taxi scene. In the U.S. in particular, there is great vibrancy in the 9–10 seater and the training market. These are exciting times!

In the meantime, we can continue to increase the number of electric components in our aircraft and gradually eliminate those components that have the greatest negative impact on the environment and the highest financial costs. Hybrid propulsion systems represent one solution. We also need to understand how to achieve certification of these new systems.

The key to making continued progress is to create an environment of continuous innovation that spans aerospace manufacturers and their suppliers, government agencies, research centers like the IAT and technology providers like ANSYS. We also need to learn from disrupters and startups. By working together to share both our requirements and our advances, we can continue to make progress and create a meaningful impact. While the all-electric aircraft may be decades away, the more electric aircraft is becoming a reality right now, thanks to ongoing advances in technology and an atmosphere of strong collaboration across the global aviation industry. D

University of Nottingham at a Glance

Founded in 1881
Sixth-largest university in the U.K.
Number of students: 33,000+
Campus locations: Nottingham, U.K.; Ningbo, China; Semenyih, Malaysia

About Hervé Morvan

Hervé Morvan joined the faculty of the University of Nottingham in 2003 as a professor in applied fluid mechanics. Since then, his positions at the university have included founder and head of the Gas Turbine and Transmissions Research Centre (G2TRC), a 50-person strong organization with a $20 million portfolio, as well as lead for the aerospace and transport technologies research priority area. In addition to directing the Institute for Aerospace Technology, Morvan also served as associate pro-vice chancellor for Innovation, Business Engagement and Impact. For the past decade, he has served as a consultant to Rolls-Royce and to Speedo during its 2008 and 2012 Olympics campaigns. Morvan holds master's and Ph.D. degrees from the University of Glasgow.

University of
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> ***"We need to engineer well-integrated propulsion systems, lightweight battery technologies and more efficient energy storage mechanisms that may, one day, enable the progressive replacement of gas turbines."***

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

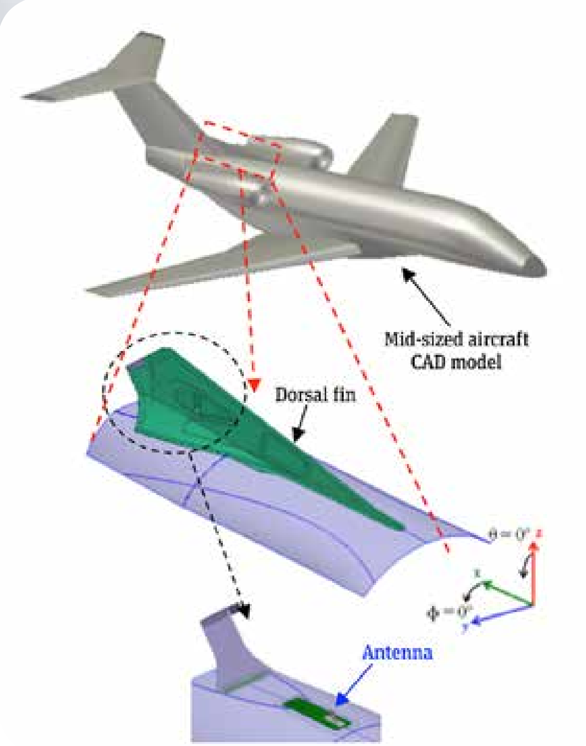
Inside Story

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.



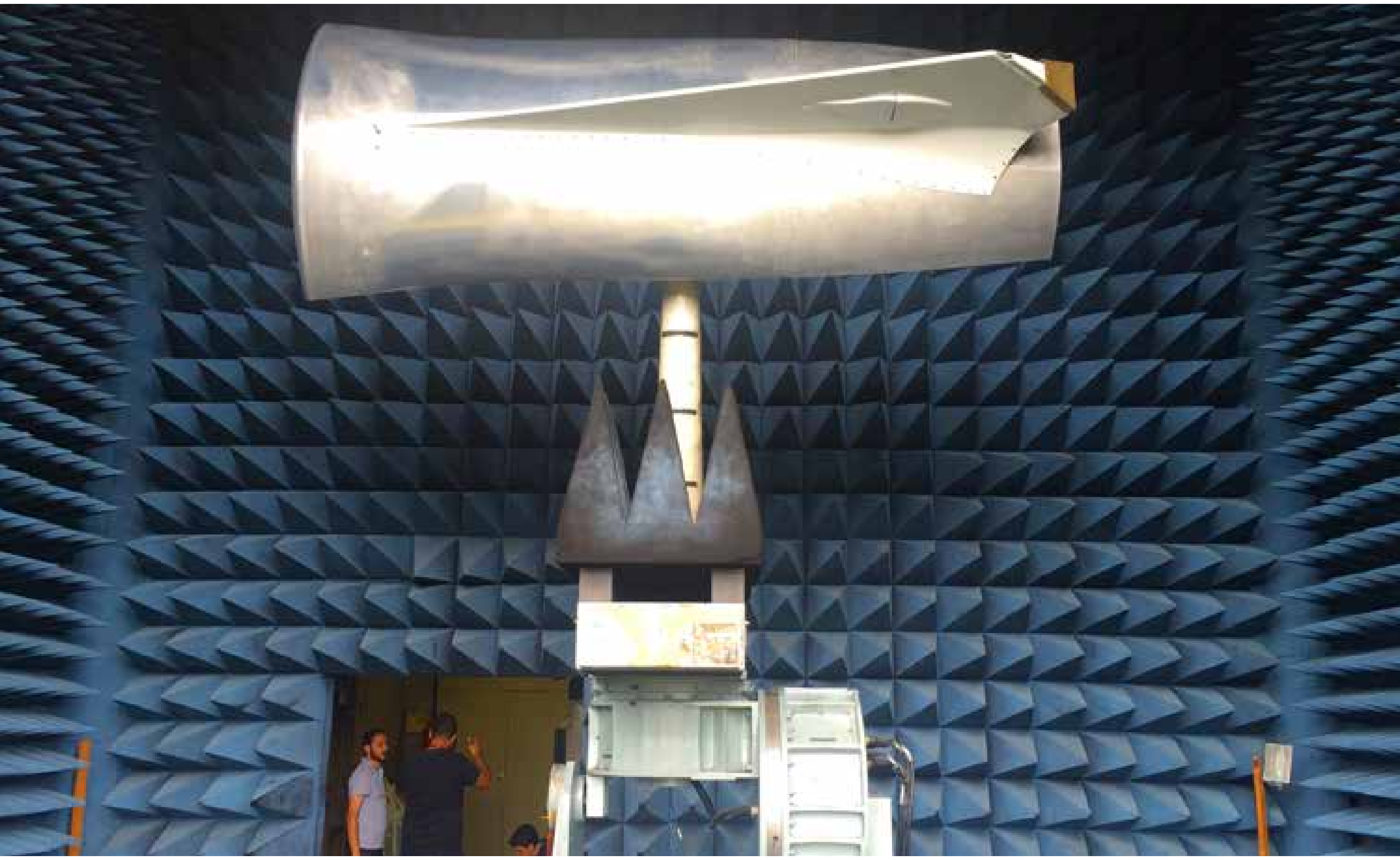
A light jet aircraft and the ANSYS HFSS numerical model of its dorsal fin

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

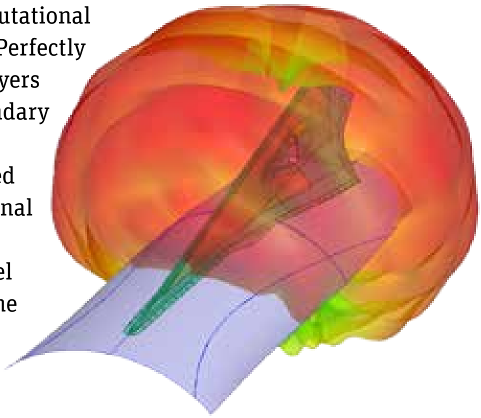
They built a physical prototype of a composite dorsal fin sheltering an existing antenna. They excited the antenna and measured the resulting radiation pattern in an anechoic chamber, which enables accurate measurement of antenna radiation by eliminating reflections of electromagnetic waves as well as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

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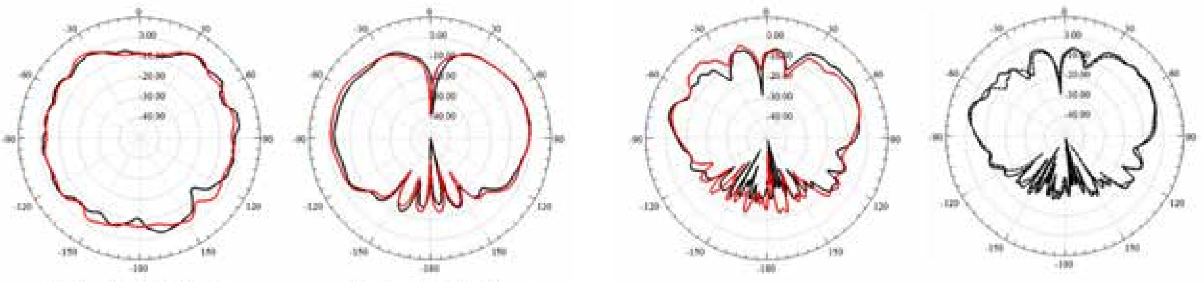
> “Engineers discovered that the *position of the antenna* with respect to the composite and the thickness of the *composite structure* had the greatest impact on antenna performance.”

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.

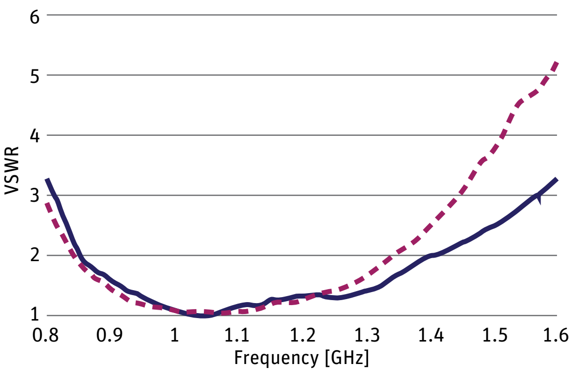
ANSYS HFSS computed the full electromagnetic field pattern inside the structure and calculated all modes and all ports simultaneously for the 3-D field solution. The simulation results correlated well with physical testing, validating both the measured material properties and the HFSS simulation model.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


(a) $\theta = 90°$ (XY plane) (b) $\phi = 90°$ (YZ plane) (c) $\phi = 0°$ (XZ plane) (d) $\phi = 0°$ (XZ plane)

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.

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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

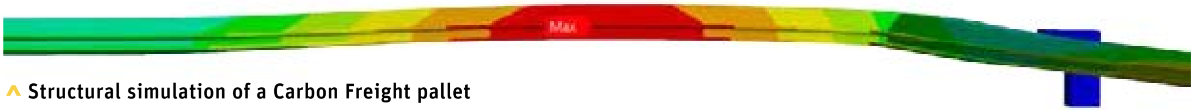
Carbon Freight — a startup based in Pittsburgh, U.S.A. — is attacking this issue with flexible, lightweight cargo pallets that are 18 percent lighter than traditional pallets. "There hasn't been much innovation in the air cargo industry, certainly not compared to the aerospace leaders' focus on new materials 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.”



^ Structural simulation of a Carbon Freight pallet

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.”

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

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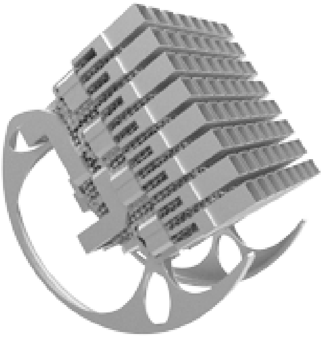
Tuning in to Antenna Design

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

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

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

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

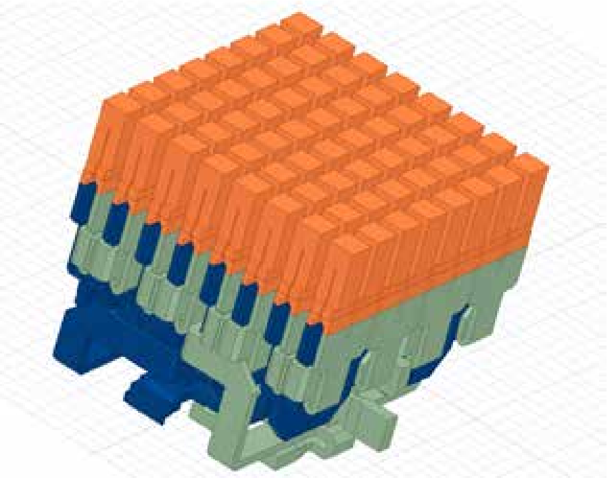
> *"Using engineering simulation with Rescale's big compute platform provided Optisys with massive efficiency gains and the ability to reduce design cycles from months to weeks."*

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

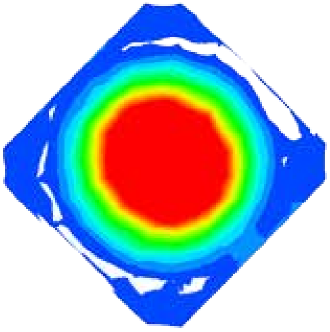
Three-dimensional printing is revolutionizing high-frequency antenna design by realizing levels of integration and performance far above conventional fabricated antennas. To gain the full potential benefits of 3-D printing and other new manufacturing processes requires engineers to redesign the antennas 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

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


E-field inside antenna horn

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

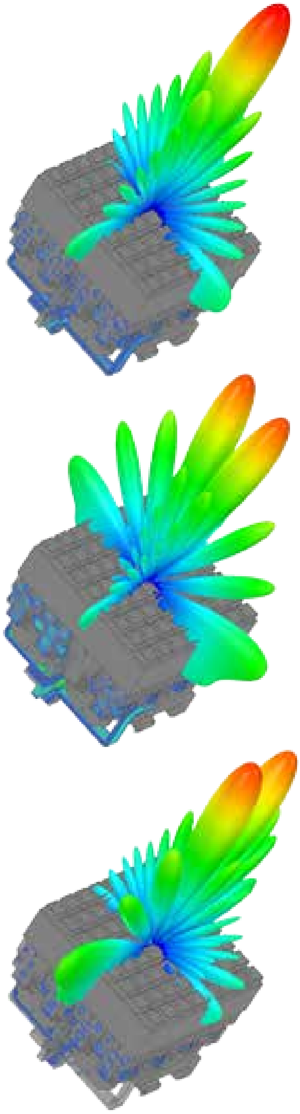
how much was reflected back. The optimizer stepped through the design space by following gradients toward an optimal design that minimized insertion losses and reflected energy. Engineers frequently generated e-field and surface current plots of the waveguide cavities for the designs generated by the 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.



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

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

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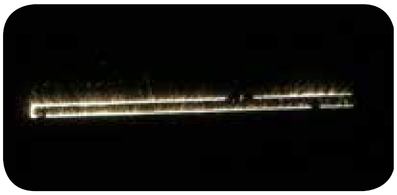
> *“Optisys engineers used ANSYS simulation software to deliver order-of-magnitude reductions in size, weight and development time for a new array antenna.”*

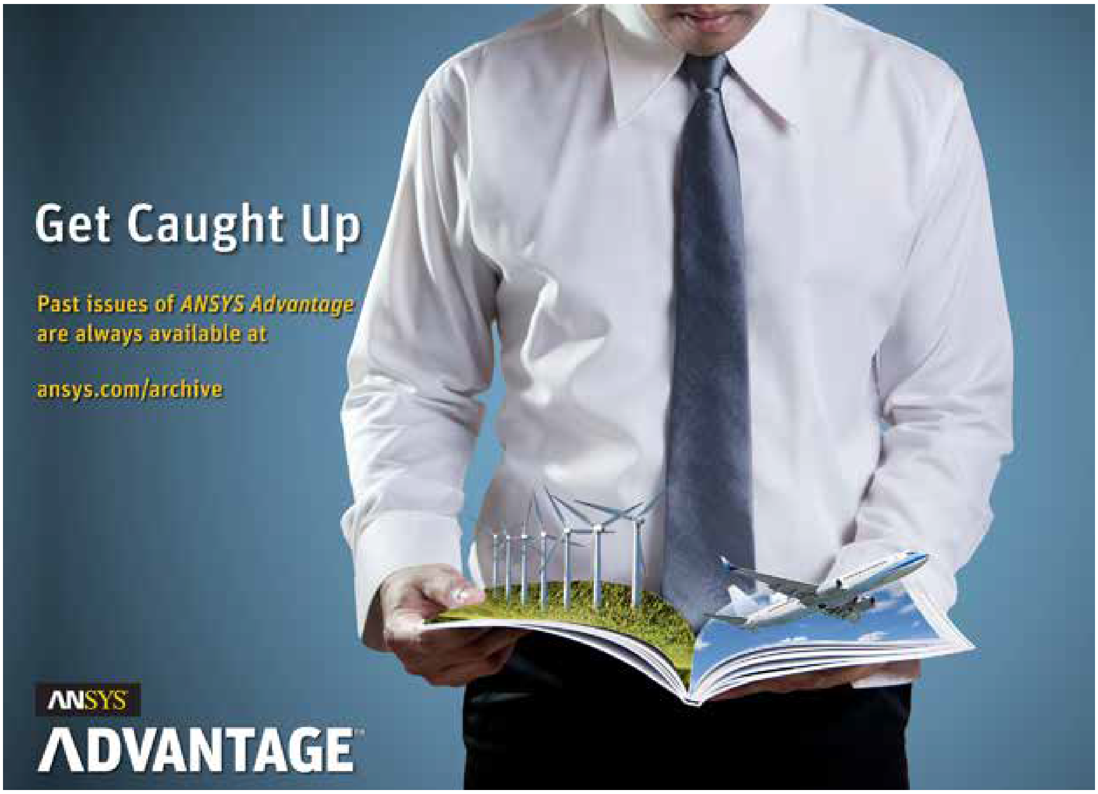
The design of the XSITA array showcases the level of integration that can be achieved with 3-D printing when engineers leverage ANSYS HFSS to optimize complex RF designs and the power of virtually unlimited scaling available on Rescale’s cloud HPC platform. The success of startups like Optisys depends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



CLIMATE CONTROL GETS ELEVATED

Extreme temperature and pressure differences outside the aircraft while in flight and on the ground must be accommodated to keep passengers comfortable and safe. Systems-level simulation and detailed thermal analysis are combined to meet industry standards.

By Xiong Shen, Tianjin Key Laboratory of Indoor Air Environmental Quality Control, School of Environmental Science and Engineering, Tianjin University, Tianjin, China
Qingyan Chen, Professor of Mechanical Engineering, Purdue University, West Lafayette, USA

Reliably comfortable and safe commercial air travel requires creating a cabin that is a hospitable in-flight environment throughout a wide range of extreme external climatic conditions. To successfully design a cabin for passenger comfort, a system of aircraft components must work in concert within industry standards for cabin climate control to maintain suitable pressure and temperature inside the plane.

An airliner's environmental control system (ECS) consists of several key parts, including heat exchangers, pipelines, compressors, fans, turbines and a water separator. At a cruising altitude of 30,000 to 40,000 feet, the outside air temperature is around –50 C to –60 C (–58 F to –76 F) and the pressure is 0.3 atm to 0.2 atm (4.2 psi to 2.9 psi). These conditions are much too low for traveler safety and comfort, and must be raised inside the cabin. To do this, several systems must effectively work together. For example, in a two-wheel ECS system, hot high-pressure air bled from the engine is cooled by ram air in a heat exchanger. A compressor then further pressurizes the air to reach the desirable pressure but at a high temperature. The hot air is cooled again in the main heat exchanger and, after passing through a turbine, the air temperature is cooled to the required cooling temperature and a suitable pressure. The cooling process leads to water vapor condensation so the condensed water is removed by a water separator. Finally the cool air mixes with the filtered return air from the cabin to deliver a suitable temperature and pressure. The ECS then distributes air from the mixing manifold to the cabin to remove heat in cabin air produced by passengers, crew and equipment, and to maintain a pressure in the cabin similar to that at around 6,000 feet above sea level.

SYSTEMS SIMULATION

For the benefit of ECS designers, it is important to understand the interaction of these components before testing them during an actual flight. Researchers at Tianjin University in China and Purdue

To successfully design a cabin for passenger comfort, systems must work together to maintain suitable pressure and temperature inside the plane.

The MD-82 aircraft and GAC system used to heat or cool the cabin on the ground

Researchers have been investigating the behavior of an ECS using both systems-level and CFD simulation tools from ANSYS.

University in the U.S. have been investigating the behavior of an ECS using both systems-level and computational fluid dynamics (CFD) simulation tools from ANSYS. The two universities work together using ANSYS software to study the problems related to human health, safety and comfort in the field of transportation. Aircraft manufacturers such as Boeing and the Commercial Aircraft Corporation of China (COMAC) are members of the Cabin Air Reformative Environment (CARE) consortium, as is ANSYS. The universities' work supports CARE goals.

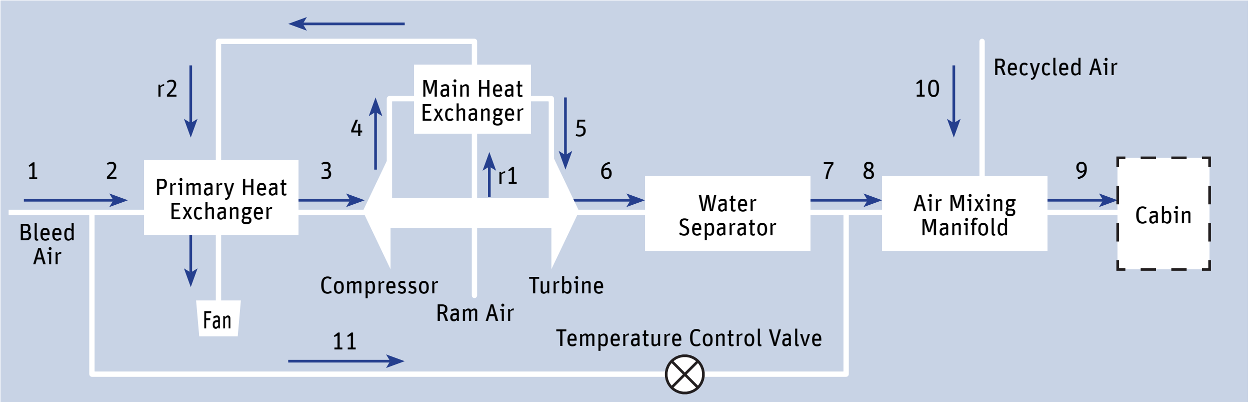
PASSENGER COMFORT AND SAFETY — WEB PAGE
ansys.com/passenger101

At the overall system level, the cabin thermal environment is regulated by a temperature controller, in which feedback signals from the cabin are used to modify the flow rate of the supplied engine bleed air. The controller contains proportional–integral–derivative (PID) logic, which the research team implemented into a systems-level model using the built-in PID module in ANSYS Simplorer. At the detailed level, the team created a 3-D model of the first-class cabin of an MD-82 jet in ANSYS Academic Research CFD (ANSYS Fluent) software using geometry obtained from a laser tracking system and employing a mesh with 6.4 million cells.

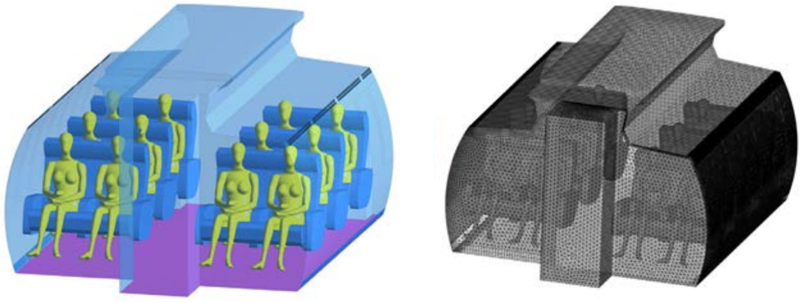
Researchers then coupled the Simplorer and Fluent models to analyze the transient impact of the ECS on the cabin thermal environment. During the coupled simulation, Simplorer predictions of the air temperature supplied to the cabin provided boundary conditions to the detailed CFD cabin model. CFD predictions of temperature at various cabin locations were compared to the desired temperature set point, and any deviations directed the temperature controller to adjust the flow rate of engine bleed air. This flow rate was a new boundary condition for the Simplorer ECS model, and iteration proceeded to completion.

GROUND-BASED CLIMATE CONTROL

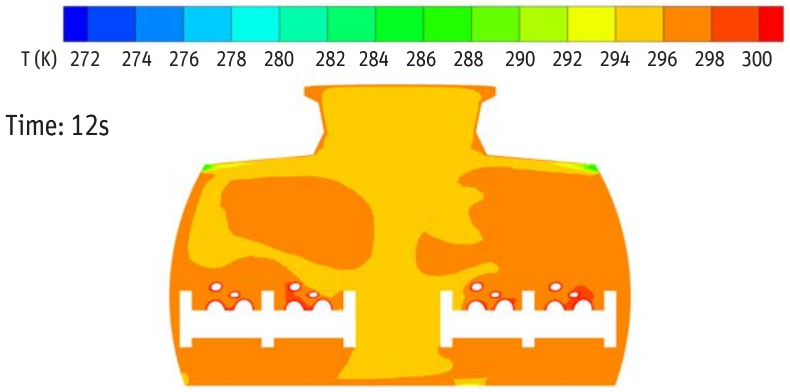
Prior to modeling the ECS, however, the team needed to evaluate the effectiveness of simulation on a climate-control system that did not require them to physically conduct in-flight testing. The first step was to analyze the ground air-conditioning cart (GAC) system, in which a mobile vehicle pipes outside air into the plane while it is idle at the airport. The GAC contains a heating coil, a cooling coil and a centrifugal fan that can heat the cabin in cold months and cool the cabin during warmer months. The team followed a similar process to build a systems-level model of the GAC in Simplorer, and then coupled it to the CFD model of the MD-82 cabin.



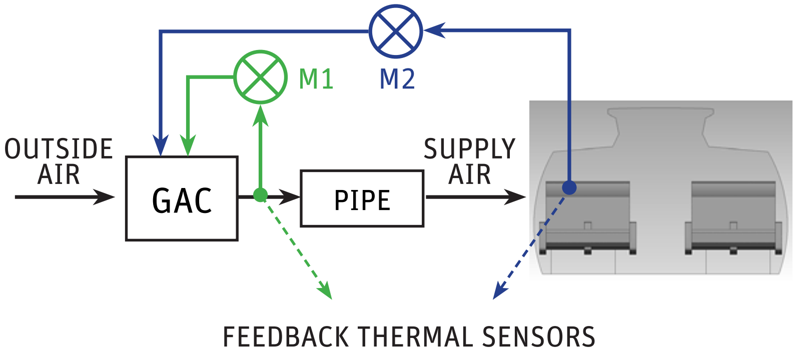
Process diagram of airflow from the engine into the cabin through the components of the ECS



Geometry (left) and mesh (right) for the CFD model of MD-82 first-class cabin



Detailed ANSYS CFD predictions of temperature within the cabin during the initial taxiing stage of a simulated flight on a hot day



Process diagram of airflow from the external environment into the cabin through the GAC system. M1 and M2 represent the locations of two different temperature controllers being studied.

Researchers evaluated the impact of different locations for the sensors sending data to the PID modules controlling flow. The first temperature feedback location studied was at the GAC outlet pipe sending air into the plane, while the second location was inside the cabin at passenger breathing height. Air temperature and velocity test data measured from an MD-82 cabin in Tianjin during January and June — with respective outside temperatures of about –5 C (23 F) and 35 C (95 F) — agreed closely with predictions made by the Simplorer GAC system model and the detailed CFD cabin model. The results helped the team learn that locating temperature feedback sensors closer to passenger seats provided more uniform temperature distribution at different heights within the cabin.

IN-FLIGHT CLIMATE CONTROL

Having developed and validated this simulation procedure, the research team then used the coupled Simplorer–Fluent analysis to simulate ECS behavior for conditions that a commercial aircraft would encounter during the typical seven stages of a short flight. These conditions included a four-minute taxi on the runway, one minute for takeoff, 15 minutes of climbing, five minutes of cruising, 20 minutes descending, 40 seconds for landing, and five minutes to taxi back to the gate. Simplorer predicted the changing mass flow rate of engine bleed air required to keep the cabin at the desired temperature set point of 23 C (73 F) during all seven flight stages. As expected, CFD simulations predicted that the in-flight cabin air velocity and temperature would fluctuate more when it is hot at ground level because of the larger temperature difference between the ground and the flight altitude.

Over the course of seven different coupled simulations of GAC and ECS cases, the team typically completed model setup in Simplorer and Fluent

The researchers coupled ANSYS Simplorer and ANSYS Fluent models to analyze the transient impact of the ECS on the cabin thermal environment.

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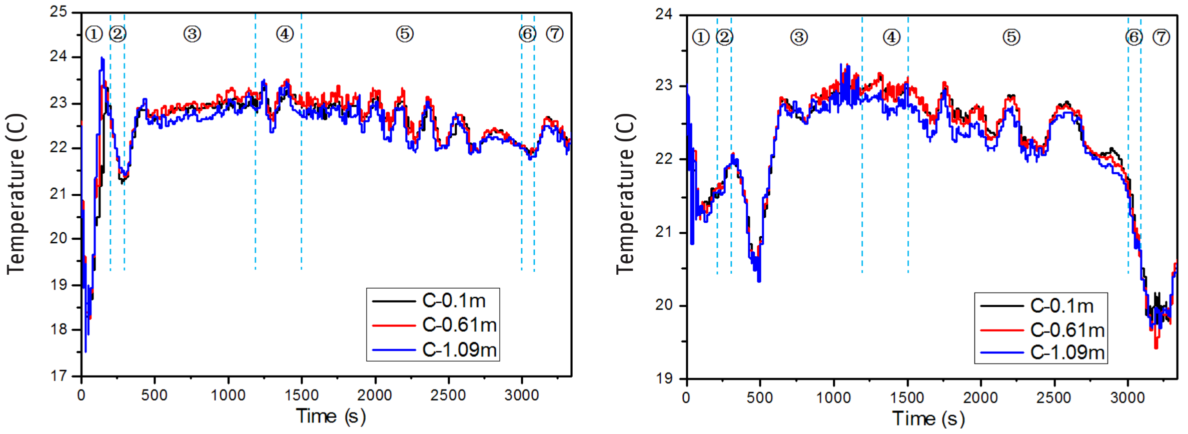
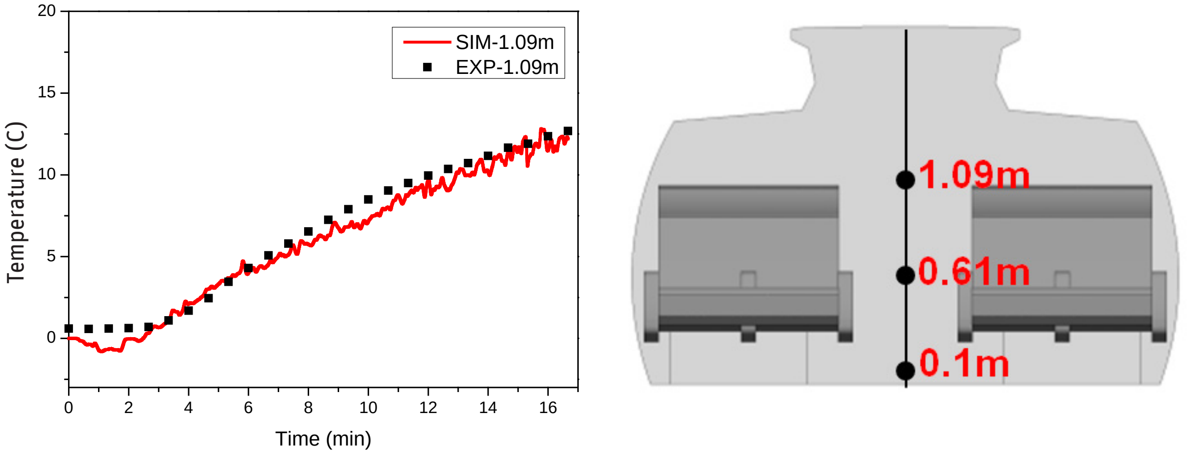


▲ ANSYS Simplorer predictions for air temperature in the cabin for the seven simulated flight stages on cold (left) and hot (right) days. These results indicate that the control strategy should produce reasonably uniform temperatures at different heights within the cabin over the flight duration.



▲ ANSYS Simplorer predictions for air temperature in the cabin being heated by the GAC system in January compared well to experimental results measured at different heights inside the cabin.

in about four hours. Simplorer models ran very quickly, while a typical highly detailed transient CFD analysis of cabin airflow during simulated flight conditions required about 60 hours running on 32 processors. Work is continuing to implement a reduced-order model (ROM) representation of the ANSYS Fluent CFD model of the cabin so that overall system simulation time can be drastically reduced without sacrificing the accuracy of the simulation output.

The Tianjin and Purdue team shared its findings with researchers at Boeing and COMAC through the CARE consortium. Early indications are that these manufacturers will be setting up their own virtual platforms for simulation of future ECS designs. Future experimental validation of the team's ECS predictions done in collaboration with CARE industry partners is also on the horizon to help further elevate the performance of such aircraft systems.

CFD simulations predicted that the in-flight cabin air velocity and temperature would fluctuate more when it is hot at ground level.

Bruno Darboux (right), vice president, Systems General Engineering for Airbus, and Pascal Gendre (left), senior expert, Modeling and Simulation for Airbus, explain how the aerospace giant uses simulation to manage and integrate the increasingly complex, distributed smart systems that comprise the modern jet aircraft.

Dimensions: What is the biggest challenge in the aerospace industry, and how is Airbus approaching it?

Bruno Darboux: Over the past decade, systems for large aircraft have become more complex. They have transitioned from a loose coupling of systems to a more tightly coupled situation. In the past, systems were designed so that they did their own job with limited information exchange (loose coupling) with other systems. They were somewhat standalone systems. This is no longer true. Now all of the systems onboard our planes are increasingly interconnected. And they share a lot of common resources — computing platforms and interface devices, for example — which makes everything tightly coupled and quite complicated. Not only are the resources shared, but the functionality is spread across several systems.

Pascal Gendre: In addition, how a system interfaces with the real world has advanced. At Airbus, we now measure more physical phenomena, such as icing, EMI/EMC, thermal environments, material behavior and fluid–structure interaction, with more precision, and that helps interacting systems to optimize the overall flight experience. You can't fly an unstable airplane. But by using an advanced flight control system that interfaces extremely closely with the physical world, you can deliver optimum flight performances under safe conditions.

MASTERING COMPLEXITY

> *“Heavy and costly are not viable from a business perspective.”*

BD: This complexity has compelled us to put heavy and costly processes into place to develop a new airplane. But heavy and costly are not viable from a business perspective. So we have introduced — and are trying to introduce more — ways of mastering this complexity by means of advanced system engineering methods. We have already started to deploy model-based systems engineering for the successful development of the A350, and want to deploy even more for our next product developments.

Dimensions: You mentioned safety briefly. The management of embedded software to ensure its safety is obviously critical for airplanes. What processes does Airbus have in place to manage embedded software?

BD: Guaranteeing the safety of embedded software is well under control thanks to compliance to aerospace standards. This includes external standards such as DO-178C and SAE ARP 4754A, along with our own internal standards. However, there are cost and lead time challenges associated with adhering to these standards. Full demonstration of compliance is very costly, so we don’t want to repeat the demonstrations 10 times, because the software evolves with each design iteration. We need fast iteration loops. And, as the design matures, we have to fine-tune our software, even during the very late stages of development, including the flight test stage.

> ***“We have already started to deploy, and want to deploy even more, model-based systems engineering.”***

Various sections of Thai Airways International’s first A380 jetliner were joined at the Airbus Final Assembly Line in Toulouse, France, in November 2011.

Dimensions: So you can make software changes even that late?

BD: Absolutely. This is where the value of simulation software really comes into play. Tools for modeling embedded software, such as ANSYS SCADE Suite and ANSYS SCADE Display, allow engineers and designers to express the design specifications in a formal manner. These tools generate the actual flight software in an automatic way from the models. Using this method, we can produce software with a significantly reduced certification cost as well as reduce the number of very expensive test demonstrations. Software modeling and simulation has reduced our software generation time from typically two months to as short as two days during flight tests. That is a great improvement and time-to-market advantage.

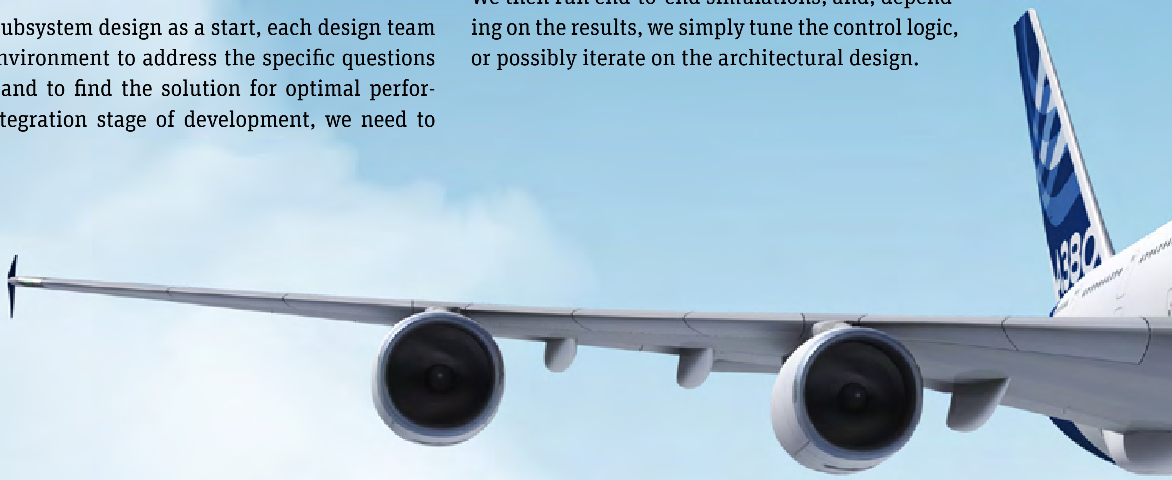
Dimensions: How does simulation fit into the development process?

PG: Considering subsystem design as a start, each design team models its own environment to address the specific questions it has to answer and to find the solution for optimal performance. In the integration stage of development, we need to combine extensive simulations in a single simulator called the “Iron Bird.” This simulator must accommodate several separate systems with their different physics and ways of interacting.

Dimensions: Because an aircraft is made of many models, how do these separate models come together?

BD: It’s obvious that each team needs not only its own model but also a representation of what’s around it. For example, the hydraulic system team needs a good representation of the engine performance and nacelle environment on the power side, and of the landing gear extraction/retraction sequences on the consumer side. This has driven us to develop an approach through which we can share models and assemble them into a larger system.

We then run end-to-end simulations, and, depending on the results, we simply tune the control logic, or possibly iterate on the architectural design.



Airbus at a Glance

- Founded: 1967
- Headquarters: Toulouse, France
- Workforce worldwide: 58,000 (100 nationalities)
- Reach: 8,340 Airbus aircraft currently in operation

PG: Whether you want to check the kinematics of control surfaces, study human factors in cockpit design, or design and calibrate an air conditioning or ventilation system, you need to use different modeling techniques, and you must simulate lots of different combinations of parameters.

The main point is to carry out much more of the integration work upfront using modeling and simulation during the tuning of the design, and reduce the number of test points during the final testing phase with the complete aircraft on the ground or in flight.

Dimensions: What is your vision of the best way to combine physical testing with modeling?

PG: We have experts who really understand how to interpret simulation results. Most of the physical testing with the real vehicle or mock-ups is aimed at double-checking that what the simulation delivers corresponds to reality. You can then use simulation to validate the aircraft behavior in the complete design and off-design envelope.

> *“Software modeling and simulation has reduced our software generation time from two months to two days during flight tests.”*

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Dimensions: What other challenges are you experiencing?

BD: At Airbus, we have very diverse, competent teams in-house, but also we have a lot of collaboration with the engineering teams of our suppliers. While we are responsible for systems architecture and integration, we contract out 95 percent of our systems' detailed design and equipment manufacturing. Five percent we do in house, 95 percent we buy. The suppliers bring technologies, supply smart design solutions, and participate as part of the integration effort. So we must exchange models with our suppliers to help us accomplish more simulation upstream and perform fewer tests on the final product.

PG: To exchange models, we need to rely on strong standards. We already have exchange standards in place like Airbus AP2633, but we cannot yet say we have a truly superior set of standards to do the job in an optimum manner. We are working on developing these standards, in an industry-wide effort; the MOSSEC initiative is an example. MOSSEC stands for modeling and simulation information in a collaborative systems engineering context.

Dimensions: What technological trends do you believe will play a big role in the aerospace industry in the next five or 10 years?

BD: Innovations are not so easy to predict. However, the fields for which we generate and capture innovations are the ones that add value to our airplane customers: superior passenger experience, continual improvement of airplane performance, and seamless fleet operations.

The trend in all this is clearly digitalization — making the most knowledgeable use of data to design the best solutions. Capturing the best data and routing it to provide the best real-time services to end users is also important.

Whether you consider multiphysics optimization or the setup of distributed functionality across onboard and ground computing platforms, it is clear that modeling and simulation bring much to our business. They allow us to reduce our development cycle and costs, bringing innovation to the market much faster. And thanks to modeling and simulation capabilities, we continually develop better products, like our new A320 Neo, which delivers an improvement of more than 15 percent in fuel efficiency.

2015 ambience A350 XWB engine

A380 cockpit

Bruno Darboux has worked for Thales, ATR and Airbus. He was involved in numerous developments of civil and military platforms, in both engineering and program roles. He currently leads the definition of Airbus processes, methods and tools for systems development, and manages the teams that perform Airbus aircraft safety and qualification demonstrations.

After earning a Ph.D. in computational fluid dynamics (CFD) for aerospace, **Pascal Gendre** worked for Lacroix and Airbus. He employed modeling and simulation to develop products before devoting his efforts to developing modeling and simulation processes. He currently manages R&T projects for the modeling and simulation required for all engineering aspects of the aircraft program at Airbus.

“Thanks to modeling and simulation capabilities, we continually develop better products.”

CALM LANDING

Performing flight tests that include water landings of unmanned aerial vehicles is cost-prohibitive. Simulation of this challenging landing maneuver that includes multiphase flow, compression of water and small computational time steps saves physical testing time and costs.

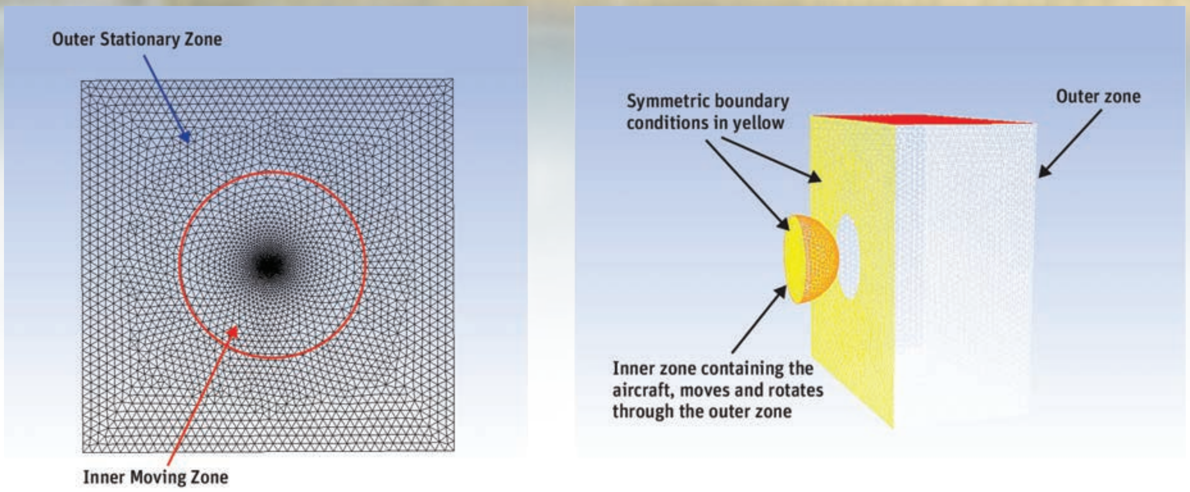
By **Keen Ian Chan,**
Principal Engineer,
Singapore Technologies
Aerospace, Singapore

Unmanned aerial vehicles (UAVs) are being tasked to complete an increasingly diverse set of missions. These can include flying over large bodies of water to perform operations such as maritime surveillance.

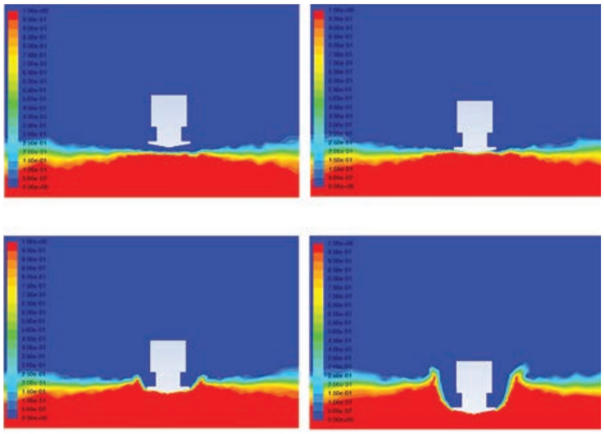
Depending on the UAV's size and its payload, an unplanned water landing, or ditching, can cause damage costing thousands or millions of dollars and even result in the loss of the entire system. For example, impact with water at speed generates large transient pressure loads on the air frame, and the natural properties of the water (dynamic buoyancy and compressibility) may cause the UAV to tumble. Either eventuality can cause airframe failure and break-up. Understanding how to mitigate such scenarios is therefore an important design consideration for UAVs.

However, performing flight tests of a water-landing maneuver for a new UAV design is not practical because of the time and cost involved to build prototypes, arrange airspace clearance, extensively instrument the test aircraft, and understand and replicate the sea state and environment in which the impact occurred.

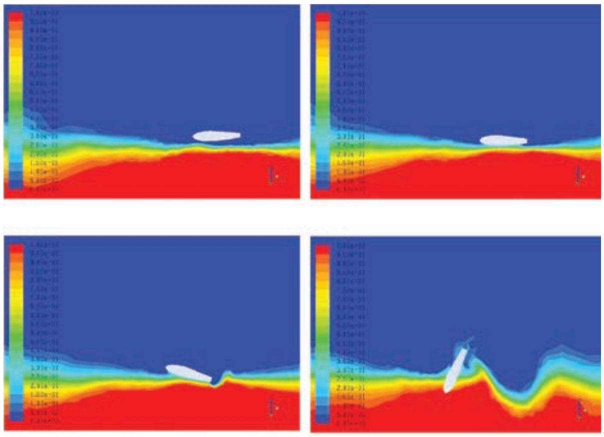
Simulation of water-landing scenarios is a practical alternative to extensive flight testing, but it can be challenging because engineers need to consider multiphase flows (air and water), the compressibility of water, and the very small computational time steps



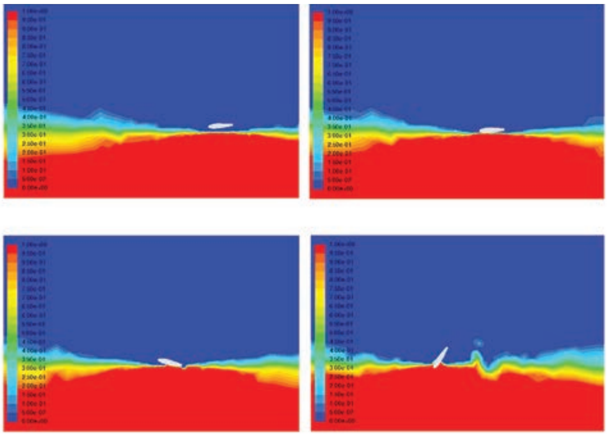
^ Engineers were able to reduce time step size by dividing fluid domain into two zones.



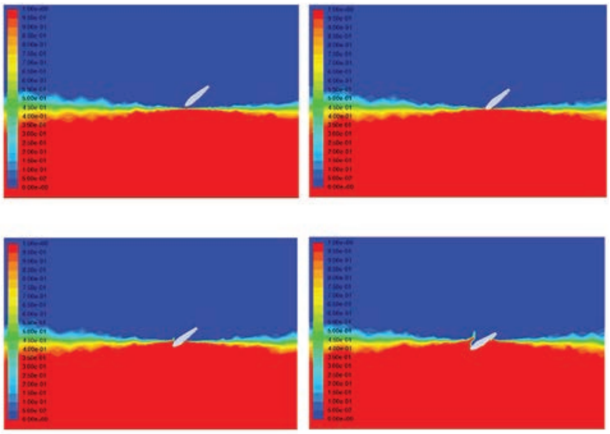
^ Validation of the simulation method



^ Steep descent landing shows undesirable tumbling behavior.



^ Belly landing maneuver simulation reveals undesirable tumbling behavior.



^ Nosedive landing maneuver simulation with desirable results

required to capture impulse loading. Singapore Technologies Aerospace (ST Aerospace) engineers used ANSYS CFD software to overcome these challenges and accurately simulate a wide range of water-landing scenarios. This saved a large amount of time and money.

MULTIPHASE FLOW

ST Aerospace is an integrated service provider that offers a wide spectrum of maintenance and engineering services to a customer base that includes the world's leading airlines, airfreight and military operators. To capture the multiphase properties of the flow fields in water impact simulations, ST Aerospace engineers used the volume of fluid (VOF) model in ANSYS Fluent. In this model, the volume fraction of each phase, which is defined as a fraction of volume occupied by that phase in a computational cell, is tracked throughout the domain, and the interface between phases is captured simultaneously. The geometric reconstruction interface-capturing scheme used in this study computes the evolution of the water surface by representing it using a piecewise–linear approach. This scheme is most accurate and compatible with unstructured, moving and deforming meshes (MDMs).

The pressures generated during water impact are large enough to compress seawater, so the compressibility of water must be included in the simulation. During the simulation, a user-defined function (UDF) calculates the compressibility of water by determining its density based on its bulk modulus, which is defined in terms of pressure and density change.

DIVIDING FLUID DOMAIN TO LENGTHEN TIME STEPS

To simulate the aircraft moving relative to adjacent cells, the time step needs to be small based on the fine adjacent grid resolution. In this case, engineers were able to increase

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> “Performing ***flight tests*** of a water-landing maneuver for a ***new UAV design*** is not practical.”

the time step size by dividing the fluid domain into two zones. An inner hemispheric zone contains the aircraft and remains fixed relative to the aircraft, so that as the aircraft moves and rotates in response to forces generated by water impact, the inner zone also moves and rotates. The outer zone is stationary and fixed in space. This is accomplished in ANSYS Fluent using the MDM modeling approach. MDM efficiently re-meshes the volume cells at the interface of the two zones as the inner zone moves through the outer zone as the computation progresses. The time step size is based on the larger volume cells at the interface of the two zones, rather than the much smaller cells directly adjacent to the aircraft, enabling larger time steps to be used and greatly reducing the number of time steps required to complete the simulation.

Engineers used symmetry boundary conditions in the CFD model so that only half of the aircraft was modeled. This halved the number of volume cells and reduced the computational time by 50 percent. A limitation of this approach is that pitching motion can be captured but rolling and yawing motions cannot.

The water impact simulation starts with the aircraft a short distance above the water and proceeds in small time steps. At each time step, CFD simulations are performed to resolve the flow field at that instant. The flow field yields the forces and moments acting on the aircraft. The forces and moments are input to Fluent’s built-in six degree of freedom (6DOF) solver to compute an incremental translation and rotation for that time step. The UAV is moved to the new position and orientation, carrying the inner fluid zone with it. The movement of the aircraft and body-fixed inner zone distorts the volume cells at the boundary with the outer fluid zone. Regions of distorted cells are re-meshed by MDM to maintain good quality. The cycle is repeated for each successive time step.

VALIDATING THE METHOD

ST Aerospace engineers validated their computational approach by simulating a published experimental test case [1]. The case involves dropping a 160-degree cone into the water at different masses and impact velocities. The impulse forces upon impact were measured. Simulations were performed for the case of a 0.324 kg mass impacting the water at 5.04 m/s. The experimental measurements showed a peak force of 317.844 N while the simulation showed a peak force of 310.977 N, a difference of only 2.2 percent.

EVALUATING DIFFERENT WATER-LANDING APPROACHES

With the simulation method validated, ST Aerospace engineers ran 20 different water-landing simulation cases for the new UAV. The team simulated steep-descent landings, belly landings and nosedive landings. They also modeled a belly landing in which the UAV’s belly was replaced with a NACA 84 flying boat hull.

The steep descent, belly landing and flying boat hull landings all showed tumbling behavior, which is an undesirable result because it increases the forces on the UAV. The nosedive landing, on the other hand, was free of tumbling behavior and provided the lowest forces. Images of the water landing are as seen from the symmetry plane of the UAV, extracted from animations of the simulations.

The CFD simulation of the UAV landing on water yielded valuable results and insights that were used in the airframe’s structural design to enable it to withstand impact with the water. The results will also be valuable for UAV operators to determine the best procedure to execute a water-landing maneuver. These solutions were achieved without having to embark upon a costly and high-risk flight test campaign, thus substantially reducing the time and cost required to design the UAV. Λ

Singapore Technologies Aerospace is supported by ANSYS channel partner CAD-IT Consultants (Asia) Pte Ltd.

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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

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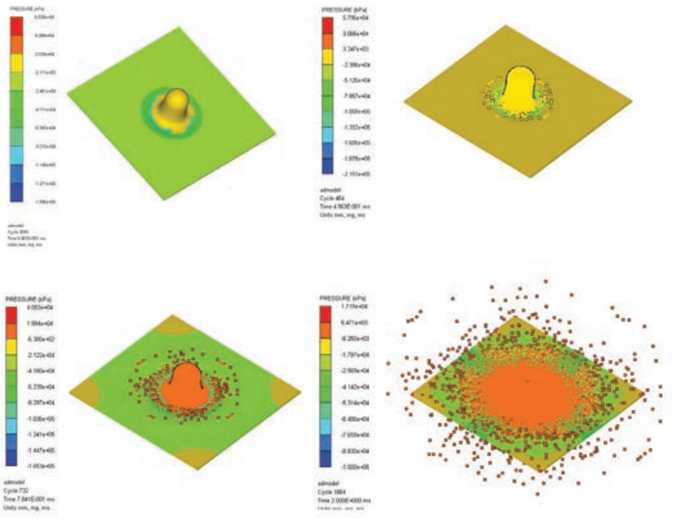
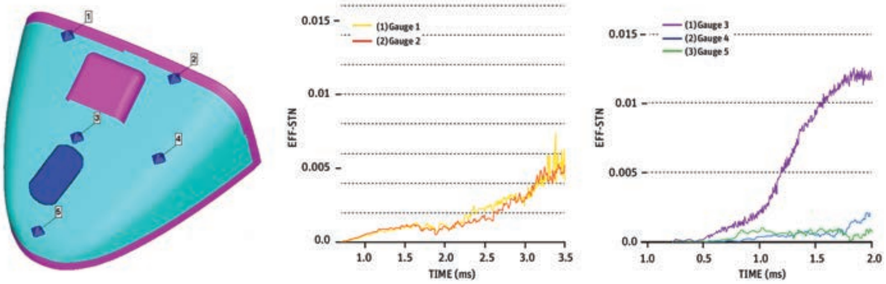
In an effort to protect crew and passengers from the dangers of bird strikes, regulatory authorities, including the Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA), have issued regulations regarding the ability of helicopters to survive bird strikes. For example, 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.



^ Simplified simulation of bird model into flat plate

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.



^ Effective strain plot predicted by simulation

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.

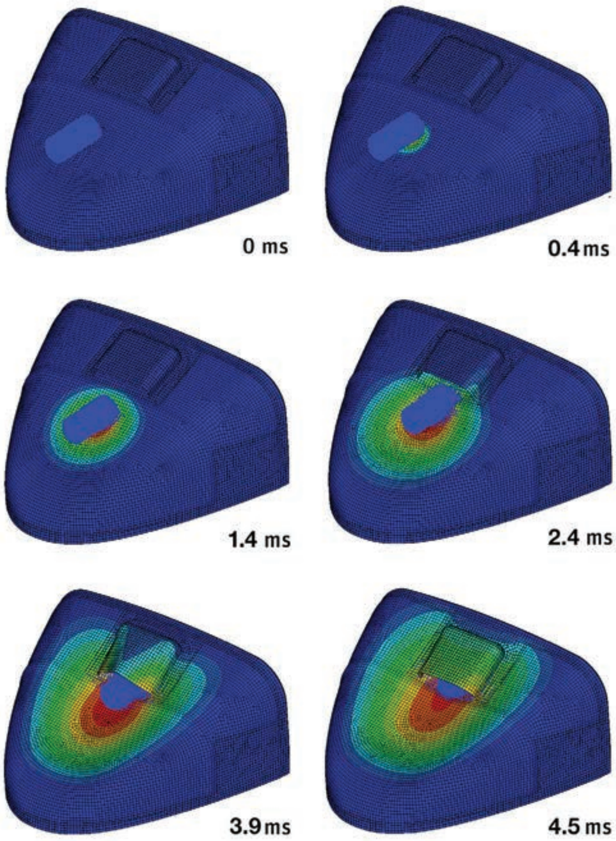
DEFINING COMPOSITE GEOMETRY

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 on square specimens were performed according to ASTM standards to determine the properties of the core. The composite

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

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.



^ 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.

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Impact
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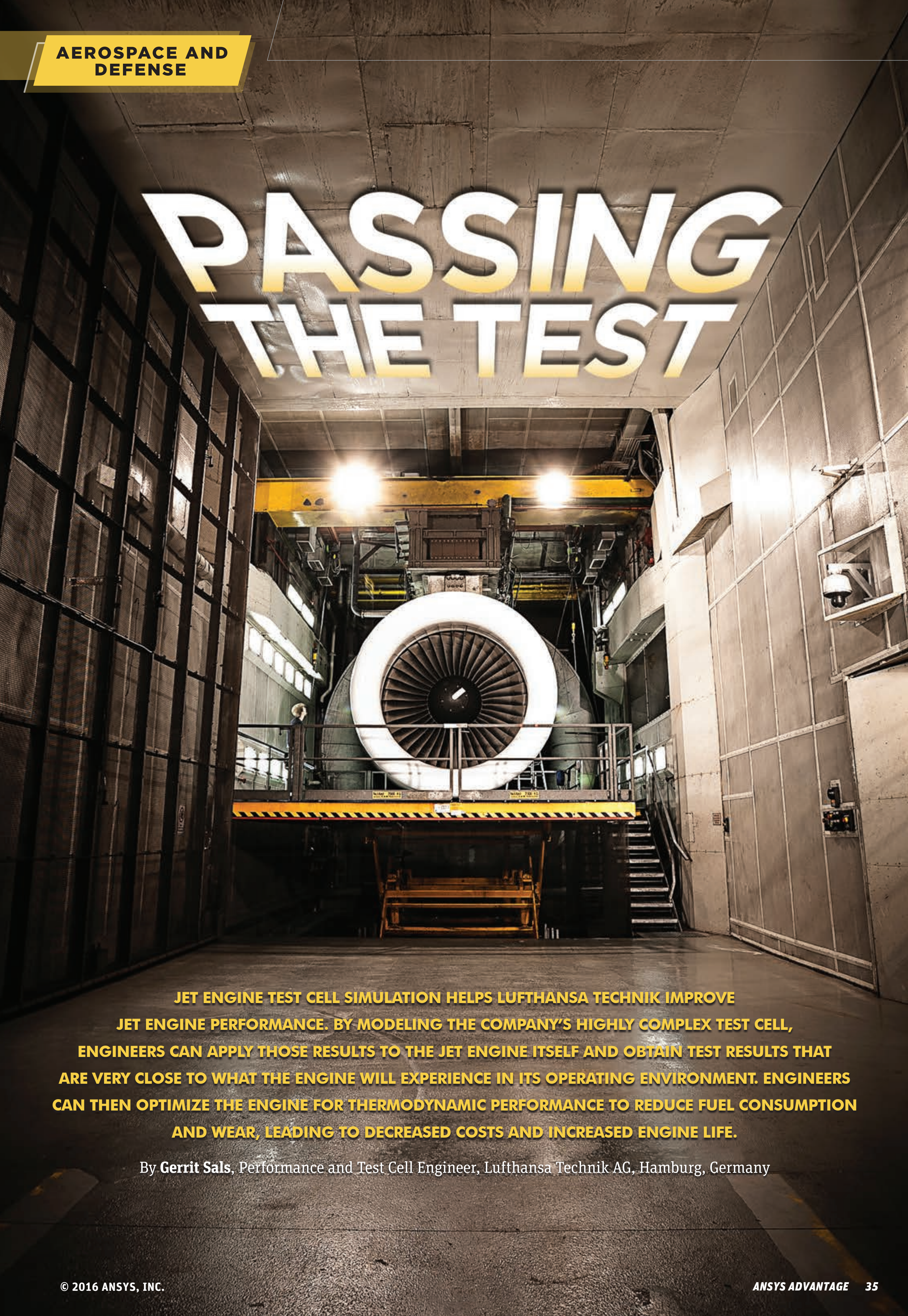
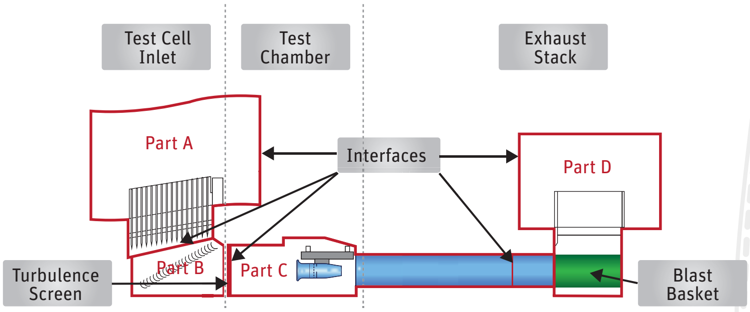


PASSING THE TEST

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

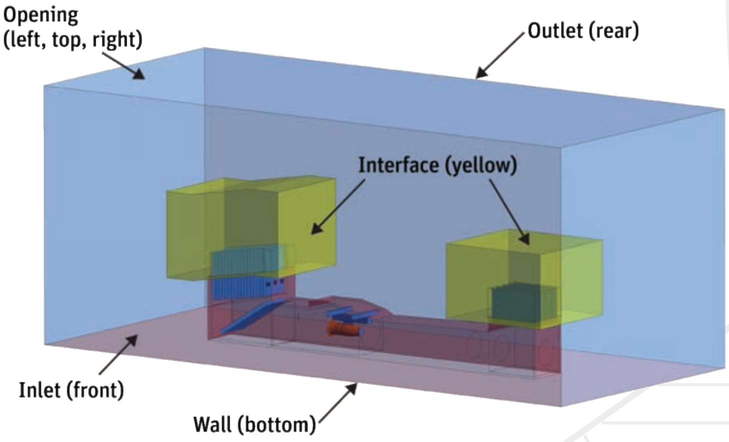
Overhauling a typical commercial jet aircraft engine might cost about $2 million as an expert team inspects and services or replaces up to 40,000 parts. Such an overhaul could be necessary each time the engine flies between 2,000 and 10,000 flights. Overhauls can vary greatly in their work scope, which 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 thermo-dynamically 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

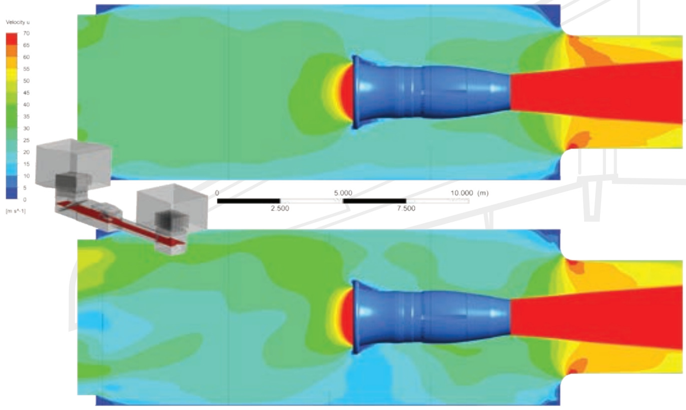
Lufthansa Technik AG is one of the world's leading providers of aircraft maintenance, repair and overhaul services. To improve engine efficiency while avoiding unnecessary work during engine overhauls, detailed knowledge of the internal interactions in the engine is essential. Lufthansa Technik constantly 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,

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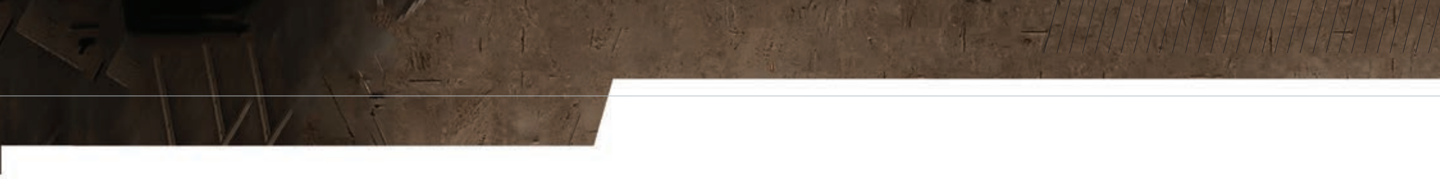
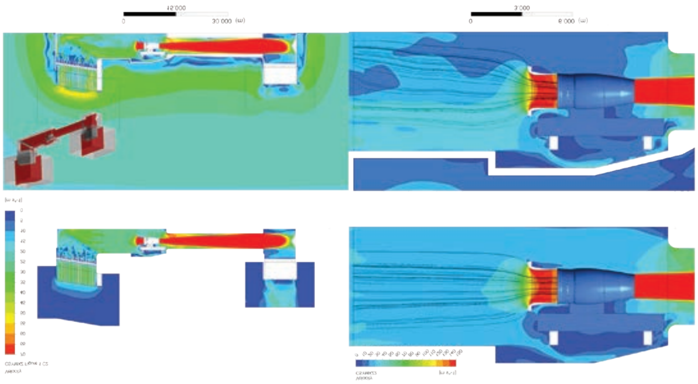


increasing the temperature, velocity and total pressure behind the engine. This in turn leads to an acceleration of the air bypassing the engine, which is called the ejector effect. The exhaust gas then leaves the test cell through the augmenter tube, blast basket and exhaust stack.

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.



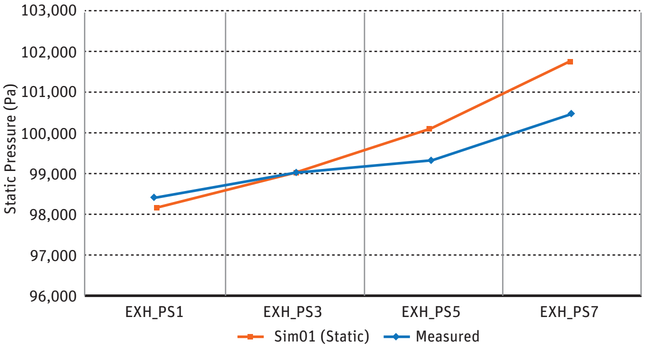
Fluid flow in the test cell predicted by simulation for static conditions (top) and crosswind (bottom). This enables engineers to better understand the test cell under real-life conditions to aid jet engine overhaul.

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.

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.



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

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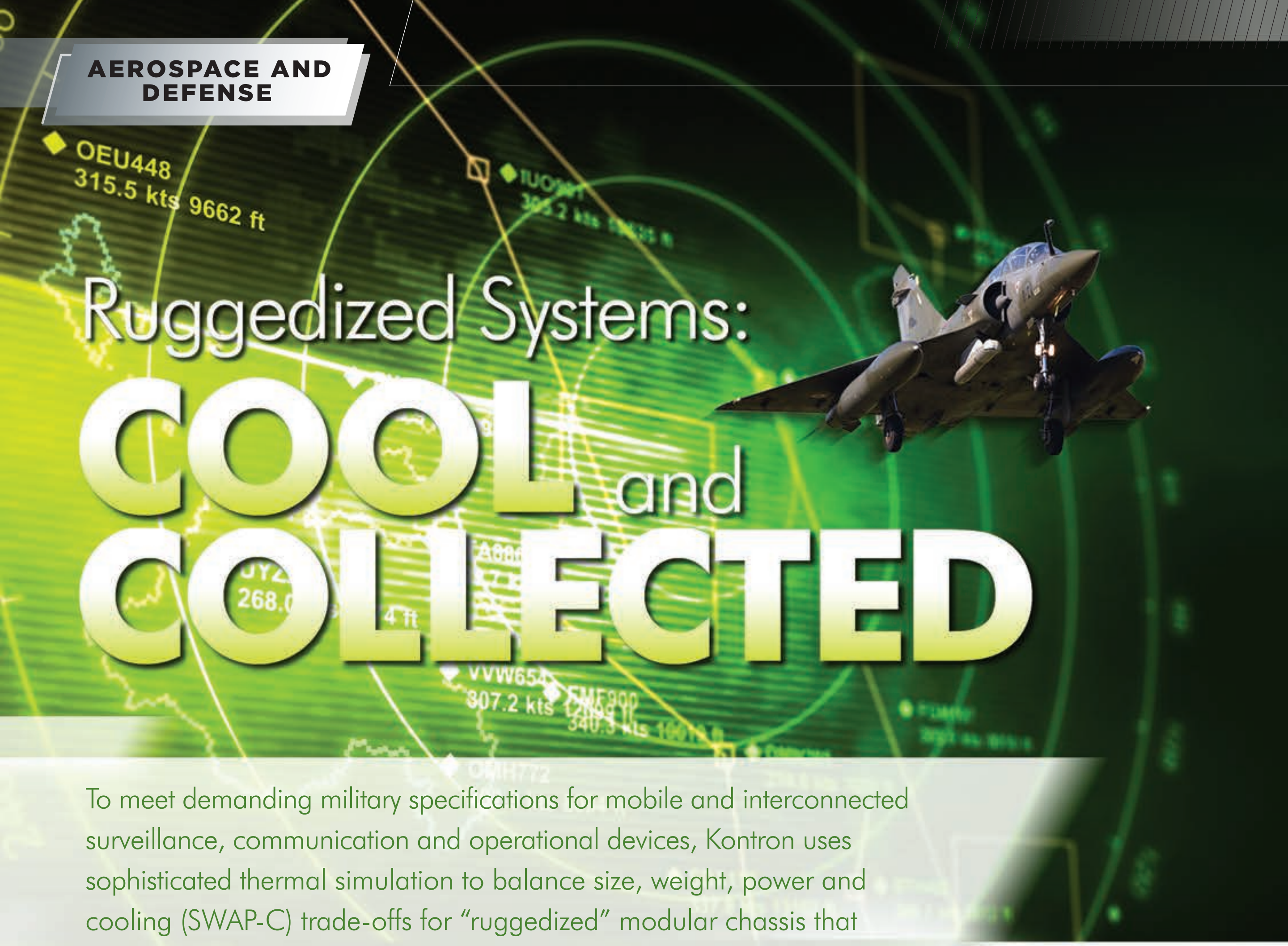


Ruggedized Systems: COOL and COLLECTED

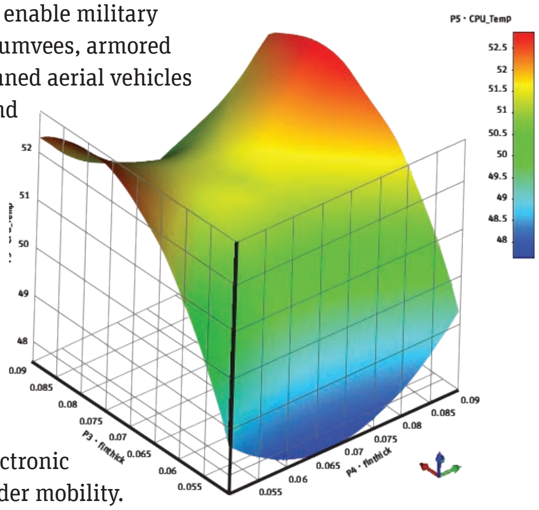
To meet demanding military specifications for mobile and interconnected surveillance, communication and operational devices, Kontron uses sophisticated thermal simulation to balance size, weight, power and cooling (SWAP-C) trade-offs for “ruggedized” modular chassis that support customized solutions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

By **Simon Parrett**, Conceptual/Structural/Thermal Engineer, Kontron, Poway, USA

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.

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



^ Parametric optimization of enclosure cooling fins

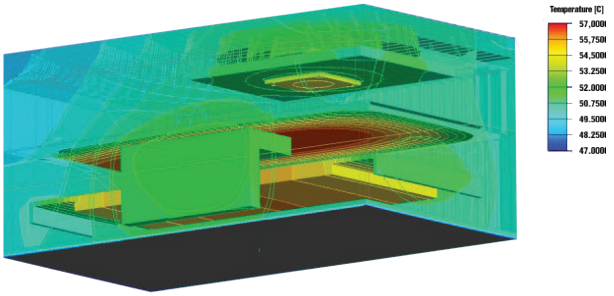
> **“Defense contractors must meet a host of requirements and specifications to satisfy the military’s demand for *flexible electronic* systems.”**

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.

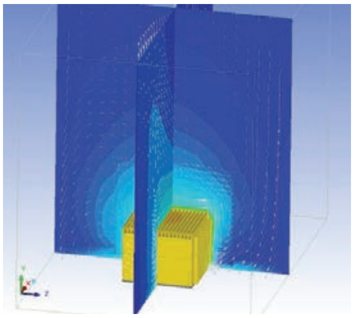
The Kontron design team uses CFD analysis to evaluate and optimize chassis thermal performance.
Some key activities are:

- 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.

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

- Determining placement of electronic components and subsystems within the chassis and balancing 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. Λ

ANSYS Icepak
ansys.com/icepak

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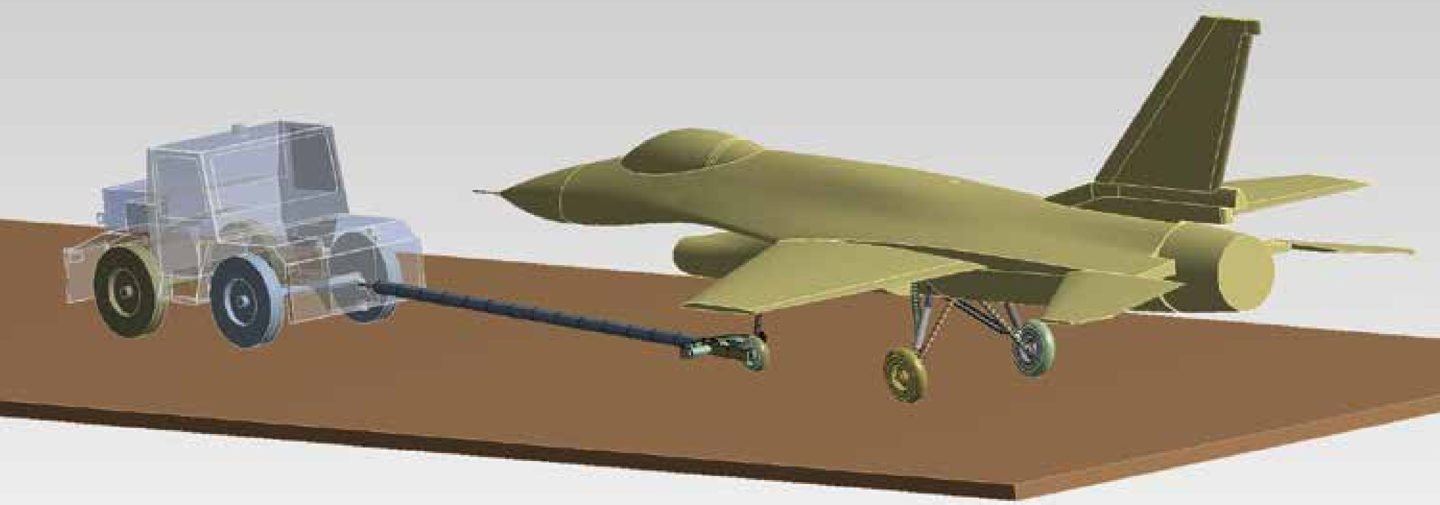
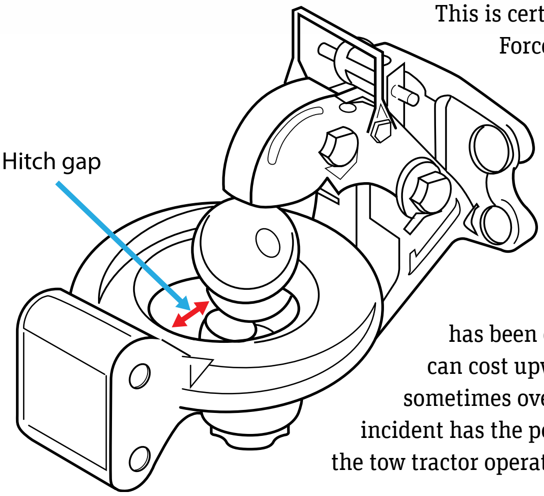


Hitting the Brakes

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.

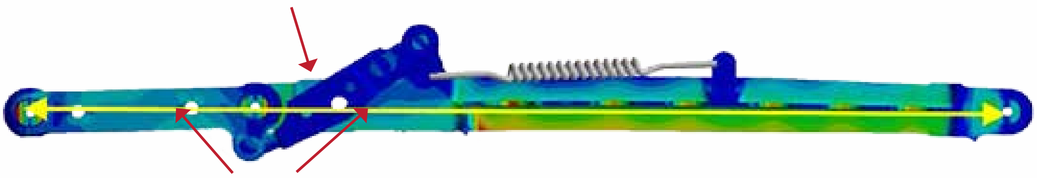
By **Andrew Clark** and **Jared Butterfield**, Lead Structural Analysis Engineers, United States Air Force, Hill AFB, USA

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.


Low stress in toggle and link assemblies

The load path is primarily through the lower drag brace into the upper drag brace.

^ 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:
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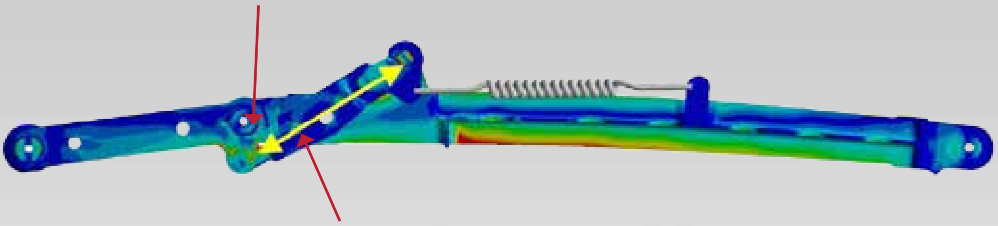


After the drag brace bends, the primary load path shifts to the down lock link assembly.

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.

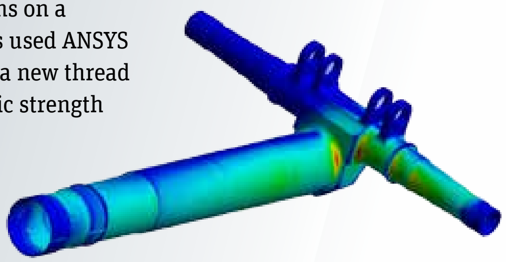
Engineers concluded that the shape of the braking model depends upon the tow operator. This in turn affects the load response and causes significant variation from event to event. In spite of this, they determined that the maximum compressive force that develops from the impact event was highly dependent 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.



THOUGHT LEADER

AIMING HIGH

By **Eric Besnard**
Chief Technical Officer
Vice President of Engineering and Co-Founder
Vector, Tucson, USA

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.

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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.

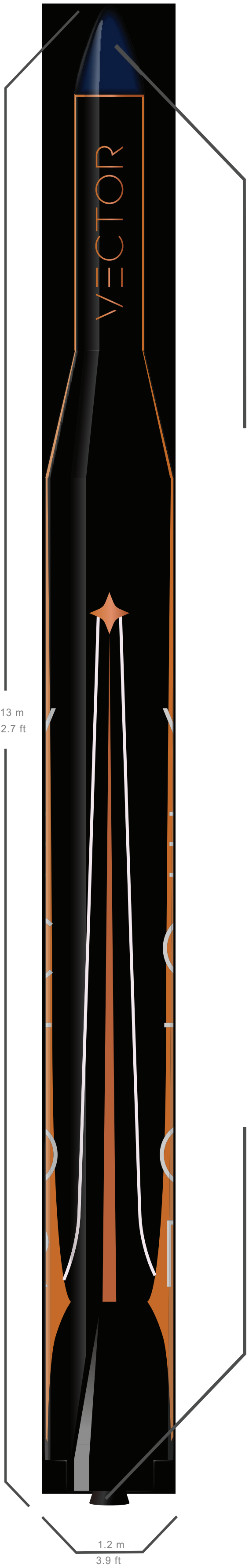
A NEW INDUSTRY SEGMENT TAKES OFF

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.

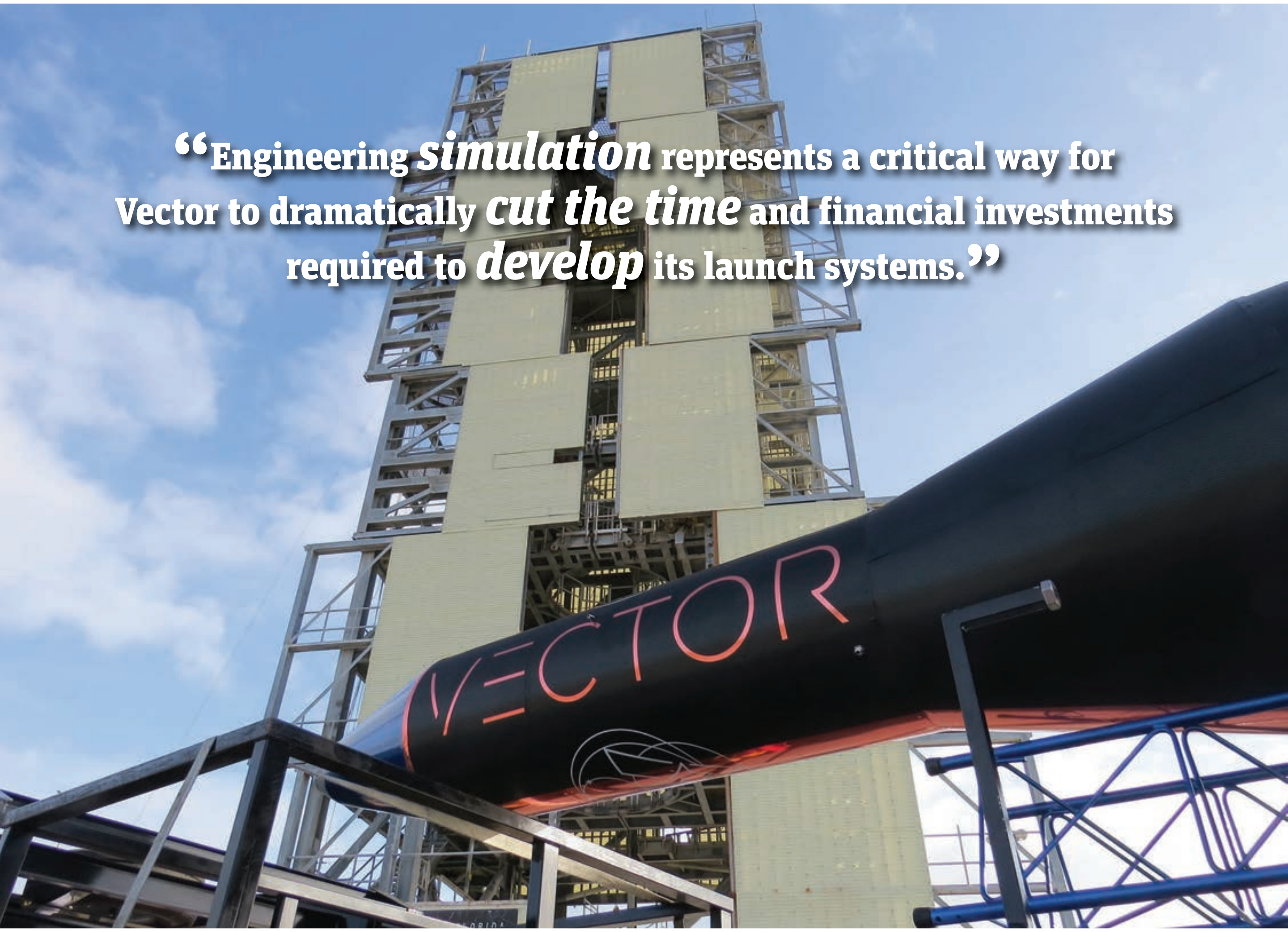
Engineering simulation represents a critical way for Vector to dramatically cut the time and financial investments required to develop its launch systems. By using a unified set of multiphysics simulation tools acquired via the ANSYS Startup Program, Vector developers can design products in a virtual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

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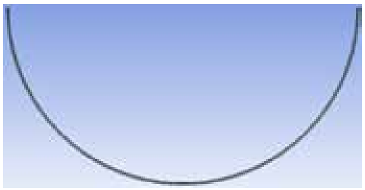
Decreasing Spacecraft Fuel Sloshing

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

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

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

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



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

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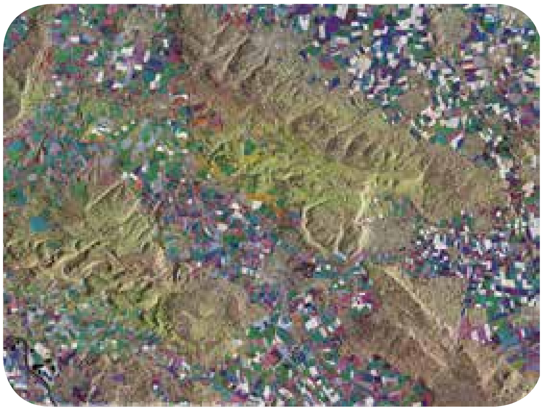
> *“Spacecraft designers must determine whether remediation is needed to achieve attitude control specification and identify an approach that will meet the specification with the lowest cost and weight penalty.”*



Typical image captured by Airbus spacecraft

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

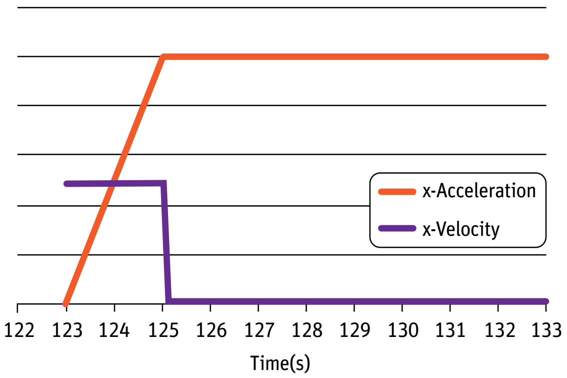
Spacecraft often use remediation measures to reduce sloshing so that the spacecraft can be controlled within the allowable attitude window. One approach is to use physical barriers, such as baffles or compartments, to control sloshing. Another common method is to use an elastomeric membrane to divide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

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

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

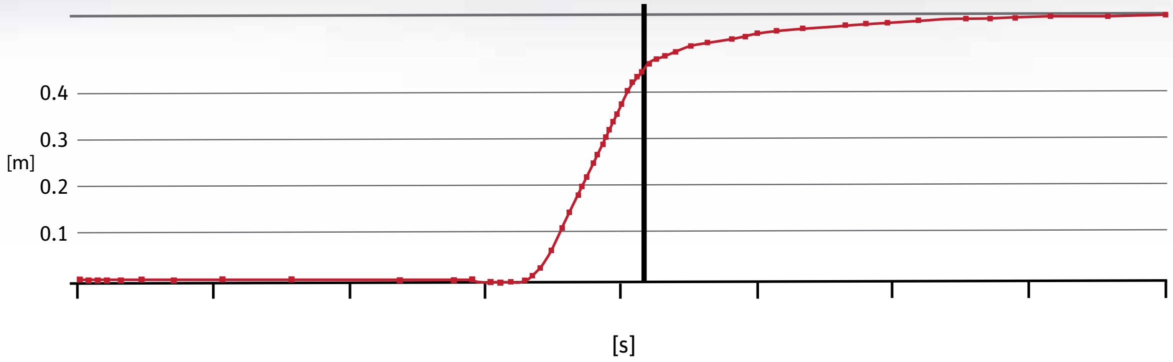
Design Study for a Spacecraft

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



Typical translation profile applied during FSI simulation

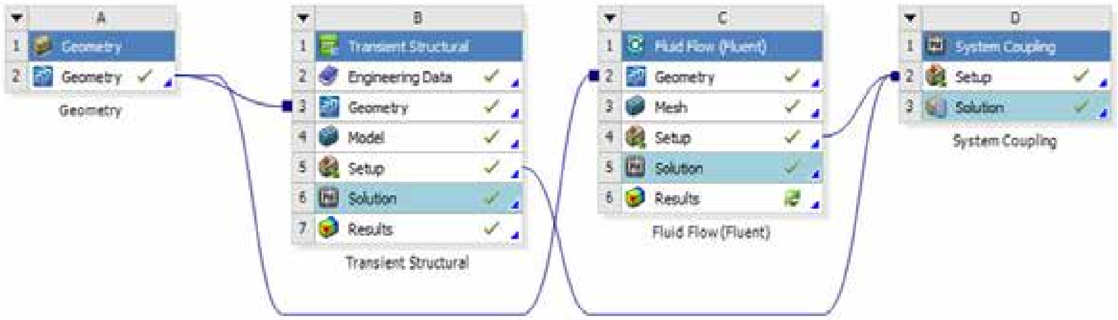
> *“FSI and other multiphysics simulations enable Airbus engineers to make more informed design decisions at a stage in the design process when it is possible to have a substantial impact.”*



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

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

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

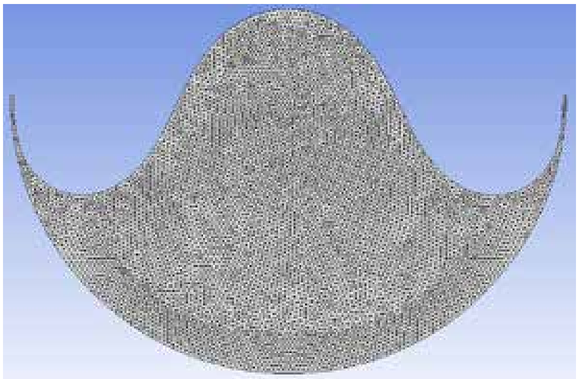


Airbus engineers linked fluid and structural codes by dragging the output of one code to the input of another.

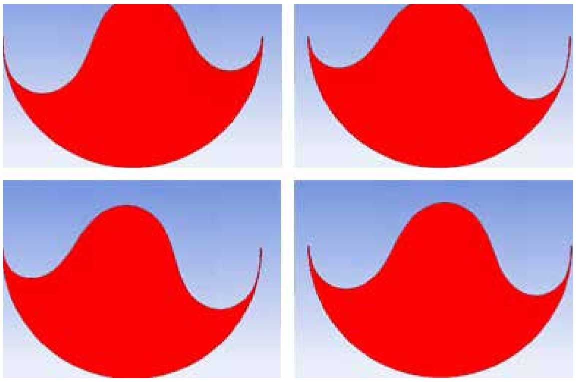
> *“ANSYS software provides the complete physics required for FSI simulation, including CFD and FEA solvers integrated in the ANSYS Workbench environment.”*

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

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



Stabilized position of membrane after tank drained to partial level



FSI results

Performing Fluid–Structure Interaction Simulation

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

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

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

Mastering Complexity
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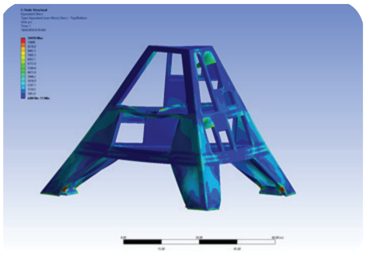
AEROSPACE AND DEFENSE

Balloon-Borne Vehicles Provide a Bird's-Eye View

It costs hundreds of millions or even billions of dollars to launch a satellite into a geosynchronous orbit where it hovers above a point on earth for observation or communications. Now, World View Enterprises' balloon-borne Stratollite vehicles can carry large payloads to altitudes up to 95,000 feet and park them there for weeks or months at a cost orders of magnitude less than a satellite or other comparable technologies. World View engineers saved an estimated eight months and about $600,000 by using ANSYS simulation software to determine the right design before building and testing a prototype.



Stresses experienced by payload module during 7g landing

By **Zane Maccagnano**, Lead Engineer, Design Structures & Mechanisms, World View Enterprises, Tucson, USA

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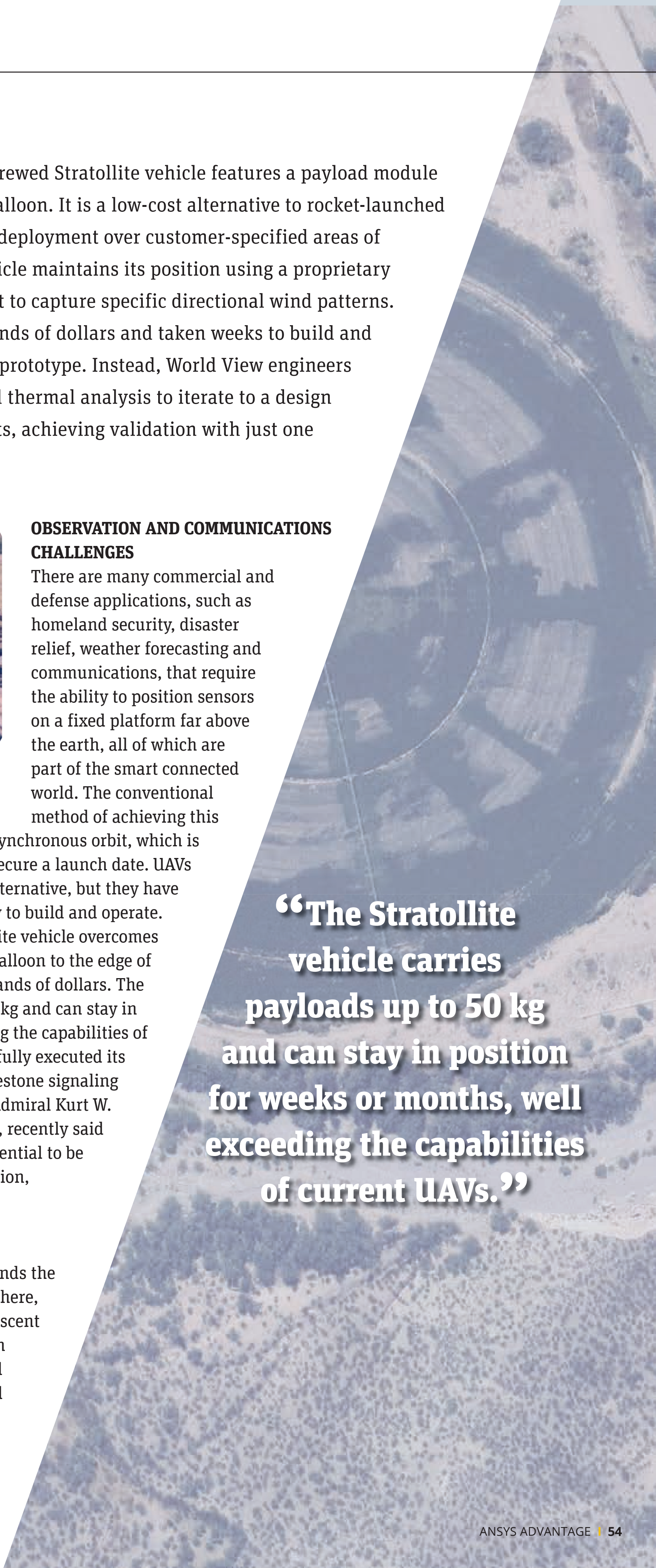
The remotely controlled, uncrewed Stratollite vehicle features a payload module carried by a high-altitude balloon. It is a low-cost alternative to rocket-launched satellites for long-duration deployment over customer-specified areas of interest. The Stratollite vehicle maintains its position using a proprietary ballast system that raises and lowers it to capture specific directional wind patterns. It would have cost hundreds of thousands of dollars and taken weeks to build and test each thermal or structural design prototype. Instead, World View engineers used ANSYS Mechanical structural and thermal analysis to iterate to a design that meets the company's requirements, achieving validation with just one structural and one thermal prototype.

High-resolution imagery captured during a Stratollite mission over Arizona

OBSERVATION AND COMMUNICATIONS CHALLENGES

There are many commercial and defense applications, such as homeland security, disaster relief, weather forecasting and communications, that require the ability to position sensors on a fixed platform far above the earth, all of which are part of the smart connected world. The conventional method of achieving this goal has been to launch a satellite into geosynchronous orbit, which is costly and may require years of waiting to secure a launch date. UAVs do provide a more affordable and flexible alternative, but they have limited flight times and are still quite costly to build and operate.

World View's remotely controlled Stratollite vehicle overcomes these limitations by riding a high-altitude balloon to the edge of space at a typical cost of hundreds of thousands of dollars. The Stratollite vehicle carries payloads up to 50 kg and can stay in position for weeks or months, well exceeding the capabilities of current UAVs. Recently, World View successfully executed its first multiday Stratollite mission, a key milestone signaling the commercial readiness of the platform. Admiral Kurt W. Tidd, Commander, U.S. Southern Command, recently said of the Stratollite, "We think this has the potential to be a game-changer for us — a great, long-duration, long-dwell surveillance platform."



> **"The Stratollite vehicle carries payloads up to 50 kg and can stay in position for weeks or months, well exceeding the capabilities of current UAVs."**

SIMULATING MECHANICAL LOADING

Ensuring that the Stratollite vehicle withstands the thermal loading experienced in the stratosphere, as well as the mechanical loading during descent and landing, was a critical part of the design process. Fewer load cases than conventional satellites were required because the payload module does not experience the high vibration and shock loads faced during launch. The greatest mechanical loading

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occurs when the parachute opens during its descent and when it lands on the earth.

> **“Engineers saved up to eight months and about $600,000 by using ANSYS simulation software.”**

The Stratollite payload module frame is built using riveted sheet metal to create a semi-monocoque structure that holds the altitude control and avionics equipment, and the payload. At the bottom of the structure are three skids with energy absorbers used during landing. Testing of the structure under the mechanical loads experienced during descent requires construction of a prototype that can cost hundreds of thousands of dollars and take about three weeks for each design iteration. World View engineers need to ensure that the structure can withstand g-force parachute opening loads of 5 g and landing loads of 7 g. Buckling is the most likely failure mode. The structure also needs to be as light as possible to maximize payload weight.

Through Elite Channel Partner Phoenix Analysis & Design Technologies (PADT), World View joined the ANSYS Startup Program, which provides full access to simulation software bundles that are designed and priced specially for startup companies. By working closely with PADT for many years, World View's engineers have gained access to an impressive level of expertise and support, which ensures that Stratollites are designed to withstand the rigors of launching into, flying through and coming back from the stratosphere.

The original geometry of the structure was produced in SolidWorks computer-aided design (CAD) software. Using the ANSYS–SolidWorks import tool, World View engineers were able to easily bring the CAD model into ANSYS Workbench. Engineers used ANSYS DesignModeler to create surfaces from the original CAD file and then, employing ANSYS Workbench, generated meshes from the surfaces with computationally efficient shell elements. When the constraints and loads were applied to the structure, the static analysis showed that stresses due to parachute openings, launch loads and landing loads were well within yield limits. World View engineers knew that, with a semi-monocoque structure, material static strength efficiency is not always the limiting design factor. The thin members, with reduced cross-sectional areas that can lower modulus or stiffness, created design challenges leading to the need for ANSYS’ advanced capabilities in buckling analysis.

Engineers added a second analysis branch for buckling analysis. They ran the analysis for several buckling modes, which produced the buckling mode shapes and load factors for each mode shape. The buckling load factor is the ratio of the load that will cause the structure to buckle to the actual load — in other words, the margin of safety against buckling. In several cases, load factors were below acceptable levels, so engineers modified the SolidWorks model to, for example, add stringers (ribs with a cross section that are riveted to the structure). They imported the

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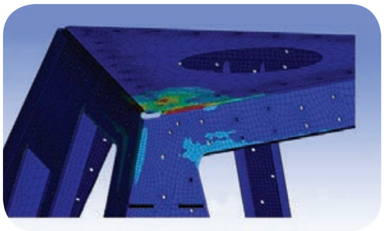
new geometry from SolidWorks while maintaining the same constraints and loads from the previous version of the model. Over a series of eight iterations, engineers added stringers in the legs above and below the payload, until they were satisfied that the structure could handle the buckling loads. ANSYS simulation helped World View add the minimum amount of structural supports to meet their design requirements while minimizing the weight of the structure.

SIMULATING THERMAL LOADING

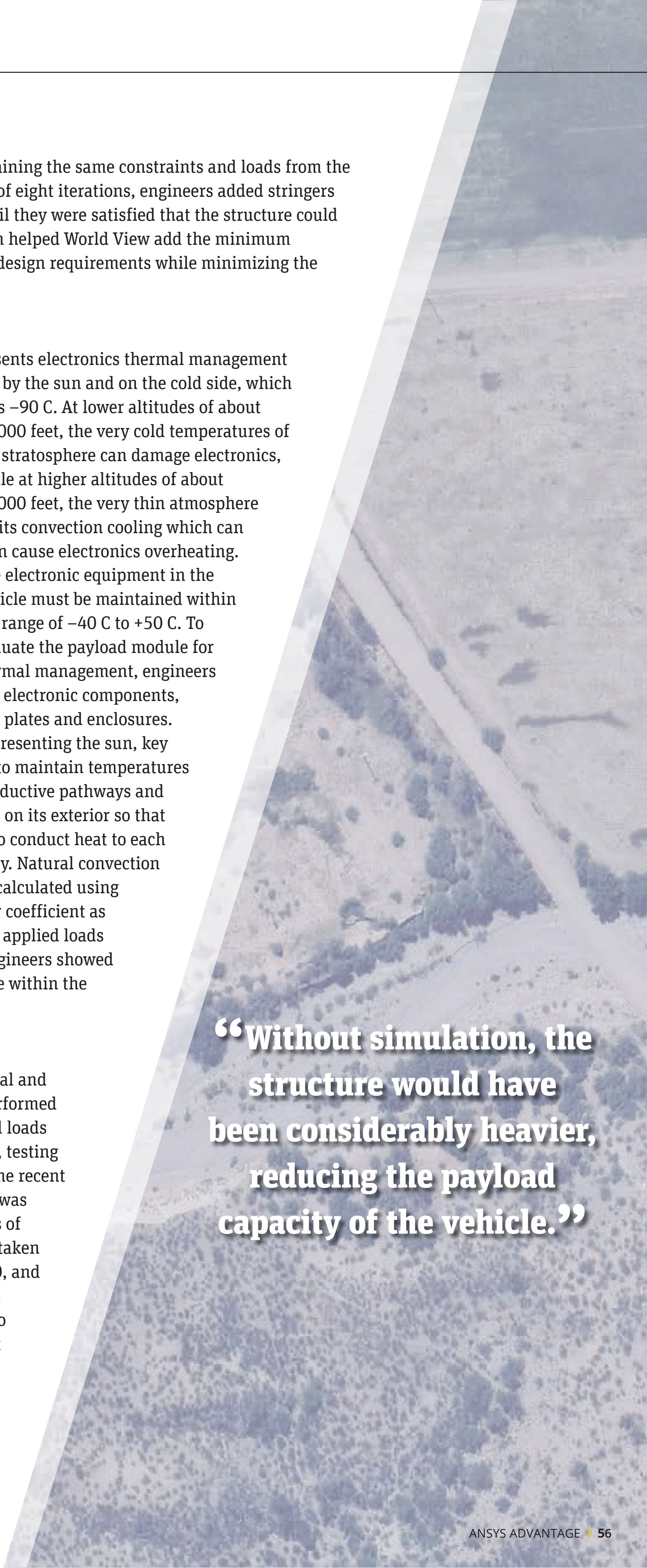


Stresses during a 5 g parachute opening

Thermal loading on the payload module presents electronics thermal management concerns both on the side of the craft heated by the sun and on the cold side, which is exposed to ambient temperatures as low as –90 C. At lower altitudes of about 50,000 feet, the very cold temperatures of the stratosphere can damage electronics, while at higher altitudes of about 95,000 feet, the very thin atmosphere limits convection cooling which can then cause electronics overheating. The electronic equipment in the vehicle must be maintained within the range of –40 C to +50 C. To evaluate the payload module for thermal management, engineers added geometry to the structure to represent electronic components, including circuit boards, heat sinks, radiator plates and enclosures. They loaded the model with heat sources representing the sun, key integrated circuits and the heaters required to maintain temperatures within the acceptable range. They added conductive pathways and radiant constraints within the enclosure and on its exterior so that the virtual components could be simulated to conduct heat to each other, and to radiate internally and externally. Natural convection of the external surface of the enclosure was calculated using a lookup table to determine the heat transfer coefficient as a function of surface temperatures. With the applied loads and constraints to the model, World View engineers showed that the expected cold case and hot case were within the electronic component temperature limits.

BENEFITS OF ANSYS SIMULATION

World View engineers optimized the structural and thermal design with simulation and then performed an iteration of ground testing for mechanical loads and another for thermal loads. In both cases, testing showed that the design met requirements. The recent flight test further confirmed that the design was correct. Simulation saved at least two rounds of structural ground testing, which could have taken about two months and cost around $300,000, and two rounds of thermal ground testing, which could have taken around six months and also cost around $300,000. Furthermore, without simulation, the structure would have been considerably heavier, reducing the payload capacity of the vehicle. Λ



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