With the Flow

Precise airflow control promises significant reductions in fuel burn and noise

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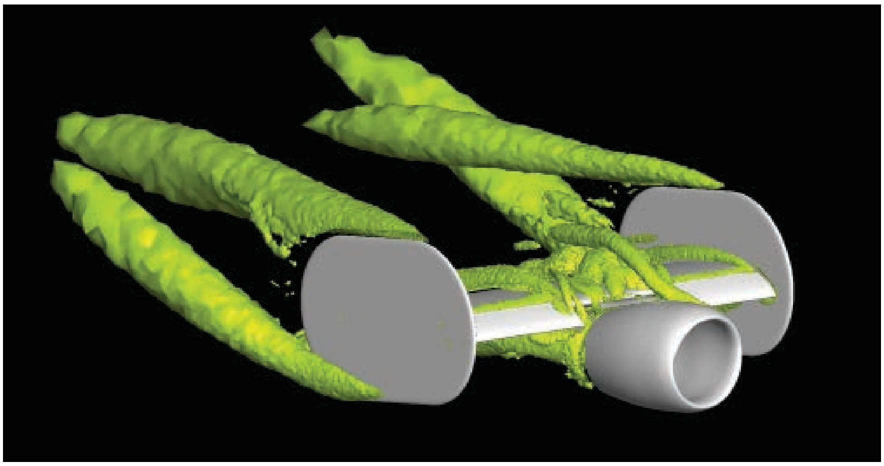
Precisely controlling the airflow over an aircraft's wing and tail, particularly in areas sensitive to flow separation that increases drag, could provide the next significant reduction in fuel consumption, emissions and noise.



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Simulation of flow over the pylon-wing AFC wind-tunnel model.

Europe is maturing a range of airflow, noise and vibration-control technologies under a four-year, €37 million ($40.7 million) research program now entering its third year, which will include the manufacture of hardware for demonstrators.

Led by Airbus, the AFLoNext program (for Active Flow—Loads & Noise Control on Next-Generation Wing) is focused on hybrid laminar flow control (HLFC) to reduce drag in the cruise; active flow control to increase performance on takeoff and landing and allow installation of higher-bypass engines; passive noise control; and vibration mitigation.

The program is maturing promising existing flow-control technologies that participants plan to hand over for large-scale integrated demonstrations under Clean Sky 2, the €4 billion public-private aeronautical research program now getting underway in Europe.

Begun in June 2013 and to run until May 2017, AFloNext involves 40 partners in 15 countries, and includes flight demonstrations of passive noise control on the landing gear and flaps of German aerospace center DLR's Airbus A320 testbed in 2016 and HLFC on the A320's vertical fin in 2017.

HLFC achieves drag-reducing laminarity by removing the slow-moving boundary-layer air using suction through a perforated leading edge to delay the transition to turbulent flow. Flight test of the modified vertical tailplane is scheduled for the second quarter of 2017. "We will go into hardware manufacture in 2016," says Airbus's Martin Wahlich, ALFoNext project coordinator.

Both active HLFC using a compressor and passive flow control using the pressure differential between ambient air and inside the tail—as used by Boeing on the 787 fin and tailplane—will be tested, says Wahlich. An overall fuel-burn reduction of up to 9% is predicted from using HLFC on the wing and fin. "This is a numerical simulation so far. It has to be proven in reality," he says.

As part of the laminarity technology stream within AFLoNext, HLFC integration into the wing leading edge will be validated by a ground-based demonstration. This will involve a 2.5-meter-span (8.2-ft.) section of outer-wing leading edge with suction system, wing ice protection system and a deployable Kruger flap to shield the perforated panel from contamination by insect impacts.

"This is just a demo, to get a feeling for integration, and the outer wing is more critical because of the limited space available. It will be an enabler for a future project under Clean Sky 2. This may be full span; it has not been decided," he says.

Airbus flight tested a hybrid laminar flow fin on an A320 in 1998, "but this was a very preliminary system, with a lot of tubing and no way to integrate it," says Wahlich. The AFLoNext HLFC system "is between experimental and production. The goal of this design is to enable integration on serial aircraft."

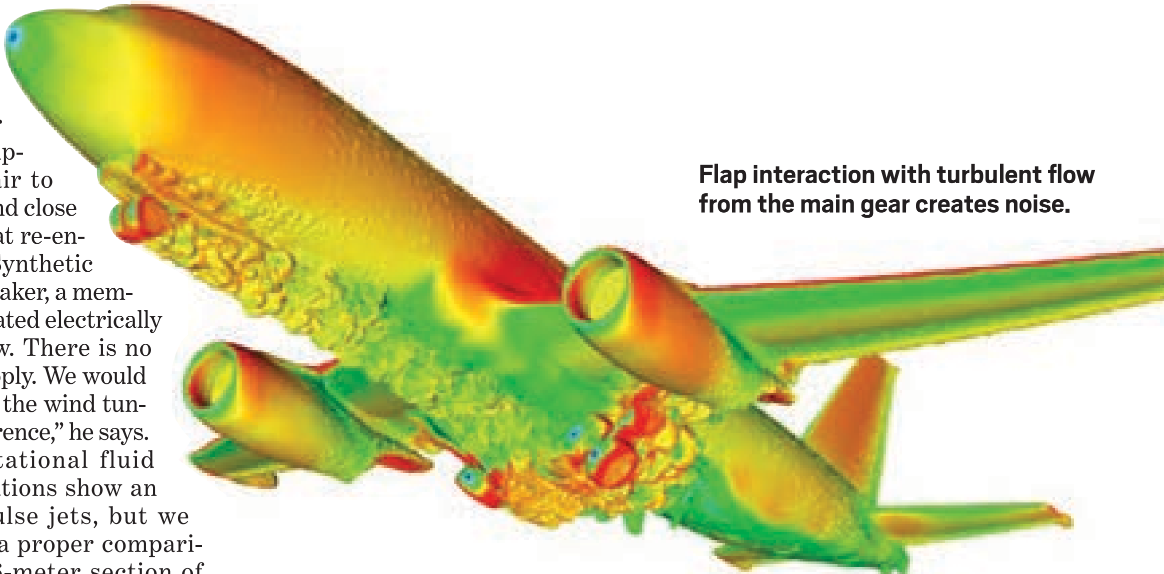
The system is not intended to be retrofittable. "The A320 is just the development tool, not the target aircraft. HLFC on the fin makes sense only on medium-to-long-range aircraft," he says.

Active flow control (AFC) is being investigated under three technology streams within AFLoNext—on the outer wing, the junction of the engine pylon, and wing leading edge. All three involve the local application of AFC to enable more efficient designs.

On the outer wing, active flow control would enable more aggressive wing-tip designs for cruise drag reduction, with projected fuel-burn savings up to 2%. With conventional high-lift systems, flow separation outboard of the deployed leading-edge slat hits the winglet. "AFC could help push the separation to an area where it does not affect the high-lift behavior," says Wahlich.

As aircraft move to more fuel-efficient ultra-high-bypass-ratio geared turbofans, the nacelle diameter will become bigger. "If we don't raise the wing height to increase ground clearance, we have to lift the engine closer to the wing," he says. The cutback in the leading-edge slat to make room for the nacelle becomes larger and the area of high-lift devices is reduced. "We have to recover that to get the same high-lift performance," he says. AFC will be used locally to prevent flow separation and increase performance.

AFLoNext is looking at two types of AFC actuator: pulse jet and synthetic



Flap interaction with turbulent flow from the main gear creates noise.

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jet. Pulse jet uses engine bleed or compressors to supply pressurized air to valves that open and close to produce jets that re-energize the flow. "Synthetic jet is like a loudspeaker, a membrane that is oscillated electrically to produce airflow. There is no need for an air supply. We would like to test both in the wind tunnel, to see the difference," he says.

"CFD [computational fluid dynamics] simulations show an advantage for pulse jets, but we would like to get a proper comparison." Tests of a 6-meter section of wing, complete with engine nacelle, pylon and slats, is planned for the end of 2016 in a low-speed wind tunnel at Russian aerohydrodynamic institute TsAGI. The model represents a long-range aircraft. Smaller-scale tests will be conducted at Tel Aviv University.

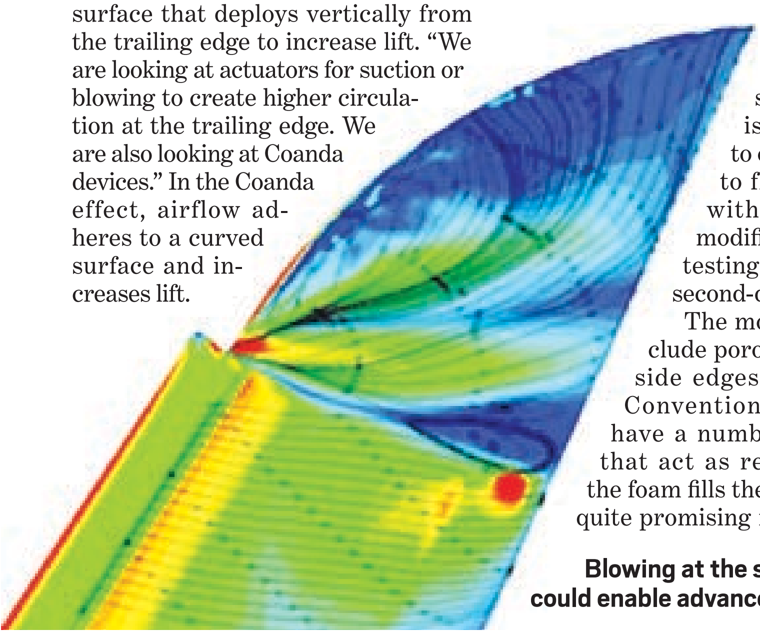
"In parallel we will investigate AFC on short-range aircraft," says Wahlich. "The area where we would like to place the actuators is dense with systems on the A320. If we want to integrate AFC we need a multidisciplinary approach where we know we have to integrate it from the beginning. Retrofit is hardly possible here," he says.

The third area of active-flow-control application being looked at under AFLoNext is the wing trailing edge, with a goal of 1-2% fuel savings. "We want to introduce a fluidic Gurney flap," Wahlich says. A Gurney flap is a small surface that deploys vertically from the trailing edge to increase lift. "We are looking at actuators for suction or blowing to create higher circulation at the trailing edge. We are also looking at Coanda devices." In the Coanda effect, airflow adheres to a curved surface and increases lift.

Only a small-scale wind-tunnel test is planned. Most of the AFLoNext streams are intended to reach a technology readiness level (TRL) of 4-5, ready to move into Clean Sky 2 for large-scale demonstrations to mature them to TRL 6, suitable for product development. Wing trailing-edge AFC "is a basic research investigation for future development," targeted at reaching TRL 2-3, he says.

The noise-control technology stream has two areas: interaction of airflow over the main landing gear and trailing-edge flaps, and treatment of the outboard edge of the flap. Several tests have already been conducted in the DLR-AWB and DNW-NWB wind tunnels at Braunschweig, Germany, to select the landing-gear and flap modifications. The results show a high potential for noise reduction, Wahlich says. The team is now working to obtain a permit to fly DLR's A320 with the selected modifications. Flight testing is planned for second-quarter 2016.

The modifications include porous metal-foam side edges on the flaps. Conventional flap edges have a number of cavities that act as resonators and the foam fills these in. "It looks quite promising for integration on aircraft and could be enabled for existing aircraft," he says. The landing-gear modification includes covers and shields over sources of noise. "There are challenging designs that work in theory, but not on the aircraft, and others with high potential to integrate on aircraft."



Blowing at the slat outer edge could enable advanced tip designs.

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The vibration-control technology stream stands apart within AFLoNext because while flight tests are planned, they are not intended to demonstrate devices. Instead, the team is developing a CFD aerodynamic model coupled with a finite element analysis (FEA) structural model to provide an aeromechanical tool for predicting vibration in early design.

"This has not been done before in Europe," says Wahlich. "We fly, find vibration and look for a remedy. That's expensive, and we want to avoid it by having a predictive method." The focus of the project is main-landing-gear door vibrations. Ground vibration testing on an A320 door has been conducted and flight tests in second-quarter 2016 will complete validation of the coupled CFD/FEA models.

Two types of gear-door vibration mitigation have been designed for later testing, outside AFLoNext. These are aerodynamic methods such as vortex generators, spoilers and meshes, and mechanical devices such as dampers.

With AFloNext in its third year, "we are on a good track to complete our projects more or less on schedule and with the expected results," says Wahlich. "Next year will be a challenging year, with flight-test preparations, building hardware and our biggest hurdle—getting permits to fly."