In the VicToria project, the researchers simulated the noise of the high-lift system, the flight dynamics and the wing deformation of DLR's A320 ATRA in the computer. They then compared the simulations with real flight test data and designed a long-range aircraft taking all relevant disciplines into account.

DOWN TO THE VERY LAST DETAIL

As aeronautics goes increasingly digital, how will simulations and experiments complement each other in the future?

By Yvonne Buchwald

Aviation is undergoing a transformation, and the Corona pandemic could accelerate this process. The question of how future aircraft might look is not just a matter of alternative propulsion systems; it is also a question of how to get there. How will new aircraft and technologies be developed and evaluated? Will certain tasks be performed faster and more economically using computers? And will there still be a need for experiments? Will aeronautics research really be fully digitalised before long? And have we not dreamed of all this before? Stefan Görtz was in charge of DLR's VicToria project (Virtual Aircraft Technology Integration Platform), the largest of its kind ever to be conducted in the field of digitalisation in European aeronautics research. It was completed in late 2020. Some 160 scientists from 13 DLR institutes and facilities were involved, developing methods to evaluate new technologies for more economical and environment-friendly flight in a more timely manner in the future and to enable new aircraft to be designed (almost) exclusively using computers.

Professor Görtz, the first crucial steps towards virtual aircraft development and flight testing using high-fidelity simulation methods had already been made in earlier projects. Where do things stand at the moment?

: We are making consistent and purposeful progress towards digitalising aeronautics, but there are always going to be different expectations, setbacks, changing conditions and diverging visions. We are getting closer to the idea of the virtual product, step by step. This is a highly accurate mathematical and numerical representation of the aircraft, with all of its characteristics. Today, we are able to model aircraft geometries in far greater detail.

Image: Private

Stefan Görtz is head of C²A²S²E (Center for Computer Applications in AeroSpace Science and Engineering) at the DLR Institute of Aerodynamics and Flow Technology in Braunschweig. The 46-year-old aerospace engineer has been Professor of Multidisciplinary Design Optimization at TU Braunschweig since December 2019. He was the Principal Investigator of DLR's interdisciplinary VicToria project between 2016 and 2020, was involved in its predecessor project, Digital-X, and continues to be involved in the cross-sectoral project Simulation-Based Certification (SimBaCon).

Most importantly, however, we are no longer looking at technologies and disciplines individually, but rather in combination. We were able to perform calculations for entire aircraft 30 years ago and have done plenty of aerodynamic simulations since that time. But that alone is not enough, of course. An aircraft is also elastic. The wings flex and the fuel sloshes back and forth during manoeuvres. There are a lot of things to take into consideration, and that is precisely what we are doing here. By coupling our new, high-fidelity simulation methods, we are creating an interdisciplinary simulation and design environment that allows us to understand the physical characteristics of an aircraft and the interaction between different disciplines more accurately than ever before.

In 2013 you said, "Only when an aircraft behaves in the computer as it does in reality will a digital aircraft complement a flight-test aircraft on an equal basis". How close are we to achieving that goal?

: Five to 10 years ago, people could not yet claim that simulations were on a par with real test flights, or that a digital aircraft could replace a real one. In the VicToria project, for instance, we compared virtual flight tests with real, highly-instrumented flight- and wind tunnel tests – with a level of detail that is, in fact, unique worldwide. In spring and autumn 2019, we carried out flight tests with DLR's research aircraft A320 ATRA both in the air and on a computer. In doing so, we found that we can very accurately simulate its flight dynamics with the highly accurate methods we have at hand today and create a model of the ATRA in the computer with the help of dedicated virtual flight tests.

"We are no longer looking at technologies and disciplines individually, but rather in combination."

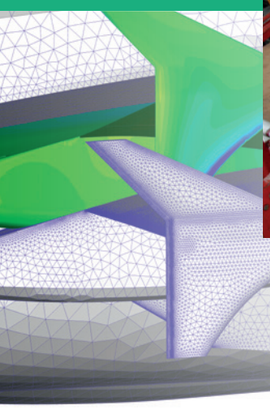
This marks another important step along the path towards digital design and simulation-based certification. That said, we have to achieve even greater accuracy and incorporate even more details into our simulations in order to arrive at a perfect match between virtual and real flight tests.

Apparently minor details, such as the exact mass distribution in the aircraft, play an important role. Simply put, things like knowing whether the pilot was carrying a wallet on the test flight also plays a role in the end. We have to keep thinking about what will get us close enough to reality.

A stereo camera system installed in the aircraft cabin was used to measure the deformation of the wing during various flight-test manoeuvres

Image: Wilbri GmbH

The wings of the A320 ATRA were covered with a special foil in order to optically measure their deformation during flight



When will our simulations be good enough that we can rely on them completely? On the one hand, it is important to engage in a dialogue with the regulatory authorities. On the other hand, test pilots will in the future be able to compare a virtual model of the airplane or helicopter with the handling qualities of the actual aircraft in a flight simulator.

The first wave of enthusiasm for digitalisation swept through the research landscape back in the 1970s; conventional experiments seemed to have fallen out of favour. According to the predictions, numerical simulations would replace wind tunnel and flight testing.

: Yes, that was the thinking. When numerical flow simulation methods were first developed and used to tackle problems that appear pretty rudimentary today, people were convinced that they would soon replace experiments altogether. But that was far too optimistic, and not just in terms of timing. Researchers soon realised that there were certain shortcomings, especially when it came to the modelling depth and the lack of interaction between the disciplines involved. Computing resources were also limited; the Cray supercomputers in the 1980s only had the computing power of an iPhone 4. While at that time models were being calculated for comparatively simple cruise flight conditions, today we can model complex flow phenomena and simulate dynamic flight manoeuvres. When all that became clear, wind tunnel and flight tests were reappraised and deemed to be indispensable once again. So much the better for us today, as we can use them to improve and validate our simulation methods.

After the continued importance of experimental research had been realised, numerical simulations, wind tunnel and flight testing were deployed together. Right now, however, the focus seems to have returned to digitalisation. Is this still an equally balanced triad of research methods, or has numerical simulation emerged triumphant after all?

: There were times when it was thought that simulations would soon replace all of the conventional methods. And there were times when scientists believed that wind tunnels represent the absolute truth. The fact is that all methods are mere approximations of reality. But for all that, there has indeed been a shift – today it is clear to us that experiments will continue to be conducted, albeit in lower numbers, but they will be more targeted and of higher quality. And they will take place at a different stage in the design and development process. Simulations have become more important in the early stages of design, as they allow us to perform trade studies and to explore the design space to steer the design in the right direction. In future, it will not be a matter of using a wind tunnel or flight tests to design an entire aircraft. Instead, things will happen the other way around – for example, first come the simulations, then the numerical design, and only then will the experiments take place, for the purposes of verification and validation. What is more, by using not only more powerful computers, but also better measurement technologies, we can continue to improve our computer models through dedicated experiments. In doing so, we are consistently pursuing the path from digital design to virtual certification.

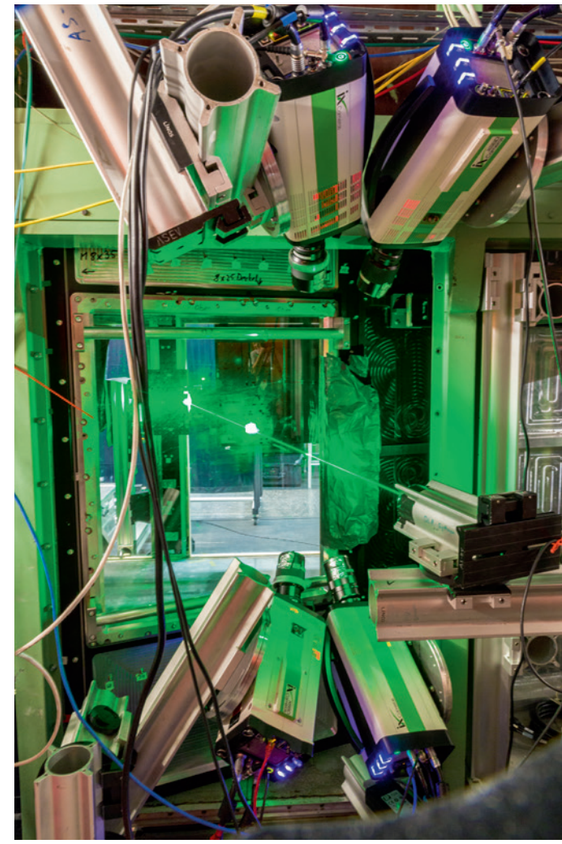
When talking about performing virtual first flights for certifying an aircraft, numerical data continues to be subject to much greater distrust than real tests. Where do you stand on that?

: In the VicToria project, we laid the groundwork for digital development and the characterisation of aircraft and helicopters by means of numerical simulations. The project is unique in the sense that all of the relevant disciplines, such as aerodynamics, aeroelasticity, load analysis, flight dynamics and structure, were brought together for virtual flight tests and multidisciplinary design. Only DLR can do something like this, not a university and, to this extent, not an industrial company. For the first time, we conducted experiments purely to check our models and simulations – several wind tunnel tests and two flight test campaigns with the ATRA. The processed measurement data were used to improve the numerical methods and check the accuracy of their predictions.

"There will continue to be experiments, fewer in number but more focused and of higher quality."

Now, we are in a position to carry out virtual flight tests that can be compared with real flight tests in detail. This means that we can construct a virtual model of an aircraft or helicopter with all of its characteristics. To give one example, such a model could be used to design a system to reduce the loads caused by gust encounters or during manoeuvres, thus increasing passenger comfort. And that's not all – we can now make use of these methods for new aircraft like the iSTAR (see article in DLRmagazine 164) or even use them to design, test and fly aircraft that do not yet exist. In the future, it will be possible to provide a 'digital twin' for an aircraft or helicopter, which can be used to assess the potential of new technologies in a virtual design environment and to determine their impact on the environment.

The interview was conducted by **Yvonne Buchwald,** who is responsible for communications at the DLR Institute of Aerodynamics and Flow Technology in Braunschweig.



With a new high-resolution measurement technique, scientists have studied flows in detail, as they occur when air moves around aircraft components, using the Eiffel Wind Tunnel at the Bundeswehr University Munich. With the data, they were able to improve their models and validate their simulation methods.

THE VICTORIA PROJECT AT A GLANCE

VicToria is a showcase project because …
"we had the unique opportunity to bring all of the relevant disciplines in aeronautics research together in this DLR project."

This topic is very relevant because …
"the development, testing and manufacturing of new aircraft is associated with considerable timing and financial risks. The Coronavirus pandemic has made it all the more important to step up the introduction of innovative technologies in order to make flying more economical and environmentally friendly, while giving us greater control over the technological risks."

One thing that was completely new was …
"Unlike the projects that came before VicToria, here we combined wind tunnel experiments with real and virtual flight tests based on validated and enhanced simulation methods. In addition, we have considered all relevant disciplines relating to flight physics."

The project in numbers
3.75 years duration (2016–2020)
36 million euro project funding
13 DLR institutes and facilities involved
160 contributing scientists

SIMULATION-BASED CERTIFICATION

It can take several years for new technologies or vehicles to receive certification, including time consuming test drives or flight tests. With simulation-based certification, the majority of the data required for certification can be provided using computers. As part of DLR's cross-sectoral project Simulation-Based Certification (see the article in DLRmagazine 161), several DLR institutes and facilities are working together to develop tools for digitalised certification. The goal is to further develop the simulation processes to the point where the authorities accept them as reliable means of certification.