A CREATIVE DRIVE FOR THE FUTURE OF FLIGHT

Bringing e-mobility to the sky requires whole-system thinking

By Jana Hoidis

Global mobility is facing society's ever more pressing need to significantly reduce the environmental effects of air transport and bring its impact into line with the Paris climate goals. Air transport is currently responsible for approximately 2.8 percent of all carbon dioxide emissions worldwide. DLR is conducting a concept study with a view to bringing an ecologically efficient, medium-haul aircraft into commercial service by 2040.

There are high demands for future aircraft. They must operate without negatively impacting the climate, while remaining cost-effective in both production and use – two often contradictory goals. "DLR has all of the necessary skills to determine which aircraft are the most environmentally friendly for which application, with which propulsion systems and at which altitudes," says Johannes Hartmann, Head of the Exploration of Electric Aircraft Concepts and Technologies (EXACT) project, which was launched in January 2020. Twenty DLR institutes from the fields of aeronautics, energy and atmospheric research are contributing their expertise to the study. In the past, the primary consideration during the development of an aircraft was the associated production, maintenance and operating costs. With EXACT, the environmental impact, together with cost-effective operations, are incorporated into the conceptual aircraft design from the very beginning. "We are turning this process around for the first time," adds Hartmann. "And this is revolutionary."

Johannes Hartmann
studied aerospace engineering at the Technical University of Berlin. After several years of research and development work at Airbus in the field of virtual product design, he moved to the DLR Institute of System Architectures in Aeronautics in Hamburg in 2018. Here he is engaged in the design and development of system architectures for hybrid-electric flight. Hartmann is the overall manager of the EXACT project and coordinates work across Germany at the participating DLR locations. He is married and has three children who share his passion for aircraft. In his free time, he enjoys flying model aircraft with his family.

Towards climate-neutral aircraft

Conventional aircraft engines have been continuously developed and improved since their introduction. As a result, they are much more energy-efficient today than they were just a few years ago. However, with the development of lightweight materials and the optimisation of aerodynamics and propulsion systems, the potential for further reducing carbon dioxide emissions has been almost completely exhausted. An entirely new approach is therefore necessary. Electric, hybrid-electric or hydrogen-based propulsion concepts, utilising batteries, hydrogen fuel cells and synthetic fuels, could help the air transport system to operate in an environmentally friendly yet economical manner. DLR researchers are aiming to develop an aircraft with at least 70 seats that can cover a distance of 2000 kilometres by 2040.

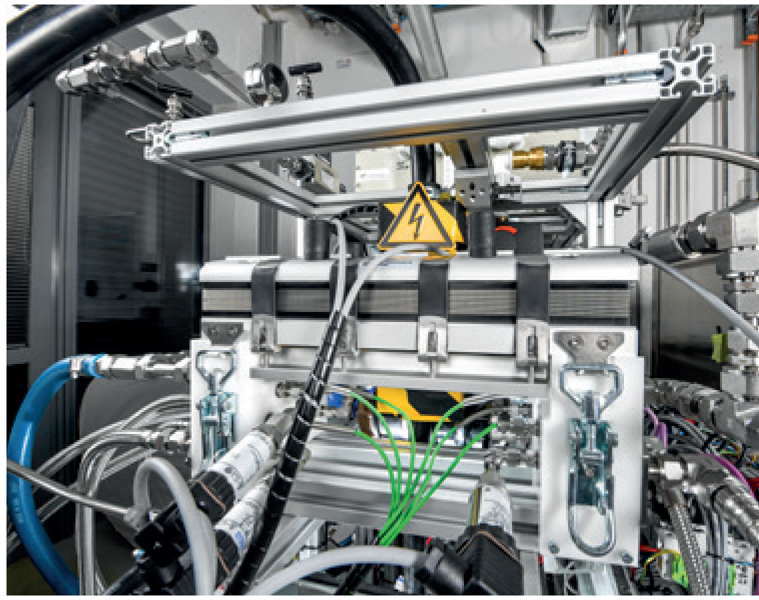
Using various modern technologies, small aircraft are already flying short routes almost emissions free. In September 2016, the world's first four-seater passenger aircraft powered by a hydrogen fuel and cell battery system alone, the HY4, took off from Stuttgart Airport. The HY4 was developed by the DLR spin-off company H2Fly in conjunction with the Slovenian aircraft manufacturer Pipistrel. The first aircraft powered purely by electric propulsion – the two-seater Extra 330LE aerobatic plane powered by a Siemens electric motor – was also officially approved and certified in 2016.

However, aircraft with up to 19 seats are responsible for less than one percent of all emissions generated by aviation. "We want to be as creative and radical as possible in our approach to the aircraft development process," explains Hartmann. "So, we are looking at various configurations with 19 to 200 seats. We may gain groundbreaking knowledge for small aircraft that can also be scaled and applied to larger ones." Aircraft the size of an Airbus A320, with approximately 150 seats, account for around 50 percent of aircraft emissions. This presents considerable opportunities for savings on short- and medium-haul routes. Such aircraft currently burn kerosene in their engines, not only to provide propulsion, but also to supply their on-board electrical systems. These systems could be powered by batteries relatively easily. Longer flights, on the other hand, could probably only be accomplished by the burning of energy-dense fuels. The Power-to-Liquid process produces fuel from renewable forms of energy, while also removing carbon dioxide from the atmosphere. This carbon dioxide reacts with hydrogen to form a mixture of hydrocarbons, from which gasoline, diesel or kerosene can be derived. During subsequent combustion, these fuels release only as much carbon dioxide into the atmosphere as was previously removed. Could this be the win-win solution we need?

Both environmentally friendly and economical

Reductions in emissions are already possible by mixing conventional kerosene with synthetic fuels. However, these new fuels are currently only available in small quantities and are disproportionately expensive. Using a mixture containing 10 percent Power-to-Liquid fuels would raise the operating costs of an airline operating primarily from Germany by 11 percent. If we are to ensure that environmentally friendly air transport becomes a reality, aircraft must continue to be economically viable.

As hydrogen is already being used as a raw material for synthetic fuels, the EXACT project will also investigate propulsion systems that burn hydrogen directly. While Power-to-Liquid fuels are inherently climate-neutral, fossil fuels are still required to produce and transport them today. Using hydrogen directly as a fuel could remove some intermediate steps and reduce costs. But there is a catch; although hydrogen is very light, it has such a large volume for a given energy content that aircraft would have to be completely redesigned to accommodate it.



Fuel cells for use in aviation are being researched in the laboratory of the DLR Institute of Engineering Thermodynamics in Hamburg

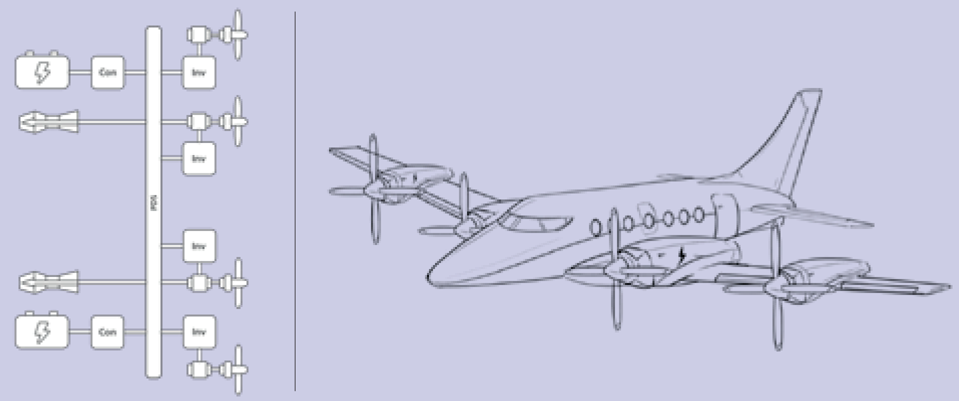
For economic reasons, aircraft manufacturers are guided by the principle of commonality. They ensure that components are compatible for installation in all aircraft of the same family. Airbus has always used this concept to optimise its production. The A319, A320 and A321 aircraft, for example, all use the same vertical stabiliser despite the different lengths of their fuselages. Hybrid-electric propulsion systems are fundamentally different from their conventional counterparts and will place completely new demands on aircraft structures. So, the question becomes – when a hybrid-electric short-haul aircraft is being designed, how can these technologies be adapted for the corresponding medium-haul aircraft while ensuring that their production is still cost-effective?

A completely new air transport system

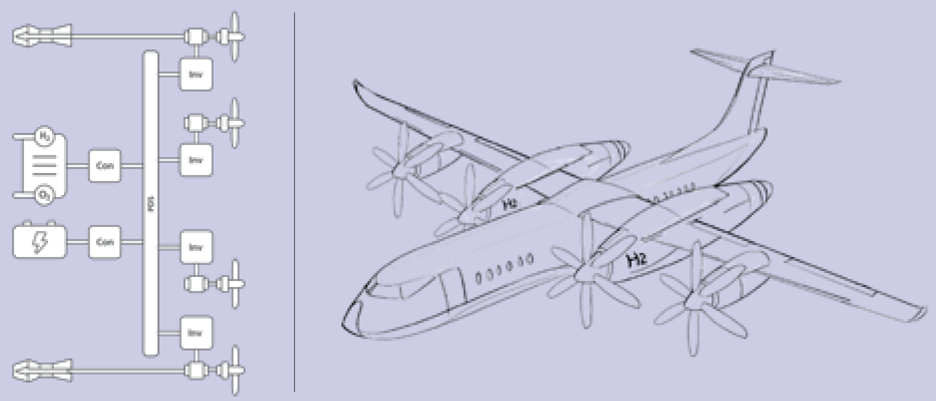
Changing the nature of the commercial aircraft fleet could be a relatively simple way of moving towards environmentally friendly flight. At present, airlines like to purchase a 'universal aircraft' that they can

CONFIGURATIONS STUDIED IN THE EXACT PROJECT

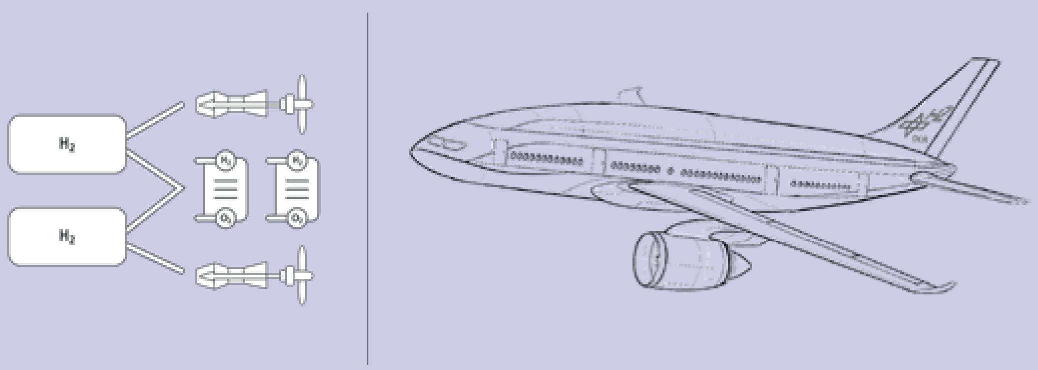
Propulsion systems and associated aircraft concepts



A completely battery-powered propulsion system is feasible for smaller, 19-seater aircraft for flights of up to 200 kilometres. Fuel would be carried only as a reserve in case of emergencies, or if the aircraft were required to fly longer routes.



Medium-sized, short-haul aircraft flying up to 2000 kilometres could reduce CO_2 emissions through a clever combination of different propulsion systems. Hydrogen fuel cells power the aircraft during cruise and when taxiing on the ground. Batteries supply the on-board electrical systems. Hydrogen gas turbines provide the necessary thrust for take-off and potential go arounds.



Larger aircraft carrying 150 passengers or more on medium-haul routes of over 2000 kilometres require greater propulsive power. Fuel cells are used when taxiing on the ground, while gas turbines that burn synthetic fuels allow for faster cruising flight. When used in parallel, both systems combined can generate enough power for take-off.

Hydrogen fuel cell | Battery | Gas turbine | **Con:** Converter **Inv:** Inverter **PDS:** Power distribution system

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Project meeting at the DLR site in Hamburg: (from left to right) Berit Gerlinger, Kai Wicke, Johannes Hartmann and Giuseppa Donelli work together on developing visionary aircraft configurations.

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use for both short- and medium-haul flights. This way, pilots, flight attendants and maintenance staff only need to be trained to deal with a single type of aircraft. Although this is practical and saves time and money, it is not ideal from an environmental point of view. There is enormous potential for improvement here and Hartmann envisages adapted fleet concepts as the solution to this issue: "Depending on the route, aircraft with more environmentally friendly prolusion systems could be used for shorter flights."

DLR aeronautics researcher Kai Wicke is currently studying the operational and ecological integration of new aircraft configurations as part of the EXACT project. He is also considering their impact on the air transport system as a whole. "Whether a new aircraft is powered by hydrogen, fuel cells or batteries, it will be interesting to see its impact on both the environment and the air transport system," he says. "How will it affect airports, airlines, air traffic control and the atmosphere?" A new type of aircraft will influence these systems, and vice versa. If aircraft are to be refuelled with hydrogen, new fuel delivery systems will be required. How do contrails generated by the combustion of hydrogen affect the atmosphere? Would they lead to greater cloud formation, and could this affect the climate? Extensive use of batteries will require dedicated areas for charging and storage. What will our energy system look like in the future when coal-fired power plants are shut down? Can renewable forms of energy consistently provide the amount of power we need? How will energy prices develop? How can enough batteries be produced? Can they be recycled at the end of their life?

All of these questions need to be answered over the next four years, during which an initial strategy will be developed. Aircraft engineers, atmospheric researchers and electrical engineers from 20 different DLR institutes are working together to establish reliable models and answer as many of these questions as possible. Hartmann is enthusiastic: "The EXACT project is giving DLR an opportunity to demonstrate its unique expertise."

Jana Hoidis is responsible for communications at DLR sites in northern Germany (Hamburg, Bremen, Bremerhaven and Oldenburg).

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- Institute of Aerodynamics and Flow Technology
- Institute of Propulsion Technology
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- Institute of Composite Structures and Adaptive Systems
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