The Aircraft of the Future

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eRay

Four TUM students have blazed a trail in the world of aircraft engineering with a highly advanced cross-disciplinary collaborative project to design the most economical aircraft possible. Featuring a turboelectric propulsion system, their jet won them the 2018 DLR/NASA Design Challenge.

These four aerospace students jointly won the DLR/NASA Design Challenge in 2018 with their design for a new aircraft concept: Alexander Frühbeis, Isa Held, Artur Usbek and Patrick Sieb (from right).

Picture credit: Kurt Bauer, Graphics: ediundsepp (source: A.Frühbeis, I.Held, P.Sieb, A.Usbek/TUM)

Kurzfassung

Das Flugzeug der Zukunft fliegt mit fast zwei Dritteln weniger Treibstoff

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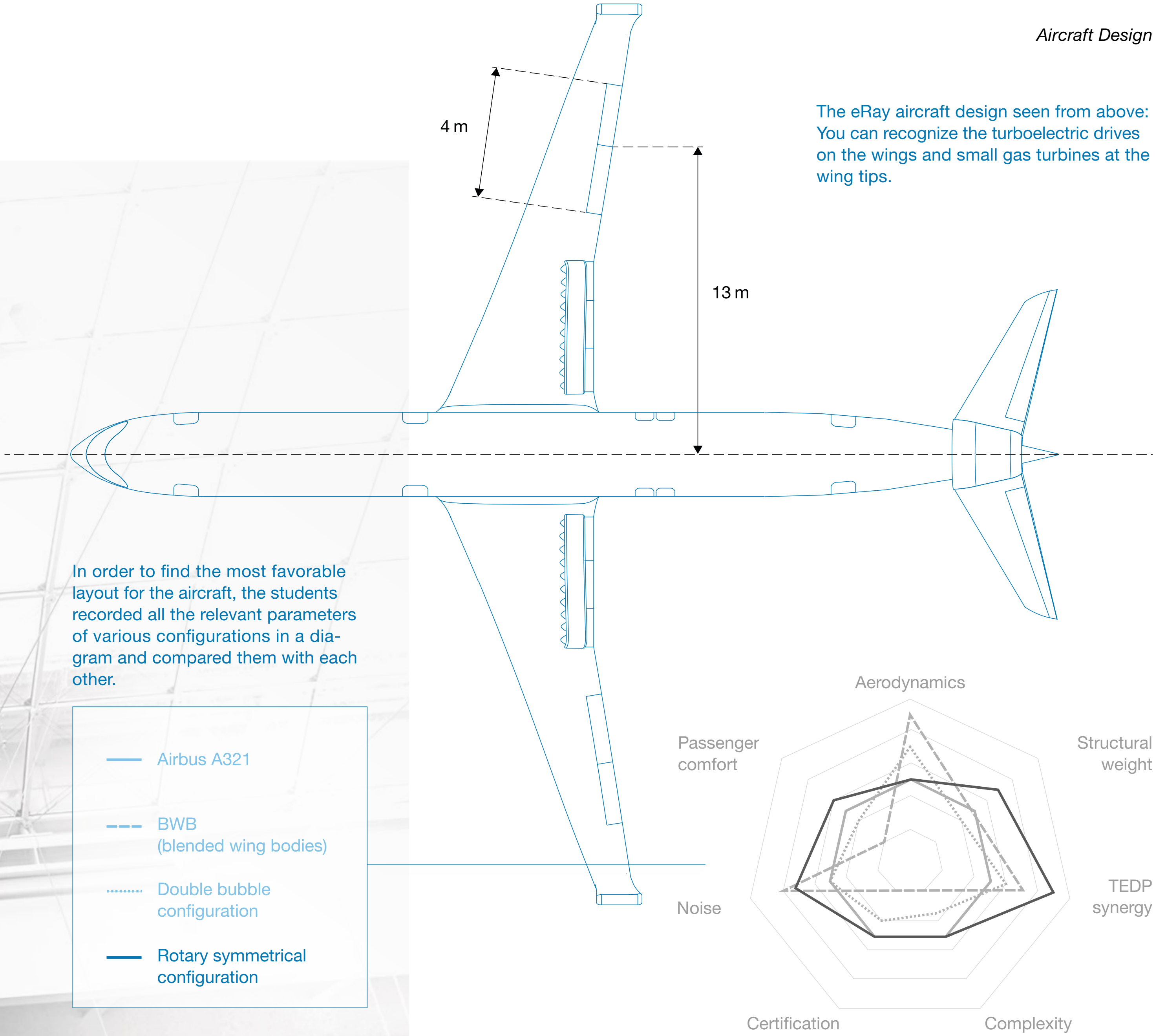
Den Masterstudierenden Alexander Frühbeis, Isa Held, Patrick Sieb und Artur Usbek gelingt 2018 ein Entwurf für ein Verkehrsflugzeug der Zukunft, der aufhorchen lässt. Mit seinem „eRay" gewinnt das Team der TUM die DLR/NASA Design Challenge. Das Flugzeug soll im Vergleich zu einem heutigen Airbus 321 bis zu 64 Prozent Energie einsparen und damit entsprechend umweltschädliche Emissionen vermeiden. Sein Ansatz: Synergieeffekte von Neuerungen in den Bereichen Antrieb, Aerodynamik und Struktur nutzen und damit ein ultraeffizientes Gesamtsystem schaffen. Der fensterlose Jet hat einen Rumpf aus Carbonfasern mit einer größeren Fanstufe am Heck und kleinen, an der hinteren Tragflächenkante angebrachten elektrischen Antriebseinheiten. Mit seiner cleveren Kombination einzelner Verbesserungen ist der „eRay" leichter, hat einen effizienteren Antrieb und weist weniger Luftwiderstand auf als heutige Verkehrsmaschinen. □

The eRay aircraft design seen from above: You can recognize the turboelectric drives on the wings and small gas turbines at the wing tips.



In order to find the most favorable layout for the aircraft, the students recorded all the relevant parameters of various configurations in a diagram and compared them with each other.

"The world of aviation faces a huge challenge. We all know we're not doing the environment any favors with ever-growing air traffic and passenger numbers doubling every 15 to 20 years," declares Alexander Frühbeis. Studying for his Master's in Aerospace Engineering at TUM, the 24-year-old is convinced that, "Balancing this immense growth with environmental concerns calls for completely new aircraft concepts."

The German Aerospace Center (DLR) and US National Aeronautics and Space Administration (NASA) launched a joint Design Challenge for German and American university students with the aim of specifically encouraging groundbreaking designs for the future of aviation such as the one described by Frühbeis. The competition is now in its second round. In the 2018 competition, the focus was on aircraft concepts that radically reduce harmful emissions. The task was to achieve energy savings of 60 percent or more in comparison with today's Airbus A321-200 with a design offering comparable transport capacity, at least three hours' range over water, direct connections between small airports, and the lowest possible manufacturing and operating costs. As Frühbeis recalls, "As soon as I heard about this, I knew I would take part, since it unites my two biggest passions: a fascination with flying and the desire to help shape a greener society."

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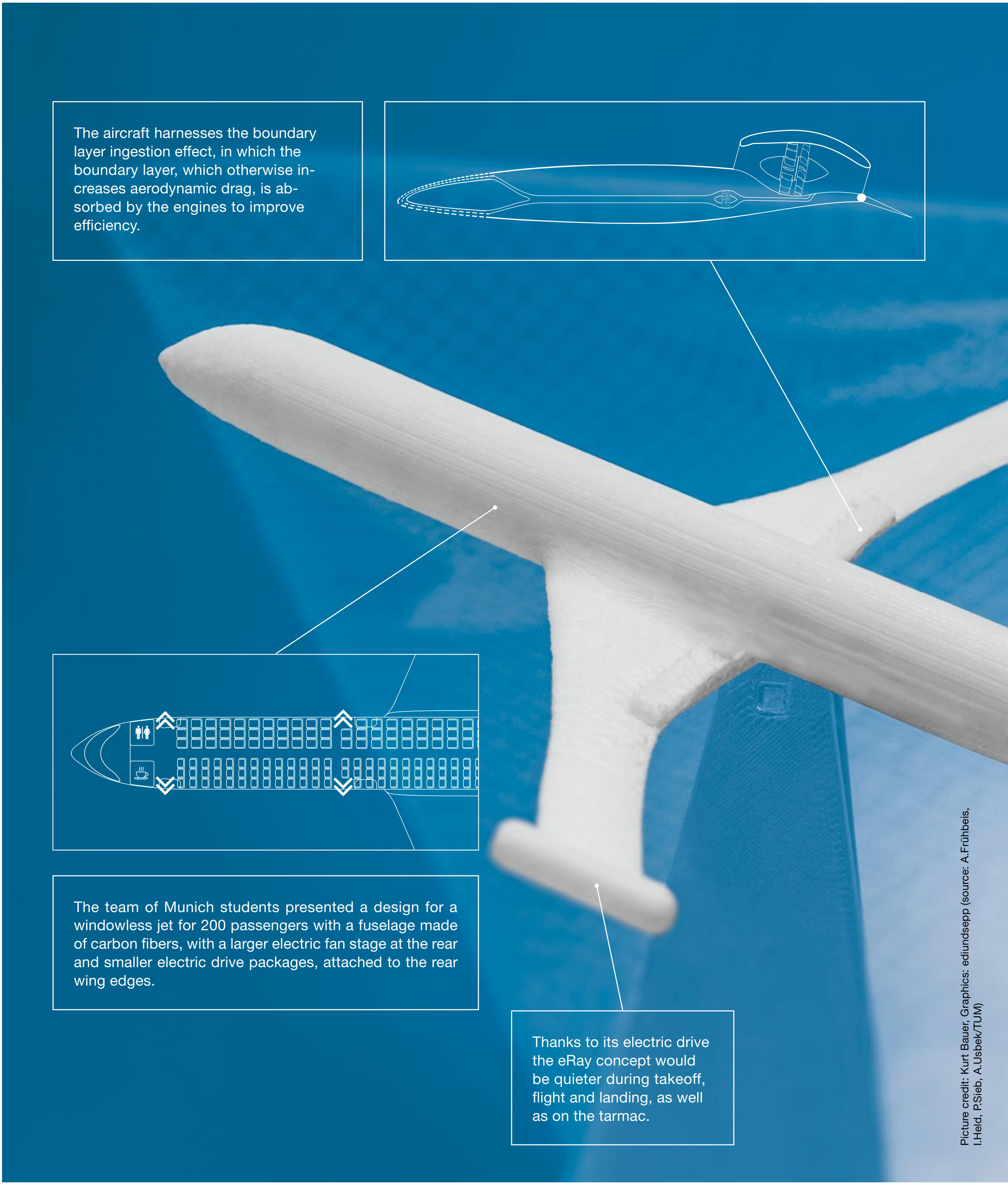
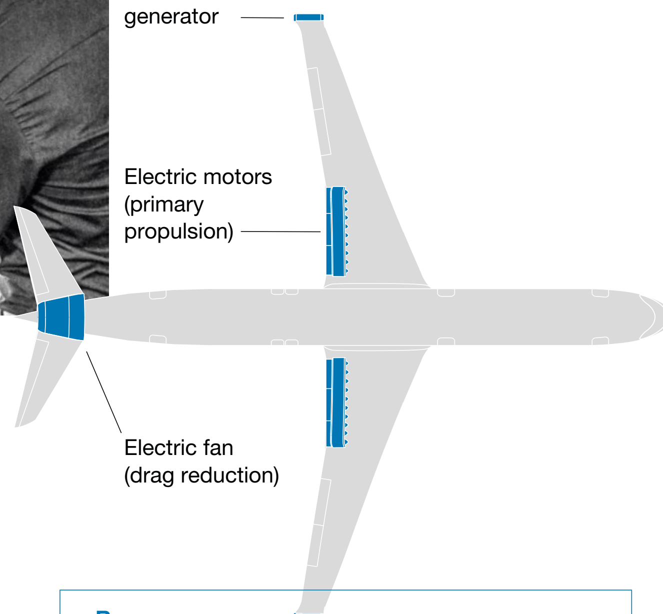


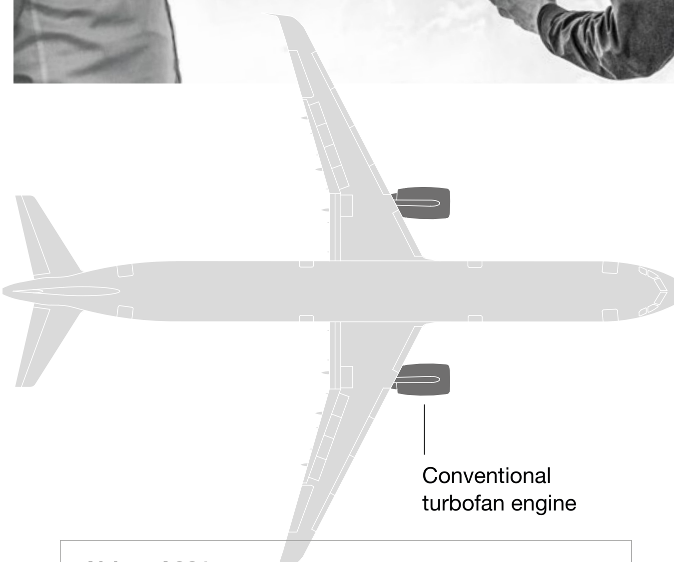
Picture credit: Kurt Bauer, Graphics: ediundsepp (source: A.Frühbeis, I.Held, P.Sieb, A.Usbek/TUM)

Flight of the future poised for take-off

In January 2018, what was to be the winning German team first formed at TUM, consisting of Master's students Alexander Frühbeis, Artur Usbek, Isa Held and Patrick Sieb. The first general meeting for all participants across various German universities took place in Hamburg in February. Between that and the final presentation of their concepts in Braunschweig at the start of August – so within only around six months – the team completed their design for an ultra-efficient aircraft, which they christened eRay.

Prof. Mirko Hornung, Chair of TUM's Institute of Aircraft Design, and research associate Lysandros Anastasopoulos were on hand to support the students with this competition. The latter outlines the challenges framing the project: “In terms of cruising speed, payload capacity and range, today's jet-powered commercial aircraft are about to reach their technical limits. Recent research has focused a lot on environmental compatibility, aiming to reduce emissions such as carbon dioxide, nitrogen oxides and soot, as well as noise pollution. So even in this area, it now takes considerable effort to realize any significant improvement.” ▷





Airbus A321

The comparator aircraft for the competition was the 2005 Airbus A321-200 powered by two conventional engines. The task was to develop a concept for an aircraft that consumes at least 60 percent less energy with comparable transport capacity.

eRay

The eRay design, which won the competition, is electrically powered and shows a 30 percent reduction in mass and 48 percent improvement in propulsion power compared to the A321, leading to a 64 percent overall reduction in energy consumption.

Smart use of synergies

Against this backdrop, the Munich students focused both on improving specific aircraft components and, above all, on harnessing synergy effects across the areas of propulsion, aerodynamics and structural design. Frühbeis and his team presented a design for an electrically powered, windowless jet with a carbon fiber fuselage, featuring a larger stage fan in the tail and smaller electric propulsion units attached to the trailing edge of the wings (turboelectric distributed propulsion, TEDP). Their eRay boasts a lower weight, increased propulsion efficiency and improved aerodynamics – the latter thanks to use of the laminar flow control (LFC) principle as well as a reduced, V-shaped tail surface and active reduction of wind resistance against the airframe. This intelligent overall package came out on top when the Design Challenge winners were announced in August. Rolf Henke, DLR Executive Board Member for Aeronautics Research, commended the winners: “My fellow jury members and I were impressed by the systematic dovetailing of complementary technologies that were a perfect fit for each other.”

64 percent fuel saving

The eRay is significantly lighter than an Airbus 321, with just as many passengers on board (although some of them travel standing). This is made possible by the use of new materials, the absence of windows and the comparatively small amount of fuel, which the aircraft only needs to carry for the two gas turbines attached to its wingtips. These use their generators to produce electrical energy to power the electric engines. Various synergies (see box) are used to reduce aerodynamic drag on the eRay, which also contributes to fuel savings.

The aircraft is designed to meet the growing demand for short and medium-haul direct flights in Asia, while offering a number of general advantages too. For instance, its electric propulsion makes it quieter during take-off, flight and landing, as well as on the tarmac. The eRay could thus unlock night-flight potential for airports running at full capacity during the day.

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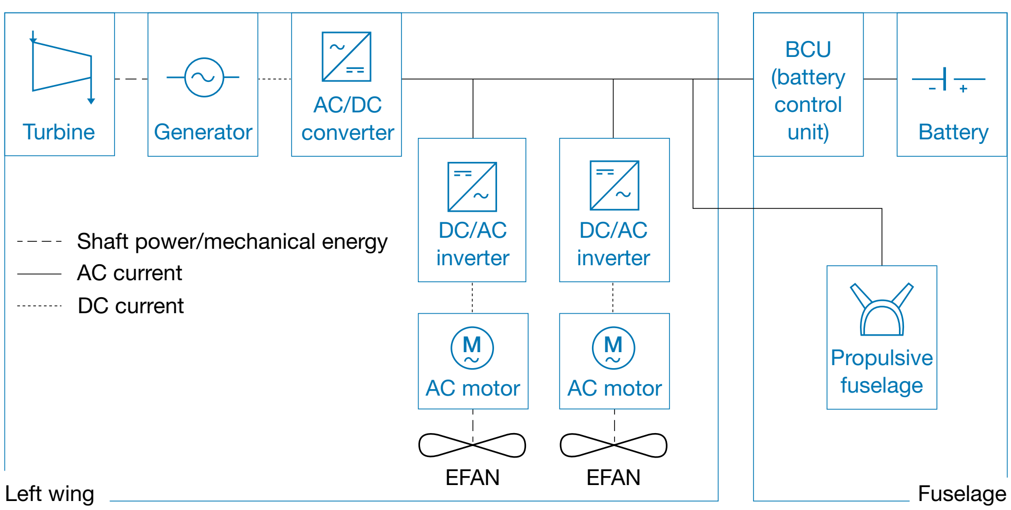
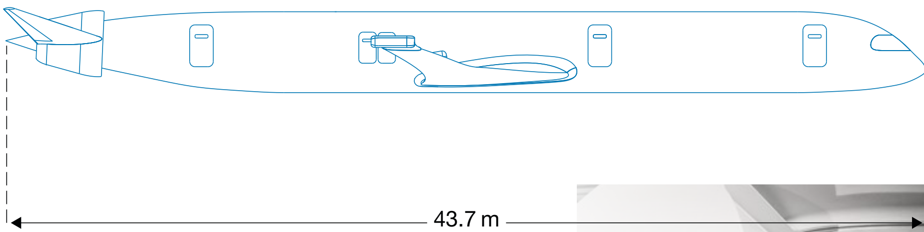
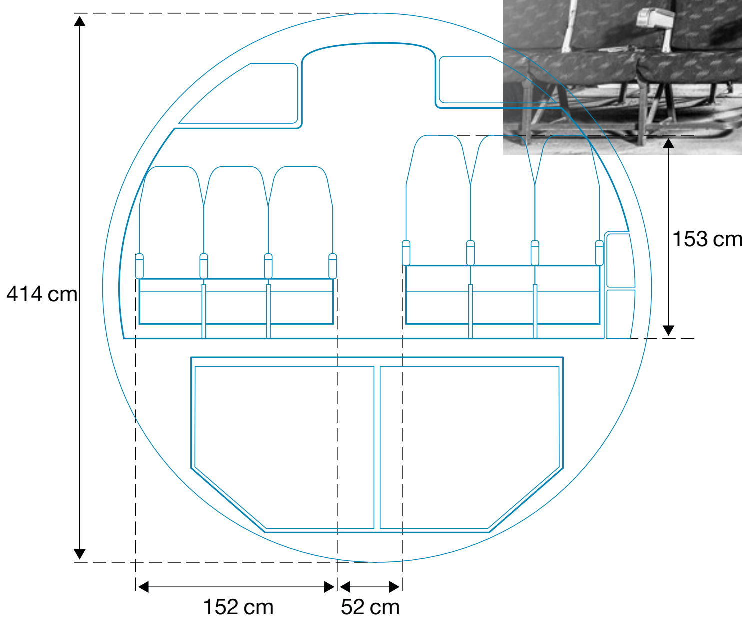


Schematic arrangement of the electric drive system of the aircraft: The gas turbines supply the turboelectric drives and the electric turbines at the end of the fuselage via generators and rectifiers. At the same time, they supply batteries as a buffer for the higher energy consumption during take-off and landing.

To save weight, the outer skin of the aircraft was planned in carbon fiber, as shown here by Patrick Sieb and Isa Held.



The winning design in side view: The entire plane is 43.7 meters long, 1.3 meters shorter than an Airbus A321.



In order to accommodate more air travelers, the students planned to allow some of the passengers to travel standing up.

Getting off the ground

Whether the students' predictions come true and the eRay will really be suitable for everyday use from around 2045 onwards still depends on certain developments. The Munich team's concept relies on rigorous progress in battery technologies (the eRay uses batteries as a buffer for high energy demand during take-off and landing), as well as a significant improvement in flight control systems and certain amendments to regulatory approvals. Equally, the prospect of flying without windows and standing during the flight – both a given in the winning design's most efficient scenario – would have to resonate with passengers in the real world. However, the first virtual windows, which display images from an on-board camera instead of giving passengers a real view outside, have recently launched in the new first-class cabin of Emirates' Boeing 777-300ER aircraft. TUM's young scientists are optimistic that flying will develop in line with their vision. "What I found most fascinating during the Challenge was the realization that there is still so much room for innovation. The aircraft in its current form is by no means the best imaginable," emphasizes Frühbeis. "The next stage is implementing and testing out these new concepts. Business leaders and policymakers need to be bold in leading the way here and actively embrace innovation. Concepts like the eRay require a high

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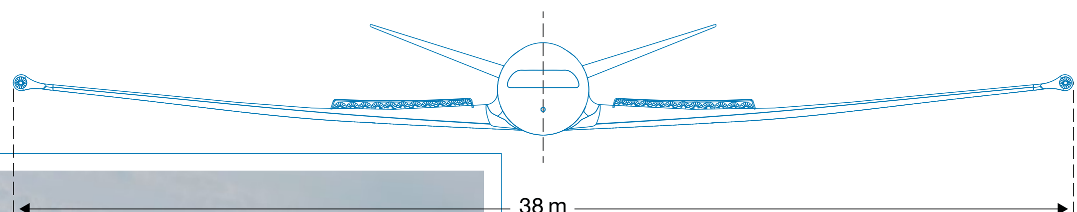
> *Rolf Henke, Member of the DLR Executive Board*



The quiet and fuel-efficient aircraft is designed in particular to meet the growing demand for short and medium-haul direct flights in Asia.

level of cooperation – as we already experienced in our own small team. Aerodynamics experts really have to get to grips with the propulsion system and vice versa. And this is at odds with the strict division of labor in the industry today. In the long term, I want to contribute to driving this transformation.”

Artur Usbek exemplifies this collaborative approach: The 24-year-old is a student of mechanical engineering, aerospace engineering, management, and product development and engineering design. With four Master’s degrees under his belt, he could envisage working as an engineer focusing on the entire system design of military jets or engine systems. He concludes: “It quickly became clear to me that developing new aircraft concepts is all about workable compromises. I particularly enjoyed the contact with other aerospace enthusiasts during this competition and would recommend taking part in a project like this to anyone.”

Altogether, over a hundred students participated in the German-US Design Challenge. In September 2018, the two winning groups were honored at a symposium at NASA headquarters in Washington D.C. And TUM is already gearing up for similar competitive challenges later this year. ■

Karsten Werth