Ansys

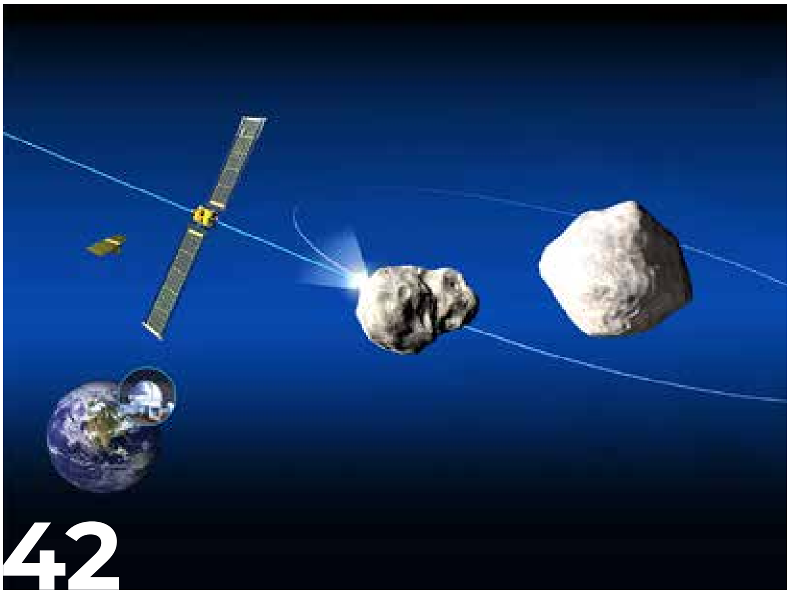
ADVANTAGE

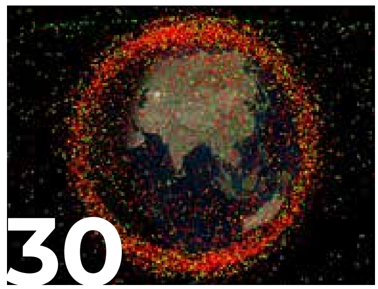
EXCELLENCE IN ENGINEERING SIMULATION

ISSUE 1 / 2023

DIGITAL ENGINEERING *TAKES FLIGHT*

Table of Contents





Focus on Aerospace & Defense

ON THE COVER:
An artist's rendering of the Vertical Aerospace VX4 electric vertical takeoff and landing (eVTOL) aircraft; not an actual simulation visualization.

ADVANTAGE

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

The Editorial Staff
ansys-advantage@ansys.com

Editorial Adviser
Matt Ladzinski

Executive Editor
Jamie J. Gooch

Managing Editor
Tim Palucka

Copy Editor
Abby Humphreys

Contributors
Laura Carter, Aliyah Mallak, Erik Ferguson, Jennifer Procario, Matt White

Editorial Contributor
Ansys Customer Excellence

Art Director
Ron Santillo

Designer
Dan Hart Design

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

Subscribe at ansys.com/subscribe

Hit the "I Believe" Button for Digital Transformation

By **Steve Bleymaier**, Brig Gen (USAF Ret), Chief Technology Officer for Aerospace & Defense Ansys

The aerospace and defense (A&D) industry was one of the first to embrace computer-aided engineering (CAE), but it has since acted slowly to expand digitalization efforts. For example, a recent survey of 50 A&D executives revealed that 85% of them plan to adopt digital thread technology[1], but only 5% have actually deployed solutions so far. Stepping forward into digital transformation will help these companies solve many of their challenges faster and at lower cost, delivering products to market sooner. So, it's worth asking the question: Why haven't they taken this step earlier?

One potential answer comes from a meeting I had with an A&D executive a few years ago. After a 45-minute presentation making our case to transform his department using digital engineering, he pointed to a coaster on his desk.

"See this? That's the 'I believe' button." He paused to make sure we understood. "I can't hit it. I just can't hit it. Help me hit it."

He suggested the next step.

"You need to work with my chief engineer and convince him," he said. "You convince him, you convince me — and then I can hit that button."

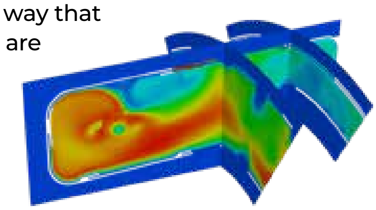
In the immediate moment, this roadmap was simple enough to follow. But that conversation also reveals the deeper truth: For many A&D organizations, the value of digital engineering is still not intrinsically accepted. Our challenge, then, is as plain as it is bold. We must show an entire industry that when it comes to digital engineering, they should always hit that button.

AFFECTING CHANGE IN A&D

To change the way A&D organizations see digital engineering, it's not as simple as getting chief engineers and top executives on board. There must also be acceptance from the bottom up — and that's not easy to achieve. For example, engineers with lots of experience building and testing prototypes may need some convincing that digital engineering can improve the efficiency of such rigorous processes.

In the short term, simulation solutions must meet engineers where their problems are. As you'll read in this issue, one such place that now "believes" in digital engineering is the Air Force Test Center (AFTC). The engineers at AFTC were struggling with repetitive flight tests that were costing them excessive time and money. To qualify, their tests require exacting flight conditions, which — no surprise — cannot be assured in the natural world. These constraints, which could change at any time, mid-flight, were forcing AFTC to scrap test data and repeat flights. Ansys is helping AFTC to overcome these obstacles with a model-based process that improves test effectiveness, optimizes real-world test plans, and provides insight into potential design improvements. This approach — fusing test data with models — is attractive to the engineers at AFTC because it directly improves *their* effectiveness.

There is much more to be said about changing the way that A&D organizations see digital engineering. The future of this discipline is almost certain to extend into university systems and change the very way that aerospace engineers are educated. But this industry cannot wait for the workforce of tomorrow, because there's so much that must be done today.



THE CHALLENGES WE FACE

Digital engineering holds enormous potential for efficiency and innovation across all the great initiatives now before A&D organizations. Let's take a quick survey:

Sustainability

Global passenger traffic is expected to return to 2019 levels by 2024, and then double them by 2040 — from 4 billion passengers to about 8 billion.[2] So, aircraft OEMs are investing in more fuel-efficient aircraft to reduce operating costs while emitting lower or zero emissions. A&D companies aim to reduce greenhouse gas emissions by more than 50% by 2030.[1] To achieve this goal, they're considering an array of new technologies from alternative fuels to propulsion systems such as hybrid-electric, electric, and hydrogen. The use

BUSINESS SPACE

72 *rockets were launched in the first half of 2022*

1,022 *spacecraft were carried by those rockets*

94% *of these launches were commercial ventures*

of hybrid-electric propulsion extends beyond sustainability, as evidenced by recent news of a next-generation engine for stealthy drone design using this propulsion technology.[3]

Autonomy

Hundreds of organizations are working on more than 700 electric vertical takeoff and landing (eVTOL) concepts and designs.[4] They are using simulation to improve autonomous flight controls, electronic data sensors, and signal processing to avoid crashes. In addition, collaborative combat aircraft (CCA), like the autonomous unmanned combat air vehicle (UCAV), must be able to interact with crewed and uncrewed aircraft.

Spectrum

In an increasingly integrated world, the ability to sense and communicate among multiple systems in a contested environment — and to quickly analyze and decide on the incoming data — is paramount. The Department of Defense's strategy is called Joint all Domain Command and Control (JADC2, see page 48), which requires resilient radio frequency and optical communications, accurate imaging and sensor systems, artificial intelligence/machine learning (AI/ML), and more.

Speed

The U.S. Air Force is funding development for supersonics, including a strategic partnership with Boom Supersonic to accelerate the supersonic capabilities of Overture, the company's commercial aircraft. NASA and Lockheed Martin are developing the X-59 QueSST, an experimental supersonic aircraft, which will provide regulators with the information required to establish an acceptable commercial supersonic noise standard. Equipped with such a standard, we will be able to lift the current ban on commercial supersonic travel over land in the United States.[1]

Space

Private businesses now account for about 80% of the $447 billion (2020 value) worldwide space industry.[5] In the first half of 2022, 72 rockets launched 1,022 spacecraft,[6] and 94% of these launches were commercial ventures.[1]

The future holds large constellations of small satellites, the need to reduce space debris, low Earth orbit (LEO) development, and increased in-orbit manufacturing. Other opportunities include reusable launch systems with renewable or non-toxic fuels, asteroid mining, security and resilience in the face of cyberattacks, accurate sensor technology for detection and tracking, space tourism, and space-based solar power.

PRESENTING THE PROOF

The most powerful evidence is, of course, empirical evidence. Where is our proof? Well, some of it is right here in these pages. This issue of *Ansys Advantage* is dedicated to telling the stories of A&D organizations that have committed to digital engineering to transform new product development and operations. We talk about their goals, their challenges, their struggles, and ultimately, how digital engineering has been instrumental to their success. We hope these stories might help you to hit the "I believe" button.

References

1. Deloitte. "2023 Aerospace and Defense Industry Outlook," https://www2.deloitte.com/content/dam/Deloitte/us/Documents/manufacturing/us-eri-2023-outlook-aerospace-and-defense.pdf
2. International Air Transport Association (IATA). "Global Outlook for Air Transport Sustained Recovery Amidst Strong Headwinds," https://www.iata.org/en/iata-repository/publications/economic-reports/global-outlook-for-air-transport---december-2022/
3. Breaking Defense. "General Atomics developing hybrid-electric engine for stealthy 'MQ-Next' drone design," https://breakingdefense.com/2022/10/general-atomics-developing-hybrid-electric-engine-for-stealthy-mq-next-drone-design/
4. Electric VTOL News. "Vertical Flight Society Electric VTOL Directory Hits 700 Concepts," https://evtol.news/news/press-release-vertical-flight-society-electric-vtol-directory-hits-700-concepts
5. Washington Post. "Companies are commercializing outer space. Do government programs still matter?" https://www.washingtonpost.com/politics/2022/01/11/companies-are-commercializing-outer-space-do-government-programs-still-matter/
6. Fortune. "Space travel is heating up — and so are rocket fuel emissions. These companies are developing cleaner alternatives to protect earth first," https://fortune.com/2022/12/05/space-travel-is-heating-up-and-so-are-rocket-fuel-emissions-these-companies-are-developing-cleaner-alternatives-to-protect-earth-first/

Education is Key to Aviation Innovation

By **Tim Palucka**, Managing Editor, Ansys Advantage

The user experience is an important engineering consideration. In commercial aviation, engineers rightly focus on technologies to advance the safety and performance of passenger aircraft, but consumer preferences can determine which innovations succeed in the market. Is it worth the effort of developing autonomous planes if people are too afraid to ride them? How much do passengers care about their carbon footprint when they book a flight, and are they willing to pay more for a greener flight if the technology is available?

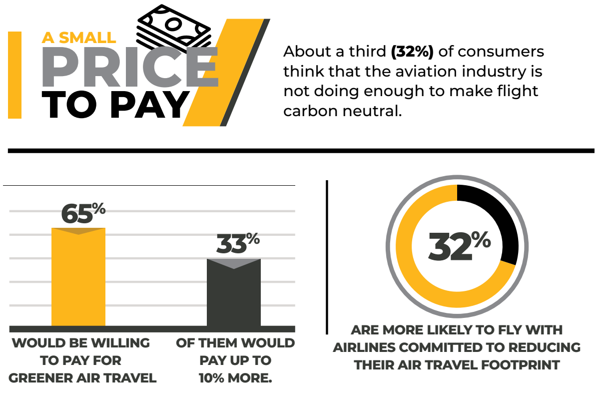
To help answer these questions. Ansys commissioned a survey of more than 6,000 people in France, Germany, the United Kingdom, and the United States. The results reveal their opinions and knowledge of the engineering efforts currently being made in the field of aviation, including some surprises when it comes to today's accepted procedures and what technologies could shape the future of aviation.

CAPTURING CARBON FOOTPRINT CONCERNS

When asked if they think about the emissions related to their business or personal air travel, nearly 63% said they are very or somewhat concerned, but almost half don't know how to obtain carbon footprint info for their flights. Reinforcing the need for the industry to share its sustainability story: About a third of respondents say airlines are not doing enough to make flight carbon neutral, and 28% have no idea what airlines are doing to make flight carbon neutral.

What does that mean for commercial flight bookings? It's a mixed bag, with half of those surveyed responding that one way they would lessen their carbon footprint is by reducing their air travel. On the plus side, 65% said they would be willing to pay for greener air travel.

When broken down by country, respondents in France were the most concerned about carbon emissions in aircraft. Seventy percent of French respondents said they were very or somewhat concerned about carbon emissions from the aircraft, vs. 65% from Germany, 63% from U.K., and 53% from the U.S.

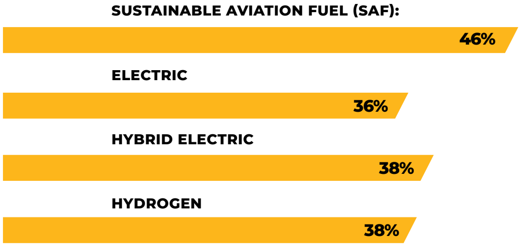


U.S. respondents were the least likely to check the carbon emissions of flights before making a booking. The U.K. and U.S. markets were the most likely to not know what the aviation industry is doing to make flights carbon neutral. About a third (34%) of respondents from the U.K. and 39% of those from the U.S. said this, compared to 22% of those from Germany and 16% of those from France.

The majority of the public's sustainability concerns may bode well for new and emerging aircraft power sources — if they knew what those alternative power sources were. On average, 36% of respondents had never heard of sustainable aviation fuels (36%), electric-powered aircraft (35%), hybrid-electric aircraft (37%), or hydrogen-powered aircraft (37%).

FUELING THE FUTURE

Many consumers would travel in aircraft powered by these alternatives in the next five years.



PROVING TECHNOLOGY

Half of the respondents said they would not fly on aircraft with new and emerging power sources because the technology hasn't been proven yet. However, their level of trust was increased with the knowledge that "simulation enables engineers to see how their digital designs will — or won't — behave in millions of real-world scenarios, while reducing or even eliminating the need for costly physical testing." Confidence also increases after being told how alternative fuel sources had been extensively simulated and tested using methods applied to aircraft safety for the past half century.

Armed with that information, 69% said they would be more likely to trust these new technologies.

That same trend holds true when asked about autonomous flight. The more people know and understand, the more likely they are to be comfortable with technology.

At first, the prospect of autonomous flight found muted support from survey respondents, even when they were given this information: "For the first time, artificial intelligence (AI) has just flown a plane for 17 hours without human assistance. Would you consider flying in an autonomous (self-piloting) aircraft?"

About a third of respondents said they would be willing to take an autonomous flight in the next five years, with an almost equal amount saying they would never do so.

Respondents from France (52%) and Germany (51%) were the most likely to say that, within 5 years or later, they would consider flying in a self-piloting plane, vs. 44% of those from the U.K. and 41% of those from the U.S. saying the same.

Informing those surveyed about the prevalence of autonomous assistance on current flights made a difference. Survey takers were told: "On your last flight, it is likely that only the first 10 minutes and final 10 minutes were controlled by a pilot. The rest was autonomous. Does this change your perception of how safe autonomous flying is?"

In total, 74% of respondents said this information changed their perception of the safety of autonomous flight. Forty percent of them said they were "shocked it's not common knowledge that the vast majority of my last flight was likely autonomous." The two most likely markets to say this were respondents from the U.K. (45%) and France (44%).

Sustainability Age Gap

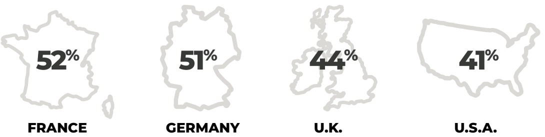
Younger consumers were more likely to say they were concerned about carbon emissions from aircraft: 33% of the 18-24 year-old respondents vs. 16% of the 65+ respondents.

More than half (54%) of the 18-24 year-olds said they checked the carbon footprint of a flight before booking, vs. 11% of the 65+ respondents.

AUTONOMOUS AVIATION GAINS ALTITUDE

Globally, almost half **(47%)** of consumers are ready to fly in an autonomous plane in their lifetimes.

READY FOR AUTONOMOUS FLIGHT



3/4 OF CONSUMERS SAID THEY WOULD FEEL SAFER FLYING IN AN AUTONOMOUS PLANE AFTER THEY WERE TOLD HOW MUCH OF A FLIGHT TODAY IS ALREADY AUTONOMOUS.

INNOVATE AND EDUCATE

The survey results highlight the role that education plays in advancing innovation across the aerospace industries. When it comes to commercial aviation, consumers are often suspicious of what they don't understand. Simulation can not only help the aviation industry gain insights on cutting-edge solutions as engineers develop the future of flight, but it can also be used to help consumers gain confidence in what's ahead. /\

Going Up: Simulation Advances eVTOL Development

By Ansys Advantage Staff

An artist's rendering of the Vertical Aerospace VX4 electric vertical takeoff and landing (eVTOL) aircraft; not actual simulation visualization.

You can't tell just by looking skyward, at least not yet, but there's a race to control the urban airways, and Ansys computational fluid dynamics (CFD) software is helping one contender gain a lead.

The goal is to get a new class of aircraft — highly automated, exceptionally complex electric vertical takeoff and landing (eVTOL) vehicles — off the ground, and the sooner, the better. Designed to take off and land like a helicopter and fly like a plane, eVTOL aircraft are expected to usher in a new era of urban air transport, kicking old-fashioned, land-based traffic jams to the curb.

The potential market for eVTOLs is enormous, which explains why so many companies are jockeying for first mover advantage — or are at least trying to be among the pioneers. "The sky's the limit," Morgan Stanley declared in their analysis of urban air mobility (which, in addition to eVTOLs, includes the "Jetsons"-esque category of "flying cars"). They anticipate the market will be worth around $1 trillion in 2040 and soar to nine times that in 2050.[1]

> ***"Having access to the Ansys software tool set enables us to tackle these hard problems, which may not be possible within a wind tunnel, or which could put our precious test assets at too high a risk to execute them at full scale yet."***
>
> **— KURT CLEMENT,** Vertical Aerospace

Once certified and commercialized, eVTOLs will be a convenient way for people to travel short distances between airports or into city centers. Not only will eVTOLS revolutionize air travel, but by being all-electric and purely battery powered, they could help decarbonize it too, even as transportation demand grows.

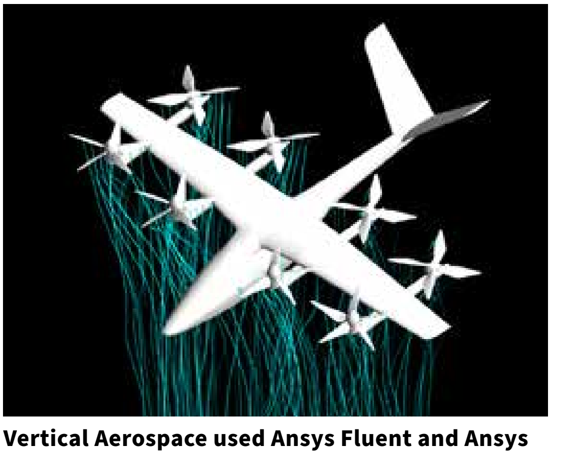
NEW WAYS OF WORKING

U.K.-based Vertical Aerospace is working to capture their share of what promises to be a high-flying new transportation market. They have partnered with some of the leading names in automotive and aerospace systems to develop the VX4 vehicle, including Rolls-Royce, which designed the VX4's electric powertrain, and Honeywell, which devised the flight controls.

Of course, when you combine the DNA from different types of aircraft, you can no longer rely on what Kurt Clement, Vertical Aerospace's IPT Lead for Aerodynamics, Aeroacoustics, and Thermodynamics, calls "the old ways of working." That's why Vertical Aerospace is using Ansys Fluent and Ansys CFX simulations to understand the complex flow around eight spinning rotors and to optimize the rest of the airframe.

"When you have a full airframe, all eight rotors spinning, all control surfaces deployed, in some complicated transition or conversion maneuver, it is no longer possible to determine how interaction wake flows will react with downstream components via simplified or empirical methods," Clement says. "There needs to be a certain amount of a realization that these problems are just really, really difficult to quantify, and that they often will require more than just wind tunnel testing and other simplified test processes to increase confidence in the aircraft's performance."

To ensure the stable, predictable, and safe performance of the five-seat VX4 vehicle (it accommodates four passengers and one pilot — a piloted aircraft being preferred to



Vertical Aerospace used Ansys Fluent and Ansys CFX to understand airflow around the VX4's eight rotors.

> ***"Ansys provides higher fidelity, helping us to check that the empirical calculations we've done actually work in a more real sense."***
>
> — **KURT CLEMENT,** Vertical Aerospace

an autonomous vehicle by regulators and the public) — engineers relied on Ansys CFD software to understand how air moves over the aircraft surfaces, and to model the intricate flow interactions between multiple components, including the aircraft's wing, rotors, and fuselage. Simulation also helped them to understand what happens during the transitions of flight: take-off, hover, transition, cruise, conversion, and landing.

"Having access to the Ansys software tool set enables us to tackle these hard problems, which may not be possible within a wind tunnel, or which could put our precious test assets at too high a risk to execute them at full scale yet," Clement says.

REDEFINING HYBRIDS

Looking at the VX4 is like seeing something familiar with a little bit of fabulism mixed in for good measure. If the V-22 Osprey and an ASK-21 glider had an offspring, this would be it: a never-before-imagined hybrid mixing utility, grace, and quiet operation.

The aircraft has the fuselage of a helicopter — albeit one that's sleek and aerodynamic — with electric motors. Lift and hover are provided by eight rotors, four five-blade propellers at the front and four four-blade props at the back. The front props tilt down from 90 degrees and are used throughout the flight envelope; the props at the back provide for efficient hover but they scissor and stow in a lower-drag position during flight. Engineers shaped the propeller blades to optimize thrust while also taking aim at one of the more common complaints about helicopter travel: noise. The VX4 is 100 times quieter than a helicopter, according to Vertical Aerospace, as shown quantifiably using Ansys Fluent for aeroacoustics. And during testing of the propellers, Clement said "it is actually quite remarkable how quiet they really are. We had a helicopter fly over the airfield a hundred meters up or something, and it drowned out our aircraft entirely."

That's not the only place where the VX4 sheds its conventional helicopter identity, however. A 49-foot (15-meter) fixed wing atop the vehicle makes cruise flight feasible. The wing also makes it possible to achieve the payload and range (up to 100 miles/161 kilometers) required to make flying the VX4 economically a cheap, and therefore viable, form of transport for everyone.

TACKLING HARD PROBLEMS

Understanding how highly sophisticated, interdependent systems will affect one another in the real world — with a cruise speed of 150 mph/240 kph — can't be done accurately enough with pen-to-paper, assumption-laden calculations when you are riding so close to the cutting edge of technology. It takes a new way of working, and this, Clement says, is where Ansys software comes in as one of these ways; especially its ability to deliver incredibly complicated models with tremendous speed.

For example, the meshing capabilities of Ansys Fluent enabled Vertical Aerospace engineers to capture intricate and complex flow interactions by performing unsteady simulations with up to 650 million cells.

Before simulating interdependent systems, though, Vertical Aerospace first used Ansys software to learn how different conditions and forces affected the performance of individual components.

Initially, engineers modeled how rotor performance changes when the rotors are mounted on a pylon or are subjected to a variety of factors and forces: edgewise flow, ground effect, pressure changes, and turbulence among them. They applied the same process to other parts, including the wing, fuselage, tail, landing gear, and so on. This helped them make critical decisions about lift, thrust, weight, and speed, and to ultimately design in passive stability — that is, an aircraft's ability to self-correct for conditions acting upon it and to ensure that it would never be in a situation where it couldn't recover from an undesirable dynamic flight mode.

"Ansys provides higher fidelity, helping us to check that the empirical calculations we've done actually work in a more real sense," Clement says. "Instead of making 50 different assumptions based on an idealized system that would never exist in real life, we have answers that are closer to reality, to make sure that the aircraft actually does what we think it will. From there, we can then apply these known cases to an extremely varied simulation data set, and ensure it is all well-bounded and quantified."

SAFETY, CERTIFIED

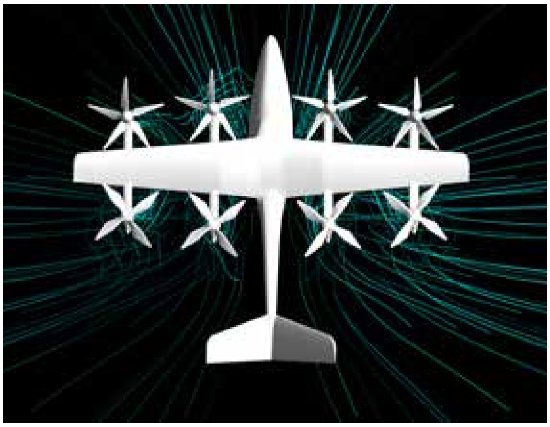
Vertical Aerospace engineers expect their aircraft to be 100 times safer than a helicopter. Even Clement admits the number sounds a little too rounded to be true, more like a marketing gimmick than a documentable specification. But the proof is in the certification. To meet European Union Aviation Safety (EASA) requirements, "100 times safer" is the standard they'll have to achieve and accurately prove to the authority: a catastrophic risk chance of 10-9, or one failure in 1 billion flight cycles.

Ensuring safety without sacrificing reliable performance is important for every commercial vehicle design engineer. But with stakes this high, Vertical Aerospace can't leave anything to chance. The company's partnerships with Rolls-Royce, Honeywell, and Solvay — who all boast proven track records of aircraft certification — will likely help get the VX4 to final approval, but pushing the envelope of performance and achieving their vision means tackling those hard problems Clement refers to with accuracy and precision.

The rigorous testing and modeling made possible by Ansys CFD simulation enabled the engineers behind the VX4 to draft a design that eliminates dependence on the continuous operation of a single rotor for both lift and thrust. With power distributed across multiple motors and the added capabilities of a high-aspect-ratio wing, the VX4 should prove to be safer than a traditional rotary-wing aircraft.

CFD technology also improves accuracy when replicating real-world conditions. Ansys CFD enables aerodynamicists to run full-sized simulations instead of relying solely on scaled-down models and augmented data or having to bear the additional expense and physical limitations of aerodynamics laboratories — that is, wind tunnels. Don't be fooled though: Wind tunnels remain a valuable tool in a design engineer's arsenal. However, the gap between CFD and wind tunnels is reducing year on year.

While wind tunnel tests provide valuable data related to scaled-down versions of the complete aircraft and still play an important role in the design process, they can't accurately reflect some of the more dynamic interactions between components, and all of the variables that impact them. For example, when testing a scaled-down model of an aircraft featuring a rotor array as complex as the one found on the VX4, Clement says that, "because of the different scaling parameters of Reynolds and Mach Numbers, one of the two will often be incorrect for a given point due to the differences in rotor tip speed vs. airframe equivalent velocities at wind-tunnel scale, as we put the model through its full range of test points."



The five-blade front props tilt down from 90 degrees and are used throughout the flight envelope; the four-blade props at the back scissor and stow during flight.

In 2022, Vertical Aerospace successfully completed a piloted hover flight of its full-scale, fourth-generation VX4 prototype. The company was recently awarded its Design Organizational Approval — the first eVTOL DOA issued to an eVTOL manufacturer by the UK Civil Aviation Authority. Vertical Aerospace has now formally commenced its certification journey with four aviation regulators in the U.K., Europe, U.S.A. and Japan.

While there are still challenges to overcome in producing safe, reliable eVTOLs, Vertical Aerospace is making great progress with Ansys' high-fidelity CFD testing solution. It has enabled them to capture data regarding all the physics variables affecting their design, accelerating the VX4 closer to market lift off.

Hermeus Disrupts Aviation at Hypersonic Speed with Ansys Simulation

By **Jennifer Procario,**
Staff Writer,
Ansys Advantage

Hermeus simulates the flowfield around Quarterhorse using Ansys Fluent.

Imagine boarding a flight in New York City and landing in Paris 90 minutes later or flying from Los Angeles to Honolulu in an hour. Such accelerated air travel may seem impossible, but a team of engineers has been working diligently since 2018 to make it a reality.

American startup Hermeus is developing air-breathing engines and hypersonic aircraft. Unlike rocket engines that carry both fuel and a supply of oxygen on board, air-breathing engines use oxygen from the atmosphere in the combustion of fuel and are much more efficient for atmospheric high-speed flight. The company is developing Chimera — a proprietary turbine-based combined cycle (TBCC) engine that serves as the life force of Hermeus aircraft.

> ***“Hermeus is on a multiyear mission to test, de-risk, and prove our engine technology with autonomous aircraft before attempting passenger travel. For us, Ansys simulation is an accelerant.”***
>
> — **SKYLER SHUFORD,** *Founder and CEO, Hermeus*

The Chimera engine is capable of accelerating aircraft to reach Mach 5 speed — approximately 3,836 mph (6,173 kph) — and versions of this engine will power two uncrewed aerial systems (UAS) before being used in Halcyon, a first-of-its-kind hypersonic passenger aircraft that could transport passengers five times faster than today's commercial aircraft.

Flying at such speeds comes with a distinct set of challenges, including extreme temperatures and a host of engineering dynamics that require careful investigation before takeoff. For this reason, Hermeus has outlined an incremental product roadmap to analyze and de-risk the milestone engine technology using Ansys multiphysics simulation to ensure speed and safety for thermal, structural, fluid, and electromagnetic (EM) characteristics.

By integrating Ansys solutions, Hermeus validates engineering using a multiphysics approach, minimizes and complements physical testing with virtual validation, and maintains short- and long-term project goals. At this speed, the startup is aiming to debut Halcyon in 2029, which will not only improve personal travel, but has the potential to increase global economic growth significantly by accelerating the speed of commerce and enhancing cultural exchange.

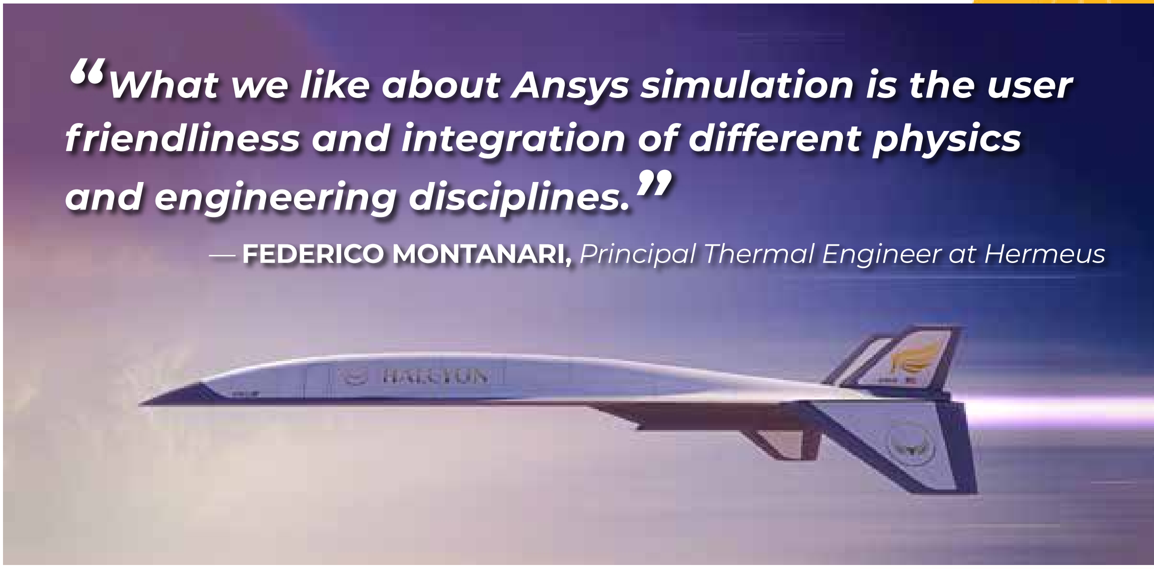
SIMULATING FOR SPEED

The Hermeus team has a saying: “It's engineering, not science.” This philosophy drives their ambition to radically accelerate air travel. Essentially, Hermeus engineers believe that once you validate core technologies, you just have to piece those technologies together. They proved this when developing Chimera, which consists of an off-the-shelf turbojet, a ramjet, and a proprietary pre-cooler that reduces the temperature of air entering the turbojet.

The pre-cooler enables the turbojet to reach supersonic speeds around Mach 2 and then the ramjet can kick in and continue to accelerate up to Mach 5. As a result, the hybrid turbojet–ramjet engine demonstrates it is possible to transition from turbojet to ramjet mode — a transition that is necessary to take off from a regular runway at subsonic speed and accelerate to hypersonic speed successfully.

By implementing Ansys simulation, Hermeus gained the critical engineering insights needed to create a fully integrated system without having to build many physical prototypes.

Hermeus' first aircraft, Quarterhorse, is an autonomous uncrewed aerial system (UAS) that will test the Chimera engine's capabilities for speed and reusability later this year.



Halcyon is a hypersonic passenger aircraft that will transport passengers five times faster than today's commercial aircraft. Hermeus is on a multiyear mission to debut this aircraft by 2029.

Engine analyses explored thermal and structural environments through Ansys Mechanical and computational fluid dynamics (CFD) in Ansys Fluent. With a comprehensive simulation tool set, Hermeus engineers virtually test dynamic environments, unprecedented speeds, and extreme temperatures more quickly, efficiently, and safely than physical testing allows.

"What we like about Ansys simulation is the user friendliness and integration of different physics and engineering disciplines," says Federico Montanari, Principal Thermal Engineer at Hermeus. "For Chimera, we can look at details of its assembly from a thermal, mechanical, and fluids point of view, then put it all together."

Through research and development opportunities, Hermeus will build autonomous uncrewed aircraft that de-risk the technology. These aircraft will provide Hermeus with the data and confidence necessary to operate and maintain safe commercial aircraft. Chimera will prove its power later this year with Hermeus' first aircraft, Quarterhorse — a small UAS that will test the engine in flight, hit high-Mach speeds, and prove reusability.

"Hermeus is on a multiyear mission to test, de-risk, and prove our engine technology with autonomous aircraft before attempting passenger travel. For us, Ansys simulation is an accelerant," says Skyler Shuford, founder and chief operating officer of Hermeus. "Developing hypersonic aircraft is complex and testing can be very expensive, so we don't want to build something that inherently isn't going to work. With Ansys simulation, we gain more confidence in the hardware we are building in a rapid way."

Hermeus' second aircraft, Darkhorse, is a fully reusable, hypersonic, mid-size UAS. It will be powered by the Chimera II, a larger TBCC that will integrate the Pratt & Whitney F100 turbofan, which is used in F-15 and F-16 aircraft. By securing an off-the-shelf turbine engine, Hermeus will save significantly on the time and cost associated with research and development, while remaining on schedule to test the Chimera II in 2024 and debut the Darkhorse by 2025.

GET UP TO SPEED:

As explained by NASA, the ratio of aircraft speed to the speed of sound in the gas determines the magnitude of compressibility effects within the surrounding air. Due to the importance of this speed ratio, aerodynamicists have given it a parameter called the Mach number in honor of Ernst Mach, a late 19th century physicist who studied gas dynamics.

- Subsonic: Mach < 1.0
- Transonic: Mach = 1.0
- Supersonic: Mach > 1.0
- Hypersonic: Mach > 5.0

Halcyon is Hermeus' largest development project. The passenger aircraft is capable of traveling more than 125 transoceanic routes at hypersonic speed, which is more than twice the speed of the now-retired supersonic Concorde. It has not yet been determined which engine will power the groundbreaking aircraft.

VALIDATING THE HARDWARE

In addition to the team's use of Ansys simulation software, Hermeus integrates real-world data and physical testing to complement virtual testing. Hermeus will continue to use simulation as an active design tool to gain engineering insight and maintain its product roadmap goals. This aligns with a broader trend to "shift simulation left" by incorporating simulation earlier in the design process to inform development — rather than as a late-stage verification or post-analysis tool.

"Having simulations to couple the problem early gets us to a place where we can start building these systems, testing them, and then anchoring and validating these models," says Shuford. "Then once we're interpolating within the space of data that we have, we can move very, very fast."

Hermeus engineers use a combination of both low- and high-fidelity tools to explore design space areas depending on the level of analysis needed. In the near future, the team anticipates a stronger focus on Python-based application programming interfaces (APIs) to support greater integration across tool sets. Ansys' portfolio supports such a shift with an open ecosystem that provides a rare opportunity to amalgamate different simulation workflows. Currently, Ansys' multiphysics simulation tools help the team confirm sensitive engineering details through virtual testing and prototyping before building physical prototypes. Another advantage of virtual testing and prototyping is that by reducing physical testing the team cuts down on wasted material, cost, and energy consumption during manufacturing.

"We test ways in which we're going to build things and to assess environments, for example, a thermal environment, which is one of the biggest challenges that we're going to face as we fly faster," says Montanari. "That is a very good place for a sophisticated, accurate, and fully capable simulation tools like Ansys Mechanical and Mechanical APDL to help us to predict heat transfer modes."

Ansys Parametric Design Language (APDL) is a structured scripting language used to interact with the Mechanical solver. Mechanical APDL (MAPDL) helps automate tasks within Mechanical, including creating geometries and establishing solver settings for complex analyses.

With additional support from Ansys Elite Channel Partner Rand Simulation, Hermeus discovers new ways to incorporate the technology, such as how to apply MAPDL and Ansys' EM tools to perform radiative transfer calculations more efficiently. As its name suggests, radiative transfer, also called radiation transport, is the transfer of energy in the form of EM radiation.

Another advantage of virtual testing and prototyping is that by reducing physical testing the team cuts down on wasted material, cost, and energy consumption during manufacturing.

Hermeus' proprietary turbine-based combined cycle (TBCC) engine, Chimera, is a hybrid turbojet-ramjet engine capable or powering hypersonic aircraft at Mach 5 speeds.

SOARING INTO THE FUTURE

The aviation industry is embracing digital transformation more than ever before to meet consumers' needs, support sustainability, and achieve cost-efficient productivity.

Like fellow aircraft manufacturers, Hermeus is adopting Ansys' multiphysics simulation tools to reach these goals. Unlike many other aircraft manufacturers, the company is transforming the future of flight with predictive insights. Hermeus is breaking down barriers to next-generation air travel by applying simulation to accomplish unprecedented engineering feats to make hypersonic passenger travel a viable mode of transportation.

Immersive Soundscapes for Human Perception of **Aviation Acoustics**

By **Scott Granger**, Director, USAF and USSF Programs, Ansys

Urban air mobility (UAM) is an emerging approach to satisfy the growing demands of air transport and operations around suburban and urban settings. The objective for UAM implementation is to create a safe and efficient transportation system for people and cargo within surrounding populated areas. Considering the potential applications in logistics, defense, and humanitarian efforts, a new generation of aircraft development is underway to create systems that are optimized for UAM missions. The emerging class of UAM aircraft are battery powered, largely autonomous, and suitable for commercial and defense applications.

"The results were spectacular. I was truly amazed at the quality and clarity of the audio, especially for a virtual aircraft design. It sounded so real, and I remember playing those first audio results over and over again — like 10 times in a row. The process is that good."

— **DR. NICHOLAS KUPROWICZ,** Chief Innovation Officer, Infinity Labs

UAM safety is a primary concern for operators, as well as the surrounding populace. Acoustics are a critical consideration for UAM platforms in urban settings due to community health risks associated with increased noise pollution. Adverse health conditions that could result from UAM noise exposure include fatigue, psychoacoustic impacts, and tinnitus. Throughout the aviation community, acoustic-based analyses and advanced noise reduction techniques are considered vital to the sustainability of UAM practices.

TO INFINITY AND BEYOND

To inspire more companies to develop and field a wide range of electric vertical take-off and landing (eVTOL) technologies, the United States Air Force sponsored the Agility Prime initiative. The program was designed to leverage and accelerate commercially available capabilities. Infinity Labs pursued the opportunity to integrate leading-edge Ansys capabilities into a next-generation acoustics analysis framework to benefit the UAM community.

"The original idea I had was analogous to Google Maps, where you can use Google Street View to jump into a map and look around in three dimensions," says Dr. Nicholas Kuprowicz, Chief Innovation Officer at Infinity Labs and Principal Investigator for acoustics work. "I wanted a similar capability for aircraft acoustics, where you can become immersed in a virtual/simulated environment and hear the sound of aircraft flying nearby — at any time and from any location."

Infinity Labs successfully demonstrated high-fidelity modeling and simulation capabilities that enable human perception of aircraft acoustics in virtual airspace environments. The team leveraged commercially available tools, including Ansys Fluent and Ansys Sound, to establish the capability, with verification and validation of the approach based on eVTOL airframes and rotor acoustics. Infinity Labs has directly enabled government research and industry hardware development with this capability, and they are expanding their application to a broader range of aircraft types and operational environments. The company expects significant growth in commercial and defense applications in which human perception of acoustics is a primary driver of aircraft route planning.

TRUST THE PROCESS

The fundamental process is simple in concept: pressure flowfield data from computational fluid dynamics (CFD) simulations of aircraft operations is input to an auralization method that transforms the pressure data into perceived sound at observer locations.

Infinity Labs established the process through two different applications designed to verify and validate the capability. The first application involved a notional eVTOL

You can listen to an audio recording of the virtual aircraft design by using your smartphone camera on the QR code to the right.

airframe and rotor design with simulated flight operations in an urban setting. In this case, they used compute resources at the Ohio Supercomputer Center, and simulations from Fluent and Star-CCM+ were compared and auralized using Sound.

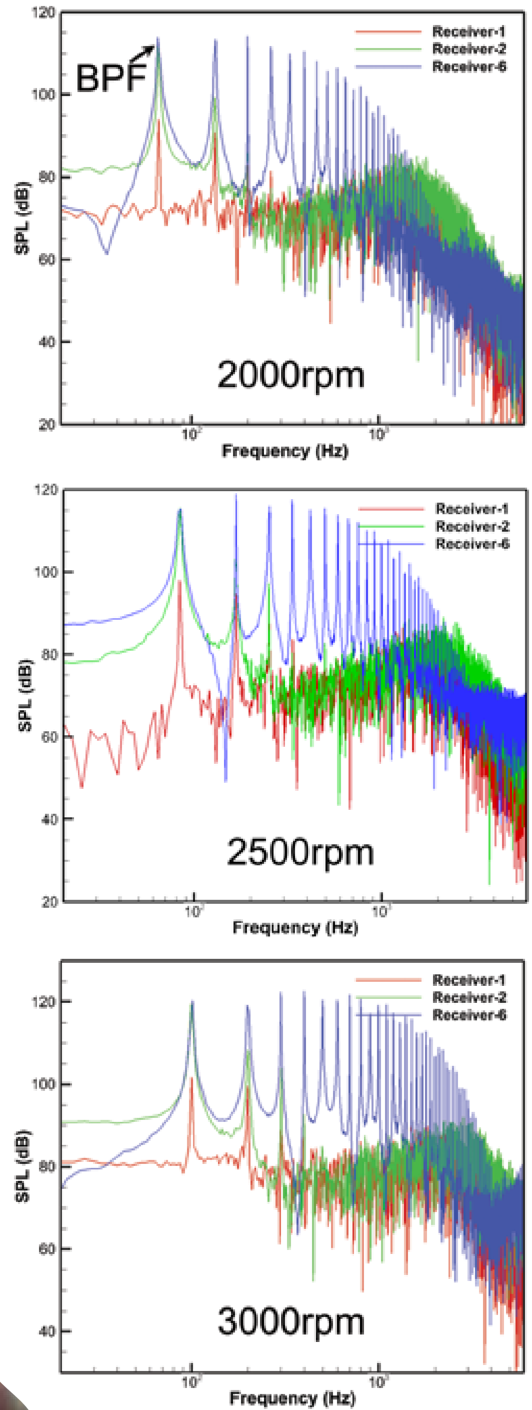
The second application involved a proprietary rotor design and test hardware with physical experimentation in an anechoic chamber. In this second case, compute resources from Ansys Cloud were used directly with Fluent, and simulated flowfield characteristics were compared with high-resolution experimental flowfield data. In addition, the simulated results from Sound were compared with measured acoustic spectra at multiple receiver locations.

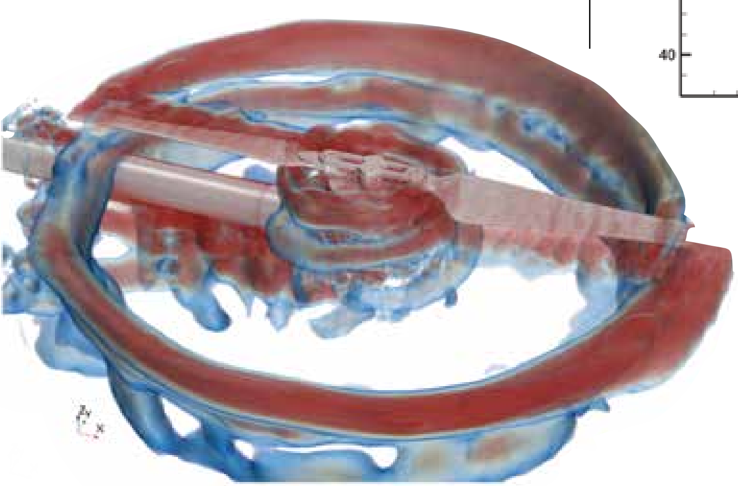
EAR RINGING RESULTS

The CFD simulations accurately captured the dominant flowfield physics and the auralization realistically converts the pressure data into audible sound.

"The results were spectacular," Kuprowicz says. "I was truly amazed at the quality and clarity of the audio, especially for a virtual aircraft design. It sounded so real, and I remember playing those first audio results over and over again — like 10 times in a row. The process is that good."

By using mature and robust Ansys capabilities, Infinity Labs rapidly and successfully transitioned a novel idea for aircraft acoustics analysis into a prototype and operational use. Continued work will focus on the acoustics of larger aircraft types and the implications of acoustics in early-phase digital aircraft design processes.





Acoustic spectra are obtained after Fast Fourier Transform (above). Blade passing frequency (BPF=rpm/60*2) and its harmonics are accurately predicted by the simulation (left). As expected, receiver 1 is less than receivers 2-5, which are less than receivers 6-9.

ANSYS and ATI FLYZERO use Digital Engineering to Design Concept Aircraft

Donna Dykeman, Manager R&D, Ansys

All major automotive original equipment manufacturers (OEMS) have announced that they are going fully electric within a few years, now the spotlight is turning toward the aviation industry to drastically reduce carbon emissions. Many aviation leaders are vowing to reach net-zero carbon emissions goals by 2050[1], so OEMs in aviation are striving to adopt new initiatives and technologies to reach these goals safely.

By embracing digital transformation and integrating simulation into workflows, engineers can design cleaner, faster, and smarter systems that reduce carbon emissions, material use, and noise pollution. Digital engineering enables engineers to integrate sustainability best practices into all phases of the life cycle, including the concept design phase.

CONCEPTING TO MEET GOALS

To support the commercial aviation industry's goal to meet emission reduction targets[2], Aerospace Technology Institute (ATI) FlyZero is using Ansys solutions to develop three aircraft concepts with zero in-flight carbon emissions for use in 2030.

ATI FlyZero wanted to compare the sustainability impact of three benchmark aircraft against the three concept aircraft. The benchmark aircraft are hydrocarbon fuel kerosene aircraft that could be expected to be in service in 2030. The concept aircraft explore new propulsion technology, such as hydrogen combustion and hydrogen fuel cells with electric powertrain.

1. FlyZero midsize using hydrogen combustion versus the benchmark midsize, which is an Airbus A330-200-like aircraft with expected 2030 improvements.
2. FlyZero narrow using hydrogen combustion for propulsion, while the on-board power system is changed to fuel-cell technology versus the benchmark narrow, which is an Airbus A320-300-like aircraft with expected 2030 improvements.
3. FlyZero regional using hydrogen fuel cells for propulsion and the power systems versus the benchmark regional, which is an ATR42-like aircraft with expected 2030 improvements.

The aircraft were divided into five main design modules:

1. Airframe
2. Propulsion
3. Electrical systems
4. Power systems
5. Cabin

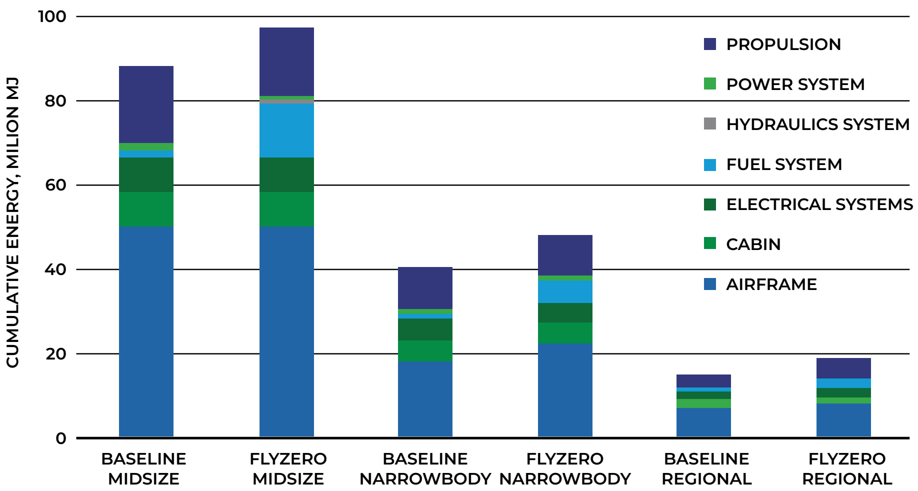


Figure 1. Energy use for materials, manufacturing, maintenance, and repair by module

FlyZero used the materials data library in Ansys Granta MI and Ansys Granta Selector to establish reference data for the materials and manufacturing processes. This compares technical, cost, and sustainability information — supported by a streamlined life cycle analysis (LCA) tool and methodology (Eco Audit in Granta) — and tools for screening restricted substances and social impacts. The Ansys software suite addresses materials information management for technical and sustainability information, with integration to engineering design processes:

1. Coordination of the bill of materials (BoM) using Granta MI
2. Assignment of reference data from MaterialUniverse
3. Screening for restricted substances
4. Calculation of the environmental impact for each line in the BoM
5. Screening for social impacts
6. Screening for environmental hot spots across the product life cycle
7. Substituting material and manufacturing choices to improve the sustainability of the product (e.g., risk, environmental, social impacts) against technical design decisions
8. Reporting to stakeholders

Figure 2 indicates where in the product development workflow the Ansys toolset can intervene early for sustainability assessment and trade-off decisions.

The FlyZero team determined the highest material environmental impact was carbon fiber-reinforced plastic (CFRP) used for the airframes of all aircraft. CFRP can replace steel and aluminum thanks to its high strength-to-weight ratio, which greatly improves fuel savings — CFRP density can be half that of aluminum and four times lower than steel.

However, the materials and manufacturing process of CFRP — and its low recyclability — should be re-evaluated against lower CO_2 propulsion options. Bio-based carbon and recycling technology may present an opportunity for lower environmental impact, but it faces other challenges, such as low fire resistance and strength, and is currently still on the pathway to scalability.

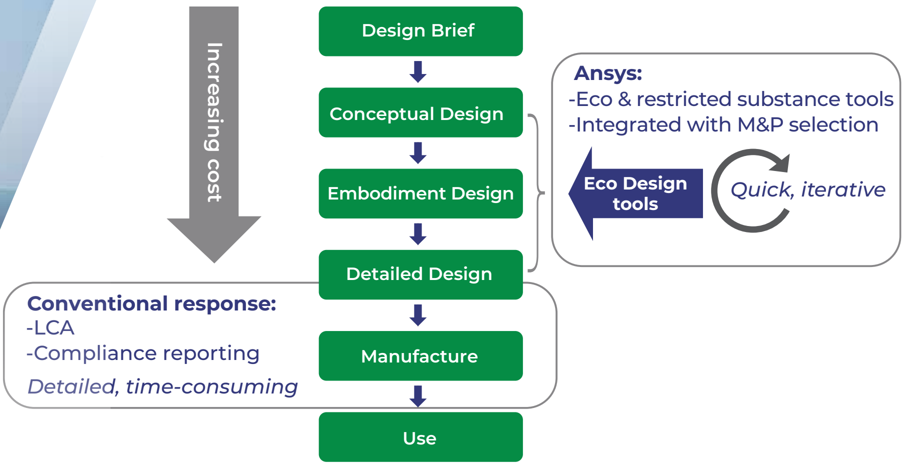


Figure 2. Ansys' approach to eco design implementation of tools and data for streamlined life cycle analysis (LCA) in the early stages of engineering design processes

Screening for restricted substances also indicated that plastics — including epoxy — contained some of the highest risks, followed by nickel-based materials. In terms of social performance, the list of elements with highest impact deviated from the lists of substances and materials highlighted as risks for the environmental and restricted substances lists, and instead identified elements having either price volatility due to geopolitical sourcing issues and/or scarcity.

Figure 3 identifies high-level stages of the design process and indicates the integration of Ansys materials software tools and data to enable quick screening of materials and manufacturing for effective eco design, with insight on end-of-life options. The concept design phase is a critical moment in the life of a product as this is the point at which materials, manufacturing, use phase design, and end-of-life decisions are essentially decided and up to 80% of life cycle impacts and costs are locked in. However, it is also the design phase with the most options (materials, processes, geometry, etc.), yet has the least amount of detailed information available due to supplier confidentiality and/or lack of primary measurements.

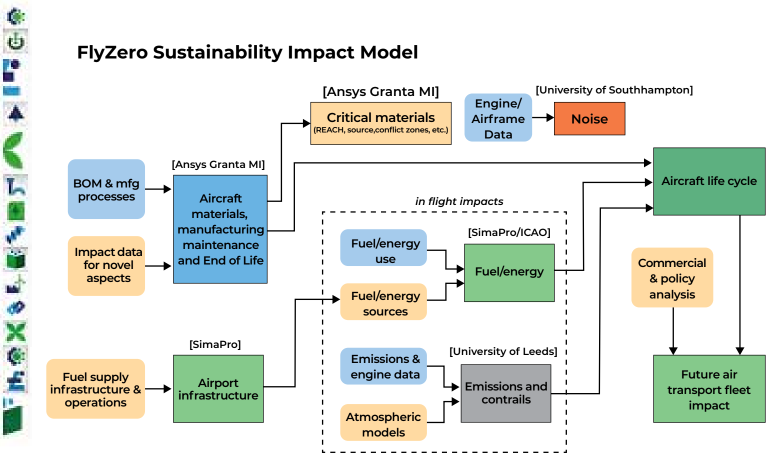


Figure 3. Sustainability impact model outlined by FlyZero indicating life cycle scope and tools applied

This work informed the FlyZero team of the environmental impact of the aircraft quantitatively (global warming potential, embodied energy) and qualitatively by identifying hazardous/restricted materials, security of supply or unethical sourcing, recyclability, etc. The results of this work will inform decisions for future research and development challenges, such as the need for material or manufacturing process substitution.

References

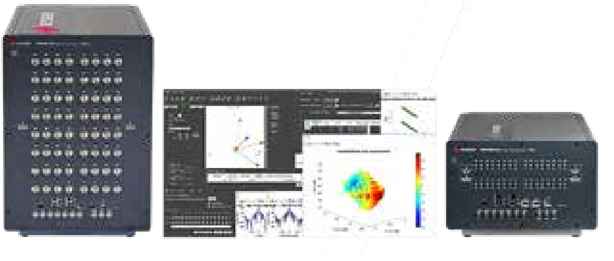
1. ACARE Goals, https://www.acare4europe.org/acare-goals/
2. "Our Commitment to Fly Net Zero by 2050," IATA , https://www.iata.org/en/programs/environment/flynetzero/

Charting and Validating the Course Ahead with Keysight and Digital Mission Engineering

By **Maura Callahan**, Senior Product Marketing Manager, Ansys

What if you could monitor, predict, and plan for the unseen in space or on Earth? Think of an airport — as flights prepare for takeoff, a number of planes approach the area to land. Airport traffic management is well-versed in these types of situations, but traffic bottlenecks go beyond the physicality of planes vying for runway space. There are invisible networks, signals, and frequencies emanating from these planes that cause interference with each other. Even the most advanced traffic controller might be unable to predict such variables or potential interference.

This is just one example of how Ansys and Keysight Technologies, a leading manufacturer of electronic test and measurement equipment, are helping customers see the unseeable to chart and validate the best course of action on the ground, in the air, and beyond. By pairing Keysight's hardware and software validation solutions with the Ansys Systems Tool Kit (STK) digital mission engineering platform, engineers and designers can ensure success in even the most complex missions.



Keysight's PROPSIM channel emulators bring hardware-in-the-loop (HIL) to the testing routine. These emulators can be integrated with the Ansys STK digital mission engineering platform.

> ***"By using Keysight and Ansys tools together, you can compare measurement results with simulation results throughout the product life cycle, from design through validation and even actual operations — making a determination if the models need to be improved or if there's something wrong in the hardware. It becomes a virtuous cycle as you go through iterations of a design."***
>
> — **PHIL LORCH,** *Director of the Space and Satellite Test Solutions business unit, Keysight Technologies*

CLOSING THE LOOP WITH SIMULATED DATA

Keysight provides solutions for a range of industries, including aerospace and defense (A&D), telecommunications, consumer electronics, automotive, and industrial equipment — influencing many devices and systems that impact our daily lives. For example, your cell phone may have been designed and tested using Keysight's verification tools, or your favorite internet service provider may have undergone rigorous cyber testing from Keysight to ensure its security and improve loading time.

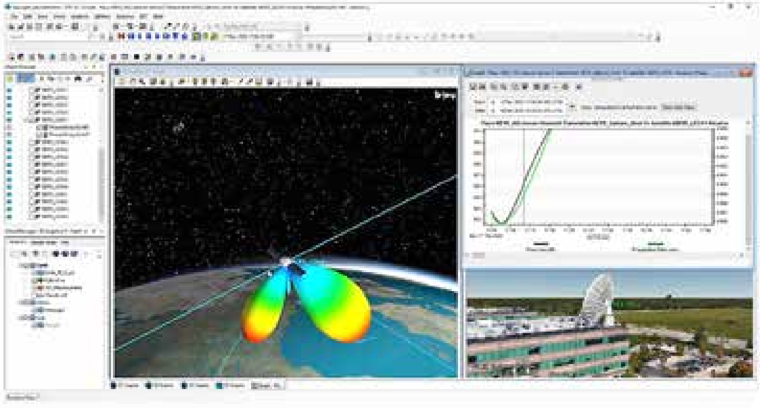
These hardware-in-the-loop (HIL) and software-in-the-loop (SIL) solutions serve as an important bridge between simulation and real-life products. However, in certain scenarios, static simulations can only forecast so much, even with the best design validation tools. Radio frequency (RF) signals, for example — like all electromagnetic (EM) phenomena — are active, ever-changing, and in motion.

By integrating STK, designers and engineers achieve enhanced understanding of system performance and can explore design alternatives across dynamic platforms in STK's high-fidelity, system-of-systems ecosystem.

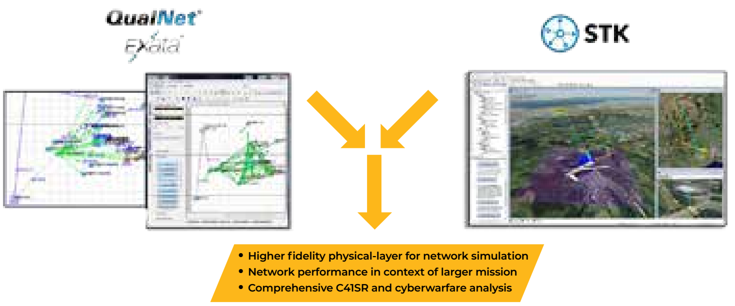
"A trend we've seen lately is performing more comprehensive simulations of systems during early conceptualization phases," says Phil Lorch, Director of the Space and Satellite Test Solutions business unit at Keysight Technologies. "The value of pairing Keysight and Ansys technologies is helping our customers accelerate through the stages of the product life cycle in a more streamlined way, from the earliest engineering using the STK platform for simulation through detailed design development and building the prototype with RF and network design simulation, and then with hardware validation and HIL testing."

Time-dynamic 4D system-level simulation is one of STK's greatest assets. With STK, you can model complex systems inside a realistic simulation that includes high-resolution terrain, imagery, RF environments, and more. Further, you can select, build, and import precise models of ground, sea, air, and space assets and combine them to represent existing or proposed systems. Similarly, you can simulate the entire system of systems in action, at any location, and at any time, to gain a better understanding of system behavior and mission performance. In addition to saving time and costs, there is also a greater success rate for the first run of demonstration missions and initial integrations of different subsystem components.

"By using Keysight and Ansys tools together, you can compare measurement results with



Simulation shown in Ansys STK integrated with Keysight's PathWave System Design (formerly SystemVue) software, which offers component level design approaches for engineers to create digital representations of their anticipated radio frequency (RF) systems. This simulation illustrates an uplink-downlink situation utilizing a specified communications system and a phased array antenna design.



Keysight's QualNet and EXata network simulators enable designers to model the full network stack and understand how data would be delivered through a network of connected devices with multiple routes, priorities, and dynamically changing links. The QualNet/EXata-Ansys STK integration offers better prediction of performance such as latency and packet loss in operational environments by establishing highly realistic mission scenarios and improved levels of fidelity in the analyses of mobile communications.

simulation results throughout the product life cycle, from design through validation and even actual operations — making a determination if the models need to be improved or if there's something wrong in the hardware. It becomes a virtuous cycle as you go through iterations of a design," says Lorch. "The value here is helping customers get through the loop a lot quicker and get their products and systems to their customers faster and in a much more reliable way."

Another incentive for joint solutions is the A&D industry's push toward digital transformation. Several governmental branches funded by the Department of Defense (DOD) — such as the U.S. Air Force and U.S. Space Force — are starting to mandate more thorough designs simulated using digital twin technology before accepting proposals or bids from system vendors.

"By linking our products together more seamlessly, we can help our customers meet governmental requirements for digital twins and accurate digital simulations with a high degree of reliability," adds Lorch.

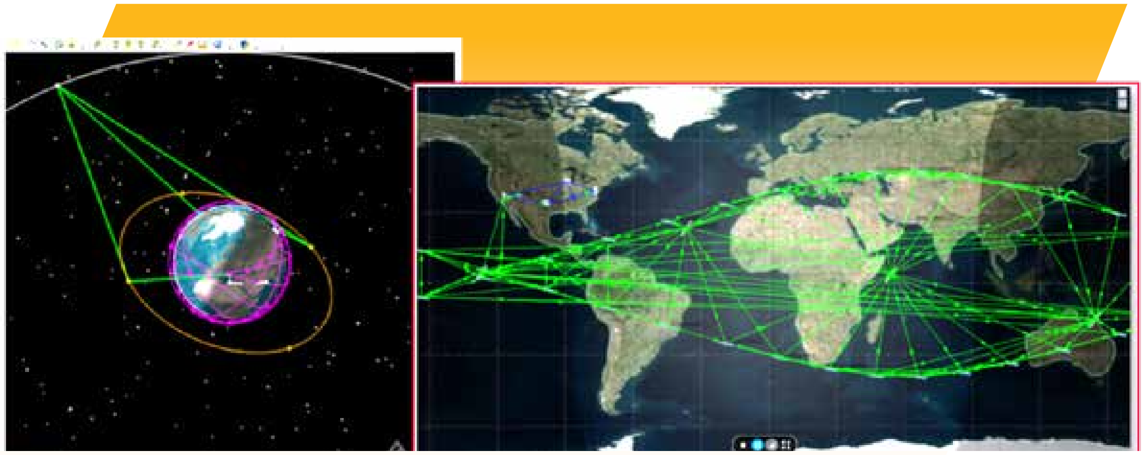
The ensured reliability is supported by Keysight's renowned validation technologies, including three that are currently integrated with Ansys software:

• PathWave System Design (formerly known as SystemVue)
• PROPSIM channel emulators
•Network simulators such as QualNet and EXata, which are products they've adopted through their acquisition of Scalable Network Technologies

PathWave System Design is an RF-system-simulator that incorporates detailed and regularly updated libraries of RF and microwave behavioral models used in communication systems. This enables RF system engineers to virtually prototype and simulate their phased array antennas, and RF front-end and back-end architectures with very high fidelity before committing to hardware realization.

As demonstrated in the airport example earlier, using network simulators like QualNet or EXata in tandem with STK enables designers to simulate communication networks with a high degree of fidelity. These insightful joint workflows enable users to detect unseen interference and network traffic issues in scenarios with numerous simultaneous radio signals.

Still, whether the mission is in its early stages or final stages, terrestrial or non-terrestrial, the Keysight-STK integrations provide insight in



These images illustrate the same scenario visualization in STK (left) and Keysight EXata (right).

These images show Ansys STK modeling a ground-based network of cellular towers and repeaters with vehicles traveling within the designed environment to analyze connectivity, signal strength, and other metrics. Through a co-simulation with Keysight's QualNet and EXata network simulators, the STK simulation can be used to analyze the performance of the entire network.

real time to improve performance and success, from the smallest details to full system analyses.

"The connection with Keysight is critical in getting users like system designers to the milestone portions of the product life cycle faster," says Nate McBee, a senior manager of product management in digital mission engineering at Ansys. "It gives them an opportunity to go back and revisit their designs without having to rip apart design scaffolding or use piecemeal integrations. "

A WEALTH OF APPLICATIONS FOR DIGITAL MISSION ENGINEERING

The potential for Keysight-STK integration is nearly limitless and extends beyond A&D with a wide scope of applications, many of which affect our daily lives — such as inflight Wi-Fi, transit system communications, cell phone reception, and satellite radio.

"Digital mission engineering brings in the dynamics. A lot of designs are static, saying, 'Here are the requirements, go design and build this thing and you're done,'" says Lorch. "But it doesn't take into account the dynamics — what are the changing environmental conditions that are the result of a mission profile? And it doesn't have to be a military mission; it could be a task or challenge, like 'I need to make sure I have a communication link that's going to work for this ship from point A to point B and I don't know if there will be cell towers along the way.'"

According to Lorch, digital mission engineering strengthens the concept of the mission from the start with the ability to account for the time variance of parameters, which improves design accuracy and product performance.

This can be demonstrated with the example of a satellite. While simulating a satellite in STK as it moves toward a ground station, Keysight test equipment can apply a Doppler shift to the signal as it crosses overhead and illuminate this with a spectrum analyzer. This collaboration provides insight that enables a more accurate simulation of an orbiting satellite in motion, including the shifting parameters of radio links between the satellite and ground station in real time.

The technology pairing can also help when disaster strikes. When the volcano erupted at Hunga Tonga-Hunga Ha'apai Island earlier this year, it severed undersea internet cables, obliterating communication with the outside world. It was satellite communications that allowed recovery teams to regain connectivity.

"Having a network that is robust, that's been modeled very well, and can handle massive increases in traffic is really important and practical from a saving-human-lives standpoint, and getting first responders and help to areas before ground networks have been reestablished," says Lorch. "Through the Keysight-Ansys integrations, we can help ensure these robust, reliable, and critical systems work under normal as well as extreme conditions."

BUILT ON A STRONG FOUNDATION

The Keysight and Ansys relationship goes back more than a decade, beginning with Keysight and AGI, which was acquired by Ansys in 2020.

"For well over 10 years we've had some level of demonstrable scripting or integrations, and the recognition was, we've got a lot of joint customers and these tools are commonly used together, so there should be a more elegant integration between them that benefits all sides," says McBee.

Today Ansys and Keysight's streamlined and interoperable workflows combine industry-leading tools that enable engineers to accelerate the product life cycle, garner critical insights to improve decision-making, significantly reduce human error, and produce higher-fidelity designs.

SIMULATION Puts Planes in the Air Faster

Ansys Advantage Staff

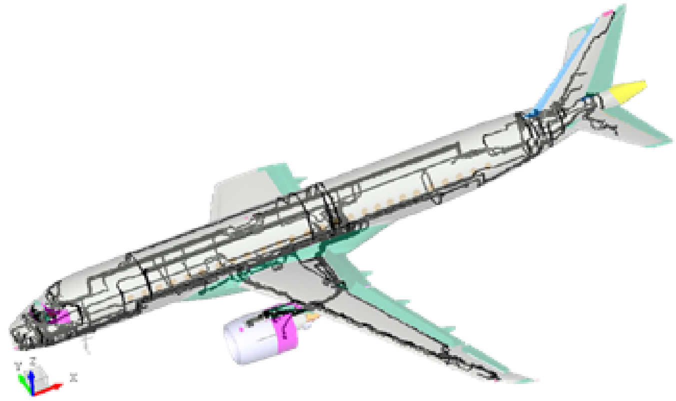
Lightning strikes, or "attaches to," airplanes much more frequently than passengers realize. That such strikes go largely unnoticed is due to meticulous engineering and testing before the aircraft ever leaves the ground. But physically testing an entire airplane prototype to ensure operational safety when lightning strikes is expensive and time-consuming. Brazilian aircraft manufacturer Embraer has turned to simulation to deliver a safe plane faster and at lower cost.

"Hey, let's go zap an airplane with an artificial bolt of lightning and see what happens."

While that sounds like one of those statements no one ever said, the opposite, in fact, is true. Airplane manufacturers have for years been subjecting prototypes of their planes to the electrical transient equivalent of a bolt of lightning just to see what will happen to the electrical equipment.

Ideally, nothing will happen. And that's good, because airplanes are struck by real lightning more frequently than you might think. By one estimate, every plane in the U.S. commercial fleet is struck by lightning more than once a year.[1] Because the plane is well engineered, none of its electronics will be affected by a pulse of high energy surging through the miles of cables in the plane. No fires will erupt due to current arcing at cable connection points. No one in the plane will be injured, killed, or even shocked by this event.

However, using an airplane prototype to validate its ability to survive a lightning attachment is costly, and the tests can take weeks to complete, even when all the testing proceeds without hiccups. Parked in a hangar and festooned from nose to tail with electromagnetic sensors, the prototype is effectively frozen in place for as long as it takes to complete the tests. Other scheduled tests simply need to wait until the lightning certification tests are complete. If the certification tests reveal issues — that critical electronics systems could be damaged or that lightning attaching to the wing could spark a fuel tank explosion — then the company might



Transport category aircraft CEM model developed for lightning ATL simulations. Exterior surfaces are shaded to show interior cable routing.

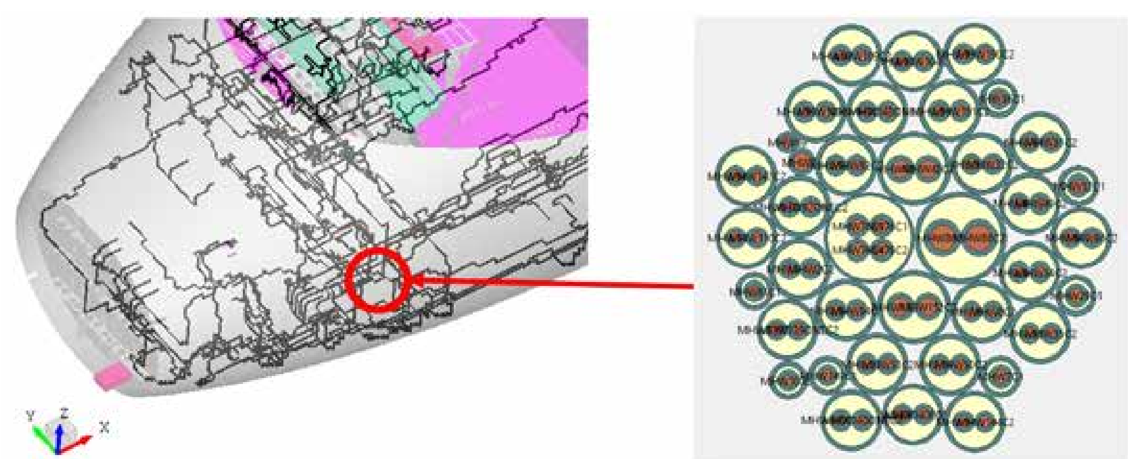
be looking at product corrections and redesigns that could be very expensive, and weeks or months of development time may be lost.

For all these reasons, the Brazilian airplane manufacturer Embraer strives to conduct as much of its indirect effects of lightning certification testing as it can via simulation. Using Ansys EMC Plus (formerly Ansys EMA3D Cable), Embraer's product development engineers can perform all the critical tests *in silico* — along with additional "what-if" tests — that would be required to verify an airplane for lightning certification. In doing so, the company is able to bring a plane to market faster and at a notably lower cost.

TESTING THE PLANE BEFORE THE PLANE EXISTS

Embraer is the third largest manufacturer of commercial jets in the world, producing more than 8,000 planes in the last 50 years. Known for its innovation and solid engineering, it's no surprise that Embraer has embraced

ANSYS EMC PLUS ROUTING | **MHARNESS CABLE PACKING**



Cable packing example configuration for forward electronics bay harness

"We have to make a certain number of assumptions when we're running simulations, but we have to make a lot of assumptions when we're conducting physical tests as well."

— **RODRIGO FREIRE,** product development engineer, Embraer

simulation. EMC Plus provides Embraer's engineers with a dedicated, platform-level electromagnetic cable modeling simulation tool that specializes in analyzing lightning-induced electromagnetic (EM) effects as well as cable EMI/EMC problems to support EMC certification.

"We use Ansys EMC Plus to calculate the induction levels in the cables during a lightning attachment," explains Rodrigo Freire, a product development engineer at Embraer. "To get certification to deliver a new aircraft, we need to show that the induction levels appearing at the interface of each device are within acceptable limits during a lightning attachment."

If the end goal of simulation sounds like the end goal of physical testing, you're right. Both approaches need to demonstrate that a lightning attachment won't cause malfunctions of the electronics or the structure of the plane. The difference is that the team at Embraer doesn't even need the physical plane to start analyzing whether those induction levels will be within acceptable limits.

In fact, Embraer has found it better for the entire development process if simulation takes place before a prototype is built. That way, if simulation uncovers concerns, the plane's designers can address them before the plane is constructed and such modifications become much more complicated.

"Late in the design stages, it would be very difficult to move a cable harness or use a different component," adds José Mariano, another product design engineer at Embraer. "Those are just not situations we would like to face at that point."

THE CHALLENGE OF TESTING BIG MODELS

The challenge when simulating a lightning strike and its effects is that one ultimately does need to look at the entire airplane structure, and that's not something all simulation tools can do easily or reliably. A bolt of lightning might attach to a plane's extremities, coursing through all the cabling and conductive material between the two attaching points in fractions of a second. EMC Plus provides Embraer with the ability to work with both the smallest and the largest models required. It enables engineers to import cable and harness information from tools like Zuken and Capital Harness; it integrates that data with CAD drawings of airframes and printed circuit boards (PCBs) from Ansys Mechanical. Engineers can then run simulations involving everything from the effect of a lightning attachment on specific interfaces or specific materials to the effect of that attachment on the entire plane.

During physical testing, electrical discharges are created in a structure enveloping the aircraft. Induced current passing through a critical component's harness is measured to evaluate the effects of lightning strikes. *Image courtesy of Embraer.*

Some of the simulations run in just a few hours; others run to completion over the course of several days. Indeed, because it can conduct so many more tests in a relatively short period of time, Embraer gains insights faster than might normally happen if the only option were physical tests.

"We may be running several simulations on just one or two designs just to see how design tweaks affect performance," notes Mariano. If Embraer relied exclusively on physical tests of a component's response to lightning, it would become difficult to explore such design optimizations in the same way, as it takes more time and money to build, test, rebuild, and retest a physical model. Simulation enables Embraer to perform such comparative testing early in the design cycle, which enables the engineers to work more efficiently than they could otherwise.

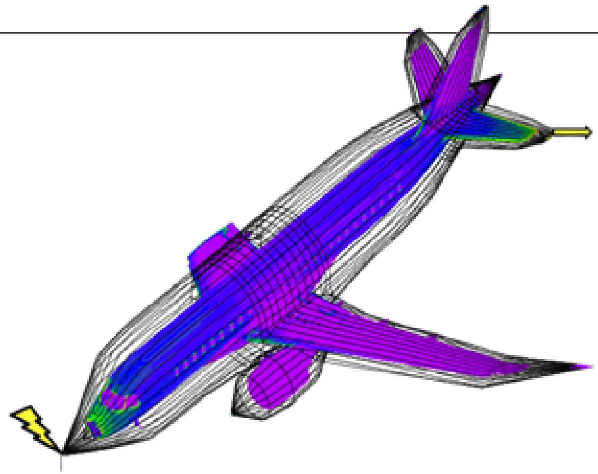
Some estimates attribute using simulation to support complete EMC and EMI certification to cost savings in the millions of dollars.

THE PHYSICAL VALIDATES THE SIMULATED

Physical tests still play a role in lightning certification at Embraer, but not the same role they used to. Today, smaller scale physical tests can be run as a point of reference against which the simulation results can be compared. Embraer has been able to show a high correlation between its simulated outcomes and those captured in the physical baseline tests, which inspires a high confidence level that other simulation results would match the results of physical tests that were run.[2]

"We have to make a certain number of assumptions when we're running simulations," says Freire, "but we have to make a lot of assumptions when we're conducting physical tests as well. Test results do not always match the exact conditions that were anticipated for a plane experiencing a given lightning strike, but over time we've developed a pretty good idea of what to expect. Our simulations use the same standardized lightning characteristics — for example, amplitude and time-to-rise — that are important when it comes to analyzing and accurately anticipating the effects on electronic equipment.

"We have to show that the aircraft will still perform under the extreme electromagnetic conditions to which nature can subject an aircraft," Freire continues. "As long as the simulations can capture the lightning transients



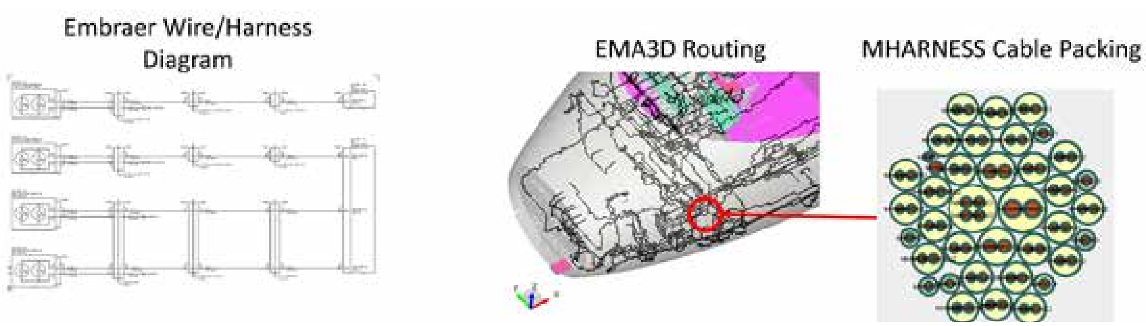
Visualization of the surface current distribution computed by Ansys EMC Plus, showing the point of lightning attachment at the nose of the plane and its exit from the tail.

as well as the physical tests would, and as long as the equipment shows that it can withstand those levels, then we're going to meet the standards that are required for certification."

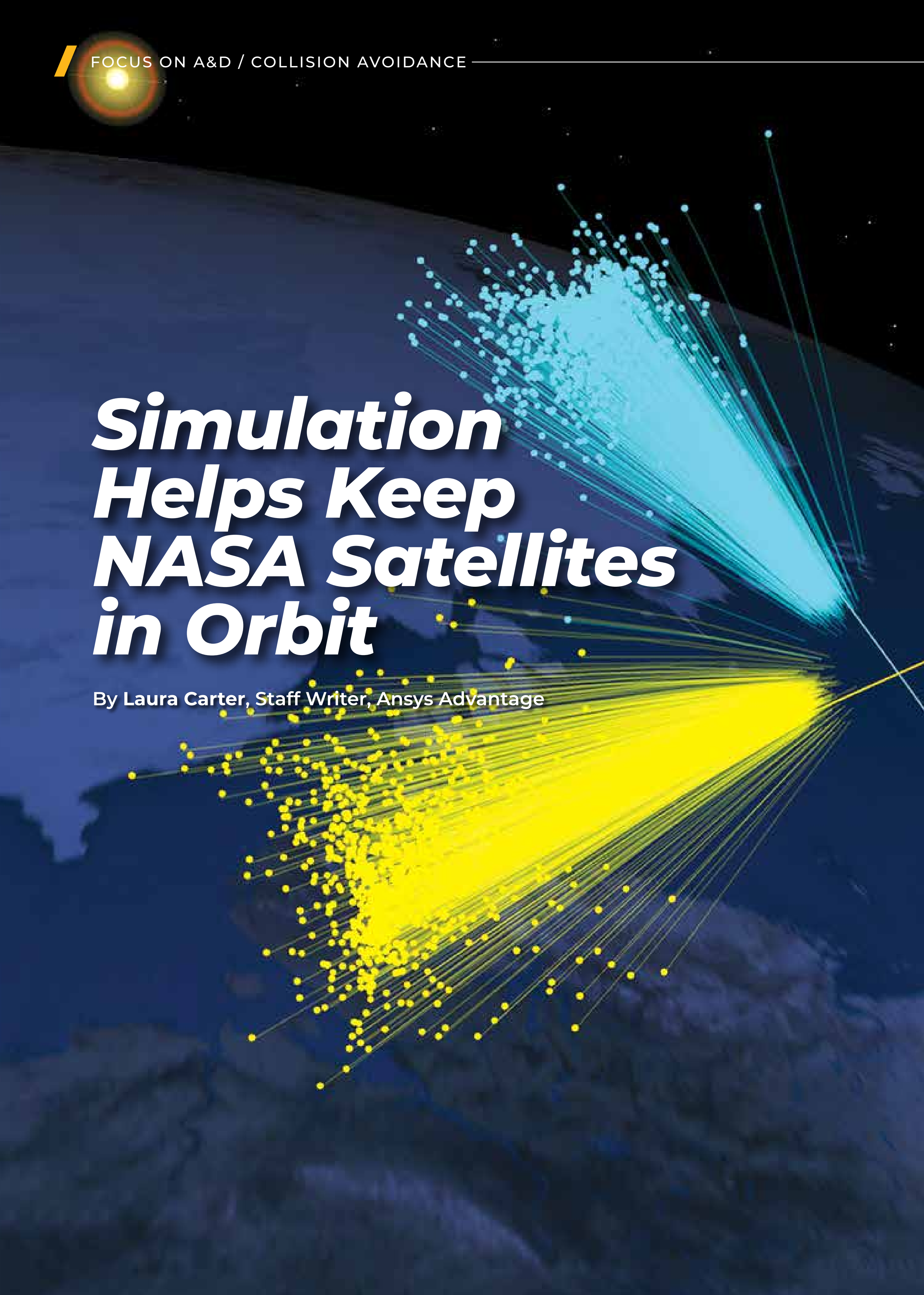
In the end, Embraer's use of simulation to achieve EMI and EMC certification may be proving the same thing that physical tests have always proven, that its planes are safe and well-engineered, that cargo and passengers will be safe, and that lightning attachments won't cause problems when — not if — they occur. But Embraer's use of EMC Plus is also proving something else: that simulation can dramatically reduce the time and cost of bringing a new, high-quality plane to market, and that is a benefit that has airplane manufacturers around the world sitting up and taking notice.

References

1. Scientific American. "What happens when lightning strikes an airplane?," https://www.scientificamerican.com/article/what-happens-when-lightni/
2. International Conference on Lightning and Static Electricity. "Validation of Numerical Simulation Approach for Lightning Transient Analysis of a Transport Category Aircraft," Weber, C., Mariano, J.A., Freire, R.C.C, Durso-Sabina E, - 2019.



Wire/harness diagrams used to create cable packing in MHARNESS

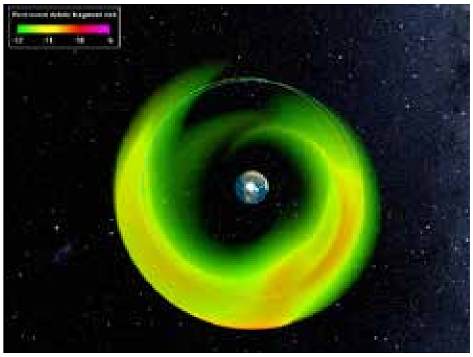


Simulation Helps Keep NASA Satellites in Orbit

By Laura Carter, Staff Writer, Ansys Advantage

Right now, there are thousands of satellites orbiting Earth, and several orbiting the Moon. We need them for weather monitoring, GPS navigation, the internet, and for space-based surveillance critical to national security, among other things. Like too many cars on a congested freeway, satellites are crowding into the same space — but they're traveling at thousands of miles per hour.

To make matters worse, all this activity is happening with few formal standards or controls in place. As the number of satellites in orbit continues to grow, any collision event only compounds matters by creating debris for other spacecraft to avoid.

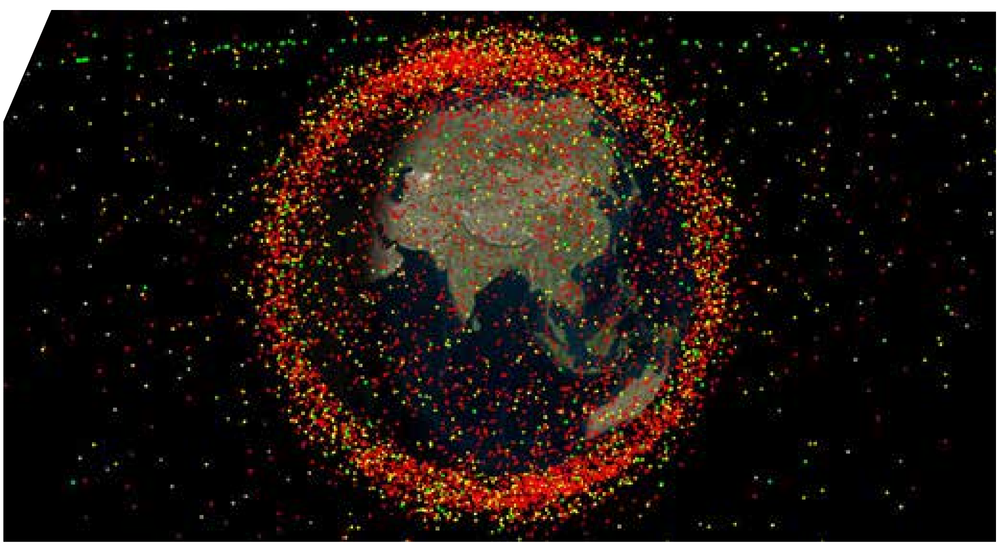


CAM GEO-Post-Collision-Debris

To address these risks, efforts are underway to publish standards and behavioral norms to follow when sending a satellite into orbit. For instance, NASA has published the "NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook." Similarly, the United States Space Command (USSPACECOM) published a "Spaceflight Safety Handbook for Operators," which details processes for on-orbit conjunction assessment and collision avoidance. In addition, the Federal Aviation Administration (FAA) and the Federal Communications Commission (FCC) review operators' collision avoidance plans before granting launch and operating licenses.

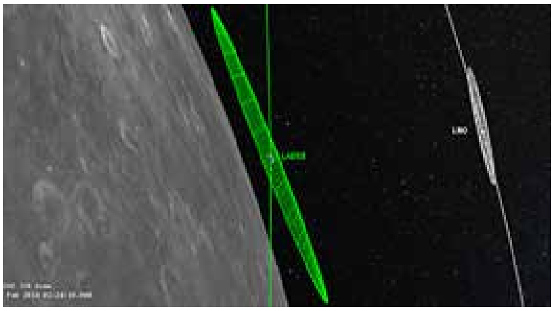
Spacecraft operators are also promoting safe operations protocols — and in fact, Ansys is one of many companies that endorsed the Space Safety Coalition's "Best Practices for the Sustainability of Space Operations." The aim of this publication is to create industry standards and improve collaboration around the world to mitigate the growing space debris problem. Still, many satellite operators have questions about how to respond to these recommendations.

"The tricky part is how do you implement these safe and sustainable best practices," says John Carrico, owner and CTO of Space Exploration Engineering (SEE), which has designed, planned, and operated a number of satellite missions.



An Ansys Systems Tool Kit (STK) simulation of the thousands of satellites and debris pieces floating in orbit around Earth

"We know that each satellite operator has the goal of making sure their spacecraft can accomplish its mission. The fortunate thing is that when the satellite operations team performs their job in a non-negligent way, it not only keeps their mission safe, but it also prevents harm and interference with other spacecraft. While it's easy to say we want to perform operations in a sustainable way, it actually requires carefully planned activities that rely on precise calculations, and Ansys software has been specifically designed to enable this."



Ansys Systems Tool Kit (STK) image of the orbit geometry of the NASA LADEE, provided by Ansys Orbital Determination Tool Kit (ODTK), and LRO spacecraft near their closest approach on February 27, 2014

SIMULATION YIELDS SAFER PASSING DISTANCES FOR NASA SATELLITES

In February 2014, Carrico, as part of the flight dynamics team for the NASA Lunar Atmosphere and Dust Environment Explorer (LADEE) satellite, was at NASA's Ames Research Center doing orbit determination and planning maneuvers. An important element of Carrico's job was using Ansys Systems Tool Kit (STK) and Ansys Orbit Determination Tool Kit (ODTK) to analyze the trajectories of satellites in space, then planning a collision avoidance maneuver (CAM) to prevent them from making unwanted contact with other satellites or space debris.

Originally there was an orbit maintenance maneuver scheduled for LADEE later that month. After the team shared the satellite's anticipated trajectory based on an exchange of predicted ephemeris files (tables of astronomical positions of spacecraft trajectories at a particular time), it appeared that LADEE and another spacecraft — the Lunar Reconnaissance Orbiter (LRO) — were going to come too close for comfort. The inherent uncertainty in the predicted orbits made the probability of collision too risky to ignore.

At the time, both satellites were orbiting the Moon. The job of the LRO[1] was to map the Moon's surface, enabling discoveries about the origin and evolution of Earth and the solar system, while LADEE[2] gathered information about the structure and composition of the lunar atmosphere. It was important scientific work. A collision would have brought these efforts to a permanent halt, costing NASA two satellites worth hundreds of millions of dollars and adding more debris for other satellites to avoid. Relying on the predictions from STK and ODTK, the LADEE and LRO teams came together and decided to cancel an originally scheduled collision avoidance maneuver, thereby enabling the spacecraft to pass each other at a safe distance.

Scenarios like this aren't "one-and-done" situations by any means. Commercial and federal spacecraft operators maintain dedicated teams that receive continual updates on the position of satellites relative to each other and any detectable space debris as they orbit Earth or the Moon, to avoid the possibility of collision.

Every satellite will most likely encounter other satellites or debris multiple times over the course of its travels. Sometimes the best course of action is no action, while other

DID YOU KNOW?

In addition to supporting NASA and other organizations in their launch efforts, Ansys also works with companies that are using simulation to remove objects from orbit. These companies are exploring ideas for devices like satellite nets, robotic arms, and magnetic grappling hooks — there are even sponge-like materials being designed to reduce the speed of shrapnel and trap it to mitigate the risk of collision with a spacecraft.

REFERENCES:

1. Lunar Reconnaissance Orbiter (nasa.gov)
2. LADEE - Lunar Atmosphere Dust and Environment Explorer | NASA
3. Explained: How India's Lunar Orbiter Chandrayaan-2 avoided Collision with NASA's LRO, WION, updated June 1, 2022.

"During a collision, the hypervelocity impact and shock waves can rip an entire structure apart. One satellite mission could create dozens of orbital objects including satellites, payload fairings, and spent rocket stages ..."

times, mitigation requires a maneuver. These maneuvers must be planned well in advance — anywhere from a few hours to a week — based on predictions using simulation.

PLOTTING A DIFFERENT COURSE

When satellites from different agencies are involved, simulation can help fill in the gaps left by a lack of international standards. For example, the Indian Space Research Organization (ISRO), like NASA, has launched a series of spacecraft, including the Chandrayaan-2. The Chandrayaan-2 consisted of a lunar orbiter and a lunar rover, and its objective was to study lunar surface composition and the abundance of water on the Moon. It just so happened that NASA's LRO shared a similar mission.

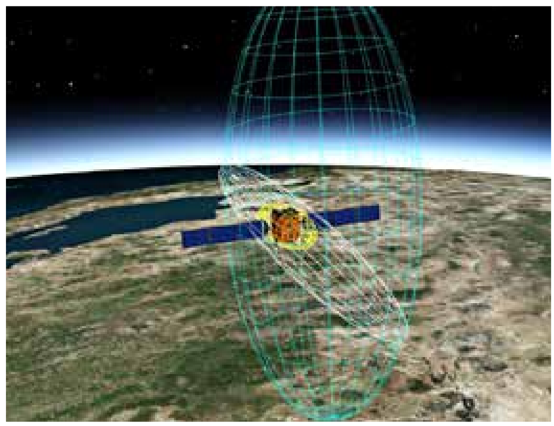
In October 2021, both spacecraft were scheduled to come very close to each other as they were both studying the Moon from a polar orbit. Using STK, the team determined that the spacecraft would be less than 100 meters apart. With support from Ansys software and a mutual agreement with NASA, ISRO executed a CAM based on this information, and it added calculations based on a new orbit that would help both satellites avoid close passes like this in the future.[3]

"In the case of the Chandrayaan-2 orbiter and the LRO, most of the international data available could not necessarily capture the information needed to plot these maneuvers successfully," says Ravnish Luthra, CEO of ITGlobe, an Ansys partner supporting ISRO. "Simulation provided the truest picture of what was happening around the Chandrayaan-2, enabling ISRO to execute a precise CAM and plot a different course for the future."

While the travels of the LRO may not be governed by a definitive set of codified rules, they are supported by a dedicated team of scientists, engineers, and other experts using simulation to make predictions about the trajectory of satellites in space. For them, Ansys simulation delivers real-time, accurate data with near-perfect precision that leads to more positive outcomes.

MAKING A POSITIVE IMPACT ON SATELLITE COLLISION AVOIDANCE

With so many governments and commercial organizations relying on satellites, we need to contend with the challenges of congestion that could eventually impede our efforts to look beyond Earth's atmosphere. The result of satellite collisions — the tremendous amount of debris they leave behind — has the potential to create even greater congestion, which could lead to even more collisions.



Iridium 33 - Cosmos 2251 satellite collision debris field reconstructed from measured data using Ansys Systems Tool Kit (STK)

"During a collision, the hypervelocity impact and shock waves can rip an entire structure apart," says Adam Gorski, Enterprise Account Manager, Aerospace and Defense Sales at Ansys. "One satellite mission could create dozens of orbital objects including satellites, payload fairings, and spent rocket stages. Then there have been collisions where one satellite became thousands of pieces of trackable, potentially catastrophic debris."

While there may not be any universally accepted rules in space now, commercial and federal space operators are working toward establishing clear standards and governance for the space domain. Through collaborative data and models, simulation is helping to build an essential bridge to make space safer for now. And, once those rules are in place, simulation will be essential to complying with them.

To the Moon and Beyond

By Ansys Advantage Staff

A lot has changed since NASA last sent astronauts to the Moon in 1972, including the way new space exploration technologies are developed and deployed. Today, startup companies are leading the effort to prepare the Moon's surface for a human landing as part of NASA's Artemis program. A key factor in winning these prestigious NASA contracts is a focus on innovation, supported by best practices that include engineering simulation.

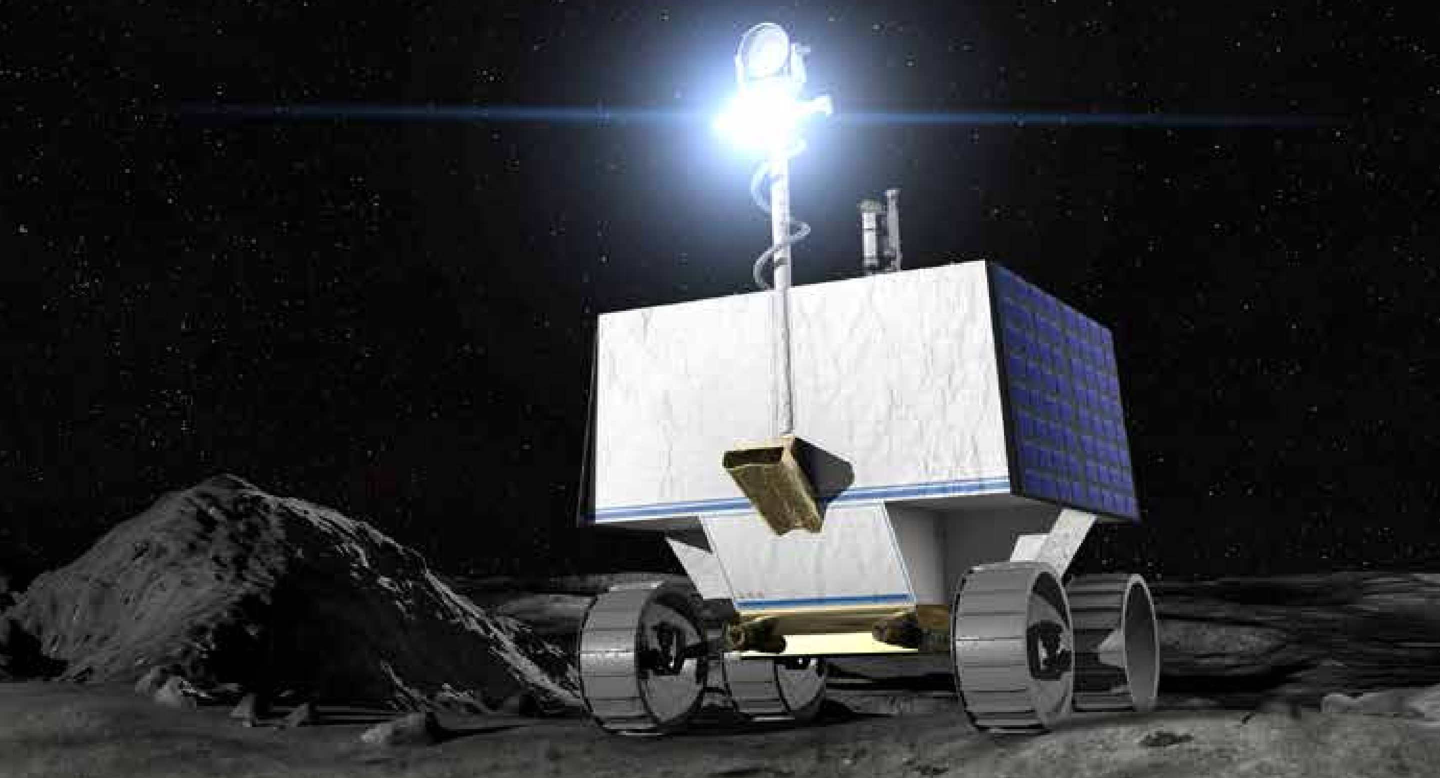


Illustration of NASA's Volatiles Investigating Polar Exploration Rover (VIPER) on the surface of the Moon. Ansys client Astrobotic Technology of Pittsburgh was awarded $199.5 million to deliver VIPER to the Moon's South Pole. Image credit: NASA Ames/Daniel Rutter

In November 2022, NASA made history when it launched its most powerful rocket ever produced, the Space Launch System (see page 38), which carried the unmanned Orion capsule into the Moon's orbit before it returned to Earth 25 days later. This groundbreaking event marked the first mission in the space agency's ambitious Artemis lunar-exploration program, which aims to land humans on the moon in 2025.

The Artemis program marks NASA's first journey to the Moon with humans aboard in over 50 years, and many things have changed since the final Apollo mission in 1972. Today, NASA is not developing all the required space technologies on its own, but is instead partnering with a range of private companies — from giants like SpaceX to smaller startups like Astrobotic Technology, Intuitive Machines, and Firefly Aerospace (all part of the Ansys Startup Program) among others — to source critical components and execute missions.

According to NASA's Johnson Space Center Director Vanessa Wyche, the concept of public-private collaboration is foundational to NASA's mission of innovation and discovery today. "This mission paves the way for the expansion of human deep space exploration and presents new opportunities for scientific discoveries, commercial, industry, and academic partnerships and the Artemis Generation," said Wyche in a press release.

SMALL COMPANIES FUEL NASA'S SUCCESS

Over the next two years, NASA will continue to send unmanned test flights to the Moon, as it demonstrates the capabilities of both the rocket and the space capsule to safely complete the nearly half-million-mile round trip. At the same time, NASA will also deliver supplies to the Moon's surface as it performs science experiments, tests new field technologies, identifies a landing position, and builds an Artemis Base Camp in preparation for human missions.

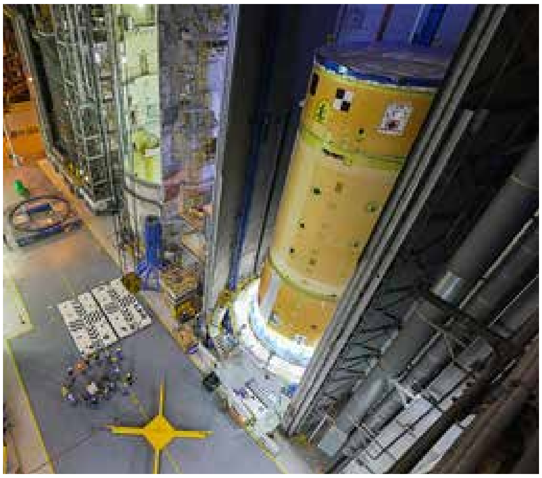
Private companies, including a number of Ansys customers, are playing a leading role in delivering these supplies to the Moon. Engineering simulation is a key component of these companies' efforts. It enables to meet mission requirements as they develop components faster and less expensively than they could the old way, by building and testing multiple prototypes.

"Engineering simulation is purpose-built to design and validate products in a low-risk, low-cost virtual environment where physical testing is time-consuming, expensive, or simply not possible," says James Woodburn, Ansys Fellow in digital mission engineering. "Obviously these companies can't run test flights to the Moon. So it only makes sense to apply simulation to develop and verify their spacecraft, launching systems, and landing systems in advance of those critical missions. With the entire world watching, Ansys simulation helps give them the confidence that their innovative designs will perform as expected in incredibly demanding conditions."

Through NASA's Commercial Lunar Payload Services (CLPS) initiative, more than $2.6 billion in contracts has been awarded to these partners through 2028. According to a statement by the space agency, NASA analyzed multiple factors as it reviewed funding proposals, including technical feasibility, price, and schedule.

After it screens vendors, assesses proposals, and awards funding, NASA provides minimal oversight beyond dictating the landing sites and specifying the payloads for delivery. In sharp contrast to the NASA missions of 50 years ago, these small companies are independently developing and deploying their own spacecraft, as well as designing launching and landing systems.

In announcing the first round of awards, Chris Culbert, CLPS program manager at NASA's Johnson Space Center in Houston, said, "NASA is committed to working with industry to enable the next round of lunar exploration. The companies we have selected



NASA's Space Launch System (SLS) team fully stacked three hardware elements together to form the top of the rocket's core stage for the Artemis II mission.
Image credit: NASA/Eric Bordelon

"Leveraging the suite of Ansys tools allows us to ensure a design works with limited test iterations, providing up to $5 million in cost savings in engine cooling design, $10 million in increasing engine thrust and up to $500,000 in mass optimizations."

— **Tom Markusic,** CEO, Firefly Aerospace

Firefly Aerospace's Blue Ghost lunar lander is slated to deliver 13 commercial and government payloads to the lunar surface in 2024. *Image credit: Firefly Aerospace.*

represent a diverse community of exciting small American companies, each with their own unique, innovative approach to getting to the Moon. We look forward to working with them to have our payloads delivered and opening the door for returning humans to the Moon."

ENABLING EXTREME INNOVATION WITH SIMULATION

Three of the startup companies awarded funding through the CLPS program are Ansys customers: Astrobotic Technology, Intuitive Machines, and Firefly Aerospace. According to Woodburn, that shouldn't come as a surprise.

"What's truly impressive about these three companies is their commitment to extreme innovation — and their use of advanced engineering practices like simulation to deliver that innovation," Woodburn says. "It's been gratifying to watch these small companies make incredibly ambitious plans and achieve them. Ansys is honored to play a part in their historic accomplishments."

Here are the details on the three Ansys customers receiving CLPS funding.

Astrobotic has been awarded $303.5 million to deliver 11 payloads to Lacus Mortis, a crater on the near side of the Moon, beginning later this year. In 2024, this Pittsburgh-based startup will deliver NASA's Volatiles Investigating Polar Exploration Rover, or VIPER, to the South Pole of the Moon to study the availability of water to support human exploration.

"We work through very rapid iteration and design changes to narrow in on a structure capable of withstanding the launch environment, the harsh vacuum of space and all its temperature differences, as well as the actual landing itself," said Lauren Whitehouse, Structural Analysis Engineer at Astrobotic. "Simulation is critical for understanding these environments, the

From left: Canadian Space Agency astronaut Jeremy Hansen, and NASA astronauts Victor Glover, Reid Wiseman, and Christina Koch greet the crowd at Ellington Field near NASA's Johnson Space Center on April 3, 2023. Image credit: NASA.

stresses, and the behaviors of the structures we are creating. Astrobotic's use of Ansys has been incredibly valuable and is essential to the mission."

Intuitive Machines, based in Houston, is using $201.5 million in CLPS funding to deliver five payloads to Mare Crisium, a low-lying basin on the Moon's near side, in 2023. The company will also deliver NASA's Polar Resources Ice Mining Experiment-1 (PRIME-1) ice-sampling system to the lunar South Pole later this year. In 2024, Intuitive Machines will make four trips to Reiner Gamma, a lunar swirl, to deliver the equipment needed to study this unique natural phenomenon and its impacts for human explorers. The company was initially able to access Ansys Mechanical, Ansys Fluent, and Ansys HFSS as part of the Ansys Startup Program, which provides promising young companies with affordable licensing to support their critical engineering innovations.

Firefly Aerospace is another graduate of the Ansys Startup Program. Based in Cedar Park, Texas, Firefly will use a $93.3 million CLPS award to deliver a suite of 10 technology demonstrations to Mare Crisium in 2024.

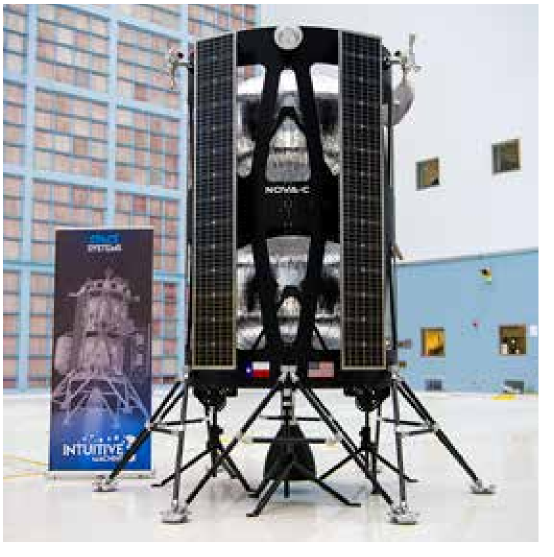
"At Firefly, our work is quite literally rocket science," said Tom Markusic, CEO of Firefly, in a press release. "It takes an enormous amount of simulation and modeling to design components that withstand the tremendous liftoff, flight, and space environments. Leveraging the suite of Ansys tools allows us to ensure a design works with limited test iterations, providing up to $5 million in cost savings in engine cooling design, $10 million in increasing engine thrust and up to $500,000 in mass optimizations."

Astrobotic and Firefly are also using Ansys digital mission engineering products, Systems Tool Kit (STK) and the Orbit Determination Tool Kit (ODTK), to design the mission trajectory and navigate their landers on their way to the moon. The use of STK and ODTK during the pre-launch phase allows CLPS providers to validate that their mission design is robust over the entire range of expected launch and spacecraft engine performance conditions. The significant portfolio of prior lunar missions flown operationally with STK and ODTK gives providers confidence in achieving a successful mission.

COLLABORATION FUELS A NEW LUNAR ECONOMY

While the primary focus of the CLPS program is on delivering payloads for NASA that prepare for the 2025 Artemis landing, the space agency also encourages awardees to carry commercial payloads.

For example, Astrobotic's first trip in 2023 will include 28 separate payloads — representing six countries, dozens of science teams, and hundreds of individuals. This approach is a far cry from the competitive "space race" of the 1960s and 1970s — more evidence of how much NASA has changed over the ensuing decades.



Intuitive Machines lunar lander at Goddard Space Flight Center.
Image credit: NASA/Aubrey Gemignani

"Demand for access to the Moon is rapidly increasing as our Artemis program takes shape, and we're proud to support a growing lunar economy with our CLPS project," said Thomas Zurbuchen via a NASA blog post. Zurbuchen is associate administrator for the Science Mission Directorate at NASA Headquarters in Washington.

NASA recently announced another historic milestone: The Artemis crew will include the first woman, first person of color, and the first Canadian to embark on a lunar mission.

"The Artemis II crew represents thousands of people working tirelessly to bring us to the stars. This is their crew, this is our crew, this is humanity's crew," said NASA Administrator Bill Nelson when announcing the crew in April. "Together, we are ushering in a new era of exploration for a new generation of star sailors and dreamers — the Artemis Generation."

Simulation Helps Artemis Keep in Touch and on Track to the Moon

By **Jamie J. Gooch**, Executive Editor, Ansys Advantage

In the 1820s Baron Franz von Paula Gruithusen, a German physicist and astronomer, turned his small telescope toward the Moon and saw what he imagined was a city there, which he named Wallwerk. “Imagination will often carry us to worlds that never were,” said the American scientist Carl Sagan more than 150 years later. “But without it we go nowhere.” And in 2022, the first Artemis Moon mission launched, paving the way for humankind to not only return to the Moon after a 50-year absence — but to live and work there.

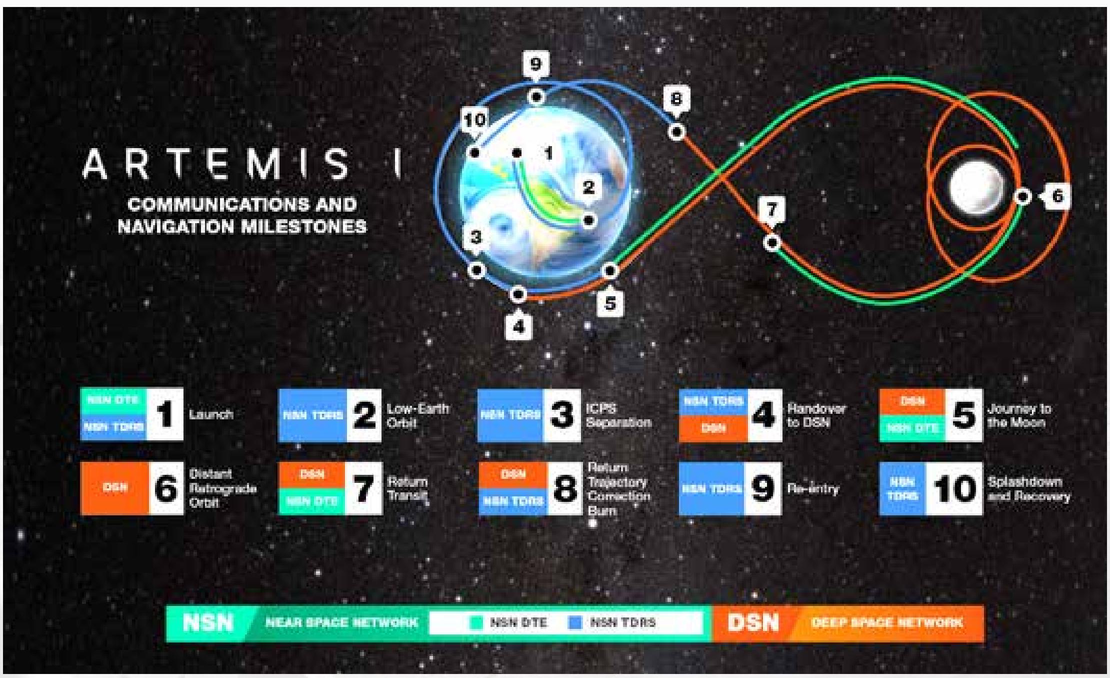
Artemis I is the first of three increasingly complex missions. The uncrewed mission is a test of NASA's deep space exploration systems, including the Orion spacecraft that will carry astronauts from Earth to lunar orbit and back, the Space Launch System (SLS) rocket — the most powerful rocket in the world — and ground systems needed to support the launch and recovery of the spacecraft after its 1.4-million-mile journey beyond the moon and back. Future missions are planned to land astronauts on the Moon, deploy a spaceship in lunar orbit to act as a long-term gateway to the Moon, and to build a base camp on the Moon. What is learned from the Artemis missions could be used to explore destinations farther from Earth, including Mars.

CONNECT AND COMMUNICATE

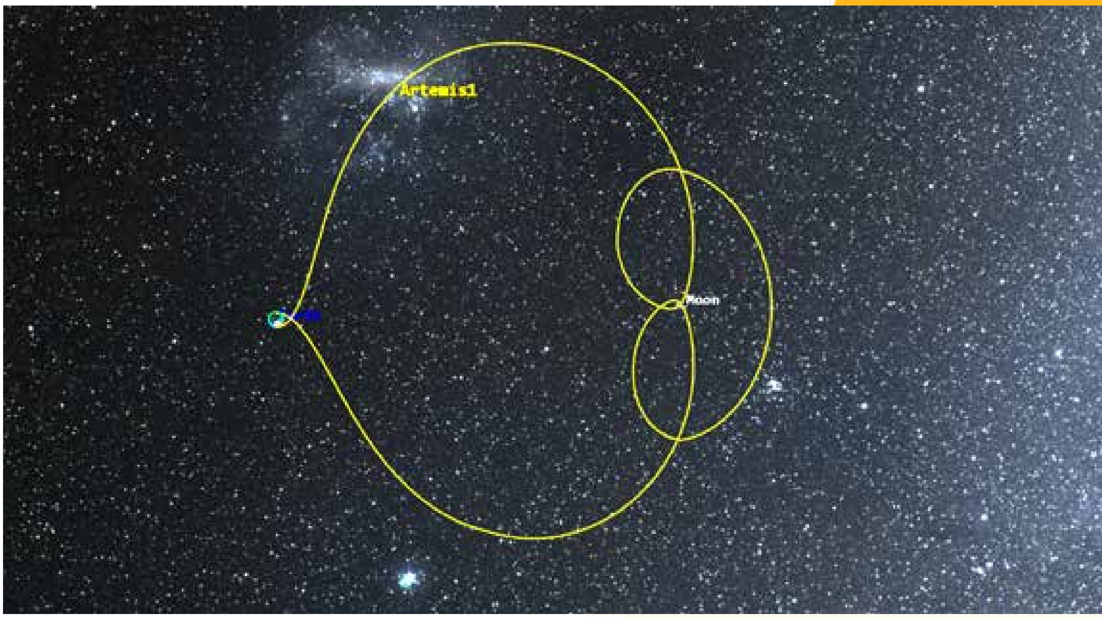
Artemis is a prime example of digital mission engineering (DME), which is defined as the use of digital modeling, simulation, and analysis to incorporate the operational environment and evaluate mission outcomes and effectiveness at every phase of the life cycle. Since its inception, every state in America has made a contribution to the success of the Artemis program, not to mention the systems being designed in Europe. The system complexity and collaboration involved are astounding, and Ansys is proud that our software has played several roles in the Artemis mission.

For example, the RF Communications Team at NASA's Marshall Space Flight Center routinely uses Ansys HFSS 3D electromagnetic simulation software and Ansys Systems Tool Kit (STK), a physics-based modeling environment for analyzing platforms and payloads. For the Artemis missions, the team is using STK for all of its SLS communication link analysis, and to visualize flight trajectories, contact with ground stations, and antenna radiation patterns.

Seamless communications are critical, of course, to send and receive data at each stage of the mission — enabling flight controllers to send commands to the spacecraft and receive data from Orion, the SLS, and the rocket's upper stage. Navigation, or tracking, services enable the flight controllers to calculate where the spacecraft are along their trajectory through space.



NASA's constellation of tracking and data relay satellites (TDRS) provides near-continuous communications services during launch and the low-Earth orbit phases until the interim cryogenic propulsion stage (ICPS), when the Deep Space Network takes over. *Image courtesy: NASA*



A depiction of the Artemis 1 trajectory constructed with STK Astrogator. The animation (right) captures the general structure of the Artemis 1 trajectory and illustrates the unique path the spacecraft follows, a path that harnesses the simultaneously combined gravitational influence of both the Earth and the Moon. Also sharing a ride up with the Artemis 1 spacecraft are several ride-share missions. Some of these missions utilize both the Astrogator capability set within Ansys Systems Tool Kit (STK) as well as the Ansys Orbit Determination Tool Kit (ODTK).

NASA's communication network is divided into two parts: the Near Space Network (NSN), which links to both Orion and SLS during prelaunch and launch for Artemis I, and the Deep Space Network (DSN), which is used for communications beyond low Earth orbit. The two networks work together to support navigation for Orion via three-way Doppler tracking. With two ground stations on Earth in contact with Orion simultaneously — one from each network — NASA can triangulate Orion's location relative to the ground stations.

WHAT'S BREWING IN ARTEMIS' SECONDARY PAYLOADS?

The Artemis missions' ultimate goal is something that has only been seen in science fiction: to establish a long-term presence on the Moon where astronauts can live, explore, and advance our scientific knowledge. But there is a lot of science to be done along the way. Some of that science is being conducted with the help of 10 tiny spacecraft. The 6U CubeSats measure just 10 cm x 20 cm x 30 cm and weigh less than 30 pounds, but they're packed with technology … and yeast, in one instance.

International space agency partners and universities are involved with several of the secondary payloads, which were deployed from the Orion stage adapter after NASA's Orion spacecraft separated and was a safe distance away. To ensure the shoebox-sized spacecraft got where they're going, some of the secondary payloads

BioSentinel's microfluidics card, designed at NASA's Ames Research Center in Silicon Valley, California, is being used to study the impact of interplanetary space radiation on yeast. The in-orbit growth and metabolic activity of the yeast will be measured.
Image courtesy: NASA/Dominic Hart

used the Ansys Orbital Determination Tool Kit (ODTK) for navigation, including BioSentinel and LunIR.

BioSentinel uses single-celled yeast to study the impact of deep-space on living organisms over a long period of time. The CubeSat flew by the Moon to a spot beyond Earth's protective magnetic field. The BioSentinel team at NASA's Ames Research Center are triggering a series of experiments remotely, activating two strains of the yeast *Saccharomyces cerevisiae* to grow in the presence of space radiation. Samples of yeast will be activated at different time points throughout the six- to-12-month mission.

Other CubeSats are being used to map near-surface hydrogen, function as a space weather station, image the Earth's plasmasphere, investigate an asteroid, observe the interim cryogenic propulsion stage with advanced optics, compete in NASA's Space Derby,

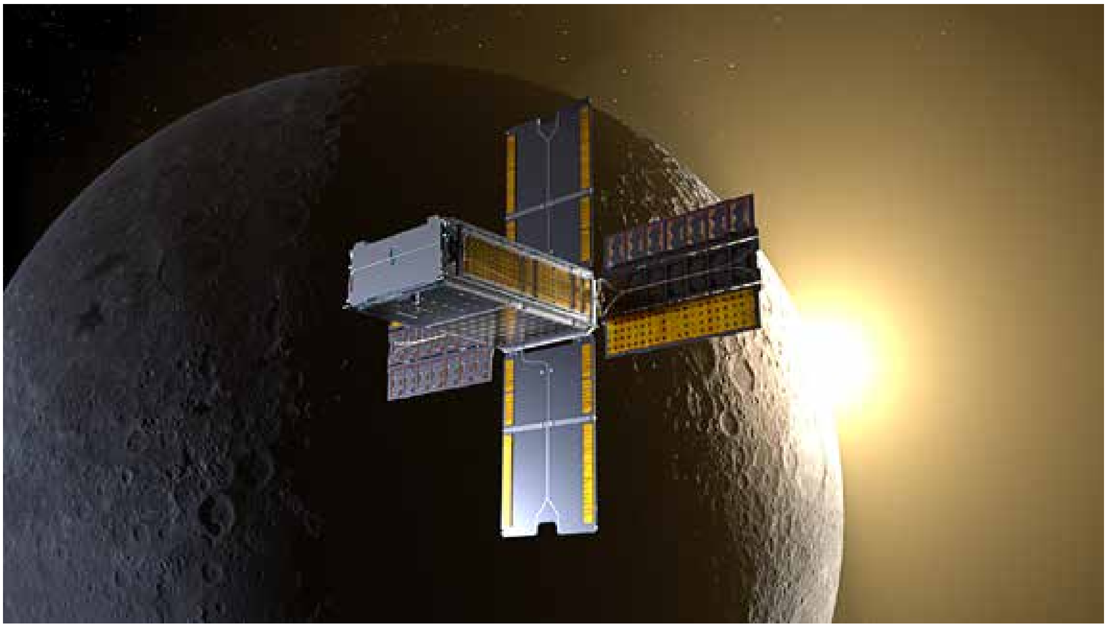


Illustration of BioSentinel's spacecraft flying past the Moon.
Image courtesy of NASA/Daniel Rutter. Image courtesy: NASA

and even attempt to land the smallest ever (weighing just 700 grams) spacecraft on the Moon. The range of science being carried out by the CubeSats is indeed exciting, including several firsts for humankind.

However, what scientists will learn about safely sending a crew to the Moon and back from the broader mission is difficult to measure. The Artemis I Orion spacecraft splashed down in the Pacific ocean and arrived back at NASA's Kennedy Space Center December 30. It flew farther away than any spacecraft built for humans has ever flown and returned faster and hotter than ever before.

"NASA's Space Launch System rocket has laid the foundation for the Artemis Generation and the future of spaceflight in deep space," said John Honeycutt, SLS Program manager in a press release. "The correlation between actual flight performance and predicted performance for Artemis I was excellent. There is engineering and an art to successfully building and launching a rocket, and the analysis on the SLS rocket's inaugural flight puts NASA and its partners in a good position to power missions for Artemis II and beyond."

Artemis I could lay the foundation for a space economy and for human exploration of ever-more-distant regions of our solar system — something Baron Gruithusen no doubt imagined hundreds of years ago.

How the Double Asteroid Redirection Test (DART) Hit a Bullseye

By **Jamie J. Gooch**, Executive Editor, *Ansys Advantage* magazine

Anyone who has played darts knows that it takes some skill to hit a bullseye. You have to account for trajectory, speed, distance, and any anomalies that might stop the dart from flying true. Now imagine if the dart was the size of a bus and the bullseye was 7 million miles away — and moving.

On November 24, 2021, NASA and the Johns Hopkins Applied Physics Laboratory (APL) took that shot, hitting a bullseye 10 months later on September 26, 2022. The Double Asteroid Redirection Test (DART), a joint project between NASA and APL, sent a spacecraft hurtling through space at roughly 14,000 miles per hour (22,530 kilometers per hour) to hit an asteroid measuring about 525 feet (160 meters) in width.

> ***"DART is turning science fiction into science fact and is a testament to NASA's proactivity and innovation for the benefit of all."***
>
> — **BILL NELSON**, *NASA Administrator*

Commonly referred to as Earth's first planetary defense test mission, DART aimed to test the kinetic impactor theory to determine if it was possible to change the orbital period of Dimorphos around Didymos, a pseudo-stable binary asteroid system. What does that mean? A slightly simplified and imperfect explanation is that Dimorphos is a moonlet that "orbits" the larger Didymos. The objective was to determine if it's possible to change Dimorphos' speed by the slightest amount. In the event of an asteroid bound for Earth, this nudge could mean the difference between a direct hit and a near miss.

"DART is turning science fiction into science fact and is a testament to NASA's proactivity and innovation for the benefit of all," said NASA Administrator Bill Nelson in a press release. "In addition to all the ways NASA studies our universe and our home planet, we're also working to protect that home, and this test will help prove out one viable way to protect our planet from a hazardous asteroid, should one ever be discovered that is headed toward Earth."

To be clear: Neither Dimorphos nor Didymos posed any hazard to Earth before or after DART's controlled collision with Dimorphos.

Prior to DART's impact, it took Dimorphos 11 hours and 55 minutes to orbit its larger parent asteroid, Didymos. Since DART's intentional collision with Dimorphos on September 26, astronomers have been using telescopes on Earth to measure how much that time has changed. Now, the investigation team has confirmed the spacecraft's impact altered Dimorphos' orbit around Didymos by 33 minutes, shortening the orbit to 11 hours and 23 minutes. This measurement has a margin of uncertainty of approximately plus or minus one minute.

"DART has given us some fascinating data about both asteroid properties and the effectiveness of a kinetic impactor as a planetary defense technology," said Nancy Chabot, the DART coordination lead from APL in Laurel, Maryland, via a press release. "The DART team is continuing to work on this rich dataset to fully understand this first planetary defense test of asteroid deflection."

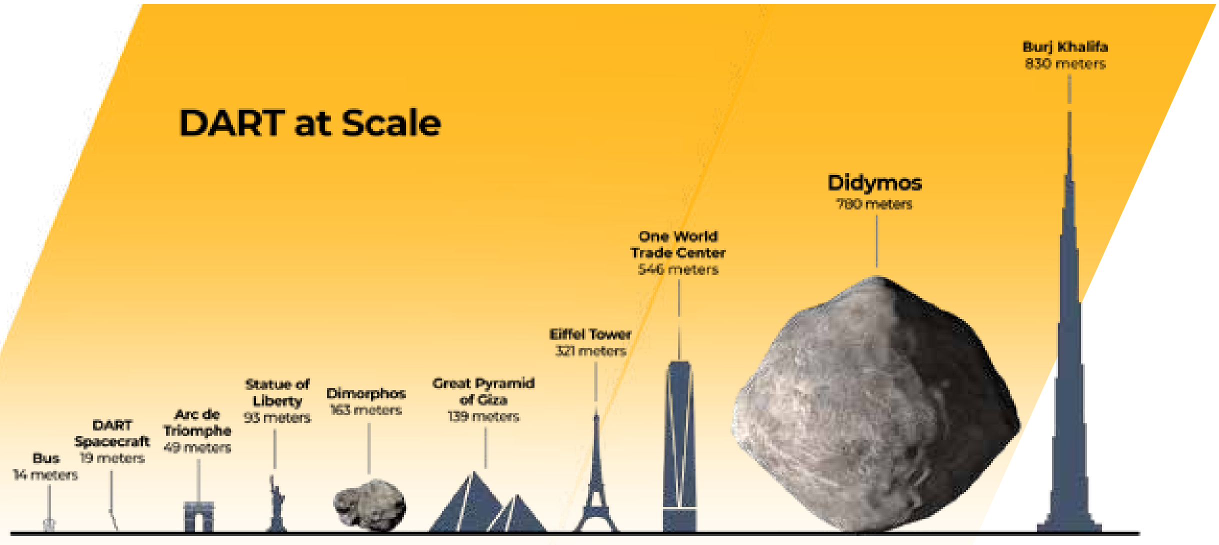
To date, three papers have been written based on analysis of data collected via the DART mission.

CONFIDENCE THROUGH SIMULATION

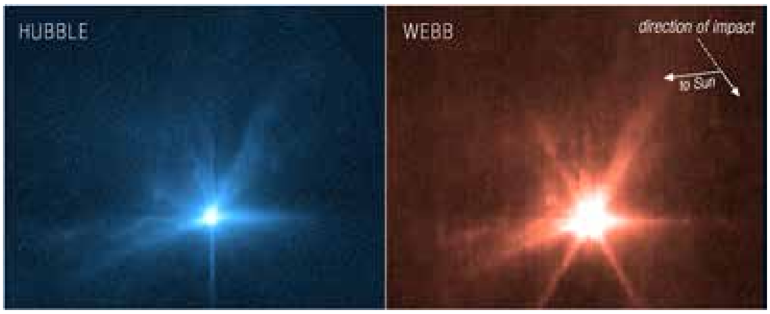
This early mission planning performed by Johns Hopkins APL relied extensively on Ansys Systems Tool Kit (STK). The formulation of

Illustration of NASA's DART spacecraft and the Italian Space Agency's (ASI) LICIACube prior to impact at the Didymos binary system.
Credit: NASA/Johns Hopkins APL/Steve Gribben

DART's trajectory to the double-asteroid system was largely planned using STK, and the team continued to use STK to visualize relevant vectors and attitude throughout the mission-planning process. The thermal team appreciated STK's full mission environment when checking the location of the Sun relative to the satellite during critical slews and maneuvers.



Everything is relative. The size of DART and its target — the asteroid Dimorphos — relative to objects on Earth *Credit: NASA/Johns Hopkins APL*



These images, from the Hubble Space Telescope on the left and the James Webb Space Telescope on the right, show observations of the Didymos-Dimorphos system several hours after NASA's Double Asteroid Redirection Test (DART) intentionally impacted the moonlet asteroid. *Credit: Science: NASA, ESA, CSA, Jian-Yang Li (PSI), Cristina Thomas (Northern Arizona University), Ian Wong (NASA-GSFC); image processing: Joseph DePasquale (STScI), Alyssa Pagan (STScI).*

STK was also used in the DART Mission Operations Center (MOC) from launch until impact. The 3D graphics, physically accurate trajectory, and six-degrees-of-freedom satellite simulation allowed the operations team to visualize the DART trajectory and attitude of the spacecraft. STK also helped the team visualize thruster pulses performed by the satellite as it used its onboard automatic control system to navigate to the asteroid system.

EYES IN SPACE

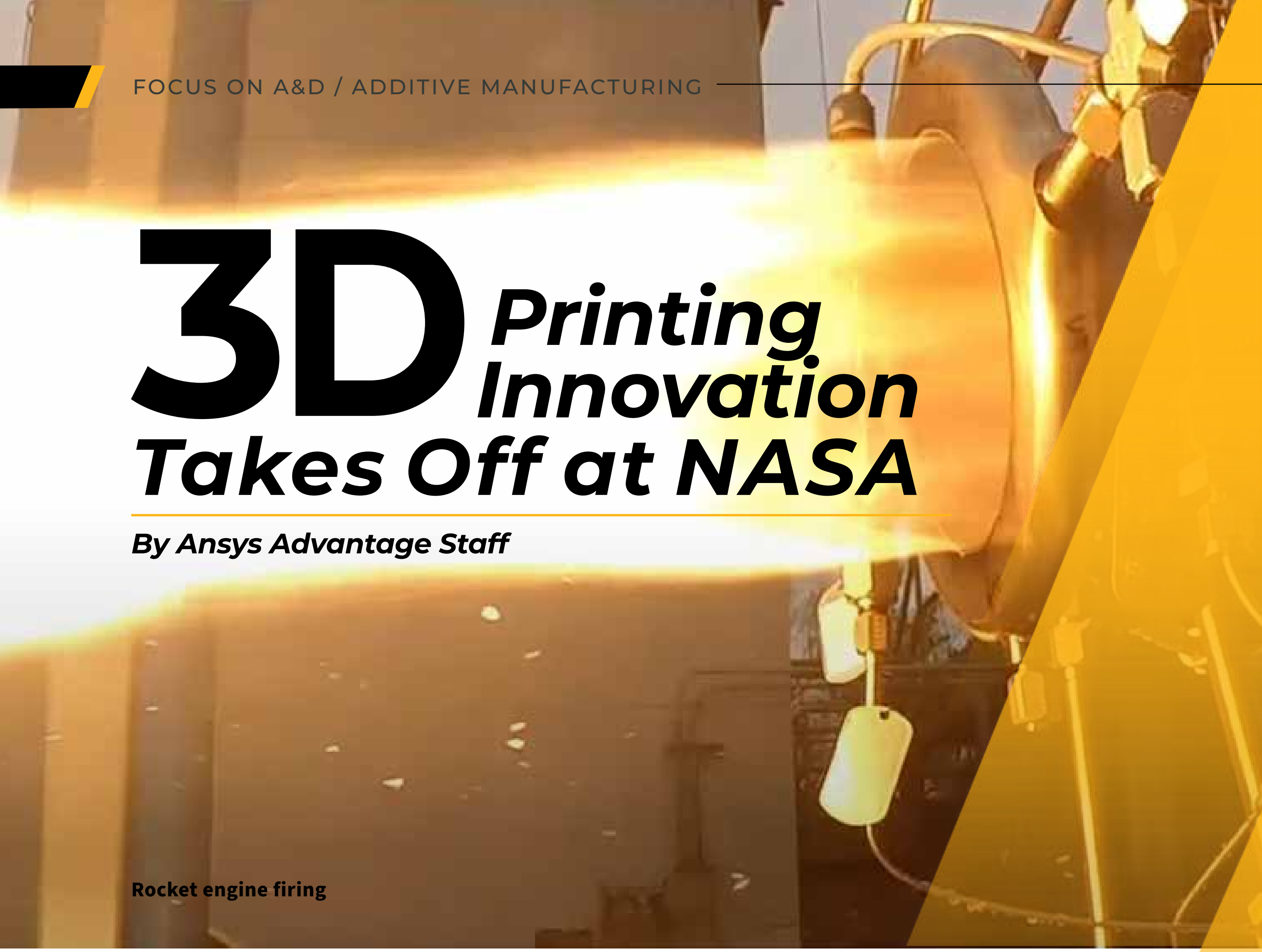
One aspect of this mission that some may overlook is that footage of this event was livestreamed from the DART spacecraft using its imager — the Didymos Reconnaissance and Asteroid Camera for Optical navigation (DRACO).

As part of this same mission, LICIACube, an Italian CubeSat, monitored the collision and sent images back in the days, weeks, and months that followed.

The James Webb Space Telescope, another incredible feat that relied on Ansys solutions, and the Hubble Space Telescope were also able to observe from a distance by capturing the collision across a wide array of wavelengths, which provided the first signs that the impact was much greater than anticipated.

DART by the Numbers

After a **10-month journey** of almost **7 million miles** (11 million km) in space, a **1,345-pound** (570-kg) spacecraft, traveling at **14,764 mph** (23,760 kph), hit a **525-foot-wide** (160 meters) asteroid after flying autonomously for the final **4 hours** and altered the asteroid's orbit by **33 minutes.**



3D Printing Innovation Takes Off at NASA

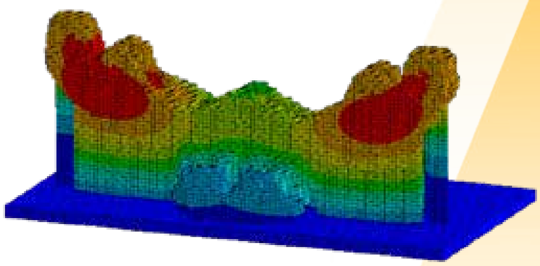
By Ansys Advantage Staff

Rocket engine firing

When you hear the term 3D printing, you might think of a small product or a repair part easily produced on a tabletop machine. But if you work for NASA, you might instead imagine 3D printing a 7-foot-tall rocket nozzle capable of supporting long-duration space flight. Even more exciting, you might envision astronauts producing that rocket nozzle at a space station, or on a distant planet as they prepare for their trip back to Earth.

Fredrick Michael, a structural materials engineer at NASA's Marshall Space Flight Center (MSFC) in Huntsville, Alabama, is leading an effort to make these kinds of ambitious visions a reality with the Ansys Additive Manufacturing solution suite. Michael is an enthusiastic advocate of engineering simulation and other advanced tools that are turbo-charging NASA's historic product development approaches — pushing the boundaries of both simulation and additive manufacturing.

"In 2015, NASA created a 25-year plan called Vision 2040, which emphasizes the importance of multiscale modeling and simulation-based design of materials and systems for aerospace applications," says Michael. "Our partnership with Ansys and



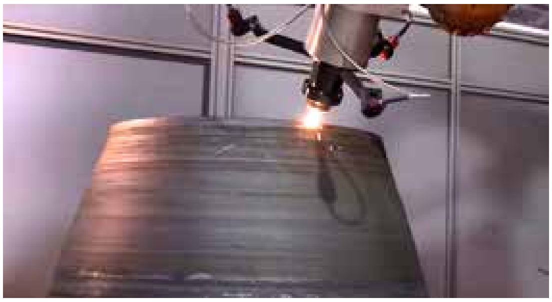
Ansys Additive 2022 R1 used for Thermal Analysis

our focus on additive manufacturing, or 3D printing, are helping our team at MSFC honor that commitment to innovation. By leveraging new computational methods and advanced processes such as 3D printing, we're doing our part to keep NASA at the forefront of global aerospace engineering."

AN EARLY ADOPTER OF ADDITIVE MANUFACTURING

NASA has been a user and proponent of additive manufacturing since the earliest days of the technology's commercialization. The space agency has combined its internal expertise with insights from industry and academia to pioneer new methods of printing rocket parts capable of powering journeys to the moon, Mars, and other destinations.

"NASA has invested in perfecting additive manufacturing techniques for a range of components, from smaller parts such as injectors to very large, single-piece rocket engines and their components either in single builds or multiple builds," Michael



NASA uses simulation to optimize additive manufacturing of rocket nozzles and other large components.

says. "Additionally, we have begun to explore, via additive manufacturing and related computational modeling, large-scale tanks and structures. Last, but not least, our in-space manufacturing on Low Earth Orbit (LEO) and our Lunar Orbit and Lunar Habitats programs are rapidly developing and being paralleled by existing and needed computational modeling of the additive manufacturing and welding processes. Whatever the size of the finished part, there are a number of common engineering and production challenges that we use Ansys software to address.

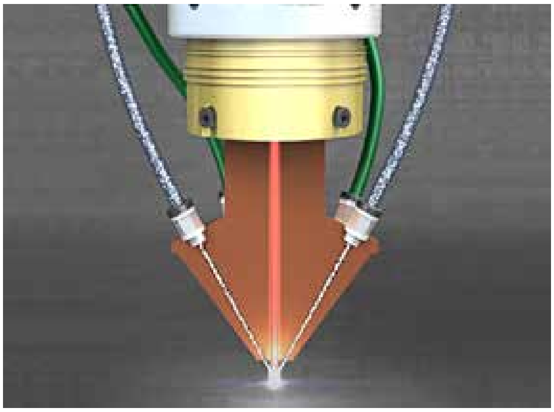
"Primary among these challenges is ensuring that the printed parts will hold up well structurally over time when subjected to the extreme temperatures and physical forces associated with aerospace applications," Michael continues. "Deformation and shrinkage are common, so we model the parts in Ansys, creating a sort of digital twin, and subject that virtual model to real-world conditions and harsh operating parameters such as high temperatures."

The Ansys Additive Manufacturing suite also enables NASA to test different powders and alloys with varying grain structures and morphologies so engineers can minimize defects at the very smallest scale. "We can characterize the materials before the build and after the build," Michael says. "We can look at their microstructure and their overall structural strength. We can quantify the effects of heat treatment. Ansys provides us with the advanced tool kit to assess these printed parts at every possible scale and under a wide range of possible conditions, which has really been invaluable."

OPTIMIZING DIRECTED ENERGY DEPOSITION PROCESSES

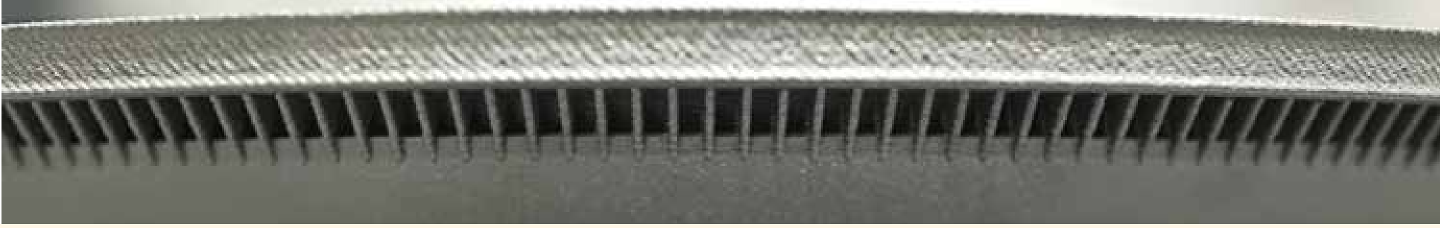
The Additive Manufacturing suite has proven critical to NASA's success in using directed energy deposition (DED), a specialized production technique, to make very large components — including rocket nozzles measuring 7 feet (2.13 meters) tall and 5 feet (1.52 meters) in diameter.

In the DED process, a robot moves a laser-powered 3D print head in a specific pattern as it deposits molten metal one layer at a time to create a predefined geometric shape. NASA uses DED to create large-scale rocket nozzles



In the directed energy deposition (DED) process, material is added alongside a heat input to deposit molten metal one layer at a time to create a predefined geometric shape.

> ***“Not only does Ansys software help us optimize the final product shape and its performance features, including materials properties, but it also has unique capabilities that enable us to optimize the DED process itself.”***
>
> — **FREDRICK MICHAEL,** *Structural Materials Engineer, NASA’s Marshall Space Flight Center*



Complex internal coolant channels are easily manufacturable through additive technology.

with complex shapes — and even internal cavities — more quickly and cost effectively than by relying on traditional forging methods. In fact, rocket nozzles can be produced via DED in just 30 days, compared to a year for more conventional manufacturing techniques.

“Not only does Ansys software help us optimize the final product shape and its performance features, including materials properties, but it also has unique capabilities that enable us to optimize the DED process itself,” Michael says. “We’ve been able to simulate the use of multiple laser heads, for example. We’ve been able to determine whether we should print the product right side up, or upside down. We also will be optimizing the laser’s path and the amount of material that it deposits. Ansys has collaborated with NASA to make the outcomes of this lesser-utilized additive manufacturing process easier to understand and control.”

3D PRINTING IN SPACE: THE FINAL FRONTIER

One of the more exciting developments at NASA is the possibility of using DED and other additive manufacturing techniques to produce repair parts or new equipment in space. As teams of astronauts explore the Moon or live on space stations, they need to make products on demand instead of storing them. 3D printing would enable astronauts to easily and rapidly manufacture the exact parts and tools they need.

While the first 3D printer was launched into space by NASA in 2014, the technology is still not used on a widespread basis. According to Michael, simulation is proving essential in making additive manufacturing in space more feasible and widely adopted.

“Manufacturing parts in space brings a whole new range of temperatures and production parameters into play,” he says. “There’s no directionality, no gravitational pull, no buoyancy. Heating is accomplished by radiation and part-conduction, not convection if in vacuum. Traditional materials may not be available or feasible, as they are not adapted to the additive manufacturing process or the microgravity and vacuum conditions either partially or fully. It’s a completely different landscape. Ansys is critical in helping our team model that world and increase our understanding of it, reducing the need of resorting to process development and testing large matrices on somewhat limited resources in zero-gravity drop chambers or other physical testing elements, such as repeated microgravity parabolic flights or even the International Space Station.”

Could Ansys software itself be used in space to optimize 3D printing projects?

“I think we’re just at the beginning of seeing what simulation and DED can accomplish,” says Michael, “and I applaud the efforts of Ansys to develop specialized capabilities for this emerging area. I can say with confidence that the software workflows created by Ansys have been very, very useful in getting NASA this far. Ansys software allows even our newest engineers to jump right in and start optimizing the additive manufacturing process. So, I’d say the full utilization of computational modeling of additive manufacturing and related manufacturing at every step of our terrestrial and in-space efforts as enabled by Ansys is what we envision the future of this collaboration to be.”

Electromagnetic Simulation Makes Connections with the US DoD's JADC2 Implementation

Tim McDonald, President of EMA and **Matt Miller**, Co-owner and Principal RF Engineer II of EMA

Everyone who uses a cell phone may not realize that the electromagnetic spectrum that allows for connection to the network is regulated by governments around the world. In the United States, much of the bandwidth for modern networks has been released from exclusive use by the Department of Defense (DoD). Those discrete bands of frequencies were auctioned off to private entities over the course of several years to form the basis of 4G and 5G networks. To enable those auctions, the DoD began studying ways that it could use less rigid methods to allocate spectrum, which is a band of frequencies used for radio frequency (RF) communications, radars, and sensing. By developing new policies and procedures, they opened the door to allocate spectrum for operations by individual DoD branch entities in a more agile and dynamic manner.

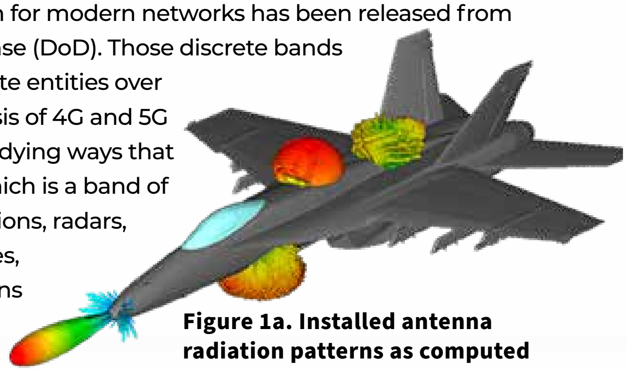


Figure 1a. Installed antenna radiation patterns as computed with Ansys Electronics Desktop

The U.S. DoD would like to take advantage of the ability to remain always-connected and benefit its operations in-theater. Ironically, the ability to be more agile with spectrum management that was set in motion by the process of the DoD giving up exclusive ownership of spectral bands for commercial use has opened the possibility of even more capable spectrum operations to support a new DoD initiative.

Electromagnetic simulation will play a key role in the success of the initiative. Its impact will be felt as the technologies are developed and again as the DoD seeks to speed the acquisition of enabling hardware.

JADC2 AND SPECTRUM OPERATIONS

The DoD's Joint All-Domain Command and Control (JADC2) initiative is about rapidly fielding new capabilities and tools across multiple domains — which include land, sea, air, and cyber — across multiple service branches. JADC2 is implementing the connectivity of many systems, doing so in a joint fashion, across everything that the U.S. DoD does to help make faster and better decisions in the field. That connectivity will ultimately involve the electromagnetic spectrum in nearly every aspect of its implementation.

"With respect to spectrum: we sense, we communicate, and then try to prevent adversaries from doing those first two things," says Joshua Weaver, Director of Spectrum Initiatives and Analysis at the Office of the Under Secretary of Defense for Research and Engineering. "The goal of JADC2 is to be able to move sensor data to the commander to build that common operating picture and ultimately reduce the latency to decision and action to achieve the desired effects."

What makes achieving the JADC2 spectrum operations goals so challenging are the small amounts of time required to do complex tasks. For example, decisions that previously took days now must be made in hours or minutes. Those challenges are both technical and procedural. On the technical side, it becomes a big data problem, where the size of data that must be moved is immense. We have all experienced bad data links that prevent us from connecting to the internet. For DoD, there is the additional complication that there is an adversary that is actively working to break their network connectivity. Electromagnetic modeling of the link is a critical technology to accurately predict connectivity.

On the procedural side, decisions are made at infrastructure far from forward operation after careful deliberations by people in a defined chain of command. Those decisions are based on rigid rules and guided by testing or analysis performed years or decades ago. To speed those decisions from days to minutes, both the technology and the bureaucratic processes must evolve. Electromagnetic simulation combined with machine learning (ML) techniques will be an important part of making faster decisions.

DYNAMIC SPECTRUM OPERATIONS

The roadmap for future military systems must consider the fact that the amount of electromagnetic spectrum is finite. In the past, advanced militaries defined their spectrum use and developed their systems using a very long procurement cycle. Potential adversaries might have chosen to exploit this lack of flexibility and implement their own use of spectrum management that is more agile and adaptable. That is why JADC2 places an emphasis on a system of dynamic spectrum operations.

"Agile electromagnetic spectrum operations will leverage modernized, networked command, control, and communication systems and support electromagnetic spectrum superiority, which in turn enables JADC2 operations," according to the U.S. Defense Spectrum Organization's Electromagnetic Spectrum Enterprise Capabilities and Services Booklet.

However, with agility comes risk. But spectrum can be allocated and risk can be managed in other ways besides giving exclusive use of parts of the spectrum to specific industry sectors. Electromagnetic simulation allows interference risks to be quantified so that good spectrum management decisions can be made.

Lastly, we must consider the fact that the new hardware cannot be fielded immediately. There is a clear process that must be followed in acquisition. It is easy to find stories of commercial equipment that was placed in a military environment and immediately ceased functioning or degraded the performance of other equipment. As a result, a risk-based approach to verification of electromagnetic effects during acquisition is required to allow new technologies to be fielded quickly but in such a way as to minimize interference that could be catastrophic. Electromagnetic simulation is the key to quantifying the risk and ensuring a high likelihood of compatibility.

INDUSTRY'S ROLE IN LINK MODELING

"There's a need for digital engineering and simulation at the platform level including spectrum effects or communication effects," says Regina Tyrrell of the U.S. Army Program Executive Office for Simulation, Training and Instrumentation (PEO STRI). "It's an area that is ripe for development and maturation."

The goals of JADC2 require close partnership between government and industry. Fortunately, new technologies are emerging to allow for faster evaluation of risk to allow for greater agility. These methods use first-principle simulation technologies coupled with artificial intelligence (AI) and ML to achieve the speed and accuracy necessary to make good decisions faster or even automatically.

The first way that simulation can provide support is in understanding data links. Ansys Systems Tool Kit (STK) can be used to model scenarios with multiple platforms, each with RF systems, and their dynamics through space and time to predict link quality. This product is directly coupled to Ansys Electronics

Desktop, which allows for link analysis in a range of scenarios. Accurate modeling is needed to provide information on the link performance. This is no longer simply about whether the link is up or not. JADC2 requires communications and data exchanges that are resilient, preferably with multiple paths that can gracefully degrade. This can only be predicted with highly accurate link modeling. Prediction is essential to make good decisions about which frequencies should be used in each domain. Figure 1 shows installed antenna patterns computed by Ansys Electronics Desktop for military aircraft.

The goal is to use digital engineering to create scenarios and link models that are an analog to what happens in the physical environment, which will ultimately be translated into risk scores to aid in fast decision making. Spectrum managers will use digital engineering to inform their decisions. Implementation of their decisions is made via control messages sent to hardware in the environment to change frequency, change modulation, change location, or cease transmitting. The radios collect link information to course correct in real time or provide data sets to test simulation accuracy. Thus, simulation may be refined to allow it to improve over time.

Modeling in electromagnetics has improved to the point where it can be accurate for military scenarios. The frontier in spectrum management is in combining the physics solvers with AI/ML techniques to allow for faster scenario evaluation. The timescales of JADC2 do not allow for six months of computational studies that are then validated by another six months of field testing. Instead, simulation provides inputs to AI/ML model training that provides risk-based scores accurately and quickly. The initial result may be augmented by real-time sensor data that further improves the accuracy and grounds it in the operational truth.

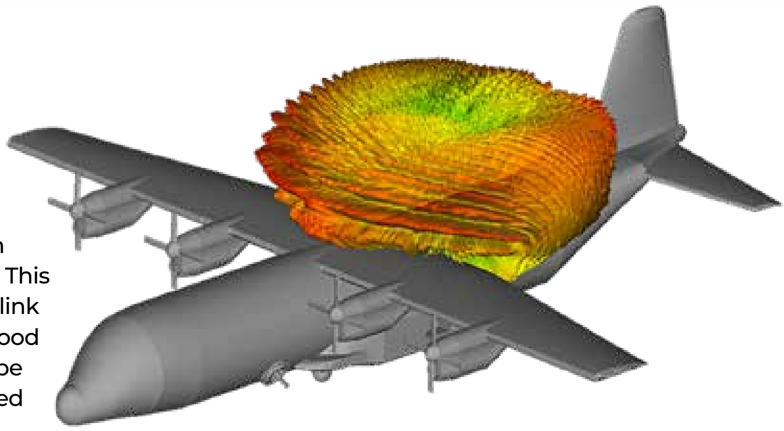


Figure 1b. Installed antenna radiation patterns as computed with Ansys Electronics Desktop

INDUSTRY'S ROLE IN ACQUISITION AND ENSURING COMPATIBILITY

Each service has its own acquisitions programs. They will continue to procure spectrum-dependent systems. Acquisition and compatibility considerations are key challenges standing between having the new operational initiatives demonstrated versus implementing them in joint operations. The current approach is to follow MIL-STD-461 testing with the assumption that operational frequencies are static. There are two drawbacks to this approach. The first is the fact that there are gaps in the MIL-STD-461 approach that will become more challenging in a more agile spectrum environment. The second is the amount of time required to complete a full MIL-STD-461 development and verification in a standard acquisition environment.

IMPROVE RADIO FREQUENCY INTERFERENCE ANALYSIS

Even if a unit meets MIL-STD-461 requirements for emissions or susceptibility, compatibility is not automatically guaranteed. The appendix for 461 is very clear about this. Even if all RF systems meet the 461 requirements, primes must perform an RF interference analysis given the proximity of these systems and all other items that can be added to the RF architecture including filters, amplifiers, cables, and directional antennas.

Department of Defense Form 1494 (DD 1494) is standard for all RF systems. When combined with scenario modeling and link analysis, it should allow for the accurate prediction of unwanted interference. The problem is that the data in DD 1494 is often not accurate or complete.

A solution to the inaccuracy in the data on DD 1494s is to quickly improve the fidelity of RF system receiver and transmitter information. New technologies that automate the collection of the out-of-band RF system performance are available. One example is the Automated Radio Measurement System (ARMS), which combines off-the-shelf test equipment, custom filter banks, and automation software to improve the speed of accurate data collection by two orders of magnitude.

Automation is also essential for RF systems that operate over many channels, modulations, and power levels. Some modern military RF systems can support tens of thousands and sometimes a few hundred thousand channels. Manually measuring the performance of even a subset of so many channels involves a large cost and time commitment. With ARMS, the user can program the channels, modulation, and power levels that they wish to measure, click "Run" and walk away until the measurements are complete.

ARMS is also capable of measuring the wideband susceptibility of a receiver. For a susceptibility measurement, the intended signal is injected into the receiver and a baseline performance metric is established. Then an interfering signal is simultaneously injected out-of-band and the performance metric is monitored for degradation. With this approach, one can characterize the susceptibility of a receiver as a function of frequency as shown in Figure 2. In this example, the measured selectivity of the receiver is much broader than stated on the receiver specification sheet and there is a spurious response near 1.28 GHz that is not captured on the receiver specification sheet.

Using measured RF system data from ARMS in simulation tools such as Ansys EMIT dramatically improves the accuracy of RF interference analyses. As can be seen in Figure 2, specification sheets and DD 1494s can be wildly inaccurate with regards to the wideband performance of the RF systems. Without measured data, it is often a garbage-in, garbage-out scenario when it comes to predicting RF interference. A typical RF interference scenario as modeled in EMIT is shown in Figure 3.

For RF interference simulations, you need wideband data for all of the components in the RF architecture (e.g., filters, cables, amplifiers, etc.), the antenna-to-antenna coupling, and the RF systems. Vendors are increasingly providing

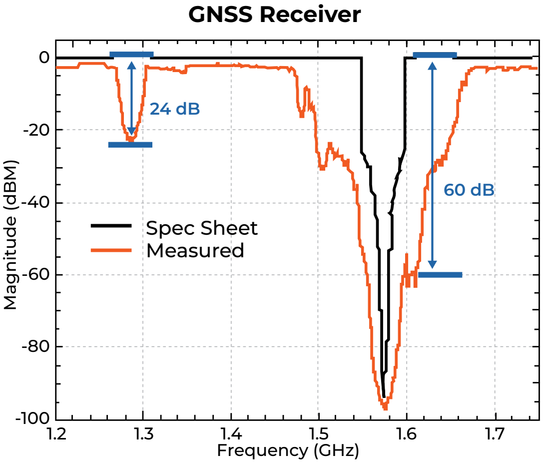


Figure 2. A comparison between measured data and a specification sheet for the wideband performance of a GNSS receiver

measured or simulated scattering parameters (S-parameters) for filters, cables, and other components. When data is not available from vendors, tools such as Ansys Nuhertz and Ansys Nexxim can be used to simulate performance. It is also possible to very accurately predict the antenna-to-antenna coupling using tools such as Ansys HFSS and SBR+. So, you can see how through the combination of powerful simulation tools from Ansys and measured data from ARMS that all of the necessary input data for RF interference simulations is possible.

ELECTROMAGNETIC REQUIREMENTS

DoD Directive 5000.01 guides the U.S. Defense Acquisition System policies and procedures. The directive gives a clear ability to waive requirements to meet faster procurement

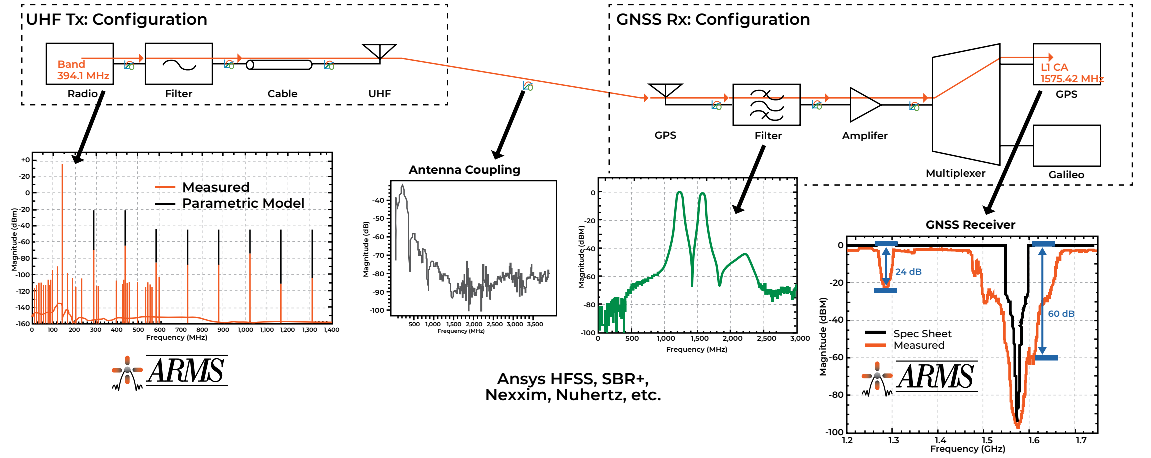


Figure 3. EMIT requires wideband data for all of the components found in RF architectures as well as the antenna-to-antenna coupling.

cycles, but a wholesale removal of interference compatibility analysis would negate the benefits of choosing to proceed with agile spectrum operations. Instead, a risk-based approach would allow for the logical tailoring of electromagnetic compatibility and electromagnetic environmental effects requirements using physics-based engineering simulation.

Ansys EMC Plus (formerly Ansys EMA3D Cable) enables engineers to predict electromagnetic compatibility effects at the platform and equipment levels. It provides quick and efficient conversion of 3D computer-aided design (CAD) to an EM model of the entire vehicle. Thus, EM teams can maintain a virtual EM test environment that is traceable and is useful to predict the integrated vehicle performance with respect to several EM requirements and environments. (See Figure 4.)

The full-vehicle model is helpful to determine the level of tailoring that is acceptable to maintain compatibility and a low-risk path to meeting vehicle-level requirements.

Examples of EM virtual testing tasks include:

- EMC requirements per MIL-STD-461 and DO-160
- E3 requirements for lightning SAE ARP5415 or ARP5416
- E3 requirements for high intensity radiated fields (HIRF) per SAE ARP5583
- Electromagnetic interference (EMI) and intra-system compatibility of the platform

Ansys EMC Plus can model complex electrical wiring interconnect system cables that have over-braids, shields, multiple conductors, branches, and terminations. It enables engineers to specify 3D routing of the cables from the CAD document. Then, engineers can specify the shields and conductors by importing the harness connectivity from wiring database software. Design information from CAD, wiring diagrams, and other sources are efficiently converted into an EMC Plus virtual test environment model.

Engineers can create models of entire vehicles in a reasonable time and determine if requirements may be safely relaxed or tailored.

SIMULATION IS KEY TO CONNECTIVITY

We enjoy modern connectivity that is robust and ever-present due to spectrum management and spectrum sharing. DoD is moving toward a new paradigm to achieve robust and agile connectivity, even in a contested environment.

Electromagnetic effects and spectrum management are essential parts of DoD's new JADC2 initiative. For the new initiative to be successful, electromagnetic modeling, simulation, and testing will play a key role in the transition. This includes new simulation technologies to support link modeling, to include AI/ML to speed results. It will also require interference analysis and testing to include better characterization of radio out-of-band characteristics. Finally, EMC simulation of full platforms and equipment are needed to allow for accelerated procurement through careful tailoring of electromagnetic requirements to maintain mission success.

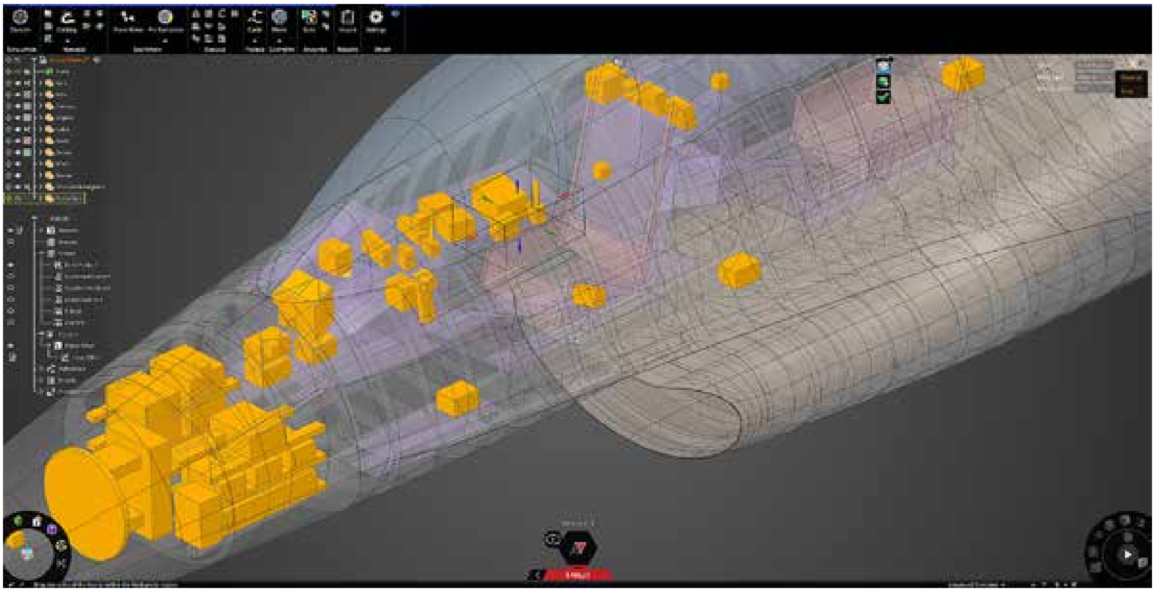


Figure 4. Ansys EMC Plus allows new development programs to analyze the performance of new equipment in the MIL-STD-461 environment to determine if tailoring is appropriate.

Ansys Earns Its Wings at the Air Force Test Center

With $31 billion in assets and more than 18,000 personnel, the Air Force Test Center ensures that aircraft, control systems, and weapons systems perform safely and reliably under real-world conditions. AFTC complements its exhaustive physical ground and flight tests with Ansys simulations. By helping AFTC conduct early-stage analysis and strategically plan its testing parameters, simulation drives faster, more cost-effective physical tests that enable innovative new defense systems to be launched confidently and quickly.

"If we don't help with the pathfinding for digital materiel management, the Air Force will lag. The Test Enterprise is foundational for capability development and ensuring credible capability is rapidly delivered to the warfighter"

—**MAJ. GEN. EVAN DERTIEN**, AFTC commander.

With a mission to "forge our nation's sword and shield," the Air Force Test Center (AFTC) bears an enormous responsibility. It conducts developmental and follow-on testing and evaluation of manned and unmanned aircraft, related avionics systems, flight controls, and munitions and weapon systems. AFTC has flight tested every aircraft in the Army Air Force's and the United States Air Force's inventory since World War II.

Headquartered at Edwards Air Force Base (AFB) in California, AFTC also conducts flight tests at Eglin AFB in Florida and ground tests at Arnold AFB in Tennessee. The center owns more than $31 billion in assets and employs over 18,000 military and civilian personnel — all focused on delivering critical safety and reliability evaluations for aircraft and related systems.

In addition to flight-testing and evaluating new aircraft, AFTC's work includes testing upgrades to aircraft already owned by the U.S. Air Force, the Department of Defense (DoD), the National Aeronautics and Space Administration (NASA), and other government agencies. Typical AFTC projects are aimed at assessing proposed improvements to radar, weapons-delivery, and navigation systems, along with their underlying software.

TOP-TIER TESTING REQUIRES TOP-TIER RESOURCES

Because it's imperative that AFTC's test programs are as thorough as possible, with a high degree of scientific rigor, the center operates some of the world's most advanced physical testing facilities. It owns nearly 70 aerodynamic and propulsion wind tunnels, rocket and turbine engine test cells, environmental chambers, ballistic ranges, and an over-water test range in Florida that spans 120,000 square miles. AFTC augments these assets with advanced technologies in engineering and design so that its personnel are equipped with tools that meet their mission.

"If we don't help with the pathfinding for digital materiel management, the Air Force will lag. The Test Enterprise is foundational for capability development and ensuring credible capability is rapidly delivered to the warfighter," says Maj. Gen. Evan Dertien, AFTC commander.

Rachel Garrard, a test manager with the Propulsion Test Branch of Arnold Engineering Development Complex (AEDC), explains how the C-1 altitude engine test cell works to Maj. Gen. Evan Dertien, commander, Air Force Test Center. In C-1, large military and commercial engines are tested at simulated altitude conditions. U.S. Air Force photo by Jill Pickett

John Hile, center, an Arnold Engineering Development Complex (AEDC) test engineer, speaks with Maj. Gen. Evan Dertien, commander, Air Force Test Center, about the use of arc heaters, such as the one seen in the background, for characterizing and evaluating thermal protection systems. Also pictured is Frank Wonder, arcs capability manager. U.S. Air Force photo by Jill Pickett

"Our ability to collaborate digitally with other AFMC Centers like AFRL, LCMC, and AFSC and partners like the AF Warfare Center, AFOTEC, and industry is critical to future mission success. If we're going to rapidly integrate new capabilities to be competitive in a peer environment, we need a digital environment that can leverage new tools and enhance collaboration."

AFTC's advanced engineering tool kit includes Ansys engineering simulation software. By applying Ansys simulations at an early stage of testing design to replicate physical trial conditions, AFTC can identify areas of interest — whether a specific aircraft component or a real-world operating parameter — to ensure that its physical tests are focused and efficient. While there's no substitute for physical testing when so much is at stake, AFTC uses simulation to make that testing smarter and faster.

"When we align personnel and assets from around the country with the permissions in place to go fly, we need to make it score for count! We need to gather as many viable test points for both developmental and operational flight testing and share that data with any future projects with those associated systems," says Christopher Hereford, the AFTC digital engineering lead.

MINIMIZING UNCERTAINTY, WHILE MAXIMIZING TESTING EFFECTIVENESS

When AFTC receives a new aircraft or system from a supplier, it first conducts uncertainty modeling. Based on the supplier proposal, AFTC needs to ensure that the physical design will deliver the promised performance. Because it's impossible to exhaustively test every system and every component under every possible operating parameter, AFTC relies on preliminary Ansys simulations to narrow the field and identify the areas of greatest risk.

For example, the engineering team at Arnold AFB uses Ansys Fluent and Ansys Twin Builder to create a virtual model of a product system — whether a scale aircraft model or a component such as a wing — and a virtual model of a wind tunnel. By running its planned tests in a virtual landscape, AFTC can predict the likely results of those tests at a very early stage. Out of hundreds of variables that might impact the success of a mission, Ansys simulation studies can narrow the areas of potential interest down to tens of variables — leading to refined wind-tunnel studies and more insightful test results.

Ansys software is also helping AFTC design more intelligent tests that reveal critical performance factors as quickly and cost-effectively as possible. Ansys STK is ideally suited to this task, since it enables engineers to model complex systems inside a realistic, time-dynamic 3D simulation environment that includes high-resolution terrain, imagery, and radio frequency (RF) characteristics. AFTC engineers can create precise models of ground, sea, and air assets and then insert moving product systems into this virtual landscape.

Ansys Test and Evaluation Tool Kit (TETK), an extension of STK, improves the efficiency and effectiveness of test and evaluation activities across the digital engineering product life cycle.

For example, the test design team at Eglin AFB uses TETK to plan its aircraft testing routes over open water. When AFTC launches an F-16 over the Gulf of Mexico and has it perform maneuvers such as roll-overs to ensure that its new communications systems work properly, that's a very time- and cost-intensive endeavor — as much as $100,000 per hour. Ansys TETK helps sharpen the focus and limit the number of real-world maneuvers that are required. Test pilots can focus on critical flight parameters — using a smaller set of aerial exercises — with the insights provided by TETK. And, TETK also helps resolve anomalies by ingesting actual flight data and enabling post-flight analysis.

"The Gulf of Mexico is an invaluable asset to the Eglin Test team because it represents an over-the-water range to conduct high-risk or long-range weapons' tests," says Dr. Elisabetta Jerome, AFTC technical advisor for armament and weapons test and evaluation. "To do so in the most efficient and safe way, we must have a network of instrumentation, real-time data acquisition and AI-supported data analyses."

Nicole Prieto, a test manager with the 717th Test Squadron (717 TS), 804th Test Group, Arnold Engineering Development Complex, and 2nd Lt. Paul McCormack, a test engineer with the 717 TS, look at data from a non-interference stress measurement system training environment in the Innovation Center at Arnold Air Force Base. *U.S. Air Force photo by Jill Pickett*

A CASE IN POINT: CHARACTERIZING THE PERFORMANCE OF AN IRST

Recently, the AFTC team at Edwards AFB used Ansys Fluent, Ansys Mechanical, and Ansys Speos to solve a complex multiphysics problem centered around an infrared sense-and-track (IRST) system mounted under a plane's wing. IRSTs include optical sensors that enable pilots to see objects on their dashboard displays, then launch a rapid, effective air-to-air or air-to-ground strike.

Obviously, there's no room for error when weapons are being deployed. But, ensuring that an IRST will deliver accurate images poses an intricate challenge on an aircraft traveling at Mach 1, in all kinds of atmospheric conditions, with the sensor assembly strained by physical forces and thermal gradients. Deformation of the sensing window is a special concern, because it can lead to distorted images and inaccurate targets.

Test practitioners at AFTC are creating detailed models of the sensor in Speos and Mechanical, then using Fluent to simulate thermal and aerodynamic forces on them. AFTC engineers can study how the sensor is affected by natural forces — such as clouds, air temperature, the speed and altitude of the plane, and the speed and altitude of the target — without ever launching an aircraft. While physical flight testing is still required, these multiphysics studies are helping to identify potential failure modes for the IRST, which can then be carefully studied in the air.

AFTC FEELS THE NEED FOR SPEED — AND ANSYS DELIVERS

According to Dr. Eileen Bjorkman, AFTC executive director, one of the biggest challenges for AFTC is rapidly validating innovative new systems that can strengthen U.S. defense while ensuring that rigorous testing and verification have been conducted for each of these systems.

"Advanced modeling and simulation techniques are the key to developing and fielding systems faster, but also for making rapid changes to those systems after they're fielded to keep up with an evolving threat," she says. "If we have a digital environment and high-fidelity model of the system, designers can start modifying the system as soon as operators detect the need for change. At the same time, AFTC engineers and pilots can jump into the digital environment to start evaluating the proposed changes, and they can start planning for live testing if needed to resolve issues that can't be fully explored in the simulated environment. The goal is an end-to-end modification process that can be completed in days or weeks, or even a few hours, instead of months or years."

By enabling AFTC engineers to arrive at preliminary findings in a low-cost virtual testing environment, Ansys solutions are accelerating the deployment of new aircraft and systems. As the U.S. military targets groundbreaking technology improvements that safeguard lives and improve defense capabilities, digital engineering has earned its wings by speeding up this process, while also reducing costs.

Simulation in the News

Ansys Acquires C&R Technologies for Enhanced Thermal Simulation

Understanding thermal behavior is critical to engineering systems in aerospace and defense. To better provide enhanced thermal simulation capabilities, Ansys acquired C&R Technologies (CRTech) in late 2022. C&R Thermal Desktop (now Ansys Thermal Desktop) software uses a thermal-centric modeling approach to provide fast and effective system-level simulation capabilities. Together, Ansys Systems Tool Kit (STK) and Thermal Desktop enable engineers, operators, and analysts to connect modeling and simulation efforts across all phases of the engineering product life cycle.

Ansys Thermal Desktop uses many unique technologies to aid in heat transfer analysis, thermal radiation, environmental heating, and fluid flow design. These include a new plugin in Thermal Desktop that imports a vehicle's trajectory for thermal environment calculations. Engineers have used the software to understand the thermal performance of the James Webb Space Telescope, the InSight Mars Lander, battery systems, cryogenics systems, rocket nozzles, and more.

The Cloud Helps Many Companies with CAE

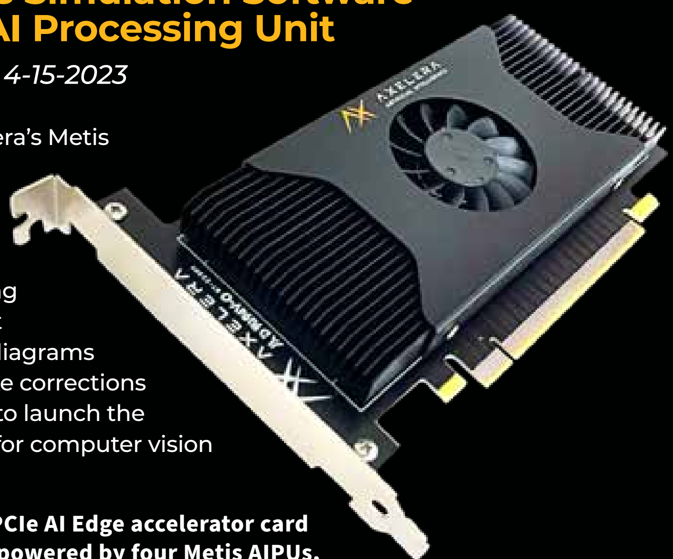
Engineering.com 4/17/2023

Computer-aided engineering (CAE) has been around for a long time, but as products and processes get more complex, the ability of in-house computing systems to handle the large amounts of data generated by CAE is decreasing. Also, it can be very expensive to maintain a sophisticated, high-performance computing (HPC) infrastructure onsite. Many companies are turning to the cloud to run platforms like Ansys Cloud Direct to obtain access to the computing power they need on an on-demand basis, saving them time and money.

Axelera AI Uses Ansys Simulation Software to Validate its Metis AI Processing Unit

Digital Engineering Magazine 4-15-2023

With up to 100 million gates in Axelera's Metis AI Processing Unit (AIPU), validating its digital performance integrity was difficult using traditional methods. To overcome that challenge, they developed a two-step workflow using Ansys simulation solutions to detect vulnerabilities in integrated circuit diagrams and perform failure analyses to make corrections where needed. This helped Axelera to launch the recently released Metis AI platform for computer vision AI Inference.



Axelera AI's PCIe AI Edge accelerator card (pictured) is powered by four Metis AIPUs, validated using Ansys simulation software.
Source: Axelera

Ansys Earth Rescue Online Video Series Wins American Business Award

The American Business Awards honored Ansys with a Silver Award for the online video series Earth Rescue. With the tagline "The climate crisis is here. And so is the human ingenuity to fight it," Earth Rescue was produced to reveal what visionary companies are doing today to engineer radical new ideas in the fight against climate change. Our video team interviewed companies who are using Ansys simulations to develop renewable energy resources, novel mobility solutions, and processes to clean up the environment. In crafting this video series with the highest production standards, they demonstrate how simulation is doing its part in helping to save the Earth from climate change.

Ansys Joins the European PowerizeD Project on Power Electronics and Decarbonization

Electroniques, 4/17/2023

Ansys has joined the European research project PowerizeD to help reduce Europe's carbon footprint by developing digitized power electronics for energy generation. PowerizeD is aiming for:

- 25% reduction in power loss during the power conversion process
- 10% reduction in chip size
- 30% extension of device and system lifespan
- 50% reduction in product development times

Ansys' contribution to the project will focus on developing new workflows to maximize the power of digital twins to help reach the project's goals.

Digital Twins Aid in Operation of Nuclear Plant

Digital Engineering 24/7, 4/6/2023

The ConnexITy Consortium, led by the French utility firm Électricité de France (EDF), is using Ansys Twin Builder to design a digital twin of a turbogenerator in a nuclear plant to optimize its performance and maintenance. EDF operates 58 nuclear power plants mostly in France. It plans to validate the benefits of using a digital twin internally before offering the technology to other nuclear power companies.

"The Ansys Twin Builder technology is an essential component in our digital twin," says Fabien Leray, ConnexITy project leader. "We used Twin Builder to create reduced order models, using aggregated simulation results. This reduced order model is at the core of the digital twin."

Globe Fuel Cell Systems Chooses Ansys CFD Technology to Reduce Development Costs

Industry USA
4/6/2023

Creating an efficient fuel cell depends greatly on understanding temperature regulation, which is in turn related to mass flows of air, temperature drops, and flow distribution around the fuel cell. To better understand these phenomena, Globe Fuel Cell Systems uses Ansys computational fluid dynamics (CFD) simulation solutions to save money while developing hydrogen fuel cell systems for carbon-neutral power production. Using simulation to optimize the cooling loop of the fuel cell system by maximizing the air flow guides Globe engineers in designing the most efficient fuel cells possible.

Ansys simulation enabled Globe's XLP80, a complete hybrid fuel cell system combined with lithium-ion battery power, to deliver high-energy output in support of a pro-hydrogen economy.
Image courtesy of Globe Fuel Cell Systems.

Ansys Launches All-in-one Hub for Simulation

Aerospace Manufacturing, 4/24/2023

The Ansys Developer portal brings together developer tools from the entire Ansys portfolio into a single hub with documentation, examples, guides, and use cases. The portal equips users to accelerate their work by extending simulation workflows across the Ansys portfolio. It also includes a community forum for customers, partners, and internal developers to collaborate, share ideas, ask questions, and suggest features while providing direct access to open-source initiatives like the PyAnsys project Python libraries.

Ansys is committed to providing customers with the tools needed to speed innovation and achieve goals. By simplifying and streamlining the availability of this set of resources, Ansys is enabling engineers, architects, and developers to better design new solutions for automating repetitive and complex simulations and workflows across physics and engineering domains. Facilitating access to these resources through the portal will significantly reduce the time required to complete tasks and minimize the potential for errors. The portal is a key foundation for building new solutions in simulation, including those used to train artificial intelligence/machine learning (AI/ML) models.

What's the Next Step for Digital Twins?

Technology Record, 4/19/2023

Digital twins are high on the agendas of chief information officers. Most enterprises want to deploy this technology, but very few realize its full potential.

Today, digital twins are generally used as real-time digital models of products or systems via simulation. However, Microsoft and Ansys are helping customers use them on a larger scale. For example, the partnership between Microsoft and Ansys enables customers to combine the physical world, simulations, and artificial intelligence and machine learning models to make more accurate, data-driven predictions. This leads to more efficient operations and less prototyping, material waste, and energy use.

Coming Around Again

Develop3D, 5/1/2023

A recent collaboration among simulation software developer Ansys, several recycling companies, and a producer of automotive parts has demonstrated how recycled plastics could be more widely used in products, to the benefit of the environment.

To make it easier for recyclers and their customers to produce viable recycled plastics and use them in products, Ansys collaborated with Impact Recycling, Impact Solutions, and Far-UK to undertake the Plastic Recycling in Stochastics Modelling (PRISM) Project. For Ansys, the PRISM project showcases how material circularity and smart eco design can be achieved by applying the right solvers connected with a simulation digital thread.