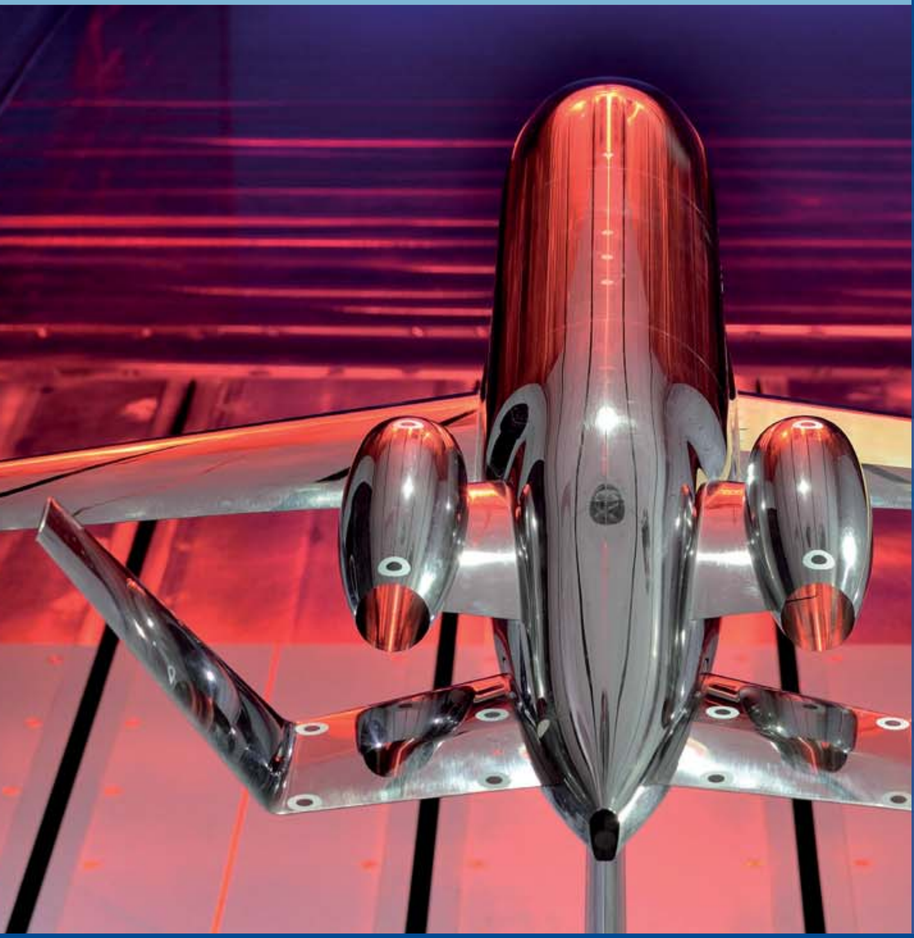
EUROPEAN TRANSONIC WINDTUNNEL

NEWS 19

DECEMBER 2020



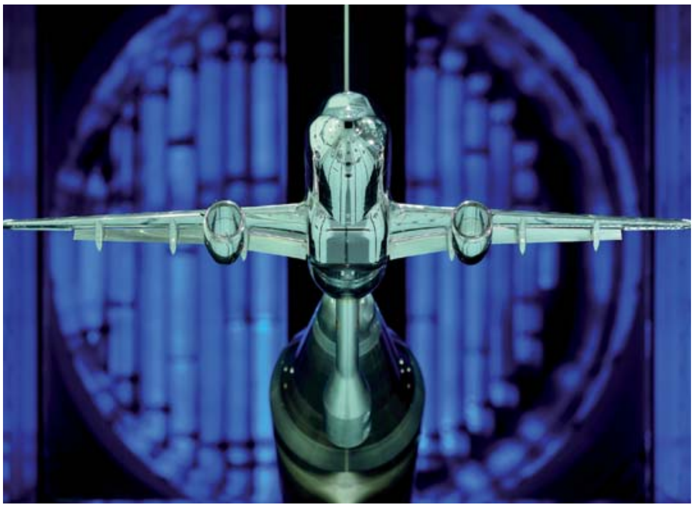
Continuous Development to Safeguard our Futures

The publication of this 19th ETW News coincides with the most difficult time in aviation history amid the COVID-19 pandemic. Despite immense challenges, the aviation industry remains upbeat and united in the ambition to realign innovation and product strategies to enable a sustainable Green recovery.

Targeted investments by our Shareholders and public funded research continue to mature and keep up-to-date the services that ETW is able to offer the aerospace community. The capability developments described in this issue underline the significant progress that has been made to upgrade the facility, to improve productivity and skills, and to provide new capabilities aligned to continuously evolving future needs thanks to the support of our Shareholders. The development and implementation of complex optical techniques in the cryogenic environment has enabled a step-change in the scope and detail of services that ETW can offer customers at true flight conditions. Many of these techniques have been developed with support from national and European agencies, in collaboration with international partners. These techniques, together with a paradigm shift in productivity achieved by implementing remote control techniques, enable future designs to be evaluated with confidence using a combination of physical testing at ETW and validated simulation methods and tools.

The future will see aviation invest in technologies to enable step-changes in cleaner and quieter designs. These essential elements will ensure that aviation can operate sustainably and gains the Greener credentials necessary to maintain public acceptance. ETW will continue to do its best to support aerospace research and development in these challenges ahead, contributing to innovation and risk mitigation.

Low Speed Full Span Model Test Campaigns



AIRBUS

A full span, low speed high lift cryogenic model representing the A320-200 CEO aircraft configuration at 4.6% scale was tested in two major campaigns. Using a test temperature of 114 K Reynolds numbers of up to 14 million were achieved in a range of Mach numbers from 0.18 to 0.35 with incidences beyond maximum lift. In total, 12 configurations were tested for clean, take-off and landing configurations. The landing configurations were equipped with Minitufts to visualise surface flow characteristics and SPT markers to determine wing deformation.

The main objectives of these test entries were to acquire low speed performance data over an extensive range of Reynolds numbers and low speed Mach numbers to validate the ability of CFD to predict absolute and incremental lift and drag. Model manufacture for such small, high precision wing components presented a most challenging task and was successfully achieved with excellent absolute accuracy and build repeatability. A novel solution for rapid configuration changes also contributed to a very productive test campaign.

EMBRAER

Embraer used the Embraer 190 E2 low-wing, twin-turbofan single aisle aircraft as a reference to perform studies in the PROHYPER Research & Development project. Tests were performed at ETW with a 4.8% scale full span model of the next generation E190E2 aircraft. The model was designed and manufactured by Deharde Maschinenbau GmbH in Germany.

The purpose of this wind tunnel test with a full span model in high lift configurations was to study the airplane flight characteristics for high Reynolds numbers at low speed conditions by investigating mainly take-off and landing performance and assessing the stall characteristics of different configurations. In addition, "clean wing" configurations with slats and flaps retracted were tested. An assessment of the boundary layer transition location on the wing, slats and flaps over a wide range of Reynolds numbers from 3 to 12 million was performed at the start of the test campaign. For these tests the port wing was painted with Temperature Sensitive Paint (TSP). Transition detection tests were supported by the German Aerospace Centre DLR. The assessment of model deformation effects was achieved by using the ETW SPT system.

01 | CLIENT TESTING

Business as usual

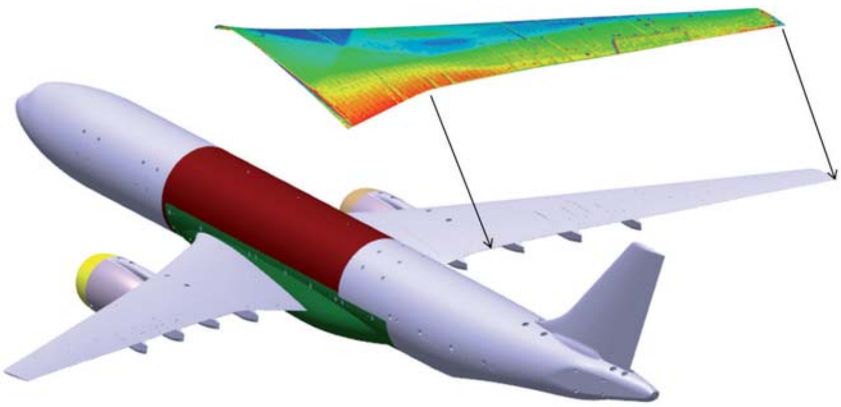
AIRBUS FeRiT Test Campaign

As part of the UK funded WINg Design MethodologY Programme, WINDY, Airbus employed the Feature Rich Testing philosophy, FeRiT, to investigate characteristics of the generic XRF1 configuration using a new full span cryogenic model with various movable control surfaces represented. The experimental data are used in conjunction with CFD studies at off-design conditions and at high Reynolds numbers aiming for an interacting analysis of both experimental and computational data during a series of test campaigns.

To use ETW's capabilities in the most efficient way the standard measurements of forces, moments and steady pressures were complemented by unsteady pressure measurements with wing-mounted Kulites, wing deformation measurements with ETW's Stereo Pattern Tracking System, SPT, and with the support of DLR experts by the first industrial application of the cryogenic Pressure Sensitive Paint technique, Cryo-PSP. The Client request for multi-physics and multi-purpose experiments was realised in a further step forward in data complexity and productivity.

The model was equipped with over 300 wing pressure ports on both wings and 22 Kulites with the diaphragm mounted flush to the wing surface. The wing deformation measurement was achieved with 46 markers placed on the lower wing surface observed by two cameras recording images during continuous pitch polars with 58 Hz frequency. Wing deformation was measured for the majority of the configurations tested.

Two configurations were tested with PSP applied to the wings resulting in the acquisition of over 350 test conditions providing impressive PSP results during very productive test sequences. The industrial application of deformation measurement, temperature or pressure sensitive paints and also Laser techniques in the same test campaign is now offered to Clients after several years of intensive development and represents enormous benefits due to increases in data capture capability and productivity.



PSP was used for the clean wing and for an aileron deployed configuration using a pitch pause technique.

02 | FACILITY UPGRADE

GADE completion

Implementing New Capabilities to Improve Accuracy, Productivity and Efficiency

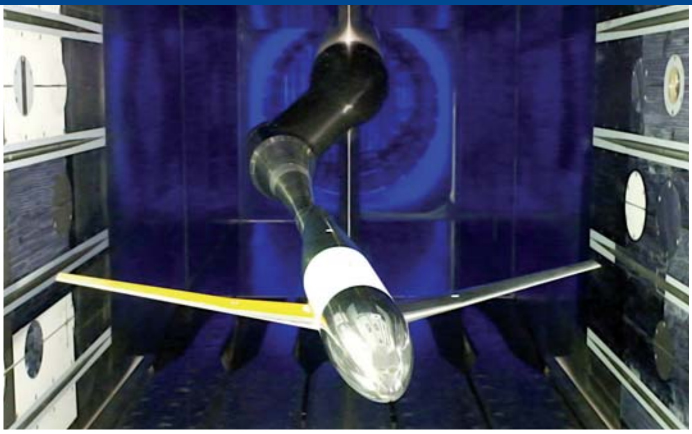
In late 2019, the "Green-Aircraft Design Enabler Upgrade Investment 2012-2019" GADE was completed. Thanks to the support of ETW's Shareholders it covered vital preservation efforts as well as the implementation of essential investments to ensure the proper quality and future optimal performance of the ETW wind tunnel. It preserved, enhanced, expanded and upgraded facility components and added new key capabilities which are relevant for the development of future generations of aircraft. All projects in the present newsletter benefited from the GADE investments. Here, four particular capability enhancements are pointed out:

> Lean Secondary Roll

A slender double roll mechanism designed for low interference measurements of transport aircraft configurations up to high yaw angles enables affordable flight Reynolds-number handling quality testing with reasonable productivity. Especially suitable for laminar wing design concepts, continuously driven wings-level yaw measurements are essential investigations for the determination of robust wing designs.

> Cryo Pressure Sensitive Paint PSP

Beside the development of paint to obtain the surface pressure distribution over a wing region quantitatively with a high spatial resolution at cryogenic conditions and providing excellent surface quality the facility needed to develop provisions for operation. To realise the required low but constant oxygen concentration of about 1,000 ppm a special oxygen injection method was established and synchronised with the nitrogen injection of the tunnel. By means of new equipment for UV LED lighting and high resolution cameras working under cryogenic and pressurised conditions excellent results were achieved in subsequent industrial tests.



> Temperature Sensitive Paint TSP

To boost laminar testing productivity by enabling continuous TSP pitch polars an IR-Laser application was pursued to enable model surfaces to be locally heated to achieve results similar to the previously used technique of temperature changes of the flow inside the test section. As a result of this successful application, significant savings of energy and time are offered to Client test programmes allowing highly economic and productive test scenarios to be accomplished. Non-intrusive surface-oriented techniques, like PSP (Pressure Sensitive Paint) and TSP (Temperature Sensitive Paint) allow localizing the footprints of the main flow-field phenomena both rapidly and cost-effectively as required for highly productive ETW testing.

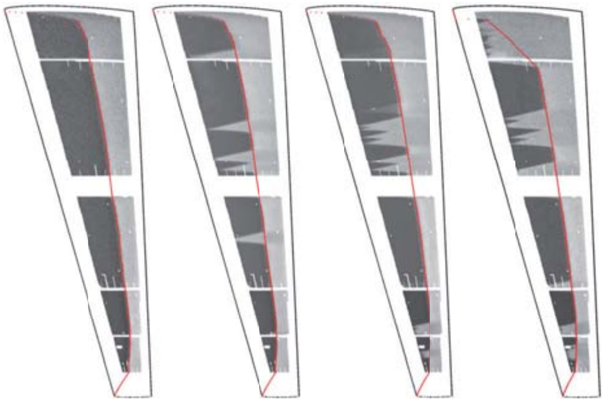
> Icing Simulation for High Lift Performance Testing

To enable icing simulation for models tested at ETW the GADE project included investment in 3D printing capabilities to produce high precision model parts. Materials have been selected compatible with the cryogenic environment, which can be attached directly to the leading edges of models to simulate representative ice shapes at high Reynolds number conditions. The ability to produce model parts on-site at ETW in short timescales provides Clients with flexibility to adapt their test programmes to focus on specific features.

The original aim to finish the GADE 2012-2019 project on time and within budget was achieved due to excellent Project Management provided by Altran Deutschland S.A.S. & Co. KG. About 1,800 contracts were successfully handled to finish the 44 tasks originally specified for the €20 million project funded by ETW's Shareholders.

This work received funding from the European Union JTI-CS under grant agreement no. 641455 and 338517

Natural Laminar Flow Wing High Speed Performance Tests



Clean Sky Smart Fixed Wing (SFWA) has defined the Natural Laminar Flow Technology as a key technology stream. This includes a robust "laminar performance" under typical flight conditions. Wind tunnel tests at high Reynolds numbers have been performed in the past to investigate the impact of surface quality, e.g. waves and steps, on the robustness of laminar flow. As a next logical step performance tests were carried out for the assessment of relevant aerodynamic characteristics at representative flight conditions.

Besides confirming a number of already mature and successfully applied measuring techniques, these investigations allowed to validate a new evaluation process by quantitatively determining areas of turbulent flow on the wing, e.g. generated by turbulent wedges inside the laminar flow region. Calculating the difference in drag due to laminar and turbulent flow by post-processing provides a tool for correcting the overall drag as measured by the balance.

At the end of the test series the knowledge about the sensitivity of laminar flow development over wings due to local shape imperfections was improved considerably. The results gathered will enable manufacturing tolerances and surface finish requirements to be specified for real aircraft scales. The experience gathered during this test series allows improvements in model preparation and test sequences for such types of investigations and expands the unique competence of the facility for similar investigations in the future.

High Speed Wind Tunnel Tests of a Laminar Wing Bizjet

By providing flight Reynolds number test capabilities ETW is regularly engaged in natural laminar flow investigations. Within the CleanSky project HiLamBiz a business jet model featuring a modern natural laminar flow wing design and an innovative motorised U-Tail configuration with rear mounted engines was tested at ETW at flight Reynolds numbers.

The test objectives included the assessment of aerodynamic performance including the buffet boundaries for demonstrating the achievable benefits of laminar wing concepts. The test programme comprised two different wings tested transition free together with one wing tested with transition fixing for reference purposes. Wing and Horizontal Tail Plane (HTP) deformation due to aerodynamic loads were measured by the Stereo Pattern Tracking (SPT) system. Its enhanced capabilities additionally allowed the HTP setting angle to be set and remotely controlled in closed loop during wind-on conditions.

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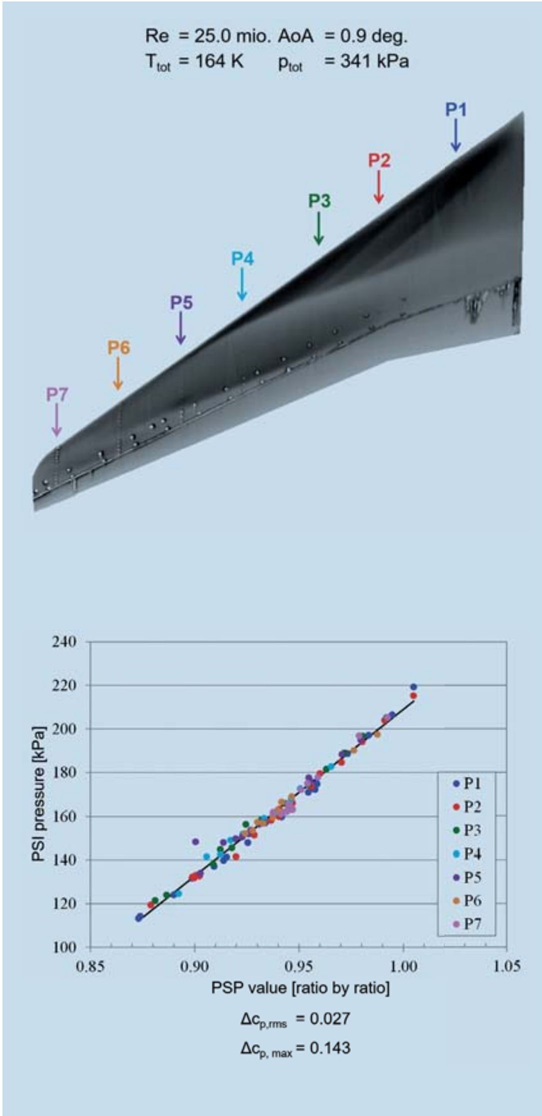
aufgrund eines Beschlusses des Deutschen Bundestages

Application of Cryogenic Pressure Sensitive Paint at Flight Reynolds Numbers

Pressure Sensitive Paint (PSP) was used to visualize and to determine the pressure distribution of special regions of an aircraft model at both, low and high speed conditions. The development of the PSP technique was conducted in cooperation with the German Aerospace Centre (DLR), the University of Hohenheim, and FH Münster.

The principle behind pressure measurement by the PSP method is based on a photo-physical phenomenon. The intensity of the emitted light depends on the local concentration of oxygen in the paint layer. Assuming a constant gas mixture the intensity corresponds to the local pressure above the surface. To realise the low but constant oxygen concentration of about 1,000 ppm inside the ETW test section a special oxygen injection method was developed and synchronised with the liquid nitrogen injection. By means of the special technical equipment using UV LED lighting and high resolution cameras, both working under cryogenic and pressurised conditions, ETW is able to offer a new valuable minimal intrusive method for complex flow pattern investigations. The applicability in ETW covers the entire operational envelope from low speed and ambient temperatures up to cruise flight conditions at cryogenic temperatures.

The thickness of the PSP coating which is sprayed directly onto the model surface is about 5 µm and in most cases the change of geometry due to the coating can be neglected. Even the static pressure tappings are not affected by the coating providing that it is correctly applied. The paint surface roughness was reduced to an acceptable value of less than 0.25 µm. The PSP results show good agreement with pressure tap data demonstrating an accuracy in Cp better than 0.05 at cryogenic conditions. Although the results from these initial commissioning trials were very promising, the integration of the measured pressure distributions to provide component forces was limited by partly obscured surfaces or other omissions of local data. PSP is seen as a valuable extension to surface pressure tap data, enabling increases in local resolution, and visualisation of global flow features. By using this technique models with significantly reduced pressures instrumentation can be used, although a small number of discrete pressures are still required for in-situ calibration purposes.
Following several years of intensive development, including wind tunnel trials with different paint formulations to increase the pressure sensitivity, to decrease the temperature susceptibility, and to reduce the coating roughness to acceptable levels, industrial tests are successfully performed since 2018. Further research to capture unsteady phenoma with Cryo-PSP is work in progress.



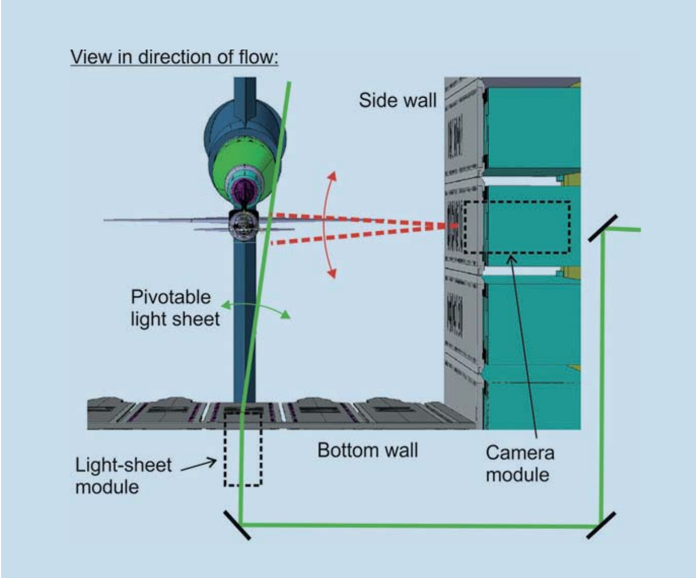
This development project has been supported by the Federal Ministry of Economics and Technology (BMWi) within the Aerospace Research Programme.

SEVENTH FRAMEWORK PROGRAMME

This work received funding from the European Union FP7 under grant agreement no. 227816

Application of High-Speed PIV

The time-resolved Particle Image Velocimetry (PIV) technique has been applied at ETW in the framework of the European research program ESWIRP (European Strategic Wind Tunnels Improved Research Potential). The model used was the NASA Common Research Model (CRM) provided by NASA Langley for this investigation. The PIV measurements were carried out by the DLR Institute for Aerodynamics and Flow Technology (IAS).



For these tests the existing Cryo-PIV system was equipped with high-speed PIV components providing a temporal resolution of 2 kHz in the velocity data. The Cryo-PIV system consists of optical modules for the placement of cameras and light-sheet optics behind test section windows. Because of the cryogenic environment, these modules were placed in heated housings and were remotely controllable. The PIV laser was placed outside the wind tunnel and the laser beam was directed via laser mirrors through a small window in the plenum pressure shell to an optical module containing the light-sheet-forming optics installed in the test section bottom wall.

To compensate for laser light beam deflections due to optical and mechanical effects when changing the tunnel temperature or pressure, a beam monitor was employed in this module which permitted automatic repositioning and redirection of the laser beam using motorised mirrors. To produce flow tracers tiny ice crystals were used that were generated by injecting a small amount of vapour into the saturated cryogenic environment of the wind tunnel.

The light sheet was aligned parallel to the direction of the free stream velocity for a good dynamic range of the measured velocities. Different measurement positions were achieved by pivoting the light-sheet using motorised laser mirrors inside the light-sheet module. The field-of-view of the camera could also be adjusted accordingly using a mirror setup and a specially designed lens adapter inside the camera module.

The PIV results achieved both at subsonic and transonic stall conditions showed turbulent flow structures in the wake of the wing providing an insight into the turbulent energies and frequency spectra. For the first time time-resolved PIV measurements have been successfully carried out at Mach numbers up to 0.85 and Reynolds numbers up to 30 million.

The progress gained in this project is now used in a new research group to investigate "Unsteady flow and interaction phenomena at high speed stall conditions". Their project started in 2020 and is funded by the German Research Foundation (Deutsche Forschungsgemeinschaft; DFG) and the Helmholtz Association of German Research Centres (Helmholtz-Gemeinschaft Deutscher Forschungszentren; HGF); as an industrial partner, Airbus provided a model as a test vehicle.

03 | RESEARCH

LuFo - Research supported by Germany

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2D RCA SMA Inboard Spoiler tested in PETW

Multiple RCA-SMA movables tested on 787 half model in ETW

SMA Remote Control Actuation for High Speed Applications

Shape Memory Alloy (SMA) is a metal with unique properties that allow it to change shape, meaning it can stretch or twist, by heating and cooling and still "remember" its original shape. A team of experts from Boeing, Deharde GmbH, and ETW targeted the application of a Boeing patented SMA technique to actuate several model movables installed on a representative high speed configuration at cryogenic conditions. The first milestone in this development was to test a controllable Boeing 787 model-scale inboard spoiler built into a two-dimensional airfoil in the Pilot ETW. The wind tunnel tests were designed to validate that the spoiler could be moved and controlled under maximum and minimum temperatures and loads while acquiring aerodynamic, thermal, sensor and model positional data within stated accuracy, precision and repeatability target levels. Based on the significant progress made during the PETW tests the Remote Control Actuator (RCA) team was honored with the Boeing Performance and Innovation award for their contribution to Boeing's competitiveness and productivity.

The second milestone in the validation of this SMA based RCA technology for cryogenic high speed wind tunnel application was the testing of a modified 4.5% Boeing 787-8 half model with multiple RCA surfaces. Three primary RCA surfaces: aileron, outboard spoiler, and inboard spoiler were designed and incorporated into a new wing and subsequently tested at representative flight conditions. With the push of a button, the RCA team was able to control spoiler or aileron settings on the 787 half model from the ETW control room. These changes were made wind-on at minimum tunnel speed, saving significant time and energy costs, to acquire a robust dataset for multiple RCA settings. In early 2020 the RCA team's achievements were recognised by the Boeing Engineering Team of the Year 2019 award.

This development has been supported by the Federal Ministry of Economics and Technology (BMWi) within the Aerospace Research Program "ISL-SMA" (Innovative Structures for Aircraft & Aircraft Models by Shape Memory Alloys). ISL-SMA will make SMA applicable as compact, robust and powerful actuators to drive movables on wind tunnel models. This leads to valuable cost and time savings in performing wind tunnel tests at actual flight conditions, as they are vital to design future eco-efficient and quiet aircraft.

Learn more about SMA:

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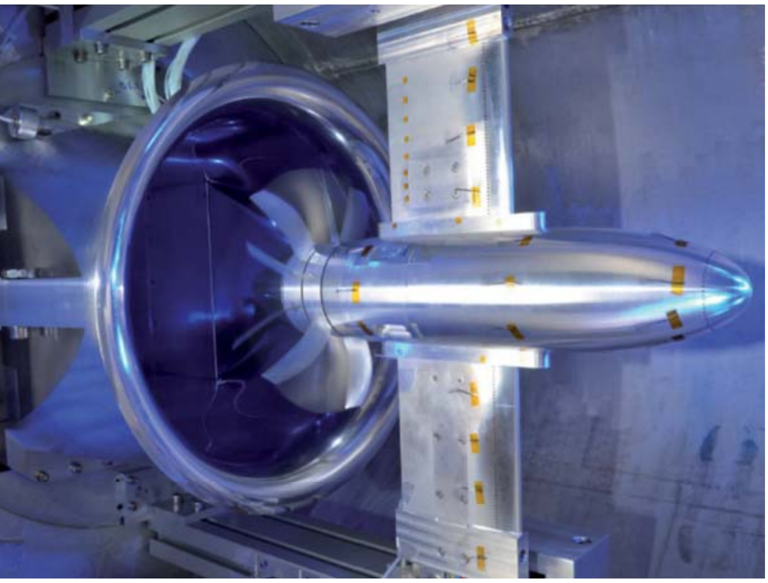
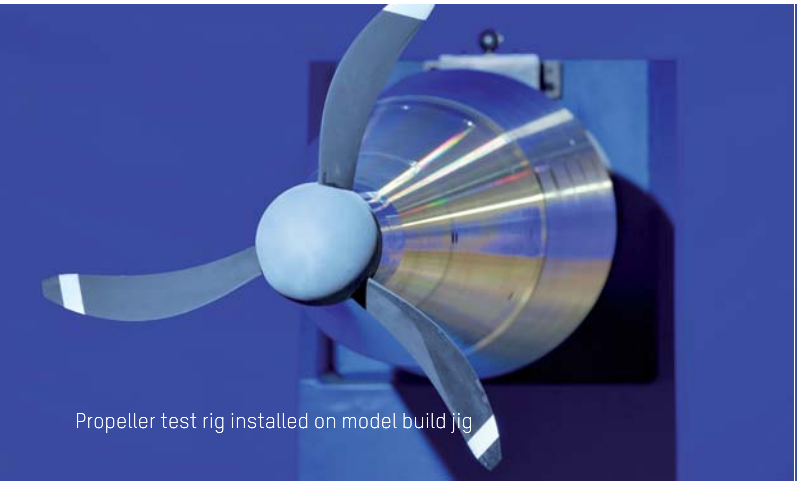

Counter Rotating Open Rotor tested in PETW

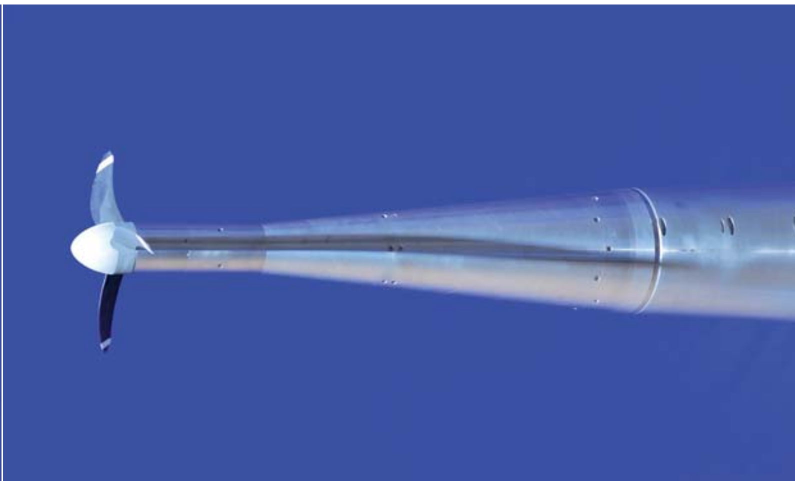
First Tests of a CROR in Cryogenic Conditions

A Counter Rotating Open Rotor (CROR) model was tested for the first time under cryogenic conditions. Within the LuFo-IV Project ITS (Innovative Triebwerks-Simulation) a scaled model of a generic open CROR was built and driven by an electric motor. Initial investigations were carried out on the bearings with cooling and heating when subjected to ambient and cryogenic conditions respectively. After pre-tests in a large cryo-chamber, the test rig was transferred to the Pilot ETW tunnel. The experiments revealed the feasibility of powered propellers for wind tunnel testing in a cryogenic environment.

Developing Engine Simulation Potential

There are still few reliable results available today on the influence of the Reynolds number on the aerodynamics of propellers, especially on the transition behaviour of the boundary layer. For future investigations, a test facility for rotating systems under cryogenic conditions has been developed within the LuFo-V-2 Project ReSK (Reynoldszahl-Effekte und Strömungskontrolle). The test facility is based on a high power density electric motor capable of providing power levels up to 168 kW at rotational speeds up to 8,850 rpm. The thermal management of the motor is achieved by the supply of gaseous nitrogen controlled at variable temperature and pressure levels compatible with the operating conditions. Future collaboration with external organisations is sought and shall progress this capability using balances and optical techniques.


Propeller test rig installed on model build jig



04 | LATEST NEWS

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First Full Model Tests of a Remote Control Aileron at Cryogenic Conditions

Robust remote control movables at full-model scale are essential to achieve a step change in productivity in ETW's cryogenic operating environment. A patented concept now enables efficient performance and handling-quality testing at true flight conditions.

A team of experts from Deharde GmbH and ETW targeted the application of remote controls for an aileron installed on a high speed full model. This device has been designed to be adjusted wind-off in the test section at cryogenic and pressurised conditions over the complete range of deflections encountered at high speed conditions – no transport or manual rigging efforts needed. Subsequently, the new position is locked for wind-on testing. A first test series in 2020 successfully demonstrated this capability on a representative full model at transonic Mach numbers, and at conditions representative of flight Reynolds numbers. The tests included two deflected aileron settings together with a datum-undeflected configuration.

As with RCA-SMA (see page 9), Clients may benefit from this capability by ordering one-stop shop service at ETW including model design, manufacturing, rigging and operational support from Deharde GmbH, Varel, Germany.

The concept developed here complements the outcome from the separate LuFo project "ISL-SMA" described on page 9.

It has received funding from the Federal Ministry for Economic Affairs and Energy (BMWi) within the Aerospace Research Programme LuFo under grant agreement no 20Q1501B.

A video clip showing details of the concept is available on ETW's website.

Research Programmes

ETW has been acknowledged as a Large Research Infrastructure (LRI) by the European Commission. It contributes to various European and nationally funded research programmes. These activities aim on the one hand as a tool to achieve scientific progress since researchers and engineers harness ETW's capabilities for advancing aeronautical science into aircraft innovation by accessing real-flight conditions in this cutting edge ground-test laboratory. On the other hand, the activities advance ETW´s testing capabilities and the means to make best use of it.

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