Clean Sky

Innovation takes off

Horizon 2020
European Union Funding
for Research & Innovation

Clean Sky at a Glance

www.cleansky.eu

Content

Foreword

By Eric Dautriat

Executive Director Clean Sky Joint Undertaking

Clean Sky is a Joint Undertaking of the European Commission and the European aeronautics industry and part of the EU Horizon 2020 research and innovation programme. It develops innovative, cutting-edge technology aimed at reducing CO_2, gas emissions and noise levels produced by aircraft. In doing so, Clean Sky contributes to strengthening European global leadership and competitiveness. The new Clean Sky 2 Programme (2014-2020) represents a total budget of €4 billion over 7 years.

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 and local air quality improved.

By coordinating and funding a Europe-wide research and innovation network in green aeronautical technologies, Clean Sky is the main contributor to reaching the industry-supported ACARE 2020 goals:

- 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 life cycle of aircraft and related products[1]

To develop the cutting-edge technologies required to meet these goals, Clean Sky was born in 2008 with a budget of €1.6 billion, contributed to on a 50/50 basis by the Commission (in cash) and the aeronautical industry (in-kind contribution). The mainstream of Clean Sky activity is to integrate technologies into high maturity, full-scale, representative demonstrators: it is an industry-led programme, involving the full spectrum of an innovation chain. The calls are based on focussed research themes (topics) proposed by the Members. The best proposals are evaluated and selected by independent external experts and become projects performed by the Partners, integrated within the overall work plan.

The more than 600 partners from 24 European countries involved in the projects to date are mainly aeronautical industries, SMEs, universities, and research centres. Their work and commitment is paramount to the success of Clean Sky.

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 summarises the facts and figures of the 16 Calls for Proposals (CfPs) of the first Clean Sky programme (2008-2016) and provides you with insights into our programme. In parallel, the Clean Sky 2 programme, part of Horizon 2020, has started: the relevant data will be included in the next update of this brochure.

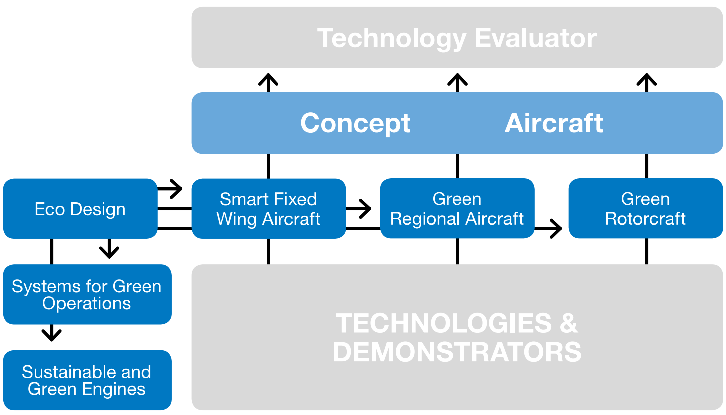
I hope that you will come away as convinced of the relevance of our work as I am.

Best wishes,

[1] All goals compared with levels in the year 2000.

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 are developing, delivering and integrating technologies into concrete aircraft configurations. The three transversal ITDs are focused on propulsion, systems, and design methodologies. They 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** –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 **Airbus D&S** –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** – 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** –design and build five engine demonstrators to integrate technologies for low fuel consumption, whilst reducing noise levels and nitrous oxides. One of them concerns the Open Rotor ground demonstration. The others address geared turbofan technology, low pressure stages of a three-shaft engine, and a new turboshaft engine for helicopters.

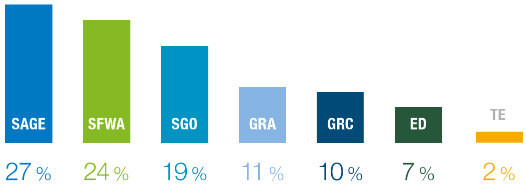
Systems for Green Operations (SGO) – co-led by **Liebherr** and **Thales** –focus on all-electrical aircraft equipment and system architectures, thermal management, capabilities for environmentally friendly trajectories and missions, and improved ground operations. This is developed with a view to fully exploit the benefits of the 'Single European Sky', in coordination with SESAR.

Eco-Design (ECO) – co-led by **Dassault Aviation** and **Fraunhofer Gesellschaft** –support the ITDs with environmental impact analysis of the product life cycle. Eco-Design focus is 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 centres. It assesses the environmental impact of the technologies developed by the ITDs and integrated into the concept aircraft. In this way, the TE enables 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 is assessed at airport level and across the global air transport system.

The current status is presented below in the document.

The global budget is pre-assigned to the different ITDs according to the Statutes, as follows:



Broad and open participation

The final participation is presented here:

12 ITD leaders representing **50% of funding**

65 Associates representing **25% of funding**

527 Partners through calls representing **25% of funding**

Statistics of participation

Partners

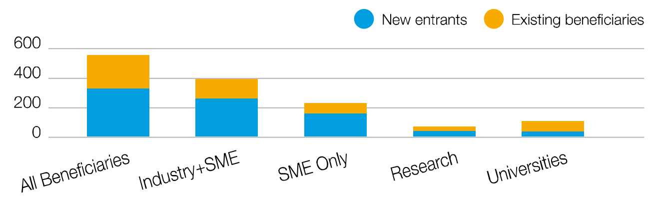
Clean Sky has been an unambiguous success story not only environmentally, but also in establishing a robust innovation network that will bring even more benefits to Europe's economy and its skills and technology base in years to come.

Number of Calls	Eligible Proposals	Funded projects	Average Project value
16	1519	482	€600 000

Success rate of applicants: 32%

More than half the winning entities are newcomers to European-funded research programmes.

New beneficiaries in Clean Sky

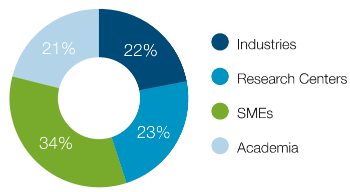


Categories of Participants

Distribution of Funding for Partners

Applying as a single entity is possible under Clean Sky rules. This was the case for 41% of the funded projects. The maximum funding rate for Partners ranges from 50% up to 75% of project value, depending on the participant category (for example, SMEs, research centres and academia are eligible for 75%).

The average funding rate is 69%.



SME Statistics

SMEs are actively involved in Clean Sky through Calls for Partners (CfPs)

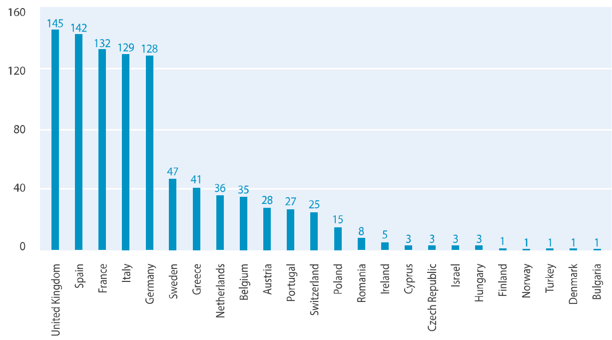
- SMEs CfPs funding share 34%
- SME average size of topics 600 k€
- SME % of mono-beneficiary 41%

Country distribution

The figures indicate the number of Clean Sky participating organisations per country.[2]

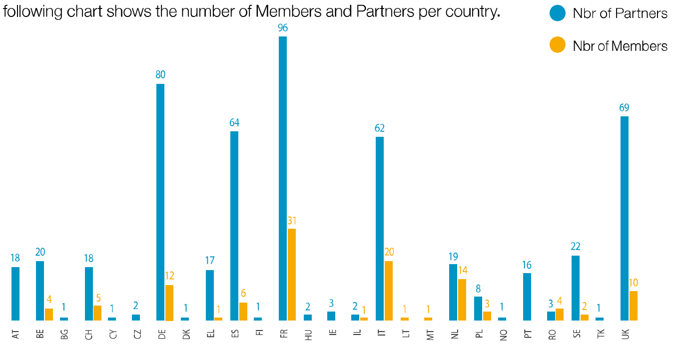
[2] Participating organisations are counted once in the map. They may however participate in multiple projects. Therefore, in the participation chart, the number of participations takes into account all projects where they were involved.

Number of participations



Members and Partners

The following chart shows the number of Members and Partners per country.



Development strategy

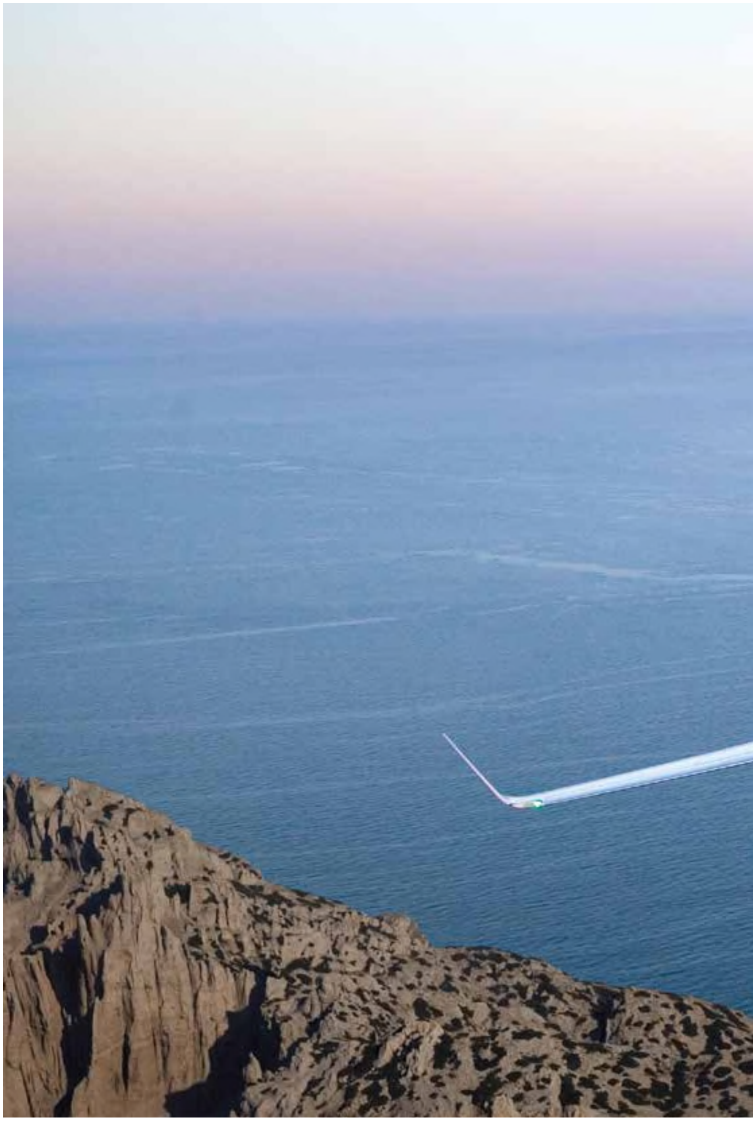
Technologies, concept aircraft and demonstration programmes form the three complementary instruments used by Clean Sky to meet its goals:

a) **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. They were identified as the most promising in terms of potential impact on the environmental performance of future aircraft.

b) **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: large commercial aircraft, regional aircraft, and business jets, as well as rotorcraft. Clean Sky's environmental results are measured and reported mainly by comparing these concept aircraft to reference aircraft representing state-of-the-art technology from the year 2000.

c) **Demonstration projects are the core elements of Clean Sky activities.** They 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.

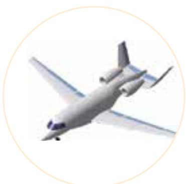
The most significant technologies matured to high TRL are quoted in the relevant description of the demonstrators.



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 [LSBJ]

Incorporating these technologies and configurations:

- Low drag natural laminar wing
- U-Tail or innovative empennage for noise masking
- Engine with a 2020 EIS (SN)
- Less hydraulic power architecture
- Electro thermal WIPS
- Load control
- Smart flap

■ High-speed business jet [HSBJ]

Incorporating these technologies and configurations:

- Load and vibration control
- NLF (Natural Laminar Flow) on lifting surfaces control
- Innovative 3 engine afterbody
- NLF wing lower side
- DA 2020 engine

Regional Concept Aircraft

Most of the technologies currently under study are valid for both regional jet and turboprop types of aircraft that will be flying between 2020 and 2040.

■ Large Turboprop aircraft [TP90]

Incorporating these technologies and configurations:

- Advanced Metallic Material
- Advanced Composite Materials
- Structure Health Monitoring
- Low Noise Landing Gear
- Low Noise & High Efficiency High Lift Devices
- Advanced Electrical Power Generation and Distribution System
- Electrical Environmental Control System
- EMA (Electro-Mechanical Actuators) for Primary Flight Control System Actuation
- EMA for Landing Gear Actuation
- Mission Trajectory Management optimization

■ Regional jet [GTF 130]

Incorporating these technologies and configurations:

- Advanced Metallic Material
- Advanced Composite Materials
- Structure Health Monitoring
- Natural Laminar Flow wing
- Low Noise Landing Gear
- Low Noise & High Efficiency High Lift Devices
- Advanced Electrical Power Generation and Distribution System
- Electrical Environmental Control System
- EMA for Primary Flight Control System Actuation
- EMA for Landing Gear Actuation
- Aerodynamic & Aero-acoustic Integration
- Geared Turbofan SAGE 4 engine

Large Commercial Concept Aircraft

■ Short/medium-range (SMR) aircraft, [APL2]

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 of a representative Laminar Wing and of a full-size CROR engine demonstrator are now planned beyond the framework of the programme and moved to the Clean Sky 2 programme.

Advanced systems and new flight trajectories already matured to appropriate level are included in the architecture.

Incorporating these technologies and configurations:

- SFWA Natural Laminar Flow (NLF) wing
- Snecma conceptual CROR engines
- SGO MTM (Management of Trajectory and Mission) Optimized trajectories, in the FMS (Flight Management System):
    - A-IGS (Adaptive-Increased Glide Slope)
    - MCDP (Multi Criteria Departure Procedure)

■ Long-range aircraft (LR), next generation large turbofan [APL3]

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. The focus of Clean Sky in this aircraft category is predominantly on improved engines and systems.

Incorporating these technologies and configurations:

- SAGE 3 Rolls-Royce Advanced Turbofan engines
- SAGE 6 Rolls-Royce lean burn system (combustor)
- SGO MTM (Management of Trajectory and Mission) Optimized trajectories, in the FMS (Flight Management System):
    - A-IGS (Adaptive-Increased Glide Slope)
    - MCDP (Multi Criteria Departure Procedure)

Rotorcraft Concept Configurations

The rotorcraft configurations are defined according to these 5 classes:

- Single Engine Light (SEL) with Maximum Take-Off Weight (MTOW) ≤ 4 metric tons
- High Compression Engine (HCE) with MTOW ≤ 4 metric tons
- Twin Engine Light (TEL) with MTOW ≤ 4 metric tons
- Twin Engine Medium (TEM) with 4 ≤ MTOW ≤ 8 metric tons
- Twin Engine Heavy (TEH) with MTOW > 8 metric tons
- Tilt-Rotor (TR) separate class for advanced configuration

■ Single-Engine Light helicopter [SEL/HCE]

The light single-engine helicopter concept, equipped with either a future generation single turboshaft or diesel piston engine (HCE), will be developed within the Green Rotorcraft ITD of the programme.

■ Light/medium/heavy multi-engine helicopter [TEL/TEM/TEH]

Generic light, medium and heavy multi-engine helicopter concepts, equipped with 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 aerodynamic modifications
- Advanced electrical systems (including an electric tail rotor) to eliminate the use of noxious hydraulic fluid and to reduce fuel consumption

■ Tilt-Rotor [TR]

The conceptual tilt-rotor aircraft is based on the European ERICA 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.

The role of the Technology Evaluator

In comparison with the reference levels from the year 2000, the environmental performance gains being confirmed through demonstration are presented in the table below, as assessed in mid-2015. They are representative across different aircraft types and sectors (business jets, regional aircraft, large commercial aircraft, and rotorcraft).

In the business jet sector, a novel, radical redesign of the empennage shows very substantial benefits in shielding from engine noise in operation at low altitude: in some cases up to a two-thirds reduction in noise footprint on take-off can be achieved.

The figures in these assessments for the single-aisle short/medium-range large passenger aircraft assume the use of rear-mounted CROR as engine architecture, along with a laminar wing: at this "virtual" aircraft level, this brings a very promising CO_2 improvement and a positive noise result as well. Long-range commercial aircraft are set to benefit from 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 Single-Engine Light helicopters).

Clean Sky is well on its way to being the main contributor to achieving the emissions and noise targets of ACARE 2020.

Product	Wide-body 2020	Narrow-body 2015	Regional 2020	Corporate 2020	Rotorcraft 2020	
Programme objectives at global fleet level*	26% (Global fleet level)					CO_2
	60% (Global fleet level)					NOx
	50% to 75%					Noise**
Results from the 2015 TE assessment	-19%	-40%	-30%	-33%	-20%	CO_2
	-50%	-44%	-34%	-34%	-58%	NOx
	-79%	-55%	-71%	-58%	-25%	Noise

Summary table of the Clean Sky 1 objectives and results to date per flying segment

*Reduction percentages are compared to emissions and noise produced by an aircraft manufactured with year 2000 technology.
**The percentage value shows the reduction of the noise footprint in areas surrounding airports for same noise levels produced by currently operating fleets.

Demonstration programme

While some technologies can be assessed during their development phase at component or system level, many key technologies will need to be validated via dedicated test programmes, involving large-scale ground or in-flight demonstration installations: this is the major goal of Clean Sky. These demonstrators integrate several technologies at a major system level or at aircraft level, enabling them to be tested in a relevant operating environment.

To date, more than 30 main demonstrators of different sizes – some of which are in a technical sequence - are being developed at a very high technological maturity level. Demonstrations enable technologies to reach a higher level of maturity (TRL), which is the mainstream goal of Clean Sky.

In the following section the most significant and representative demonstrators from each ITD are presented with the highlights of their content.

Main Demonstrators achieved

Main Demonstrators achieved (date and Technology Readiness Level (TRL) reached)

July
2010

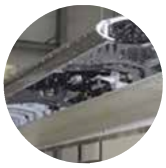
SFWA Advanced Lip Extended Acoustic Panel (ALEAP)
Airbus

April
2013

SAGE 5 First rotation of TECH800
TURBOMECA

Fully operational from
2014

ECO DESIGN Electrical Test Bench – [COPPER Bird]
Labinal Power System



September
2014

SFWA Laminar Wing GTD (Ground Based Demonstrator)
Airbus, GKN, Manufacturing Technology Centre at Coventry, ASCO, P3VOITH, SUPERFORM, NCC, Airbus Group Innovations

September 2014 › December 2014

SGO Skin heat exchanger (LSHX) A320 ATRA Flying Test Bed
Airbus, DLR and Liebherr

2014

2015

SAGE Contra-Rotating Open Rotor (CROR) demo engine flying test bed– test in DNW windtunnel
Airbus, Snecma, ONERA, DLR, NLR IBK, ARA, NUMECA, VKI, ISAE, Swerea, Magsoar, DNW

January
2013

GRC Demonstration of Diesel powered light helicopter
Airbus Helicopters, Marignane

November 2013 › February 2014

SGO Multi Criteria Departure Procedure (MCDP) function
Airbus, Thales

April
2014

SAGE 3 (ALPS) first flight
Rolls-Royce

November
2014

ECO DESIGN Thermal Test Bench
Fraunhofer IBP

Fully operational from
2015

March 2015 › April 2015

SGO Primary Ice Detection System (PFIDS)
Zodiac Aerospace

May 2015

GRC Demonstration of Helicopter Low Noise Procedures
Airbus Helicopters

June 2015

SGO Electrical Power Distribution Centre
Zodiac Aero Electric (Zodiac Aerospace group)

November 2015

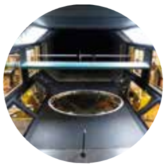
GRC Demonstration of Diesel powered light helicopter
Airbus Helicopters, Marignane

December 2015

SFWA Wing assembly for the BLADE demonstrator
AERNNOVA

SFWA Fluidic control surfaces
Fokker Elmo, Fraunhofer, TU Delft, University of Twente, NLR

June 2015



SFWA Vibration control demonstrator
Dassault, ONERA

May 2015

GRA ATR first flight, Crown Panel
Alenia, ATR, Fraunhofer

July 2015

SAGE Geared Turbofan
MTU

November 2015

SAGE TECH 800
TURBOMECA

November 2015

Smart Fixed Wing Aircraft

Advanced Lip Extended Acoustic Panel (ALEAP)
Airbus

TRL 5 - July 2010

Main outcome:

- The technology to reduce the fan noise of large turbofan engine was validated in operational conditions at original scale in a flight test campaign in 2010

Expected benefits:

- After the successful validation in flight, the technology to manufacture the key parts relevant for this technology shall be reviewed and matured to reach TRL 6 (activities to be carried out outside of SFWA)

Airbus A380 ALEAP flight test demonstrator team after the successful Clean Sky flight test campaign in 2010

Vibration control demonstrator
Dassault, ONERA

TRL 5 - May 2015

Objectives:
- Development of innovative design for aircraft next generation to benefit from advanced technologies to alleviate loads and vibrations and reduce structural weight

Main features:
- Development and demonstration of the technologies developed in this domain on a ground vibration test

Main outcomes:
- It demonstrated the capability to implement an efficient closed-loop vibration control with a significant vibration level reduction and validated the vibration control law design methodology

Falcon 7X s/n 001
Dassault flight test centre (Istres, France)

Fluidic control surfaces
Fokker Elmo, Fraunhofer, TU Delft, University of Twente, NLR

TRL 4 - June 2015

Objectives:

- Enhancement of control surfaces performances via active flow control at leading edge and at flap/spoiler region and to support load control function

Main features:

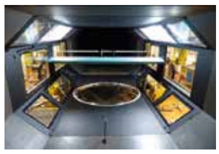
- Development of an Integrated Active Component Demonstrator (IACD) for maturation of low TRL technologies such as flap with fluidic actuation and verification of physical integration in an Iron Bird

Expected benefits:

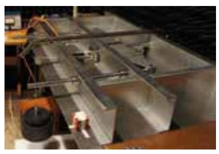
- Better low speed/high lift performances (lower size, weight of high lift components, simplified layout of movables)

Main outcomes:

- For the fluidic actuator, CFD and experiment proves that the pulsed actuator works in full blowing (by CFD, up to 9% lift gain)
- Electromagnetic Compatibility (EMC) measurements have been carried out on the cable harnesses and tests for thermal verification have been set up
- The test rig is fully operational for further investigations



Fluidic actuator



Laminar Wing GBD (Ground Based Demonstrator)

Airbus, GKN, Manufacturing Technology Centre at Coventry, ASCO, P3VOITH, SUPERFORM, NCC, Airbus Group Innovations

TRL 5 - September 2014

Objective:

- Design, manufacture and test a full scale element of a SRA (Short Range Aircraft) NLF (Natural Laminar Flow) wing leading edge including all relevant systems

Main features:

- The GBD (Ground Based Demonstrator) is a 4.5m long by 1m wide section of flight-representative wing leading edge attached to a partial wing box assembly. The leading edge accommodates a Krueger flap in two sections, allowing two different design philosophies to be investigated

Main outcomes:

- Ground Based Demonstrator (full scale leading edge) fully functional
- Formal integration of electro-thermal anti-ice system, moveable Krueger flaps, electrical bonding network, and lightening protection
- Successful bird strike tests
- Numerous manufacturing & assembly lessons learnt (esp. accessibility)

Ground Based Demonstrator (on equipping fixture)

This ground demonstrator is the first step of the NLF (Natural Laminar Flow) wing full-scale demonstration effort, aimed at flight testing of a fully representative laminar wing.

The flight testing, based on an A340 flying test bed and featuring two different NLF wing demonstrators, will be started later, but still in the framework of the CS SFWA activities.

Contra-Rotating Open Rotor (CROR) demo engine flying test bed – test in DNW windtunnel

Airbus, Snecma, ONERA, DLR, NLR, IBK, ARA, NUMECA, VKI, ISAE, Swerea, Magsoar, DNW

TRL 4 - January 2013

Objective:

- To demonstrate viability of full scale innovative engine concept in operational condition

Main features:

- New propeller design (high performance, low noise)
- Engine – pylon – aircraft integration concept
- New CROR – engine integration technology
- Advanced CROR aero-acoustic design

Expected benefits:

- Fuel burn saving on short/mid range aircraft compared to current fleet

Wind tunnel tests

Wing assembly for the BLADE demonstrator

Aernnova

TRL 5 - December 2015

Main features:

- As the evolution of the concept to a flyable demonstration, after the successful ground based demonstrator, two semi wings (8m span each) were designed and manufactured with the involvement of SAAB and GKN UK for two different solutions (fully integrated composite, standard wing design), both of them complying with the stringent requirements of tolerance, stability, and accuracy of the shape of the wing to keep the laminarity in all flight regimes

Main outcomes:

- After this assembly the wings will be delivered to Airbus for integration in the A340 flying test bed. Wind tunnel tests have been conducted to assess the handling qualities of this modified configuration

Demonstration wing

Ceremony at Aeronnova, 16 December 2015

▪ Green Regional Aircraft

ATR first flight, Crown Panel

Alenia, ATR, Fraunhofer

TRL 5/6 - 9 July 2015

Objectives & Main outcomes:

- Innovative sensorized EPOXY CFRP fuselage "crown" panel
- Integrated Technology Demonstrator of Alenia (research, development, design, manufacturing and optical fibres sensor instrumentation), ATR (installation and operation; test aircraft), and Fraunhofer (panel piezo-electric sensor instrumentation),
- Aim of flight test campaign was to support the development of innovative EPOXY CFRP panel with embedded layer to provide additional acoustic damping, as well as two different technologies for Structural Health Monitoring (SHM)

Expected benefits:

- They concern weight, internal noise, assembly costs and structural health monitoring

ATR72 Flight Test Bed on 9 July 2015

Preparation for the Flight Tests

▪ Green Rotorcraft

Demonstration of Diesel powered light helicopter
Airbus Helicopters, Marignane

TRL 5/6 - Iron Bird tests - February 2014 - Flight tests - November 2015

Objectives:

- A flying demonstrator based on an EC120 serial helicopter and fitted with a newly designed High Compression Engine (HCE, a reciprocating engine using Kerosene) has been developed by Airbus Helicopters in the frame of GRC 4
- For this research project, Airbus Helicopters teamed up with TEOS Powertrain Engineering, France (leader of the Consortium), and AustroEngine GmbH, Austria (partners of the project HIPE 440 selected in 2011)

Main features & benefits:

- In the power class related to EC120 engines (300 to 400kW), the main advantages of HCEs compared to turboshaft engines are the lower specific fuel consumption, lower CO_2 emissions, and higher performance in hot/high conditions thanks to the superchargers. Target Mass-to-power ratio < 0.8 kg/kW

Modified EC120 FTB

Demonstration of Helicopter Low Noise Procedures
Airbus Helicopters

TRL 6 - May 2015

Objectives:

- The low-noise IFR (Instrument Flight Rules) approach procedures were flown using accurate lateral and vertical guidance provided by EGNOS (European Geostationary Navigation Overlay Service), the European Satellite-Based Augmentation System (SBAS), and in the presence of airplane traffic, which proved the suitability of these helicopter-specific procedures to achieve Simultaneous Non Interfering (SNI) aircraft and rotorcraft IFR operations at a medium-size commercial airport

Main features & benefits:

- The procedures are based on the noise optimised flight paths successfully validated in 2013 with an H155 and have demonstrated noise footprint reductions of up to 50%
- Detailed design and integration of the procedures in Toulouse airspace was performed by partner project GARDEN (coordinated by Egis Avia)

H175 helicopter,
heliport of Toulouse-Blagnac

▪ Sustainable and Green Engines

Advanced Low Pressure System (ALPS) first flight
Rolls-Royce

TRL 6 - October 2014

Objectives:

- Rolls-Royce's goals to deliver a 20% fuel efficiency improvement, compared to the first generation of Trent engines for the Advance and UltraFan™ engines (for a timeframe of 2020 and 2025), are pursued through the Advanced Low Pressure System (ALPS), part of the SAGE 3 ITD. One of the most striking advances has been the testing of the composite fan that will be incorporated into both engine designs

Main outcome:

- The CTi (Carbon Titanium) fan blade and associated composite engine casings deliver a weight saving of around 1,500 lb on a twin engine aircraft. Composite panels containing electrical harnesses and pipework fit around the fancase, reducing weight and simplifying maintenance
- Testing in 2014 consisted of first test bed runs in Derby, UK, to crosswind testing at the Rolls-Royce facility at the John C. Stennis Space Centre, Mississippi, and most recently full flight tests on a Rolls-Royce Boeing 747 flying test bed at Tucson, Arizona, where one of the four RB211 engines was replaced with a Trent 1000 "donor" engine with CTi blades
- A total of six flights took place over eleven days in October 2014

ALPS at the B747 Flying Test Bed

Geared Turbofan Demonstrator
MTU

TRL 5 - November 2015

Main objectives:

- Advanced Geared Turbofan Demonstrator, with MTU and Partners' contribution with innovative technologies concerning materials and manufacturing processes
- Engine components concerned:
  - New highly efficient high-pressure compressor
  - Lightweight, high speed low-pressure turbine
  - Advanced lightweight and efficient turbine structures
  - Lightweight and reliable fan drive gear system
  - New systems for a more electric engine

Geared Turbofan Engine Test Bed

First rotation of TECH800
Turbomeca

TRL 5 - April 2013

Objectives:

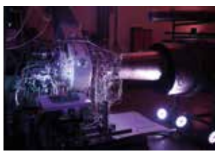
- Core turboshaft engine demonstrators in the power range 1,000-2,000 SHP

Main features:

- High efficiency compressor, combustion chamber, high-pressure, and low-pressure turbine

Main outcomes:

- Turbomeca developed the technologies with support of several partners
- Full scale and life cycle validation achieved



TECH 800 Engine Test Bed

Systems for Green Operations

Multi Criteria Departure Procedure (MCDP) function
Pilot-in-the–loop ground tests in AIRLAB Thales simulator - Airbus, Thales

TRL 4 - April 2014

Objectives:

- MCDP function is developed to optimise aircraft trajectories with respect to environmental criteria and flight operation efficiency
- Define green trajectories (departure, cruise, and final approach)
- Demonstrate the environmental friendliness of the functions in a representative operational environment

Main outcomes:

- The technical maturity of the technologies and system architectures

Cockpit with real software products and simulated equipment

Electrical Power Distribution Centre
Zodiac Aero Electric (Zodiac Aerospace group)

TRL 4 - June 2015

Main features:

- An innovative Electrical Power Distribution Center (EPDC) adapted to "More Electrical Aircraft" architecture and sized for a single aisle airliner has been developed
- The EPDC is the vital link between the electrical power sources of the aircraft and the electrical power users

Main outcomes:

- The EPDC was integrated in the PROVEN test rig

EPDC HVDC & Power Electronic modules

Skin heat exchanger (LSHX) – A320 ATRA Flying Test Bed
Airbus, DLR and Liebherr

TRL 5/6 - December 2014

Main features:

- As part of the development for advanced cooling systems, a Skin heat exchanger (LSHX) has been installed on the DLR A320 ATRA for two test campaigns (September to December 2014)
- The LSHX performances have been assessed for different conditions, analysing the aerodynamic data (boundary layer, heat transfer coefficient), allowing the validation and improvement of numerical models

ATRA (Advanced Technology Research Aircraft)

Primary Ice Detection System (PFIDS)
Performance in NRC Icing Wind Tunnel (IWT)

TRL 5 - April 2015

Main features:

- 3 weeks of testing conducted, covering Design verification: Thermal tests, conditions in App C, App O FZDZ and App D Ice Crystals & Mixed phase

Main outcomes:

- Preparation for flight tests by Safety of Flight (D0160 + Hail + Lightning)

Primary Ice Detection System by Zodiac Aerospace

Eco-Design

Electrical Test Bench – COPPER Bird
Labinal Power System

Fully operational from 2014

Main features:

- The COPPER BIRD® was created in 2002 to meet the needs of more electrical aircraft, in the context of the POA (Power Optimised Aircraft) European project to characterise an innovative electrical architecture and define a new integration methodology for Electrical Aircraft Equipment
- With Clean Sky the Labinal Power System's test rig has reached further capabilities, complying with airframers' new requirements, and providing a state of the art Electrical Test Bench for small aircraft and helicopters, towards the More Electric Aircraft architectures
- COPPER - Characterization and Optimization of Power Plant Equipment Rig

COPPER BIRD

Thermal Test Bench
Fraunhofer IBP

Fully operational from 2015

Main features:

- The TTB plays a key role in the simulation and testing of new systems with regard to thermal behavior, allowing a wide range of thermal measurements to be conducted on a genuine aircraft fuselage split into the three main sections of cockpit, cabin, and empennage
- The test facility also includes the Aircraft Calorimeter (ACC) that simulates extreme conditions such as rapid decompression and thermal shock, i.e. extremely rapid changes in temperature
- The main benefit offered by the TTB is the reduction of real-life test flights, while simultaneously protecting the environment

Thermal Test Bench

Major Demonstrators planned

Major Demonstrators planned

2016

February
2016

GRA
All-Electric
Aircraft
demonstrator
Alenia, ATR, Partners

March
2016

GRC Active
Gurney Flap
AgustaWestland

May
2016

GRC
AW139 VFR
procedures,
Pilot evaluation
and flight trials
AgustaWestland

June
2016

GRA
Fuselage demonstrator
One Piece Barrel
Alenia Aermacchi, DEMA, Hellenic Aerospace Industry, Fraunhofer-Gesellschaft IBP

June
2016

GRC
Passive
Optimized
Blade
Airbus Helicopters

June
2016

SGO A320 e-FTD
(electric Flying
Test Demonstrator)
Airbus, Liebherr, GKN, Zodiac, Thales

June
2016

SAGE Lean burn
Demonstrator
Rolls Royce

July
2016

End of wing assembly of
(BLADE)
Breakthrough Laminar Aircraft Demonstrator in Europe
Airbus, Dassault, Aernnova, Saab, INCAS, Romaero, ONERA, DLR; SERTEC, DIAS, GKN, ASCO, Aritex, Ascamm, ITA, VEW, 5micronGmbH, FTI, Engineering Network GmbH

SGO Multi Criteria Departure Procedure
Airbus, Thales

September
2016

September
2016

GRC
Electric Tail Demonstration
AgustaWestland

GRA Cockpit demonstrator
Airbus Defence & Space

September
2016

September
2016

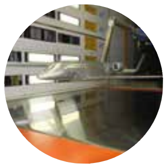
SFWA
High-speed business jet Demonstrator
Dassault, ONERA, CMA-VALLET

SFWA
Low-sweep business jet Demonstrator
Dassault, ONERA, NL-Cluster, INCAS, AVIOANE Craiova, ARA, FAM, DNW, ETW

September
2016

From September
2016

SAGE 2 CROR
Ground test demonstrator, Istres
Safran, Snecma



End
2016

SFWA Low Speed BizJet (LSBJ)
Dassault, DNW

Smart Fixed Wing Aircraft

Breakthrough Laminar Aircraft Demonstrator in Europe (BLADE)

Airbus, Dassault, Aernnova, Saab, INCAS, Romaero, ONERA, DLR; SERTEC, BIAS, GKN, ASCO, Aritex, Ascamm, ITA, VEW, 5micron GmbH, FTI Engineering Network GmbH

TRL 5 - 'Power-on' of the Aircraft planned by end of 2016 - Start of flight-test activities in 2017

Objective:

- To demonstrate in flight that the Natural Laminar Flow (NLF) wing produced at 'industrial scales' will confer significant performance, with low maintenance and operational costs

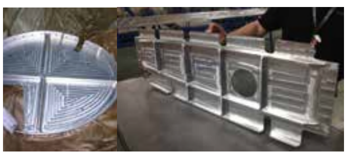
Main features:

- Test Aircraft modifications (A340-300) and manufacturing
- 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 Krueger high lift device

Expected benefits:

- Fuel burn saving on short/mid-range aircraft compared to an equivalent aircraft with a conventional wing

SAAB and GKN upper covers



A340-300 test Aircraft in Tarbes and Asco Krueger flap, Romaero Wing Tip Pod and Aernnova Wing box

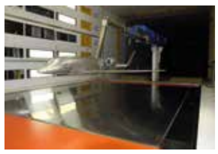
SFWA Low Speed BizJet (LSBJ)

Dassault, DNW

TRL 5 - end 2016

Objectives:

- Scaled model representative of the LSBJ conceptual bizjet aircraft with U-tail (based on a Falcon configuration)
- Aerodynamic characterisation tests in DNW WT to be followed by acoustics tests on the same model with dedicated test set-up



DNW set-up

Low-sweep business jet Demonstrator
Full Scale Ground Demonstrator

Dassault, ONERA, NL-Cluster, INCAS, AVIOANE Craiova, ARA, FAM, DNW, ETW

TRL 4 - September 2016

Objectives:

- Noise shielding measurement, acoustic and fatigue characterisation and thermal characterisation for U-Tail configuration

Main features:

- Far field microphones installed on the ground for installation effect measurements
- Metallic and composite panels installed on the U-Tail for thermal and acoustic fatigue measurements

Expected benefits:

- Noise reduction on short range flights compared to current fleet

Ground test set-up

High-speed business jet Demonstrator
Aerodynamic demonstration of smart flap for Bizjets
Dassault, ONERA, CMA-VALLET

TRL 5 - September 2016

Objectives:

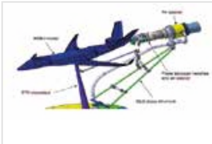
- To validate the aero efficiency and aero loads of innovative control surfaces (smart flap). Global and partial force measurements will be used, combined with detailed pressure distribution. Another test campaign will have an inlet rake

Main features:

- Handling qualities of innovative HTP (Horizontal Tail Plane), canard, flaperon, continuous settings slats
- Air intake unsteady distortion measurements
- Model manufacture technique: SLM (Selective Laser Melting (additive manufacturing technique))

Expected benefits:

- Fuel burn saving and noise reduction on long haul operations compared to current fleet


Wind tunnel model

Green Regional Aircraft

All-Electric Aircraft demonstrator
Alenia, ATR, Partners

TRL 5 - February 2016

Objectives:

- The ATR 72 FTB (flying test bed) A/C will be modified at the end of the structural test campaign for the AEA Technologies in flight demonstration

Main features:

- EPGS: Electrical Power
- Installation of 270 HVDC Generation distribution including Electrical Power Center (EPC) and Simulated Resistive Electrical Load (SREL)
- E-ECS (Electric Environmental Control System) (35 kW), with a dedicated control rack
- EMAs: Installation of two electrical actuators (one for FCS, one for LG (each mounted on a dedicated test bench, both located in Cabin)

An FTI/Flight Test Station (FTES) will also be installed in the cabin.

Expected benefits:

- Implementation of more electric aircraft architecture


ATR 72 Flying Test Bed

Fuselage demonstrator One Piece Barrel
Alenia Aermacchi, DEMA, Hellenic Aerospace Industry, Fraunhofer-Gesellschaft IBP

TRL 5 - June 2016

Main features:

The fuselage demonstrator has 2 components:

- The fabrication of the fuselage barrel as a Composite 'one piece barrel'
- The testing of this barrel for fatigue and static behaviour

Main benefits:

- New fuselage concept architecture


One Piece Barrel Demonstrator

Cockpit demonstrator
Airbus Defence & Space

TRL 5 - September 2016

Main features:

- A second cockpit ground demonstrator has been prepared, and has achieved a major step towards the internal target of 10% weight saving

Main outcomes:

- Different frame materials are under investigation to identify the best material for acoustic, fatigue and crash behaviour


Cockpit demonstrator

Green Rotorcraft

Active Gurney Flap
AgustaWestland

Flight tests, TRL 6 - March 2016

Next-generation helicopters will consider adaptive and innovative components within their rotor blades in order to obtain performance benefits.

AgustaWestland and its partners are developing and testing an Active Gurney Flap system through a series of progressive tests consisting of:

- Model Rotor test (controlled environment test)
- 2D Static Test, University Twente (initial fully sized blade data)
- 2D Dynamic Test (at CIRA IWT1) (blade representative testing, controlled environment)
- Whirl Tower (full scale rotor; full systems capability test ahead of flight)
- Flight test on an AW139 helicopter TRL 6

Expected benefits:

- Demonstration of advanced Rotor Blade concept


Active Gurney Flap tests

Electric Tail Demonstration
AgustaWestland, University of Bristol

TRL 5 - September 2016

Main features:

- Electrification of the tail rotor drive function
- The 'Electric Tail Demonstrator', based on concepts explored by the ELETAD project, incorporates the high power/weight ratio laboratory motor design into a high integrity aircraft system capable of installation and dynamic evaluation on an aircraft tail demonstration rig

Main outcomes:

- The Electric Tail Demonstrator system is currently TRL3, with the key motor parts from ELETAD that are at TRL 4
- The ground demonstration will dynamically evaluate the system representing flight mission profiles, reaching TRL 5

Expected benefits:

- Assessment of innovative helicopter tail Rotor architectures

Dedicated ground test bench

Demonstration of Helicopter Low Noise Procedures
AgustaWestland

TRL 6 - May 2016

Main objectives:

- Gain confidence in the acoustic benefits of steep departure and approach procedures with respect to conventional ones, based on correlation with AW139 prototype flight acoustic measurements on-board and on-ground
- Involvement of partner project MANOEUVRES, to improve the acoustic prediction capability for manoeuvring unsteady conditions, and to propose the concept of a Pilot Acoustic Indicator, able to provide on-board noise predictions allowing the adaption of the flight path

Main outcomes:

- After completing pilot handling, guidance and workload validation of the VFR environment friendly paths, using an engineering simulator AWARE, demonstration in flight of the noise abatement for this project in Q2 2016

AW 139 Helicopter Demonstrator

Passive Optimized Blade
Airbus Helicopters

TRL 6 - June 2016

Main features:

- New rotor blades optimised for efficiency and noise signature, compatible with variable speed rotor. Modelling and predictions to be compared with full-scale testing on whirl tower and in flight

Expected benefits:

- Demonstration of advanced Rotor Blade concept

Main Rotor Whirl Tower

Sustainable and Green Engines

CROR Ground test demonstrator, Istres
Safran, Snecma

TRL 5 - From September 2016

Objectives & benefits:

- The Contra Rotating Open Rotor (based on a geared unducted architecture) is an aircraft engine offering a 30% fuel burn reduction compared to the the year 2000 turbofan reference engine, allowing a significant decrease of the CO_2 emissions

Main features:

- The Open Rotor configuration aims at meeting several technological challenges such as a new propulsion mode, an innovative aerodynamic configuration and unprecedented manufacturing processes
- The main innovative elements of the design concern the blades of the propellers, the blade pitch change mechanism, the gearbox and the rotating structure

Main outcomes:

- By intensive aero-acoustic wind tunnel testing of several design optimisations, Safran demonstrated that this architecture is compliant with the new noise standards for certification (chapter 14) and consistent with expected performance level
- Safran is leading the SAGE 2 Consortium (including several Partners) which aims at delivering and ground testing a full-scale Open Rotor engine on a brand-new Safran open-air facility located in Istres

Contra Rotating Open Rotor concept

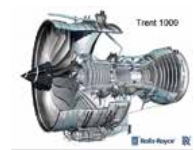
Lean Burn Demonstrator
Rolls-Royce

TRL 5 - June 2016

Objectives & features:

The Lean Burn Programme objective is to deliver a verified generic Lean Burn System against a set of validated requirements complying with regulatory and company demands for emissions and safety, and with acceptable reliability at minimum life cycle cost and weight.

- The test programme is based on Trent 1000 donor engines (ALECSYS) for engine ground testing
- Emissions capability at representative future cycles has been demonstrated in a dedicated core engine experiment on the EFE (Environmentally Friendly Engine) vehicle
- The programme is also envisaging a full scale flight test campaign on a B747 flying test bed
- The programme is scheduled to achieve TRL 5/MCRL 4 by mid-2016



Lean Burn demonstrator

Systems for Green Operations

A320 e-FTD (electric Flying Test Demonstrator)
Airbus, Liebherr, GKN, Zodiac, Thales

TRL 5 - June 2016

Main features and outcomes:

The A320 will be configured for flight testing in two test campaigns of More Electric Aircraft architecture, integrating the following items:

- Liebherr 50kW e-ECS, verifying the interaction & control laws between compressors & scoop air intake & A/C, and the electrical functionality and associated DC system/power electronics. Also part of this effort is the scoop air intake performance
- The Electrical Power Centre is based on HVDC and several sensors
- The Primary Ice Detection System (PFIDS), whose goal is to automatically activate the Ice Protection System when the A/C encounters icing conditions (from -40°C to +10°C), is currently at TRL 5 as a component, after Verification of the Detection performance in Icing Wind Tunnel (IWT)

A320 e-FTD

Pilot-in-the–loop ground tests
AIRLAB Thales

TRL 5 for A-IGS/MSC - September 2016

Expected benefits:

- Adaptive-increased Glide Slope (A-IGS) and Multi Step Cruise (MSC) functions are developed to optimise aircraft trajectories with respect to environmental criteria and flight operation efficiency. Tests will be performed in AIRLAB Thales simulator

Objectives:

- Define green trajectories (departure, cruise and final approach)
- Demonstrate the environmental friendliness of the functions in a representative operational environment
- Follow up the technical maturity of the technologies and system architectures

Main features:

- Cockpit with real software products (real code on native platform) and simulated equipment


Pilot-in-the-loop simulator

The Future: Towards Clean Sky 2

Clean Sky 2 is now fully set towards the ACARE 2020 goals, while starting the journey for further environmental improvements beyond this timeline, and is playing an increasing role in creating growth and jobs and securing Europe's competitiveness.

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.

Clean Sky 2 has gathered an impressive momentum in its first "extended year" of operation, i.e. from July 2014 to the end of 2015. No fewer than 5 Calls have been launched in this short period, demonstrating the JU's and the Industry's ambition and sense of urgency in addressing the challenges in the H2020 timeframe, and the CS2 high-level objectives. Three Calls - two for Core Partners [to join as Members] and one Call for Proposals (CfP) - have been evaluated and have had grants placed, or their preparation and implementation is underway.

And what is equally impressive is the level of interest and appetite in participating, as witnessed by these statistics to date:

- Based on the two Calls for Proposals [Partners] to date, nearly 200 new Partners have been selected, covering close to 400 participations [individual project areas]. A 3rd Call for Proposals [Partners] is underway in the first half of 2016, to be followed by a 4th in the latter part of the year.
- With two Calls for Core Partners also completed and the technical preparation of the 2nd call underway, some 125 new Members have joined or will soon join the Programme. The 3rd Call for Core Partners will lead to a further selection and accession of additional Members throughout the course of 2016, with a final 4th call expected to then complete the selection and accession of Members in 2017.
- Going forward, a regular schedule of two Calls for Proposals [Partners] per year is foreseen through to 2020, with roughly €90 million available in indicative call value per year.

For more information about participation in the Clean Sky Joint Undertaking, visit the Clean Sky website at **www.cleansky.eu.**

Clean Sky

This project is funded by the European Union

*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:*

Follow us on:

Members

ITD Leaders

AgustaWestland - Airbus - Alenia Aermacchi - Dassault Aviation - Airbus Defence & Space - 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

Clean Sky Partners

Clean Sky works with more than 500 partners in 24 European countries.

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

March 2016