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ATRA

A new dimension in aeronautics research

DLR

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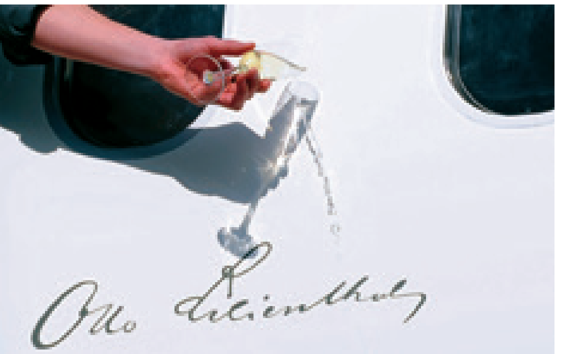


The Airbus was named 'Otto Lilienthal'

With a wingspan of 34.10 metres, the Airbus A320 is the largest research aircraft in Europe.

ATRA has been part of the DLR research fleet since 2006

Research aircraft for the aviation of tomorrow

In addition to fundamental research, the German Aerospace Center (DLR) primarily carries out application-oriented aeronautics research. The aim is to strengthen the competitiveness of the national and European aeronautics industry and air transport sector, and to meet the expectations of government and society.

DLR has set itself the challenge of making the rapidly growing air transportation sector efficient, environmentally friendly and sustainable. In view of the capabilities of its institutes, its investment in wind tunnels and its fleet of research aircraft, DLR has the necessary tools to consider the air transport system as a whole. Its research can be subdivided into the areas of fixed-wing aircraft, rotor craft, propulsion systems, air traffic management and flight experiments.

With its 13 dedicated aircraft and helicopters, DLR is the largest civilian operator of research aircraft in Europe. Consequently DLR can carry out an impressively broad range of missions for either its internal institutes or for external customers. DLR's largest research aircraft is the Advanced Technology Research Aircraft (ATRA). This Airbus A320 has been in operation since late 2008.

The DLR ATRA is a modern and flexible flight test platform which sets a new benchmark for flying test beds in European aerospace research – and not just because of its size. For example, ATRA is used to test aeroelastic measurement techniques, to investigate interior space acoustics, to measure airflow noise as well as turbulence on the wings and tail section, and for atmospheric and engine measurements.

ATRA is also used for tests with people as subjects – studying the workload and work distribution of the pilots in the cockpit, for example. Comfort and safety concepts in the cabin are also investigated and new communication technologies are tested in flight and on the ground.

The aircraft's basic equipment is continuously being further developed and its scope of use broadened. Many of the installations and conversions made to ATRA are directly related to individual experiments, and so are only temporary. Its flexibility makes it ideal for a wide range of missions. A modern research platform for tackling questions concerning aerodynamics, avionics and engine research, ATRA is the only aircraft of its kind in Europe.

The turbine is the driving force that sets the aircraft in motion and the major source of noise

In an extensive measurement campaign, noise researchers are using ATRA for a range of 'run-ups' in the Lufthansa Technik Noise Protection Hangar

Researching the topic of lacquering technology while paying homage to Otto Lilienthal

History of research aircraft

Key dates in the history of ATRA:

1997 – 2006

Maiden flight: March 1997 – Aero Lloyd

Subsequent operator: FlyNiki

2006

14/03/2006: Signing of the purchase agreement for the Airbus A320-232 MSN 659

12/06/2006: D-ATRA lands in Braunschweig for the first time. The responsibility of ownership is transferred to the Airbus development centre for modifications of the aircraft.

The following modifications were carried out by the manufacturer:
- General conversion from an airliner into a research aircraft
- Certification of various role specific retrofit kits
- Installation of basic sensors and measurement equipment
- Avionics upgrade
- Antenna modifications (SatCom, S-band data link, GPS etc.)

2008

ATRA is exhibited as a fuel cell demonstrator at the static display during the ILA Berlin Air Show 2008 in cooperation with Airbus.

The experimental fuel cell is demonstrated in a public display:
- Electrical supply of the 'blue' hydraulic pump
- Movement of the control surfaces
- Demonstration of the operating parameters of the active fuel cell system

2009

Since 2009:
Numerous projects have been carried out by DLR on board ATRA (under the ownership of Airbus):
- TVT (Taxi Vibration Test/Aeroelasticity) – first DLR experiment on ATRA
- LINA (GBAS approach procedure/flight guidance research)
- FAGI (taxiway guidance at the airport/flight guidance research)
- SINTEG (cabin air conditioning)
- SIMKAB (cabin acoustics research)
- ELBASYS (demonstration of an electrically powered nose wheel, supplied with electricity by a DLR fuel cell – fuel cell research)

From holiday aircraft to research aircraft

On 24 January 1997, under the serial number MSN 659, today's ATRA completed its initial flight in Toulouse under its previous designation of F-WWIN, and barely six weeks later it was delivered to airliner Aero Lloyd as D-ALAE. Following the company's insolvency in 2003, the aircraft was then passed on to Austrian airline FlyNiki as OE-LOE. As a holiday aircraft, it flew to many vacation destinations in Europe.

Following intense negotiation, DLR signed the purchase agreement for the Airbus A320 from the Munich-based leasing company GOAL in March 2006. DLR's research aircraft, ATRA (Advanced Technology Research Aircraft), was 're-born' in 2006.

After its official presentation by DLR on 12 June 2006, ATRA was moved to the Lufthansa Technik hangar at Berlin-Schönefeld for maintenance, and then to Airbus at Hamburg-Finkenwerder for conversion into a research aircraft. The modifications carried out there included the installation of basic measurement equipment, as a fundamental element of the permanently installed Flight Test Installation (FTI) system. The FTI collects the measurement data from the original basic sensors already on board the A320 and data from temporary experimental installations. An additional power supply system for up to eight equipment stations was also installed and. further equipment was placed in the cockpit so that an additional display showing test data to the pilots could be installed when necessary. Finally, numerous antennas were added and provisions made for fitting cameras, pressure sensors and cables.

With the acquisition of the A320 ATRA, DLR's fleet of research aircraft stationed in Braunschweig reached a new dimension in terms of size. A new hangar had to be built. When it was inaugurated in April 2010, ATRA – which, during its first year, was still being flown in the old Niki 'attire' – was presented to the public in its new uniform, in DLR colours and with its own name. The then DLR chairman, Johann-Dietrich Wörner, as well as the DLR Executive Board Member for Aeronautics Research at the time, Joachim Szodruch, and aircraft mechanic Regina Gebhard named the Airbus after aviation pioneer Otto Lilienthal.

In view of the modifications to the aircraft required for the research work, and because of the manufacturer's expertise in this area, ATRA was operated in close cooperation between DLR and Airbus, whereby the partners shared the utilisation phases. As the owner, DLR leased the aircraft to Airbus during the initial conversion phase. Consequently, the aircraft temporarily bore the French registration F-WWDB and only thereafter received its final German designation of D-ATRA. Since September 2012, DLR has been entirely responsible for the operation of ATRA. In preparation for this major responsibility, it was necessary to strengthen both DLR flight operations and, especially, the internal technical aeronautics development organisation to operate an Airbus A320 as a research aircraft.

The A320 ATRA made its public debut as a research aircraft (specifically as a fuel cell demonstrator) at the 2008 International Aerospace Exhibition (Internationale Luft- und Raumfahrtausstellung; ILA) at Berlin Schönefeld Airport. In tandem with the DLR Institute of Engineering Thermodynamics, Airbus fitted the aircraft with a Michelin emission-free fuel cell system. To enable this to be installed, ATRA got a cargo loading system, permitting the experimental fuel cell and required infrastructure and water supply to be installed and fitted in the rear cargo compartment. It was then a matter of installing the computers and measurement instruments for monitoring the equipment in the cabin during the flight experiments, and connecting them with the basic measurement system. During the subsequent flight experiments,

ATRA's central 'blue hydraulic system' was operated using electrical energy from the fuel cell. This system, which is part of the overall flight hydraulics, is a key system of the aircraft, responsible for moving the control surfaces during flight. As the fuel cell took over a critical part in controlling ATRA, it was thoroughly tested in a wide range of flight manoeuvres.

The next milestone in the introduction of the new research aircraft was the Taxi Vibration Test (TVT) in 2009. Still under the ownership of Airbus at the time, this was the first DLR test campaign with ATRA – in terms of planning, coordination and execution – conducted at Manching airfield near Ingolstadt, at Bundeswehr Technical Centre 61. For this TVT, researchers attached no fewer than 140 sensors to measure the local acceleration on the fuselage, wings, engines and tail section of the DLR aircraft. The TVT supplements the stationary Ground Vibration Test (GVT), with the aim of appropriately reducing this GVT, as is necessary for aircraft certification. During the rolling test, instead of an electrodynamic exciter, researchers use the random vibration excitations of the aircraft caused by the unevenness of the taxiway for their measurements. Hence, before an aircraft's maiden flight, it is possible to determine that the superposition of various different types of vibration will not cause the feared fluttering that, in exceptional cases, can lead to structural failure and a crash. The GVT is therefore used to check whether the vibration frequencies and types that are determined in advance through computer simulation conform to those on the actual aircraft.

Similarly, in 2009 DLR used ATRA to investigate new approach procedures that are quieter and use less fuel. The first approach flights with subsequent pull-up manoeuvres were carried out at the Braunschweig-Wolfsburg research airport. The Advanced Continuous Descent Approach (ACDA) was put to the test – a process in which aircraft continuously descend until landing, rather than descending in stages. In doing so, the pilots completed approaches that were controlled both by the autopilot and manually on preset routes outlined on a display specially installed in the cockpit for these approach flight tests.

In summer 2011, the A320 ATRA was taken to the Lufthansa Technik maintenance hangar site at Hamburg-Fuhlsbuettel Airport to test the deployment of an on board fuel cell again. With an output of 20 kilowatts on this occasion, it provided the energy for an engine developed by DLR in cooperation with Airbus and Lufthansa Technik, and consisted of two electric motors installed on both rims of the nose wheel. In the demonstration – the first and only one of its type in the world – ATRA moved completely independently and 100 percent emission-free while its engines were switched off, with the electric nose wheel being operated by the fuel cell.

To coordinate the requirements of internal and external scientists, and to guarantee high utilisation of the only flying research platform of this magnitude in Europe, the ATRA Management department was founded at DLR. Its scope of activity extends from the acquisition of users to allocation planning, coordination of flight experiments as well as identification and implementation of test-related modifications on the aircraft, through to full-service user support during research projects. During the induction phase itself, and finally with the change of ownership from Airbus to DLR in September 2012, numerous additional test campaigns using ATRA took place that are shown in the research focuses in this brochure.

Key dates in the history of ATRA (continued):

2010

2010: Painting of ATRA in the livery of the DLR aircraft fleet

15/04/2010:
- Inauguration of the new aircraft hangar as part of the acquisition of ATRA
- First landing of ATRA in its new livery (after being repainted) in Braunschweig
- Naming of ATRA as 'Otto Lilienthal'

2012

2012: HINVA F/V I: First joint LuFo project carried out in cooperation with Airbus

13/09/2012: First change of ownership and initial transfer of ATRA to the DLR development organisation

09/2012: SIMKAB F/V II: first flight experiment project carried out by DLR completely under its own responsibility and ownership

2013 to present day

2013: SANDRA: first EU data communication project (autonomous)

2014: WEAA: Wake Encounter Avoidance and Advisory System Project: first joint flight experiment using two DLR research aircraft (Falcon D-CMET) to research wake turbulence

2014: ProWingS – preliminary aeronautics research – laminar research

2012 – 2014: Repeated use of the aircraft as a development aircraft by Airbus with the correspondingly alternating ownership responsibility

2015: HINVA F/V II: first-time implementation of a LuFo project in cooperation with Airbus under DLR ownership responsibility

To date: Intensive use of ATRA as a research aircraft within DLR and in projects funded by the aviation industry

Flight preparation for test flights for noise-optimised approach procedures

ATRA flying low during a noise measurement campaign

Environmental research

For some 20 years, research projects to reduce the external noise of aircraft have been an integral part of the national and EU-wide research landscape.

The high level of maturity of numerous noise-reduction technologies and methods today bears witness to the progress made, as well as to the need to conduct flight experiments to continuously develop and validate these measures in order to reduce the complex aerodynamic sources of noise.

The effective reduction of overall aircraft noise on the ground – for example, for the benefit of inhabitants in the vicinity of airports – can only be quantified through flight experiments.

If one takes into consideration engine noise, which is generally mentioned first in this regard, noise emission can be reduced, for example, by using serrated nozzle trailing edges. Partially air-permeable component shields on the landing gear or the application of porous materials to the side edges of the flaps are two examples of the steps taken to reduce aerodynamic noise, which is the predominant source of noise of a commercial aircraft during certain stages of the landing approach. To carry out acoustic overflight measurements, all of the noise abatement methods must first be transferred to an aircraft and then prepared for the flight test.

Some of these very extensive modifications cannot be made to a commercial aircraft. With the ATRA research aircraft, DLR provides an experimental test bed that can be fitted with these innovative noise-reduction measures and therefore used for acoustic overflight tests. The use of ATRA to conduct research into noise-reduction measures is carried out both as part of EU research projects and as DLR noise research.

Reduction of noise distribution on the ground using noise-optimised approach procedures

DLR scientists carry out technical engineering research ahead of industrial developments. They work in the areas of flight guidance and air traffic management. One focus is placed on 'operational procedures'.

With the steadily growing volume of civil air traffic, issues such as flight noise and environmental sustainability are becoming increasingly important. By developing new systems to support precision approach procedures, options that allow changes to approaches that reduce noise levels on the ground are created. In this regard, approaches that have two different glide-path angles are being investigated. During approaches that use a steeper approach angle, the aircraft initially finds itself at a higher altitude above the ground. This can reduce the noise level on the ground compared with shallow approaches. The final part of the landing approach is then performed using a standard angle of approach.

In order to test this approach procedure in flight, the DLR-ATRA research aircraft was modified and the approaches carried out at the Braunschweig-Wolfsburg research airport. This created a basis from which to investigate these approaches on commercial aircraft as well. The processes are currently being tested in everyday operation in collaboration with external aircraft companies.

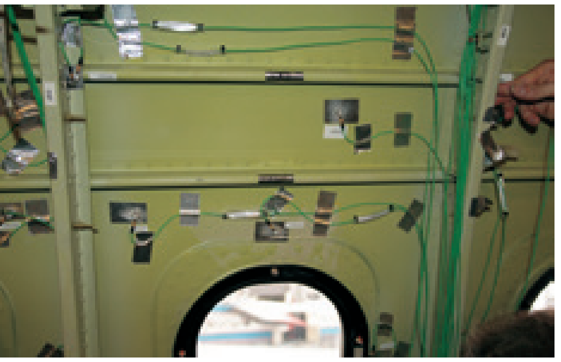
Assistance system for noise-optimised approach procedures

Reducing flight noise over populated areas is the goal of a DLR research project that is being carried out in cooperation with a German commercial airport. To achieve this, a pilot assistance system for a noise-optimised approach procedure is being developed and tested in real approach operations. The landing phase is generally the most mentally-intensive part of a flight during which amongst other tasks, the pilots must extend the flaps and landing gear at predetermined speeds. It is often difficult for pilots to assess the ideal point to make these selections that will allow part of the landing phase to take place entirely with an engine at idle that is at its most quiet and fuel-efficient.

In order to support pilots with the implementation of the actions for an approach with the lowest possible noise levels, an appropriate pilot assistance system has been developed by DLR researchers in Braunschweig. This system tells the pilot exactly when each action should be carried out (change of speed, deployment of flaps, lowering the landing gear) via a display in the cockpit. So far, the system has already been successfully tested in the simulator and in research flights with the A320 ATRA at a regional commercial airport with no other surrounding air traffic. In the next step, the assistance system is due to undergo testing within the intense activity of a major European airport.

Weather conditions, poor visibility, the weight of an aircraft and flight safety requirements affect landings in different ways. DLR researchers want to find out how these variable influences affect the new assistance system and how professional pilots respond to it. Hence, pilots from different airlines take their place one after the other in the ATRA cockpit, next to a DLR test pilot, and carry out the approaches. Before the actual flight tests are performed, detailed tests are completed in DLR's Air Vehicle Simulator (AVES). A major airport, with its high level of air traffic, is an ideal test site for the new assistance system. In the tests, the existing noise measurement sites in the vicinity of the airport can be used to accurately determine how significantly the noise is reduced when using the optimised approach procedures.

Using satellite navigation and the latest aircraft systems, curves with fixed radii between two waypoints can be accurately planned and curved approaches flown with high precision.



Installation of acceleration recorders on the exposed outer skin of the ATRA aircraft structure

Microphone array that can be moved longitudinally during flight to measure noise pressure and frequency at various cabin positions

Passenger research

Passengers' comfort during a flight largely depends on the background noise inside the cabin.

In order to optimise aircraft cabins and provide more comfort, a precise understanding of the sources giving rise to noise and their transfer paths to the passenger are essential. Different noises can dominate the interior space depending on flight conditions and position. Noise from the engines and dynamic effects in the fuselage boundary layer can trigger vibrations in the aircraft structure. These vibrations are transferred via the fuselage structure to the air inside the cabin where they are perceived as cabin noise in various seat positions. Another source of noise is the air-conditioning system inside the aircraft.

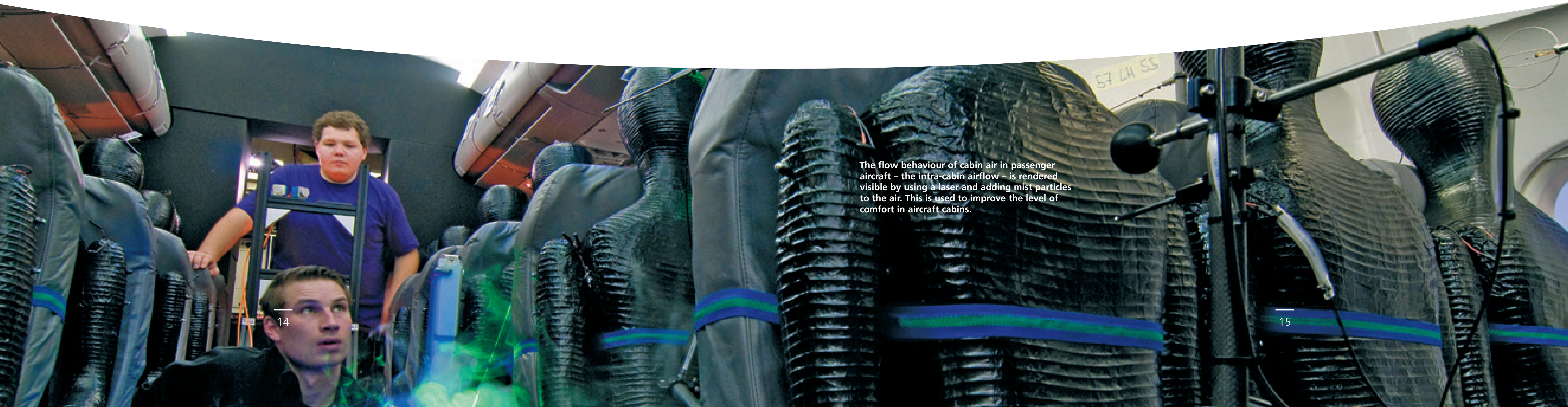
The aspects of individual sources of cabin noise that are currently least understood in modern commercial aircraft are being investigated in measurement flights with ATRA. To do so, measurements taken at various sections of the fuselage in (almost) standard cabins are required, depending on the flight conditions and position.

As such, it is possible to both quantify the volume of the individual sources and determine the transfer behaviour of the airframe in terms of respective sources, sound pressures and frequencies. In previous projects, DLR has already succeeded in recording acoustically relevant sources, local vibration effects on the fuselage structure, and noise pressure reaching passenger locations during various flight phases. A complex acoustic measurement system using more than 250 microphones and acceleration sensors was used. The results are used as validation data for digital models of cabin noise and hence for improving the simulation and design tools for the cabin acoustics of future commercial aircraft.

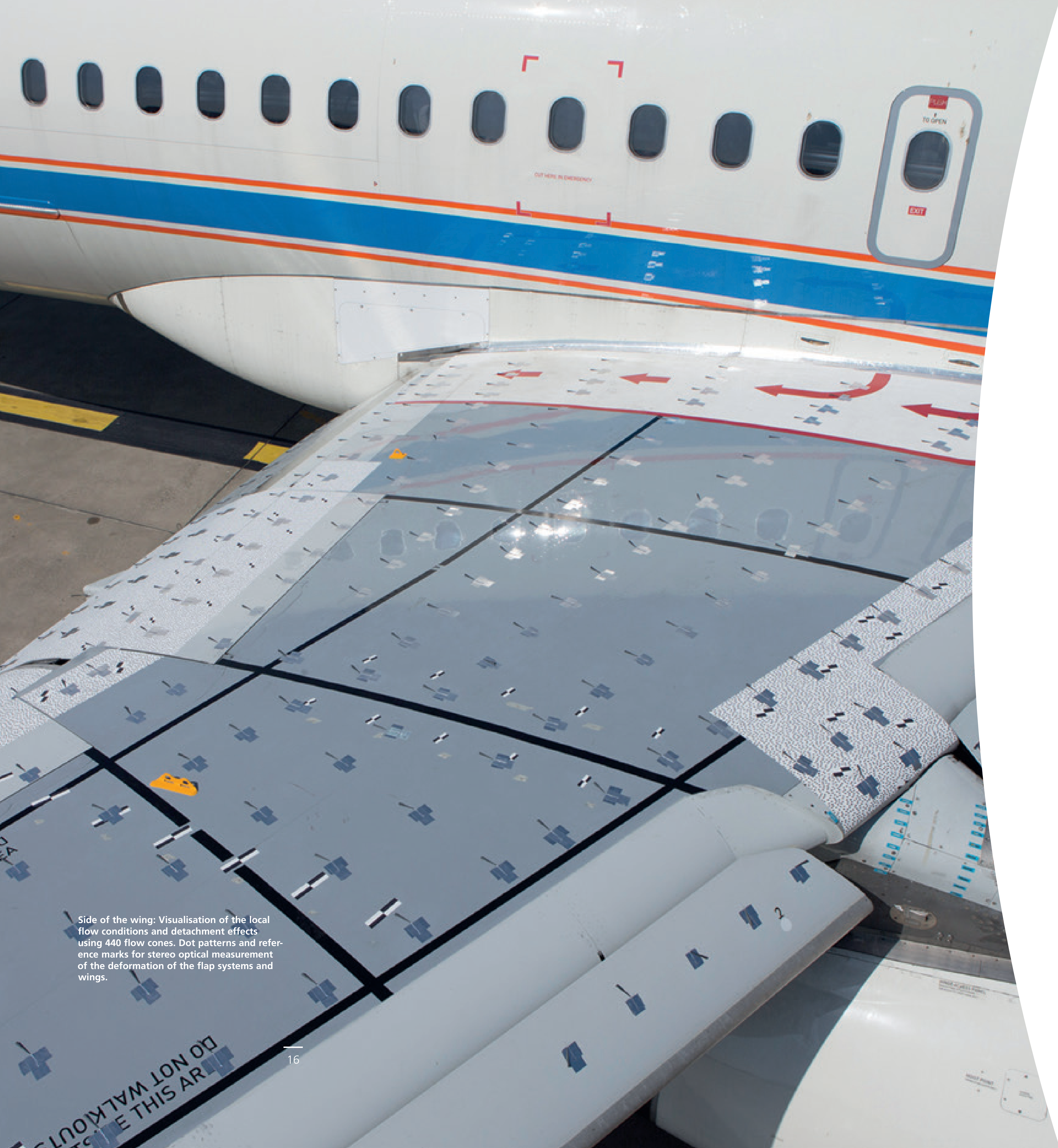
As part of the ATRA flight experiments, DLR is also investigating ventilation systems that enable efficient heat transfer while allowing for high thermal passenger comfort.

The air-conditioning equipment in modern passenger aircraft is responsible for the air pressure in the cabin and hence the oxygen supply to the passengers. It also has the job of dissipating the excess heat of the passengers themselves and of the on-board electronics in order to stabilise cabin temperature at a comfortable level. Rising passenger numbers and the increased use of entertainment electronics in modern passenger aircraft cabins require highly efficient, yet comfortable, ventilation systems. In this regard, conventional methods based on the principle of mixed ventilation are limited. For this reason, researchers have developed a specialised cabin measurement unit for the experimental representation and recording of cabin climate, which can be used to investigate new source ventilation methods and conventional mixed ventilation methods under real conditions.

Measurement section of the cabin equipped with static microphones. Acoustic separation from the remaining section of the cabin using a foam partition.



The flow behaviour of cabin air in passenger aircraft – the intra-cabin airflow – is rendered visible by using a laser and adding mist particles to the air. This is used to improve the level of comfort in aircraft cabins.



Side of the wing: Visualisation of the local flow conditions and detachment effects using 440 flow cones. Dot patterns and reference marks for stereo optical measurement of the deformation of the flap systems and wings.

High-lift aerodynamics research

High-lift research

High-lift systems essentially determine how slowly, steeply and silently an aircraft approach can be. The most advanced digital and experimental simulation methods used in industry to date were employed in a joint project headed by DLR. The aim of this project was to understand the extremely complex flow phenomena in this phase of a flight and to improve aerodynamic prediction methods for maximum lift.

More precise prediction and greater reliability of the methods used to predict flight performance is the basis for more efficient and ultimately lighter – hence more environmentally friendly – aircraft. But, especially when complex threshold ranges are involved, the aircraft flies very slowly, making it extremely difficult for scientists to obtain reliable results. In order to better assess the performance of aircraft and their systems in the future and to continue developing them, complex aerodynamic systems must first be better understood – so more research data is needed. For this reason, researchers involved in the project headed in a new direction. They combined three major prediction methods: digital simulation, wind tunnel experiments and flight tests. For the first time, researchers set up identical measurements and calculations using an entire aircraft configuration in a single project. The DLR Airbus A320-200 ATRA was used as the joint configurative basis.

Two flight test campaigns were carried out in France and Germany using DLR research aircraft. The study included recording static and dynamic pressure measurements, boundary layer measurements using hot films, flow visualisations, and mechanical deformation measurements on ATRA's wings and flap systems. The information acquired directly influenced the creation of the wind tunnel and CFD models, with the result that the two complementary methods exactly reproduced the circumstances in the flight test and could be scientifically investigated in the model. Thus, ATRA became the first aircraft to carry out stall flight experiments in the maximum lift range. At the limit of feasibility, the air flow on the wings and flap systems during extremely low-speed flight could be measured with high precision. It was also the first time that the air flow over the wings of a commercial aircraft was visualised using the PIV (Particle Image Velocimetry) laser-measurement technology developed by DLR.

Together with the flight tests, digital simulations and wind-tunnel tests provided a database with which, using the synergetic interaction between the three methods, the fundamental parameters of the effects that have an impact on the maximum lift could be determined. This knowledge is now being used in a new simulation strategy for the use of digital processes and for the European Transonic Windtunnel (ETW) to enable the maximum lift for a commercial aircraft configuration to be determined with a variance of less than two percent.

Laminar aerodynamics research

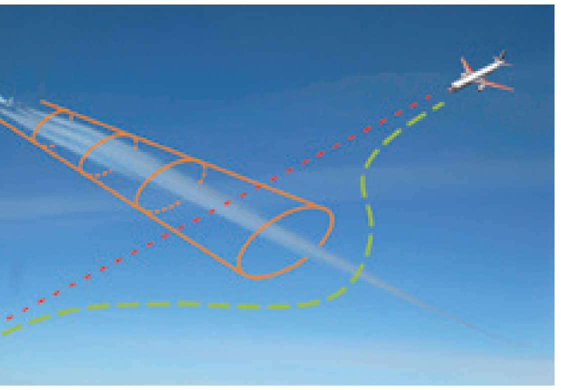
It is very clear to the aerodynamics engineers that laminar flow plays a key role in the development of economical, environmentally friendly aircraft. It is the final major step in aerodynamics to make flying more efficient. Two projects have looked at the reduction of friction drag during flight and how advances in laminar flow technology can be achieved.

In one of these projects, multiple wind tunnel and flight tests were carried out at the same time. The tests using the DLR ATRA Airbus A320 became known as the 'insect catching' flight tests, in which the effects of insect debris on the surface of the aircraft were investigated as part of a LuFo research project. Using a special camera system, the leading edge of the wing was observed during the flight test for online assessment. The subsequent non-time-critical evaluation of the insects found on the surface was then carried out using thin, removable, adhesive films that could be analysed in the laboratory. To do this, eight different test points were flown, in which the speed, flap configuration and weight all differed. Six to 12 low-level flights per test point were performed at different times over the landing strip at an altitude of just 15 metres. The results are now being used to calibrate computer models. The results are expected to be employed in the development of leading edge flaps to protect the wings from insect contamination.

Aerodynamics with a research focus on Hybrid Laminar Flow Control (HLFC) is making another important contribution to the desired reduction in fuel consumption and pollutant emissions. With this technology, a small proportion of the air around the boundary layer is sucked in through the micro-perforated outer skin of the body it is flowing around, i.e. the surface of the aircraft. By doing so at high Reynolds numbers, the proportion of laminar, low-friction flow areas on the wing can be substantially increased beyond the level that could be achieved using simple shaping of the profile geometry – so-called natural laminar flow control. By doing so, large laminar lengths on the wings can be achieved even at the high cruising speeds of present long-haul aircraft. The aerodynamic feasibility of an HLFC system was first demonstrated in 1998 in a flight test on a vertical stabiliser at high Mach numbers. However, the HLFC system used at the time was very cumbersome, heavy and expensive. As part of an EU project, a simplified, improved suction system is now set to be tested in flight for the first time under realistic environmental and flight conditions. The HLFC system for this project is integrated into the central segment of the vertical stabiliser of the nose on the A320 ATRA research aircraft. The instrumentation specially developed for this enables functional verification during the test flights and the acquisition of the data required for validation of the results after the flights. If this test proves the feasibility of the simplified suction system under real flight conditions as well, the next logical step is the development of HLFC technology for the wing, to evaluate the potential of HLFC technology as accurately as possible.

ATRA flying at a height of 15 metres with the undercarriage retracted

Wake turbulence rendered visible in the flight test



Wake turbulence conflict with avoidance scenario

Flight systems technology research

Wake Encounter Avoidance and Advisory System – WEAA

For safety reasons, the problems associated with wake vortices in air traffic is managed by using minimum distances intended to minimise risk during landing. To further increase passenger comfort and flight safety, DLR is working on a Wake Encounter Avoidance and Advisory System (WEAA). The aim of this is to enable a threat of wake turbulence during landing to be detected autonomously on board an aircraft and to initiate appropriate countermeasures.

The WEAA system receives traffic and meteorological data from nearby aircraft and from the aircraft's own on-board systems, carries out a data fusion of the necessary meteorological parameters, and uses this as a basis for forecasting the paths of the aircraft involved as well as the development and movement of the wake vortices. In the event of conflicts, a small avoidance manoeuvre can be computed, displayed and implemented if necessary.

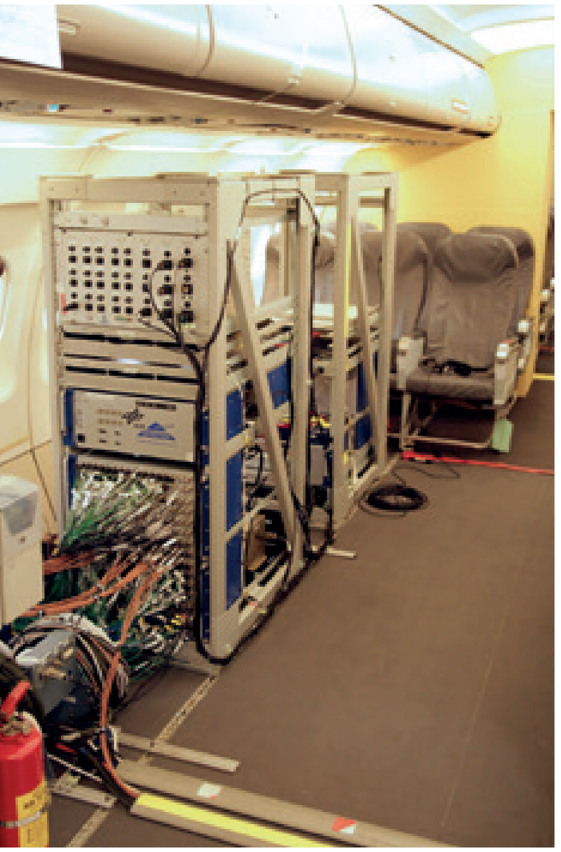
The system is being developed and tested by DLR researchers, partly on behalf of Airbus and in collaboration with international standards boards (SAE, RTCA), flight-safety organisations and potential users.

When designing the system, efforts were made to integrate it properly into the avionics architecture of modern commercial airliners. One of the goals of the development work is to demonstrate that the system works in practice.

When integrating the WEAA, one of the first steps was to test it by using DLR's A320 ATRA research aircraft as the WEAA system carrier and DLR's Falcon 2 research aircraft as the vortex generator. A universal experiment rack was used on board ATRA for data processing, providing the computing capacity, screens and input devices for the experiment. The relevant information for the pilot was shown on the test pilot's experimental folding screen in the cockpit. In the flight test, the functionality of the vortex forecasting and conflict detection was demonstrated under operational conditions.

Ongoing implementation of system functions will be supplemented with additional flight tests following successful testing in the DLR Air Vehicle Simulator (AVES).

Integration of the WEAA display in ATRA



Acoustic measurements in the cabin

Measurement technology research

A wide variety of measurement technology is available for different mission objectives in A320 ATRA flight tests. This enables flow measurements to be taken both outside the aircraft – on the wings, tail section and engines – and inside the cabin. This technology, developed by DLR, can be used to carry out measurements to reduce cabin noise, improve the climate in the cabin, as well as to measure external noise and the aircraft's aerodynamics.

These methods generally have their roots in the laboratory and have only been passingly suitable for the challenging, realistic measurements made using the A320 ATRA. Through continuous development and testing – both on the ground and in flight campaigns – DLR has been able to bring these measurement technologies in recent years to a level of maturity that is unrivalled.

Optical processes such as Particle Image Velocimetry (PIV) and the Background Oriented Schlieren Method (BOS), along with static and dynamic pressure measurements and boundary layer measurements using hot films, are all used for measuring or visualising the flow. By measuring the flow behaviour on the wings and flaps during low-speed flight – especially in the engine nacelle area – the wings can be optimised for slower, quieter approach flights in the future. With the PIV laser-measurement technology developed at DLR, it is possible to use high-performance cameras to capture the real-time movement of micrometre-sized particles and thus to visualise local flow fields. In the flight experiment, DLR researchers use the naturally available droplets in the clouds instead of artificial particles. Using specially developed software, the entire flow field being studied can be defined and displayed in two dimensions. This enables scientists to measure all three speed components in the flow around a wing on a passenger jet in two dimensions under real flight conditions.

Sources of noise in the engine jet and fan can be investigated using DLR technology. In extensive measurement campaigns, noise researchers use the A320 ATRA for a range of static engine tests.

As a result, it has been possible to simultaneously study the engines mounted onto ATRA with an array of microphones and laser-optic field measurement processes. Laser light can be used to measure turbulent flows in the radiation cone. These are the places in the engine flow in which noise is generated as a result of large turbulent speed and density fluctuations. At the same time, microphones installed in the vicinity provided the scientists with the volume level for the flow phenomena rendered visible in laser light.

As a result of the tests using ultra-modern measurement technology, the acquired knowledge subsequently influences the increased efficiency of an aircraft, the production of new models or the modifications to existing models.

Laser measurements above the wing

In addition, technical innovations based on this knowledge lead to significant noise reduction both inside the cabin – increasing the comfort level – and outside the aircraft, improving the environmental sustainability of aircraft.

Simultaneous noise and flow measurement on the engine

Experimental display in the cockpit

Scientists' workstation

Cockpit and basic measurement system

Interfaces between research aircraft and researchers

The A320 ATRA is a versatile research aircraft in which scientists install a wide range of instruments and sensors depending on the subject of their investigations. Whatever research instruments are installed in ATRA, all of the data is fed into the basic measurement system permanently installed in the forward area of the cabin. Using the six screens installed, two measurement engineers or flight experiment engineers can sit in front of the basic measurement system, direct the flight experiment, and display a vast range of experiment- or aircraft-related data. In addition, the measurement data from the sensors already available on the A320 and the basic flight data are pooled together here, where they are forwarded to the customised workstations of test engineers and scientists.

The eight workstations can be set up as required, offering racks, consoles, and computers, as well as input and display devices. An additional on-board power supply provides the power required for the measurement installations in the cabins.

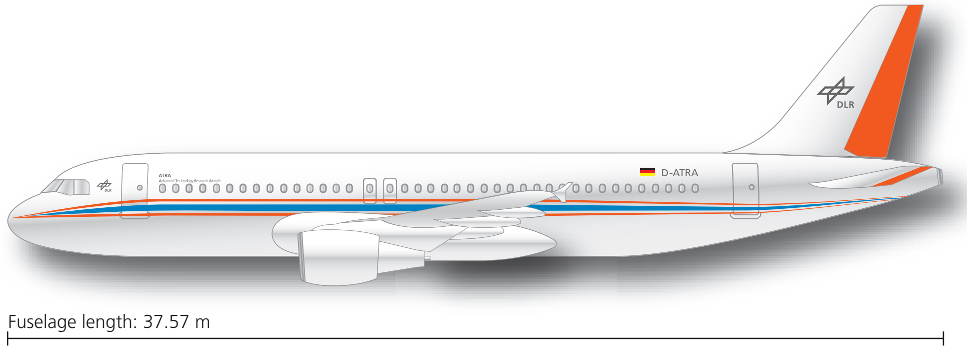
In the cockpit, the coder provides the two test pilots with an additional display that shows current data for the respective flight experiment. This additional interface means that the pilots are also directly involved in the acquisition of experimental data during a test flight. Other instruments are installed on the glare shield in the cockpit. This is a narrow, board-shaped instrument console directly underneath the cockpit windshield on which more measurement values for the angle of attack and the sideslip angle are displayed. Next to this is a display of the G-forces acting on the crew – forces that can be particularly strong during tight flight manoeuvresand are normally given as a multiple of the acceleration due to gravity. ATRA also has a head-up display. The system software and hardware enable the design to be customised and varied according to the respective test.

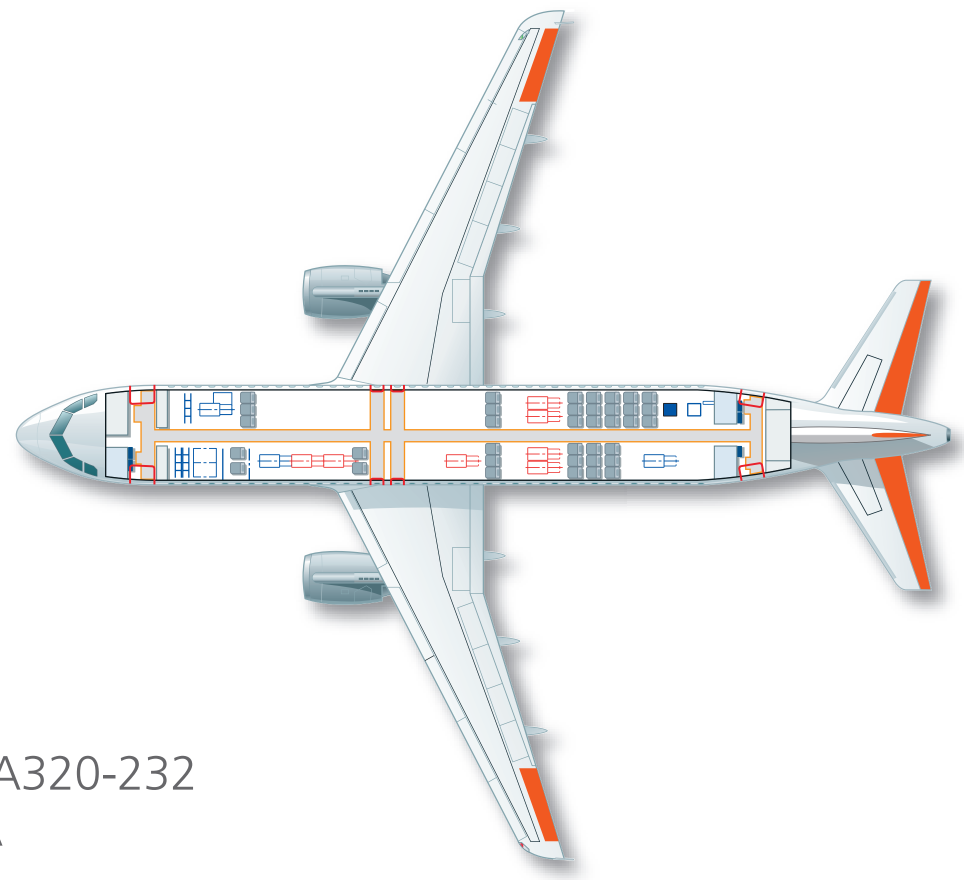
Scientists also need pre-processed flight test data for the scientific publication of the measurement results. This gives the flight experiment set-up according to each research flight.

Panoramic view of the aircraft cabin. The front rows of seats in ATRA have been replaced with the basic measurement system, which enables a vast range of research and mission types

The basic measurement system in the ATRA cabin. The flight experiment data are pooled here

The ATRA cockpit with the additionally installed instruments





Airbus A320-232
D-ATRA

Technical specifications	Airbus A320 D-ATRA		
Length:	37.57 metres	Propulsion:	two International Aero Engine V2500 engines
Height:	11.76 metres	Thrust:	111 kilonewtons each
Wingspan:	34.10 metres	Range:	4,800 to 5,700 kilometres
Cabin length:	29.10 metres	Flight altitude:	maximum 11,800 metres (39,000 feet)
Cabin width:	3.7 metres	Speed:	up to 840 kilometres per hour
Cabin height:	2.4 metres	Flight duration:	up to 2.5 hours for test operations
Seating capacity:	maximum of 179	Tank capacity:	23,858 litres
Unladen weight:	42.3 tonnes	Original purpose:	civil use – passenger aircraft
Total weight:	75.5 tonnes maximum	DLR flight operation:	Braunschweig

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DLR at a glance

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