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Simcenter news

Aerospace edition

June 2018

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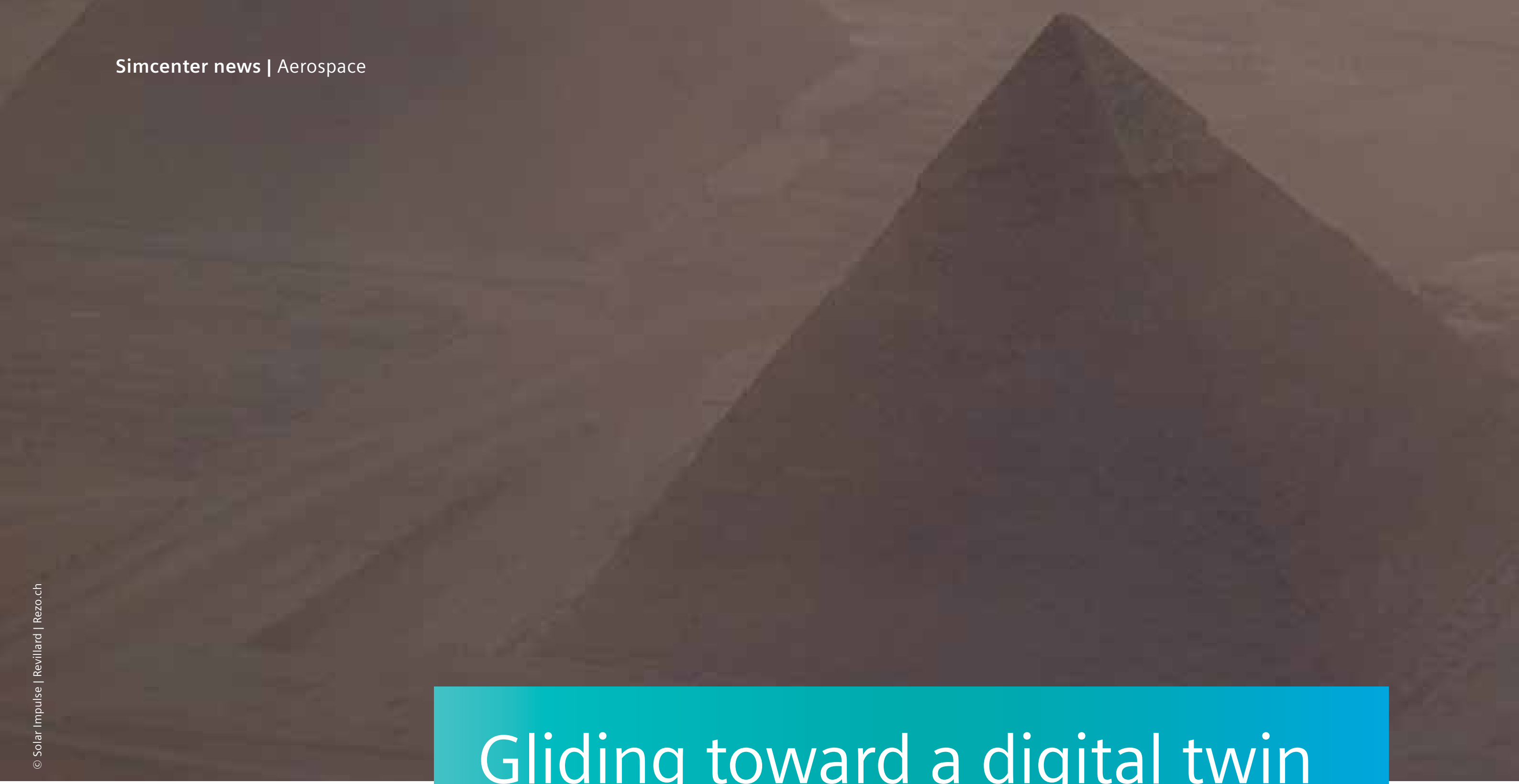

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Gliding toward a digital twin

Siemens PLM Software

Jan Leuridan
Senior Vice President
Simulation and Test Solutions

Welcome to the special aerospace edition of Simcenter News. As you know, the aerospace industry is enjoying an innovation boom. And we are pleased to note the Simcenter™ portfolio has played a significant role in helping inspire innovation in aerospace design and process development over the years. We have tried to cover as many of our customer success stories as possible in this 68-page issue, our longest yet. For our cover story, we spoke to the engineers behind the Pilatus PC-24 success story. The Pilatus development team not only created and certified the new Super Versatile Jet in record time by using a production-driven digital twin, they have also revolutionized the aircraft development and certification process, proving that our predictive engineering analytics vision in support of digital twins has become a reality.

In this issue, we continue to follow the exciting world of e-aviation with the Siemens eAircraft project. The team in Erlangen, Germany is busy using the complete set of Simcenter simulation and testing tools as well as Teamcenter® software and NX™ software to optimize their models and make sure that upcoming testing campaigns will be done in the most effective way.

Along more commercial lines, there is an excellent story about Airbus' approach to cabin comfort using the Simcenter™ STAR-CCM+™ software solution for computational fluid dynamics (CFD). The team at Airbus Helicopters, long-time pioneers in the field of model-based systems engineering (MBSE), shares its experience using Simcenter Amesim™ software. And we invite you to read the story about the Chinese commercial aircraft program, the COMAC C919, and how Simcenter 3D is being used to help drive the certification process with the Chinese agency, SAACC.

Our aerospace edition wouldn't be complete if we didn't cover space. Airbus Space and Defence explains how the Simcenter environmental dynamic testing solution helped the European Space Agency (ESA) successfully launch the GAIA telescope, while Orbital ATK decided to integrate Simcenter 3D into the Teamcenter and NX process to improve its design for NASA's Space Launch System (SLS). So whether you want to explore the tools and technology behind the aircraft of the future, or take a look at how digital twins and data analytics are changing aerospace development, make sure you pack this issue in your carry-on bag. We guarantee that you will have something good to read on the plane. ■

In this issue

Supersonic innovation and much more...

Aerospace engineers seem to be exceeding the speed of sound these days. Everywhere you look, from the Pilatus PC-24 Super Versatile Jet to the Siemens eAircraft projects, the world of aerospace is enjoying an innovation boom.

And this boom promises to continue with serious technology demonstrators, like the CityAirbus (pictured) and the Airbus E-Fan X, which will be ready to take to the skies in the near future. If all this talk of futuristic travel is a bit too much, make sure to catch up on the newest takes on industry classics. The Pilatus PC-24 is set to redefine the private jet market with the first production model already delivered, and the Chinese are ready to take on Boeing and Airbus with the approaching certification of the COMAC C919.

So aviation and aerospace fans, whether you are one of the lucky few who enjoyed a transatlantic flight on the Concorde, the world's first supersonic jet; someone who has started making plans for their first commercial e-flight in 2030, or perhaps are just in the mood to check up on how ESA's GAIA telescope is doing mapping the universe, we have something for everyone who is dreaming big these days in the world of aerospace.

Dream big and enjoy!

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Airbus

Simcenter

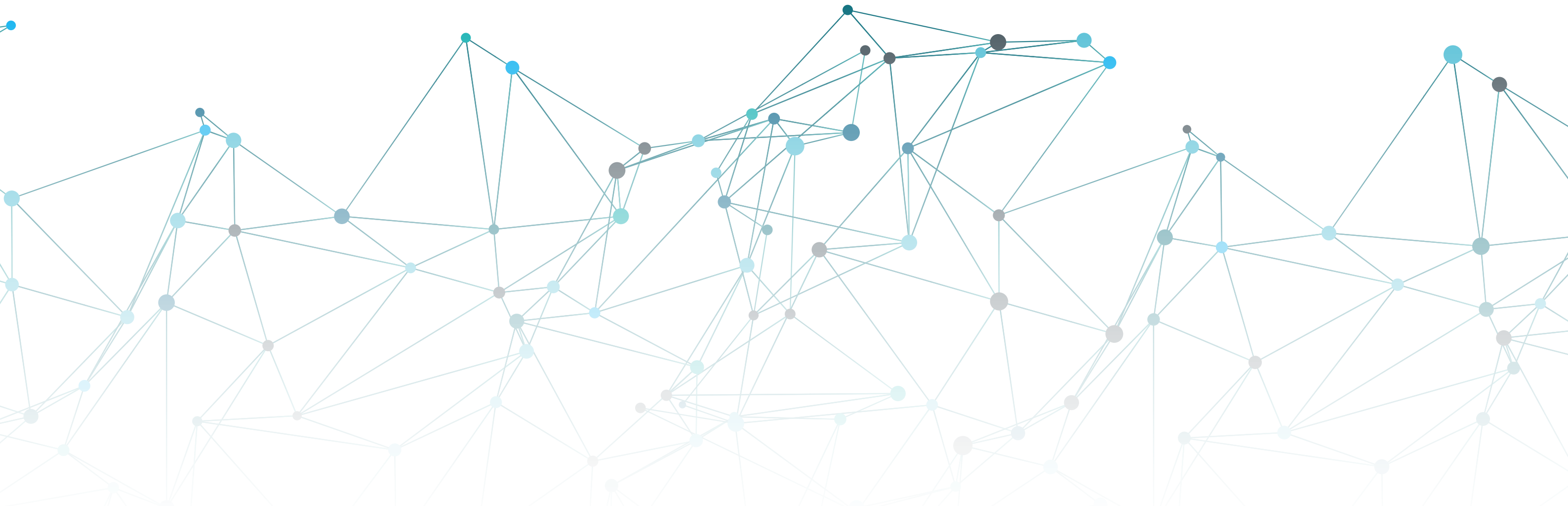
Will twins help us set foot on Mars?

On March 27, 2015 at the Baikonur Cosmodrome in Kazakhstan, a Soyuz spacecraft was launched to send NASA astronaut Scott Kelly and Roscosmos cosmonaut Mikhail Kornienko to the International Space Station (ISS) for a one-year mission. Their goal? Collect scientific data, just like they would do during any other ISS expedition, but this time also act as guinea pigs in a study on the effects of long-term space flight on the human body.

NASA's choice of Kelly was not coincidental because he had already participated in three space missions. But this time, his participation yielded another special bonus: Scott has an identical twin brother, Mark, who is also an astronaut. This gave NASA the exceptional opportunity to compare two identical sets of genes: one in space, and one on the ground. And so the famous NASA Twins Study was born. As we write this, researchers are publishing their results. These unique insights will bring us one step closer to long-term space exploration, like taking humans to Mars, which NASA hopes to accomplish somewhere in the 2030s.

However, the Kelly twins won't be the only ones to play a role in this next giant leap for mankind. To achieve this new milestone in human history, unprecedented technological advancement will be required in many fields, such as new propulsion methods, better telecommunication systems, revolutionary electronics, ultra-light and sustainable structures and materials, and much more. Amongst this myriad of innovation, there is one constant. Whatever kind of craft qualifies for such an ambitious mission will need to be lighter than what is available today, more resistant to extreme conditions over longer periods of time, and more autonomous. To meet such challenging requirements, it will be crucial that conventional approaches to design, certification, maintenance and sustainability will shift to the next paradigm: the digital twin.

Using a digital twin approach can best be described as building and maintaining a large collection of ultra-realistic models and data that can predict product behavior during the entire lifecycle via simulation and, preferably, in real time. These models come in several scales and instances for various applications, integrate multiple aspects, contain the best available and physical descriptions, and mirror the life of the real product. When a digital twin is deployed to its full extent, it tracks information on all the parameters that influence a product's operation. This includes initial design and further refinement, manufacturing-related deviations, modifications, uncertainties and updates as well as sensor data from the on-board integrated vehicle health



management (IVHM) system, maintenance history and all available historical and fleet data obtained using data mining.

The advantages that come with a digital twin approach will help us surmount many of the current obstacles we face before we set foot on the Red Planet. First of all, it will help engineers be more precise during development and manufacturing. Ultra-realistic modeling allows them to work with smaller design tolerances, minor fabrication uncertainties and lower stochastic variability for product use. This will result in a huge weight reduction, a better chance to meet the mission-critical fuel requirements, and a more accurate view of sustainability. On top of that, once the mission has started, a digital twin will allow systems to continuously send feedback to the design team so that engineers can evaluate performance and health, verify if everything works according to plan, and take corrective actions if needed. Ultimately, a digital twin could make products smart and autonomous by enabling self-healing mechanisms, or systems that automatically adapt the mission profile to loading, performance and energy consumption. For missions like the one to Mars, this could dramatically increase the probability of success.

As a leading provider of product lifecycle management (PLM) and manufacturing operations management (MOM) solutions, Siemens PLM Software helps thousands of companies across industries realize innovation by helping them optimize processes, from planning, development, manufacturing and production to product use until end of life. Converting the digital twin vision into an infrastructure with tangible solutions naturally fits these activities. Siemens PLM Software wants to offer engineers the most comprehensive, state-of-the-art solution set to build and maintain the digital twin.

There is still work to be done, however, even though the digital twin concept has already proven valuable on many occasions. For example, think of Curiosity, the Mars rover, which was virtually tested with Siemens PLM Software solutions, before executing hundreds of complex steps without human intervention and making a safe landing on the Red Planet. Today we are seeing the digital twin process emerge throughout the aerospace industry, and we hope you enjoy discovering some of the many examples of that in this magazine. Nevertheless, aviation and space manufacturers expect many new methods and developments during the coming decades that will enlarge the current scope of the digital twin, especially in the fields of modeling realism, computational power as well as powerful and robust data management.

At Siemens PLM Software, we are organizing our development efforts to meet this demand. Our new Simcenter™ software portfolio has been designed to offer engineers a holistic set of cutting-edge technologies that support them during the entire development cycle and help them deliver innovations for complex products more effectively and with greater confidence. Using Simcenter enables you to integrate 1D simulation, 3D computer-aided engineering (CAE), controls, physical testing, visualization, multidisciplinary design exploration, and data analytics in a managed context. It combines decades of experience by putting well-known products such as Simcenter Testlab™ software, Simcenter Amesim (formerly LMS Imagine.Lab Amesim™ software), Simcenter™ Nastran® software, Femap™ software, Simcenter STAR-CCM+™ software, HEEDS™ software and more under one umbrella. It features Simcenter 3D as the combined successor of NX CAE, LMS Virtual.Lab™ software and LMS Samtech™ software. By connecting Simcenter to Teamcenter as its underlying data management system, Siemens will be removing all boundaries that exist between design and life after product delivery.

Will this alone bring humans to Mars? No. Saying so would disregard all the inventive thinking that our customers are doing every day. But just like what Scott and Mark Kelly did for NASA’s Twins Study, a Simcenter digital twin could possibly provide the critical information you require to complete your mission. ■

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HB-VSA

Crafted in Switzerland: The Super Versatile Jet

In 2010, the Pilatus PC-24 was an idea on paper. As the engineers like to say, it was a clean sheet. In February 2018, only eight years later, the first PC-24 was certified by the European Aviation Safety Agency (EASA) and Federal Aviation Administration (FAA) and delivered on time to the first customer, PlaneSense, an American fractional aircraft ownership service provider.

There are a lot of things that make the PC-24 truly unique. Sure, it has that famous Pilatus land-almost-anywhere, short-field performance – a trait that is part of the Pilatus DNA.

And taking a note from the successful Pilatus PC-12, it has a pallet-size cargo door so passengers can easily load up all the luggage they need, including a motorbike.

But unlike its rough-and-tough little brother, the famous PC-6, or the popular turboprop, the PC-12, the twin-engine PC-24 adds a certain element of jet-set glamour to the Pilatus menu with a spacious, customized cabin, a light jet performance range, and the ability to land at over 20,000 airports -- including unpaved and high-altitude runways.

But how do you make something like this? We tracked down several members of the development team in the quaint Alpine town of Stans, Switzerland to find out firsthand. ■

The making of the PC-24

The first thing you hear when you talk to Nicola Buonomo and Alessandro Scotti is just how passionate they are about the Pilatus PC-24, a jet the two engineers have been working on the past eight years.

A team of over 300 highly skilled engineers was tasked with the development of the PC-24, the next great aircraft from Pilatus. We talked to Nicola Buonomo and Alessandro Scotti, who were part of this team. Buonomo is an Italian loads and dynamics lead engineer, who started working at Pilatus in 1999 as the sole loads engineer. Today, there is a team of seven experts. “The first plane I worked on was the PC-21, then the PC-9, the PC-7, the PC-12 and now the PC-24. That’s my career in a nutshell. Nineteen years. Time flies.”

Scotti is from Milan, Italy and is a loads and flutter specialist, who started at Pilatus eight years ago by working on the computational load data for flutter testing for the PC-21. He joined the PC-24 team to help Buonomo develop the aeroelastic simulation model that would allow the team to deal with the complexity of designing a plane like the PC-24.

“When we started to develop the PC-24, we tried to bring the flexibility of the PC-12 into the PC-24 design," says Buonomo. "We knew that our customers wanted to have a plane that could fly faster and longer while keeping the same Pilatus PC-12 characteristics, like the cargo door and the flexible landing and takeoff capabilities. One idea was that our customers could load a motorbike in the back of the plane. Obviously, doing all this was a challenge."

> *"The sooner you can get the right data on a test, the more confident everyone in the development process is. This can be the easiest and most difficult of tasks."*
>
> **Alessandro Scotti**
> **Loads and Flutter Specialist, Pilatus**

The clearest path to success
Unlike other companies in the aerospace sector, Pilatus is privately held and does not receive public funding. So Buonomo and Scotti and their team are always on the lookout for the clearest path to success. The team started with the concept design phase, then moved to preliminary design and, finally, a refined design. At the beginning, the team just used legacy tools to get a rough starting point for the computational data.

"We started with a blank piece of paper and we thought about the wings. Where do we put them: high or low? Where do we put the horizontal tail? Should it be high or low? What about the engines?" asks Buonomo.

"The more we progressed with the conceptual phase, the more we understood the limits," says Scotti. "Then we started looking at other tools. Nicola and I have different backgrounds, so he was already looking at the Simcenter portfolio and I had experience with similar LMS testing tools at my former job. We were definitely going in the same direction."

Providing value early in the process
They started to think about how to integrate tools like Simcenter 3D (formerly LMS Virtual.Lab software) and Simcenter Testlab software early in the process. Working in loads, they knew they had to think ahead to when the concept would be finalized and the real work would begin.

"We knew that there would be a learning curve. We started using Simcenter Testlab because we knew it was a valuable tool as well as Simcenter 3D to look at our GVT process. We started exploring these tools way before we even had to do a test because we had to think ahead. Otherwise, we would be late with the data. Since we are at the beginning of the chain, we would slow down the entire PC-24 process," adds Buonomo.

The team integrated the Simcenter tools in parallel with the PC-24 development process. When they started they were still using methods used during the PC-12 development, but the team knew they would have to do things differently this time.

"The PC-24 was a challenge. Technically speaking, we were going from a turboprop to twin jet engines. This speed range was a big jump for Pilatus. We were exploring areas where we had never been before," says Buonomo.

"We needed to find the right tools so that we could achieve our goal, which was basically to provide the right load data and analysis results to the other internal teams. The other teams are always complaining that we load engineers are always late. Being a loads engineer, you constantly have a target on your back."

"The sooner you can get the right data on a test, the more confident everyone in the development process is. This can be the easiest and most difficult of tasks," adds Scotti.

"You can't forget about the test pilots as well. They are the ones that have to fly the prototype to the limits on the flight envelope and they do ask questions about flutter and wing movements and loads during test flights. With Simcenter Testlab, we could show them the mode shapes. This gives them the confidence in the plane to continue to push the limits and fly to the edge."

Moving toward a digital twin
The team wanted the best possible solution for the PC-24 using the Simcenter tools. They started using Simcenter Testlab to handle all the testing they would have to do on the PC-24, a new design for Pilatus. This was especially important because they would need to be compliant with the various certification agencies to get the plane in the sky commercially.

"Getting Simcenter Testlab into the process at the beginning was our main goal, but then we added Simcenter 3D into the picture. This step really improves the quality of the finite

The maiden flight of the PC-24 aircraft, instrumented with extra sensors for certification, with the team in the background.

element model using the GVT testing data and correlation. So we started to count on Simcenter 3D as well to update our models and optimize them so that they reflected reality," explains Scotti.

Creating an accurate digital twin is tricky, but when engineers know they have an accurate simulation, showing compliancy becomes much easier. Engineers can prove what they are measuring is well correlated to what was originally calculated numerically in the beginning of the process.

"The final result has to be a digital twin according to the certification agencies. It has to reflect reality. From an engineering point of view, we tend to talk about correlation. It all does work together. You use the test data to test the physical aircraft, but you also use it to improve your finite element models. I guess you could say that it is a joint venture between physical reality and the digital world," adds Buonomo.

Certification success

One of the concerns that you hear in the hallways of some aircraft manufacturers today is certification issues. But not at Pilatus. The company successfully obtained both EASA and FAA certification in December 2017. It was the first European company to apply successfully for a light jet in the AMC-S20 certification area.

"EASA put a lot of pressure on us in terms of requirements. Whether we liked it or not, we had to improve the way we worked. In terms of testing, they wanted to know what we were doing and why. This is when we could really use the Simcenter tools to present the GVT and flutter test results. With GVT testing, we could show that we had good correlation with our models and our test data. With the flutter test, we could show how it was going and what modes were changing," explains Scotti.

"Those two Simcenter tools, Simcenter 3D and Simcenter Testlab, really helped us build confidence in our certification case. It was a very positive experience," adds Buonomo.

Tackling tough deadlines with Simcenter Engineering

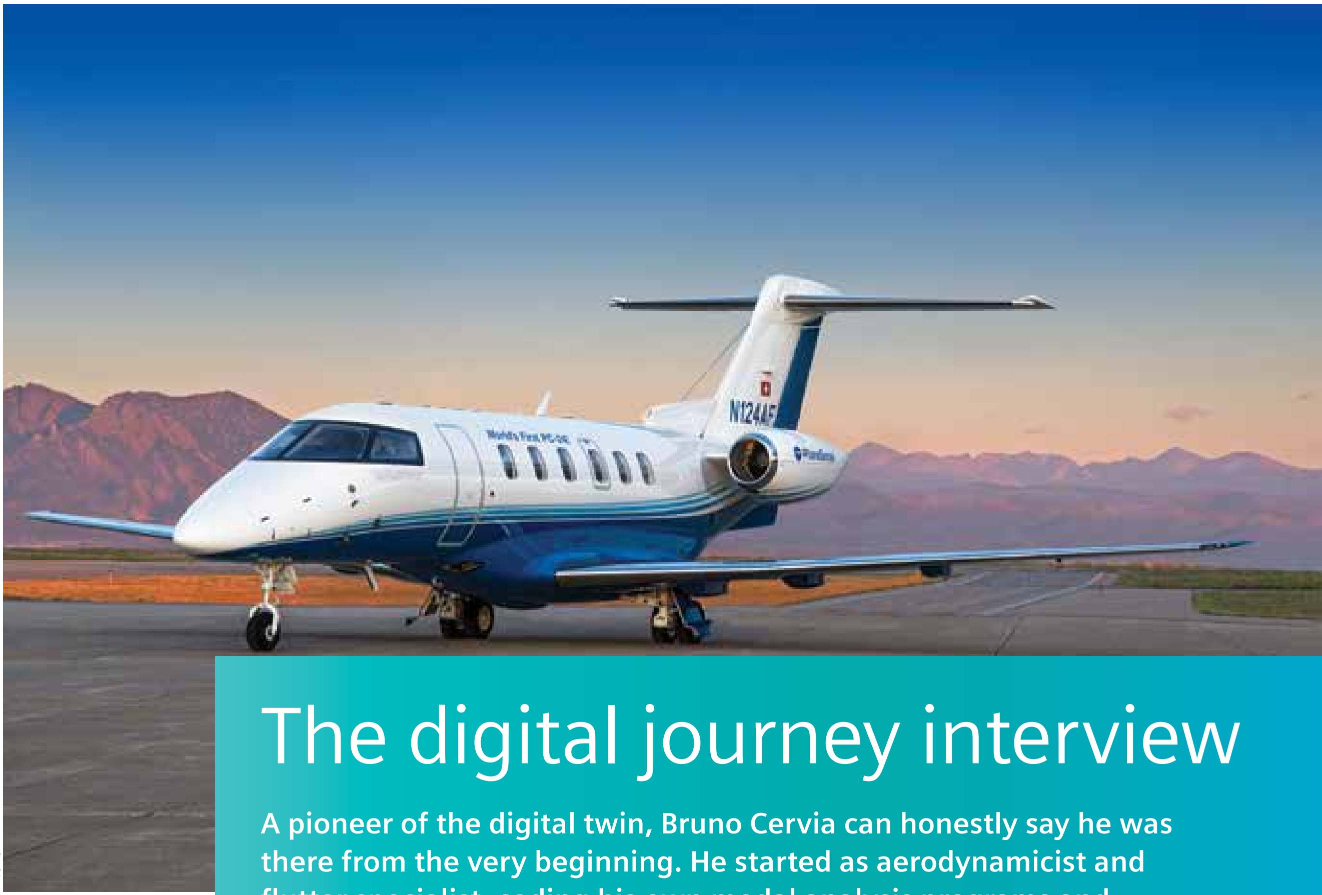
Since the PC-24 was a clean sheet project, the team knew they needed to learn a lot from the first ground vibration test (GVT) and its results. Using these two Simcenter tools provided a shortcut to speeding up the process and improving structural knowledge, the models and the prototype.

Like most GVT campaigns, the team spent two weeks testing 24/7 along with the GVT experts from Simcenter Engineering services. Thanks to Simcenter Engineering's own Simcenter SCADAS™ hardware system with 256 channels, the team could get to the data they needed by just adding an accelerometer or two.

"We changed a few things during the design so we had to test for that during the GVT as well. Luckily, with the Simcenter tools and the team we had from Simcenter Engineering, we could explore exactly what we needed during the testing phase," says Buonomo.

Scotti adds, "By adding Simcenter 3D to the picture, we could see that we were going in the right direction. A key point of success for our GVT was that we were using the same software as the Simcenter team. Since we all were using Simcenter Testlab and Simcenter 3D, we could read the data right onsite. It was a main reason that our testing campaign went so quickly and in the right direction.

"The flexibility of the Simcenter Engineering team and their quick response was really one of the key success points of getting this GVT done on time while proving that our solutions were working as well. Everyone at Pilatus really appreciated the help from the Simcenter Engineering team. The flexibility and know-how from the Simcenter team helped us stick to really tight deadlines." ■



The digital journey interview

A pioneer of the digital twin, Bruno Cervia can honestly say he was there from the very beginning. He started as aerodynamicist and flutter specialist, coding his own modal analysis programs and running tests using the classic hammer-on-the-wing method.

Today, Cervia is the vice president of research and development and deputy chief executive officer (DCEO) of Pilatus, and he leads the team that revolutionized the aircraft development process on the Pilatus PC-24. This enabled Pilatus to create one of the industry's first accurate digital twins and put the new PC-24 in the skies in record time.

What makes Pilatus so exceptional?
Pilatus is the right size. We are bigger than the small OEMs that might not be able to afford the right tools and processes. At the same time, we are not too big. When I started we were 800 people and today we are 2,000. With 2,000 employees, we keep all the core aspects here in Stans, Switzerland. We have research and development, production, customer service, flight testing and an airport. This is all a huge advantage because we can afford to use the same state-of-the-art tools that Airbus or Boeing use, but at the same time our communication processes are very short across all the disciplines. We are very multi-disciplinary.

You started working on the digital twin decades ago, correct?
When I started 32 years ago, I was working on the wind tunnel testing for the PC-12 and we were using Unigraphics, the predecessor of NX, which was then owned by McDonnell Douglas. This was our first attempt at creating a digital twin of the PC-12. We were taking the CAD model of the PC-12 and utilizing the mesh to create a computation of the fluid dynamics to run the aeroelastic model. It was an embryo of the digital twin. The tools were very basic, even primitive compared to what we use today.

It sounds like quite the journey. How do you explain your success today?
At Pilatus, we always say: Think big. Start small. We started with a great vision and it has been a pleasure to go through all these tool developments concurrently with our product development over the years, with what is today Siemens. In all fairness, the real partnership started mainly with Siemens. Siemens understood that Pilatus was the ideal company to do concurrent development.

You have your production on the same site. How did this impact the digital twin process?
Thirty years ago, we started with the CAD side of the digital twin as well as the CAM side. This was really a key to success to have these early digital twin tools productive from the start.

If we look back to the beginning, this was already an excellent experience. At that time, there were no links to computational aerodynamics or aeroelastic calculations. There were some very basic links to stress analysis. With Nastran, we didn't have major interfaces with the CAD side.

Siemens understood the importance of mastering the digital twin and started to acquire the tools that we had from different suppliers, like the FE modeling, the aeroelastic analysis, the dynamic analysis of the landing gears, and, from Mentor Graphics, one of its newest acquisitions, the electronics and cabling assembly, for example.

With Siemens, we have moved way ahead. We feel that we are really in a partnership with Siemens. It is a long-term partnership based on trust and reciprocal respect.

Obviously, this digital twin didn't happen overnight. Could you share some key milestones?
When we started, our 3D digital twin was mostly used for machining components. Over time, we developed it more extensively. There were more features to develop 3D surfaces. This was a major step when we could efficiently utilize the CAD model in a free form not only from the modeling side, but also the tooling and manufacturing side.

The next step was to introduce composites with Fibersim and other products that belong to the same digital twin now. This let us do laser positioning and the correct layering. We could increase the use of composites as such. This was a great advantage.

When we built the PC-21, this was the first time that we integrated the cabling in the digital twin. Prior to that, we were only doing wire diagrams, but this was not enough. You needed to optimize the cable positions in the fuselage. We started to pioneer the digital twin work in this area and finally with the PC-24, we could fully exploit all the digital twin cabling with the Mentor Graphics solution.

What about your experiences on the testing side?
If I remember correctly, 30 years ago we ran an aeroelastic flutter test on our PC-9 and then the PC-12. I wrote the acquisition program so I was basically exciting the frame with a hammer and trying to find out if the accelerometers were matching the plot and making the mode shapes for the modal analysis basically by myself. It was good fun, but you have to consider at the time we were developing strictly subsonic aircraft. They weren't certified to fly transonic.

Bruno Cervia (vice president, R&D/DCEO) together with Othmar Ziörjen (director airworthiness & services) holding the PC-24 certificate.

I imagine this has changed quite a bit with the PC-24?
On the PC-24, we fully exploited the Simcenter Testlab and Simcenter 3D solutions. We could do a full correlation of the Simcenter FE model with the GVT data. This was paramount when working in transonic. Transonic is a bit of a devil. It is not fully predictable. The fully nonlinear behavior of the aerodynamics, the interaction of the shock waves with the boundary layer, the complex structure, the modal analysis: mistakes are not allowed. You must be able to safely predict the aeroelastic behavior of the structure.

Why was this so exceptional?
The major advantage with using Simcenter Testlab was that we could perform modal analysis in real-time during the flight test. We tried to do it before, but we were only looking at each individual accelerometer and then transferring the data into real time in the frequency domain, and watching the graphs in the telemetry room. This was more of an art than a science.

With the PC-24, thanks to the Simcenter software suite and the expertise of our engineers, we could perform real-time multi-input/multi-output analysis. This provided not just a fast development cycle, but a safe development cycle. You can imagine that you risk your pilot, your program and your reputation if anything goes wrong. It is a huge risk that you take as a company when you run your first program in the transonic envelope.

What did the pilot think about the new testing process?
The pilots actually entered into the loop. They were working with our engineers and specialists. They could look at the models and see, almost feel, the shapes of the modes and the bending of the structure. This provided a high level of confidence for the flight test team. When you have a tough and demanding program, this is an incredibly positive experience. Basically you can consistently and seamlessly flight test without any interruption. You do not need to stop and analyze the data. With a 500 million Swiss franc program like this, every day of flight testing is incredibly valuable because the customers are waiting for the aircraft.

You received parallel certification from the European Aviation Safety Agency (EASA) and the Federal Aviation Administration (FAA). How did the test results impact the certification process?
The biggest challenge for any new program is certification. You can see this issue with several of our competitors when the certification process has dragged on for years. You have to validate your prototype and show conformity of your prototype for certification. In other words, when you certify an aircraft, you must prove that your test article is fully conformant with the article you want to certify. We had to prove that the PC-24 we were flying was conforming to the models and drawings that were presented to the certification organizations, who were overviewing the project and reviewing all our flight test results in order to grant us certification.

What role did your digital twin play in the certification process?
If you want to certify a product, you need 100 percent accuracy in your digital twin. Any element can affect the outcome of your flight test in such a complex environment, so you need this accurate predictability.

"Our digital twin is a real one-to-one digital twin with a design and production organization behind it."

Bruno Cervia
Vice President of Research and Development and Deputy CEO - Pilatus

Our digital twin is not a dream. It is not some isolated digital twin buried in an engineering department run by a group of geeky scientists - no, our digital twin is a real one-to-one digital twin with a design and production organization behind it. You know everyone calls their models a digital twin, but I think I would refer to what many are doing as a digital cousin. Many people confuse a digital cousin with a digital twin.

Why the need for 100 percent accuracy?
This is where there was a really big gain in the process. People say this software feature is better than that one or that this software is more user friendly. This is the last 10 percent of the story. The first 90 percent of the story is to show the full conformity between the design and the product. And this is not an easy task.

We put Siemens under enormous pressure to prove their products and integrate the bill-of-materials (BOM) into the digital twin process. We knew we needed this to be successful. The best thing is the recognition from both the EASA and FAA. Once the certification agencies had the confidence that our test articles fully conformed, it was a rather easy game.

Mastering the bill-of-materials was critical then?
This was an incredible but a very tough experience. We had the best Siemens specialists here from all over the world to support us. We looked at thousands of parts with a very dynamic project management considering how many times the prototypes change because of production issues and improvements you implement during the flight tests.

Did Teamcenter play a role as well?
We have two pillars in Pilatus. One pillar is Siemens' Teamcenter, our interface for production. Our other pillar is SAP, which we use for logistics and production planning.

Today, the limitation is managing the huge amount of data and information. Just the PC-24's bill-of-materials is incredible: it is four times bigger than what we had on the PC-12. We have to spend some time to optimize the tools so they can run bigger assemblies and bigger amounts of data.

So what is next?
As partners, we need to start to work more on big data. The PC-24 is flying now and producing huge amounts of data. I need to manage this data and get feedback from the aircraft in real-time. When the aircraft flies, I want to see how things are going. We need to take care of the digital twins throughout the entire lifecycle.

This program has been a major commitment for us. Our customer base was looking for this product. It has been an incredible experience and we already have received the first positive customer feedback.

Of course, we had to almost double the infrastructure of our company. We have invested more than 500,000 Swiss francs in the development program itself and 250,000,000 in new production infrastructure. We couldn't afford any risk.

We are grateful to Siemens for their assistance. And by the way, we plan on selling 50 PC-24 Super Versatile Jets a year for many years to come. ■

The Spirit of Erlangen

Experts are predicting that 2030 is the year – the year when we will all be able to book a flight on a hybrid-electric plane. With continuous progress on a variety of eAircraft projects, the team at Siemens has quite a few propulsion systems for flying demonstrators in the pipeline, including the E-Fan X partnership with Airbus and Rolls-Royce, the CityAirbus demonstrator, and, of course, the continued work on the Extra 330LE aircraft. So buckle up, e-flight is approaching faster than you think.

Electrification represents an overwhelming amount of innovation and it is excellent news for the future of the global aviation community in regards to industry sustainability and environmental, noise and pollution issues. But perhaps most amazing is the timing. Less than a decade ago in 2011, the world's first hybrid-electric aircraft, the DA36 eStar, took its maiden flight. Inside this unique airplane was a revolutionary integrated drive train from Siemens' Drive Technologies Division in Erlangen, Germany.

The innovative spirit that started the eAircraft revolution in Erlangen, Germany continues at record-breaking speed today. Within just three short years, a young and enthusiastic team of experts has gone from the electric concept stage to developing a working digital twin and flying two-seater, the Extra 330LE.

Weighing approximately 1,000 kilograms (kg), the Extra 330LE serves as a demonstrator and test bed for the new electric drive system. Since it is an aerobatic airplane, it is particularly well suited for taking the system to its limits to test and enhance the design. Currently, test flights take about 20 minutes, including take-off, climbing and five minutes of full-performance flight. The Extra 330LE completed its maiden flight on July 4, 2016 in Dinslaken, Germany. It was the first time an electric plane had flown in the performance class of a quarter of a megawatt. This event was a milestone, paving the way to the development of hybrid-electric planes with more passenger seats.

The electric motor weighs just 50 kilograms, yet supplies permanent electrical power of 260 kilowatts – five times the level of comparable drive systems. The underlying technology serves as the basis for several of its e-flight partnerships, including the CityAirbus and the E-Fan X.

The beauty of electric drives is their scalability. Siemens hopes to see the first hybrid-electric planes with 100 passengers and a range of about 1,000 kilometers by 2030. ■

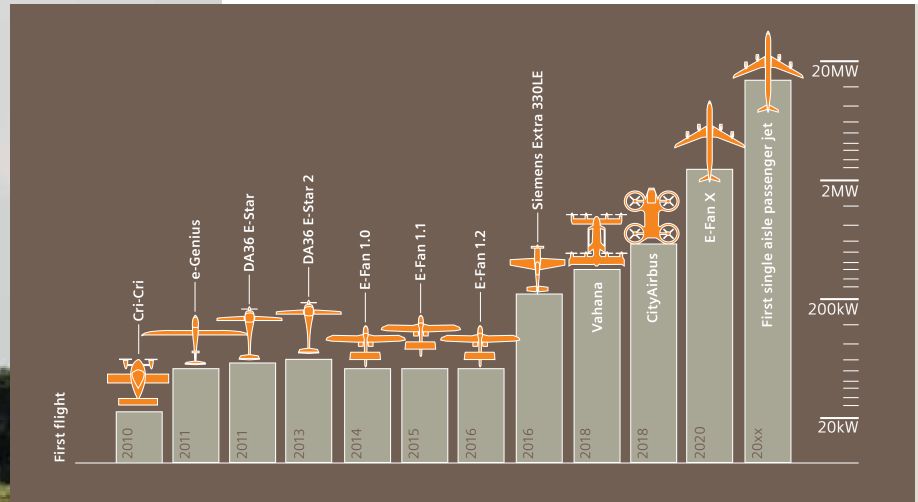
Siemens AG

Behind the scenes with the Siemens eAircraft team in Erlangen, Germany

In early January 2018, we caught up with the team responsible for the digital twin development in Bau 32 (Building 32) on the Siemens campus in Erlangen, Germany. Once you clear the security post, it is just a short walk down the street and past a rather lovely pond that you discover the real hub of Siemens eAircraft activity.

By now, we all know that Simcenter plays a big role in the success story that is the Siemens powered Extra 330LE. But the million-dollar question is how exactly? Basically, the engineers created an accurate digital twin that let them design everything in the virtual world before building it in reality. But the beauty of the Simcenter portfolio is that, from an engineering standpoint, it is an all-encompassing solution.

“The setup is very special because all the software is connected," states Toni Amende, engineer with the Siemens eAircraft team. "So we come from Teamcenter, where the data is stored, and then we go to the NX CAD application, and from this application we jump into CAE, which, in this case, is the thermal simulation. From here, we can go bi-directionally into Simcenter STAR-CCM+. This gives



The evolution of the various e-planes continues to progress not only in size, but in power as well — and all in a rather short period of time.

us more CFD capabilities in terms of bigger models, simulating all systems, and a greater degree of accuracy in the details."

Although today the team is focusing more on the details, when they started the process, Simcenter was a critical tool, especially tackling overall weight reduction required for the Siemens eAircraft. During the early development phase, the team used the topology optimization tool within Simcenter to investigate which type of structure would be optimal.

Dr. Gunar Reinicke, lead engineer, Siemens eAircraft team, explains, "We are always interested in having the lightest components, which fulfill our needs. Simcenter gives us the right tools in order to develop, investigate and understand the product in detail and also deliver the product on time."

Another area in which the team revolutionized the process was systems architecture engineering, using Simcenter Amesim software, a unique suite of tools for modeling and analyzing multi-domain systems. Using a set of libraries containing predefined components for different physical domains, system architects can model, analyze and predict the performance of the mechatronics system in the Extra 330LE.

"I need to look at many different architectures and configurations. To do this I need to be able to quickly rearrange the model. With the tools we used before such as in-house codes and 3D simulations, this would take weeks and with Simcenter Amesim, we can do this in a matter of days," states Marcus Sons, system architect, Siemens eAircraft team.

Today the team is using the 1D solution Simcenter Amesim to test physical components individually by simulating the surrounding individual components within Simcenter Amesim.

"So we do hardware-in-the-loop and software-in-the-loop testing. And we only have one physical component and Simcenter Amesim can do the rest. For me, 1D simulation is all about speed and flexibility," adds Sons.

As the team starts the journey towards final testing and flight certification, the industry-standard testing solutions in the Simcenter portfolio will help verify and validate the Siemens eAircraft.

This will be especially challenging because even though there are established procedures for testing aircraft that have been developed over generations, this is not the case for electric aircraft. Since the certification standards still need to be worked out, it is important to have the right testing tools.

"The Simcenter SCADAS XS is very nice because it is small and light. We just have to worry about putting sensors into the airframe," says Anton Dilcher, integration project manager. Simcenter SCADAS XS can be put almost anywhere. By combining this with a Simcenter Testlab system, we are able to very quickly look at test data right after the flight to make sure that the data is right and that we have good data. At the same time, it remains a very powerful tool so that we can do detailed analysis when we are back in the office."

"And this is the real secret. You can only take such big steps by simulating all the effects that dominate the design of such a machine at the same time in a consistent environment. This is how Simcenter has helped us do this leap ahead," concludes Dr. Frank Anton, head of Siemens eAircraft. ■

The world of aviation is electrifying

How did Siemens become involved in the eAircraft project?
Dr. Anton: The first discussions started around 2010 with the former CTO of Airbus Jean Botti. Both of us felt that electric propulsion could be feasible. We started with very small test flights: just a 60-kilowatt motor glider. We realized that there was more potential than we thought. Today, Siemens, Airbus and Rolls-Royce have started a bigger partnership, the E-Fan X, to show the feasibility of using even more powerful two-megawatt electric generators on board a regional plane by 2020.

How is the Siemens eAircraft influencing new concepts in aviation?
Dr. Leuridan: The Siemens eAircraft is actually quite revolutionary. We will see aircraft evolve into different structures, like blended wing structures and more distributed propulsion. It will push the systems that are integrated into the aircraft as well in terms of new technology. On the production side, we will see progress with additive manufacturing and new materials, like components. New aircraft design will also take advantage of connectivity, like the Internet of Things and cloud computing. This can be used to optimize lifecycle management when the planes are in service. This information will be used during the next stages of development as well.

What are some of the challenges facing electric propulsion?
Dr. Anton: There are two challenges. The first is the power density needs to be one degree of magnitude higher than a normal drive train. For example, one kilogram of machine weight usually required one kilowatt, but for electric propulsion we have to count on 10 kilowatts or even more. This is challenge number one. The second challenge is certification. Aviation needs absolute safety. All subsystems and components have to be certified. This is the second and maybe the bigger challenge that we are facing.

What still needs to happen from an engineering point of view?
Dr. Leuridan: There is definitely a further need to integrate systems engineering into the design process. By coupling

systems engineering with product lifecycle management, we can provide more capabilities for end-to-end traceability from requirements to functional analysis and logical system design. This is also critical when meeting safety standards.

What is the secret of success for the Siemens eAircraft?
Dr. Anton: I get asked this question quite often: what is the secret to this machine? Are we using the best materials? Yes, of course, we are using the best available materials. We are using the best technologies. The most important thing is that we simulate all the effects of the electric drive train – the machine, the power electrics, the magnetic effects, the stress-strain balances, the cooling – everything at the same time in one Simcenter environment. This is the basic secret.

Most of the design work happens on the digital twin and not on a physical prototype, correct?
Dr. Anton: The digital twin changes along the way. As the engineers come up with better ideas, we test these ideas on the digital twin to find out whether the idea is good enough or not.

At the end, we have our final digital twin and the real prototype, in this case the Siemens eAircraft. So from this point, the development works in parallel. We use the Simcenter portfolio to prepare the digital twin and prepare for the physical testing phase.

As the industry shifts towards simulation, what happens to testing?
Dr. Leuridan: Obviously, you will never fly a plane before completing an elaborate certification process. Testing will continue to play an important role in this process. Within the Simcenter portfolio, we have a number of solutions that are already used throughout the industry worldwide for certification like ground vibration testing (GVT) and flutter testing.

Of course, with the Siemens eAircraft, you can think differently about fly-over noise, another industry challenge at the moment. We have been working together with Dr. Anton's team and I think we've done the first-ever fly-over noise measurements on an electric airplane in the world.

So when will we all be flying a Siemens eAircraft and where will we be able to go?
Dr. Anton: We share the vision with Airbus that by 2030 hybrid-electric aircraft will be carrying 100 to 150 passengers over typical regional distances of 500- to 600-kilometers, maybe even 1,000 kilometers. We are seeing this developing very fast.

My personal goal is in my lifetime I will buy a ticket for a hybrid-electric flight between Nuremberg and Paris. I will be sitting in a hybrid-electric plane with 50 other people who have bought a ticket for the same purpose – to get from A to B and finding this absolutely normal. ■

"The most important thing is that we simulate all the effects – everything at the same time in one Simcenter environment. This is the basic secret."

Dr. Frank Anton
Head of eAircraft, Siemens AG


AIRBUS
AIRBUS

Shrinking time-to-market

Airbus Helicopters uses Simcenter Amesim and Simcenter Engineering from component and system design to real-time simulation

In 1993, NHIndustries, a joint venture between Airbus, Leonardo Helicopters and Fokker Aerostructures, started to design the NH90, a heavy military helicopter. Thirteen years later, it entered into service. Today, the competition has become so fierce that helicopter manufacturers usually have no more than four years to develop their most sophisticated models.

The pace of technological change has markedly increased. As a result, manufacturers must make the right choices when designing increasingly complex systems. They have to validate systems integration earlier in the development process by applying a collaborative modeling approach throughout the design cycle.

In addition, rotorcraft manufacturers must provide their customers with reliable pilot training solutions. However, flight simulators must often be delivered before the first helicopter is produced. The level D full flight simulator (FFS), which is the current standard with comprehensive high-fidelity aerodynamic and systems modeling, is increasingly being requested, most recently for the Airbus Helicopters H160, a new medium-sized twin engine helicopter.

Investing in simulation

Airbus Helicopters, part of the Airbus Group, is Europe's leading fully integrated aeronautical company, known for its high-performing, cost-effective, safe and comfortable helicopters, such as the H160.

To maintain its leadership position, the company has invested in virtual testing to meet many needs along the development cycle, such as rapid prototyping, desktop simulation, real-time pilot-in-the loop simulation, test rig development and training solutions. Airbus Helicopters' simulation policy stipulates that, if possible, a unique model should be used for each component throughout the V-cycle. To apply this simulation approach to physical system modeling, Airbus Helicopters needed a tool that was highly predictable and could be used to easily integrate models into the real-time environment. The company found such a tool in Simcenter Amesim software from Siemens PLM Software.

Reducing hydraulic system prototype costs

Airbus Helicopters has used Simcenter Amesim for hydraulic and air conditioning system simulation since 2007. In 2009, the company extended the use of Simcenter Amesim to thermo-hydraulic component and system modeling.

Prior to adopting Simcenter Amesim, specialists in the hydraulic and flight controls department at Airbus Helicopters were only able to obtain a quasi-static representation of the hydraulic system. The majority of parameters were determined during the prototype testing phase. Moreover, these hydraulics models were incompatible with a broader co-simulation environment. To take into account the behavior of the hydraulic circuit in real-time simulation, Airbus Helicopters previously built another model using a specification that a hydraulics specialist had prepared for a supplier. However, those simulations had not been predictive and required the involvement of the hydraulic engineer. The use of Simcenter Amesim enabled hydraulics design engineers to move from a quasi-static to a dynamic world. Now, not only can they model hydraulic systems and subsystems, such as pumps, actuators and tanks, they can also use the same model to gain insight into the systems' behavior when interacting with thermal, mechanical or electrical systems.

"By using Simcenter Amesim for the hydraulic system design, we estimate that we have reduced optimization time by a factor of three, and prototype costs by a factor of four," says Thibaut Marger, former analysis and simulation specialist in the hydraulic and flight controls department at Airbus Helicopters Research and Development. "The first prototype that we manufacture is to fine-tune the Simcenter Amesim model. The system optimization is performed virtually. That leads to the creation of a new prototype that is very close to optimizing performance."

Providing top-notch services

Siemens PLM Software has also helped Airbus Helicopters find a solution to carry out real-time simulation, which supports system engineering as well as test rig and full flight simulator design.

Thanks to its experience in methodology development, Simcenter Engineering and Consulting services provided Airbus Helicopters with best-in-class support to convert hydraulic circuit plant models built using Simcenter Amesim into real-time compatible models. These models were then used on Airbus Helicopters' unique real-time simulation platform for the development of the Airbus Helicopters H175.

"Simcenter Amesim enabled integration specialists to create easily understandable models which can be shared within our organization."

Franck Nicolas
Head of Simulation and Tools, Airbus Helicopters

First, Simcenter Engineering and Consulting analyzed the computer processing unit (CPU) time required by existing hydraulics models, and helped Airbus Helicopters optimize its models, taking into account potential dysfunctions, such as a broken hydraulic pump, actuator leakage or inadvertent back-up pump activation. Next, the company used a unique model so it could understand the thermal dynamic behavior of the system for many scenarios. Finally, the model was reduced in order to keep only the phenomena that are compatible with the real-time, fixed step solver frequency.

Using several standard Simcenter Amesim libraries, capabilities and tools made this project feasible. These included the Simcenter Amesim Hydraulics library, the Simcenter Amesim Hydraulic Component Design library, the Simcenter Amesim Signal, Control library and the Simcenter Amesim Mechanical library; and super component functionality, activity index, linear analysis and performance analyzer tools.

Reducing flight test hours by half

Following the successful use of Simcenter Amesim for hydraulic system design and validation, the company decided to launch a benchmark project aimed at extending this simulation approach to the fuel system. The integration of the fuel system into the H160 had been mainly validated during intensive test rig sessions and flight tests. Even though the H160 was nearing entry into service, the goal of this pilot project was to validate this simulation approach for future helicopter models, and enable Airbus Helicopters to reduce the fuel system test cycles by a factor of two.

Moreover, there was room for improving design processes: earlier on, in addition to the physical model developed by fuel specialists, a real-time model had been developed by integration specialists that provided input on the fuel system's macroscopic behavior vis a vis the other components. Without continuous collaboration between the two groups, it was difficult to efficiently address complex engineering challenges, such as: valve and pipe sizing, the design of complexly shaped fuel tanks, fuel transfer analysis that depended on the attitude and accelerations of the helicopter, and physical fluid characteristics analysis that depended on environmental conditions such as temperature or pressure.

It was also critical to validate the location of fuel gauges to precisely estimate the fuel remaining in each tank (throughout various mission types, and as a function of helicopter attitude) and facilitate the integration of the fuel system with the avionics, and thus to be able to reliably inform the crew on the remaining mission time.

“Using the thermal, hydraulic, mechanical and fuel equipment capabilities of Simcenter Amesim, we can create a model that enables us to accurately predict the fuel system’s behavior,” says Stéphane Amerio, simulation engineer at Airbus Helicopters. “It would be too costly and dangerous to carry out this analysis on real test benches.”

“As a flight test engineer, I provide information to the design office in order to fine-tune the simulation model and continuously improve our way of working,” says Nicolas Certain, flight test engineer at Airbus Helicopters. “Not only does simulation enable us to reduce test cycles, it also allows us to focus on major issues related to the flight performance.”

“Simcenter Amesim enabled integration specialists to create easily understandable models that can be shared within our organization,” explains Franck Nicolas, head of simulation and tools at Airbus Helicopters. “The unique model can be adapted to our analysis goal, and can be used for system design, controls validation, simulators and test rigs.”

Adapting to customer needs

This benchmark project has enabled Airbus Helicopters to build a predictive model and validate it by comparing simulation and test results.

“This new approach is being used on new innovative concepts during the design phase and has enabled us to reduce the fuel system design phase by 12 months and the integration phase by nine months,” states Nicolas. “After three months of joint work with the Simcenter Engineering and Consulting team, aimed at defining a step-by-step, real-time methodology to achieve desired performance, the specialists in fuel simulation have been convinced and the decision has been made to extend this approach to all real-time fuel models.”

This project has resulted in Airbus Helicopters identifying new opportunities to enhance its simulation process. Since the same model is re-used and refined throughout the design cycle, development specialists are now interested not only in the performance of their system, but also in the way it interacts with other systems.

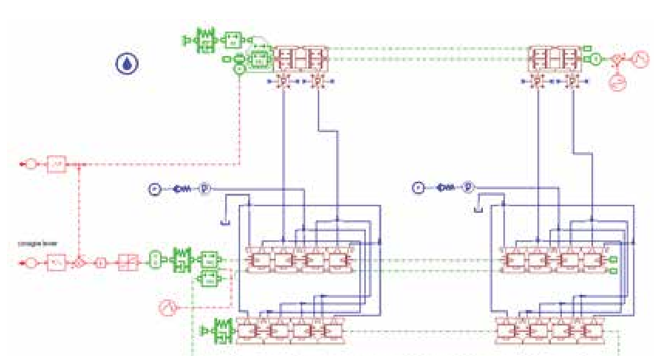
It allows them to assess the system performance under different conditions and modes as well as to anticipate undesirable behavior in the system prior to it being integrated into a helicopter.

“Being able to anticipate a problem is a significant source of cost and risk reduction,” says Nicolas Damiani, simulation expert within the simulation department of the engineering directoraty. “This approach allows us to master the development cycle and delivery time as well as to reduce our risk exposure related to the fuel development and integration activities that we usually face in such programs.”

Airbus Helicopters is studying the possibility of extending this process to other systems, and this approach is attracting interest from other Airbus entities.

“The use of Simcenter Amesim is part of a broader model- and simulation-based systems engineering approach aimed at detecting specification and design errors early in the design cycle,” says Pascal Paper, model-based systems engineering (MBSE) method and tools stream leader at Airbus Helicopters. “Model-based systems engineering is a key enabler of requirements validation, knowledge capitalization and multidisciplinary collaboration within Airbus entities.” ■

The pilot project is aimed at validating the simulation approach in the H160 in order to reduce the fuel system test cycles by a factor of two for upcoming helicopter models.



Simcenter Amesim allows Airbus Helicopters to analyze detailed transient hydraulic actuator behavior.

The route to the digital twin

Nicolas Damiani, an expert in simulation and operational analysis in the simulation department at Airbus Helicopters Research and Development in Marignane, France, has spent more than 28 years working in the digital world. Today, he supports the research and development teams at Airbus Helicopters. He took some time earlier this year to explain the ever-changing world of simulation and why Airbus Helicopters is well on its way towards developing a digital twin, or virtual iron bird, as experts in the industry like to call it.

Nicolas, what is your role at Airbus Helicopters today?
As an expert in digitalization and simulation, I have quite a few roles. I have to keep an eye on the standards and the overall simulation architecture. I also support various project teams when needed and prepare the simulation technologies for the future. Basically, I try to make sure that our overall work in simulation results in successful products – delivering our helicopters on time and within budget that also meet quality requirements.

How has the role of simulation changed at Airbus Helicopters?
I have been lucky to witness the evolution of the field over the past 28 years. Starting from simple problem-solving and troubleshooting project work to our groundbreaking model development with Simcenter Amesim, I have seen the simulation side grow brick-by-brick, you might say. Some decades ago, simulation was mainly used in the upper part of the V-cycle for man-machine interfaces and a few research studies.

Today, we have a solid simulation strategy and model architecture in place in which simulation plays an enormously important role in our product development. Our simulation products are now part of the test means for performing the verification and certification activities. It is not yet perfect, but it is well on its way.

Why has simulation become so essential?
Simulating a helicopter is an immensely complex task. It has even become more complex as the amount of embedded software and number of stakeholders, including suppliers, has drastically increased. Nevertheless, the simulation architecture is constantly evolving as certain systems and subsystem models have gained maturity.

Like other companies, Airbus Helicopters not only uses simulation to iron out development issues, it also plays a vital role in making sure that we can deliver our products on time and within budget. In our industry, reducing the development cycle and detecting design inconsistencies as early as possible have become key factors of success. Simulation is an answer to our time-to-market and design-to-cost constraints.

In your opinion, how mature is your model?
Our simulation model as a whole could be considered very precise. Of course, there are some areas that are more mature than others in the overall architecture. When we talk about our simulation model, what people tend to forget is that it is actually a hugely complex model that contains 400-to-500 individual models that work together in real-time and in a validated environment.

That must take an enormous amount of computing power.
We are lucky the world of computing is getting faster and faster as well as more efficient economically. When we run the full simulation, we use approximately 24 CPUs. It doesn't take up all of our capacity, but it comes close.

What is a typical trend you see today at Airbus Helicopters?
With more precision in our simulation models, we are truly on the right path to predictive engineering in the world of simulation. If you look at this mega-model that we have, composed of 400-to-500 individually validated models, it is a system within systems. Just think about all the original source code that goes into something like this. It is immense. The source code is validated. It is locked into the model and we don't review it. It is precise without having to question it.

Nicolas Damiani, expert in simulation and operational analysis in the simulation department at Airbus Helicopters Research and Development.

The next challenges for Airbus Helicopters will be our capacity to perform joint development in a simulation environment and to progressively replace physical verification by virtual verification, the simulation being a means of compliance.

Are there specific areas that you are focusing on?
Of course, like other industries, we focus on fuel efficiency. In our development process, this happens at a very early stage during the modeling of the hydraulic, fuel and electric subsystems using Simcenter Amesim. To give an example, the actual model physics, be it the pressure or the pump action, are validated in Simcenter Amesim. With this type of validation so early in the process, you can start to answer bigger questions like fuel efficiency using simulation in a predictive fashion. Our system solution for fuel efficiency that we developed with Simcenter Amesim and Simcenter Engineering is certainly beginning to bear fruit.

"Our system solution for fuel efficiency that we developed with Simcenter Amesim and Simcenter Engineering is certainly beginning to bear fruit."

Nicolas Damiani

What are the other ways that you use this model?
Our model is critical to confirm the quality of the prototype, what we call Helicopter Zero. Before the first flight we are beginning to use it for supply chain validation. More and more, we are seeing our suppliers involved and using the validated model to create parts and components that are suited for the job.

What do you think you'll be focusing on the next five years?
My job is critical considering the enormous complexity of helicopter development. There are still an enormous amount of bad surprises or things that can go wrong. Today, you can't fly without simulation: at the modeling stage, the pilot-in-the-loop stage, the prototyping stage, the validation stage, the flight simulation and the training stage. Simulation is critical to the entire development chain and my main concern in the next years will be to support more engineers as they jump into this new digital way of designing helicopters.

One of the most typical simulation applications that everyone knows is the flight simulator. Is there a connection?
What is surprising after all these years is that the answer is 'yes.' In recent years, the simulation world was divided between engineering simulation and training simulation, with limited sharing of models or tools. Basically, a training simulation (like a flight simulator) was developed after the helicopter certification (despite the customer expectation to get trained before receiving their first helicopters) by re-using a limited part of the engineering simulation. Nowadays, the same simulation product is continuously improved from preliminary design phase up to the certification phase. At any moment in time, we can derive from our engineering simulation product a training simulation product (compatible with the helicopter delivery).

So your development model can easily be linked to the final product or the flight simulator. In other words, the digital twin can be recycled for other applications?
The beauty of simulation is that it can be coupled with various other types of simulation. All you need is the code. This means that you can link the virtual flight simulator as well as pilot-in-the-loop development to practically any application. This might impact flight tests, other co-simulations like maintenance schedules, and even other in-house development programs. The possibilities are endless.

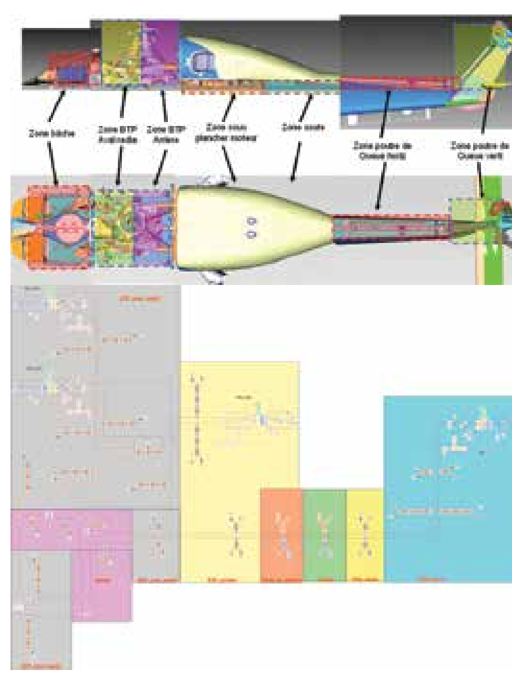
This is rather a tough question:
Will there eventually be a truly virtual test bench?
We place an enormous amount of importance on virtual testing at the moment. If you look at how we work with Helicopter Zero and the physical iron bird, this has totally changed! Today, the heart of testing is Helicopter Zero; tomorrow it will be simulation. By using real-time validated models and virtual iron bird (VIB) solutions, we can certainly engineer an extremely accurate helicopter solely in the virtual world.

What does the future of helicopter aviation look like?
Lots of technology, but as experts, it is up to us to make the right choices. There is a lot of technology out there and we need to be vigilant and make the right choices as experts when it comes to smart technology and artificial intelligence.

There is a side of smart technology in which it becomes artificial intelligence and where machines will really be able to learn behavior. This cannot be taken lightly. Once we open that door, there is no going back. ■

The Simcenter platform supports numerous key engineering processes at Airbus Helicopters to help engineers assess thermal and structural aspects from the component level through system integration validation. For instance, dynamic and vibration analysis are major challenges throughout the lifecycle from the initial helicopter development program until in-service operation. From both a comfort and safety perspective, Airbus Helicopters relies on various products in the Simcenter simulation and testing portfolio to develop an accurate digital twin. For example, using the Simcenter 3D package as well as dedicated Simcenter Testlab and Simcenter SCADAS solutions, experts can evaluate accurate loads within transmission systems, perform predictive FE models, assess the structural or acoustic performance in flight and perform ground vibration testing to collect data for model correlation. In the future, the digital twin could even be enriched with data analytics captured during in-flight operations.

The virtual iron bird of the Airbus H160 at the test facilities of Airbus Helicopters Research and Development in Marignane, France.



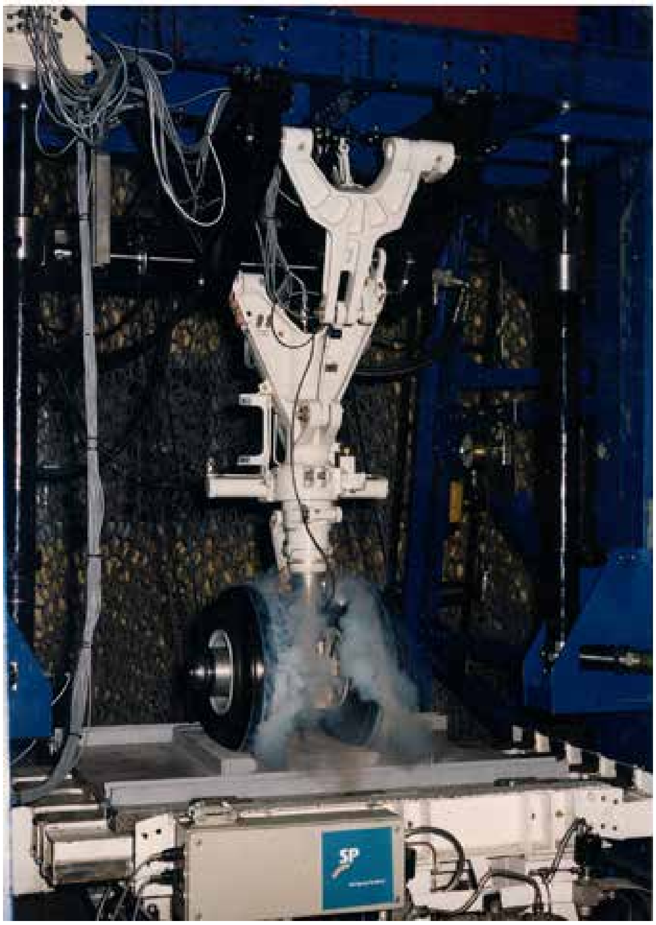
Saving weight without compromising performance

GKN Aerospace Fokker Landing Gear counts on Simcenter to design safe and reliable landing gear

Credits: rypson - iStock Editorial / Getty Images Plus

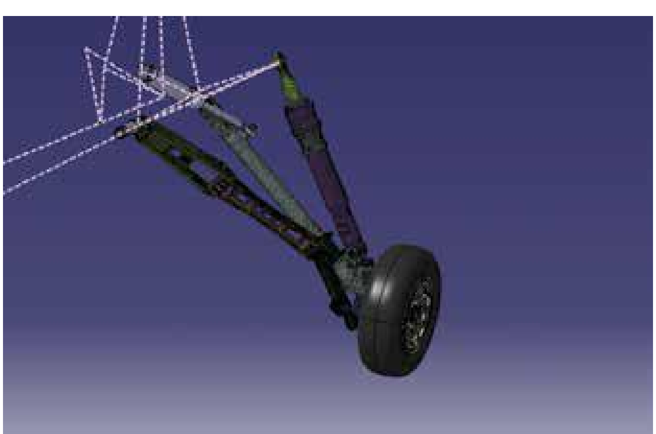
Flying around in enormous mechanical birds has been one of the greatest achievements in human history. When talking about planes, most people think of parts such as wings, engines, airframe or tail. But just as no bird could ever survive without strong legs so it could touch ground safely, a robust and reliable landing gear is among the most vital parts of an aircraft. Landing gear designs can come in various shapes and sizes. Because the choice of a certain configuration greatly impacts many overall behavioral aspects of the entire aircraft, the landing gear needs to be developed along with the rest of the structure.

The main purpose of a landing system is to reduce impact loads by absorbing and dissipating kinetic energy. But it also must provide suspension as well as wheel steering and braking while the plane is taxiing on the tarmac. Most landing gear systems, especially for faster aircraft, are retractable to reduce aerodynamic drag during flight. But these are usually heavier and can take up to 3 percent of the total aircraft weight. Especially for military gear, design engineers must make sure that it all fits in a limited volume with prescribed aircraft interfaces.



GKN Landing Gear

Landing gear drop test.



GKN Landing Gear

Multi-body simulation of the landing gear.

Reducing weight and volume without compromising operational performance and safety is a real challenge. And as the development shouldn't delay the design of the overall aircraft, landing gear manufacturers are looking for solutions that help them investigate as many alternatives as possible in the shortest possible time.

Over 30 years of experience

The engineers at GKN Aerospace Fokker Landing Gear in Helmond, the Netherlands have mastered the art of delivering safe and reliable landing gears to aviation original equipment manufacturers (OEMs). For more than 30 years, specialists have gathered competencies in design, development and production, as well as for the repair and overhaul of landing gear systems for helicopters and airplanes. GKN Landing Gear delivers exceptional value to its customers through tailored designs, optimized development processes, rigorous qualification and certification standards, cutting-edge production technologies and maintenance, repair and operations (MRO) capabilities. Among their current programs are prestigious aircraft such as the Lockheed Martin F-35 Lightning II Joint Strike Fighter military airplane and the Boeing Apache AH-64 helicopter. GKN Landing Gear is making large investments in research and development (R&D), aiming to soon deliver the first load-carrying composite parts on a landing gear.

Dr. Bert Verbeek, a specialist in developing engineering dynamics, and Guus Kolster, commercial director at GKN Landing Gear, have been around for many years. They have seen on many occasions how proof of experience has played an essential role in being considered a reliable partner by OEMs. But they also feel that over the last decade the pressure on time and budget has dramatically increased, and they've noticed the industry has evolved to even tighter schedules. These trends significantly influence product design. "Unlike consumer products, landing gears don't come in huge sales volumes," says Kolster. "As a consequence, the time and budget we spend on development has an enormous impact on commercial success. There is little room for trial and error."

Increased credibility and a 30 percent time gain

Providing powerful software tools and delivering efficient simulation solutions are core business objectives of Siemens PLM Software. For many years, the software solutions in the Simcenter portfolio have been part of the standard development process at GKN Landing Gear. These included LMS Virtual.Lab™ Motion software for 3D multibody dynamics analysis, now part of Simcenter 3D, and LMS Imagine.Lab Amesim software for 1D multiphysics simulation, now Simcenter Amesim.

Verbeek was one of the first engineers to begin the successful collaboration between GKN Landing Gear and Siemens. "Before we had a different software package for 3D multi-body simulation of the mechanism, which we had to combine with a lot of user programming for damping models and other systems," he says. "The process was time-consuming and error-prone. Moreover, it was a real hassle to transfer knowledge to new members of the team, which is greatly improved now by using Simcenter Amesim. We realized that we needed a more professional and streamlined process. That would not only make our lives easier, but it would also increase our credibility and ability to collaborate with industry partners."

Simcenter 3D and SImcenter Amesim resonate well in the aviation market, and the market acceptance was certainly one of the crucial arguments in selecting these products. "As landing gear development needs to happen in parallel with the rest of the structure, we have to be able to effectively exchange information and ideas with our partners," says Verbeek. "Our customers give us the information we need to calculate ground and interface loads, and from our side we give them our models so that they can refine the full aircraft simulation. All this can happen much more easily if we work on a similar platform, or at least with software packages that communicate well with each other. Also, when we meet during a project to exchange ideas or preliminary results, it increases our credibility if we show that we have been using a professional solution with a solid reputation, and if we can present data and display it in a format that looks familiar."

"When we compare the current process using Simcenter to the previous one, we can for certain say that we saved up to 30 percent in time."

Dr. Bert Verbeek
Specialist, Development Engineer Dynamics, GKN Landing Gear

Deploying a new solution is never easy. It takes training and effort to adapt users to a new graphical user interface (GUI), initiate a set of models and build databases with validated components. "The support professionals from Siemens PLM Software helped us with the daily use of the software," explains Verbeek. "In addition, we do small projects with their R&D team to improve the modeling accuracy of certain parts."

Along with the new software environment, the effective collaboration with Siemens PLM Software engineers resulted in a spectacular time gain. "When we compare the current process using Simcenter to the previous one, we can say for certain that we saved up to 30 percent in time," confirms Verbeek. "We could use this time to further validate and improve physical descriptions in our models and to do additional simulations. We are working towards parametric 3D models for most of the important landing gear configurations as well as parametric 1D libraries for shock absorbers and tires."

Automating the optimization process

At present the engineers have the entire simulation process installed and it is operating smoothly, including interfaces between various software, as well as parametric models and optimization loops for performance, weight and cost. Now the company wants to take it to the next level and automate the process. To do so, they are again collaborating with Siemens PLM Software. "First of all, we are further extending and improving our libraries," says Verbeek. "We are creating additional 1D models for shock absorbers, as well as 3D multibody models and computer-aided design (CAD) parts. And we are looking into new shimmy modeling options. And secondly, we are having scripts created to run the entire simulation process without user interaction. This is yet another project that we have started with Siemens PLM Software experts."

The engineers are convinced this additional work will further boost their productivity. "By moving the original process to a professional software environment, we had already saved about 30 percent of time, but we expect even more from this automation," Verbeek says. "In the current process we still actually evaluate just one configuration that we choose upfront, as we don't have time to build several more. This means that we still have to rely a lot on intuition and experience. We are sure that this situation will change when we have these automation scripts." Kolster is also very optimistic about the outcome. "Considering that we have about three or four fundamentally different 3D layouts that we can each combine with a few shock absorber models, my rough estimation is that after automation we could investigate about 15 to 20 design layouts within the same timeframe," he says. ■

Powering the flights of the future

March 21, 1999: somewhere in the Egyptian desert. Bertrand Piccard had just succeeded in an around-the-world ballooning trip on the Breitling Orbiter 3. But he knew he had to take it further. The next time around he decided he would fly without fuel. This was the idea that started Solar Impulse.

Today, most of us know about the success story that ended in Abu Dhabi on July 26, 2016. After more than 40,000 kilometers, 16 stops and 8 world records, Solar Impulse 2 and its pilots Piccard and André Borschberg made aviation history. They also most likely changed the way we think about powering the flights of the future.

Around the world in a solar airplane with the Simcenter portfolio

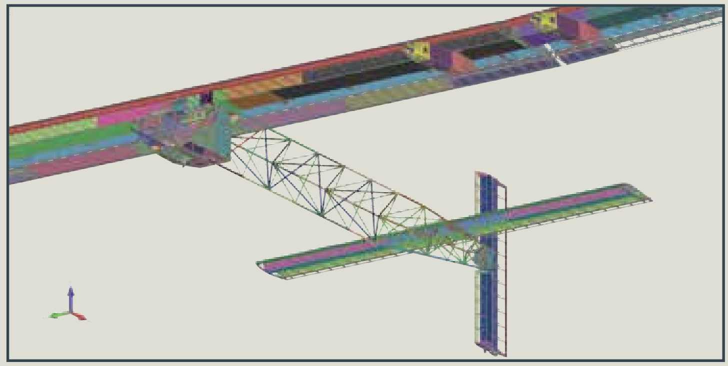
For those of you who don't know the story: Solar Impulse is a solar-powered aircraft project led by Piccard, a Swiss psychiatrist and aeronaut who co-piloted the first balloon to circle the world nonstop, and Borschberg, a Swiss engineer and entrepreneur. The project's goal was to circumnavigate the earth in a fixed-wing aircraft that used only solar power. The journey started March 9, 2015 in Abu Dhabi.

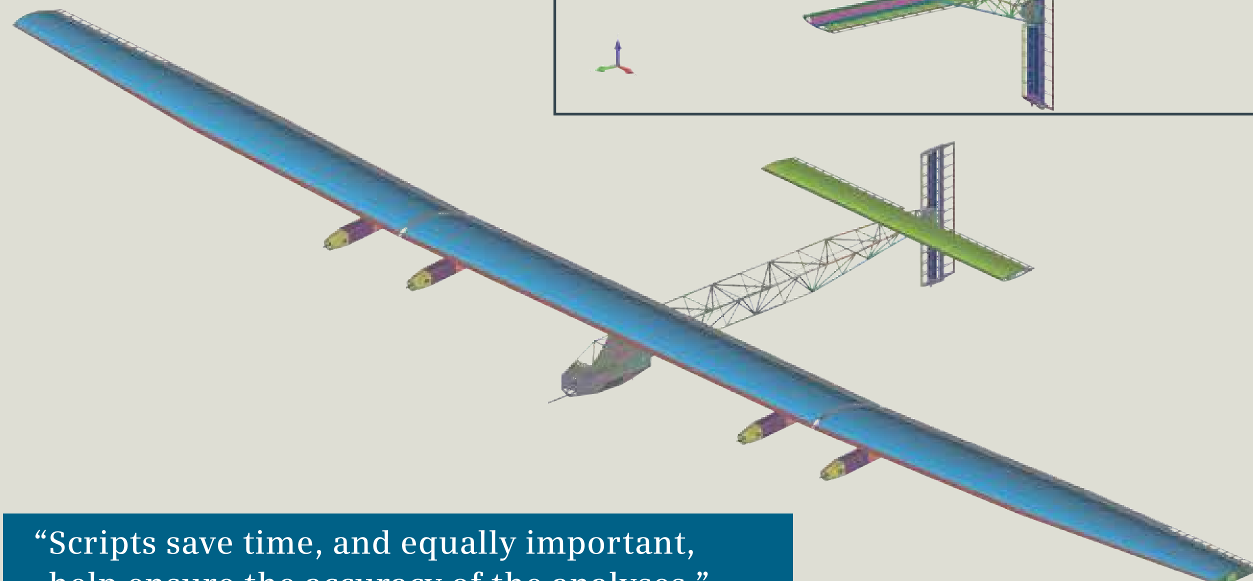
Solar Impulse 2 bears the Swiss aircraft registration HB-SIB. Its predecessor was the HB-SIA, which took its maiden flight in 2009 and flew an entire diurnal solar cycle, including nearly nine hours of night flying, in a 26-hour flight in July 2010.

Based on experiences with the HB-SIA, Solar Impulse 2 was given a longer wingspan of 71.9 meters/236 feet, slightly less than that of the world's largest passenger airplane, the Airbus A380. It also has a cockpit that's three times larger to allow for multi-day transcontinental and transoceanic flights.

One of the most remarkable aspects of Solar Impulse 2 is that even with such a massive wingspan and all of the batteries required (633 kilograms), it weighs just slightly more than an average automobile (2,300 kilograms). Obviously, minimizing weight was one of the most critical design challenges.

"The plane needs a lot of batteries, and batteries are heavy," explains Geri Piller, head of structural analysis at Solar Impulse. "Yet the plane gets only a small amount of energy from the solar cells, so it has to be really light."





> "Scripts save time, and equally important, help ensure the accuracy of the analyses."
>
> **Geri Piller**
> Head of Structural Analysis, Solar Impulse

One FEA solution for many types of analysis

Piller's structural analysis team, which consists of Piller and four other engineers, used Femap™ software with the NX™ Nastran® software solver, part of the Simcenter portfolio, as the finite element analysis (FEA) solution for the design of both the HB-SIA and the HB-SIB.

Piller chose Femap with NX Nastran for the Solar Impulse project because it is used by the Swiss engineering company and Siemens PLM Software partner AeroFEM, which was contracted by Solar Impulse to perform special analyses like aeroelasticity and rotor dynamics. Using Femap with NX Nastran supports all types of analysis (strength, buckling, large deformation, etc.) required for the Solar Impulse project, and choosing this solution allowed the two groups to collaborate seamlessly.

"The engineers at AeroFEM are like part of my team," Piller says. "Our collaboration is really great."

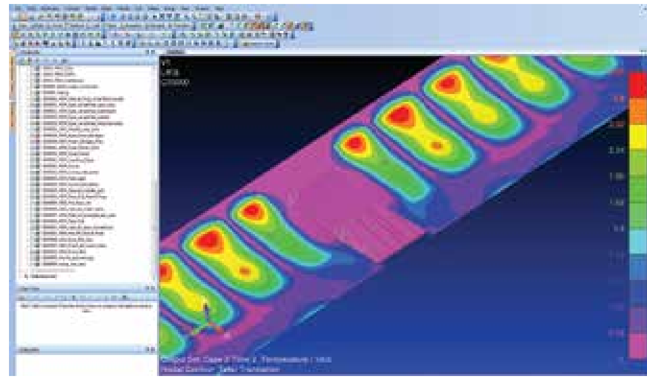
Strong functionality for setting up analyses and interpreting results

The Solar Impulse design team's geometry, which was created with CATIA® software in STEP or IGES format, can be used in Femap. The geometry becomes the basis for finite element (FE) models. Femap also has its own modeling functionality, which Piller finds easy to use, especially for the composite materials that make up a large portion of the plane. "Ply definition is really easy," he says. "We were able to jump into that topic very quickly using Femap."

As an example of how the analysts use both imported geometry and the modeling tools in Femap, Piller describes some work done on the plane's wing structure. The analysts initially used the geometry of the wing's outer surfaces (generated with CATIA) to create a simple analysis model in order to look at load paths. Later, using Femap, they added 3D solid elements representing the Kevlar® aramid paper honeycomb core for more detailed analyses such as local and global buckling.

FE models for the plane's metal components range in size from 50,000 to 500,000 elements. The model of the main wing structure contains two million elements. Normally, the analysts evaluate 10 to 20 load cases, but endurance analyses look at as many as 160.

Piller's team took advantage of the Femap application programming interface (API) to write scripts that automated some of the analysis work. One very useful script applies the



By using Femap on this project, Piller and his colleagues were able to quickly determine how best to minimize the plane's weight while still meeting the rigors of an around-the-world adventure.

company's own programmed strength criteria for the composites, helping to automate laminate verification. Another runs the analyses of composite parts, and automatically evaluates the results according to the ply with the highest stresses, quickly showing where the failures are in the laminate or sandwich structure. "Scripts such as these save time and, equally important, help ensure the accuracy of the analyses," says Piller.

The analysts use the Femap data table frequently as a way of quickly summarizing and interpreting analysis results. The data ranking function, for example, quickly shows minimum and maximum stress values. "We use this capability a lot; what makes it really useful is that it's possible to combine output sets," Piller says.

Determining how to minimize weight

A concrete example of the value of the Simcenter solution is the plane's cockpit, where the FEA solution played a role in minimizing weight. The single-seat cockpit is tiny (3.8 cubic meters/134 cubic feet), but it's three times larger than the cockpit of the first Solar Impulse plane. (In fact, the Solar Impulse 2 cockpit is so much roomier, the Solar Impulse web site jokingly claims that the company had "upgraded the pilot to business class.") Although the second cockpit is three times larger, it weighs less than twice as much as the original (60 kilograms/132 pounds for the new cockpit versus 42 kilograms/93 pounds for the original).

The wing structure is another place where the Simcenter solution contributed to a significant weight reduction. The wing consists of a Kevlar honeycomb core covered with an advanced carbon fiber material. Analysts used Femap to optimize the amount of the carbon fiber plies so they could meet the needed loading conditions with the least amount of added weight. They were able to go from using a material weighing 100 grams per square meter to one weighing 25 grams per square meter, a significant weight reduction. Similarly, the motor gondola of the Solar Impulse 2 had to carry a heavier load, but the weight increase was kept to a minimum, in part by changing from a framework structure with fairing to a sandwich structure and, in part, by using FEA to optimize components such as facings and spar caps.

By using Femap on this project, Piller and his colleagues were able to quickly determine how best to minimize the plane's weight while still meeting the rigors of an around-the-world adventure. "Using Femap, we could quickly see what we had to work on and where we could optimize," Piller says. ■

"Using Femap, it was really fast to see what we had to work on and where we could optimize."

Geri Piller
Head of Structural Analysis, Solar Impulse

Sky_Blue/Getty Images

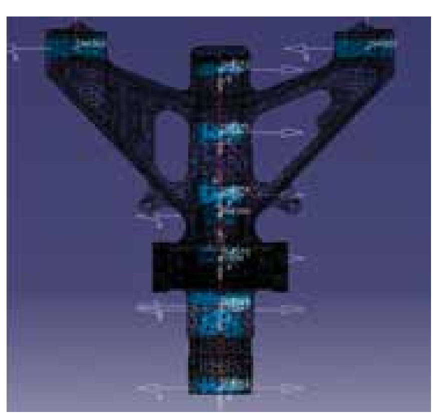
The rise of the Chinese aviation dynasty

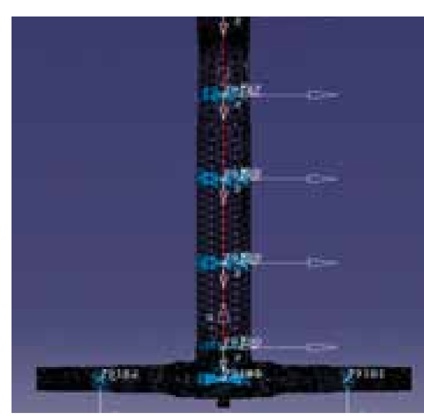
Chinese certification center SAACC supports COMAC C919 development with Simcenter

China is now one of eight countries on the planet that has developed a large aircraft. The other countries are the United States, Russia, Brazil, Canada, the United Kingdom, France and Germany. But developing a large commercial airliner and getting it certified are two different things. The Chinese aviation community seems to know this and they are taking the certification process of the COMAC C919 extremely seriously. The second of six planned test aircraft, the C919 AC102, successfully completed its maiden voyage in December 2017. Over the next several years, six (planned) test aircraft need to complete more than a 1,000 compliance verification tests as well as a series of ground vibration test campaigns, including static and fatigue tests for the entire aircraft.

For the global aviation industry, safety is the top priority. Any aircraft model must pass certification by a competent aircraft airworthiness certification authority, and it is a precondition for commissioning the aircraft model. Because of the technical content of airworthiness certification work, only a few nations with strong aviation technologies have authoritative airworthiness certification institutions. These include the U.S. Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA). In China, this important responsibility is borne by the Civil Airworthiness Certification Center under the Civil Aviation Administration of China (CAAC). The center has five certification institutions, including the Shanghai Aircraft Airworthiness Certification Center (SAACC) of CAAC, one of the earliest aircraft airworthiness certification bodies established in China. SAACC is responsible for airworthiness certification of all civil jet-propelled transportation aircraft, including Boeing, Airbus and other foreign aircraft models, before they enter the Chinese market. Other institutions are for post-certification management of qualification certificates for the domestically-made COMAC ARJ21-700; and for airworthiness certification of large firefighting/water-rescue amphibious aircraft and large aircraft such as the COMAC C919.

These responsibilities pose huge challenges for SAACC. These include how to define the airworthiness certification method and the content of verification in a timely manner





Parameterized landing gear simulation model established using Simcenter 3D.

General airworthiness compliance verification methods

Compliance verification work	Method code	Compliance verification method	Corresponding documents
Engineering review	M C0	Compliance statement – Quoting model design documents – Selection of formula and coefficients – Definitions	Model design documents compliance record
Test	M C1	Illustrative documents	Illustrations, drawings technical documents
	M C2	Analysis/calculations	Comprehensive illustration and verification report
	M C3	Safety evaluation	Safety analysis
	M C4	Lab test	Statement of test work
	M C5	Ground test	Test program
	M C6	Flight test	Test report
	M C8	Simulator test	Test results analysis
Check	M C7	Aircraft check	Observation/check report manufacturing compliance check records
Equipment qualifications	M C9	Equipment qualification	All of the above compliance test methods can be included in the equipment qualification program

considering the rapidly changing new technologies and increasingly complex application scenarios, and how to improve the efficiency and quality of airworthiness certification work while confirming safety. SAACC must also support and encourage aircraft makers to innovate various verification technologies.

Engineering challenges
In the process of aircraft airworthiness certification, aircraft makers must provide supporting documents for different certification items depending on the compliance verification methods specified by the airworthiness certification authorities. The above table lists general airworthiness compliance verification methods and corresponding documents required.

Airworthiness compliance verification methods
With respect to airworthiness certification of landing gear systems, past simulation means were not fully confirmed and demonstrated, so SAACC had to request that applicants adopt verification methods such as lab tests, ground tests and flight tests. The entire verification process was costly and time-consuming. Most of the tests require close cooperation with aircraft makers and overseas suppliers, which typically incurs significant communication costs.

Landing gear system certification involves multiple disciplines, such as the aircraft's overall design, landing gear structure design, control system design and hydraulic transmission system design, and is affected by various environmental factors (including tire and runway materials), so comprehensively judging the effects of such design and external environmental factors is an important component of landing gear airworthiness certification work. Considering such complex engineering issues, physical testing methods are limited. Simulation techniques must be used extensively to establish a complete and efficient parameterized analysis model and a compliance verification method based on analysis and calculation.

SAACC's choice
On the recommendations of several partners, in 2014 SAACC introduced LMS Virtual.Lab Motion software, now Simcenter 3D Motion, part of the Simcenter portfolio, as the key tool for solving the aforementioned issues. With professional technical support from Siemens PLM Software, SAACC successfully established a rigid-flexible multi-body dynamics simulation model for the landing gear system. The model is fully parameterized, so it can rapidly adjust the landing gear systems of different aircraft models, thus helping certification experts improve analysis verification and airworthiness judgment efficiency. The model also considers various complex design parameters and environmental parameters, which enables airworthiness certification experts to simulate conditions that are difficult to reproduce under many test conditions, thus significantly improving overall certification efficiency and confidence in examination work.

First airworthiness certification method developed in China
Using simulation, SAACC successfully developed a landing gear airworthiness compliance verification method based on analysis and calculation, and in 2016 successfully completed the "Research on Airliner Swing Vibration Airworthiness Certification Technology," which was

	Comac C919	Bombardier CS300	Irkut MC-21-300	Boeing 737-800	Airbus A320	Embraer E195
Entry into service	2019	2016	2016	1998	1988	2004
Seats	168	160	180	162-189	150	122
Length	38.9m	38.7m	42.3m	39.5m	37.5m	38.6m
Wingspan	35.8m	35.1	35.9	34.3m	34.1m	28.7m
Range	5,555km	6,112km	5,900km	5,765km	5,700km	4,077km

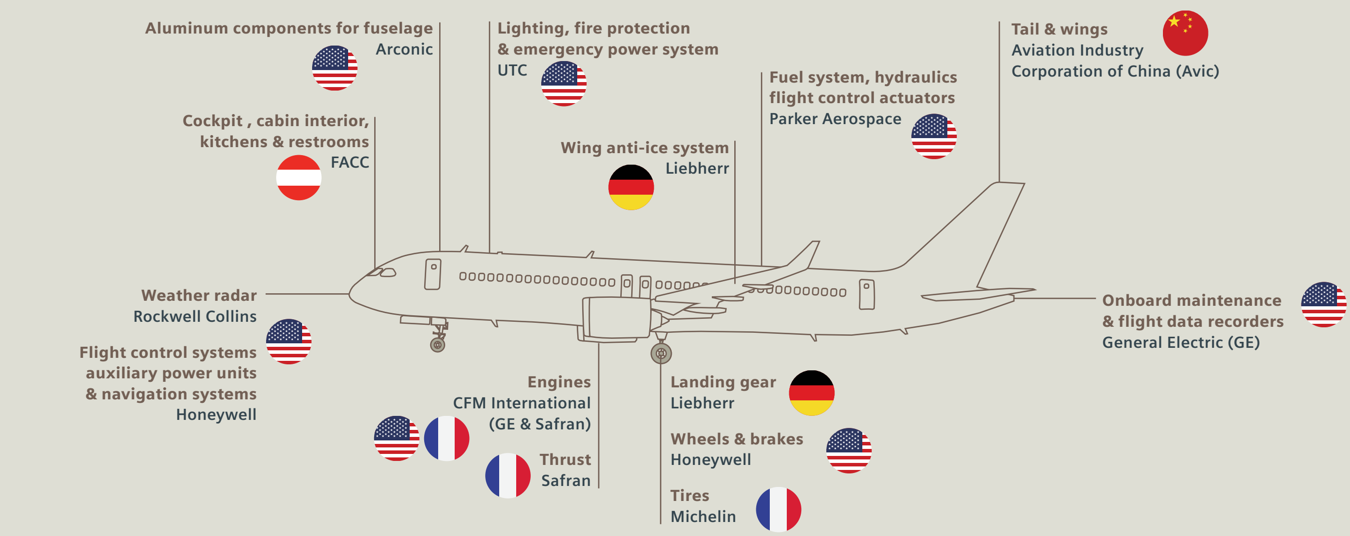
Source: Bombardier, United Aircraft Corporation, Boeing, Airbus, Embraer

the first airworthiness certification method developed in China.

With this method, SAACC successfully promotes the airworthiness compliance verification method for domestically-made large firefighting/water rescue amphibious aircraft and large aircraft, and provides important guidelines for subsequent analysis and test verification of relevant items.

“Simcenter plays a key role in our research and development of the landing gear airworthiness means of compliance and in assisting our compliance findings,” says Dr. He Xufei, landing gear airworthiness certification representative at SAACC. “Part of the case study and calculation work for this method is based on this software. Its ease of use and reliability of calculation are the key factors we considered in making this choice. In the future, we will also consider other simulation tools in Simcenter. We believe our cooperation with Siemens PLM Software will greatly help us further improve airworthiness certification work efficiency and quality, help civil aircraft manufacturers innovate, achieve the expected safety of new civil aircraft models and secure the safety of passengers.” ■

COMAC 919 supply chain overview



Source: Bloomberg, U.S. Global Investors, Airframer.com

Getty Images

Taking the brakes off innovation

Simcenter Amesim helps Aeronautics Institute of Technology prepare new engineers for the Brazilian aircraft industry

Like many countries around the world, Brazil is looking to improve the link between its engineering and science education and industry needs. Over the last decade, there has been an aggressive push that has resulted in improvements in education. During that time, the graduation numbers in the engineering and science fields have doubled. Compared to trends in other emerging countries, Brazil is now well positioned for the future.

This recent push also lets Brazil strengthen the links between research and industry. An example of a strong link between research institutions and industry is the Brazilian aerospace industry. One of the hubs of that partnership is São José dos Campos, the home of Embraer as well as the the Aeronautics Institute of Technology (Instituto Tecnológico de Aeronáutica, ITA), one of Brazil's strongest institutions for higher education and advanced research in the aerospace field.

ITA's mechanical engineering department, led by Professor Dr. Luiz Góes, conducts research on topics related to current industrial needs. One of these topics was braking-system performance and the antiskid technology in normal and failure modes.

Keep improving the aircraft braking system performance
The brake system is obviously critical to the safe operation of aircraft. However, the definition of acceptable performance and reliability has become stricter over the last few decades as aircraft landing weights and speeds have increased substantially, and regulatory authorities have improved their certification requirements, aiming for safer operation.

Therefore, brake-system design, architecture and functionalities have evolved through the years and the development of the antiskid system, part of the brake system on several aircraft since 1940s, marked an important milestone in the industry. In addition to the main function of preventing the locking of braked wheels, the antiskid system is also normally responsible for other secondary functionalities in the brake system.

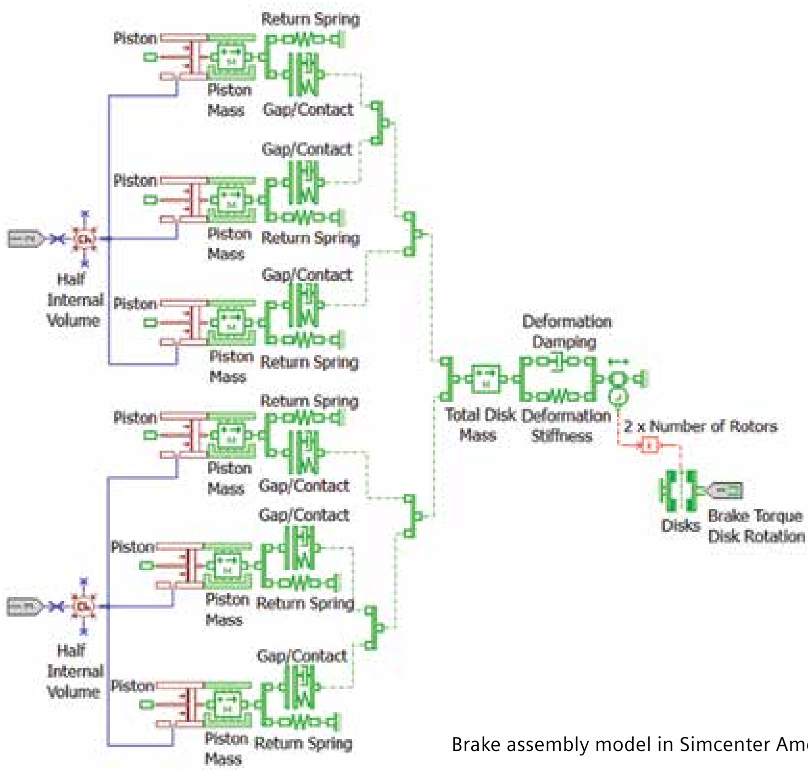
Aerospace original equipment manufacturers (OEMs) and suppliers work with mature and trusted braking system technology. Nevertheless, it remains crucial to consider all the typical failures that can impact braking-system performance and antiskid capabilities, and how the system reacts and compensates for such losses.

ITA uses system simulation
To provide an alternative option, the mechanical engineering department of research at ITA, especially Góes and Mario Maia Neto, a PhD candidate, have researched this issue. They proposed a complementary approach that lets aeronautical engineers accomplish a quicker preliminary assessment by troubleshooting typical failure impacts on aircraft braking system behavior.

The traditional way of assessing brake system performance is by conducting rig tests and flight test campaigns. But this process is laborious, time consuming and expensive. That's why Neto and Góes worked on a new methodology based on computational simulation of the aircraft hydraulic brake system. Their academic study aimed to demonstrate the usefulness of system simulation to design and validate the model of a hydraulic brake system to assess the behavior of system-relevant variables in normal operational conditions, and the potential effects of typical failures in system performance. It could be in the industry's interest to complement its systems design activities with safety and reliability assessments.

An efficient modeling tool
Neto and Góes used Simcenter Amesim to model the hydraulic design of the braking system. Prior to modeling the complete hydraulic brake system, it was important for Neto and Góes to know what the system was comprised of and how it worked. Then they were able to transpose it properly into a model and reach the right design solution decisions.

Neto and Góes based their research for this study on one type of braking system. This brake system is supplied by the aircraft hydraulic power generation system, which is later



Brake assembly model in Simcenter Amesim.

duplicated to independently provide hydraulic power for each brake assembly. In each subsystem line, a hydraulic accumulator is installed to allow the brakes to be applied in emergency conditions or with the main hydraulic system turned off. Antiskid valves and metering valves, required by the system architecture and responsible for modulating the braking demand applied by the pilots, are located inside a unique valve assembly. The metering valve consists of a control pressure valve; its output pressure is directly proportional to the force applied by the pilots on the brake pedals.

Once the input signal is received from the antiskid system control unit, a new force balance is established in both stages of the antiskid valve, leading to control of the hydraulic pressure in the brake assemblies. Finally, each brake assembly is supplied by both hydraulic subsystems, existing in total segregation between the piston chambers operated by each subsystem in the interior of the brake assembly.

The next step is to model the system with Simcenter Amesim. The model is composed of three elements with well-defined boundaries: the valve assembly, brake assemblies and input blocks. Components associated with the hydraulic generation and distribution system, represented by the power source, reservoir, accumulators, tubing, hoses and a check valve, are also part of the model.

According to Neto, "Simcenter Amesim is a great tool for quickly creating system models, mainly due to its facility for dealing with the physical blocks found in its libraries. Since preliminary assessments of system behavior could be done, as an engineer that improved our confidence in the design solution decisions."

Predicting system behavior in case of typical failures

Once the model was designed and validated, the goal of Neto and Góes was to arbitrarily choose three major typical failures. Anticipating these failure cases enables the user to evaluate which strategies can be implemented to compensate for the failure effects so the antiskid brakes can continue to perform its primary functions.

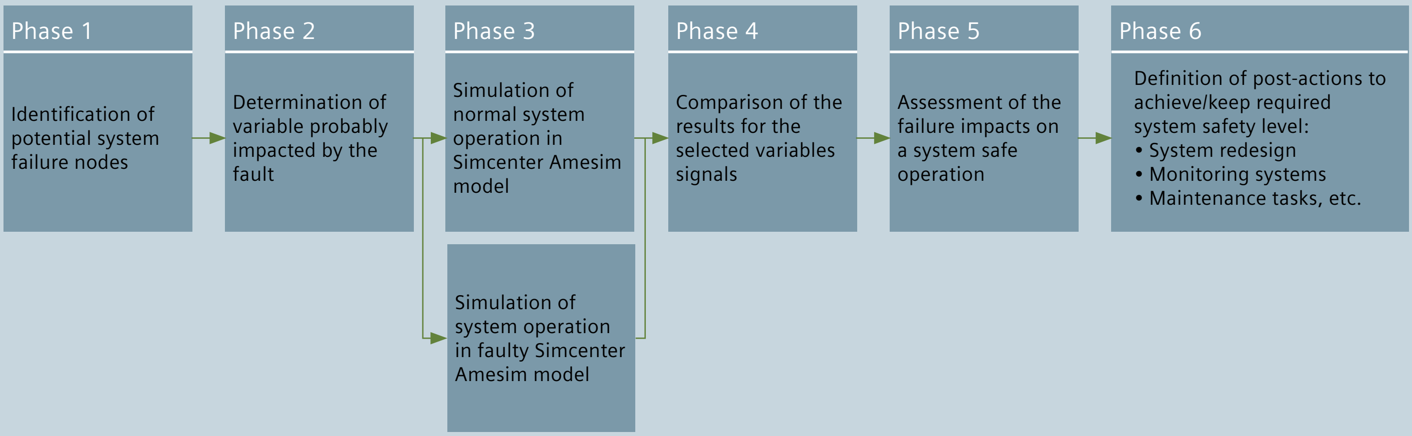
Neto says, "Using Simcenter Amesim helped us develop a computational, parametrized model for the aircraft hydraulic brake system to assess the behavior of its relevant variables in normal operational conditions and when typical failures are simulated.

"Due to the fast simulation time of a physical modeling software like Simcenter Amesim, the present approach could represent a good solution for a quick, preliminary assessment of system behavior in particular conditions."

One example of failure consisted of the jamming of a piston part of the brake assembly acting on a brake disc. Implementing this failure mode in Simcenter Amesim model is straightforward. In fact, it is achieved by just changing the numerical value of a component parameter.

Afterwards Neto compared the behavior of the two simulated modes and tried to find the right way to address the performance loss due to the failure mode. The researchers found the piston jam condition might be responsible for a reduction in the available torque (loss of 16.5 percent in the torque value) of a brake assembly, as well as for the existence of residual torque on it. As a result, the overall aircraft stopping distance in landing might be jeopardized by the first effect and an adverse condition referred to as dragging brake might occur due to the second effect.

Model based fault assessment approach in system operation



A dragging-brake condition may eventually lead to inadvertent yaws on the ground or even a tire bursting due to the generated heat. For the last step of this computational methodology, the strategy was to define post actions to maintain the required system level, such as iterate on the existing design and introduce specific maintenance tasks.

Satisfied with the use of the Simcenter Amesim platform, Neto explains, “The physical modeling with Simcenter Amesim is easy to implement. Being able to click, drag and connect the physical blocks found in its several libraries allows the creation of complex models without the need for writing entire mathematical formulations for every subsystem in the model. The integral causality, numerical algorithms compilation and execution are also fast.”

Ensuring performance analysis

The work led by Neto comprised an academic study addressing a hydromechanical engineering topic with no quantifiable benefits. However, Neto explains:

“Some of the qualitative good points of using simulation models in product development cycles are highlighted in the article, such as the reduction of aircraft system development cycles, the help in predicting system operational problems and the support for troubleshooting activities to identify the root causes of real field issues.

“In the current context, modeling and simulation has the potential to improve the execution of several design development activities, such as system architecture study, requirements validation, performance analysis and optimization, safety and assessment, fault detection and diagnosis.”

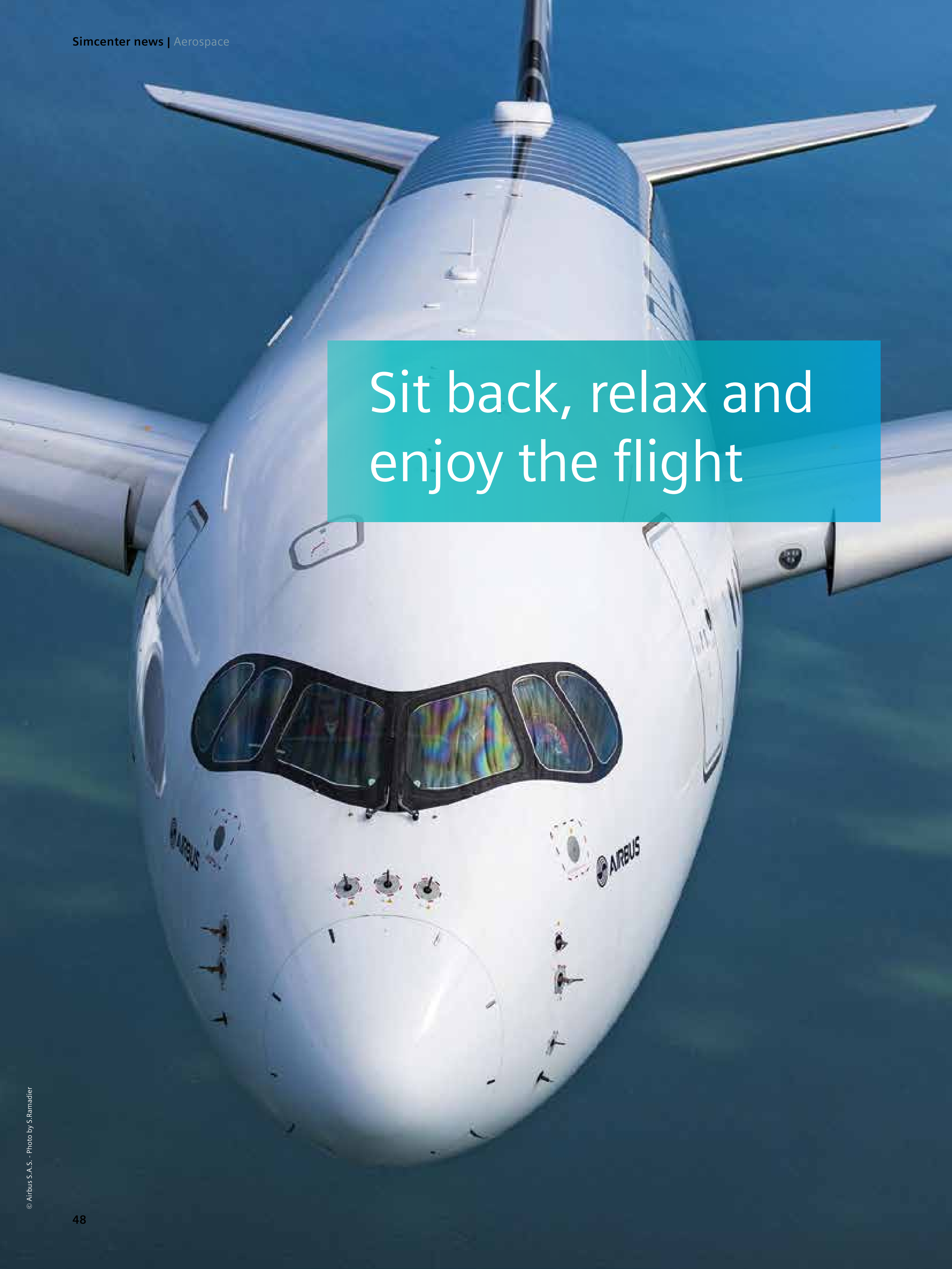
Brazil invests and counts on its future generations in order to strengthen the competitiveness of its industry with an emphasis on engineering and science education. One strategy covers the need to know how to manage the main engineering tools of the industrial players. That is a vision proposed by the ITA and supported by Góes:

“At ITA, our mission is to prepare the future engineers to face the challenges of their professional lives, especially in a competitive sector such as the aeronautical industry. We believe that preparing the future engineers of Embraer with this specialized knowledge has greatly improved company productivity, leading to a safer and more competitive product in the global market.”

ITA and Embraer partnered in 2000 to develop a professional master’s program, which serves as a pipeline of aeronautical and aerospace engineers to meet Embraer’s needs. This requires dedicated teaching in order to ensure future graduates can manage software used by Embraer, such as Simcenter Amesim. “Having the capacity to develop system models and run simulations will help our students improve their understanding about system behavior, allowing the execution of post activities that will help them develop better products and systems in the future, like system optimization and sensitivity analysis,” says Góes.

Góes appreciates the partnership between ITA and Siemens PLM Software, saying, “Providing the students with a bundle of advanced software tools such as Simcenter Amesim has made a big difference. Opening access to the basic features of the multi-physics energy port environment simulation in the Student Edition of Simcenter Amesim has been a great way for Siemens PLM Software to introduce the students to the important features of this advanced simulation methodology.” ■

Sit back, relax and enjoy the flight

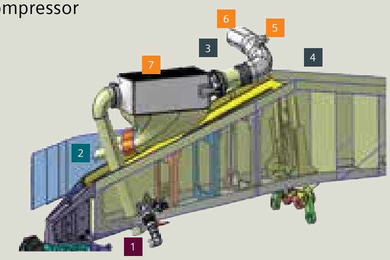


Bleed air system of an Airbus A320 neo aircraft

Intakes
1 Hot bleed air from the engine's compressor
2 Cooling air from the engine's fan

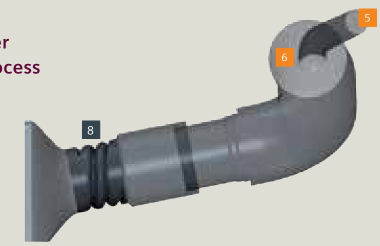
Hardware
3 Static mixer
4 Temperature sensor

Outputs
5 To wing anti icing
6 To air conditioning system
7 Cooling air exhaust



Design concept of helical mixer used in initial optimization process

8 Helical mixer



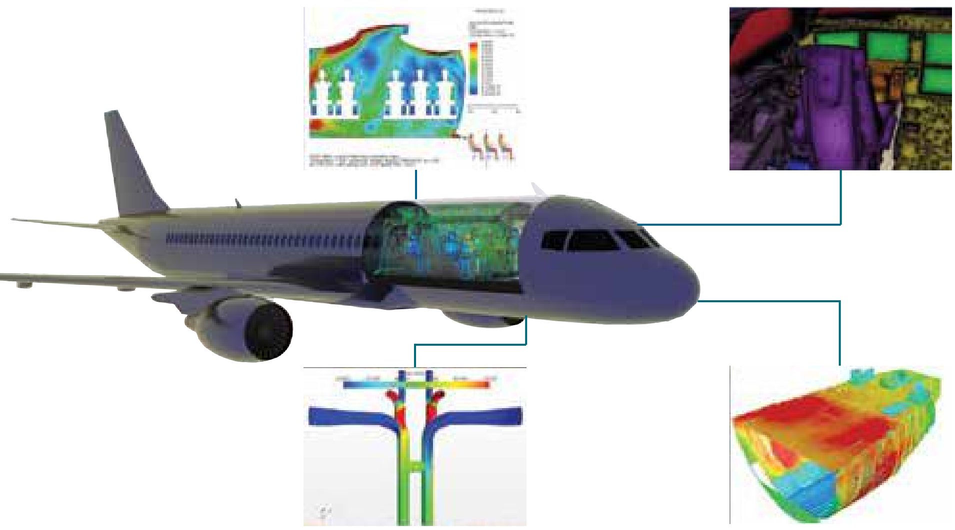
How often do we marvel at the fact that humans are flying around in climate controlled metallic tubes 30,000 feet above the ground in an extreme environment? Providing a comfortable cabin atmosphere when the external conditions are around -40 degrees to -60 degrees Fahrenheit (F) is a complex task involving the air conditioning and cabin pressurization system. Making this more challenging is the additional demand for preconditioned air for the avionics and ice protection systems. Moreover, stricter environmental regulations necessitate an efficient system that improves fuel efficiency and reduces emissions as air traffic grows by five percent per year.

In the aircraft industry, the environmental control systems (ECS) typically refers to the systems and equipment that work to provide a comfortable atmosphere for the aircraft payload, including people, avionics and other systems within the aircraft. Environmental protection systems (EPS) involve systems protecting against external conditions, including extreme temperature and pressure, ice buildup, etc. A well-designed aircraft ECS and EPS not only leads to a comfortable flight for passengers, but also helps improve fuel economy since ECS is the second biggest power consumer of engine power after thrust. With increased competition and demand to design more comfortable aircrafts with better fuel efficiency, the design of the ECS and EPS plays a critical role in the success of an aircraft in the market.

At Airbus, nonstop innovation and pioneering technical solutions go hand-in-hand, creating better, more efficient ways for airlines and passengers to fly. The ECS group at Airbus Operations GmbH is no stranger to this issue, constantly looking for better and faster ways to design the best performing ECS. Taking advantage of improvements in hardware resources and numerical modeling, the ECS group has deployed numerical simulation in many areas, helping them understand and improve systems and subcomponents faster than with expensive physical testing. Some of the areas where simulation, particularly computational fluid dynamics (CFD) tools, have been beneficial include cockpit design, avionics cooling, mixing and pressure loss in ducting and cabin thermal comfort. Recently, the ECS group has been leveraging design space exploration in a production environment for improving the bleed air system in future aircraft.

The static air mixer

Bleed air from the engine fan and compressor sections is used to pressurize and heat the main cabin, as well as supply hot air to the aircraft's ice protection system. A typical bleed air system of an Airbus 320 new engine option (neo) is located in the pylon under the wing. This system delivers preconditioned air at a given temperature and pressure for cabin air conditioning and wing ice protection. Hot bleed air from the engine compressor and cool air from the engine fan pass through a plenum into a heat



Use of simulation at Airbus ECS group for cockpit, avionics, ducting and cabin thermal comfort.

exchanger. The bleed air is cooled down to roughly 200 Celsius (°C) in the heat exchanger. Uniform and thorough mixing of the core and bypass air is achieved by a static mixer and is critical for maintaining subsystem performance. The temperature of the mixed air from the static mixer is monitored via temperature sensors before being delivered to the various systems. Optimizing the static mixer performance leads to a better functioning system delivering conditioned air with improved efficiency.

At Airbus, a goal was set to improve the current static mixer design and meet the design objectives, including a total pressure loss of less than 5 kilopascal (kPa) between pre-cooler and the temperature sensor and a temperature range of less than 12 Kelvin (K) at the sensor location.

Initial optimization process

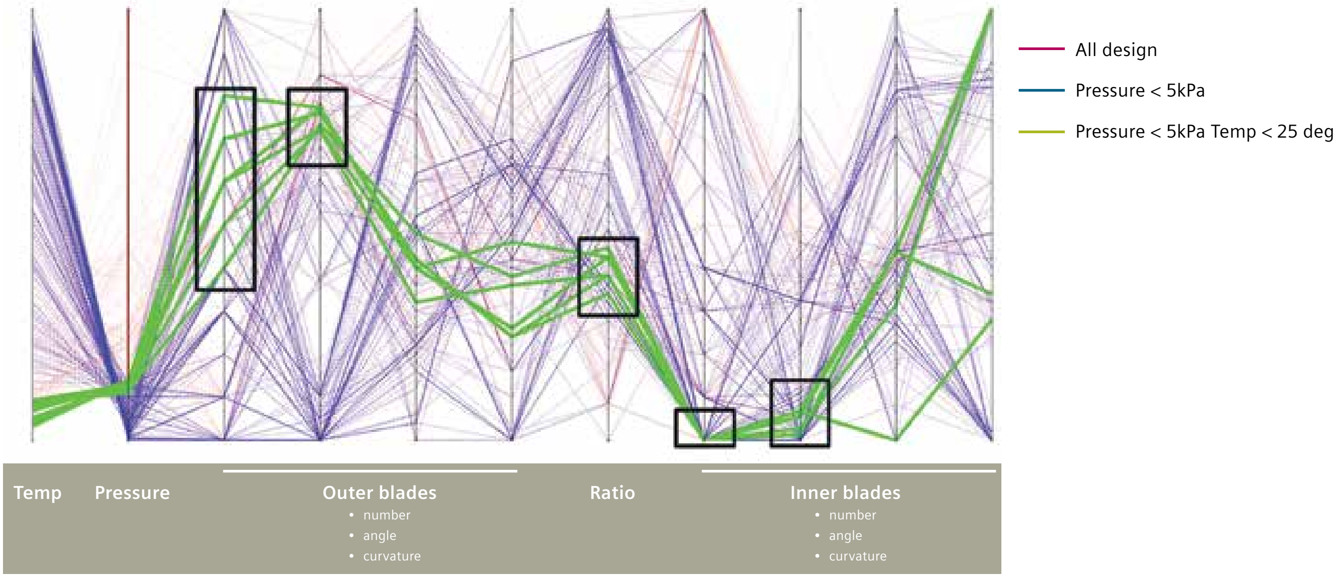
Finding the optimum design and the best compromise between the conflicting objectives is quite valuable if the optimum design can be identified as part of the design cycle. This not only saves time and money, but leads to the best possible design to go into production. The challenge though is to identify and deploy an efficient optimization process that fits within the constraints of the production cycle. To go from an initial geometry to the optimum design, various steps are involved, including design of experiments, 3D geometry modeling, low fidelity CFD modeling, surrogate modeling, pareto front identification and postprocessing. The first optimization workflow that was evaluated involved a mixture of commercial and in-house tools to perform these tasks. The helical mixer concept was optimized to evaluate the viability of this process. Three design parameters were used in the optimization – radius of curvature of the helical channel, depth of cut into the duct and the width of the helical cut.

The workflow was challenging due to infrastructure and communication issues between the different tools; consequently, only two design parameters were used in the optimization to meet the time constraints. The optimization study identified a design offering a pressure drop of 5,000 pascal (Pa) and a temperature difference of 45 K at the sensor location. The total turnaround time for the initial project was six months. The final design had improved the temperature difference but was not close enough to the design objective. The question remained: how best to meet the design objective while reducing the turnaround time to make this process viable in a production environment? To resolve these concerns, Airbus decided to collaborate with Siemens PLM Software to identify a new process.

Leveraging the concentric mixing blade concept

The answer to shortening the turnaround time for design optimization was using Simcenter STAR-CCM+ software. Using Simcenter STAR-CCM+ enables the user to facilitate the analysis and exploration of real-world problems by accurately predicting product performance through numerical simulation. Optimate+, a Simcenter STAR-CCM+ add-on, provides design exploration and optimization powered by the SHERPA search algorithm of HEEDS software, a multidisciplinary design optimization tool also from Siemens. The SHERPA algorithm intelligently adjusts search strategies to find the best solution in the allotted time using hybrid, adaptive search techniques. This new process eliminates the need to use and communicate between different tools and brings the entire design optimization process into a single environment.

To meet design objectives, a concentric mixing blade design was chosen instead of the helical mixer with an eye toward meeting the design goals. This design involved two concentric rows of mixing blades. A total of 11 design parameters were chosen for the optimization study. The design concept was chosen to provide maximum flexibility in the design space, and the direct optimization technique meant that no simplification of the design space was needed. The geometry modeled in CATIA was modified using Optimate+ software based on the design parameters.



Plot showing influence of different design parameters.

With the automated workflow of Simcenter STAR-CCM+, Optimate+ was used to evaluate 211 design variants by varying the independent parameters. For each simulation, a polyhedral mesh was automatically generated with a cell count of between 2.4 million and 3.5 million cells. The segregated flow solver was used with constant density air and the shear stress transport (SST) k-omega turbulence model. All simulations started from a converged solution for the baseline design. Convergence was achieved when the average pressure drop was within 50 Pa and maximum temperature difference was within 4 K over 1,000 iterations. Designs that didn't converge after 15,000 iterations were rejected.

Optimized design in two weeks

The baseline design achieved a pressure drop of 996 Pa and temperature difference of 153 K. By using the SHERPA algorithm, the Optimate+ add-on was able to be used to find the best compromise between the conflicting design objectives from 211 design iterations. The best performing design achieved a pressure drop of 4,775 Pa and a temperature difference of 16.4 K. Based on a pareto optimization plot of the results, it was apparent the best performing designs had a small number of blades and smaller curvature. Armed with this information, 57 additional design iterations were performed from the optimum design to minimize the temperature difference further. A plot in Optimate+ can compare the temperature and pressure drop for all the designs and the individual design parameters. The red lines show all design iterations and the blue lines show the designs that achieved the required pressure drop objective. The best designs are shown in green, achieving both objectives. From the plot, the influences of various design parameters on the best designs can be found. The best designs had a higher number of blades on the outside, fewer blades on the inside, higher outside curvature and a lower curvature on inner blades. The diameter ratio for the best designs was around 0.5.

The best design from the optimization had nine outer blades at 62° curvature, moderate curvature at 25 percent chord, three inner blades at 5° curvature and mild curvature at 48 percent chord. A pressure drop of 4,961 Pa and temperature difference of 13.6 K was achieved. The total turnaround time for the best design was two weeks.

The new optimization process with Simcenter STAR-CCM+ and Optimate+ achieved a 90 percent reduction in turnaround time. This method will be deployed in future design cycles, allowing Airbus to find better ECS designs faster. The result is an improved ECS system with better mixing, reduced time-to-market, reduced testing, better energy efficiency and a better customer experience. Just remember, in the future when you're onboard an Airbus aircraft at 30,000 feet, one of the reasons you are comfortable is Simcenter STAR-CCM+. ■

	Pressure drop (Pa)	Temperature difference (C)	Turnaround time (weeks)
Helical mixer	5,000	25	25
Concentric blades dual objectives	4,775	9.11	2
Concentric blades single objective	4,961	7.56	

Comparison of optimization results.

Integrated design and analysis pays off on NASA's next-generation launch vehicle

Use of Simcenter 3D for motion and finite element analysis – in an integrated process managed with Teamcenter – helped engineers make sure that a larger nozzle wouldn't hit launchpad structures during lift-off.

Image credit: NASA/MSFC

One of ATK's current projects involves the Space Launch System (SLS), which is the successor to the Space Shuttle. NASA describes the SLS as "the biggest, most capable rocket ever built for entirely new human exploration missions beyond earth's orbit." The SLS will be NASA's first exploration-class vehicle since the Saturn V took American astronauts to the moon over 40 years ago, but the SLS will take astronauts farther into space, eventually including missions to Mars. Its first flight is currently scheduled for December 2019.

ATK's work involves the SLS's solid rocket boosters, the twin external structures on either side of the core stage, which provide extra thrust for the first two minutes of flight. Early SLS missions will use modified Space Shuttle solid rocket boosters, which ATK also designed. ATK's current work, however, involves designing advanced boosters that will have more thrust and be used on later SLS missions carrying bigger payloads. ATK has used product lifecycle management (PLM) technology from Siemens PLM Software for nearly a decade, including NX software for design, the Simcenter portfolio for performance simulation and Teamcenter software to manage product information and processes.

"We've had a long-standing partnership with Siemens PLM Software," says Ramesh Krishnan, a senior staff engineer in the ATK Engineering Processes and Tools group. "It started with visionary leadership that saw the benefits of an integrated system."

In recent years, the group has been working to better integrate analysis into the design process. "Our challenge is to integrate CAE (computer-aided engineering) engineers early in the product development cycle so we can impact design," says Nathan Christensen, senior manager of the ATK Engineering Tools and Analysis group. "This can be a tall order given our nature as engineers and the complexity of our tool set." The work being done for the SLS program that is related to the advanced booster rocket's nozzle offers a good illustration of how they are meeting this challenge.

"The size of the nozzle is going to increase quite a bit to get better performance out of our motors," explains Krishnan. "There are a lot of structures that a larger nozzle could possibly hit on its way up off the pad."

The aft end of the booster has a skirt, and attached to that skirt are launch mounts that hold the rocket in place while it is on the launchpad. ATK is designing retractable mounts – a first for ATK – that will retract at launch so the nozzle won't hit them.

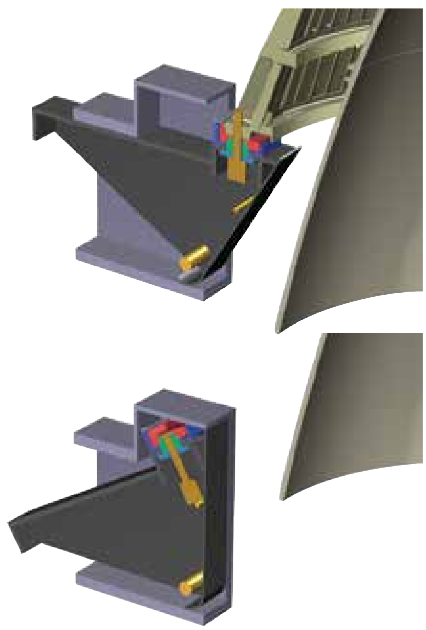
Using NX, ATK modeled the aft end of the booster, including the skirt and the retractable launch mount assembly. That digital geometry was then used for two different types of analysis, motion analysis and finite element analysis (FEA).

ATK used Simcenter 3D Motion to simulate the movement of the launch mounts during the rocket's lift-off. "For the speed of the rocket, we used a curve that we input into Excel and then linked the motion simulation speed to that spreadsheet," Krishnan explains. "That was thrust versus time, and it worked quite well. The rocket took off with appropriate acceleration.

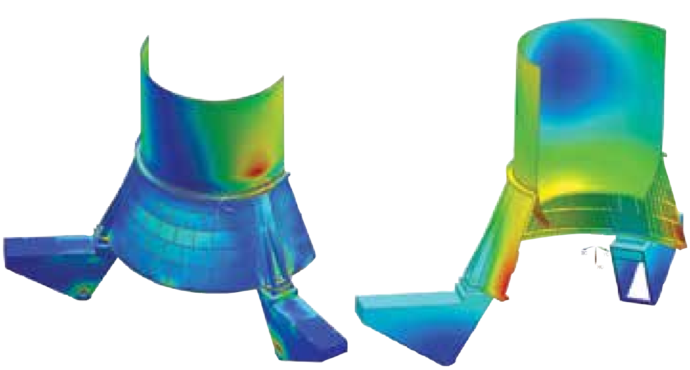
"The engineer working this project had never used Simcenter 3D Motion, but he picked it up quickly and figured it out; within a few days he had a full model working." The simulation he created even includes a launch mount's 4-inch bolt, which drops away at launch due to a frangible nut. Using motion simulation, ATK soon got to the point where the launch mounts retracted correctly. "The main intent was to use Simcenter 3D Motion to capture the timing sequence of the rocket taking off and the retractable launch mounts moving back, and we did achieve that," he notes.

Next, the team undertook FEA. ATK had access to numerous FEA preprocessors and solvers. As part of the move to better integrate analysis and design, ATK is working to consolidate its CAE tools, making Simcenter 3D and NX Nastran software the standard applications and filling in with other solutions when necessary. "This way, engineers will use company standards, not favorites," Christensen explains. "It should reduce the costs we have now of supporting multiple tools with similar functionality, and it will facilitate the hand-off of work between analysts."

Starting with design geometry, ATK used Simcenter 3D to prepare the finite element model of the booster rocket's aft assembly. "Many finite element modeling packages don't handle assemblies very well, but Simcenter 3D does," Krishnan explains. The best part of working with Simcenter 3D, in his opinion, is that changes made to the assembly model are maintained in the finite element model. "What's really nice is the ability to make modifications in the modeling portion and transfer those over to FEA," says Krishnan. "It's very seamless. The mesh automatically updates and it's very convenient. Also, you maintain associativity. All the connections you've made in the assembly stay in the assembly all the way through the FEA. You don't have to try to move stuff around in the FEA."



Using NX, ATK modeled the aft end of the booster, including the retractable launch mount assembly.



Simcenter 3D was used to prepare the finite element model of the booster rocket's aft assembly.

ATK also liked the ease of creating geometry using Simcenter 3D. "We like that we could model the bolts very quickly as beam elements and spider elements," Krishnan explains. "We could take these parts that were free-floating in space and tie them all together with a tool that allows you to select all surfaces or edges of the bolt hole, and it automatically creates beam elements. That saved a lot of time."

Although ATK did some FEA to determine whether the launch mounts were strong enough to handle their loads, more of the FEA was directed at the aft skirt, the interface between the rocket and the launch pad, which must withstand the weight of the rocket (2 million pounds axial load when empty of fuel; 7 million pounds when full) as well as wind loads (hurricane force). The loads involved were huge. "We've never dealt with loads of this magnitude in an aft skirt before," says Krishnan.

In addition to saving time, the more important benefit to ATK of integrated NX design and Simcenter 3D analysis was that it gave the company confidence that its model was accurate. "We had confidence that what we drew using NX was coming right over to the finite element package and that's what we were analyzing," Krishnan explains. ATK spent less time checking analysis model thanks to that. "Also, one of the problems with modeling contact in large finite element assemblies is you have to make sure you're line-on-line. With Simcenter 3D, you're line-on-line from the beginning. There's no fuss to maintain contact and make sure everything is in the correct location. It's always in the correct location." In addition, this process is less error-prone in general since there are no translations between software packages.

Integrating analysis into the design process includes using Teamcenter to manage CAE workflows, and the Teamcenter data vault to store CAE models, results, reports and links to the product structures. "This helps ensure that we don't analyze the wrong parts or configurations, and that analysts stay in-sync with design changes, reducing CAE rework," notes Christensen. As with the company's design process, Teamcenter is also used to keep analysis projects on track. The Teamcenter solution for reporting and analytics is used to track project status (on-time, projected late and late), cycle time and first-pass yields.

Christensen summarizes the effect of standardizing on Simcenter 3D for analysis, and of better integrating analysis and design this way: "Integrating CAE tools early in product development shortens the design cycle, and lets us focus on overall design cycle times instead of analysis cycle times. Also, we believe that significant cost savings and productivity gains can be accomplished with careful and strategic CAE tool standardization. Most important, CAE is most effective if engaged early with the design team." ■

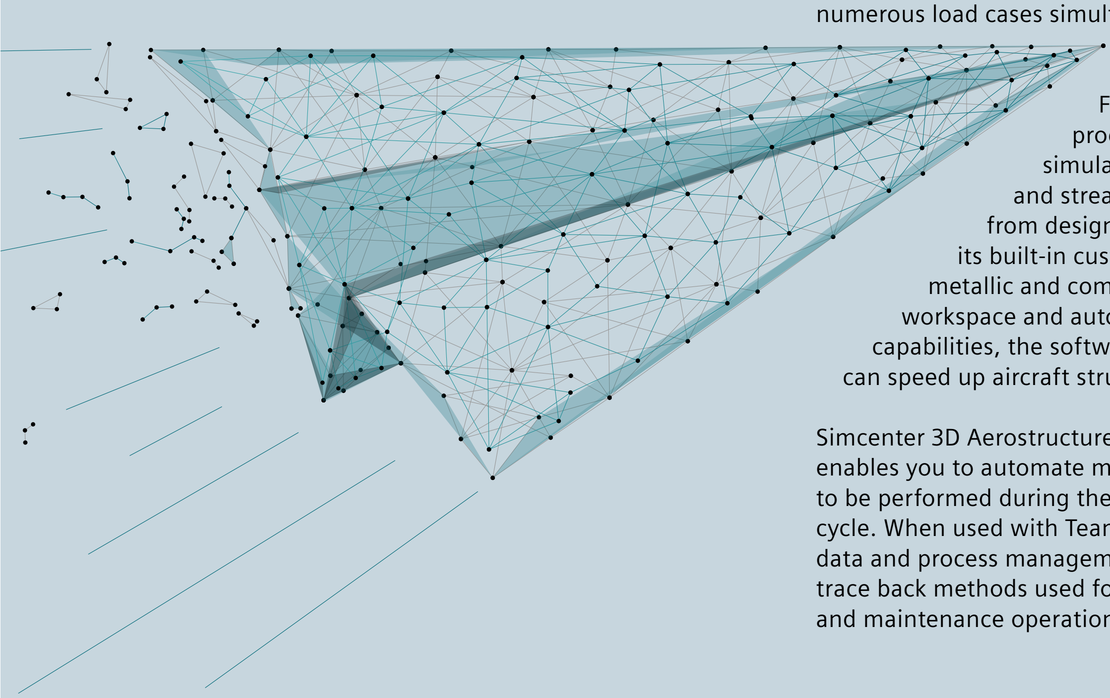
A critical tool to improve airframe structural certification

Leading aerospace companies rely on digital simulation for cost-effective functional performance engineering. But the evolving regulatory and competitive pressure to develop more efficient aircraft, improve safety, lower emissions, and employ lightweight composite materials as well as global sourcing, has significantly impacted the structural certification of new aircraft programs. Moreover, to maximize their investment returns, customers expect service lives of up to 50 years. Such realities have a serious impact on airframe structural analysis working processes and the simulation data generated to secure certification.

Aircraft structural certification mandates aerostructure sizing, which involves detailed failure analysis on the structure, its binding bolts and joints. The complete documentation of the process – input data, methods used and associated margin of safety (MoS) results – are obligatory for certification. Structural development accounts for 60 percent of commercial aircraft's development cost and is close to 30 percent for military aircraft.

According to Boeing, the nonrecurring structural analysis hours per pound of airframe structure has increased tenfold and the aerospace industry has evolved from the notion of five designers per analyst to one or two designers.

The structural group performs millions of analyses to reliably predict the safety of every component. Estimating structural components' MoS involves idealizing CAD data originating from designers, preparing simulation models, computing structural loads employing several in-house or commercial off-the-shelf (COTS) structural solvers and establishing MoS using in-house or conventional analytical methods. Teams carrying out the tasks are often working in different global locations. This poses unique challenges to aerospace companies, such as ensuring the right methods and processes are followed for MoS calculations across the broader team, maintaining traceability of the input, improving efficiency and decreasing the aircraft program's nonrecurring cost.



Any delays in the planned airframe development program adversely impact the manufacturers' reputation, profitability and future opportunities. With shorter decision cycles, lack of consistency in the MoS estimation and absence of collaboration across engineering during design through certification, program efficiency is hindered and can cost aviation companies several billion dollars.

Delays in structural certification begs the need for boundary-less collaboration across the aerostructure sizing process. Aerospace structural development programs promote an environment that provides an integrated solution for aerostructure sizing; offers an open and scalable solution to embed COTS and in-house MoS methods; enables data traceability and steers consistency for certification and efficiently manages design changes with CAD/CAE associativity.

Leveraging decades of experience in delivering simulation, test and data management solutions to the global aerospace industry, Siemens has introduced a dedicated solution for aerostructure sizing.

Delivered as part of the Simcenter 3D multidiscipline simulation application, Simcenter 3D Aerostructure enables you to harmonize margin of safety calculations for numerous load cases simultaneously. The open and extensible solution allows you to federate your favorite FEA solvers, MoS methods and processes in an integrated simulation environment, and deploy it and streamline the analysis workflow from design to structural certification. With its built-in customizable failure methods for metallic and composite structures, collaborative workspace and automatic report generation capabilities, the software minimizes human errors and can speed up aircraft structural certification processes.

Simcenter 3D Aerostructure provides consistency and enables you to automate millions of FEA analysis that need to be performed during the aircraft structure development cycle. When used with Teamcenter software for simulation data and process management, you can store and precisely trace back methods used for validation during certification and maintenance operations. ■

Image Courtesy: Port of Felixstowe

Image credit: Joby Aviation

Conceptual electric designs

Joby Aviation paves the way for an electrical future with the Simcenter STAR-CCM+ CFD solution

If the industry buzz is correct, electric propulsion is on the verge of causing the biggest change in aviation since the advent of the jet engine. At first glance, it may seem that the excessive weight of modern batteries limits electric aircraft to, at best, a few niche markets. However, the different properties of electric propulsion compared to traditional combustion power, coupled with recent technology advances, promise to significantly relax typical design constraints for many aircraft configurations, which will allow for new types of aircraft that were previously impractical or impossible. This is particularly true for shorter-range designs, which have traditionally been relatively small and powered by pistons.

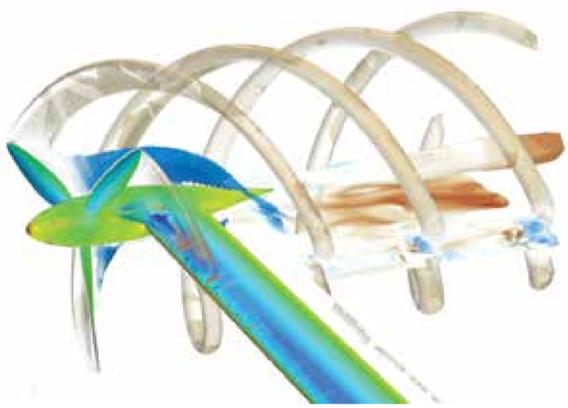
Why electric?

Because of the size, weight and maintenance requirements of piston engines, most designs are limited to a small number of engines located in a small number of practical locations. This is why most modern general aviation airplanes and helicopters look similar to designs from the 1950s.

In contrast, electric powertrains are much smaller and lighter, and they are incredibly simple. Some have only a single moving part compared to the relative complexity of piston engines, which include a coolant system, an electrical system, an oil system, a fuel system and so forth. This reduced complexity translates to much lower maintenance requirements.

While smaller combustion engines suffer from lower power-to-weight and efficiency, electric motors are relatively scalable. This means the power-to-weight and efficiency will be similar to between, for example, a 1 kilowatt (kW) motor and a 1,000 kW motor. An electric powertrain is also about three times as efficient as combustion. Electric motors can operate effectively on a much wider range of rotations per minute (RPMs), and they can change RPM relatively quickly. Electric powertrains are significantly quieter than combustion powertrains, as anyone who has heard an electric car can attest.

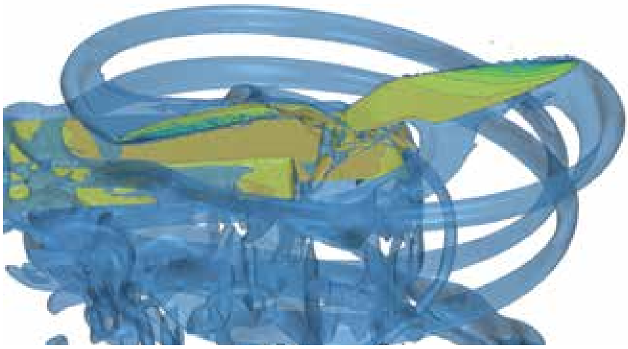
Although replacing a combustion engine with an electric motor will result in lower noise and higher powertrain efficiency, much greater advantages can be gained by designing an aircraft with electric propulsion in mind from the start. The properties of electric propulsion mean that aircraft can effectively employ a large number of small motors without incurring an undesirable amount of complexity and maintenance costs, and without compromising motor weight or performance. These motors can be located in a much larger range of positions on the aircraft due to their relatively low weight and small size. Additionally, the drawbacks of carrying motors that are only used in some portions of the flight, like takeoff and landing, are relatively minor since the motors are so light.



The CFD simulation of the wingtip propellers.

Although traditional propulsion installations often compromise aircraft performance, the flexibility of electric propulsion allows for propulsion installations that result in beneficial aerodynamic interactions. One such example is locating propellers on the wingtips, where they can recapture some of the energy lost to the wingtip vortices.

With expertise in electric motor design and fabrication, high-fidelity aerodynamic analysis and composite airframe design and fabrication, Joby Aviation is capitalizing on this new technology to develop several aircraft that provide capabilities that were never before possible. However, due to the complex nature of these interactions and the lack of previous designs to extrapolate from, a large amount of high-order aerodynamic analysis was performed in the design process. For this reason, Joby Aviation has leaned heavily on CFD analyses using Simcenter STAR-CCM+ in the development of its unconventional designs.



The CFD analysis of the Lotus wingtip propeller at takeoff.

JOBY S2

Joby Aviation's main development effort is the S2 Vertical Takeoff and Landing (VTOL) aircraft, which addresses the high noise, high operating costs, low speed and relatively low safety levels that have severely limited the proliferation of conventional VTOL aircraft of this size, like helicopters. The S2 employs multiple propellers in takeoff and landing to increase safety with redundancy. In cruise, most of these propellers fold flat against their nacelles to reduce drag. The design of these propeller blades is a compromise between propeller performance and the drag of the nacelles with the blades folded, and higher-order tools were required to properly analyze this tradeoff. A variety of propeller designs were assessed under various operating conditions in Simcenter STAR-CCM+, and the nacelle was analyzed in the cruise configuration using the γ-Reθ transition model. The results indicate where reshaping the propeller blades may increase laminar flow and reduce cruise drag.

Joby Lotus

Another Joby Aviation project is the Lotus aircraft, which is exploring a novel VTOL configuration on the 55-pound unmanned aerial vehicle (UAV) scale. In this aircraft, two-bladed propellers on each wingtip provide thrust for vertical takeoff. After the aircraft picks up enough forward speed for sufficient wing lift, each set of two blades scissor together and the individual blades become wingtip extensions, forming a split wingtip. A tilting tail rotor provides pitch control during takeoff and landing and propels the aircraft in forward flight. As one might expect, the design of these wingtip blades, including the span, airfoil choice, twist and chord distribution, pitch and dihedral, was an interesting compromise between propeller and wingtip performance. Dozens of CFD simulations were run on different combinations of these design variables in the cruise configuration to maximize cruise performance within the constraints of the configuration. At the same time, the performance of these blades in the propeller configuration was also analyzed with CFD to validate lower-order design methods.

LEAPTECH

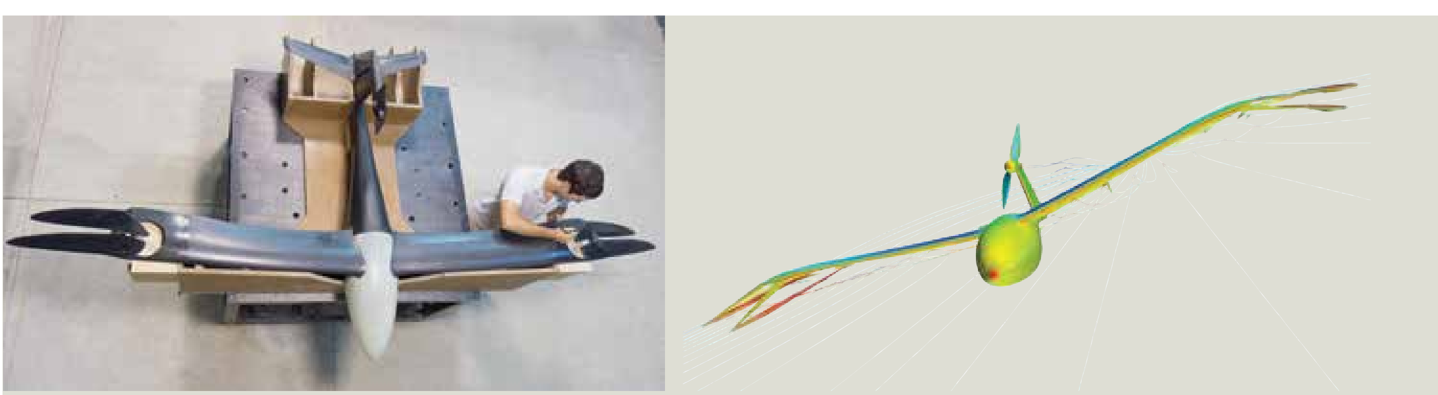
The third project Joby Aviation is participating in is LEAPTech (Leading Edge Asynchronous Propeller Technology), a partnership with NASA and Empirical Systems Aerospace. The goal of this design is to investigate potential improvements in conventional fixed-wing aircraft with electric propulsion. A row of small propellers is located along the leading edge of the wings and during takeoff and landing, these propellers increase the velocity and, therefore, the dynamic pressure over the wings. This increases the lift produced by the wing and allows for a smaller wing to be used for the same stall speed constraint. Since many small aircraft use a wing sized to meet a stall speed constraint that is too large for optimal cruise performance, this smaller wing allows for more efficient cruising.

Additionally, the ride quality is significantly improved due to the higher wing loading. However, the performance of this blown wing is difficult to analyze with lower-order tools, particularly since much of the required analysis occurs around stalling conditions. Therefore, a large number of CFD simulations were performed in the design process, looking at various combinations of propeller sizes and powers, wing aspect ratios and sizes, and angles of attack. To reduce the computational expense, the propellers were modeled as actuator disks with the body force propeller method in Simcenter STAR-CCM+, which negated the need to resolve the actual blade geometry, drastically decreasing the required mesh size.

The first phase of testing this configuration was to build the full-scale wing, propellers and motors, and mount them above a modified semi-truck, which was run at takeoff speeds on the runway at NASA Armstrong Flight Research Center. Outside of takeoff and landing, these leading edge propellers are designed to fold against their nacelles, similar to the S2 propellers; as mentioned above, wingtip propellers will provide propulsion. Although lower-order analysis methods were evaluated for estimating the drag and efficiency impact of operating these propellers concentric with the wingtip vortex, unsteady CFD proved to be the most reliable analysis method. A range of design parameters were analyzed.

Joby Aviation is quickly advancing the state of general aviation aircraft with its revolutionary electric propulsion concepts, and simulation is playing a big role in understanding the complex nature of their state-of-the-art ideas and in the design and development of their unconventional concepts. The S2, Lotus and LEAPTech concept designs show great promise for becoming part of the electric future of aviation that we never thought was possible. ■

Image credit: Joby Aviation



The Lotus during assembly in cruise configuration (left) and the CFD analysis (right).

Mapping the Galaxy and possibly solving the mysteries of the universe…

With a little nod of thanks to the dedicated, in-house Simcenter environmental dynamic testing solution at Airbus Defence and Space

Aiming for the stars
Launched from the European Space Port in French Guiana in December 2013, the Gaia spacecraft is taking precise positional measurements of approximately one billion stars and radial velocity measurements of the brightest 150 million objects. Set to operate until 2019 with a possible extension until 2023, Gaia will be sending back information about the composition, formation and evolution of the galaxy we live in, the Milky Way.

Scientists hope the mission's data will shed some light on some of the basic questions about space. Gaia's spectrophotometric observations from each of the billion stars will help determine the origin, structure and development of galaxies, solar systems, planet systems, quasars and even asteroids.

Built by Airbus Defence and Space for the European Space Agency (ESA), Gaia is a complex two-ton machine packed with sophisticated instrumentation, including a billion-pixel spectrophotometric array aligned to two telescopes, an atomic clock and a 10-meter sunshade. The spacecraft is orbiting 1.5 million kilometers from Earth and sending back data that could possibly answer the mysteries of the universe.

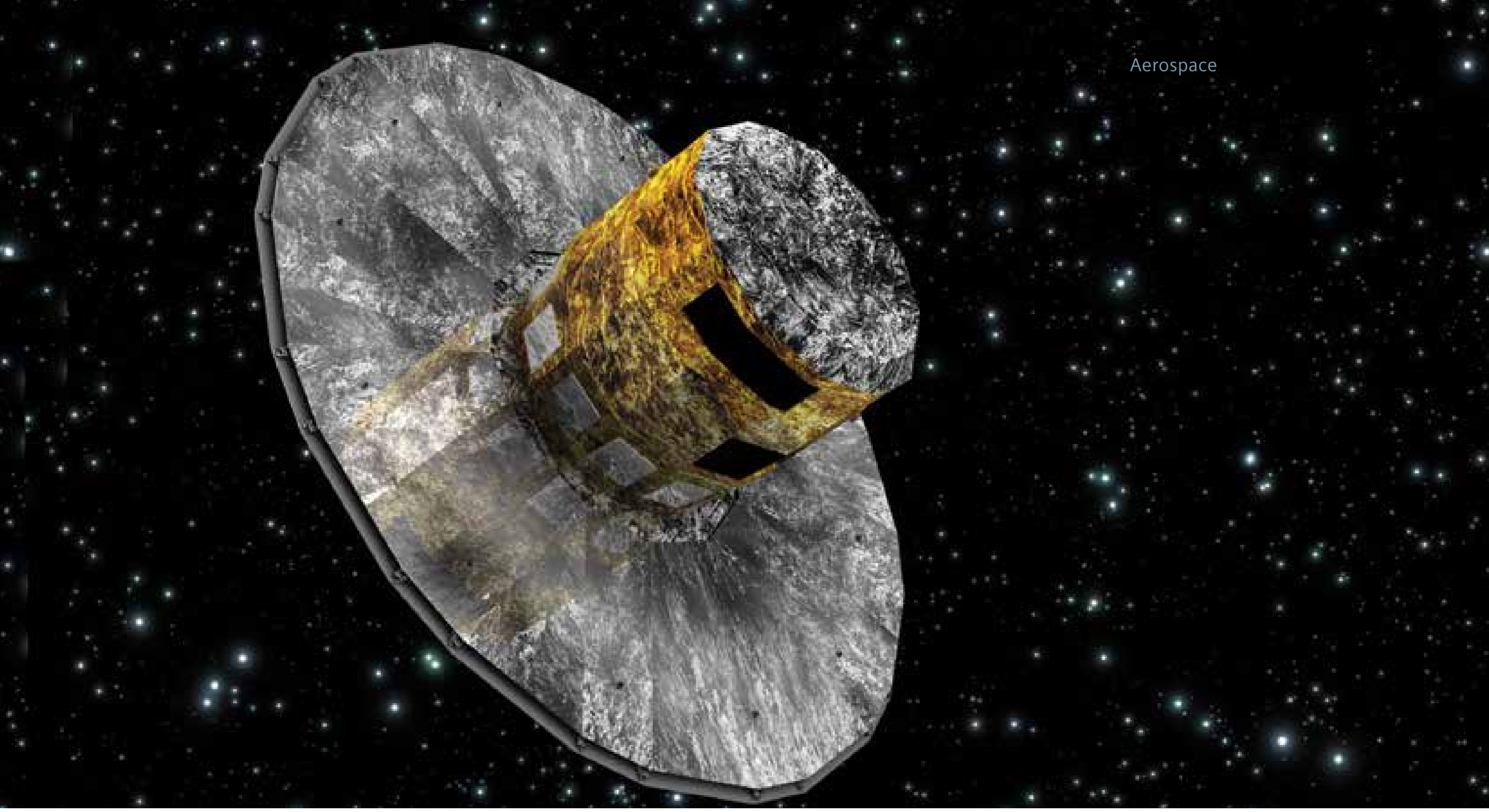
How do Gaia and other priceless space payloads make it from the launch pad to the depths of space with everything intact and in perfect working order? For people like Paul-Eric Dupuis, head of environmental test programs and research and development (R&D) at Airbus Defence and Space, and his team at the environmental test center in Toulouse, France, the answer is simple: use the latest simulation and testing solutions in one of the most advanced test facilities with some of the world's most experienced people, hand-in-hand with customers.

More than 30 years of experience
Airbus Defence and Space houses a leading environmental test center in Toulouse, which was formerly known as Intespace. The team has more than 30 years of experience and has been part of the international space testing scene since 1983. The 20,000-square-meter test facility is directly connected to the satellite integration room at the Airbus Defence and Space production site.

More than €11.5 million has been invested in the site since 2000, and the facility attracts attention from outside the French aerospace community as well, including from the United States. The United States' DIRECTV 15 satellite was tested at the facility and launched in 2015 from French Guiana.

Since an increasing number of satellite integrators and component manufacturers are counting on the team's expertise to test and validate their multimillion-dollar payloads, the test center is busy at times. Airbus Defence and Space relies on Simcenter solutions, including Simcenter SCADAS hardware and Simcenter Testlab software.

"My team has many shakers with two acquisition systems to run test campaigns," says Carine Pont, mechanical test manager at Airbus Defence and Space. "The smaller one, featuring a 128-channel Simcenter SCADAS hardware control system, is used about 10 to 12 times a year. The 96-channel Simcenter SCADAS control system on the big multivibration system shaker gets used every week. Our campaigns aren't always on big



satellites. Testing subsystems, like telecom satellite reflectors, is a main part of our job as well. Just recently, we were quite excited because we completed the first test campaigns on the telescope for the CHEOPS mission."

The team at Airbus Defence and Space has the right to be excited. CHEOPS (CHaracterising ExOPlanet Satellite) is a special project led by Airbus in Spain, and its telescope is managed by ESA and the Swiss Space Office. Scheduled to launch in 2018, CHEOPS is a spacecraft that will carry a single payload: a Ritchey-Chrétien telescope developed by Almatech. It will orbit around the Earth at a height of about 800 kilometers to study the formation of extra-solar planets similar to ours.

Europe, North America and beyond
The CHEOPS telescope, Gaia and the American DIRECTV 15 satellite are just a few of the many projects the center handles annually. The center is known for managing all the volume with its highly advanced and efficient process based on years of experience.

"We always had a very efficient way of testing based on our own software, DynaWorks," explains Dupuis. "This software is really a collection of all the experience that we have accumulated these past 30 years in the space industry. Today, we have a clear process that we intend to put to work."

For the testing side of the solution, the team had been using a custom-built, one-of-a-kind system since 2000. This system was integrated into the DynaWorks® process and for quite some time worked very efficiently. "After a few years, we discovered there were some issues with maintenance," explains Dupuis.

"After 15 years, we found ourselves without spare parts. The supplier wasn't willing to reinvest anymore."

A quest for new testing equipment
It was decided to keep the aspects that worked and find a different solution for the testing equipment. The old data acquisition system was completely programmable. The entire preparation and all of the various sensor setups could be automated and traced back into the DynaWorks platform. An entire batch of valuable setup information, including types of sensors and channel cable connections, was sent to the data acquisition station on the floor to program the amplifiers and channel connections. After the test run, all the collected data was sent back to DynaWorks for postprocessing and archiving.

Efficiency and security was something the test center wanted to enhance with its new hardware choice, but this time with a supplier willing to provide support and essential spare parts. For the next system, the call for bids was quite strict regarding these specifications.

Industry-standard excellence
The center contacted more than eight suppliers. In the end, they selected the Simcenter environmental dynamic testing solution featuring dedicated Simcenter SCADAS hardware and Simcenter Testlab software.

"The Simcenter solution opens the right doors for us to send the information as effectively and test as efficiently as possible today," claims Dupuis. "Combined with DynaWorks, it is the fastest and most efficient solution on the market. Previously, we took about 30 minutes to get the data back and something like 20 minutes

Gaia Deployable Sunshield Assembly (DSA) integrated onto the spacecraft and undergoing deployment testing in Toulouse.

to program the amplifiers. It is much, much faster today. With these speeds, the test center can perform a full campaign within a five-day work week. And by a full campaign, we mean three-axis sine tests and acoustic tests. I don't think any other test center can do this."

Besides high-quality tools and an efficient process, Dupuis is quick to credit the in-house knowledge and the testing teams' experience.

"We have excellent test engineers and technicians who work hand-in-hand with our customers," explains Dupuis. "Everything is under one roof. We have all the facilities and the integration laboratory and we know our job. We have more than 30 years of experience in this area. We always try to keep all our processes up-to-date to have the best solutions to offer to our customers."

High-quality, dependable tools

This is music to the ears of Pont and her team of 12 engineers and technicians who recently used their Simcenter environmental testing solution on the CHEOPS telescope. "This was the first test campaign with the new Simcenter system," states Pont. "We really noticed a difference. It was very efficient for data acquisition and programming."

On the hardware side, one big difference is that the acquisition boards are universal so it is easy to attach whatever type of sensor is required, and it is extremely easy to program the acquisition channels.

"Thanks to the monitor output function on the control system's VCF4 data acquisition cards that we specifically requested, we can record a redundant copy of the control channels on the acquisition system. Since this is supported in the setup definition software, chances of making setup mistakes are kept to a minimum," adds Pont.

The Simcenter SCADAS hardware is also a compact, singular unit. Compared to other systems, there are less connection points as well as universal cabling. This improves the quality overall.

"With the Simcenter testing system, we have a much bigger dynamic range," Pont says. "We can perform 0.1 or 0.2g sweeps. We couldn't perform tests with so low a range with our previous system. We were very satisfied with these results as well.

"With our old acquisition system, we had to wait quite a while before we got all the information from the time-history data, and now we practically get it immediately after the run. Instead of minutes, it takes seconds. We can easily easily realize time

Copyright Airbus Defence and Space

The Gaia payload module instrumented for environmental testing at the test center of Airbus Defence and Space in Toulouse, France.

savings by a factor of 10 with our new Simcenter system."

Also during the test, the team noticed other improvements, such as the online, real-time spectral data from Simcenter Testlab that contributes to overall time savings during the test runs. "With our new Simcenter testing solution, our job is getting easier," says Pont. "We will have fewer issues and a smoother process, and the data gets into the hands of the analysis team much faster than before. They are reassured that the data is correct and they get it faster – as much as 10 times faster."

512 channels

The Simcenter environmental testing solution in use at Airbus Defence and Space totals 512 channels of Simcenter SCADAS hardware equipment. Updated and installed in June 2015, it is one of the largest data acquisition systems dedicated to vibration qualification testing, including data reduction and vibration control.

Besides the 512 channels, the team thought it would be helpful to have some additional capabilities in the Simcenter SCADAS data acquisition cards, including the ability to copy the analog signal input at an output or electrical grounding selection for each channel. The Simcenter SCADAS hardware team in Breda, the Netherlands, especially developed the new voltage/charge/floating/4-channel (VCF4) card with this request in mind.

"The excellent quality of the Simcenter products is really appreciated by our technicians who use it every day," adds Dupuis. "Siemens PLM Software took into account our specifications and developed this special card, having its best experts from the Netherlands come and make sure the product matched the requirements. We understand that it is a standard, available product now delivered with the same high level of hardware and software support as the other Simcenter SCADAS products. That is a true business partner."

Taking the partnership a step further

To support its testing activities, the organization has a software division and an engineering division. Besides the test center in Toulouse and the software development for the DynaWorks platform, Airbus Defence and Space is also known for its engineering division, which has more than 25 years of experience consulting in the environmental testing business for the international aerospace community.

"We started our consulting work in Brazil 25 years ago," says Dupuis. "We have done so much consulting work at test centers around the world over the last two years that we have gained a tremendous amount of experience. We try to pass this on to our customers continuously. For example, our engineering team is involved in several projects worldwide in Argentina, Kazakhstan, Malaysia, Turkey and Korea."

"We never impose, we propose to have our customers use different data acquisition systems along with our DynaWorks software solution for managing the test campaign itself," says Dupuis. "The most useful combination is the Simcenter testing data acquisition solution and DynaWorks. Most of the time, customers request – actually insist – on using the Simcenter solutions as well. That is perfect for us since we know that Simcenter testing solutions bring significantly increased efficiency and a much lower risk factor to each and every test campaign." ■

Ask an expert

Simcenter News talks design-to-certify development with Dave Riemer vice president, aerospace and defense strategy

Where does Simcenter fit into the picture of aircraft development?

Simcenter is important from a product perspective because if we are going to design products, we've got to be able to analyze them and simulate their performance. It is key to doing the design. Often when we are designing a product, we design it and then we try to go and get it certified. By having Simcenter, we can design to certify.

This is going to shorten the cycle time for development and save companies hundreds of millions of dollars in major development programs. The ability to have a toolset like this and integrate it into the rest of the process – the design, the planning, and the manufacturing – is critical. Without it, you are missing the key element to ensure that you can create a design that is going to work.

Can you give an example?

Anytime you do analysis, it is critical that you are able to count on the results. Let's take an example about managing simulation data. We are a team doing analysis and someone has a version on a laptop. I got my version in my shared folder, and you got yours on a thumb drive. Well, we don't know if we are working on the right version of what we're analyzing, do we? Who has it? Where it is?

This is how many companies manage simulation still today. They put it on some shared drive or in some folder. Or the latest version is on the shared drive along with 10 other versions. Which one am I supposed to grab? Well, I grabbed the wrong one by mistake. And that mistake can cost you millions of dollars.

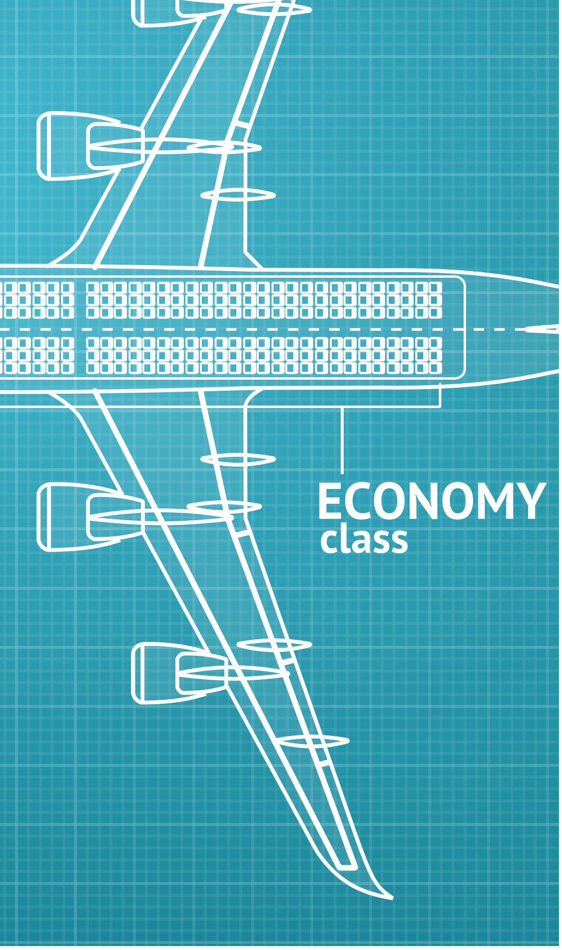
This is why managing the simulation models is important. You need to make sure the simulation models reflect the current design when you are making a design change. Which simulation models do I have to go and update? Which can stay as is? PLM plays a key part in being able to connect the analyst to the designer and the analyst to the rest of the business process.

What products are involved specifically?

There is a very clear link between Teamcenter, NX CAD and Simcenter. We will be able to keep our CAD models in sync with our CAE simulation models. As an analyst, you will get notified the designer is proposing a change and you might need to update your CAE model. Maybe it is a change that won't affect your work or maybe you'll need to redo your work, but at least you know about it.

How will this help meet the challenges of the aerospace community?

It doesn't matter if you work with satellites, rocket motors, planes, or helicopters, everything we do in aerospace relates back to the fact that somebody's life depends on it. So the tolerance for error in aerospace is zero. You make mistakes and people can pay for that mistake with their lives. I don't care if it is commercial aviation or military. We need to do our work right. The key to doing our work right is



having this foundation and being able to connect our design to our analysis, making sure the analysis matches and is linked to other analyses.

Without this type of foundation in aerospace, you have to do a lot of work, spend a lot of time and a lot of money to make sure that you haven't made a mistake. Why spend all this time and energy, when you could use Simcenter and Teamcenter and have the software tell you this is not in sync with that? Then you have the information and can take care of it immediately. It doesn't take weeks to track down the right data and compare it manually. With Simcenter, the right answer is right there.

Verification and certification are vital parts of the development process. Where do Simcenter test solutions belong in the process?
We have a catalyst solution that counts on Simcenter called Verification Management. What it does is connect requirements to a test or simulation verification method. We can keep the relationship between those so that any time we propose a change on the production side, we can tell which test article has that part in it. This helps if you have to redo or repeat tests. We can do the same thing with CAE. We can tell you what model that part is in and which CAE analysis.

Remember that aerospace programs take multiple years of test and analysis. During that time, the design does change. So if you need to redo some tests or analysis, how do you know which test or analysis needs to be rerun? Maybe that part has no effect on your area and you don't need to retest. Or maybe it does and you need to redo the analysis and test.

So it is about traceability, then?
There is traceability all the way through even to the hardware side of things. One of the things we are working on is an add-on catalyst for Verification Management and we call it Automated Test Correlation. So now, we will be able to use simulation and the Simcenter SCADAS hardware and Simcenter Testlab software to locate an instrument. I can review the simulation analysis in NX and I pick a location for the instrument and it automatically creates the test requirements, sets up the accelerometer rate, acquires the data and processes it in Simcenter Testlab, calibrates it and automatically displays it as a test result. Test engineers no longer need to go through all these channels of test data to figure out what data goes with which measurement. They just create a measurement and the results come back automatically.

So the days of test campaigns are numbered?
I don't think that the testing days are numbered. I think we are going to see an increase in the ability to verify designs through simulation. There is still so much we don't understand. Flutter is a good example. It is still something we don't clearly understand and we need to run tests for it.

The challenge is that we just don't have the room to be 'really good'; we have to be 'right'. So to answer your question, I don't see an airplane being certified without a test.

Is the Siemens eAircraft going to change the way we fly?
I think eAircraft will absolutely happen and it will fundamentally change the world. Electrification is going to change the world dramatically. Today, we are an oil-based economy. What if I can drive my car without oil and I can fly without oil? What happens to the global economy and the geopolitics? But, like other technologies, eAircraft technology is going to crawl, walk and then run. We won't see it happen overnight, but 20, yes, perhaps 20 years. I think that is doable. ■

About Dave Riemer

Dave Riemer is vice president, aerospace and defense strategy, for Siemens PLM Software. He joined Siemens PLM Software following a 35-year career in aerospace and defense. Before joining Siemens, Riemer was the vice president, science and engineering at ATK Aerospace Systems where he was responsible for all technology programs in the aerospace systems groups, including the Ares I first stage booster. He was also responsible for all engineering activities on the Space Shuttle Reusable Solid Rocket Motor, missile defense systems, strategic missile and commercial satellite solid rocket boosters. Prior to joining ATK, Riemer had a 27-year career at Raytheon Aircraft.

E-Fan X images and photo courtesy of Airbus.

Enter the E-Fan X

E-aviation is about to happen and sooner than you think

Expected to fly in 2020, the E-Fan X, co-developed by Airbus, Rolls-Royce and Siemens, is a flying test plane (or demonstrator as industry experts like to say) designed to prove the technical feasibility of hybrid-electric propulsion applied to a 100-seat passenger plane. Right now, the plan is to use a 100-seat British Aerospace (BAe) 146, a British short-haul jet. The first step will be to replace one of the BAe 146's four gas turbine engines with a two-megawatt electric motor from Siemens.

As you can guess, this is not the first time that Siemens has worked in this area. Quite a few innovation breakthroughs were made the past two years with the record-breaking Extra 330LE, equipped with a Siemens eAircraft propulsion system. Weighing in around 1,000 kilograms, the Extra 330LE holds a world record for ascent, a top-speed record of 337.50 km/h, and the privilege of being the first electric aircraft to tow a glider into the sky.

Pushing the drivetrain technology to the limit

Not only is the Extra 330LE a record-breaker, the electric drive system is a world-recorder holder as well, holding the title for power/weight ratio in its class with a continuous power output of 260 kilowatts. Weighing only 50 kilograms, this is an unprecedented power-to-weight ratio. Working from this world-record drive system, Siemens plans to develop a two-megawatt electric propulsion system for the BAe 146 regional aircraft. The system needs to be about eight times more powerful than the system that currently drives the Extra 330LE.

In the first flying demonstrator, one of the aircraft's four gas turbine engines will be replaced by a two megawatt electric motor provided by Siemens. The final E-Fan X would have four to eight motors on its wings that would drive the aircraft's propellers or fans. The electric propulsion system will get its power from a generator powered by a turbine in the fuselage. Take-off and climbing will be driven by 700-kilowatt lithium-ion batteries.

From a tech perspective, the E-Fan X is a big deal, but there is quite a bit of work to be done. Even though electric propulsion will take care of a huge part of the noise pollution issue, all these engines and batteries will still take up a lot of weight. Even with all the technology advancements like advanced lightweight engineering and high tech materials, the final E-Fan X needs to be lean-and-mean to succeed. Throw in the 2020 first flight into the development cycle and you can see how things can get rather tricky.

So when will we e-fly?

It seems the secret is Simcenter. According to the head of eAircraft at Siemens, Dr. Frank Anton, the secret recipe is not materials or topology: "The kinds of extremely light propulsion systems we are talking about can be developed and built thanks to Simcenter, a Siemens PLM Software simulation suite that takes all known physical and technical effects into account. Using this technology, we iteratively build digital twins and thus virtually optimize our prototypes. This not only accelerates development, but also results in more powerful machines." ■

Colophon

Director of publication: Peter De Clerck

Editor-in-chief: Jennifer Schlegel

Creative Director: Werner Custers

Editorial team and contributors: Els Coenen, Karen De Meyer, Adèle Dolique, Julia Hetz, Olga Korosteleva, Katia Liu, Cindy Piskor, Michael Ramirez, Al Robertson, Rajesh Ramaya Selvaraj, Ganesh Sethuraman, Prashanth Shankara, Raphael Van der Vorst, Bart Van Lierde and Els Van Nieuwenhove.

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Image courtesy of Airbus