Clean Sky

Innovation takes off

Clean Sky at a Glance

www.cleansky.eu

Foreword

Executive Director
Clean Sky
Joint Undertaking

The aviation industry is one of Europe's main industrial sectors of excellence, with globally competitive leaders and a robust supply chain. This industry has a very high societal impact through its vital role of connecting people and regions. Its environmental impact is limited – accounting for approximately 3% of global man-made carbon dioxide emissions – but the continuous growth of air transport worldwide, at close to 5% a year, makes it necessary to mitigate its CO_2 footprint. Similarly, noise must be continuously reduced. This is where Clean Sky comes in.

We are a public-private partnership founded in 2008 by the European Commission and most of the industrial leaders of European aeronautics. By coordinating and funding a Europe-wide research and innovation network in green aeronautical technologies, we are the main contributor to reaching the 2020 goals of the Advisory Council for Aeronautics Research in Europe (ACARE):

- *A 50% reduction in fuel consumption and carbon dioxide (CO_2) emissions.*
- *An 80% reduction in nitrous oxides (NOX) emissions.*
- *An external noise reduction of 50%.*
- *Improved environmental impact of the lifecycle of aircraft and related products*

To develop the cutting-edge technologies required to meet these goals, €800 million were provided by the Commission, a figure which was matched by financial and in-kind contributions from the 12 industry leaders and 65 Associates that make up our membership. Aeronautical leaders, SMEs, universities and research organisations respond to our 'Calls for Proposals' with detailed plans for research activities, aiming at developing integrated demonstrators. The best proposals are selected by independent external experts and Clean Sky then allocates the resources and coordinates the research and validation activities to deliver the aircraft technologies of the future. As such, we are the most ambitious aeronautical research and innovation programme ever launched in Europe.

The thriving research network that we have created is essential not only for guaranteeing environmental sustainability, but also for promoting European competitiveness and driving growth and jobs in the European economy. This brochure is designed to provide you with insights into our programme. I hope that you will come away as convinced of the importance of our work as I am.

Best wishes,
Eric Dautriat

Organisation

Technologies, concept aircraft and demonstration programmes form the three complementary instruments used by Clean Sky to meet its goals:

Technologies are selected, developed and monitored in terms of maturity, or 'technology readiness level' (TRL). More than one hundred key technologies are monitored. The technologies developed by Clean Sky will cover all major segments of commercial aircraft.

Concept Aircraft are design studies dedicated to integrating technologies into a viable conceptual configuration. They cover a broad range, representing the major future aircraft families: business jets, regional and large commercial aircraft, as well as rotorcraft. Clean Sky's environmental results are measured and reported principally by comparing these concept aircraft to existing aircraft, and aircraft incorporating 'evolutionary technology' in the world fleet.

Demonstration Programmes include physical demonstrators that integrate several technologies at a larger 'system' or aircraft level, and validate their feasibility in operating conditions. This helps to determine the actual potential of the technologies. Demonstrations enable technologies to reach a higher level of maturity. The ultimate goal of Clean Sky is to achieve successful demonstrations in a relevant operating environment, i.e. up to TRL 6.

Concept aircraft & environmental objectives

Concept aircraft enable assessment of the environmental benefits of Clean Sky technologies across nearly the full spectrum of commercial aviation. Some key configurations which will be developed are set out below.

Business Jet Concept Aircraft

■ Low-Sweep Business Jet:

This concept aircraft includes a low-drag laminar flow wing with low sweep, and will feature a radically redesigned rear empennage (tail surfaces). This innovative empennage aims to significantly reduce noise levels for communities on the ground from a future generation turbofan engine by blocking sound waves with elements of the horizontal and vertical tail-plane.

■ High-Speed Business Jet:

This concept aircraft includes a 'smart' low-drag, highly swept wing design, making use of passive and active laminar flow. The wing's high-speed design aims to include a 'smart flap' concept. New environmentally friendly materials and processes complemented by new flight trajectories will be included.

Regional Concept Aircraft

■ Regional Turboprop:

The 90-passenger regional turboprop aircraft represents a concept for a next generation turboprop that could enter service in 2020-2025. It features advanced technologies in almost all sub-systems: low weight structure, extensive use of electrical power in systems (bleed-less engine), and advanced flight management systems.

■ Regional Jet:

The 130-passenger regional jet aircraft is a concept aircraft that could also come into service around 2020-2025. Using a next-generation power-plant (open rotor or advanced geared turbofan) and similar advanced technologies in its sub-systems will enhance environmental performance.

Large Commercial Concept Aircraft

■ Short/Medium Range Aircraft, Open Rotor:

This concept aircraft includes the 'smart' laminar-flow wing. It will incorporate the contra-rotating open rotor (CROR) engine concept, developed within the Clean Sky programme. Flight-testing a full-size CROR engine demonstrator in the demonstration programme will help determine the full potential and maturity of the propulsion architecture. Advanced systems and new flight trajectories are planned to be included in the architecture.

■ Long Range Aircraft, Next Generation Large Turbofan:

The long-range aircraft concept will provide the vehicle-level platform to integrate the next-generation large three-shaft turbofan engine using Clean Sky technologies. Given that major new long-range aircraft will have entered the world fleet by 2015[2], no new aircraft introductions are likely in the 2020 timeframe. Thus, the focus of Clean Sky in this aircraft category is predominantly on improved engines and systems.

[2] E.g. Airbus A350 Family

Rotocraft : Concept Aircraft

■ Light Single-engine Helicopter :

The light single-engine helicopter concept, equipped with either a future generation single turboshaft or diesel piston engine, will be developed within the Green Rotorcraft ITD of the programme. Superior performance will be further enhanced by incorporating the latest innovative active blade technologies and applying radical redesign to empennage, skids and hub.

■ Light/Medium/Heavy Multi-engine Helicopter :

Generic light, medium and heavy multi-engined helicopter concepts, equipped with two future generation turboshaft engine installations, will be developed within the Clean Sky programme. Their performance will be further enhanced by incorporating the latest innovative active blade technologies, radical structural redesign, and the introduction of advanced electrical systems (including an electric tail rotor) to eliminate the use of noxious hydraulic fluid and to reduce fuel consumption.

■ Tilt-Rotor :

The conceptual tilt-rotor aircraft is based on the European ERICA3 tilt-rotor concept, characterised by a small rotor diameter and tiltable wings. Performance is enhanced by aerodynamic optimisation and the installation of a future generation turboshaft engine.

[3] ERICA : Enhanced Rotorcraft Innovative Concept Achievement – FP5/6

Environmental challenges

The attainment of the programme's environmental objectives is determined by evaluating the performance of concept aircraft in the global air transport system (set against 2000-level technology and its 'business as usual' evolution). The range of potential improvements is derived from the technology groupings which are expected to reach the maturity of a successful demonstration within the programme timeframe. Not all these technologies will be developed directly through the Clean Sky programme, but it is neither feasible nor relevant at this stage to isolate the benefits delivered purely by Clean Sky. A significant synergy effect in European aeronautics research is made possible through Clean Sky, by maturing closely linked technologies to a higher TRL via demonstration and integration.

The environmental performance gains we expect to confirm through demonstration of the technologies are depicted in the graphic. They are representative figures across different aircraft types and sectors (business jets, regional aircraft, large commercial aircraft and rotorcraft). There is broad similarity between the improvements foreseen across these aircraft types despite the different modes of operation and the different technologies involved.

Nonetheless, some specific opportunities and challenges should be mentioned.

In the business jet sector, a novel, radical re-design of the empennage shows very substantial benefits in shielding local communities from engine noise: in some cases up to a two-thirds reduction in noise footprint on take-off can be achieved. As these aircraft often operate into very noise-sensitive local airports, this design option will be further refined, potentially augmenting the gains that are feasible.

In large commercial and regional jet aircraft, a key design option concerns the incorporation of the contra-rotating open rotor engine architecture and technology. This design option involves an important trade-off: significantly more fuel burn and CO_2 reductions are expected, coupled with still substantial progress on noise reduction when compared to current turbofan engines under development; but with less potential noise gains than would be expected from a future 'ultra-high bypass' turbofan with a nacelle and duct architecture. The figures in our assessments for the single-aisle short- to medium-range large passenger aircraft assume the use of CROR as engine architecture. As can be seen, significant improvement across the spectrum of business jets, turboprop and geared turbofan-powered regional aircraft are predicted.

Long-range commercial aircraft are set to benefit from very sizeable gains made possible through new engine technology being developed in the Clean Sky SAGE programme area for large high-bypass turbofans.

In rotorcraft, strong improvements in noise footprint and emissions are foreseen. One innovation being investigated concerns the adoption of diesel propulsion (on so-called light single-engine helicopters).

The diesel engine could deliver impressive fuel burn and CO_2 benefits, albeit with a penalty in NOx performance when compared to a future turboshaft engine. The graphic depicts the range of variance this would imply for both CO_2 and NO_x.

Clean Sky concept aircraft	Noise affected area (on take-off)	CO_2	NO_x
Low-sweep business jet (innovative empennage)	-68%	-30%	-26%
TP 90 (regional turboprop)	-71%	-30%	-34%
GTF 130 (regional geared turbofan)	-76%	-20%	-34%
Short-medium range/CROR engine	-36%	-28%	N / A
Long Range/three-shaft advanced turbofan	-27%	-18%	-17%
Single-engine light helicopter	-47%	-30%	-75%
Twin-engine light helicopter	-49%	-26%	-74%

Note: these figures represent the reductions in emissions or affected area for the Clean Sky concept aircraft when compared to the 2020 ACARE reference point for each relevant category of vehicle.

Demonstration programme

While some technologies can be assessed during their development phase, many key technologies will need to be validated via dedicated test programmes, involving in-flight or large-scale ground demonstration installations. These demonstrators combine several technologies at a major system or at aircraft level, enabling them to be tested in a relevant operating environment. To date, more than 20 demonstrators are being developed at a very high technological maturity level. Their performance is evaluated in areas such as mechanical or in-flight behaviour. This will help to determine the true potential of the technologies and to provide a realistic environmental assessment. Demonstrations enable technologies to reach a higher level of maturity (TRL), which is the very justification of Clean Sky as a 'Level 3' highly-integrated project and Joint Technology Initiative (JTI) within the European Framework Research and Innovation Programme.

Contra-rotating open rotor demo engine flying test-bed

- New propeller design (high performance, low noise)
- Engine – pylon – aircraft integration concept
- New CROR – engine integration technology
- Advanced CROR aero-acoustic design
- Preliminary design review in Q3 2015, flight tests planned under a further Clean Sky 2 by 2020

> 2020

High-speed demonstrator for passive laminar-flow wing technologies

- Advanced passive laminar wing aerodynamic design
- Two alternative integrated structural concepts for a laminar wing
- High quality, low tolerance manufacturing and repair techniques
- Anti contamination surface coating
- Shielding Krüger high lift device

Q4 / 2016

Low Speed Demonstrator for advanced control surfaces for high lift

- Smart flap concept, with combined function for manoeuvre control and high lift
- Active flow control at the leading edge to replace slats
- Active flow control flaps for increased high lift performance

Q1 / 2016

Regional aircraft integrated flight test demonstration

- Advanced composite structure
- Structural health monitoring
- Electrical environmental control system
- Application and scaling of more-electric technologies and power management for regional aircraft

Q4 / 2015

Regional Aircraft Static & Fatigue Full Scale Ground Demonstration

- Multi-functional composite materials

Q1 / 2015

Regional Aircraft Large Scale Wind Tunnel Test Rotorcraft lift & drag demonstrators

- Natural laminar flow wing
- Load control / alleviation
- Low noise landing gears
- Low noise high lift devices

Q1 / 2015

Rotorcraft lift & drag demonstrators

- Innovative rotor blades:
  - Active twist blade and Gurney flap rotor
  - 3-D blade profile optimised for dual speed rotor
- Shape optimisation and flow separation control devices enabling drag reduction

Q2 / 2015

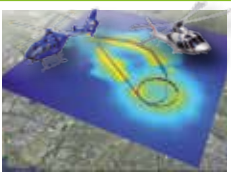
Diesel engine demonstrator for light helicopters

- Core Diesel engine design
- Power-pack integration

Q4 / 2014

Aircraft & rotorcraft systems demonstrators

- Technologies for flight path optimisation



Q1 / 2015

Copper Bird

- Technologies for 'all-electric' architectures
- Electrical actuation
- Nacelle-based systems
- Rotorcraft: helicopter electrical main rotor actuators

Q3 / 2015

Electrical demo

- Environmental control systems
- Anti-ice
- Electrical wheel drive/taxiing
- Rotorcraft: helicopter electrical tail rotor

Geared open rotor demonstrators SAGE 1/2

- Propeller/Propulsor
- Pitch change mechanism
- Gear-box
- Rotating structure

Q4 / 2015

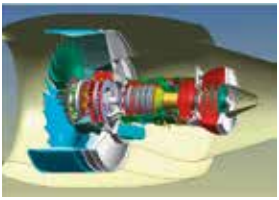
Large three-shaft engine demonstrator

- Lightweight fan system
- Advanced external engine components and accessories
- Advanced 'intercase' structures
- Lightweight and efficient low-pressure turbine

Q2 / 2014

Advanced geared turbofan demonstrator

- Advanced Geared Turbofan Demonstrator
- New highly efficient high-pressure compressor
- Light weight, high speed low-pressure turbine
- Advanced light weight and efficient turbine structures
- Light weight and reliable fan drive gear system
- New systems for a more electric engine



Q2 / 2015

Advanced turboshaft demonstrator

- High efficiency compressor, combustion chamber, high-pressure and low-pressure turbine
- Full scale & life cycle validation

Q2 / 2013

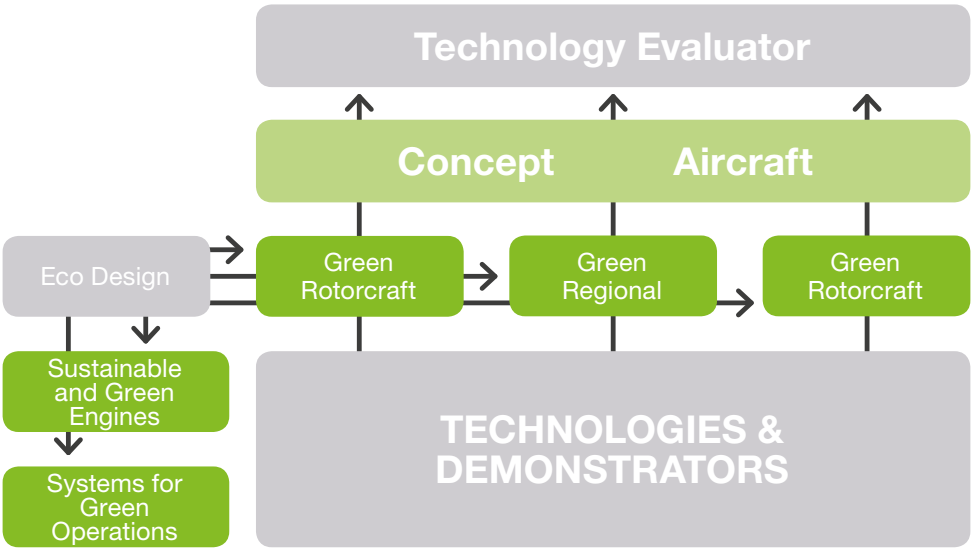
Lean burn

- Low-emission combustor
- Fuel-control system

Q1 / 2015

Programme structure

Clean Sky activities are performed within six “Integrated Technology Demonstrators” (ITDs) and a “Technology Evaluator”. The organisation is shown in the following figure.



The three vehicle-based ITDs will develop, deliver and integrate technologies into concrete aircraft configurations. The three transversal ITDs are focused on propulsion, systems and design methodologies. They will deliver technologies, which will be integrated alongside aircraft-level and airframe-based technologies in the various aircraft configurations by the vehicle ITDs.

Smart Fixed Wing Aircraft (SFWA) – co-led by **Airbus** and **SAAB** – will deliver innovative wing technologies together with new aircraft configurations, covering large aircraft and business jets. Key enabling technologies from the transversal ITDs, such as the contra-rotating open rotor, will be integrated into the demonstration programmes and concept aircraft.

Green Regional Aircraft (GRA) – co-led by **Alenia** and **EADS CASA** – will develop new technologies to reduce noise and emissions. These include in particular advanced low-weight and high-performance structures; incorporation of all-electric systems; bleed-less engine architectures; low noise/high efficiency aerodynamics; and environmentally optimised mission and trajectory management.

Green Rotorcraft (GRC) – co-led by **AgustaWestland** and **Airbus Helicopters** – will deliver innovative rotor blade technologies for a reduction in rotor noise and power consumption, technologies for lower airframe drag, environmentally friendly flight paths, the integration of diesel engine technology, and advanced electrical systems to eliminate the need for hydraulic fluid and for improved fuel consumption.

Sustainable and Green Engines (SAGE) – co-led by **Rolls-Royce** and **Safran** – will design and build five engine demonstrators to integrate technologies for low fuel consumption, whilst reducing noise levels and nitrous oxides. The open rotor is the target of two demonstrators. The others address geared turbofan technology, low pressure stages of a three-shaft engine and a new turboshaft engine for helicopters.

Systems for Green Operations (SGO) – co-led by **Liebherr** and **Thales** – will focus on all electrical aircraft equipment and system architectures, thermal management, capabilities for environmentally-friendly trajectories and missions, and improved ground operations to give any aircraft the capability to fully exploit the benefits of the 'Single European Sky'.

Eco-Design (ECO) – co-led by **Dassault Aviation** and **Fraunhofer Gesellschaf**t – will support the ITDs with environmental impact analysis of the product life-cycle. Eco-Design will focus on green design and production, maintenance, withdrawal, and recycling of aircraft. The optimal use of raw materials and energies, avoidance of hazardous materials, and the reduction of non-renewable energy consumption of on-board systems will help to reduce considerably the environmental impact of the aircraft and its systems.

Complementing these six ITDs, the **Technology Evaluator (TE)** is a dedicated evaluation platform covering all segments of the Clean Sky programme. The TE is co-led by **DLR** and **Thales**, and includes the major European aeronautical research organisations. It will assess the environmental impact of the technologies developed by the ITDs and integrated into the concept aircraft. In this way, the TE will enable Clean Sky to measure and report the level of success in achieving the environmental objectives and its contribution towards the ACARE goals. In addition to a mission-level analysis (aircraft-level), the positive impact of the Clean Sky technologies, will be shown within an airport environment and across the global air transport system.

The way forward

Where does Clean Sky go from here? The Joint Undertaking has set the following action points:

- Continue to realise the ACARE 2020 goals.
- Further engage the aeronautics industry in the programme.
- Stimulate investment, growth and jobs and secure Europe's competitiveness.
- Establish a long-term strategy to develop the aircraft technologies of the future.

With regard to the ACARE 2020 goals, the first two Technology Evaluator assessments were completed in 2012 and 2013. Their results broadly confirm the environmental objectives set for the programme. To further hone Clean Sky's effectiveness, annual implementation plans are produced every year and research priorities are (re)calibrated based on the findings obtained from the demonstration activities. As such, Clean Sky is well on its way to being the main contributor to achieving the emissions and noise targets outlined earlier.

The active engagement of the full innovation chain across Europe is a must for Clean Sky and the regular calls for proposals aim to broaden the participation of the aeronautical industry. Clean Sky is particularly pleased that following the launch of the 15th call in October 2013, close to 40% of the beneficiaries of Clean Sky funding were Europe's aeronautical SMEs. Clean Sky has thus demonstrably contributed and hopes to contribute further to growth and jobs in the European research and innovation sector.

Clean Sky is now entering an exciting and demanding phase: on the one hand, most of the current demonstrators are to be tested within the 2014 - 2016 period; on the other hand, Clean Sky 2 activities are on the edge of being started in July 2014. As part of the European Commission's Horizon 2020 Research and Innovation Framework Programme, Clean Sky 2 will be larger in scope than the initial Clean Sky Programme with a total budget of nearly €4 billion. Building on its predecessor's success, Clean Sky 2 aims to achieve a higher level of technology integration at aircraft level and to raise the maturity level of systems incorporating these new technologies. Not only will Clean Sky 2 aim to fully attain the ACARE 2020 goals, but it will also pave the way for the technologies required to implement the even more ambitious ACARE 2050 goals.

For more information about the future activities of the Clean Sky Joint Undertaking, visit the Clean Sky website at ***www.cleansky.eu*** *and look out for our other publications listed below:*

Members

ITD Leaders

AgustaWestland - Airbus Group - Alenia Aermacchi - Dassault Aviation - EADS Casa - Airbus Helicopters - Fraunhofer Gesellschaft - Liebherr Aerospace - Rolls-Royce - Saab AB - Safran - Thales Avionics

Associates

Aeronamic - Aeronova Aerospace S.A.U. - Aerosoft - Airborne Technology Centre - ATR - Avioane Craiova - Avio S.p.A. - CIRA - CSM - CYTEC - Diehl Aerospace - DLR - DEMA - EADS IW -ELSIS - EPFL Ecole Polytechnique Lausanne - ETH Zurich - Eurocarbon - Fokker Aerostructures - Fokker Elmo - Fox Bit - GKN Aerospace - Green Systems for Aircraft Foundation (GSAF) - HADEG Recycling GmbH - HAI - Huntsman Advanced Materials - IAI - Igor Stichting - IMAST - INCAS - ITP - KIN Machinebouw - LMS International - MicroFlown Technologies - Micromega Dynamics - MTU Aero Engines - NLR - ONERA - Piaggio Aero Industries - Politecnico di Torino - PZL-Swidnik - QinetiQ - Romaero - RUAG Switzerland - Selex ES - Sicamb - Stichting NL - Straero - TU Delft - University of Applied Sciences Switzerland FHNW - University of Bologna/Forlì - University of Cranfield - University of Malta - University of Nottingham - University of Naples - Polo delle S. & T. - University of Pisa - University of Twente - Zodiac-ECE/IN

May 2014

White Atrium Building
Avenue de la Toison d'Or 56-60
1060 Brussels
Phone +32 2 221 81 52