Celebrating 10 Years of Partnership
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Views from the European Union

Smart Fixed Wing Aircraft

Green Regional Aircraft

Systems for Green Operations

Green Rotorcraft

Technology Evaluator

Upcoming events
In 2017 Clean Sky’s first programme will draw to a close. When looking back and recapping those phenomenal years since the start of the programme in 2008, we can only confirm what an extraordinary journey this has been. This major aeronautics research initiative has reviewed thousands of components used in current aircraft and helicopters to identify the areas that can be significantly improved in order to reduce CO₂ emissions and noise by 2020.

A few interesting figures: since 2008, some 20 large Demonstrators have been completed by 600 participants in 24 European countries, bringing together thousands of experts from leading companies, universities, SMEs and research centres to work around a common European programme.

Above all, Clean Sky is a true European collaboration. It’s about working together at a European level to develop the green technologies that both public and private sectors believe could improve our environment and help us stay competitive. These green technologies meet European societal demands for a better quality of life and future prospects.

The great partnerships that Clean Sky has developed are even more important in these turbulent times of protectionism and nationalism, let alone globalisation. Collaborating at a European level has helped the European aeronautics supply chain stay in good shape, by spreading into new regions and countries and playing a role in building a Europe with more growth and jobs.

In this issue of Skyline, you will find a summary and results of each technology platform Clean Sky has been working on over the past 10 years. Wings, engines, systems, rotorcraft, regional aircraft and eco-design have all had their own journeys into excellent collaborative research and openness towards new partners. You will read about progress on laminar wings, more electrical aircraft, hybrid propulsion, lighter rotorcraft, composite regional planes, and new materials and appliances. These are real, tangible pieces of hardware which have been through exhaustive testing and will make a big difference once commercialised in the future.

You will also find a summary of the results of the Technology Evaluator, Clean Sky’s unique independent assessment tool to measure progress and forecast reductions in CO₂, NOx and noise.

The results of our collaborative research at Clean Sky are well-placed in the bigger picture of the EU’s vision on sustainable transport in Europe, through environment, mobility, and competitiveness pillars. On this subject, we highly value our discussions with the European Commission and the European Parliament and we would like to thank them for their continued support and encouragement.

Finally, we will be marking the closing of Clean Sky’s first programme with a special event on 21-22 March in Brussels: Europe, innovation and aviation: Are we keeping up?

It is an important question to ask ourselves: are we actually keeping up? Are we collectively doing enough to encourage and organise excellent European research, foster cross-border cooperation, invest enough financial means, and find the best talent, for the best results to keep the European leadership in this sector and to serve our society?

We are looking forward to this debate and hope to see many of you in March setting the path towards an even more successful Clean Sky in the future. We believe that it will be an exciting and promising joint flight to board. Come and join us!
"If we want Europe to remain at the forefront, we must continue to develop and improve mobility for our citizens and goods, and do so in a sustainable way. To remain competitive globally, we must invest in research to be at the cutting edge of new technologies – Clean Sky is about just that."

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Paul Rübig
MEP

“Synergies with Structural Funds are a strategic necessity in H2020, and the Clean Sky 2 JU is paving the way in making this happen: providing a win-win for regions and industry alike, ensuring better investment and support in R&I in aeronautics. With a dozen agreements already signed with several regions, Europe’s smart specialisation strategy is getting a key impulse from this initiative.”

Soledad Cabezón Ruiz
MEP

“Martina Dlabajová MEP at the Clean Sky Forum 2016”

The fact Clean Sky, a public-private partnership, exists is an undeniable asset. This joining of public and private forces will make it possible to fully deliver on two fronts: environmental friendliness and competitiveness.

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The Smart Fixed Wing Aircraft (SFWA) ITD launched several Technology Streams related to future aircraft, ranging from BizJets to Short and Medium Range (SRA) commercial airplanes.

In the Low Sweep Business Jets (LSBJ) Technology Stream, the consolidation of aerodynamic, thermal and aero-elastic performance and noise reduction levels has been obtained via complex wind tunnel testing, computations and, finally, via a full-scale (Falcon F7X) ground demonstrator (in the SHIELD Project from Partners) with an innovative ‘U-Tail’ after-body, an impressive full-scale partial tail, and movable test rig.

For the SRA, in cooperation with SAGE ITD (Safran and Rolls-Royce), significant progress has been made on the maturation of CROR (Contra-Rotating Open Rotor) technologies’ integration leading to the concept feasibility Demonstration in 2013.

Concerning Natural Laminar Flow, after having successfully passed the aerodynamic, structural (via the multifunctional Ground Based Demonstrator) and systems integration maturity gates, and despite important technical aspects which led to postponing the flight tests to 2017, outstanding progress has been made on the A340-300 Airbus test aircraft, resulting in the BLADE Demonstrator (Breakthrough Laminar Aircraft Demonstrator in Europe).

Two outer wing panels (from SAAB and GKN), as well as other key outer wing components and related innovative tooling and FTI (Flight Test Instrumentation), have been designed, manufactured, assembled and installed on the test aircraft in compliance with the tight tolerances for such an ambitious programme.

In all cases, but more specifically for LSBJ, the required performance of a NLF wing has been reached thanks to extensive numerical computations and tests at ETW (European Transonic Windtunnel).

Besides the BLADE and SHIELD flagship Demonstrators, one can note the following significant scientific progress or achievements on:

- Hybrid Laminar Flow Control (HLFC) has been advanced through the development of a promising simplified concept and maturation pursued in the frame of the European Project AFloNext (first application on an A320 Vertical Tail Plane) and Clean Sky 2.

- Flow Control: validation of the smart flap concept for HSBJ (High Speed BizJets), including structural concepts; progress on active flow control to redistribute loads (developed within the STARLET project); and fluidic actuators such as the Pulsed Jet Actuator tested at lab scale via the Integrated Active Control Demonstrator (IACD) etc. The integration of flow control devices is being pursued in Clean Sky 2.
• Load control functions and architectures, vibration control: validation of means and methodologies to mitigate loads and vibration impact for Bizjets and Large aircrafts. In particular, one can note the successful Ground Vibration Test performed on a Falcon 7X for the development of vibration control laws.

• Buffet control: very good progress on buffet characterisation, physical understanding and control via an extensive experimental database, computations and buffet control devices (BUCOLIC project).

• Advanced Flight Test Instrumentation (FTI) has been developed such as the internal waviness measurement, wing shape deformation with an innovative inertial sensor, reflectometry, shadow casting, autonomous wireless sensors, and in-flight PIV (Particle Image Velocimetry) for CROR pylon wake characterisation.

As an input for the Technology Evaluator (TE), a set of future technologies (2020/2025) developed within the ITD has been integrated via a specific Parametric Noise and Emission Model (PANEM), developed by Airbus for Large Aircraft and by Dassault Aviation for Business jets concepts.

Key statistics

ITD LEADERS
Airbus
SAAB
Dassault
Aviation
EADS-CASA
Fraunhofer
Rolls-Royce
Safran
Thales
Liebherr

ASSOCIATES
DLR
ONERA
INCAS Cluster
Netherlands Aerospace Cluster
QinetiQ
RUAG
Aernnova
KIN
Machinebouw

• 39 ITD members
• Total gross budget of ±400 M€
• 104 additional partners

At least 25% of the overall budget was dedicated to partners who were selected in a fully open and transparent Call for Proposal process that was conducted through the Clean Sky Joint Undertaking.

More than 70% of the total funding went to research institutes and SMEs.
Regional aviation is a key factor in creating resources and an efficient air transport system which respects the environment, ensures safe and seamless mobility, and establishes industrial leadership in Europe: the future Green Regional Aircraft represents the strategic asset of such an integrated system, meeting demanding emissions and noise reduction targets.

The GRA ITD, active from 2008-2016, aimed to mature, validate and demonstrate green aeronautical technologies best fitting the regional aircraft that will fly from 2020 onwards, in different domains such as advanced low-weight and high performance structures, all-electric systems, bleed-less engine architectures, low noise/high efficiency aerodynamic, environmentally optimised missions and trajectories management.

The development of such technologies addressed two different aircraft concepts, identified by two seat classes: 90-pax with Turboprop (TP) engine and 130-pax exploring other propulsion solutions: Geared Turbofan (GTF), Advanced Turbofan (ATF) and Open Rotor (OR).

Demonstrations of GRA technology readiness level (TRL) have been a key achievement of this ITD; on the one hand providing physical evidence of the contribution to ACARE’s environmental targets at aircraft level, and on the other hand delivering the final assessment of the relevant technologies, allowing the European aeronautical system to gather technical information to shape the eco-friendly regional aircraft of the future.

The outcomes of GRA in a nutshell: starting from 85 state-of-the-art enabling/specific technologies, 54 were down-selected at 2nd gate and developed at level 4/5 of their maturity, then were selected and integrated into Flight Simulator, Wind Tunnel Models, Ground and Flight Demonstrators to prove their final readiness level (5/6).
Key statistics

- GRA’s family consists of 208 Beneficiaries, 33 Members and 175 Partners from 18 countries; they have implemented the overall Programme’s actions, receiving funding for €697.84 million (Members) and €23.5 million (Partners) from the JU and contributed capital investment of par value.
- Main actors: Leonardo Aircraft, acting as coordinator, and Airbus Defence & Space co-led the Programme: Fraunhofer Gesellschaft, Liebherr, Rolls-Royce, Safran, and Thales Avionics as other ITD Leaders.
- Associates: AirGreen Cluster (Piaggio Aero, Centro Sviluppo Materiali, IMASC, Foxbit, Politecnico Torino, SICAMB, University Bologna, University Napoli, University Pisa), ATR, CiraPlus Cluster (CIRA, Aerosoft, Dema, INCAS, ELSIS), Hellenic Aerospace Industry and ONERA.
- A total of 91 SMEs, 40 Universities, 33 Research Centres, and 11 Industries involved through 101 Topics brought essential skills and competences to the Programme.

Flying test beds:

- Flying Test Demonstration (ATR 72-600 A/C) of ‘Low Weight Aircraft’ to test health monitored Crown CFRP Panel with embedded layer, providing additional acoustic damping.
- Flying Test Demonstration (ATR 72-600 A/C) of ‘All Electric Aircraft’ to test a new electrical power management system, optimising electrical power distribution and innovative e-ECS.

Ground based demonstrators:

- On-Ground Full Scale Composite Cockpit Demonstration of an overall weight reduction in primary structure, improving functionalities of the reference metallic structure, validating the advanced structural technologies applied on two cockpit demonstrators (full-composite and hybrid).
- On-Ground Full Scale Composite One Piece Fuselage Barrel Demonstration of overall weight reduction in primary structure, validating the advanced material and sensors technologies applied on a fuselage barrel structure.
- On-Ground Full Scale Composite Inner Wing Box Demonstration of SHM (Structural Health Monitoring) technologies applied on an inner wing box structure.
- Full Scale Composite Wing Box Demonstration of Liquid Resin Infusion technology maturity for regional aircraft wing box panels.
- Flight Simulation for Initial Operational Validation, performed by means of GRA Flight Simulator with all new Mission and Trajectory Management features.

Wind tunnel models testing:

- GTF A/C Natural Laminar Flow (NLF) Wing and Load Control (LC) Wind Tunnel Demonstration of the NLF wing design at cruise, and of LC performance in high-speed off-design conditions.
- GTF A/C Gust Load Alleviation (GLA) strategy WT Demonstration of the viability of the LA system (sensors, control laws, devices actuation) within an aeroelastic environment under gust occurrence.
- GTF A/C GLA Control System ground Demonstration of the GLA system control chain (sensors, control laws, devices actuation), through a test rig inserted in a realistic HW/SW operational environment.
- GTF A/C Morphing Flap Ground Demonstration of mechanism dual-morphing function, i.e. flap overall camber variation and LC tab deflection.
- GTF A/C Droop Nose Mechanical Ground Demonstration of the concerned wing L/E morphing structure, to verify mechanism ability to properly deform the skin, and device operation under representative aerodynamic loads and simulated icing/raining conditions in a climate WT.
- GTF A/C half-wing Droop Nose WT Demonstration of high-lift performance and noise emission.
- TP 90-seat A/C and GTF 130-seat A/C performance WT of A/C aerodynamic and aeroacoustic low-speed performances, and HLD low-noise devices.
- TP A/C Low Noise Half Scale Main Landing Gear WT Demonstration of low-noise technologies.
- TP A/C Low Noise Full Scale Nose Landing Gear WT Demonstration of low-noise technologies.

GRA Demonstrations and their achievements as performed, divided by approach:
The SAGE (Sustainable and Green Engines) ITD, as initially defined in the Clean Sky regulation, is the biggest ITD with 27% of the total funding. It aimed to establish, within the European industry, the capability of introducing new advanced technologies into future aero-engines to achieve significant improvements in environmental characteristics, while sustaining a strong commercially competitive position in global markets. The programme featured 6 Demonstrator engine projects, representing the propulsion requirements for important categories of modern transport aircraft. The 6 testing vehicles, distinguished by application (helicopter, narrow-body and wide-body) and by engine architecture (2-shaft, 3-shaft, open rotor) were named SAGE 1 to SAGE 6.

**SAGE 1: Geared Open Rotor Configuration**

Led by Rolls-Royce plc. with contributions from Rolls-Royce Deutschland, ITP, GKN Aerospace Engine Systems, Airbus and Leonardo.

The high-level objectives of SAGE 1 were to deliver technology and architecture that would reduce CO₂ emissions by 10-15% and noise emissions by 6-9EPNdB.

The studies and architectural work done on viable open rotor concepts delivered a 10% reduction in CO₂ emissions and a -6 to -9 EPNdB improvement in noise emissions for the low pressure “fan” system of an engine. This -10% would be in addition to any core engine benefits delivered through other research and development programmes.

The delivery of the SAGE 2 Demonstrator to the ground test facility is planned in Q1 2017, and ground tests will start in the coming months.

**SAGE 2: Contra-Rotating Open Rotor Demonstrator**


The SAGE 2 project focuses on demonstrating the following key technologies: composite propeller blades research activities including aero-acoustic optimisation; pitch control system; lightweight front and rear rotating frames; the contra-rotating reduction gearbox; the power turbine to reduce module weight and increase performance characteristics; lubrication and cooling systems; nacelle components and particularly rotating parts; control, protection and monitoring system and equipment; propeller blades electric de-icing system and equipment. The gas generator used in the SAGE 2 open rotor demonstrator is derived from a Safran Aircraft Engines M88 engine. The ground test demonstration of this full-scale engine will also validate the whole propulsion system integration.

The SAGE 2 – Contra-Rotating Open Rotor Demonstrator - Safran Aero Engines

**SAGE 3: Large 3-shaft Turbofan Demonstrator**

Led by Rolls-Royce plc. with contributions from Rolls-Royce Deutschland, ITP and GKN Aerospace Engine Systems.

The SAGE 3 project has demonstrated technologies applicable to large 3-shaft turbofan engines in the 60-95,000lbs thrust class, with a focus on an Advanced Low Pressure System (ALPS), externals and compressor structures technologies: lightweight composite fan system, including composite fan blades, composite fan case and all supporting hardware; lightweight integrated engine externals for fan case and core mounting dressings; intake developed in conjunction with the composite fan case and optimised for the composite fan as an aerodynamic and structural system including noise reduction technologies; lightweight new materials and construction techniques for low pressure turbines; technologies for higher efficiency low pressure turbines, through aerodynamic developments such as blade clocking and more advanced secondary cooling flow control; materials and construction techniques for compressor inter-cases, focusing on topology optimisation; manufacturing techniques to enable thin sections and materials with higher temperature capability.

The ALPS engine has undergone a series of ground tests on the basis of a Rolls-Royce Trent 1000 to assess the functional and structural capability of advanced dressings, flutter and aerodynamic performance, composite fan system flutter behaviour under cross-wind conditions and noise performance, and the low pressure turbine performance and thermal/structural behaviour.

Flight tests of the engine were successfully performed in October 2014 to demonstrate the composite fan blade’s in-flight operability.

Additional ground testing is planned in 2017 to assess blade integrity and bird impact capability for the composite fan system as well as icing tests to determine ice shedding behaviour of blades and impact damage tolerances of new liners.
The introduction of these new technologies should allow a 3-6% reduction of CO₂ and a 3-6EPNdB noise reduction from the composite fan system.

**SAGE 4: Geared Turbofan Demonstrator**

Led by MTU Aero Engines with contributions from Avio Aero, GKN Aerospace Engine Systems and numerous CfP partners.

The SAGE 4 demonstration programme successfully demonstrated further advancements of recent geared fan technology introduced into the regional and narrow body market, and thus provided significant contributions towards ACARE’s ambitious CO₂, NOx and noise targets for 2020. After an extensive concept phase components and modules with new technologies have been developed, built and validated through component and rig testing before being implemented into a full scale GTF donor engine. High efficient HP compressor technology building, i.e. on the NEWAC programme (Active Core work package) and national research programmes, have been matured to higher TRL levels as well as high speed LP turbine technologies derived from the CLEAN, VITAL and again national research programmes. A lightweight exhaust frame with split functionality features and advanced materials and fabrication technologies complemented the SAGE 4 GTF demonstrator programme.

An advanced Integral Drive System, embedding technologies to increase efficiency and reliability, was tested as part of the SAGE 4 demonstrator programme on a new dedicated test rig facility developed in Italy in collaboration with Get FuTuRe Consortium, with complementary activities to continue in 2017.

**SAGE 5: Advanced Turboshaft Demonstrator**

Led by Safran Helicopter Engines.

The SAGE 5 project will provide the technologies necessary for the development of a new engine family equipping helicopter classes with a take-off weight of 3 tons (single-engine) to 6 tons (twin-engine).

SAGE 5 focuses on high efficiency compressor stages: small-size high efficiency cooled HP turbine in order to improve performance and reduce dimensions of turboshaft engines and prepare a power growth capability; high efficiency single stage LP Turbine; materials and coating development and manufacturing techniques to enable static parts to cope with higher temperature; technologies for low noise devices for a quiet exhaust; technology for inter shaft architecture; technologies for control system through the development of equipment to reduce cost, weight/size or to enable higher temperature operation.

The first engine tests of the TECH 800 demonstrator were performed in February 2013, with subsequent runs until the end of 2015, demonstrating an effective 15% Specific Fuel Consumption (SFC) reduction. Most of these technologies have been incorporated into Safran Helicopter Engines’ new engine in the 1,100 to 1,300shp power class - the ARRANO - which was selected in 2015 as the exclusive engine for Airbus Helicopters’ new twin-engine H160.

**SAGE 6: Lean Burn Demonstrator**

Led by Rolls-Royce plc. with contributions from Rolls-Royce Deutschland.

Lean burn combustion is a vital technology acquisition for the European aerospace industry if it is to comply with future CAEP & ACARE emissions legislation, and for its products to remain competitive in the world marketplace. The SAGE 6 lean burn project aimed to demonstrate a lean burn whole engine system to a TRL6 maturity level, suitable for incorporation into civil aerospace applications in the 30,000-100,000+ lbs thrust classes. Significant technologies were developed concerning combustion, hydro-mechanical fuel control, control laws and associated sensing devices, whole engine thermal management, acoustic attenuation, turbomachinery thermal- mechanical integration and system health monitoring and maintenance functions. The current engine demonstration plan includes ground testing as of Q2 2017 up to flight tests in Q4 2017.

**Conclusions**

The SAGE Demonstrators have had (or will have) a considerable impact on progressing state-of-the-art technologies and will offer clear exploitation opportunities both in the near term and over the next 5-10 years for future propulsion systems, in line with the Clean Sky environmental drivers.

**Key statistics**

- Leaders: Safran and Rolls-Royce
- 80 Call for Proposal projects for a budget of more than 81 M€ (> 54M€ funding)
- Funding: ± 310 M€ budget (> 154M€ funding)
- Total budget for SAGE including CfPs: 391 M€ budget (>208M€ funding)
The Green Rotorcraft (GRC) ITD is one of the platforms of the Clean Sky Joint Technology Initiative (JTI) created by the European Commission within the 7th Framework Programme (FP7) for research. It started in 2008 and was completed in December 2016.

The GRC ITD gathered and performed activities specifically concerned with the integration of technologies and their demonstration on rotorcraft platforms (helicopters and tiltrotor configurations).

GRC’s industrial objectives were to develop innovative technologies to help meet ambitious environmental targets and to bring these technologies to a high maturity level in order to assess their feasibility from the perspective of industrial applications in rotorcraft products. The overall GRC goal is to contribute to reducing the current global level of environmental impact of the rotorcraft sector while sustaining the expected growth of rotary wing applications. The Clean Sky initiative aims to reduce the specific impact of rotorcraft operations on the environment by half before the year 2020.

The GRC platform included several technological streams addressing innovative rotor blades, aerodynamic drag reduction, integration of electrical systems and high compression engine, and the maturation of optimised rotorcraft trajectories and guidance procedures to minimise perceived noise. GRC also investigated eco-design and environmentally friendly manufacturing technologies.

Sixty technologies which were potentially able to contribute to the programme’s objectives have been explored since 2008. Most of them turned out to be capable of reducing the environmental impact of rotorcraft operations. Many technologies were brought to high Technology Readiness Levels (TRL), including 16 technologies to TRL 5 and 15 to TRL 6 with flight test validation.

A very good cooperation was built among GRC Members and participants in the 42 Partner projects. Collaboration or complementarity was developed during the GRC timeframe with other Clean Sky projects (e.g. SGO, Eco-Design, Sustainable and Green Engines and the Technology Evaluator (TE); in particular, GRC contributed strongly to TE by providing simulation tools and rotorcraft data), as well as with European, national or industry initiatives (e.g. SESAR, EASA, Bluecopter).
The administrative and financial flexibility of the Clean Sky organisation implemented by CSJU was another key to the project’s success, by facilitating work plans and budget management. This also made possible the development and management of new activities that were not initially planned.

The average values of assessment results of CS1 are: 26% reduction of CO₂ emissions through drastic reduction of fuel consumption; 53% reduction of NOx (nitrogen oxides) emissions; 55% reduction of external noise; and a green product life cycle covering design, manufacturing, maintenance and disposal/recycling.

The results achieved, in particular for the reduction of CO₂, NOx emissions and the reduction of external noise, will be presented in detail at the Clean Sky 1 Closing Event on 21-22 March 2017.
The Systems for Green Operations (SGO) ITD successfully demonstrated innovative technologies and functions in the domain of aircraft systems, providing environmental benefits typically in the range of -5% in CO2 emissions and -3dB in noise for take-off and landing flight phases in line with the initial objectives.

The first pillar of the SGO programme was the Management of Aircraft Energy (MAE), which includes the two focus areas of ‘More-Electric Aircraft Equipment Systems Architectures’ and ‘Thermal Management’. The first area aimed at demonstrating solutions for future aircraft in which electrical power consumption will drastically increase, potentially replacing hydraulic and pneumatic power. To progress towards this ultimate goal, the complete electrical chain was addressed in the project, from the electrical power generation to the main energy consuming systems, and including conversion, power management and distribution. The second objective was to adapt and demonstrate the control of heat exchanges (most relevant to the all-electrical architecture concept) and reduction in heat waste within the whole aircraft through advanced Thermal Management equipment and functions.

The second pillar was the Management of Aircraft Trajectory and Mission (MTM), which includes the two focus areas of ‘Management of Trajectory and Mission’ and ‘Smart Operations on Ground’. The first area aimed at enabling Green Trajectories, based on more precise, reliable and predictable 3-dimensional flight paths, optimised for minimum noise impact and low emissions and taking into account the meteorological situation. Specific functions have been studied in the initial climb, cruise and descent and approach phases, with impacts on the Flight Management Systems, on algorithms for the weather radar, and on new support tools for pilot decision. The second area focused on demonstrating direct drive electrical motors integrated within the main landing gear and braking systems, for aircraft motion on the ground without use of main engines.

The SGO ITD has achieved most of its objectives, with technology demonstrations up to TRL 5 and 6 in more than 25 technology threads. Major ground test rigs have contributed to the maturity evaluation. For instance, an integrated Power Management Center has been tested in a complete electrical chain, from generator to main loads. Three innovative Flight Management functions have also been demonstrated in a representative cockpit system test bench. Moreover, the scale of the project made it possible to demonstrate several technologies in flight test campaigns.

Airbus A320 Flightlab, rolling for SGO electrical systems flight tests
One of the most ambitious was realised with the flight test of the electrical environmental control system (e-ECS), on the Airbus A320 MSN01 ‘Flightlab’.

The ITD level assessment showed that the environmental benefits are achievable through the innovative functions and technologies. The mission and trajectory management technologies have the potential to reduce CO₂ emissions by 3.5% on average, considering A320 typical missions in various conditions of take-off weight, range and weather conditions. Additional benefits can be obtained in specific weather conditions, for instance in case of storm avoidance. A noise reduction of 3dB is achieved in both the departure phase and final approach. In addition, the more electrical aircraft system technologies have the potential to reduce CO₂ emissions by an additional 1%, depending on aircraft architecture implementation choices.

The technology demonstrations of SGO have been largely supported by Call for Proposal projects involving industries, small and medium enterprises (SMEs), research centres and universities. These important actors delivered critical parts of the ITD work plan; some in transverse areas like models and tools, and some directly as part of the technology maturation or for large demonstrators. In total, more than 100 projects contributed to SGO’s success.

Thanks to the large scale of the SGO ITD, the rich diversity of the actors involved, and the flexibility in the research work plan provided by the Clean Sky framework, SGO made unprecedented progress on aircraft system innovation, demonstrated through several flight tests. Based on this success, the risk for some technologies has been reduced to a level where their inclusion in a commercial project will be possible at the first opportunity. This is the case, for instance, for some of the Flight Management functions. For others, the results achieved in SGO will be further matured in Clean Sky 2 in order to reach a full TRL6 maturity.

Key statistics
- Co-ordinators: Thales – Gilles Poussin gilles.poussin@fr.thalesgroup.com and Liebherr – Sebastian Ziehm sebastian.ziehm@liebherr.com
- 107 CfP projects
- 109M€ funding for Leaders and Associates, 36M€ funding for CfP partners

Working session with pilot on Thales System bench (photo ©Thales)

SGO FUEL GAINS FOR DIFFERENT MISSION RANGES AND AIRCRAFT TAKE-OFF WEIGHT
The Eco-Design ITD, which started on 1 October 2008, was technically completed on 31 December 2015. Its activities were focused on two main pillars:

• Eco-Design for Airframe (EDA): designing equipped airframe with a minimum environmental footprint, encompassing inputs (raw materials, energy, water...), outputs and nuisances (energy/warming, liquid effluents, gaseous effluents, solid waste...) all along the out-of-operation phases of the life cycle.

• Eco-Design for Systems (EDS): suppressing non-renewable and/or noxious substances (i.e. suppression of conventional hydraulic fluids) during operations and maintenance, while keeping the aircraft at the appropriate level of quality and performance.

For EDA, apart from the technology development carried out, several demonstrators were designed, manufactured and tested. They represent around 40 realistic aircraft parts, incorporating the most relevant technologies developed upfront in the project by members and partners through Calls for Proposals in the fields of materials, surface treatments, production methods including additive manufacturing, biomaterials, and recycling.

The extensive use of novel developed LCA tools compliant with ISO guidelines and coupled to a newly-developed database for key aeronautical processes allowed for the support of a proper technology selection, providing valuable ecological assessments to compare the validity of new more eco-compliant solutions.

For EDS, two large scale ground test benches to improve the understanding of aircraft electrical and thermal aspects, in conjunction with the use of advanced modelling tools, were developed.

Test capabilities to reproduce aircraft electrical architectures were enhanced through the project managing the evolution of COPPER BIRD ground test bench at Safran Electrical & Power, providing a step forward compared to efforts made in a previous POA (Power Optimized Aircraft) EU project.

A completely new thermal test bench was developed at Fraunhofer IBP to reproduce realistic conditions to evaluate thermal management aspects inside an aircraft. Three realistic aircraft fuselage sections (composite cockpit, metallic cabin and rear section-empennage) have been made ready for the purpose.

Major achievements and potential impact

In the field of aeronautical structures, new greener surface treatment technologies have been developed and further matured to reduce the use of hazardous substances in aeronautical parts.

Aspects like lower resources consumption, waste and emissions reduction and increased recyclability of components have been considered and applied as good practices in developing new manufacturing technologies and processes. For example, Out-of-Autoclave
The funding of the project can be summarised as follows:

<table>
<thead>
<tr>
<th></th>
<th>Initial value</th>
<th>value in February 2016</th>
</tr>
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<tbody>
<tr>
<td>GAM 2008-2015+2016</td>
<td>41,79</td>
<td>39,42</td>
</tr>
<tr>
<td>GAP</td>
<td>14,51</td>
<td>15,6</td>
</tr>
<tr>
<td>TOTAL</td>
<td>56,3</td>
<td>55,02</td>
</tr>
</tbody>
</table>

and Liquid Composite Moulding technologies are suitable processes to be further enhanced for the development of composite aircraft components. Combined one-shot curing processes could reduce lead-time to produce more integrated structures.

Increased use of novel low-weight Aluminium Alloys (such as Aluminium-Lithium Alloys), titanium and magnesium parts, technologies to reduce Buy-to-Fly ratio such as additive manufacturing allow the realisation of optimised and lighter metallic structures which will be less energy-consuming to produce and to fly. Development of long life structures extending materials and parts life performance will also save raw materials production and delay aircraft ground maintenance.

End of life phase with the main focus on material identification, recovery such as carbon fibres recovery, and recycling of insulation materials also have potential for further development.

Newly-developed tools in the Eco-Design ITD will support engineers in the environmental impact assessment of new aircraft development, starting from a disciplined and ISO compliant process to collect and analyse data.

In the field of electrical architectures and components aimed at more electrical aircraft applications, Eco-Design developed and made available two key test benches (electrical and thermal) that could provide the framework to test and prove novel, more efficient solutions for aircraft on-board generation and distribution systems, accelerating the introduction of more electrical solutions into the market.

Key statistics

- Associates: a Swiss cluster led by RUAG, a Netherlands cluster led by Fokker, HAI, IAI and Airbus Group Innovation
- Total beneficiaries: 41
- 69 projects have been conducted since 2009 by Partners representing the involvement of 105 additional entities (figure 1).
Through its six ITDs (Integrated Technology Demonstrators), Clean Sky aims to bring technologies to maturity that could, as a set of solutions, deliver a substantial majority of the ACARE SRIA goals for the environment. These ACARE goals relate to aircraft technology which could be available by 2020 for introduction into future product developments.

From the very beginning it was recognised that successfully monitoring progress towards the ACARE goals would require a cross-cutting evaluation platform in the Clean Sky programme. The Technology Evaluator (TE) was born from this need, and its composition reflects the need to pool the know-how and simulation/modelling capabilities that exist among industry, research establishments and academia.

The major aeronautical research establishments in Europe are TE members, with leading roles in the main technical work packages. The 12 ITD leaders are also represented in the TE, to ensure appropriate interaction between all the actors in a fully collaborative way of working.

The process is based on the outcomes of activities conducted in the so-called ‘vehicle ITDs’: in essence, the technologies developed, matured and demonstrated in the ITDs are ‘clustered’ in coherent and mutually compatible solution sets that define a potential future aircraft (conceptual aircraft). Then, within the TE, the conceptual aircraft are used in different evaluation scenarios according to sector and segment. These conceptual aircraft are ‘flown’ (i.e. simulation scenarios are evaluated) and Clean Sky’s environmental results are measured and reported by comparing these concept aircraft to reference aircraft representing state-of-the-art technology from the year 2000.

The comparisons are performed at three levels: the level of a single flight, or ‘mission’; the level of illustrative airports; and finally across the global air transport system (ATS).

The environmental performances evaluated through this process can be summarised as follows:

- Reductions of 32% CO2 and 40% NOx for the global aircraft fleet
- Reduction of 5dB(A) noise Lden on average for 6 European airports
More specifically for large commercial aircraft, the advanced concept platform using a Contra Rotating Open Rotor (CROR) and a ‘smart’ laminar-flow wing brings a very promising CO2 improvement and a positive perceived noise result.

In the regional aircraft segment, substantial improvements in environmental performance have been confirmed in terms of CO2 and especially outstanding Noise Area reduction.

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, by halving the noise footprint on take-off.

The total environmental impacts of the whole life cycle of the conceptual business jet have been found to be reduced by about 35% for GWP (Global Warming Potential) and ADP (Abiotic Depletion Potential) fossil compared to the reference.

In rotorcraft, within the various rotorcraft classes and type of missions, improvements in noise footprint and emissions have been demonstrated. With the range of innovative technologies that has been developed for the various rotorcraft platforms, it is possible to come close to or even overcome the targets.

The TE was constructed from the outset as a 'federated system' of simulation and modelling to enable all contributing 'constituencies' in the evaluation process to best use their skills. And importantly, it allows proprietary technology and design information to reside with its owners, and this is of great importance in terms of safeguarding competitive know-how.

The TE has successfully implemented a unique Technology Evaluation process involving robust and independent analysis of performance gains and extensive simulation of aircraft in airport and air transport system level scenarios.

Key statistics
- Leaders/Coordinators: Thales – Laurent Meunier: laurent.meunier@fr.thalesgroup.com and DLR – Alf Junior: Alf.Junior@dlr.de
- Funding: 14.8 M€
UPCOMING EVENTS

6th Call for Proposals

Check our website and the European Commission’s Participant Portal for news on the upcoming 6th Call for Proposals for Clean Sky 2.

http://cleansky.eu/calls

Clean Sky 1 Closing Event - 21-22 March 2017

The Clean Sky event ‘Europe, Innovation and Aviation – Are we keeping up?’ is taking place on 21-22 March 2017. This two-day event is an opportunity to mark the closing of Clean Sky 1. The first day features a series of keynote speeches and debate by high-level representatives from the industry, European Parliament and the European Commission, all involved in Clean Sky. The second day focuses on the technical platforms of Clean Sky 1, with breakout sessions dedicated to reporting the results and achievements.

We look forward to welcoming you on 21-22 March! If you aren’t able to attend, keep an eye on our website and social media for live updates and pictures from the event!

Clean Sky at Le Bourget 2017

The International Paris Air Show (Le Bourget) will take place on 19-25 June 2017. Clean Sky will participate with a demonstration stand showcasing many pieces of innovative technology. Save the date now!

http://cleansky.eu/calls

Save the date: Joint JTI event in Strasbourg, October 2017

Clean Sky is pleased to invite you to save the date for a joint JTI event which will take place in Strasbourg in October 2017. At this two-day event, seven Joint Undertakings – Clean Sky, BBI, ECSEL, FCH, IMI, SESAR, and Shift2Rail – will join forces to present the very best of European innovation and research across a wide range of topics.

‘Innovation Takes Off’ book

‘Innovation Takes Off’, a book by Cherche Midi publishing house, charts the story of European aviation from its beginning to today. It focuses on how the European Union’s vision and policy on excellent research and innovation has led to Clean Sky as a tool to develop innovative technologies to reduce the environmental footprint of aviation. You will read about the highlights of the Clean Sky 1 programme alongside pictures and quotations from the public and private participants involved. ‘Innovation Takes Off’ is available in print in English and French. You can purchase it from www.cherche-midi.com, or please contact us at info@cleansky.eu to request your copy.

‘Innovation Takes Off’ is also available on our website now – we hope you enjoy it!