



AFLoNext

2ND GENERATION ACTIVE WING

Active Flow,
Loads & Noise controle
on next generation wing
(AFLoNext)

**AFLoNext was a five-year collaborative
research project with the objective of proving
and maturing highly promising flow control
technologies for novel aircraft configurations.**



This project was supported by the European Community's Seventh Framework Programme FP7/2007-2013, under grant agreement n°604013.

AFLONEXT

15 COUNTRIES

40 PARTNERS

200 RESEARCHERS
collaborating to meet
a double challenge

37 MILLIONS €
(total budget)

In the current context of air traffic worldwide, aerodynamic efficiency is of key concern.



AFLoNext delivered highly matured technologies in the area of flow, loads and noise control for advanced aircraft design and novel configurations.

AFLoNext was a story of an unprecedented collaboration created to rise to a dual challenge: to **improve aircraft performance** and to **reduce the environmental footprint** of air transport.

AIMS

AFLoNext aimed to prove the engineering feasibility of the HLFC technology for drag reduction on fin in flight test and on wing by means of large scale testing. The project also showed engineering feasibility for vibrations mitigation technologies for reduced aircraft weight and noise mitigation technologies.

The peculiarity of the AFLoNext proposal in terms of holistic technical approach and efficient use of resources became obvious through the joint use of a flight test aircraft as common test platform for the above-mentioned technologies.

To improve aircraft performance along the whole flight regime, locally applied active flow control technologies on wing and wing/pylon junction were qualified in wind tunnels or by means of lab-type demonstrators.

Greening of the air transport:

- ▶ More eco-efficient aircraft design
- ▶ Lower environmental footprint (noise and pollution)
- ▶ Improved aerodynamic efficiency
- ▶ Optimised energy consumption
- ▶ Improved aircraft performance and safety
- ▶ Optimised manufacturing

TECHNOLOGY STREAMS

The AFLoNext concept is based on six Technology Streams which clustered the targeted technologies and their associated contributions to advance aircraft performance as follows:

TS2 **Active Flow Control on outer wing**
Up to 2% fuel saving

Flow control technologies to enable more aggressive outer wing design for novel aircraft configurations, improving the performance in low and high-speed conditions.



TS1 **Hybrid Laminar Flow Control on wing and fin**
Up to 9% fuel saving

Hybrid Laminar Flow Control (HLFC) technology applied on fin and wing for reduced drag and increased cruise performance.



TS3 **Active Flow Control on wing / pylon**
Integration of efficient Ultra High Bypass Ratio (UHBR) engines

Technologies for local flow separation control applied in wing/pylon junction to improve the performance and the loads situation specially during landing.



TS5 **Noise reduction on flap and undercarriage**
Significant A/C noise reduction during approach and landing

Technologies to mitigate airframe noise during approach and landing generated on flap and undercarriage and through mutual interaction of both.



TS6 **Vibrations mitigation / control in undercarriage area**
Significant weight reduction on landing gear door and components

Technologies to mitigate/control vibrations the undercarriage area which are caused by highly unsteady or inhomogeneous flow conditions in take-off and landing conditions.



TS4 **Active Flow Control on wing trailing edges**
Up to 1-2% fuel saving

Technologies to control the flow conditions on wing trailing edges thereby improving the performance and loads situation in the whole operational domain.

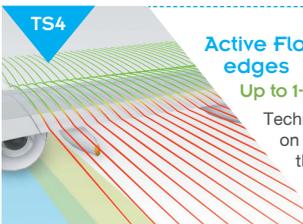




Figure 1: HLFC application installed on ATRA A320 VTP

MAJOR SCIENTIFIC AND TECHNICAL RESULTS

Hybrid Laminar Flow Control on Vertical Tail Plane (VTP)

A HLFC-leading edge segment based on the ALTTA concept has been designed, manufactured and qualified to be flight tested on the VTP of the DLR-A320 ATRA. Several systems for data measurements, a HLFC-verification system and a suction power control system have been developed and brought to flight test. Suction power is generated by either a passive or an active system, consisting of an actuator adjusted flap or a four-stage compressor respectively.

The key flight test instrumentations installed on the test aircraft are:

- ▀ Infrared cameras for transition detection
- ▀ Highly instrumented HLFC-leading edge
- ▀ Hot film arrays
- ▀ Pneumatic and MEMS based surface pressure measurements

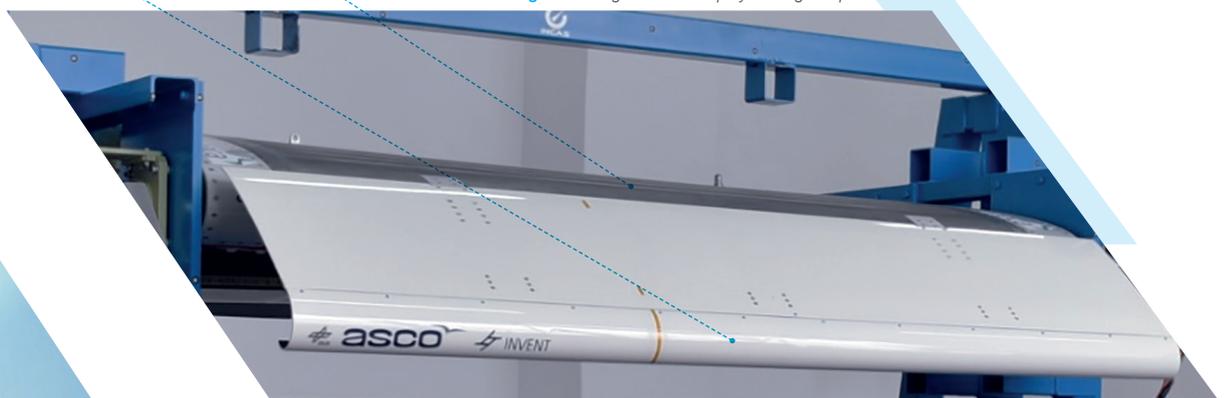
First flight was conducted successfully. The test results evidently show full functionality of the designed HLFC-system with transition delay larger than 50% of local chord depending on flight test point.

Hybrid Laminar Flow Control on wing

A HLFC wing leading-edge concept for a large passenger aircraft has been designed to enable significant drag reduction. The leading-edge concept includes a novel Krueger flap high-lift system, integrated suction and hot air anti-icing air systems. The massive effort results in a 2.3m span ground-based demonstrator, including the manufacturing of a super-plastically formed suction leading-edge panel. The effectiveness of a hot air anti-icing system has been demonstrated in an icing wind tunnel test. The structural integrity of the HLFC wing leading-edge concept has been proven by a bird strike test.



Figure 2: Wing GBD with deployed Krüger flap



Active Flow Control on wing / pylon

A large-scale wind tunnel test **demonstrated that an aircraft scale Active Flow Control (AFC) system is able to mitigate the risk of local flow separation** behind next generation under wing mounted engines with Ultra-High Bypass Ratio (UHBR), which are promising high benefits in terms of fuel consumption and noise reduction.

Two types of actuators were built and tested within the project. Pulsed Jet Actuators (*PJA, Figure 4*) provide a pulsed air flow fed by pressurized air that would be provided by the engine bleed air on the aircraft. Synthetic Jet Actuators (*SJA, Figure 5*) generate the air flow from an electric source by an oscillating Piezo-ceramic membrane inside a cavity.

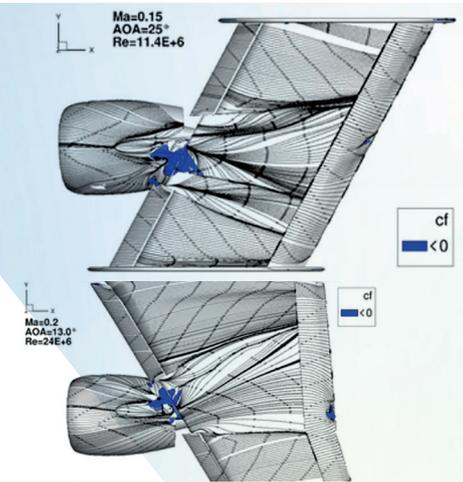


Figure 3: Comparison of flow simulations of flow separation behavior on real aircraft (bottom) and generic wind tunnel test configuration (top)



Figure 4: Pulsed jet active flow control actuator insert: (top) in test rig during ground test; (down) installed at the leading edge of the wind tunnel model

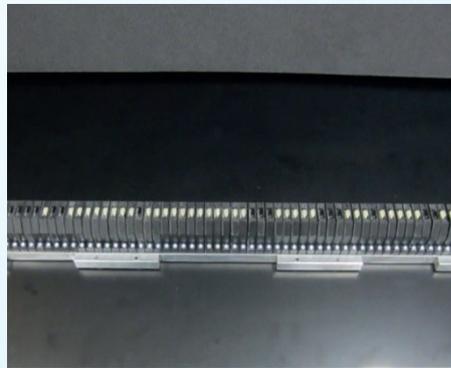


Figure 5: Synthetic jet active flow control actuator row insert (85 single SJA actuators): (left) in test rig during ground test (bottom up); (right) installed at the leading edge of the wind tunnel model



Figure 6: Generic wind tunnel model installed in the 24mx24m open test section of the TsAGI T-101 wind tunnel, Zhukovskiy, Russia

The effectiveness and efficiency of the aircraft scale AFC systems have been demonstrated in a wind tunnel test at the Russian research center TsAGI in the biggest wind tunnel on the European continent, the T-101 facility.

The testing successfully proved the ability to prevent the local flow separation downstream the wing / pylon junction with an acceptable amount of energy.

Active Flow Control on outer wing

Numerical analysis revealed that Active Flow Control (AFC) also may **prevent local flow separations at highly curved wing tip geometries and thereby mitigate the risk of an unintended drag increase during take-off**. As space is more limited than for the wing / pylon junction, a separate set of actuators has been built and passed a series of 10 tests exposing them to harsh environmental conditions, like rain, ice, high and low temperatures, and contamination by sand, dust and solid elements. **During this environmental testing the actuators survived the large majority of the extreme conditions.**

Vibrations mitigation / control in undercarriage area

Numerical studies (aerodynamic, structural, aero-structural coupling) to understand the physics and the root causes of vibrations in the U/C area have been carried out. The consortium partners have also performed hardware modifications such as a monolithic NLG door or vibration control (VC) devices on the MLG doors, flight test instrumentation and flight testing. The DLR-A320 ATRA has served as the flight test aircraft. **Numerical models and the VC devices are validated against flight test data.**



Figure 9: FTI on left hand MLG door (top) and VG's installed on MLG door (bottom) on DLR ATRA A320

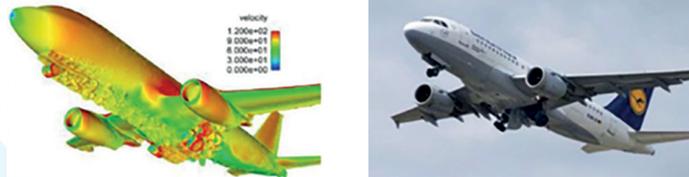


Figure 7: RANS-LES CFD simulation obtained for Nose Landing Gear in Take-Off condition of $\alpha=10.5$, 180kts, sea level $M=0.272$



Figure 8: Camera position on the DLR-320 ATRA

Noise reduction on flap and undercarriage

This technology stream is focused on the noise reduction for the two important sources:

- Landing gear wake interaction with the flap.
- Flap side edge noise.

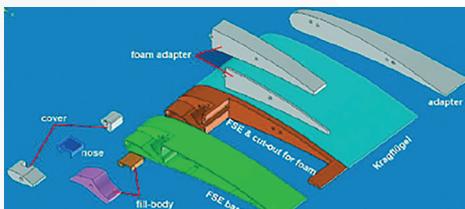


Figure 10: Modular wind tunnel model of a porous flap side edge. The geometry used is original from A320

A very good progress on the preparation of landing gear related noise reduction technology has been achieved and **all proposed noise reduction technologies for the landing gear are scheduled to be flight tested in 2018.** A concept, based on porous materials, for flap side edge noise reduction at large passenger aircraft has been further developed in AFLoNext and tested in flight during 2017. **First data analysis revealed an achieved noise reduction for the sound exposure level in the order of 1 to 2 dB.**

Figure 10 shows the modular flap side edge model, used for the wind tunnel tests.

Furthermore, there have been activities for reducing flap side edge noise on the business jet. Design feasibility studies for the application of porous material have been performed. Metallic materials with specific properties for noise reduction have been manufactured by ALM method and tested for related aircraft operations.

Active Flow Control on wing trailing edges

Based on various Computational Fluid Dynamics (CFD) assessments and aerodynamic requirements generated earlier in AFLoNext, a number of concept architectures were developed to provide options for installing the most promising Trailing Edge Devices (TEDs) on the aircraft. **Buffet control was determined to be the best application for the purposes of the AFLoNext goals, therefore the architectures were specifically targeted towards that application.** Increased lift, drag reduction and gust load alleviation are also deemed to be appropriate applications for further research, outside the scope of AFLoNext.

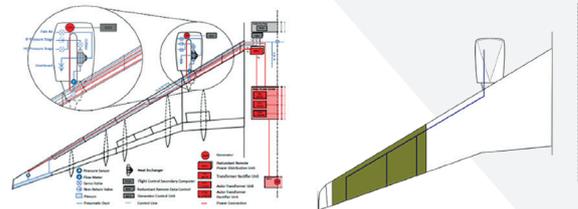


Figure 11: Main engine bleed concept (left) and simplified system diagram (right)

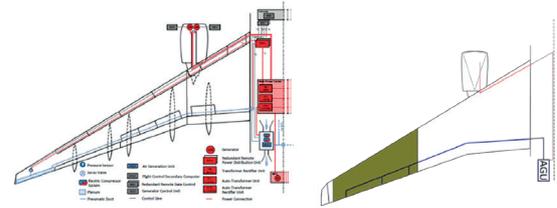


Figure 12: Central Air Generation Unit concept (left) and simplified system diagram (right)

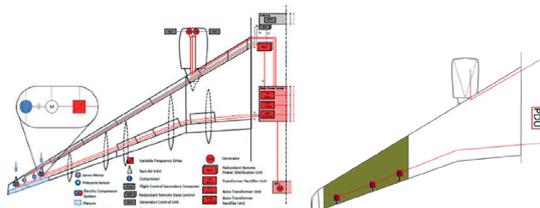


Figure 13: Local electric compressor concept (left) and simplified system diagram (right)

Hazards arising from system failures were assessed for each candidate architecture, including hazards arising from environmental threats. This included preliminary Functional Failure Modes and Effects Analysis (FMEA) and the challenges associated with safety assessment and certification. The suitability of the concepts for integration into the representative future reference aircraft were assessed in detail, including compatibility with the flight control systems, system power weight and volume.

The assessment of the use of TEDs for buffet control was successfully carried out. The study examined a range of wing planforms for a typical single aisle aircraft mission.

High span small area wings with flow control have been identified as giving fuel burn benefits, with the benefit of the control reducing with increased wing area.

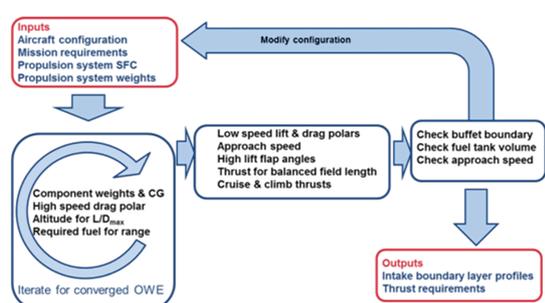
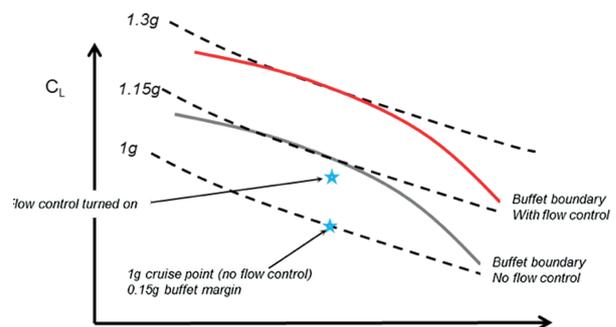
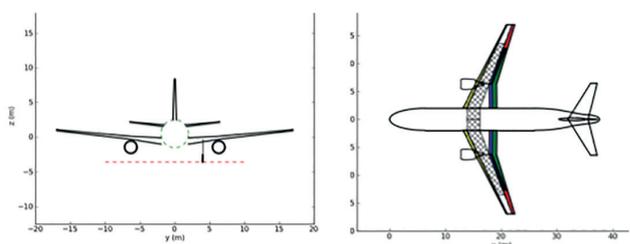


Figure 14: Illustration of how buffet suppression will be utilised



PARTNERS



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Abbreviations

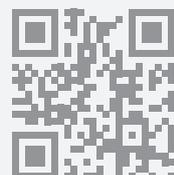
CFD:	Computational Fluid Dynamics	TED:	Trailing Edge Device
GBD:	Ground Based Demonstrator	UHBR:	Ultra High Bypass Ratio
HLFC:	Hybrid Laminar Flow Control	VC:	Vibration Control
NLG:	Nose Landing Gear	VTP:	Vertical Tail Plane
MLG:	Main Landing Gear		

In a nut shell

Title of the Project: "2nd Generation Active Wing"- Active Flow Loads & Noise control on next generation wing - **Grant Agreement Number:** 604013 - **Project type:** FP7 Collaborative Project - Large Scale (L2) - **Starting date:** 1st June 2013 - **End date:** 31st May 2018
Duration: 60 months - **Total Budget:** 37 066 858.00 € - **Total Manpower:** 2 449 Person-months - **Maximum Community Financial Contribution:** 23 612 079.00 € - **EC Project Officer:** Andrea Gentili - **Project Coordinator:** Martin Wahlich (Airbus Operations GmbH) **Project Management Officer:** Ayla Kazanci (Esploro Projects) - **Dissemination Manager:** Peggy Favier (L-UP)



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