TRANSPORT AIRCRAFT RESEARCH CHALLENGES – DLR-ONERA PARTNERSHIP

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Abstract

In a world where the demand for travel and mobility is drastically increasing despite some crisis and fuel price increase, the transport aircraft industry is continuously facing technological challenges. With regard to the objectives of Vision 2020 research establishments such as DLR and ONERA play a major role to find the best solutions in order to:

- take care of the environment with a decreased noise annoyance and a limited impact on atmosphere of the aircraft emissions (CO_2, NO_x, soot, …),
- increase the flight safety with improved handling qualities and better response to external hazards,
- improve aircraft performance, maintain their affordability,
- offer the passengers a better comfort regarding vibration and internal noise,
- integrate in a better way the aircraft in the global Air Transport System.

Facing these challenges, DLR-ONERA partnership was strengthened in 2001. This paper gives an overview of the partnership's organisation.
Some highlights on specific topics are presented.

1 Introduction

After the ONERA and DLR partnership agreement signed in 1998 for research on rotorcraft, a DLR-ONERA partnership in transport aircraft research was signed at Le Bourget air show on June 19th, 2001 as well. Based on an already excellent DLR-ONERA cooperation in the field of transport aircraft research and the existence of a European transport aircraft manufacturer Airbus, it was agreed to develop common activities through the implementation of a project-oriented approach, involving DLR institutes and ONERA departments.

A DLR-ONERA management organisation was settled in order to co-ordinate, integrate and market the transport aircraft research activities of both establishments: The Joint Management Structure (JMS) composed by four senior scientists on each side to cover all domains, including two spokespersons and a Steering Committee (SC). Proposed projects are first selected by the JMS and submitted to the approval of the ONERA/DLR Steering Committee whose members are General Directors of the two research centres.

The DLR-ONERA research programme is funded by governmental subsidies granted to the two research centres and by contracts provided by the relevant Ministries (Civil Aviation, Defence, Research, …), Industry and the European Commission.

The scientific and technical scope covered by the Common Transport Aircraft Research Programme (CTARP) includes the following eight topics: aerodynamics, aeroelastics, structures and materials, flight mechanics and systems, new configurations, environment & aircraft, virtual aircraft, air transport systems.

In-depth information exchange is organised in each of these domains and specific Common Research Projects (CRP) are set up in order to coordinate activities and to avoid duplication, but still allowing a mastered scientific competition.

2 Common Research Projects

Since the first Common Transport Aircraft Research Programme in 2003, the number of Common Research Projects has increased. Presently the 2006 CTARP includes 13 CRP listed below:

- Advanced PIV technologies
- Aeroelasticity of a wing with oscillating nacelle
- Non linear aeroelastic simulation
- Aeroelasticity of a wing with control surface dynamics
- Aircraft structural integrity under extreme loads
- Damage tolerance of advanced composite materials and structures
- Pilot role
- Intelligent monitoring and managing of unexpected events
- Performance assessment of integrated wing fuselage configuration
- Wake vortices (phase II)
- Silent take-off and landing
- Merging and development of Industrial and research computational environment
- Drag prediction tests

Each project has a 3-4 year duration and is monitored by a DLR responsible and an ONERA responsible. The project dealing with Flow control on transport aircraft wings ended in 2005; a follow-on project is under preparation.

Thanks to an involvement in all aeronautical disciplines, both research establishments have a major role to play in multidisciplinary research. A project on Multidisciplinary Design Optimisation (MDO) is in a phase of definition.

Some highlights on specific topics are presented hereunder.

2.1 Computational Fluid Dynamics for Industrial and Research Application

CFD has become a mature technology taking a key role at all stages of aircraft design processes. It is widely accepted as an essential, complementary tool to wind tunnel experiments and flight tests.

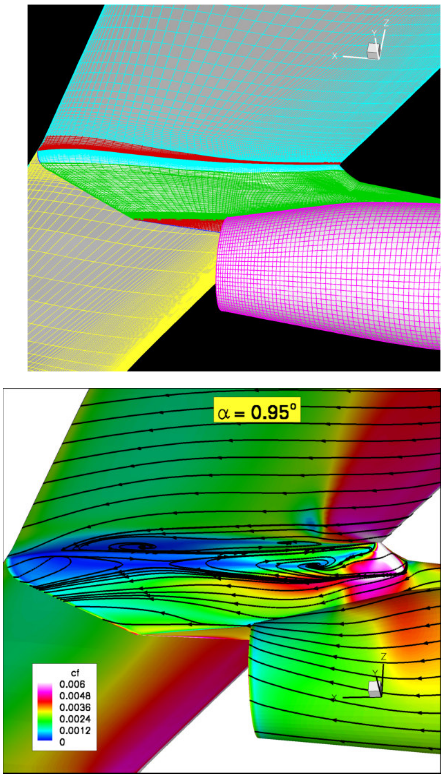
In CFD activities, a major step was performed in 2002 with the choice by Airbus of the *els*A code (structured) developed by ONERA and the TAU code (unstructured) by DLR. The harmonisation of CFD activities aims at providing a single corporate aerodynamic toolset consisting of a unified structured multi-block and a unified unstructured-hybrid mesh based Navier-Stokes solver.

The CRP “Merging and development of Industrial and Research Aerodynamic Computational Environment” (MIRACLE) launched in 2004 has the main objective in harmonizing the CFD activities and strategies of DLR and ONERA in order to better fulfil the future requirements of aircraft industry in Europe.

Despite recent advances in CFD, flow prediction for complete aircraft is still a demanding challenge for increased simulation accuracy, efficiency and robustness. Ever more complex configurations require research in grid adaptation and strategy, physical modelling (turbulence models, transition modelling).

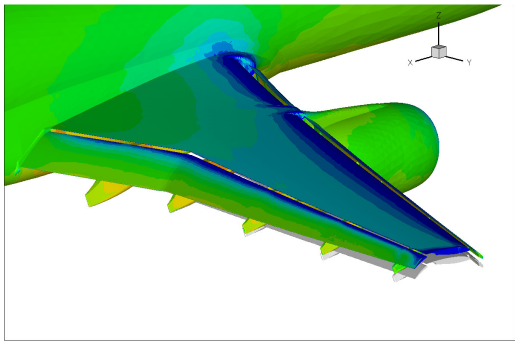
Validation covers for both solvers their capability to accurately predict viscous flow for complex aircraft configurations under industrial conditions. Fundamental validations of academic configurations devoted to assess the accuracy of advanced turbulence and transition models.

As validation examples, an assessment of turbulence modelling for predicting the separation area at the pylon-wing intersection was carried out by ONERA with *els*A.



‘Fig. 1. Simulation of power plant configuration with *elsA* using k- ω turbulence model, wall-to-wall S3Ch configuration, in off-design conditions, at M=0.84, Re=6.05x10^{6}’.

DLR activities for code validation on high-lift configurations are carried out in the framework of the European EUROLIFT II project.



‘Fig. 2. Structural model and pressure distribution on KH3Y landing configuration, coupled TAU/ANSYS computation, M=0.2, ∝=11.2°’

In order to meet the long term requirements of industry with respect to numerical simulation and optimisation, advanced software architecture is mandatory to offer the flexibility for the integration of the codes and the extension for future innovative CFD technologies. This activity will give to DLR and ONERA a leading position in Europe.

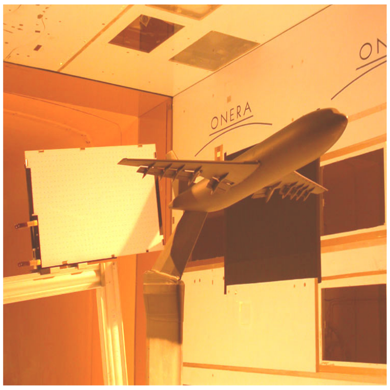
2.2 Particle Image Velocimetry for Wind Tunnel Tests

Improvement of the PIV measurement technique for aircraft industrial applications as wake vortex, transonic flows, high lift configurations, is a key for bringing the best measurement results in the major European facilities (wind tunnels, catapult B 20, …).

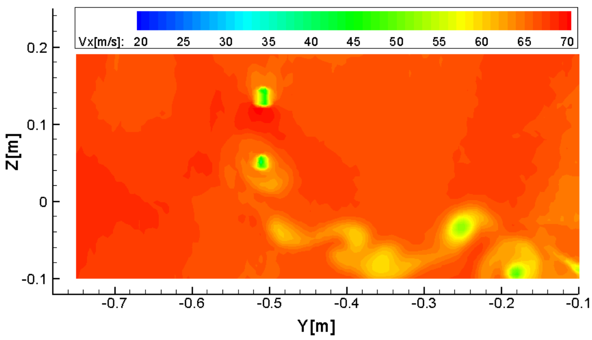
The already well-established project-like cooperation has been expanded within the DLR/ONERA Common Transport Aircraft Research Programme. On the operational side, the cooperation between the joint PIV teams of ONERA and DLR creates research synergies and helps to optimise research facilities as B20, DNW-TNG and S2MA measurements where PIV was implemented.

Most of the experiments are conducted in the frame of European projects in close cooperation with industry as AWIATOR for the wake vortices, EUROPIV and EUROLIFT for the high lift configurations. The European thematic network PivNet 2 (38 partners from 14 countries) coordinated by DLR was a excellent platform for dissemination of the experience.

Concerning the improvement of the PIV technique, ONERA has developed a stereoscopic PIV system validated on different tests experiments (free jet with swirl, wake vortex). A test was conducted in the ONERA-F1 low speed wind tunnel on a civil aircraft equipped with a high lift system in a landing configuration to analyse the wake.



‘Fig.3. Transport aircraft model’



‘Fig. 4. Out-of-plane component of mean velocity vectors obtained by stereoscopic PIV’

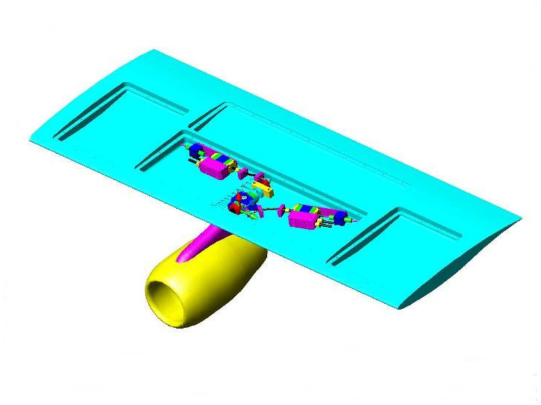
Associated with new analysis image processing, the successful simultaneous measurement of the three components of velocity vectors in a plane area in a large wind tunnel represents an attractive solution. Indeed, it allows to better understand the true physical significance of highly three-dimensional phenomena observed in some flows and to investigate problems of industrial interest around realistic aircraft configuration.

DLR has developed a Time Resolved PIV system which has been successfully applied at a flat plate trailing edge in AWB of DLR Braunschweig. The detailed analysis of measurements has allowed the identification and the reconstruction of trailing-edge-noise sources. TR PIV method is a great interest to investigate vortex-structure interactions. In terms of the aeroacoustic optimization of existing aircraft components such an “optical” detection of aeroacoustic source terms will be beneficial, since a huge amount of (at least low speed) problems could be investigated at lower costs without the need of quiet test facilities.

2.3 Aeroelastics

In aeroelastics, the CRP “Wing with Oscillating Nacelle” (WIONA) launched in 2001 deals with aeroelastic flutter stability in an extended transonic speed range. Non linear transonic aeroelastic issues due to nacelle oscillations are especially considered. The aerodynamic interactions between the wing of which the angle of attack can be dynamically varied and a propulsion installation (engine nacelle plus pylon) mobile around both its yaw and roll axis mainly concern this project.

After definition of the geometry and numerical design simulation, the WIONA wind tunnel model was built including the integration of an excitation system.

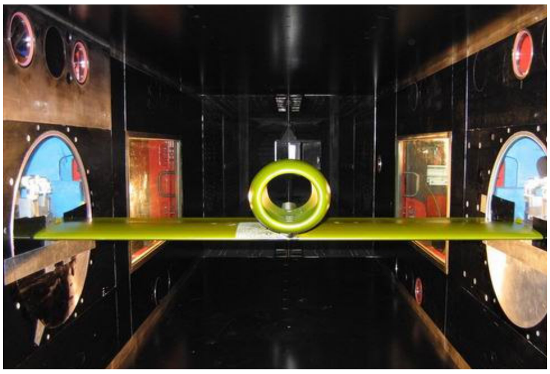


'Fig. 5. First sketch of the excitation system'

First tests were performed in fall 2003 in DNW/TWG wind tunnel at DLR Göttingen. They were devoted to steady pressure measurements.

In a second phase, a new nacelle twice lighter than the initial design was built to allow a better behaviour of the excitation system and an improved model dynamics performance. WIONA II dynamic tests were performed with success in 2005. Detailed data evaluation and physical interpretation are on-going.

These data also served as a common test case for another CRP on Non Linear Aeroelastic Simulation.



'Fig. 6. WIONA II model in the DNW-TWG wind tunnel'

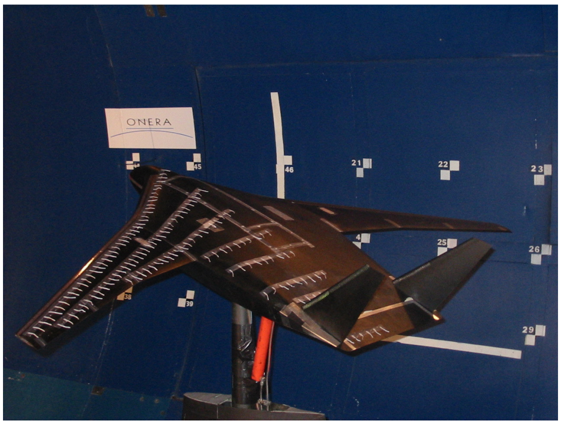
2.4 Integrated Wing Fuselage Configuration

Future concepts like integrated wing fuselage configurations are evaluated at the conceptual/preliminary design stage with the development of capabilities for performance assessment and design analysis.

In the field of unconventional aircraft configuration, to overcome the classical configuration size limits and to offer reduction in operating cost, higher efficiency and airport capacity increase, the flying wing configuration was selected and the CRP "Integrated Wing Fuselage Configuration" (IFWC) launched in 2003. The objectives of this multidisciplinary project were to develop capabilities for performance assessment at the conceptual/preliminary stage design level and on this long term perspective including new technologies to foster the connections between people working in the two establishments in different disciplines.

In a first step, performance assessment of initial design took into account aerodynamics, structural aspects and flight mechanics issues.

Low speed tests were performed in the ONERA S5 and the DNW-NWB wind tunnels under the European VELA project.



'Fig. 7. View of VELA 1 model in the S5 test section'

For high speed tests, a methodology is defined in order to assess the interference of different sting supports.

An aerodynamic shape optimisation of this initial configuration was also conducted leading to a VELA 2 configuration.

For structures, weight estimation is pursued on the initial (reference FE model) and on the optimised configuration considering for both a double shell concept.

For handling qualities, activities consisted in an analysis of the controllability of the flying wing and in a feasibility study for the free flight test of the VELA1 configuration in the ONERA B20 facility.

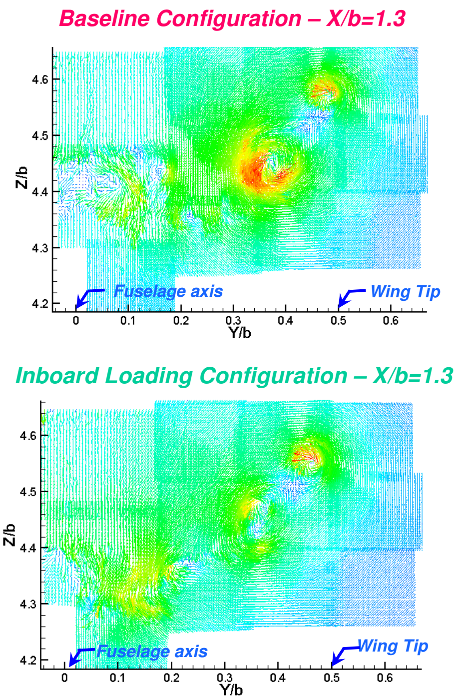
Tools development and exploitation are conducted in the basic scientific areas (aerodynamics, structures, flight mechanics, aeroelastics, acoustics,…) in more detailed studies.

2.5 Aircraft wake vortices

Research on wake vortices of civil transport aircraft is essential with respect to airport capacity and safety level increase. DLR and ONERA launched a first project (1999-2002) and agreed to continue in the CRP "Minimised Wake II" which started in 2003.

The main objectives for aircraft wake vortices studies are:

- characterisation and control including the effect of specific active and/or passive devices, jet turbine/wake interaction,



'Fig. 8. PIV tests conducted by DLR & ONERA PIV teams at the B20 facility [AWIATOR Technology Platform]'

- instabilities with the evaluation of active and passive systems to trigger them,
- numerical simulation,
- identification and characterisation by Lidar on airports.

Mutual involvement has also occurred in the on-going EU projects: AWIATOR Aircraft Wing with Advanced Technology OpeRation), FAR-Wake (Fundamental Research on Aircraft Wake phenomena) and in the thematic network WakeNet2.

3 Overview of other joint activities

3.1 Ground Vibration Test for A380

In the aeroelasticity domain, the long-lasting cooperation and high experience in experimental tests reached an important step with the Ground Vibration Test performed jointly by an ONERA-DLR team in Toulouse-Blagnac for the Airbus A 380-800.

The objective of such a non destructive test is to deliver to the manufacturer, among other specific requests, the vibration characteristics of the aircraft: resonance frequencies, modes shapes, structural damping coefficients and generalised masses.

The obtained data allow the manufacturer to validate and update the finite elements models of the structure in order to ensure safety with regards to flutter (aeroelastic instability). They also confirm the predictions of structural loads, passenger comfort level, and behaviour of the airframe and its equipment in case of fan blade loss on one engine (windmilling).

A few figures: 900 acceleration sensors installed, more than 20 exciters, more than 25 km of cables to connect the sensors, equipment installed up to the height of 24m.

The relevance of the materials and software development specifically carried out for this test campaign, along with the organisation of work in two joint ONERA-DLR teams and the motivation and seamless cooperation of specialists with Airbus engineers enabled the technical goal to be reached in the agreed timescale.

'Fig. 9. A380 Ground Vibration Test'

3.2 European Research Programs

Activities are conducted not only between DLR and ONERA on bi-national basis, but also in other frames.

DLR and ONERA among other research establishments also participate in several GARTEUR action groups in the technical areas of aerodynamics, structures and materials, flight mechanics.

With EREA partners (association of European Research Establishments in Aeronautics), universities and industry, DLR and ONERA are involved in many projects funded by the European Commission in the framework of the past and current aeronautic programmes.

In the 5th European framework programme, the AWIATOR project and the thematic network PivNet 2 were previously mentioned.

DLR – ONERA joint involvement in the 6th framework programme is important in the:

- Integrated Projects (IP) : OPTIMAL, VIVACE, NACRE, HISAC, FLYSAFE, CESAR,
- Network of Excellence (NoE) : EWA and ECATS,
- Specific Targeted Research Projects (STREP) : DESIDER, EUROLIFT II, IFATS, REMFI, SEFA, Wel-Air, SUPERTRAC, TELFONA, FLIRET, FAR-WAKE, NODESIM-CFD, ADIGMA, AVERT, SimSAC, AIM, TIMPAN, CASAM, CREDOS,
- Coordination action (CA) : KATNet 2, X3-NOISE.

In the future 7th European framework programme, the Research Establishments and especially DLR and ONERA intend to play a major role with their scientific and technical support and expertise.

4 Conclusions

DLR-ONERA partnership will increase in the future with projects as for example Flow Control, Multidisciplinary Design Optimisation. Even if enormous progress has been made in the past in Transport Aircraft Research, major innovative improvements are still possible taking advantage of new technologies, increasingly sophisticated prediction and design tools and highly efficient facilities. Cooperation will foster the results in order to satisfy the needs of the European industry and to respond to the ACARE (Advisory Council for Aeronautics Research in Europe) challenges of a more efficient and affordable, more comfortable, cleaner and safer Air Transport System.

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