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2021 was a crucial year for the Clean Sky 2 Joint Undertaking. It was the year that the decision was made to continue and accelerate Clean Sky 2's work in the form of the new European Partnership for Clean Aviation.

Clean Aviation was launched on 1 December 2021, alongside 8 other public-private partnerships that will bring together public and private resources to address some of the EU’s most daunting societal challenges through impact-oriented research and innovation. Clean Aviation will develop and demonstrate technologies which will reduce greenhouse emissions by at least 30% vs. current state-of-the-art regional and short-medium range aircraft with a targeted entry-into-service in 2035. That is an ambitious goal, but Clean Aviation is not starting from scratch, it will build on the strong foundations laid by the work of the Clean Sky and Clean Sky 2 Joint Undertakings.

Projects funded by the Clean Sky 2 Joint Undertaking will continue to run until 2024, and in 2021 we have witnessed many promising results. We are at a very exciting moment in Clean Sky 2’s trajectory - the beginning of the delivery phase for many of our demonstrators. Altogether, we have more than 30 flagship demonstrators, more than 100 other demonstrators contributing to those flagship demonstrators, and more than 1000 technologies in our innovation pipeline.

COVID-19 impacted the entire aviation sector dramatically, but its effects on Clean Sky 2’s progress were relatively contained. Although several of our projects experienced modest delays, overall we remain on track to reach our objectives.

Axel Krein  
Executive Director
The Clean Aviation Joint Undertaking will utilise the gains made in the Clean Sky 2 programmes to leapfrog beyond the next generation of aviation technologies, using a revolutionary rather than evolutionary approach. Our first call will be launched in spring 2022, and you can find out more about this in the next chapter. We will focus on three main thrusts going forwards: hybrid electric and full electric architectures, ultra-efficient aircraft architectures, and disruptive technologies for hydrogen-powered aircraft.

The budget for Clean Aviation amounts to €4.1 billion – €1.7 billion from the European Commission and €2.4 billion from the European aviation industry. But this will not be enough to decarbonise the European aviation industry by 2050. We must join forces with national and regional authorities and develop synergies with existing sources of funding, as well as teaming up with European initiatives like the Clean Hydrogen Joint Undertaking, the SESAR 3 Joint Undertaking and the Batt4EU Partnership. Lessons learned from Clean Sky 2 will be extremely valuable here – you can learn about the synergies that Clean Sky 2 forged and strengthened during 2021 on page 34.

I am certain that the Clean Aviation Joint Undertaking will continue to build on the momentum and the achievements of Clean Sky 2 to propel Europe towards climate-neutrality by 2050.
2021 marked the launch of the Clean Aviation Joint Undertaking, which will run from 2022 until the end of 2031 and has foreseen EU funding of €1.7 billion over its lifetime, to be complemented by €2.4 billion in private investment through in-kind contributions. The following specific high-level objectives for the Clean Aviation Joint Undertaking have been laid down:

- To integrate and demonstrate disruptive aircraft technological innovations able to decrease net emissions of greenhouse gases by no less than 30% by 2030, compared to 2020 state-of-the-art technology, while paving the way towards climate-neutral aviation by 2050;

- To ensure that the technological and potential industrial readiness of innovations can support the launch of disruptive new products and services by 2035, with the aim of replacing 75% of the operating fleet by 2050 and developing an innovative, reliable, safe and cost-effective European aviation system that is able to meet the objective of climate neutrality at the latest by 2050;

- To expand and foster integration of the climate-neutral aviation research and innovation value chains, including academia, research organisations, industry and SMEs, also by benefiting from exploiting synergies with other national and European related programmes and by supporting the uptake of industry-related skills across the value chain.
Throughout the year 2021 until the launch, the preparation of the membership and all related commitments and agreements were finalised. 27 Founding Members committed to the Joint Undertaking through a collective Letter of Commitment securing €2.4 billion in private in-kind contributions.

In total, the Clean Aviation Joint Undertaking closed the year with a total of 39 Members alongside the European Union.

The Strategic Research and Innovation Agenda, defining the programme’s overall technical strategy, was adopted by the Clean Aviation Governing Board on 16 December at its first meeting.

In parallel, ongoing preparations continued on the preparation of the new Joint Undertaking’s first Work Programme.

The mission of the Clean Aviation Joint Undertaking is to develop disruptive new aircraft technology to pave the way towards the EU’s ambition of climate neutrality by 2050. The JU will develop and demonstrate technologies that deliver a step change in energy/fuel efficiency of no less than 30%, compared to 2020 state-of-the-art technology. The technological and industrial readiness achieved will allow the entry into (commercial) service of new aircraft with this performance no later than 2035, enabling 75% of the world’s civil aviation fleet to be replaced by 2050.

When combined with the effect of sustainable low or zero carbon fuels, the aircraft developed as a consequence of the Joint Undertaking’s research and innovation will enable net CO₂ reductions of 86 to 90%. The Clean Aviation Joint Undertaking will contribute significantly towards the ambitious environmental impact mitigation goals of the European Green Deal and the European Climate Law, that is to say a 55% emissions reduction by 2030 compared to 1990 levels, and climate neutrality at the latest by 2050 in line with the Paris Agreement adopted under the United Nations Framework Convention on Climate Change.

Novel technologies developed and demonstrated by Clean Aviation will improve fuel efficiency by 30% or more, compared to 2020 state-of-the-art technology.

Net CO₂ reductions of 86-90% will be achieved thanks to new aircraft and low– or zero–carbon fuels.
The Strategic Research and Innovation Agenda (SRIA) sets out the way to achieve these specific objectives and the overall vision, in terms of timescales and magnitude of impact. The partnership will also build upon the important technological progress that was made under the Clean Sky and Clean Sky 2 programmes to achieve these objectives and secure the targeted impact. The Clean Aviation trajectory towards climate neutrality by 2050 defines two clear horizons:

- **2030** — demonstrating and introducing low-emission aircraft concepts exploiting the research results of Clean Aviation, making accelerated use of sustainable fuels and optimised ‘green’ operations, so these innovations can be offered to airlines and operators by 2030 for an entry-into-service (EIS) within the 2030-2035 timeframe;

- **2050** — climate-neutral aviation, by exploiting future technologies matured beyond the Clean Aviation phase, coupled with full deployment of sustainable aviation fuels and alternative energy carriers such as hydrogen.

Table 1: The Strategic Research and Innovation Agenda for Clean Aviation: Key Thrusts and Applications

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<th>Hybrid electric and full electric architectures</th>
<th>Low Emission Hybrid Electric Regional Aircraft</th>
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<td>Disruptive technologies to enable hydrogen-powered aircraft</td>
<td>Zero-Carbon Hydrogen-powered Short Range Aircraft</td>
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<td>Ultra-efficient aircraft architectures</td>
<td>Low Emission Short and Medium Range Commercial Aircraft</td>
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The three key thrusts for the R&I efforts in Clean Aviation will drive energy efficiency and emissions reductions of future aircraft. They will form the architecture of the Joint Undertaking’s 10-year programme:

- **Hybrid electric and full electric architectures** — driving research into novel (hybrid) electrical power architectures and their integration; and maturing technologies towards the demonstration of novel configurations, on-board energy concepts and flight control.

- **Ultra-efficient aircraft architectures** — to address the short, medium and long-range needs with innovative aircraft architectures making use of highly integrated, ultra-efficient thermal propulsion systems and providing disruptive improvements in fuel efficiency. This will be essential for the transition to low/zero emission energy sources (synthetic fuels, non-drop-in fuels such as hydrogen), which will be more energy intensive to produce, more expensive, and only available in limited quantities.

- **Disruptive technologies to enable hydrogen-powered aircraft** — to enable aircraft and engines to exploit the potential of hydrogen as a non-drop-in alternative zero-carbon fuel, in particular liquid hydrogen.
The target performance levels across the aircraft categories selected for demonstration in Clean Aviation are below in Table 2.

In close collaboration with the Commission as the public partner, Clean Aviation can play a central role within a European Innovation Architecture, ensuring shared roadmaps and synergies with EU collaborative research, other relevant European Partnerships and EU research programmes; national research and innovation programmes, the Next-Generation EU Recovery Funds, and European Structural Investment Funds. Within this architecture, the Clean Aviation Partnership can help mobilise further impact-orientated research aligned with the programme's goals and, as such, support the securing of the estimated R&I effort needed.

### Table 2: Clean Aviation Aircraft Category Targets

<table>
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<tr>
<th>Aircraft Class</th>
<th>Key technologies and architectures to be validated at aircraft level in roadmaps</th>
<th>Earliest EIS Feasibility</th>
<th>Fuel/energy reduction (technology)</th>
<th>Reduction in net emissions (incl. fuel effect)</th>
<th>Current share of air transport emissions</th>
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<tr>
<td>Regional Aircraft</td>
<td>Hybrid-electric, distributed propulsion coupled with highly efficient aircraft configuration</td>
<td>~2035</td>
<td>-50%</td>
<td>-90%</td>
<td>~5%</td>
</tr>
<tr>
<td>Short-Medium Range Commercial Aircraft</td>
<td>Advanced ultra-efficient aircraft configuration and ultra-efficient gas turbine engines, ultrahigh bypass (possibly open rotor)</td>
<td>~2035</td>
<td>-30%</td>
<td>-86%</td>
<td>~50%</td>
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The Clean Aviation Joint Undertaking will launch its first open call for proposals in the first quarter of 2022, so that the technical activities in all three thrusts of the programme can start before the end of this year. This call will allow for an aggressive start to the programme and commit over 40% of the funding available over the life of the programme. A second open, more modest call is foreseen in early 2023.

In addition to the calls for proposals, the Joint Undertaking will launch two open Calls for Expression of Interest (CEI) within the 2022-2023 period. The first CEI will aim to facilitate strategic cooperation with Member States, regions and associated countries and will invite all interested national and regional authorities who want to invest in the aviation sector, and share the objectives and vision of the Clean Aviation and the European Green Deal goals, to express their intention to engage with the Programme in identifying and exploiting synergies. This will increase the Clean Aviation Joint Undertaking’s impact at national and regional level. The second Call for Expression of Interest will address interested private stakeholders to become Associated Members of the Joint Undertaking. Successful applicants will be those who can demonstrate strategic and long-term commitment to the programme and who can perform core tasks and bring key capabilities to implement the programme through the research actions in which they may be or may become involved.
Our goals under Clean Sky 2 are simple: we aim to reduce CO₂, NOx, and noise by 20-30% compared to state-of-the-art aircraft from 2014. The technologies below are the tip of the iceberg, as half of Clean Sky’s main technological achievements will surface in the next two years, with the final ones being delivered from 2022 onwards. Below you’ll find a sample of some of the projects that made important strides or are nearing completion. This non-exhaustive list of highlights will provide some insights into how Clean Sky is progressing to date.
**REDUCING WEIGHT AND COSTS OF REAR-END FUSELAGES WITH ADVANCED REAR END**

Advanced Rear End aims at integrating the most fuel-efficient propulsion concepts into compatible airframe configurations and concepts for next generation of aircraft. The D02 demonstrator will deliver a rear fuselage developed via new manufacturing processes and materials. This will offer potentially significant weight reductions, costs savings and lead-time reductions which will be assessed via relevant physical demonstrators: a rear-fuselage upper-shell demonstrator, thermoplastic lateral panels, air intake system, advanced exhaust system, etc.

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**Goal**

The Advanced Rear End (ARE) demonstrator aims to integrate conceptual design, structural and systems architectures, materials, technologies and industrial processes to provide an optimum rear fuselage and empennage for the next generation of commercial aircraft.

**Method**

- A new aircraft configuration with a forward swept tail is assessed via computational fluid dynamics (CFD) simulations and wing tunnel tests;
- These configuration's requirements are inputs for the manufacturing teams which investigate new technologies and materials to support all design constraints;
- Perform a structural validation of the airframe proposed by means of physical and virtual mechanical tests;
- Leverage the full benefit of composite design to reduce recurring costs, non-recurring costs, weight and lead time.

**Process**

Having reached TRL3 at the beginning of 2021, the project is now aiming to achieve TRL4 by June 2022 with complementary studies on loads calculation, aeroelastic and aerodynamic analyses, and structural configuration performance assessment. In addition, at component and sub-component level the manufacturing of panels, frames and customised tooling was initiated, and tolerance and static/fatigue/impact tests were performed in view of the future TRL4 milestone.

**Expected results and impact:**

- Decrease weight by 20%
- Reduce recurring costs by 20%
- Reduce lead time by 50%
- Improve fuel burn at aircraft level by 1.5%
- Rear fuselage TRL6 by 2023

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**Part of the Large Passenger Aircraft initiative**
IMPROVING THE FUTURE INSTALLATION OF CLOSE-COUPLE ENGINES BY BETTER UNDERSTANDING AERODYNAMICS

Powerplants are moving towards higher By-Pass Ratios (BPR) in order to reduce fuel burn and airline operating costs. However, increasing the diameter of the Ultra High Bypass Ratio (UHBR) engines means that the engines must be installed much closer to the wing, and this has an impact on aerodynamics, as well as on noise generation. With the testing mean developed in the D13 Ultra High Bypass Ratio engines for Short-Medium Range (D13 UHBR SMR) aircraft integration demonstrator, we will have more accurate prediction tools and could sustain more complex future designs. There’s only one similar testing mean in the world – used by NASA!

Goal

The Simulator of Aerodynamic and Acoustic Fan Integration (SA²FIR) test bench has been designed according to the characteristics of the new generation of UHBR engines in close collaboration with SAFRAN. The SA²FIR rig shall serve as a test mean for the next 15-20 years to improve the understanding of close-coupling effects on aerodynamics, aero-acoustics and aeroelastics.

Method

A representative engine fan will be installed in a wind tunnel for testing and assessing the aerodynamic and aeroacoustics performance of a close-coupled engine. This consists of:

- de-risking of fan noise of future installed configurations;
- acquiring a better understanding of UHBR related acoustic sources;
- acquiring validation data for numerical acoustic prediction tools;
- increasing maturity of design tools for aerodynamic, aero-acoustic and aeroelastic issues;
- improving understanding of physical interactions between the airframe and engine (in particular with fan blades);

Process

The critical design review of the SA²FIR test bench took place from April to November 2021. Next steps will be manufacturing all elements (fan, outlet guide vane, lamppost, etc.) and the preparation of the low-speed aero-acoustic wind tunnel test campaign scheduled in 2023.

Expected results and impact:

- Achieve 2% CO₂ (and NOx) reduction though improved understanding of flow physics for close-coupled engine integration
- Achieve farfield noise reduction of 2 dB
- Reduce uncertainty of noise status from 3 to 2 dB
- TRL6 by 2023

Part of the Large Passenger Aircraft initiative
**LOWER SHELL AND UPPER SHELL MANUFACTURING GAINS PACE FOR THE MULTIFUNCTIONAL FUSELAGE DEMONSTRATOR**

The Next Generation MultiFunctional Fuselage Demonstrator (MFFD) project is examining the full potential of thermoplastic composites to help future European airliner production to become faster, greener, and more competitive. A fuselage barrel made of thermoplastic composites weighs less because fasteners are no longer needed, and the materials are more recyclable. Thanks to this initiative, Europe’s aircraft assembly lines will be better placed to respond to the 5% growth rate of the global air transport market, while reaching green objectives.

**Goal**

To produce an 8-metre long thermoplastics fuselage barrel – a world first!

**Process**

In 2021, the lower shell of the MFFD passed a critical milestone with the complete manufacturing of a 8-m long thermoplastics skin – the world’s largest. The skin was laid up using automated fibre placement, consolidated in autoclave and transported back to the Netherlands where the lower shell assembly will take place.

For the upper shell, a welding technique called continuous ultrasonic welding was leveraged to weld stringers onto an in-situ consolidated thermoplastics skin – a world first.

**Expected results and impact:**

- Reduce fuselage weight by 1 tonne
- Increase recyclability of materials
- Increase fuselage build rate to 70-100 per month: current rate is 60 per month
- Flexibility in assembly and increased possibilities for customisation
- Cost reduction ensuring European competitiveness
- TRL5 by 2023

**Part of the Large Passenger Aircraft initiative**
### REGIONAL ACTIVE COCKPIT DEMONSTRATOR TAKES FLIGHT

The regional cockpits of the future will be increasingly automated and significantly reduce the pilot’s workload, thanks to novel avionics technologies such as:

- Enhanced LightWeight Eye Visor (ELWEV)
- Voice Command (VC)
- Aircraft Monitoring Chain for Ground Support System (AMCGSS)
- Cockpit Automated Procedures System (CAPS)
- Pilot Monitoring System (PMS)

Those technologies are developed, integrated and tested in a simulator, making up the Regional Active Cockpit Demonstrator.

### Goal

The purpose of the Active Cockpit Demonstrator is to perform an on-ground human factor evaluation exercise to assess the benefits of those novel avionic technologies.

### Method

Build up an enhanced test environment, including an active cockpit simulator, enabling on-ground highly representative workload measurements and involving pilots from an early stage.

Develop and integrate a set of novel technologies focusing on flight crew workload reduction, decision-making and control functions and crew situational awareness improvement into the Active Cockpit simulator.

Perform operational evaluation and human factor assessments of the technologies in the simulator.

### Process

Novel pilot workload reduction and flight automation technology prototypes were developed and integrated into the simulator. The operational evaluation in the Active Cockpit demonstrator of each individual technology was successfully completed as well as the global operational evaluation (all the technologies operating jointly in the same scenario), thus demonstrating TRL5.

### Expected results and impact:

- Pilot workload reduction between 20% and 40% in selected scenarios
- Improve safety by enhancing the situational awareness of the cockpit crew members, reducing their workload and monitoring their health in real time
- Improve flight/mission efficiency
- Contribution to European competitiveness

Part of the Large Passenger Aircraft initiative

© Airbus
Developed within the frame of the European research Clean Sky 2 project, which involves 40 partners in 13 European countries, the RACER – Rapid and Cost-Effective Rotorcraft – is a full-scale fast helicopter demonstrator, featuring an innovative wing-box design, advanced rotor-less tail, lighter structures and increased efficiency in terms of power management. Cruising at up to 400 km/h, it aims to reduce costs by 25% per nautical mile compared to a conventional helicopter. RACER supports the ACARE Flightpath 2050 goals to improve the mobility of EU citizens while achieving ambitious environmental objectives.

**Goal ►►►**
To integrate cutting-edge technologies to develop and validate a compound helicopter high-speed architecture that can take off and land vertically for use in high-speed missions such as search-and-rescue, emergency medical services and passenger transport.

**Method ►►►**
The RACER demonstrator aims to reach TRL6 at full-aircraft level in 2022, on-boarding many breakthrough technologies. The innovative helicopter concept and architecture will allow the RACER helicopter to cruise at 1.5 times the speed of conventional helicopters. With an increased golden hour distance (the distance that can be covered in one hour of flight), the RACER could be used in the future for missions such as emergency medical services and search-and-rescue operations.

**Process ►►►**
The manufacturing phase was launched in 2020 with the delivery of major components in 2021. The assembly of the demonstrator officially started in March 2021 with the delivery of the RACER central fuselage and has progressed during 2021 with the integration of the helicopter canopy, fuel-system and rotor-less tail. Meanwhile, other important systems such as the wing-box system, doors, windshield and landing gears were delivered in Marignane for the next steps of the demonstrator assembly.
Developed within the frame of the Horizon 2020 public-private partnership Clean Sky 2, the Next Generation Civil Tiltrotor (NGCTR), is a fast rotorcraft demonstrator featuring an innovative tilting system mechanism, lighter structures, improved aerodynamics and avionics. While cruising at more than 500kph, twice the speed of typical helicopters, the Next Generation Civil Tiltrotor operates at a much more sustainable level compared to the average helicopter, supporting the ACARE Flightpath 2050 goals to improve the mobility of EU citizens while achieving ambitious environmental objectives.

To utilise cutting-edge technologies to develop an environmentally-friendly tiltrotor aircraft that can take off and land vertically without airports for use in specialised missions.

The NGCTR demonstrator aims to reach TRL6 at aircraft level in 2023 by on-boarding many breakthrough technologies. The innovative concept and architecture will allow the NGCTR to cruise at twice the speed of conventional helicopters. In terms of its mission, this will cover the gaps between conventional helicopters and turboprops.

In 2021 the demonstrator successfully completed its critical design review. Modifications of the donor fuselage were completed with provisions to accommodate the innovative V-Tail and wing. The assembly of the demonstrator officially started in October 2021 with the delivery of the fuselage to the assembly line and the integration of hydraulics and flight control systems. Meanwhile, tools for the manufacturing of major systems such as wings and fuel systems were delivered.

**Expected results and impact:**

- TRL6 by 2023
- Reduce CO\textsubscript{2} by at least 50%
- Reduce NO\textsubscript{x} by at least 14%
- Reduce noise by at least 30%
- Contribute to strengthening EU mobility
INNOVATIVE ADAPTIVE WING SAILS THROUGH LARGE SCALE WIND TUNNEL TEST IN-CRUISE CONDITIONS!

The WTT2 Wing demo is a scaled model (1:3 of an aircraft wing, with a 4.94 meter span) of a traditional wing of a regional turboprop aircraft. It is a flexible wing working with Natural Laminar Flow (NLF) in the outer region at cruise. The demo is equipped with:
- compliant morphing droop nose at the leading edge for high lift;
- multifunctional morphing trailing edge flap for high lift and loads control – alleviation in cruise;
- adaptive winglet, or innovative wingtip, for loads control and alleviation in cruise;
- an engine nacelle without a propeller to validate aerodynamic effects on wing flow.

Goal

The scope of the tests was to assess the active droop nose, trailing edge and wing tip devices in reducing drag and controlling and alleviating wing root loads.

Method

The wing loading was measured by means of wing and balance instrumentation, and load alleviation techniques were tested and verified.

Process

The wind tunnel test campaign was completed and the results assessment provided positive steps forward for loads control aspects, to be demonstrated in flight by 2023. These results are fundamental for the upcoming safety of flight analysis of the wing tip devices on the FTB1 flying demonstrator.

Expected results and impact:

- TRL5 for aerodynamics in 2021
- Target: load alleviation of 19% flexural moment at wing root

Part of Clean Sky’s Regional Aircraft initiative

© – Courtesy of DNW
PASSING THE STATIC TESTS BRINGS ADAPTIVE WINGLET AND INNOVATIVE WINGTIP ONE STEP CLOSER TO FLIGHT!

The Adaptive Winglet and Innovative Wingtip are wing extensions with an active control surface that can perform gust and manoeuvre load alleviation for the new generation of aircraft. This reduces structural weight, improves aerodynamic performance, and decreases the amount of fuel burned in line with Clean Sky 2’s sustainability objectives. The winglet has a fixed structure and two independently movable surfaces, made of composite and aluminium alloy respectively, which use a specific finger-like mechanism for a smoother and more efficient deflection. The wingtip is equipped with a moving surface and is entirely made of aluminium. The static load tests are an important milestone towards obtaining the permission to fly for the FTB1 demonstrator.

Goal
The scope of the tests was to demonstrate winglet and wingtip functionality and structural safety, under the most severe load set foreseen by the flight envelope.

Method
The verification of the structural capability was demonstrated by loading the fixed parts and the mobile surfaces with the heaviest load conditions.

Process
All the structural verifications demonstrated that the items are capable of withstanding the most severe load conditions without any permanent deformation and failure. Movables functionality was also successfully proved. The successful tests mean the development can move to the next step: item installation on the real aircraft and flight test by 2023.

Expected results and impact:

- TRL6 in 2023
- Loads alleviation target: 3 %
- Aero performance target: +2 % in climb

Part of Clean Sky’s Regional Aircraft initiative
Regional Flight Test Bed 2 Takes Off on Its Maiden Flight!

The Regional FTB2 is a technology demonstrator that combines technology lines from Clean Sky 2’s regional, airframe and systems initiatives. Based on an Airbus C295, it integrates important structural modifications in the outer wing and high lift system, exploring new materials and complex systems, high performance flight controls and new communication systems via satellite. These modifications, together with the technology integration, have been implemented by Airbus Defence and Space with key contributions coming from partners all over Europe.

**Expected results and impact:**

- TRL6 by 2022
- Up to 43% CO₂ emissions reduction
- Up to 70% NOₓ emissions reduction
- 45% noise reduction during take-off

**Goal**

The Regional FTB2 aims to demonstrate a wide range of technologies applicable to multi-mission aircraft configurations up to TRL6.

**Method**

A complete flight test demonstration will be carried out during 2022 by the Airbus Defence and Space flight test team to characterise the performance of the technologies at aircraft level.

**Process**

The programme has followed the rational milestones of a huge aircraft modification, while considering the TRL evolution of the different technology lines in parallel. The demonstrator has already performed its maiden flight and it will now embark on a flight campaign to test the innovative aerostructures and new technologies equipped in the aircraft.
IMPROVING MANUFACTURING DIGITALLY AND ENVIRONMENTALLY WITH CONNECTED FACTORIES

Digitalisation not only helps to make the factories more energy-efficient, it can also bring costs down. Connectivity is a vital part of the process and the Connected Factories project incorporates an Internet of Things (IoT) platform to which a wide range of equipment can be connected. With the support of core partner PASSARO, Airbus D&S has developed, tested and validated a software solution to connect standard test means to the IoT platform, while a hardware solution to connect small or hand-held equipment was developed, tested and validated within the Clean Sky 2 ARIESS project. The expected environmental benefits include a 66% reduction in global warming potential, primary energy demand, water pollution and NOx output due to reduced lead times and equipment localisation.

Expected results and impact:

- Efficient manufacturing (20% reduction in recurring costs)
- Reduced energy consumption due to reduced lead times (5-10% production time)
- Reduced activities due to increased robustness
- Reduced duplicate test means due to increased control

Part of Clean Sky’s Connected Factories initiative

Incorporating components from the Airframe Integrated Technology Demonstrators (ITDs)

Goal

The Connected Factories initiative intends to revolutionise the manufacture of aircraft technology by incorporating both digital and environmentally-friendly measures into factories. An integrated solution for the wireless interconnection of portable devices and tools will be developed.

Method

The project will capture, centralise, monitor and exploit digital data including state and localisation. A study will be made, and a classification of the equipment and current working methods will be established in the area responsible for carrying out the tests on the airplane. Once all the above information has been compiled and captured, it proposes personalised use cases to the needs of production:

- data capture for big data from AIM – a computer software solutions company dedicated to manufacturing;
- data monitoring for big data from AIM;
- smart location tracking;
- data capture for big data for wireless interconnection of small devices;
- data monitoring for big data from hand held equipment.

Process

The Connected Factories activities within Clean Sky 2 have been concluded successfully with testing and validation for TRL5 assessment. Further activities will be continued along the two technology lines – Test Mean connected to IoT and Hardware for Hand Equipment, as an internal R&D project by Airbus for future exploitation.
PRODIGE’S SCALED MODEL OPTIMISES THE MEASUREMENT OF LOAD AND HINGE MOMENTS

As part of Clean Sky 2’s airframe initiative, PRODIGE designed the experimental setup of a cryogenic wind tunnel test campaign with the objective to measure accurate loads and hinge moments. PRODIGE designed and built a cryogenic 1/16 scale model of a business jet equipped with a hinge moment balance. This balance has been designed as a full integral part of the wind tunnel model wing, and has been tested and calibrated to work in cryogenic conditions. It has been used to generate experimental loads and hinge moments at high Mach and Reynolds numbers.

Goal

The goal of PRODIGE was to measure accurate aerodynamic loads and hinge moments in a transonic regime at high Reynolds numbers.

Method

PRODIGE results have been achieved by designing a wind tunnel test model for transonic tests equipped with a fully integrated local balance for aileron hinge moment measurements. The model has been tested in transonic, cryogenic and pressurised conditions at the European Transonic Wind Tunnel (ETW).

Process

The project was closed in September 2021, after the processing of wind tunnel test data from the test campaign which was successfully performed at the ETW in June-July 2021.

Expected results and impact:

- Increase TRL2 to TRL4
- Reduction of CO2 due to less fuel consumption thanks to weight reduction
- A fully comprehensive set of aerodynamic experimental data at high Mach and Reynolds number was provided, enabling the development of more accurate numerical solutions for greener and more efficient aircraft design

Part of Clean Sky’s Airframe initiative
OPTIMISING MORE-ELECTRIC AIRCRAFT BY INTEGRATING INNOVATIVE WING ACTUATION SYSTEMS

The Smart Integrated Wing (SIW) Demonstrator led by Liebherr as part of Clean Sky 2’s Systems initiative focuses on electrical and hybrid wing actuation systems, while facilitating synergies with other systems, such as landing gear. The Smart Integrated Wing supports the evaluation of interactions between new systems and enables the next steps to be taken towards more-electric-aircraft. The project integrates sub-systems developed as part of national research projects that cover a wide range of technologies, from equipment and sensors to software and computers. The integration of the various pieces of equipment on one Clean Sky 2 platform will allow for the demonstration of a full system setup for more-electrical-aircraft.

**Goal**
To create a test environment for more-electrical architectures that focuses on more-electric actuation for systems in the wing area and supports fuel efficiency improvement by reducing the weight of the flight control and power-supply systems.

**Method**
Demonstration activities of electrical wing actuation systems for regional and large aircraft. The demonstrations include laboratory build-up of Smart Integrated Wing (SIW).

**Process**
Improvement of test setup in SIW for flight control systems. Integration of highly efficient hydraulic pump as hydraulic power supply for actuation systems.

**Expected results and impact:**
- TRL5 by 2022
- Electronic network weight reduction up to 200 kg for large aircraft due to removal of centralised hydraulic

Part of Clean Sky’s Systems initiative
FULL ELECTRICAL POWER CHAIN TOWARDS MORE ELECTRICAL AIRCRAFT

To contribute to environmental impact improvement, aviation is shifting towards electrification in terms of propulsion. The ultimate ambition is zero emission flight but also to replace pneumatic and hydraulic aircraft systems by electrical systems. For that purpose, a demonstrator is being developed by Airbus in cooperation with Safran, Liebherr and Thales in order to validate and verify the associated enabling technologies. This demonstrator aims to integrate novel large aircraft electrical system architectures into a ground test bench, where they will be tested at TRL5, taking into consideration industrial performance and competitiveness aspects.

Expected results and impact:
- TRL5 by 2023
- Contribution to small-medium range CO₂/NOₓ reduction objectives
- Contribution to European aerospace competitiveness

Goal
To design the next generation of electrical systems, enabling the achievement of CO₂/NOₓ objectives at aircraft level, while guaranteeing efficient manufacturing.

Method
The demonstration focuses on three pillars:
- the high voltage direct current technologies;
- the innovative ways to install and distribute electricity to the consumers;
- the capability to feed the electrical network with parallelised or hybridised electrical sources.

Process
In 2021, core partners agreed on the final design of the unitary bricks and started their validation and verification activities. This is a key input for their commissioning on the Airbus integration bench, expected in 2022. 2023 will be dedicated to the integration testing, including functional and operational scenarios needed in the frame of a more electrical aircraft.

Part of Clean Sky’s Systems initiative
The aircraft Environmental Control System (ECS) is responsible for maintaining the temperature and pressure in the cabin within appropriate comfort levels. It is the most energy-demanding subsystem in the aircraft, consuming up to 75% of non-propulsive power at cruise.

In today’s aircraft, external air is brought onboard to control the cabin air quality by dilution with a fixed air exchange rate. The ECS fuel burn penalty can be reduced by modulating the amount of external air that needs to be conditioned for the cabin. The aECS project integrates cabin air monitoring and filtering technologies to ensure a high level of cabin air quality while reducing the external air requirement.

**Expected results and impact:**

- TRL5 in Q2 2022
- A target of 2% fuel burn reduction compared to the conventional ECS
- Controlled cabin air quality within standard levels

**Goal**

The main objective of this project is to achieve up to 2% fuel burn reduction for the aircraft while meeting existing cabin air quality standards.

**Method**

The aECS project proposes an innovative cabin air ventilation control architecture including air quality monitoring and filtering technologies, which is key to a combination of good cabin air quality level and fuel burn reductions.

**Process**

The adaptive Environmental Control System was validated at TRL4 in 2021 within Collins Nord Micro facilities. A critical design review of the approach proposed in the aECS project was held with Airbus in December 2021.
### ULTRAFAN® BUILD ADVANCES

The trend towards Very High Bypass Ratio engines (VHBR) requires technology development across a broad range of complex gas turbine systems, encompassing fan inlets, complete compression systems, combustion processes, turbines and exhausts. Key technologies developed and demonstrated will include a low-speed, low pressure-ratio fan, the aerodynamic and structural design of a high efficiency multi-stage intermediate pressure turbine, the integration of novel accessories and a power gearbox. These technology developments will contribute to the goals of significantly reducing emissions and noise levels.

### Expected results and impact:

- Ground testing in 2022
- TRL5 by 2023
- 25% more fuel efficient than first Trent engines

### Part of Clean Sky’s Engines and Large Passenger Aircraft initiatives

<table>
<thead>
<tr>
<th>Goal</th>
<th>Method</th>
<th>Process</th>
</tr>
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<tbody>
<tr>
<td>To develop a suite of advanced technologies integrated into a new engine architecture with enhanced performance (fuel burn) alongside reduced emissions (CO₂ and NOₓ reduction) and additionally a significant reduction in noise, towards ACARE targets.</td>
<td>The programme has developed a suite of technologies integrated into a new engine architecture with a Very High Bypass Ratio (VHBR). The programme will design, build and test the Very High Bypass Ratio (VHBR) engine at a large engine scale with technology suitable for the wide and narrow body aircraft markets.</td>
<td>In 2021, the engine build was launched and it is now progressing to completion. Ground testing will commence in 2022. The integration of the Outlet Guide Vanes (OGVs) was a significant step in preparation for the build, as each OGV is larger than an existing in-service fan blade.</td>
</tr>
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</table>
TOWARD 20% CO₂ REDUCTION THROUGH A DISRUPTIVE PROPULSION SYSTEM FOR SHORT AND MEDIUM RANGE AIRCRAFT

In order to determine the best candidate for this disruptive propulsion system, multiple maturation studies on engine architectures were carried out. The technology was matured through modular and rig ground demonstrations of low pressure modules and associated systems. Next, checks were done to ensure that the main technology bricks were compatible with different engine architectures. Finally, the ground test demo engine was prepared for the champion engine.

Goal
The initial Clean Sky 2 objectives for the short and medium range (SMR) aircraft demo are:
- 9% CO₂ emission reduction vs 2014 reference aircraft;
- -8 EPNdB per operation relative to the 2014 situation, meaning that the individual aircraft will be less noisy.

The current Open Fan architecture has the potential for 20% CO₂ emission reduction, beyond Clean Sky 2 objectives.

Method
System level technologies are being developed that are a step change from current state-of-the-art engine architectures and capable of delivering substantial reductions in emissions. An incremental approach to TRL progression is being taken, utilising design studies and rig tests to explore and understand the technologies under development, their system interactions and the risks associated with their implementation.

Process
The technology maturation plan has progressed well through the completion of several rig test campaigns on the key enabling technologies preparing the engine ground test demonstrator. The Open Fan engine architecture has been selected for further evaluation and for preparing the engine ground test demonstrator.

Expected results and impact:
- CO₂ reduction up to 20% vs current in-service engines
- Disruptive architecture for high energy efficiency

Part of Clean Sky’s Engines initiative

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COAST’S GREEN AVIONICS TECHNOLOGIES TAKE FLIGHT

The COAST project is developing and integrating more affordable technologies towards an optimal sustainable aircraft for all-weather use in the small air transport sector. Aiming to reduce operational costs and pilot workload while improving safety, and potentially paving the way for future single pilot operations in small aircraft, here are some of the activities being investigated by COAST (Cost Optimised Avionics SysTem for small aircraft):

- Avionic system architecture development for operations from remote and hub airports
- Tactical Separation System (TSS)
- Advanced Weather Awareness System (AWAS)
- Flight Reconfiguration System (FRS)
- Hybrid surveillance (SURV) and navigation (NAV) systems
- Compact Computing Platform (CCP)
- High Integrity Electronics (HIE) for health monitoring
- Integrated Mission Management System (IMMS)

**Goal**

The goal is to develop and demonstrate in-flight the performance of affordable avionics technologies and solutions suitable for the small air transport segment.

**Method**

The new technologies will increase a pilot’s situational awareness, and reduce their workload during the most stressful phases of flight. This will increase safety, reduce the number of go-arounds and missed approaches, and enable possible future single pilot operations. The weight of the new avionics equipment will be reduced, decreasing fuel burn.

**Process**

The first batch of the COAST technologies (TSS, AWAS, FRS, SURV, CCP) was flight demonstrated on an EV-55 aircraft in 2021. The results will be used for further technology improvements in the next stages of the project.

**Expected results and impact:**

- All technologies matured up to TRL5 or TRL6 by 2023
- Assess entry-into-service potential beyond 2025
- Improved safety of small aircraft operations
- Contribute to strengthening EU mobility

Part of Clean Sky’s Systems and Small Air Transport Transverse Activity (SAT TA) initiatives
The reports reflect the technological achievements of the first five years of the programme which will end in 2024. The reports assess the environmental benefits from Clean Sky 2 technological achievements integrated into overall performance models of 11 new aircraft / rotorcraft concepts.

The Technology Evaluator has performed this assessment at three major levels:

- **Innovation potential at Mission level**: Clean Sky 2 concept aircraft are compared with 2014 reference aircraft on relevant missions regarding emissions and noise. The results are the basis upon which to quantify the success level versus Clean Sky 2’s environmental goals.

- **Realistic impact at Airport level**: A typical day at representative EU airports (fleet mix from 2014 historical and 2035/2050 forecast data) is compared for a fleet with and without Clean Sky 2 aircraft and analysed regarding emissions and noise.

- **Aviation footprint at Air Transport System level**: A year with all global flights (fleet mix from 2014 historical and 2035/2050 forecast data) is compared for a fleet with and without Clean Sky 2 aircraft and analysed regarding emissions and noise.

To monitor and assess the progress of the ongoing technology developments across all Clean Sky 2 activities, two major reporting milestones have been set: a 1st Global Assessment by the end of 2020, i.e. approximately at programme mid-term, and the 2nd Final Global Assessment by mid-2024, at programme closure.

**Expected results and impact:**

1. At fleet level (Air Traffic System), according to the present forecast (high scenario), approximately 75% of global available seat kilometres (ASK) will be operated with aircraft expected to carry Clean Sky 2 technologies in 2050, while 25% of global ASKs will still be operated by aircraft with 2014 reference technologies, not yet retired.

2. By applying the performance improvements obtained for each concept aircraft, an overall reduction of CO₂ and NOₓ emissions of about 15% and 31% per seat kilometre can be expected for the year 2050 high fleet scenario as compared to a 2050 global traffic scenario incorporating only 2014 reference technology.
CLEAN SKY 2 OBJECTIVES
2014 – 2024*

- CO₂: -20% to -30%
- NOₓ: -20% to -30%

*Refers to the impact at mission level of technology developed in Clean Sky 2 compared to state-of-the-art aircraft from 2014

CLEAN SKY 2 PLATFORMS

Innovative Aircraft Demonstrator Platform (IADPs)
Integrated Technology Demonstrators (ITDs)

FIRST GLOBAL ASSESSMENT RESULTS – 2020

MISSION LEVEL ASSESSMENT

<table>
<thead>
<tr>
<th>CONCEPT MODEL</th>
<th>CO₂</th>
<th>NOₓ</th>
<th>NOISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Range</td>
<td>-13%</td>
<td>-38%</td>
<td>&lt; -20%</td>
</tr>
<tr>
<td>Short-Medium Range</td>
<td>-17% to 26%</td>
<td>-8% to -39%</td>
<td>-20% to -30%</td>
</tr>
<tr>
<td>Long Range</td>
<td>-20% to -34%</td>
<td>-56% to -67%</td>
<td>-20% to -68%</td>
</tr>
<tr>
<td>Commuter and Business Jet</td>
<td>-21% to -31%</td>
<td>-27% to -28%</td>
<td>-20% to -50%</td>
</tr>
</tbody>
</table>

AIRPORT LEVEL ASSESSMENT

<table>
<thead>
<tr>
<th>CO₂</th>
<th>NOₓ</th>
<th>NOISE AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>-8% to -13.5%</td>
<td>-6.5% to -10.5%</td>
<td>-10% to -15%</td>
</tr>
</tbody>
</table>

FLEET LEVEL ASSESSMENT

<table>
<thead>
<tr>
<th>CO₂</th>
<th>NOₓ</th>
<th>FLEET RENEWAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>-14% to -15%</td>
<td>-29% to -31%</td>
<td>70 to 75%**</td>
</tr>
</tbody>
</table>

** Percentage of aircraft replaced by Clean Sky 2 technology aircraft concepts by 2050

** Percentage of aircraft replaced by Clean Sky 2 technology aircraft concepts by 2050
Clean Sky has successfully established a robust innovation network and quality supply chain in the aviation sector, motivated to drive cleaner, greener aviation forward.

The structure of Clean Sky 2 enables all actors in the aviation space to collaborate and share ideas easily. Researchers can learn what the industry’s needs are, and SMEs can gain access to much bigger industrial giants and their facilities. In turn, industry benefits from the innovative potential of SMEs and the deep specialised knowledge of the research centres.

**SHARE OF BUDGET FOR ALL GAPS** *(Calls 1-11) AND ALL GAMS* *(not incl GAMS 2022-2023)*

- **Industry** €941k
- **Research centres** €333k
- **Universities** €169k
- **SMEs** €181k
- **€350k**
30 Participating Countries
> 500 Grants
> 5000 Scientists & Engineers Involved
> 1987 Participations in Funded Projects
The figures indicate the number of Clean Sky participating organisations per country. Participating organisations are counted once in the map. They may however participate in multiple projects. Therefore, in the participation chart, the number of participations takes into account all projects where they were involved.
1. NUMBER OF PARTICIPATIONS

This graph shows the number of times that a country has taken part in a Clean Sky 2 project - referred to as participations. The data displayed here includes Calls for Core Partners 1-4 and Calls for Proposals 01-11.

2. NUMBER OF MEMBERS AND PARTNERS

[Graph showing number of members and partners for various countries]
Clean Sky 2 is an open and inclusive public-private partnership in Horizon 2020, that resulted in a broad and geographical spread and the widening of the aeronautics sector. The participants in the Clean Sky 2 calls for proposals (CfP01-CfP11), were geographically distributed across 155 out of 217 EU regions (at levels NUTS1 for DE, FR, UK* & NUTS2 for all the other Member States).

To foster the participation of the European regions, Clean Sky 2 launched a pilot strategic plan for synergies with Member States and regions that was successfully completed in 2021. This resulted in 18 Memoranda of Understanding (MoU) at national and regional levels, representing 33 EU regions (including the regions that are geographically placed in four Member States with a MoU at national level) out of the 155 regions that participated in Clean Sky calls.

*UK regions’ participations by end of 2020
18 Memoranda of Understanding (MoU) with Member States & Regions across Europe

- MoUs with regions
  1. Occitanie (FR)
  2. Catalonia (ES)
  3. Castilla-La Mancha (ES)
  4. Västra Götaland (SE)
  5. Östergötland (SE)
  7. Andalucia (ES)
  8. Campania (IT)
  10. Zuid-Holland (NL)
  11. Flevoland (NL)
  13. Castilla y León (ES)
  14. Podkarpackie (PL)
  16. Sterea Ellada (GR)
  18. Nouvelle-Aquitaine (FR)

- MoUs with Member States
  6. Romania
  9. Czech Republic
  12. Portugal
  15. Greece

The strategic collaborations with Member States and regions were supported largely through leveraging synergies with the European Structural and Investment Funds (ESIF). Through the 18 MoUs, 52 pilot projects were launched with a total budget of more than €50m.

In addition, 12 Clean Sky Synergy Labels have been awarded. These Labels mark the quality of complementary activities proposed by Clean Sky 2 beneficiaries, and they enabled those activities to be supported for funding by ESIF.

Furthermore, most of the Member States (Czech Republic, Greece, Romania, Portugal) and regions (Andalucia, Campania, Castilla La Mancha, Occitanie, Västra Götaland and Östergötland, Podkarpackie), with a MoU in place launched calls and funding schemes that either included topics dedicated to aeronautics that were synergetic to Clean Sky or incentivised the submission of proposals complementary to the Joint Undertaking’s activities and objectives.
INTRODUCING: CLEAN AVIATION!

The Clean Aviation Joint Undertaking is the European Union’s leading research and innovation programme for transforming aviation towards a sustainable and climate-neutral future. Launched in December 2021, it represents a complete rebranding compared to Clean Sky and a novel corporate identity.

A new logo was developed that combines the idea of innovation in aviation with the need to protect our planet, incorporating blues and greens invoking the concept of sustainability that will be the signature colours of the Joint Undertaking.

To celebrate the new Partnership, Clean Aviation created a series of promotions which were published in several magazines, held a press briefing, set up two new social media channels and was the only Joint Undertaking to unveil a new website on the day of the launch.

EVENTS

Clean Sky’s own annual conference ‘Clean Aviation for a Competitive Green Recovery in Europe: Innovative Ideas Take Flight’ was held online on 22 April 2021. With two European Commissioners, industry leaders including CEOs, SMEs and research organisations sharing their views, this event caught the attention of more than 1000 participants connecting from across Europe.

ONLINE STAND

In 2021, Clean Sky added and improved the online stand, adding two new technologies. The online stand showcases a selection of Clean Sky’s technologies and received 8000 visitors in 2021.

https://cleansky.virtualfair.be/
NEW WEBSITE LAUNCH

Website traffic since the launch of the new website

2x

Visits to the new homepage

3x

E-NEWS

Be the first to discover our updates! Subscribe to the E-news:

https://www.clean-aviation.eu/newsletter

SUBSCRIBERS INCREASED BY 24% DURING 2021

GROUND-BREAKING RESULTS

We write about our most cutting-edge breakthroughs as part of the Clean Sky 2 Results Stories series. We are just entering the delivery phase of Clean Sky 2, which means more and more demonstrators will be launched and technologies will be delivered over the next two years. Read about our greatest achievements in our Results Stories:

https://www.clean-aviation.eu/media/results-stories

Get inspired by our Executive Director! Axel Krein discusses innovation in aviation and the future of a climate-neutral airspace. You can follow his blog on LinkedIn or on the Clean Aviation website:


SOCIAL MEDIA

Follow us on Twitter @clean_aviation

Follow us on LinkedIn @Clean-Aviation-Joint-Undertaking

Website traffic since the launch of the new website

2x

Visits to the new homepage

3x

Website traffic since the launch of the new website

2x

Visits to the new homepage

3x

12,000 TOTAL SOCIAL MEDIA FOLLOWING

504.4K TOTAL IMPRESSIONS

520.9K TOTAL IMPRESSIONS
If you want more information about Clean Aviation, you can download our publications, read about our technologies and sign up to our newsletter at www.clean-aviation.eu.

Follow us on LinkedIn and Twitter for updates on all our activities!