ATRA

A new dimension in aeronautics research
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 transport 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, rotorcraft, 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 aerelastic 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.
History of research aircraft
Key dates in the history of ATRA:

1997 – 2006
- 15/04/2010: Painting of ATRA in the livery of the DLR aircraft fleet
- 11/12/2008: Signing of the purchase agreement for the Airbus A320-232 MSN 659
- 05/03/2006: First joint flight experiment using two DLR research aircraft (Falcon D-CMET)
- 12/06/2006: D-ATRA lands in Braunschweig for the first time. The responsibility of ownership is transferred to the Airbus development centre for research aircraft.
- 14/03/2006: ATRA is exhibited as a fuel cell demonstrator at the static display during the ILA Berlin Airshow.
- 24/01/1997: On 24 January 1997, under the serial number F-WWIN, the DLR’s research aircraft, ATRA (Advanced Technology Research Aircraft), was born.

2008
- 01/12/2008: After its official presentation by DLR and the Austrian airline Niki, ATRA, which was later transferred to DLR, was operated by the Austrian airline Niki.
- 10/04/2009: In summer 2011, the A320 ATRA was operated using electrical energy from the fuel cell and allowed the electric nose wheel to be operated for the first time.

2009
- 15/04/2010: The first approach flight with subsequent landing was conducted on 15 April 2010.

2010
- 10/09/2010: F-WWIN was used for the first time to research wake turbulence.
- 11/11/2011: The A320 ATRA was operated using electrical energy from the fuel cell and allowed the electric nose wheel to be operated for the first time.
- 04/10/2012: In 2009, ATRA had been flying in the old Niki uniform, in DLR colours and with DLR’s logo. In 2010, it operated in the new uniform, in DLR colours and with the DLR logo.
- 11/11/2011: In the demonstration – the first in the world – the electric nose wheel was operated for the first time. It was controlled both by the autopilot and manually on preset routes outlined by the fuel cell.

2012
- 11/11/2012: In 2009, ATRA had been flying in the old Niki uniform, in DLR colours and with DLR's logo. In 2010, it operated in the new uniform, in DLR colours and with the DLR logo.
- 11/11/2012: In 2009, ATRA had been flying in the old Niki uniform, in DLR colours and with DLR’s logo. In 2010, it operated in the new uniform, in DLR colours and with the DLR logo.
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2013 to present day
- 15/04/2015: HINVA F/V I: First joint LuFo project carried out in cooperation with Airbus
- 10/11/2015: HINVA F/V II: first-time implementation of a LuFo project in cooperation with Airbus
- 20/02/2018: Certification of various role specific retrofit kits
- 12/04/2019: First joint LuFo project carried out in cooperation with Airbus
- 02/2020: First LuFo project for the aeronautics development organisation (LuFo).
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.
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.

The flow behaviour of cabin air in passenger aircraft can be made visually visible by using a laser and adding mist particles to the air. This is used to improve the level of comfort in aircraft cabins.
High-lift aerodynamics 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 synergistic 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.

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.
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.
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).
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 micro-metre-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. 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.
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 manoeuvres and 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.

Scientists’ workstation

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.

Experimental display in the cockpit

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 ATRA cockpit with the additionally installed instruments
## Technical specifications

**Airbus A320 D-ATRA**

<table>
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<th>Specification</th>
<th>Value</th>
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<td><strong>Length:</strong></td>
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<td><strong>Original purpose:</strong></td>
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<td><strong>DLR flight operation:</strong></td>
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DLR at a glance

DLR is the national aeronautics and space research centre of the Federal Republic of Germany. Its extensive research and development work in aeronautics, space, energy, transport and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany’s space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation’s largest project management agency.

DLR has approximately 8000 employees at 16 locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Goettingen, Hamburg, Juelich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Stade, Stuttgart, Trauen, and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington D.C.

DLR’s mission comprises the exploration of Earth and the Solar System and research for protecting the environment. This includes the development of environment-friendly technologies for energy supply and future mobility, as well as for communications and security. DLR’s research portfolio ranges from fundamental research to the development of products for tomorrow. In this way, DLR contributes the scientific and technical expertise that it has acquired to the enhancement of Germany as a location for industry and technology. DLR operates major research facilities for its own projects and as a service for clients and partners. It also fosters the development of the next generation of researchers, provides expert advisory services to government and is a driving force in the regions where its facilities are located.