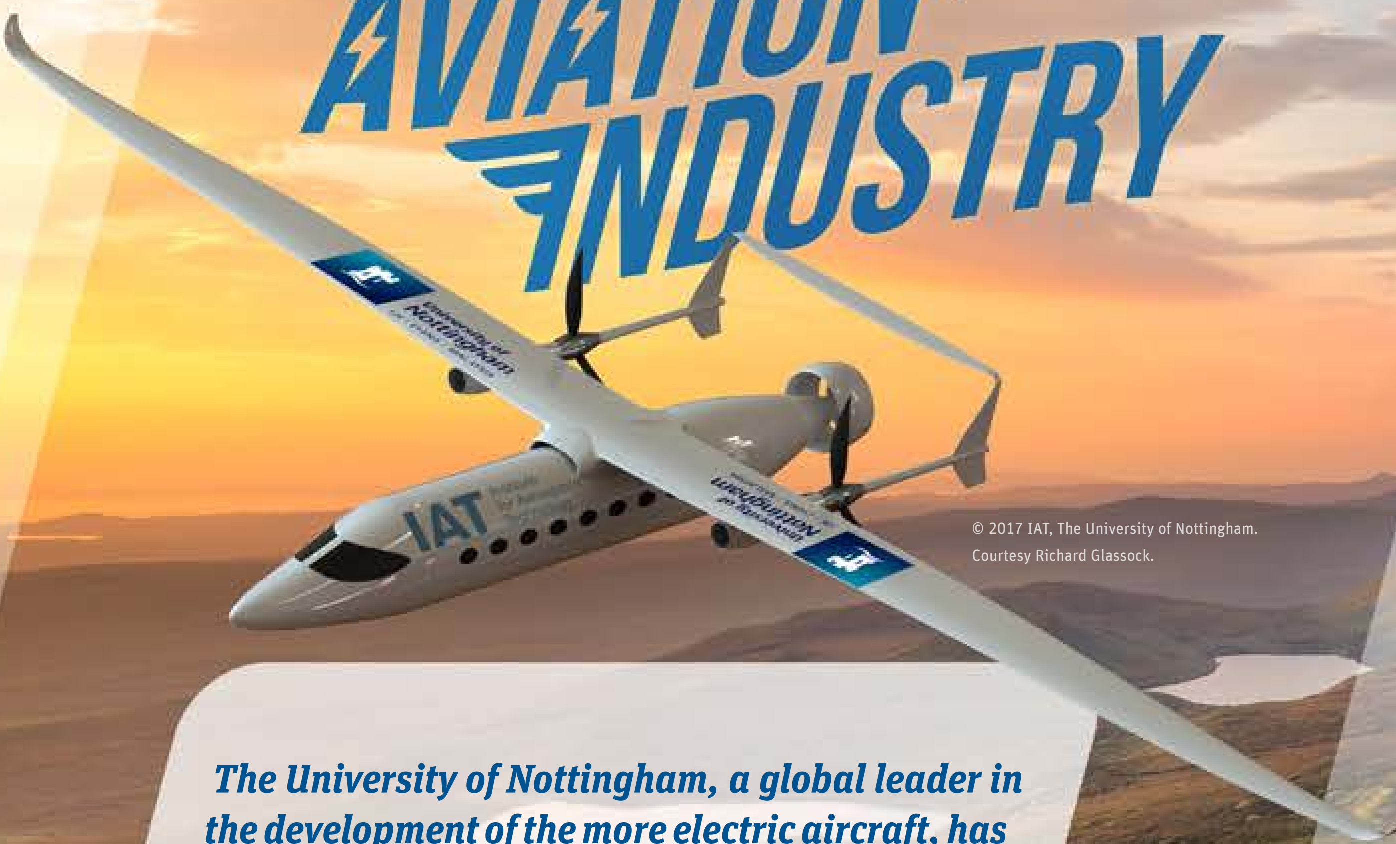
ELECTRIFYING THE AVIATION INDUSTRY



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

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

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

We also benefit from a broad interest and great dynamism in aerospace in the United Kingdom today. The U.K. already has the world's second largest aerospace sector, and global demand for air travel is accelerating. It is estimated that, by 2030, there will be around 27,000 new large commercial airliners in the skies. Air travel is projected to grow from 3.4 billion passengers in 2015 to more than 16 billion by 2050.

The European Commission, industry and the British government provide funding to our program and other initiatives that will help the nation capitalize on this opportunity — as well as meet the more stringent environmental regulations for aircraft that are so critical to achieving global sustainability and in-service efficiency. As just one example, we have 14 projects, worth €38 million (approx. US$43.5 million) that are directly tied to meeting the goals of Europe's Clean Sky 2 initiative, which spans 24 countries and focuses specifically on reducing CO_2 and other gas emissions, as well as the noise levels associated with aircraft. We also host national facilities for the Aerospace Technology Institute (ATI), the U.K. aerospace research agency.

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

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

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

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

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

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

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

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

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

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

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

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

HM: The single greatest engineering problem is generating and storing

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

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

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

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

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

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

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

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

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

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

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

University of Nottingham at a Glance

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

About Hervé Morvan

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

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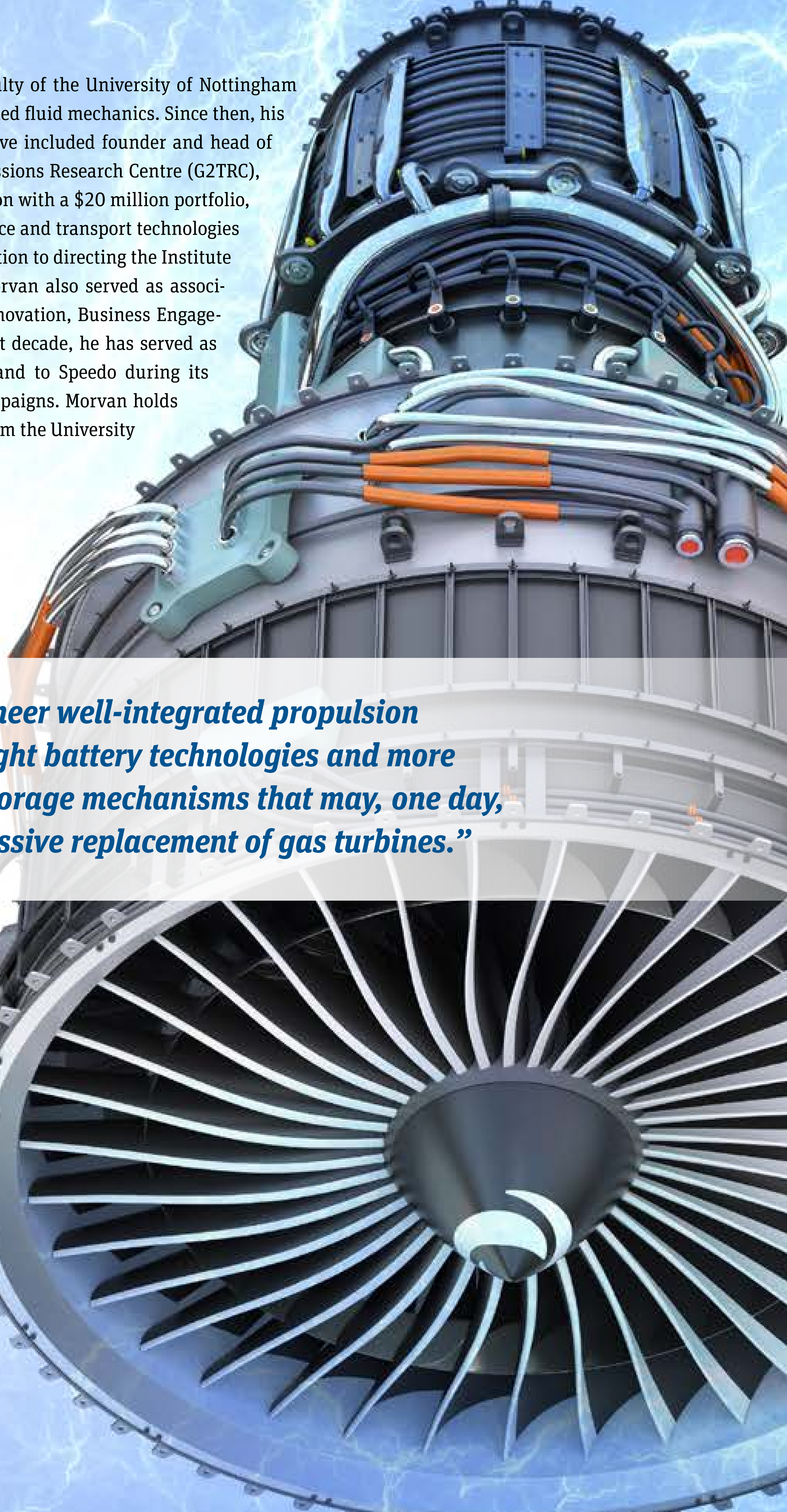

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