CLEAN AVIATION
JOINT UNDERTAKING

2021

Consolidated Annual Activity Report

In accordance with Article 26 of the Council Regulation (EU) 2021/2085 of 19 November 2021 establishing the Clean Aviation Joint Undertaking and with Article 23 of the Financial Rules.

The annual activity report will be made publicly available after its approval by the Governing Board.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

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FACTSHEET

Name	Clean Aviation Joint Undertaking
Objectives	The Clean Aviation Joint Undertaking has the following specific objectives: (a) to integrate and demonstrate disruptive aircraft technological innovations able to decrease net emissions of greenhouse gases by no less than 30% by 2030, compared to 2020 state-of-the-art technology, while paving the ground towards climate-neutral aviation by 2050; (b) to ensure that the technological and the potential industrial readiness of innovations can support the launch of disruptive new products and services by 2035, with the aim of replacing 75% of the operating fleet by 2050 and developing an innovative, reliable, safe and cost-effective European aviation system that is able to meet the objective of climate neutrality at the latest by 2050; (c) to expand and foster integration of the climate-neutral aviation research and innovation value chains, including academia, research organisations, industry and SMEs, also by benefiting from exploiting synergies with other national and European-related programmes and by supporting the uptake of industry-related skills across the value chain.
Founding Legal Act	Council Regulation (EU) 2021/2085 of 19 November 2021
Executive Director	Axel Krein, Executive Director
Governing Board	Rosalinde van der Vlies, Chair (European Commission), Sabine Klauke, Co-Chair (Airbus) Composition of the Governing Board: European Commission (DG RTD and DG MOVE) + 15 private members (Aircraft 4 seats: Airbus, Aernnova,Dassault, Leonardo; Engines 4 seats: GE AVIO, MTU, Rolls-Royce, Safran; Equipment/Systems 3 seats: Liebherr, Collins UTRC, Honeywell; RTOs 2 seats: DLR, ONERA; Universities 1 seat: University of Patras; SMEs 1 seat: Pipistrel) + EASA as observer.
Other bodies	States Representatives Group; Scientific Advisory Body; Technical Committee, ITD/IADP Steering Committees and TA Coordination Committees
Staff	41 posts filled by 31.12.2021 (excl. 1 SNE)
2021 Budget	€182.1 million commitment appropriations; €189.5 million payment appropriations (Title V unused included)
Budget implementation	99.7 % in commitment appropriations and 82.3 % in payment appropriations (Title V not included)
Grants	9 H2020 GAMs — total value €1.134 million; 543 H2020 GAPs — total value €519 million.
Strategic Research Agenda	See chapter 1 and Annex 10
Call implementation	Number of calls launched in 2021: none. Number and value of tenders (if any): none.
Participation, including SMEs	Total number of participations in funded projects: 1887[2] which consists of: 29% SMEs (555 participations), 22% IND (411 participations), 24% UNI (459 participations), 25% RES (461 participations)

[1] Not counting Leader actions and counting each funded proposal from Calls as one project.
[2] Participations in CfP01-11 and CPW01-04.

FOREWORD

2021 was a crucial year for the Clean Sky Joint Undertaking. It was the year that the decision was made to continue and accelerate Clean Sky's work in the form of the new European Partnership for Clean Aviation towards developing and demonstrating the required technologies for the climate-neutral aircraft of the future.

Clean Aviation was launched on 1 December 2021, alongside 8 other public-private partnerships that will bring together public and private resources to address the EU's research and innovation needs. Clean Aviation's goal is to make Europe the first continent to have a climate-neutral fleet of aircraft by 2050.

That's an ambitious goal, but Clean Aviation is not starting from scratch. It will build on the strong foundations laid by the work of the Clean Sky and Clean Sky 2 Joint Undertakings.

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

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

Some of the greatest success stories of Clean Sky in 2021 included strides made in the MultiFunctional Fuselage Demonstrator, the UltraFan engine, the SAAFIR propulsion test bench, the RACER helicopter, Next Gen Commercial Tilt Rotor, the Smart Integrated Wing, and many more. All of these initiatives are contributing to the achievement of Clean Sky's objectives: to reduce CO_2, NOx and noise emissions by 20-30% compared to 'state-of-the-art' aircraft entering into service as from 2014.

Clean Sky 2 monitors its progress closely, thanks to a system called the Technology Evaluator. The first Global Assessment of Clean Sky took place in 2021 and revealed that the Joint Undertaking is well on its way to achieving its goals!

The success of our demonstrators and technologies is a testament to all 5000 scientists and engineers from 30 countries, across industry, academia, research centres and SMEs, that have worked on Clean Sky 2 projects over the course of the last decade.

The Clean Aviation Joint Undertaking will utilise the gains made in the Clean Sky programmes to leapfrog beyond the next generation of aviation technologies, using a revolutionary rather than evolutionary approach. Our first call will be launched in spring 2022, and we will be focusing on three main thrusts going forwards: hybrid electric & full electric architectures, ultra-efficient aircraft architectures, and disruptive technologies for hydrogen-powered aircraft.

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

Last but not least, launching a new Joint Undertaking and showcasing our results as they come to fruition is a major communications task. During 2021, we developed and launched a new corporate identity for the Clean Aviation Joint Undertaking, updated our online stand, created a brand new website, and organised the first online annual Clean Sky conference: Clean Aviation for a Competitive Green Recovery in Europe: Innovative Ideas Take Flight, which featured two European Commissioners and attracted more than 1000 participants.

I am delighted to share this Annual Activity Report with you, to showcase the best of Clean Sky 2 over the past year. I am certain that the Clean Aviation Joint Undertaking will continue to build on the momentum and the achievements of Clean Sky 2 to fuel a climate-neutral Europe by 2050. The future looks bright!

Axel Krein

Executive Director

THE RENEWED CLEAN AVIATION PARTNERSHIP UNDER HORIZON EUROPE

2021 marked the launch of the Clean Aviation Joint Undertaking through its establishment by Council Regulation 2021/2085, as adopted by the European Council on 19 November 2021 and entering into force on 30 November. The resulting Clean Aviation programme will run from 2022 until the end of 2031 and foresees EU funding of €1.7 billion over its lifetime, to be complemented by € 2.4 billion in private investment through in-kind contributions.

The following specific high-level objectives for the Clean Aviation Joint Undertaking have been laid down in the Council Regulation 2021/2085:

a. to integrate and demonstrate disruptive aircraft technological innovations that are able to decrease net emissions of greenhouse gases by no less than 30% by 2030, compared to 2020 state-of-the-art technology, while paving the ground towards climate-neutral aviation by 2050;
b. to ensure that the technological and the potential industrial readiness of innovations can support the launch of disruptive new products and services by 2035, with the aim of replacing 75% of the operating fleet by 2050 and developing an innovative, reliable, safe and cost-effective European aviation system that is able to meet the objective of climate neutrality at the latest by 2050;
c. to expand and foster integration of the climate-neutral aviation research and innovation value chains, including academia, research organisations, industry and SMEs, also by benefiting from exploiting synergies with other national and European related programmes and by supporting the uptake of industry-related skills across the value chain.

Throughout the year, the preparation of the membership and all related commitments and agreements were finalised. 27 Founding Members committed to the Joint Undertaking through a collective Letter of Commitment securing €2.4 billion in private in-kind contributions. Importantly, in following of the Call for Ideas / Interest in Membership launched under the supervision of the European Commission late 2020, an assessment with independent experts was concluded on all submitted ideas and expressions of interest. Some key facts and figures:

- 82 ideas were submitted. After finalisation of the expert panels' assessment, 7 ideas were retained and provided to the stakeholder team preparing the update to the Strategic Research and Innovation Agenda (SRIA) for their inclusion;
- In all, 670 participations from 359 unique entities were involved in the ideas submitted. In 60 cases, the expression of interest for potential membership of the Clean Aviation Joint Undertaking was followed by further enquiries related to the parties expressing this interest. 18 parties replied with a confirmed interest and a potential ability to join the private members' commitment letter related to in-kind contributions. Ultimately, 12 entities were proposed to the Governing Board, and were accepted as Associated Members of the Joint Undertaking, from the date of the first GB on 16 December 2021.

Hence in total, the Clean Aviation Joint Undertaking closed the year with a total of 39 members other than the European Union.

In parallel, ongoing discussions and preparations focused on designing the new Joint Undertaking's first Work Programme and the technical strategy flowing from the Strategic

Research and Innovation Agenda.

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

When combined with the effect of sustainable low- or zero-carbon fuels, the aircraft developed as a consequence of the Joint Undertaking's research and innovation will enable net CO_2 reductions of 86-90%. The Clean Aviation Joint Undertaking will as such contribute significantly towards the ambitious environmental impact mitigation goals of the European Green Deal and Regulation (EU) 2021/1119 of the European Parliament and of the Council ('European Climate Law'), that is to say a 55% emissions reduction by 2030 compared to 1990 levels, and climate neutrality at the latest by 2050 in line with the Paris Agreement adopted under the United Nations Framework Convention on Climate Change.

The Strategic Research and Innovation Agenda [SRIA] was adopted on 16 December 2021 at the new Joint Undertaking's first Governing Board. It sets out the way to achieve these specific objectives and the overall vision, in terms of timescales and magnitude of impact. The partnership will also build upon the important technological progress that was made under the Clean Sky and Clean Sky 2 programmes to achieve these objectives and secure the targeted impact. The Clean Aviation trajectory towards climate neutrality by 2050 defines two clear horizons:

- **2030:** demonstrating and introducing low-emissions aircraft concepts exploiting the research results of Clean Aviation, making accelerated use of sustainable fuels and optimised 'green' operations, so these innovations can be offered to airlines and operators by 2030 for an entry into service [EIS] in the 2030-2035 timeframe;
- **2050:** climate neutral aviation, by exploiting future technologies matured beyond the Clean Aviation phase coupled with full deployment of sustainable aviation fuels and alternative energy carriers such as hydrogen.

The adoption of the SRIA also confirmed the three key thrusts for the R&I efforts in Clean Aviation, that will drive energy efficiency and emissions reductions of future aircraft. They will form the architecture of the Joint Undertaking's 10-year programme:

- **Hybrid electric and full electric architectures** – driving research into novel (hybrid) electrical power architectures and their integration; and maturing technologies towards the demonstration of novel configurations, on-board energy concepts and flight control.
- **Ultra-efficient aircraft architectures** – to address the short, medium and long-range needs with innovative aircraft architectures making use of highly integrated, ultra-efficient thermal propulsion systems and providing disruptive improvements in fuel efficiency. This will be essential for the transition to low/zero emission energy sources (synthetic fuels, non-drop-in fuels such as hydrogen), which will be more energy intensive to produce, more expensive, and only available in limited quantities.
- **Disruptive technologies to enable hydrogen-powered aircraft** – to enable aircraft and engines to exploit the potential of hydrogen as a non-drop-in alternative zero-carbon fuel, in particular liquid hydrogen.

The thrusts will chiefly target two pivotal aircraft demonstration programmes: the hybrid electric regional and the ultra-efficient short-medium range aircraft concepts. These aircraft demonstrations will enable the integration of technologies that have been matured and demonstrated into new aircraft concepts, and provide a clear understanding of the full aircraft performance achievable at a high maturity and fidelity, as of 2030. The two aircraft demonstration programmes will also anticipate the operational and certification issues (CS 25) of future aircraft models, and are relevant for an actual in-service introduction of the disruptive innovations.

The research agenda for Clean Aviation is shown in the figure below with a mapping of the potential applicability of the aforementioned thrusts to the most relevant aircraft categories.

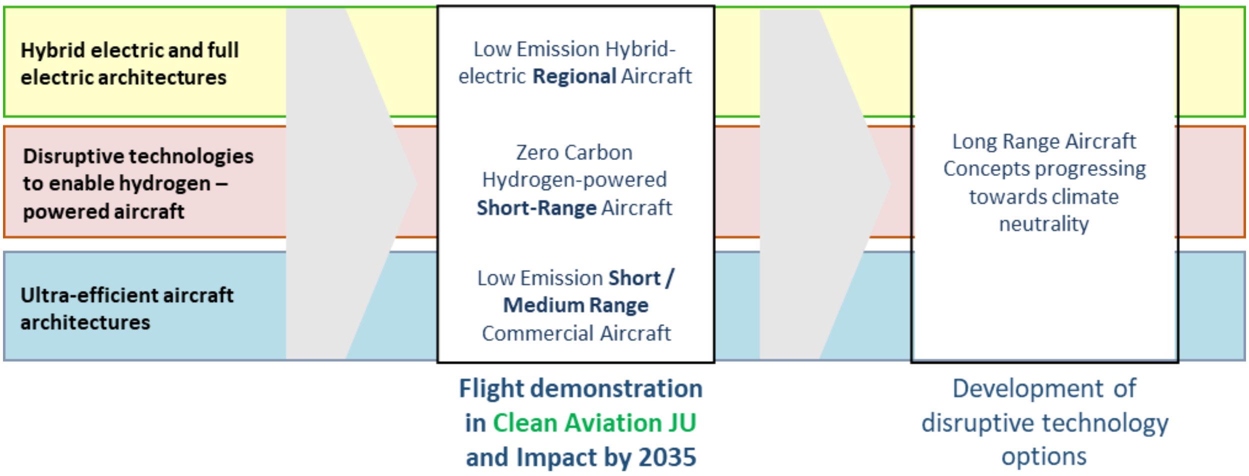

Figure: Mapping of the research thrusts against aircraft categories and concepts

The primary focus of the demonstration efforts will be on the hybrid electric regional and the ultra-efficient short-medium range aircraft concepts. The approach will involve a stepwise development and demonstration strategy, offering opportunities for technology spin-off to other aircraft categories: on one hand towards commuter and vertical lift applications that can benefit from the hybrid-electric technology development; on the other hand, from the ultra-efficient architectures towards long-range applications. This will allow a much broader deployment in the overall air transport system with important additional environmental and climate-related benefits.

Impact of Clean Aviation Programme

The target performance levels across the aircraft categories selected for demonstration in Clean Aviation are shown in the table below.

Aircraft Class	Key technologies and architectures to be validated at aircraft level in roadmaps	Earliest EIS Feasibility	Fuel/ energy reduction (technology)[1]	Reduction in net emissions (incl. fuel effect)[2]	Current share of air transport emissions
Regional Aircraft	Hybrid-electric, distributed propulsion coupled with highly efficient aircraft configuration	~2035	-50%	-90%	~5%

Short-Medium Range Commercial Aircraft	Advanced ultra-efficient aircraft configuration and ultra-efficient gas turbine engines, ultra-high bypass (possibly open rotor)	~2035	-30%	-86% ~50%

Table: Clean Aviation aircraft category targets

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

Implementing the programme: what to expect in 2022

In the first quarter of 2022 the Clean Aviation Joint Undertaking will launch its first open call for proposals, so that the technical activities in all three thrusts of the programme can start before the end of this year. This call will allow for an aggressive start to the programme and will commit over 40% of the funding available over the life of the programme. A second open, more modest call is foreseen in early 2023.

In addition to the calls for proposals the JU will launch two open Calls for Expression of Interest (CEI) within the 2022-2023 period, see chapter 3.2.5. The first CEI will aim to facilitate strategic cooperation with Member States, regions and associated countries and will invite all interested national and regional authorities who want to invest in the aviation sector, and share the objectives and vision of the Clean Aviation Joint Undertaking and the European Green Deal goals, to express their intention to engage with the Programme in identifying and exploiting synergies. This will increase the Clean Aviation Joint Undertaking's impact at national and regional level.

The second Call for Expression of Interest will address interested private stakeholders to become an Associated Member of the Joint Undertaking. Successful applicants will be those who can demonstrate strategic and long-term commitment to the programme, as well as those who can perform core tasks and bring key capabilities to implement the programme through the research actions in which they may be or may become involved.

EXECUTIVE SUMMARY

The year in perspective – member and partner research activity highlights:

Each of the programme areas managing the various research, technology development and demonstration activities, i.e. the Innovative Aircraft Demonstration Platforms (IADPs), Integrated Technology Demonstrators (ITDs) and Transverse Activities (TAs), is briefly further highlighted below.

Here below is a brief overview of the resource consumption versus milestones and deliverables at the end of 2021, when considering the 2020-2021 (cumulative) period at programme level:

2020-2021 (cumulative) Results vs. Plan (%)	
Resources	91%
Deliverables	81%
Milestones	69%

The recovery plan implemented in 2020-2021 proved to be robust in the light of 2021 results, with:

- 107 demonstrators at completion, 30% completed in 2021;
- the execution rate is situated at ~90% of the total programme members' effort and above 80% of the deliverables achieved by end 2021.

It is worth noting that the 2022-2023 planning was revised to include the carry-over from 2020-2021 (unspent efforts and re-planned deliverables) in order to report on the remaining activities until programme end. The next period will be a critical as 70% of the results are expected to be delivered in the last two years of the programme with a remaining funding of ~10% at programme level. In addition, the risk of delays in some IADP/ITD areas remains high and requires specific monitoring from the members in order to deliver their results within the lifetime of the Clean Sky 2 programme. In the next period, all IADP/ITD/TA are expected to confirm the plan to completion via the mid-year assessment (due in July 2022) and the interim progress reviews will play a central role in the assessment of the cumulative performance achieved and confirm the delivery plan of results as per schedule.

➔ LPA – Large Passenger Aircraft IADP

By the end of 2021, the IADP spent 88% of the initial resources planned to achieve 79% of the deliverables and to pass 58% of the milestones scheduled accross the period 2020-2021.
In 2021, LPA mainly focused on the continuation of its activities dedicated to large-scale demonstration of technologies integrated at aircraft level via its three distinct 'Platforms':

In Platform 1, good progress was made on the N+1 Engine Nacelle design and technology bricks for early exploitation on the Long Range aircraft type, and the design was almost completed for

integration systems of UHPE engines on Short & Medium Range (SMR) aircraft. Key decisions were taken for the future architecture of the N+2 Engine generation (e.g. the Boundary Layer Ingestion concept has now been stopped); the final architecture selection is still planned for mid-2022.
Concerning airframe drag reduction technologies, good progress was made on hybrid laminar flow technologies for airfoils with a large scale Horizontal Tail Plane demonstrator tested in Q4 2020, and TRL3 passed for HLFC applications on wings.
For radical aircraft configuration studies, significant progress was made to increase confidence and to de-risk an advanced SMR configuration for the 2035 timeframe. A Distributed Electric Propulsion architecture was thus selected for the Scaled Flight Test Demonstrator and the first flight tests on classical configurations will be performed in Q1 2022.

In Platform 2, the first major parts of the Multi-Functional Fuselage Demonstrator were produced (e.g. Lower Shell Skin) as well as most of the elementary parts. Manufacturing trials were pursued to prepare the production process for the real demonstrator parts. The latest generation of the Platform Concept Demonstrator was equipped with Cabin and Systems to bring the evidence for zero customisation at airframe as an industrial approach. Cargo fire tests on the Environmentally Friendly Fire Protection demonstrator were conducted in a real burn chamber.

In Platform 3, activities on the Large Aircraft Disruptive Cockpit Demonstrator progressed, in particular for cockpit avionics functions and technologies development, LIDAR flight test installation and the icing flight tests campaign. For the Regional Aircraft active cockpit demonstrator, progress was made on the key technologies aiming to reduce pilot workload. Considering Business Jet, progress was observed in the activities including multimodality and refinement of Pilot State Monitoring algorithm detection.

➔ REG – Regional Aircraft IADP

By the end of 2021, the IADP spent 86% of the initial resources planned to achieve 75% of the deliverables and to pass 75% of the milestones scheduled accross the period 2020-2021.
Activities related to green conceptual regional aircraft performed during 2021 further substantiated the achievement of the ambitious environmental Clean Sky 2 targets. All demonstrators achieved good progress toward the master plan. Several wind tunnel tests were completed, and the manufacturing and assembly of the on-ground full-scale demonstrators significantly progressed thanks also to recovery actions promptly activated to solve technical/manufacturing issues that had arisen during this phase. Regarding the in-flight demonstrators, an important achievement for Flying Test Bed 1 (FTB#1) was the execution of ground structural/functional tests of morphing winglet and innovative wingtip. Great achievements for Flying Test Bed 2 (FTB#2) were the completion of the aircraft modification, the completion of the flight test preparation and the achievement of the permit to fly (PtF), with the first taxi and rejected take off tests being completed. In addition, hybrid-electrical configurations studies focused on a promising architecture with Distributed Electrical Propulsion (DEP).

➔ FRC – Fast Rotorcraft IADP

By the end of 2021, the IADP spent 88% of the initial resources planned to achieve 102% of the deliverables and to pass 93% of the milestones scheduled accross the period 2020-2021.
The Fast Rotorcraft IADP consists of two separate demonstrators, the NGCTR Tiltrotor and the RACER compound helicopter. The NGCTR technology demonstrator (WP1) successfully held its aircraft critical design review (CDR) in 2021. Initial engagement was held with airworthiness authorities as a preparation for flight clearance. The basic configuration of donor fuselage was completed and the final assembly started.

The manufacturing of the RACER major sub-system made major progress in 2021, allowing the demonstrator lay-up to be started and finalising the fuselage assembly. The gear boxes' critical design review (CDR) was closed in 2021, ensuring the delivery of all drawings and the start of long lead-time items manufacturing. Key ground test benches were also run (e.g. lateral fatigue tests for permit to fly, systems integration rig, fuel system leakage tests on demonstrator) or prepared (e.g. delivery of lateral gear box test bench, delivery of structure test specimens).

➔ AIR – Airframe ITD

By the end of 2021, the ITD spent 96% of the initial resources planned to achieve 91% of the deliverables and to pass 86% of the milestones scheduled accross the period 2020-2021.Novel concepts of engine integration on rear fuselage such as scarfed nozzle and BLI were further studied. Down-selected novel aircraft architectures were further assessed and UHBR concept further matured. Development of tools for virtual modelling for certification continued. Concepts and technologies on NLF and HLFC for nacelles, wings, HTP and VTP were further developed. Manufacturing and testing of composite flaperon, innovative cargo door, and composite wing root box demonstrators were carried out. Activities on design of load and flutter control laws, WIPS integration on innovative control surfaces and study of innovative movables continued. Technologies and demonstrators maturation for large aircraft ergonomic flexible cabin and full scale BJ cabin mock-up demonstrator manufacturing started. The RACER wing component was delivered and scaled demonstrator manufacturing for SAT optimised composite wing completed. Design of the full-scale Out of Autoclave composite wing was frozen and manufacturing activities started as well as preparation of the full-scale tests. Manufacturing of regional aircraft composite HTP and VTP demonstrators was carried out. PDRs at system level for HVDC and EMAs for REG FTB#2 spoiler and aileron were performed and embedded antenna validated on ground. SAT jigless technologies were assessed and those related to affordable manufacturing fully tested. RACER's rotorless tail was delivered. NGCTR's donor structure was delivered and the tail section design was completed. Regional aircraft full scale fuselage stiffened panels were manufactured and final elements design for cabin interiors completed. Eco-Design relevant flagship demonstrators were designed in detail, continuing LCA data collection, and new materials and manufacturing technologies completed and validated.

➔ ENG – Engines ITD

By the end of 2021, the ITD spent 106% of the initial resources planned to achieve 84% of the deliverables and to pass 61% of the milestones scheduled accross the period 2020-2021.

The Engine ITD progressed in delivering results and preparing the final demonstrations. For the Ultra-High Propulsive Efficiency (UHPE) Demonstrator for Short / Medium Range aircraft (WP2), the technology maturation plan has progressed well through the completion of several rig test campaigns on the key enabling technologies preparing the Engine Ground Test Demonstrator. It is worth noting that WP2 (UHPE) tests are postponed to 2024 to align with the evolution of the engine concept architecture anticipated in the Clean Aviation programme to maximise the results. A careful monitoring is in place to ensure achievement of the objectives by the Programme end by the members. For the Business Aviation / Short Range Regional Turboprop Demonstrator (WP3), the Tech TP demonstrator was modified to integrate the PAGB with an electrical machine to start to test hybridised functions. In parallel, PAGB rig dynamic commissioning was completed and the mixed flow compressor was successfully tested at rig level. For the Advanced Geared Engine Configuration (WP4), the engine demonstrator detailed design was completed and the conceptual design of the two-spool rig compression system finalised with the Preliminary Design Review and Test Concept Review passed.
For the Very High Bypass Ratio (VHBR) Middle of Market Turbofan technology (WP5) most of the IPT aerodynamic and aero-acoustic rigs have completed testing with results analysed. The High Pressure Turbine rig was assembled and is being commissioned in readiness for the test campaign. The Very High Bypass Ratio (VHBR) Large Turbofan Demonstrator (WP6) engine programme has successfully completed the overall engine Test Readiness Review (TRR) and the first ground test engine is currently being built with testing planned for early in 2022.
For the reliable and more efficient operation of small turbine engines (WP8), the hybrid electric architecture for SAT application was selected after evaluation with the airframer. Technology development on the additive combustor progressed and the compressor studies were finalised.

➔ SYS – Systems ITD

By the end of 2021, the ITD spent 84% of the initial resources planned to achieve 78% of the deliverables and to pass 61% of the milestones scheduled accross the period 2020-2021.
In 2021 the activity progressed in line with the SPD objectives and the year's most significant achievements are hereafter summarised. To complete the Avionics and Cockpit work, the Integrated Modular Communications technologies progressed beyond TRL4, achieving its ground test to support end-to-end demonstration in 2022. Flight control systems activity delivered EMAs key tests to contribute to REG FTB#2 flight test campaign and progressed in the large aircraft smart integrated wing demonstrator with hydraulic power module integration.
In the Electrical systems domain, a preliminary definition of the large aircraft PROVEN integrated demonstrator was performed.
Landing Gear Green Taxiing progressed beyond TRL5 and the Electro-Hydraulic Nose Landing Gear Component reached TRL6 to prepare for aircraft integration in 2022.
In the field of Environmental Control Systems (ECS), the next generation Electrical ECS concept reached TRL4 and laboratory tests were completed in the area of air sensing advanced technologies, while a CDR was passed for the Adaptive ECS. Equipment development for Cabin & Cargo progressed to prepare for the final demonstration in 2022.
Regarding SAT, a first flight test campaign of EV-55 aircraft was performed integrating selected enabling technologies of future avionics paving single pilot operations.

➔ ECO – Eco-design transverse activity (TA)

By the end of 2021, the TA spent 72% of the initial resources planned to achieve 28% of the deliverables and to pass 75% of the milestones scheduled accross the period 2020-2021.
Concrete applications were defined as flagship demonstrators in each IADP/ITD for the Master Plan 2022-23 to showcase ecological and economical improvements with regard to Design for Environment DfE2020+. The Master Plan for each SPD was confirmed including the contribution of the different flagships demonstrators (FSDs), paving the way for the eco assessment in 2022-23. Coordinating and monitoring the delivery of life cycle data from SPDs to Eco TA ecoDESIGN analysis is an ongoing challenge. Based on the Life Cycle Data received to date, a set of ground pollution potential indicators has been defined and first LCA / Eco Statement reports have been issued. Due to the Covid-19 pandemic, situation meetings were limited to online sessions. Physical workshops and conference events have been postponed to the 2022/23 period.

➔ SAT – Small Air Transport Transverse (TA)

By the end of 2021, the TA spent 55% of the initial resources planned to achieve 73% of the deliverables and to pass 78% of the milestones scheduled accross the period 2020-2021.
Within the Small Air Transport Transverse Activity (SAT TA), a second design loop of the Green commuter aircraft integrating technologies matured at CDR level was done for the Green 19-seats small commuter. E-STOL (Electric/Hybrid Short Take-Off and Landing) conceptual studies have further matured. SAT Demonstrators D1 (Aircraft level 0) and D2 (Smart Wing Health Monitoring) are being prepared to start tests in 2022. Test Phase 1 of SAT D3 (Safe and Comfortable Cabin) was successfully accomplished.

➔ TE – Technology Evaluator

By the end of 2021, the TE spent 89% of the initial resources planned to achieve 89% of the deliverables and to pass 100% of the milestones scheduled accross the period 2020-2021.
Although the first assessment reports were issued as deliverables in 2020, the detailed performance results of the Clean Sky 2 aircraft concepts and their impact at airport and fleet level were unveiled in the First Global Assessment full technical report and available as an executive summary (synopsis report)[1]. The major milestone in relation to the Technology Evaluator activities in 2021 included the delivery and update of SPD aircraft models in preparation for the 2nd global assessment.
On the JU side, a major achievement was the publication, selection and launch of the Socio-Economic study (incl. Covid-19 impact) as a Call for Tender. The contract was awarded. The project is currently running and should be concluded in Q2 2022.

[1]The first Global Assessment full technical report and its executive summary (synopsis report) are both accessible via the JU website: https://www.clean-aviation.eu/media/news/clean-sky-2-is-well-on-track-says-technology-evaluator-first-global-assessment

1. IMPLEMENTATION OF THE ANNUAL WORK PLAN 2021

1.1. Key objectives 2021 and related results

The JU has implemented various tools to monitor the execution of the programme in terms of productivity, achievements, planning and risks of the operations:

- Quarterly Reports of the ITD/IADPs, which inform on the resource consumption, the achievements and the resulting forecasts for project implementation;
- Steering Committees at ITD/IADPs level with involvement of the CS2 project officers;
- Periodic Reviews of the performance of the ITD/IADPs and TAs organised by the JU with the involvement of independent experts;
- This monitoring information is summarised and reported regularly to the Governing Board.

The overall objectives for the Clean Sky 2 programme for the year 2021 have been achieved as described in the following table:

Objective in the Work Plan	Status	Comments
To execute the technical content as defined for the two-year period and ensure this is adequately incorporated in the *Clean Sky 2 Development Plan* and the grant agreements;	**Technical programme for 2020-2021 achieved [>80%]**	The Programme Office conducts yearly assessments of the strategic planning. The last and final revision of the Clean Sky 2 Development Plan (CS2DP) took place in 2021 to capture the main evolutions in terms of: financial adjustments to mitigate technical risks or seize funding opportunities, TRL decreased/increased. It is worth noting that the scope of work for most of the demonstrators (> 95%) remains unchanged, confirming the ambition at programme end. The revisions were presented to the Governing Board in October and the CS2DP was subsequently adopted at the end of 2021. The Work Plan 2022-2023 adopted by the Board in November 2021 was prepared in line with the revised Clean Sky 2 Development Plan.
To determine in the course of 2020-2021 the definitive configuration of the programme's major demonstrators and technology development themes, based on robust risk and progress reviews based on the baseline set in the CS2DP; where necessary diverting resources to safeguard the achievement of the programme's High-Level Objectives [HLOs] to start delivering the first results expected in 2021;	**Ongoing, on track**	The revision of the Clean Sky 2 Development Plan, endorsed by the Governing Board at the end of 2021, is the result of the in-depth analysis carried out by the members and the Programme Office over the year. It includes the planning of 107 programme demonstrators and the technology development schemes. It reflects on the current progress of the different demonstrators (based on results achieved and milestones passed so far) and includes the objectives at completion (maturity level). The list of major risks associated with the different areas of the programme was assessed and reported. The scope of work for most demonstrators (95%) remains unchanged confirming the ambition at

Objective in the Work Plan	Status	Comments
		programme end. A scope reduction or delay beyond 2023 was reported on 5% of the demonstrators and is a consequence of the prioritisation exercise within ITD/IADP/TAs to maximise the results at completion or to better align their contribution with the future Clean Aviation Programme. The Scientific Committee confirmed that the revised CS2DP is robust and well aligned with the High-Level Goals and the JU Work Plan. The programme entered its the delivery phase in 2021. Approximately one-quarter of demonstrators are delayed by 6.5 months on average compared to the situation reported last year. Delays are mostly due to technical difficulties that occurred during the year or due to external dependencies showing that, despite the Covid-19 pandemic still affecting the programme on some specific activities involving hardware, its impact was mostly mitigated by the members.
To implement solutions for leveraging Clean Sky 2 funding with structural funds		By the end of 2021, the following figures show progress in the action undertaken by the JU: 18 signed MoUs, 12 synergy labels, 52 pilot projects of more than €50 million in funding. The JU continues to develop strong support mechanisms to enable synergies with the ESIF by allowing complementary activities to be proposed by applicants to CS2 calls and by amplifying the scope of, adding parallel activities to, or continuing CS2 co-funded projects/activities through ESIF in synergy with the Clean Sky 2 Programme and its technology roadmap. The JU also promoted the use of ESIF to build and enhance local capabilities and skills in fields related to the programme, in order to enhance the level of European competitiveness of stakeholders in this area.
To implement effective and efficient management and governance of the programme;	Ongoing, on track	The overall management and governance of the programme is fully mature, with well-established procedures and bodies/committees. Every ITD/IADP/TA reports their results and performance to the Governing Board on a quarterly basis. Programme Coordination Committee (PCC) meetings are regularly organised (10 in total for 2021) to monitor the programme's progress and execution. In addition, annual reviews and interim progress meetings are organised along the year. The review cycle helps to properly manage and govern the programme through well targeted actions.
To implement an appropriate and agreed approach for each transverse area that allows for the transversal coordination to be executed and technical synergies to be extracted;	Achieved	For each of the TAs, coordination committees are fully operational and include key members from the contributing/participating IADP/ITDs. The JU is able to monitor progress and validate grant performance through the two axes of the periodic/annual reviews related to the TA as well as receiving reports from inside each participating IADP/ITD. In addition, the TA-related

Objective in the Work Plan	Status	Comments
		activities are clearly identified in the work breakdown structure of the IADP/ITD, allowing a proper monitoring and track record of resources and budget usage.
To implement one further call for proposals and, within this call, to implement the additional and complementary format of "thematic topics", enabling a wide range of competing technology solutions to address broad problem-oriented topics that are geared towards the Clean Sky 2 programme-level HLOs; To investigate essential breakthrough technologies (linked to future full and hybrid electrical propulsion aircraft) needed to prepare potential future Clean aviation partnership;	Achieved	The eleventh call for proposals (CfP11) launched in 2020 was the last and final call within the Clean Sky 2 Programme, and it included both complementary and thematic topics. The selected projects started in Q1 2021 and are ongoing/running.
To finalise and implement the impact assessment strategy and reference framework for the TE (including the selection of and the performance levels of reference aircraft against which the progress in CS2 will be monitored); to finalise the assessment criteria and evaluation schedule for the TE for each technical area; To complete the selection of its key participants; to conduct within the timeframe of the work plan the first TE assessment of CS2;	Achieved	The Technology Evaluator 1st Global Assessment, was publicly released in May 2021, under the form of 2 publications: the "Synopsis", a 16-page executive summary, and a 120-page "Full Technical Report". This milestone is a major contribution to the assessment of the progress towards the JU HLO, a key delivery for the TE (spanning all SPDs), and a key publication about the CS2 programme in the JU communication activities, now available to all stakeholders through the JU website. It includes the selection and the performance levels of reference aircraft against which the progress of the CS2 technology integration onto a number of advanced aircraft concepts has been assessed.
To disseminate information about the last call for proposals (for partners), in order to reach a healthy level of applications and ensure the success of the topics; including participation from SMEs higher than 35%. To proceed with the selection of participants through these calls;	Achieved	The JU has successfully maintained a good balance in terms of success rates for applicants versus wide and strong, open competition. SME participation (43% of winning applicants) remains healthy and on target. See also the reported results on KPIs.
To ensure a time-to-grant no greater than eight months for the calls for proposal in no less than 80% of topics and selected proposals;	Achieved	As reported in 2020, the "Time To Grant" (TTG) target was met with a significant margin (TTG < 8 months: 100% GA signed). The eleventh call for proposals (CfP11) launched in 2020 was the last and final call within the Clean Sky 2 Programme,

Objective in the Work Plan	Status	Comments
To execute at least 90% of the budget and of the relevant milestones and deliverables;		The JU has had a 99.6% rate[2] of implementation for the commitment appropriations in 2021. The payment appropriations were executed to 82.3% of the available funds[3].
To ensure a high level of technical and process integrity in the execution of the programme, including the calls and their resulting selection of CS2 participants; and a maximum relevance of research actions performed towards the programme's objectives.	Achieved	The monitoring and control mechanisms in place have allowed for the monitoring and proper alignment of activities (i.e. technical work as implemented across GAMs and GAPs) and the implementation of calls together with the programme objectives and the Work Plan. This exercise will continue until the end of the Clean Sky 2 Programme.

Environmental forecast

The environmental targets of the Clean Sky 2 programme are defined in the Council Regulation[4]:

a) To contribute to the finalisation of research activities initiated under Regulation (EC) No 71/2008 and to the implementation of Regulation (EU) No 1291/2013, and in particular the Smart, Green and Integrated Transport Challenge under Part III — Societal Challenges of Decision 2013/743/EU;

b) To contribute to improving the environmental impact of aeronautical technologies, including those relating to small aviation, as well as to developing a strong and globally competitive aeronautical industry and supply chain in Europe.

This can be realised through speeding up the development of cleaner air transport technologies for earliest possible deployment, and in particular the integration, demonstration and validation of technologies capable of:

(i) increasing aircraft fuel efficiency, thus reducing CO_2 emissions by 20 to 30 % compared to 'state-of-the-art' aircraft entering into service as from 2014;

(ii) reducing aircraft NOx and noise emissions by 20 to 30 % compared to 'state-of-the-art' aircraft entering into service as from 2014.

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[2] This rate is calculated excluding Title 5 which was foreseen not to be used in 2021 although within the overall budget available commitment appropriations of the year.

[3] Excluding the unused appropriations 2021 of 22,9 million € (56,3% of execution rate if the unused appropriations are included as total payment budget).

[4] Council Regulation (EU) No 558/2014 of 6 May 2014, OJ L 169/78, 7.6.2014

Clean Sky 2 Demonstrators and Technology streams

Theme	Demonstration area	Demonstrator / Technology stream in Programme Area							Contribution*			Funding	Funding
		LPA	REG	FRC	AIR	ENG	SYS	SAT	E	M	C	RoM m€	RoM m€
Breakthroughs in Propulsion Efficiency (incl. Propulsion-Airframe Integration)	Advanced Engine/Airframe Architectures	→			→				→		→	478.5	146.5
	Ultra-high Bypass and High Propulsive Efficiency Geared Turbofans					→			→		→		257.6
	Hybrid Electric Propulsion	→	→						→	→	→		24.0
	Boundary Layer Ingestion	→							→		→		8.3
	Small Aircraft, Regional and Business Aviation Turboprop		→			→			→	→	→		42.2
Advances in Wings, Empennages, Aerodynamics and Flight Dynamics	Advanced Laminar Flow Technologies	→			→				→		→	190.6	86.1
	Aircraft Wing Optimization		→		→				→	→	→		104.6
Innovative Structural / Functional Design and Production System	Advanced Manufacturing	→	→		→			→	→		→	217.5	68.3
	Cabin & Fuselage	→	→		→				→		→		138.1
	Innovative Solutions for Business Jets				→					→	→		11.2
Next Generation Cockpit Systems and Aircraft Operations	Cockpit & Avionics	→	→				→	→		→	→	146.2	134.5
	Advanced MRO	→								→	→		11.7
Novel Aircraft Configurations and Capabilities	Next-Generation Civil Tiltrotor			→	→					→	→	265.9	111.1
	RACER Compound Helicopter			→	→					→	→		117.4
	Aircraft Innovative Configuration	→	→		→				→	→	→		37.3
Aircraft Non-Propulsive Energy and Control Systems	Electrical Systems						→		→		→	184.8	102.8
	Landing Systems						→		→		→		31.8
	Non-Propulsive Energy Optimization for Large Aircraft	→							→		→		13.4
	Environmental Control System & Ice Protection System		→		→		→		→	→			36.8
Optimal Cabin and Passenger Environment	Passenger Comfort	→	→				→	→		→	→	54.0	16.0
	Innovative Cabin Passenger/Payload Systems	→			→		→			→	→		38.0
Eco-Design		→	→	→	→	→	→	→	→		→	39.3	39.3
Enabling & Long-Term Technologies		→	→	→	→	→	→	→	→	→	→	51.7	51.7

** E = Environment, M = Mobility, C = Competitiveness*

The translation of the programme's high-level environmental objectives into targeted vehicle performance levels is shown below. More details about the vehicle performance levels, in particular about the reference aircraft, are available in the Clean Sky 2 Development Plan.

Conceptual aircraft / air transport type	Reference a/c*	Window[1]	ΔCO_2	ΔNO_x	Δ Noise	Target[2] TRL @ CS2 close
Advanced Long-range (LR)	LR 2014 ref	2030	20%	20%	20%	4
Ultra advanced LR	LR 2014 ref	2035+	30%	30%	30%	3
Advanced Short/Medium-range (SMR)	SMR 2014 ref	2030	20%	20%	20%	5
Ultra-advanced SMR	SMR 2014 ref	2035+	30%	30%	30%	4
Innovative Turboprop (TP), 130 pax	2014 130 pax ref	2035+	19 to 25%	19 to 25%	20 to 30%	3
Advanced TP, 90 pax	2014 TP ref[4]	2025+	35 to 40%	> 50%	60 to 70%	5
Regional Multi-mission TP, 70 pax	2014 Multi-mission	2025+	20 to 30%	20 to 30%	20 to 30%	6
19-pax Commuter	2014 19 pax a/c	2025	20%	20%	20%	4-5
Low Sweep Business Jet	2014 SoA Business a/c	2035	> 30%	> 30%	> 30%	≥ 4
Compound helicopter[3]	Twin Engine Super-Medium (TSEM)	2030	20%	20%	20%	6
Next-Generation Tiltrotor	AW139	2025	50%	14%	30%	5

**The reference aircraft will be further specified and confirmed through the Technology Evaluator assessment work.*

[1]All key enabling technologies at TRL 6 with a potential entry into service five years later

[2]Key enabling technologies at major system level

[3]There are no direct comparisons yet; the most relevant traditional helicopter reference will be selected and then the target levels will be determined in an updated plan

[4]ATR 72 airplane, latest SOA Regional A/C in-service in 2014 (technological standard of years 2000), scaled to 90 Pax

Administrative objectives – achievement

Objective 2021	Achieved in 2021 (Yes/No/Comments)
Reliable financial management and reporting to the JU's individual stakeholders (the European Union and the private members and partners of CS) is ensured;	Yes. The JU has continued to work in accordance with the financial regulation and internal procedures in order to implement and monitor the execution of the overall budget in terms of productivity, achievements, planning and risks of the operations.
90% of GAM cost claims received are formally dealt with (validated, put on hold or refused) before end of May each year;	Yes. 100%.
The ex-post audits on H2020 projects are performed according to the plan and show a materiality of errors lower than 2% for the total programme period. The audits carried out by the Common Audit Service (CAS) for the entire research family, in particular for the Common Representative Sample, are coordinated with the audit requirements of Clean Sky 2 JU.	During the year 2020 and 2021 the Common Audit Service of DG R&I incurred some delays in finalising the audits requested by the stakeholders including CAJU. However, sufficient audit results were received by the JU until the end of 2021 to establish its specific representative error rates. Annual error rates for the CS2 programme period are below 2%. The JU succeeded in coordinating the specific requirements for audits of CS projects with the audits performed by the CAS for the research family in total.

Indicators

The Key Performance Indicator results for the Clean Sky 2 programme for 2021 are presented in Annexes 5 to 7.

1.2. Research and innovation activities

The Clean Sky 2 Joint Undertaking contributes to improving the environmental impact of aeronautical technologies, including those relating to small aviation, as well as to developing a strong and globally competitive aeronautical industry and supply chain in Europe.

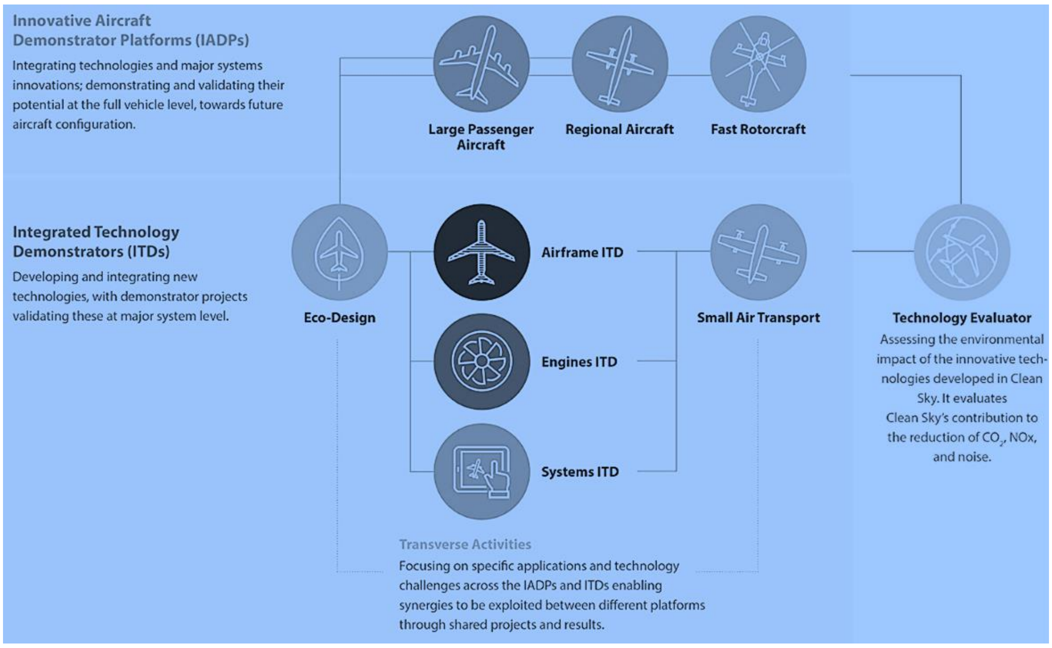
The Clean Sky 2 programme clearly demonstrates the benefits of a true Public Private Partnership (PPP). Stakeholder participation was at a high level, including SMEs (often their first participation in the European framework programme), research centres and academia. Industry is increasingly using Clean Sky as the focus of their R&I programmes because of the efficiency and effectiveness of Clean Sky research at European level. The JU has proven to be an appropriate management body.

The Clean Sky 2 programme will deliver vital full-scale in-flight demonstrations of novel architectures and configurations. Advanced technology inserted and demonstrated at full systems level will enable step-changes in environmental and economic performance and bring crucial competitiveness benefits to European industry. This will enable the European aviation sector to satisfy society's needs for sustainable, competitive mobility towards 2050. As such, the results of the Clean Sky 2 programme will enable the creation of high-skilled jobs, increase transport efficiency, sustain economic prosperity and drive environmental improvements in the global air transport system.

Clean Sky engages the best talent and resources in Europe and is jointly funded and governed by the European Union and the major European aeronautics companies. It utilises the key skills and knowledge of the leading European aeronautic research establishments and academic faculties. Small and medium-size enterprises and innovative sub-sector leaders will help to shape promising new supply chains.

Research and innovation actions delivering important technological advances that started in the Clean Sky programme were extended and continued in the Clean Sky 2 programme. New architectures, such as hybrid-electric propulsion, and new vehicle configurations addressing unmet mobility needs, will be evaluated with flight demonstrators. They will be essential in order to fulfil the ambitious objectives of the renewed ACARE Strategic Research and Innovation Agenda (SRIA). Conventional aircraft configurations are approaching intrinsic performance limits, as the integration of the most recent technologies are showing diminishing returns. Therefore, the need is even greater today for industry to develop materially different, substantially more environmentally-friendly and energy-efficient vehicles to meet market needs, and ensure their efficient integration in the air transport system.

Clean Sky 2 will continue to use the Integrated Technology Demonstrators (ITDs) mechanism. Its objective-driven agenda to support real market requirements providing the necessary flexibility is well suited to the needs of the major integrator companies. The CS2 programme will also focus on reinforcing interactions between demonstrations of improved systems for a better integration into viable full vehicle architectures. The Clean Sky 2 programme structure involves demonstrations and simulations of several systems jointly at the full vehicle level through Innovative Aircraft Demonstrator Platforms (IADPs). A number of key areas are coordinated across the ITDs and IADPs through Transverse Activities (TAs) where additional benefit can be brought to the programme through increased coherence, common tools and methods, and shared know-how in areas of common interest. As in Clean Sky, a dedicated monitoring function – the Technology Evaluator (TE) – is a key function incorporated into Clean Sky 2.



Clean Sky 2 Programme Logic and Set-up

Introduction to the IADPs, ITDs and TAs

Innovative Aircraft Demonstrator Platforms (IADPs) aim to carry out proof of aircraft systems, design and functions on fully representative innovative aircraft configurations in an integrated environment close to real operational conditions. To simulate and test the interactions and impact of the various systems on the different aircraft types, the vehicle demonstration platforms cover passenger aircraft, regional aircraft and rotorcraft. The choice of demonstration platforms is geared to the most promising and appropriate market opportunities to ensure the best and most rapid exploitation of the results of Clean Sky 2. The IADP approach can uniquely provide:

- focused, long-term commitment from project partners;
- an integrated approach to R&I activities and interactions among the partners;
- stable, long-term funding and budget allocation;
- flexibility to address topics through open calls for proposals;
- feedback to ITDs on experiences, challenges and barriers to be resolved longer term;
- a long-term view on innovation and appropriate solutions for a wide range of issues.

Three IADPs are defined in the CS2 programme:

- Large Passenger Aircraft (LPA) covering large commercial aircraft applications for short/medium and long range air transport needs;
- Regional Aircraft (REG) focusing on the next generation of approx. 90-seat capacity regional turboprop powered aircraft enabling high efficiency/reliability regional connections;

- Fast Rotorcraft (FRC) aiming at two new configurations of rotorcraft bridging the gap between conventional helicopters and utility/commuter fixed wing aircraft, both in speed and range/productivity.

In addition to the complex vehicle configurations, Integrated Technology Demonstrators (ITDs) will accommodate the main relevant technology streams for all air vehicle applications. They allow verified and validated technologies to be matured from their basic levels to the integration of entire functional systems. These technologies have the ability to cover quite a wide range of technology readiness levels. Each of the three ITDs covers a set of technology developments that will be brought from component level maturity up to the demonstration of overall performance at systems level, to support innovative flight vehicle configurations:

- Airframe ITD (AIR) including topics affecting the global vehicle-level design;
- Engines ITD (ENG) for all propulsion and power plant solutions;
- Systems ITD (SYS) covering all on-board systems, equipment and the interaction with the Air Transport System.

The Transverse Activities (TAs) enable important synergies to be realised where common challenges exist across IADPs and/or ITDs, or where coordination across the IADPs and ITDs allows a cogent and coherent approach to joint and shared technical and research priorities. TAs do not form a separate IADP or ITD in themselves, but coordinate and synergise technical activity that resides as an integral part of the other IADPs and ITDs. A dedicated budget is reserved inside the relevant IADPs and ITDs to perform these activities. TA leaders were nominated and coordinate each transverse activity. Currently, three transverse activities are running in the Clean Sky 2 programme and are specified in the Statutes of the JU:

- Eco-Design TA (ECO): key materials, processes and resources for related innovations considering the life cycle optimisation of technologies, components and vehicles; and continuing and securing advances from the Clean Sky programme;
- Small Air Transport TA (SAT): airframe, engines and systems technologies for small aircraft, extracting synergies where feasible with the other segments;
- The Technology Evaluator, as the technology and impact evaluation infrastructure, is an essential element within Clean Sky. Impact assessments at airport and Air Traffic Service level that are currently focused on noise and emissions will be expanded where relevant for the evaluation of the programme's delivered value. Where applicable they can include other impacts, such as the mobility or increased productivity benefits of Clean Sky 2 concepts. The TE will also perform evaluations at an aircraft 'Mission Level' to assess innovative long-term aircraft configurations.

1.3. Calls for proposals and grant information

No calls for proposals were launched in 2021. The last call (call 11) was launched in 2020.

The key performance indicator results for the year 2021 are presented in Annexes 5 to 7. The JU has included all H2020 indicators in its scoreboard, which have been established for the entire research family by the Commission, to the extent to which they are applicable to the JU. Comments regarding some individual indicators are provided in the annexes or in the related section of this report. In addition, the JU is presenting more detailed results of its performance monitoring in specific areas.

1.4. Activities carried out in Grant Agreement for Members (GAM)

The structure and set-up of the Clean Sky 2 programme is highlighted in section 1.2, where the top-level breakdown of actions as set out in the GAMs is described. The key elements of the technical progress in 2021 are highlighted below.

➔ LPA – Large Passenger Aircraft IADP

Summary of activities and progress of work in 2021

The Large Passenger Aircraft IADP is focusing on large-scale demonstration of technologies integrated at aircraft level in three distinct 'Platforms' as follows:

<u>Platform 1: "Advanced Engine and Aircraft Configurations"</u>
Platform 1 continued the development of the environment required for the integration of the most fuel efficient propulsion concepts into compatible airframe configurations, targeting next generation aircraft. Overall, the design of all integration technologies for both Long-Range (e.g. inlet, nacelle, etc) or Short Medium Range (Short Thrust Reverser Unit shutter, innovative pylon, etc.) were defined, and manufacturing has started.
In the context of improved engine performance and novel system architectures, real-time engine models for both bizjets and large aircraft were developed for Non-Propulsive Energy Generation (NPE).
The maturation of the hybrid laminar flow control technology (HLFC) continued with the final assembly of the ground based demonstrator for HLFC on tail and then TRL3 was passed for HLFC applied on wings.
First components (e.g. composite frames) or tools of the future Advanced Rear-End demonstrator were delivered and impact/fatigue tests started.
The scaled flight-test vehicle passed the Flight Readiness Review with its classical configuration; a six-propeller design was selected for the distributed electric propulsion (DEP) configuration.
Finally, feasibility of a MegaWatt Power Generation System was demonstrated and passed TRL4 for what concerns future hybrid-electric configuration.

<u>Platform 2: "Innovative Physical Integration Cabin – System – Structure"</u>
Platform 2 continued to develop, mature, and demonstrate an entirely new and advanced fuselage structural concept in full alignment with the next-generation cabin and cargo architectures, including all relevant aircraft systems. In 2021, the first major parts of the Multi-Functional Fuselage Demonstrator were produced (e.g. Lower Shell Skin) as well as most of the elementary parts. Manufacturing trials were pursued to prepare the production process for the real demonstrator parts, evaluate welding capabilities and structural sizing criteria. The Latest Generation of the Platform Concept Demonstrator was equipped with the cabin and systems to bring the evidence for zero customisation at airframe as an industrial approach. Finally, cargo fire tests on the Environmental Friendly Fire Protection demonstrator have been conducted in a real burn chamber.

Platform 3: "Next Generation Aircraft Systems, Cockpit and Avionics" including advanced systems maintenance activities

In 2021, the IADP LPA platform 3 activities focused on progressing the maturation of the functions and technologies contributing to the Large Aircraft Disruptive Cockpit, Regional Aircraft Active Cockpit and Business Jet ground demonstrators, and continuing their integration and tests within the different aircraft demonstrators. It is worth mentioning some of the following achievements: flight tests or ground tests for selected cockpit-avionics functions and technologies, successful start of the Proof of Concept (TRL 3 assessment) for the Disruptive Cockpit concept, completion of the standalone Human Factor assessments of pilot workload reduction functions on Regional Aircraft and their integration in the Active Cockpit Demonstrator, and finally, on the Business Jet Cockpit Demonstrator, TRL5 passed for multimodality applications, Pilot State Monitoring and Utility Management System.

Main achievements and progress of work in 2021

Platform 1: "Advanced Engine and Aircraft Configurations"

Overall, the year allowed for the proper execution of the recovery plan following the Covid-19 crisis and despite the few delays reported, very good technical progress was made.

Advanced propulsions and engine technologies

Regarding future long range aircraft concepts, nominal progress has been made on technology development for the future integration of the UltraFan® engine. The architectures for pylons and bleed systems were defined, and the design of the inlet and other nacelle components was finalised during Q3.

In relation to Short-Medium Range and UHPE integration activities, the consortium finalised the design of the test rig for the most accurate aero-acoustic measurements ever in the world planned for the large turbo fan engines at the German-Dutch Low-speed wind tunnel (DNW) in 2023. The Critical Design Review was passed in November, allowing the start of the manufacturing of all elements in 2022.

Also linked to large turbo-fan engines, real-time engine models for bizjets and large aircraft were finalised and tested. For the smart use of the Auxiliary Power Units (APU) during flight, via the APU power and loads control system, the design was finalised (passed CDR during Q3) pending an on-ground test with simulated engine models by 2023.

Considering unconventional propulsive architectures, good progress has been made on de-risking the Open Rotor engine concept in terms of installation architecture (underwing versus rear-end configuration), structure, external and cabin noise, etc., towards the down-selection of the best configuration set mid-2022. In addition, further progress was performed on the Low-Pressure Turbine with a selection of architecture and the maturation of all enabling technologies for the SMR++ engine architecture.

It is important to note the high maturity reached on active vibration control systems for business jets (rear-end installed turbo fans) via a test campaign performed on a scale aircraft.

Advanced Rear-End

For the Advanced Rear End demonstrator, TRL3 was passed during Q1. Since then, the design of components with selected materials and technologies as well as manufacturing concepts has been finalised. Manufacturing has started (e.g. highly loaded frames) in order to deliver the innovative rear-end from 2022 onwards.

Laminarity

Significant progress and a high level of maturity was achieved on flow control systems with application on horizontal tails (including business jets) and wings. Concerning HLFC on the Horizontal Tail Plane (HTP) and the large scale demonstrator, the TRL5 was successfully passed during Q3. For Hybrid Laminar Flow Control (HLFC) on the Wing Demonstrator, the work focused on preparing the critical design review (CDR) of the ground based demonstrator for which manufacturing of components started. For the Natural Laminar Flow (NLF) on HTP for bizjets, the activities continued on leading edge treatment and anti-erosion concepts.

Radical Aircraft Configuration

Radical aircraft concepts have been also matured, namely the manufacturing of a Scaled Flight Test demonstrator which aims to demonstrate the handling capabilities of distributed engines installed along the wing. The medium speed taxi tests were successfully performed in Deelen airbase in Netherlands. For the Distributive Electric Propulsion (DEP) demonstrator, aerodynamic performance assessment results allowed for the finalisation of the design of the selected 6 propellers configuration, which will be manufactured in early 2022 for a complete wind tunnel test campaign set for Q4 2022.

In order to validate the technology bricks for future hybrid-electric propulsion architectures, a 2MW electrical machine was at first successfully tested in Trondheim. Then a second e-machine was tested including a gas turbine in Bristol.

<u>Platform 2: “Innovative Physical Integration Cabin – System – Structure”</u>

In the *Next Generation Fuselage Cabin & Systems Integration* work package, the interdisciplinary design activity went on to finalise part of the design for manufacturing of the Multi-Functional Fuselage Demonstrator (MFFD). Very good results have been achieved in terms of acquisition and delivery of production tools as well as in terms of the manufacture of major parts. The lower shell skin has been successfully manufactured and delivered; it represents the biggest thermoplastic fuselage part in aviation worldwide. Most of the demonstrator elementary parts like stringers, frames and beams have been produced, waiting to be integrated into the shells in 2022. The upper shell mould is close to be completed and is to be delivered in Q1 2022. A 1-m long upper skin section was successfully produced, giving good knowledge for the layup and *in situ* consolidation of the full-size upper skin.

All production activities were accompanied by the manufacture of test parts for evaluation of welding capabilities and structural sizing criteria.

The preparation of the barrel assembly continued in the manufacturing phase and, furthermore, procurement processes for the main components were started.

Overall, the Covid-19 pandemic has made on-site support difficult and challenging when the focus is increasingly shifting towards hardware delivery. The overall plan has been updated and the planned start of the validation in the MFFD has been postponed by 3 months to Q1 2023, yet keeping the full integration by the end of the programme at stake.

With respect to the *Next Generation Cabin & Cargo Functions* work package, the following progress was made:

- The development of the Module Power Controller (MPC) was the main focus of the activities of the Universal Cabin Interface (UCI) development. MPC hardware was specified, the components delivered and first prototypes of MPC hardware components were tested.
- For the platform concept, the installation and testing of the functional equipment in the 4th Gen Demonstrator was the main activity. Installation of functional equipment was finalised in 2021. Testing to verify the simple installation and customisation have been successfully conducted.
- Regarding the fuel cell activities ("Energy Optimised Cabin") the sizing and the design of the 50+ kW LT-PEM (Low Temperature Proton Exchange Membrane) Fuel Cell stack have been initiated and partially completed.
- For the Environmental Friendly Fire Protection system, a demonstrator system to simulate flight conditions for cargo hold and fire extinguishing system on ground was completed. Tests of fire extinguishing agents by measuring oxygen concentrations for typical flight profiles and cargo loading conditions have successfully demonstrated the fire extinguishing system performance.
- For the "Customisable Passenger Service Unit" enabler technologies have been further enhanced. The development of the Customisable Passenger Service Unit integrated into the spacious cabin environment – with special attention to the pathogenic germ reduction, improved ergonomic accessibility and customisability also considering all safety aspects of the passengers during a cabin decompression emergency – has been continued according to the development plan.

In relation to the *Non-specific cross functions & ITD Airframe* work package, the focus in 2021 has been to continue development on the Fatigue Digital Twin (FDT) Load to stress transfer function, structural health monitoring (SHM) and materials characterisation and modelling. The monitoring, testing and modelling for composite and metallic support the above-mentioned demonstrators amongst others.

For the predictive virtual simulation, the activities completed in 2021 can be broken down into two main parts: (i) the characterisation of alternative composite materials (such as material with thermoplastic matrix) and (ii) the establishment of the link between the microstructure and the mechanical properties for aluminium alloy.

Platform 3: "Next Generation Aircraft Systems, Cockpit and Avionics" including advanced systems maintenance activities

In the frame of the Large Aircraft Disruptive Cockpit Demonstrator, cockpit avionics functions and technologies development continued in 2021:

- A new Lidar prototype has been delivered and installed on aircraft for its exposure on flight.
- The GPAHRS (GPS-aided Attitude and Heading Reference System) was assessed and reached TRL4 maturity.
- The Image Based Landing unit was successfully integrated into the Disruptive Cockpit Simulator.
- The Integrated System Management (ISM) was enriched with the new Arbitration Concept (TRL3 ISM Proof of Concept started in Q4 2021).

- The New Functional Protocol has been assessed up to TRL4.
- The Flexible Audio Communication development progressed through the ACM (Audio Communication Manager) integration with DiSco COM Panel.
- Finally, the LiFi (Light Fidelity) headset and tablet have reached TRL5.

The Disruptive Cockpit (DISCO) Proof of Concept (POC) started successfully in Q4 2021. Articulated around 12 thematic reviews and several demonstration sessions, it will focus on the various facets of the product, assess the maturity of the functions and technologies necessary for single pilot operation, identify the main risks as well as providing recommendations and step up actions to feed the next stages of the project in order to review the roadmap towards programme launch in line with expectations for future programme decision gates. The DISCO POC will end in Q1 2022.

The Disruptive Cockpit demonstrator dedicated to systems integration (DiscoBench) has been upgraded to version 10, ready to simulate a flight scenario including weather avoidance / engine fire with arbitration / pilot incapacitation with auto land. Three new incremental versions of the flight management and interactive displays function have been successfully integrated and validated. In addition, other test means have been deployed for the evaluation of the ATN/IPS (Aeronautical Telecommunication Network / Internet Protocol Suite) router and the flexible audio communication (SDR-Software Defined Radio/VHF/SATCOM/ACM/DACP-Digital Audio Control Panel).

Regarding activities related to the Regional Aircraft Active Cockpit demonstrator, the development and integration into the active cockpit of the pilot workload reduction enabling functions and technologies has been completed with a successful recovery plan for Pilot Monitoring System (PMS) and Voice Command (VC).

Considering ground and flight tests demonstration for Business Jet, in 2021 significant progress was made within the different topics:
- Multimodality activities were focused on the maturation and demonstration of batch 2 applications with the TRL5 gate passed in Q4 2021.
- The Pilot State Monitoring algorithm detection on sleep and drowsiness was improved and refined.
- Development, manufacturing and integration activities were pursued to increase Utility Management System's (UMS) maturity. TRL5 was held and passed in Q4 2021.
- The PROTECTeD project (centred on the mask oxygen system) human factors demonstration and test campaign progressed and a dry run occurred in Q4 2021.

Implementation of complementary grants awarded through call for proposals

During the period, 94 Grant Agreements for Partners awarded from Call 1 to Call 11 were active, 21 have been technically closed in 2021. All these projects are complementing the activities implemented in the LPA IADP Grant Agreement for Members and contributing to results described above.

➔ REG – Regional Aircraft IADP

Summary of activities and progress of work in 2021

Activities related to green conceptual aircraft continued during 2021 further confirming the ambitious environmental targets established in the initial phase of the CS2 Programme. Hybrid-electrical configuration studies focused on a promising architecture with Distributed Electrical Propulsion (DEP).
All demonstrators achieved good progress towards the master plan, in particular:

- three wind tunnel test (WTT) demonstration campaigns were completed for the TP90 concept aircraft (WTT1 large scale model, morphing fixed shapes, low speed; WTT2 large scale model, morphing, low speed and in cruise conditions; WTT3 aero-servo-elastic model including active control laws)
- manufacturing and assembly operations for the on-ground full-scale demonstrators progressed thanks also to recovery actions promptly activated to solve technical/manufacturing issues that arose during this phase. In particular, four composite stiffened large panels were manufactured for the Fuselage Demonstrators, in synergy with Airframe ITD, and important steps were achieved for the manufacturing/assembly tools of the Outer Wing Box (OWB) on-ground demonstrator.
- for the in-flight demonstrators, an important achievement for the Flying Test Bed 1 (FTB1) was the execution of ground structural/functional tests of morphing winglet and innovative wingtip. Very important achievements for Flying Test Bed 2 (FTB2) were the completion of the aircraft modification, the completion of the flight test preparation and the achievement of the permit to fly, with the first taxi and rejected take-off tests being completed.

Impacts of the Covid-19 outbreak were continuously monitored during the year. It is confirmed that the impacts are mainly in terms of delays. The initial assessment showed an average of four months' delay but at this stage there are no further schedule margins with respect to the end of the Programme for some full-scale demonstrators.

Main achievements and progress of work in 2021

High Efficiency Regional Aircraft (WP1)

- TP90Pax Regional Aircraft Conventional Configuration: In 2021 all the activities were entirely aimed at completing the final Loop3 for this 90-seat configuration; all the planned activities were regularly carried out and all the related documents released on time.
- Hybrid-Electical Regional Aircraft Configuration (40-50 Pax class): The study for the architecture with Distributed Electric Propulsion (DEP) on the wing (called configuration "C") was performed and the deliverable containing a detailed assessment of this configuration was issued. In addition, the last phase of study relating to a configuration "D" with a turbogenerator in the tail has been launched, and will end in 2022.
- Towards the end of 2021, a new activity related to sustainability of hybrid-electrical regional aircraft was defined and it will be performed in the last two years of the programme.

Technologies Development (WP2)

For the innovative structural technologies of the Adaptive Wing:

- Structural Tests: Damage and durability tests were executed on the lower liquid resin infusion (LRI) panel up to 70000 fatigue cycles and the respective results assessment was completed. Pull-off test was executed. Tool drop impact tests were executed on the large LRI curved stiffened panel. LRI spar segment static test was executed. Test on rib progressed. Structural health monitoring (SHM) tests were executed on the LRI large curved stiffened panel and the instrumentation and the test set-up was completed.

For the innovative air vehicle technologies of the Adaptive Wing:

- Morphing concepts – Structural ground demonstrators: Advanced WingLet (AWL) and Innovative Wing Tip (IWT) structural/functional tests were completed. Multifunctional Trailing Edge (MTE) manufacturing is in progress, and the test is planned to be completed in the first half of 2022.
- Large low speed wind tunnel model (WTT1): Test and results assessment were completed.
- Large high-speed wind tunnel model (WTT2): Wing box model and morphing concepts models were completed, tested and delivered to wind tunnel site. Wind tunnel tests were completed.
- Load control and alleviation-aero-servo-elastic wind tunnel (WTT3) for control laws validation: Test and results assessment were completed.
- Morphing devices high order multibody modelling: Modelling was completed, as well as predictions of ground tests.
- Future electric wing monitoring system demonstrator for compliant structures: Test of demonstrator was completed.

For the Integrated Vehicle Health Management (IVHM): the integration of data and models in the framework was finalised and final tests performed.

For the On-Board Systems Technologies: Integration and testing for the equipment parts of the Electrical Landing Gear (ELG) system progressed. The Advanced Electrical Power Distribution System (EPDS) achieved significant progress through the relevant complementary grants with the delivery and integration activities of the equipment within the Iron Bird. For the Innovative Propeller, the wind tunnel test high speed performance was executed and the ice protection feasibility study was completed.

For the innovative Flight Control System (FCS): Aileron actuation systems engineering tests were started by using the test bench, Electro-Mechanical Actuators (EMA) and Electromechanical Actuators Control Units (EACU) received from Call for Propsoal (CfP) projects. Engineering Acceptance Test Procedures (ATP) were performed for the winglet and wingtip actuation systems (EMAs+EACUs). Wingtip engineering actuation system was delivered to the Iron Bird. FCS test requirements for the Iron Bird were defined. Operative system software for the flight control computer was delivered to the Iron Bird.

Demonstrations (WP3)

Adaptive Wing Integrated Demonstrator (FTB1 and OWB)

Flying Test Bed #1 (FTB1) Demonstrator: Executed and close to completion of the purchasing/fabrication of components for introduction of the experimental modifications on the demo aircraft: equipment (power converter, flight control computer), flight test instrumentation, structural parts (adapter plug, basic wing tip, rib 33, stringers), electrical/mechanical components (electrical rack, wirings, miscellanea), tooling. The morphing Advanced WingLet (AWL) and Innovative WingTip (IWT) ground test articles were manufactured and the structural test was performed. The AWL and IWT flight test articles manufacturing and assembly were started.

Outer Wing Box (OWB) Ground Demonstrator: The OWB Digital Mock-Up update was completed once it was integrated into the models of appropriate tolerance and annotation. The request for test was reviewed. Manufacturing tools for upper panels were fabricated. The upper pre-production verification upper panel was manufactured and characterised. The first two upper panels were manufactured. Progress was made in relation to manufacturing tools for the fabrication of lower panels. The first composite ribs were manufactured, and metallic ribs manufacturing progressed. The manufacturing of the tool for spar fabrication progressed.

Fuselage/Passenger Cabin Demonstrators: Four full-scale composite stiffened panels of the fuselage demonstrators were manufactured (nine in total) by using the automated lay-up system in synergy with Airframe ITD (AIR ITD). The window frames, side frames and shear ties, door surround structures and pressure bulkheads were received from respective complementary grants. The side after stiffened panel of the Pax Cabin Demonstrator was assembled in synergy with AIR ITD. The side forward stiffened panel of the Fuselage Structural Demonstrator was assembled apart from some door surround parts. The structural test rig 3D design was completed. The mechanical installation points and features of the major cabin items between the major cabin items and the primary structure and systems were determined. The approach was defined for the implementation of the vibro-acoustic actuators and ECS ducting into the Pax Cabin Demonstrator needed for comfort testing. The measurement system DressMAN 3.2 for thermal comfort assessment was released. The NDI method for structural ice build-up detection progressed and first proof of concept tests was performed.

Iron Bird Demonstrator: The manufacturing is almost completed, except for some delayed items (i.e. those of the electrical landing gear system).
The installation of the available components was completed, allowing for their integration. The electrical power distribution system (EPDS) integration is in progress, mainly focusing on the controller area network (CAN) communication between the equipment.
Referring to the Flight Control System, efforts were done to integrate the IWT subsystem, using an engineering prototype unit. The software models were completed both in stand-alone and real-time mode. Minor updates were necessary following the integration outcomes.

Flying Test Bed #2 (FTB2) Demonstrator:

During 2021, activities were focused on:

- completion of the on-ground tests in the actuation rigs (major demonstrator from AIR ITD closely linked to FTB2). The test readiness review (TRR) was achieved and the validation campaign for handling qualities, flight control laws and crews was performed;
- completion of FTB2 aircraft modification and execution of aircraft ground tests;
- achievement of the permit to fly from the airworthiness authorities for the Regional FTB2. First high speed taxies and rejected take-offs were done.

Regional IADP Core Partners’ main achievements were related to:

- re-activation of the external wing full scale demonstrator activity (which was paused due to Covid-19 impact). A major milestone achieved was the CDR of this demonstrator in which the assembly process following jig-less + flexible jig concept was validated.
- completion of the engine mount system demonstrators.

WP4 - Technologies Development/Demonstration Results Evaluation

With relation to the interactions with the Technology Evaluator (TE), support for the two platforms (90 & 130 seats, reference and green aircraft) as well as support for the preparation of the TE Assessment was provided during 2021.

As regards the interactions with Eco TA, the OWB flagship demonstrator was further defined and updated Life Cycle Inventory (LCI) data were delivered to Eco TA for the Stage 0 (pilot activity) related to the replacement of hard chrome plating on steel as well as for the Stage 1 activity on liquid resin infusion for the Composite Outer Wing Box.

Implementation of complementary grants awarded through call for proposals

During 2021, 23 Grant Agreements for Partners awarded from Call 1 to Call 11 were active, 10 have been technically closed.
All these projects are complementing the activities implemented in the REG IADP Grant Agreement for Members and contributing to results described above.

➔ FRC – Fast Rotorcraft IADP

Summary of activities and progress of work in 2021

The NEXT GENeration Civil TiltRotor (NGCTR) demonstrator successfully finished its critical design review (CDR) in September 2021 triggering the starting of the manufacturing phase. Following the delivery of the donor fuselage airframe, the demonstrator assembly formally started in October 2021.

The completion and delivery of the RACER central fuselage paved the way to the demonstrator assembly which started in April 2021 at the Airbus Helicopters Deutchland premises. After the integration of the nose, the canopy and the fuel system, the RACER demonstrator was transferred to Airbus Helicopters France to continue its lay-up phase. All along 2021, major subsystems were finalised and delivered such as the main landing gears, the rotorless tail, the cowlings, the doors and the wings , allowing the assembly of the whole fuselage from nose to tail.
A more detailed reporting per work package can be found below.

Main achievements and progress of work in 2021

NextGenCTR (WP1)

Management, coordination and design integration: The aircraft level CDR outstanding actions were closed in September 2021 allowing major interfaces between sub-systems to be frozen. as well as the Digital Mock-Up (DMU) configuration and the weight and centre of gravity (CG) estimates which are finally aligned to the planned operational flight envelope. Liaison with the

airworthiness authorities has progressed, including trilateral meetings between Leornado , ENAC and EASA. Aircraft sub-system flight clearance plans were discussed.
Tiltrotor system design: Flight control system models were updated and parameters in all flight conditions were verified. Rotor limit and fatigue design loads were confirmed, along with airframe flight and ground loads. Structural dynamic and aeroelasticity assessments were completed. Further air intake wind tunnel tests were carried-out.
Transmissions systems: The transmissions sub-system CDR was completed. Gear and shaft designs were completed supporting the finalisation of concurrent activities with production engineering and external suppliers.
Rotors systems: Detailed design related to new rotor system components, fixed swashplate and swashplate support, gimbal ring and extended collective tube assembly were released. Kinematic analyses of the rotor system were completed.
Airframe structures: The structures design was finalised and the test plans were issued. The structure qualification plan to support the permit to fly was updated. The work on the wing, movable surfaces and nacelle CDRs was successfully completed. Wind tunnel testing was completed for both steady and unsteady state conditions. Manufacture of wing components and assembly tooling was launched. The design of the nacelle secondary structure has been also completed.
Electrical and avionic systems: The electrical systems aircraft equipment installations were frozen, the wiring diagrams completed. Cable assembly preliminary manufacture tasks progressed, aligned to the build sequence/schedule. Flight control system models were developed and control laws were refined. Software requirements were matured along with the launch and initial build of avionics test rigs.
Airframe systems: Fuel system development progressed well, ensuring all interfaces were clear and agreed. Fuel tank manufacture started and initial physical tests were performed. The fuel distribution system was finalised and new component designs progressed.
Technology demonstrator manufacture and assembly: Donor fuselage was completed in the out-of-jig stage and shipped to the final assembly line. The installation of the main structural provision installation was started.
Airframe test and demonstration: Requirements for instrumentation were finalised and the architecture confirmed. The interface definition of instrumentation to the aircraft structure was also completed.

RACER (Rapid and cost-effective rotorcraft) (WP2)

Progress on the RACER demonstrator project is given along four multifunctional technology areas. In 2021, the focus was on the sub-system manufacturing and on the start of the demonstrator assembly.
RACER flight demonstrator integration: Activities in 2021 were mainly focused on the manufacturing of sub-systems and assembly of the demonstrator. Major sub-system deliveries (e.g., fuselage, tail, wings, firewall, landing gears…) have permitted the finalisation of the assembly of the fuselage from nose to tail. The preparation of the flight tests and the associated permit to fly was pursued all along 2021 with the management of key ground tests and the installation of test instrumentation started in parallel to the assembly of the main subcomponents. Exchanges on documentation with the “Direction Générale de l’Aviation Civile” (French authority DGAC) has also been initiated.
RACER airframe integration: The manufacturing of the central fuselage structure was completed in early 2021 triggering the start of the demonstrator assembly. The central fuselage was then

equipped with the nose, the canopy, the fuel system, the firewalls and finally with the rotorless tail which was completed and delivered in October 2021. The reception of the cowlings, the windows, the doors and the upper and lower wings completed the structural parts deliveries. To support the permit to flight substantiation dossier, stress and fatigue tests have been started on the main structural elements (e.g. tail boom, wings, and main areas of the fuselage). The flightworthy nose and main landing gears and their associated actuation systems were finalised and delivered, whereas the qualification tests were pursued in parallel to support the permit to fly in 2022.
RACER dynamic assembly integration: the design of the main gear box was frozen with the closure of the Critical Design Review (CDR) and the manufacturing for all of the long lead-time items was launched (e.g. main and lateral gear boxes castings, the pinions, the bearings). The lateral gear boxes' mock-ups, used to allow in parallel the manufacturing of the gear box parts and the RACER demonstrator assembly, were completed. The lateral gearbox test bench has been also completed and delivered to the test facility. The two engines, powering the RACER, successfully passed their acceptance test procedure and were delivered to Airbus Helicopters. Concerning the actuation systems of movable surfaces, the design was frozen with the closure of the critical design review held in Q3 2021. Consequently all single parts on the actuator Model A were manufactured and the final assembly started.
RACER on-board system integration: the electrical generation distribution system (EGDS) architecture was developed. Then, an important test campaign was launched to validate and verify the specified functions and equipment. The coupling with the avionics bench was studied and validated in order to perform more representative tests. Concerning the electrical wiring interconnection system (EWIS), continuous efforts were made to freeze the electrical system drawings allowing for the launch of the manufacturing of the RACER harnesses, which were partly delivered in 2021. Some of the harnesses delivered to the prototype shop were installed on the helicopter with their corresponding supports. The work on the avionics system integration rig bench was extensively continued in 2021, with the complete avionics suite (Helionix). The maturity of each avionics function has been improved (activities at software level). The vehicle management system, navigation, flight monitoring system, and flight control system have been tested (tests still ongoing) thanks to simulation tools but also on the avionics bench.

Eco-design (WP3)

NGCTR activities were focused on life cycle assessment (LCA) and environmental analyses on specific key enabling NGCTR technologies which are under development. Selected NGCTR use cases were included as relevant for the ECO flagship demonstrator as they have a focus on additive manufacturing for transmission components (tiltrotor drive system housing), integrated carbon fibre reinforced polymer (CFRP) airframe structures (full wing box), and novel composite materials with out-of-autoclave processes for tiltrotor nacelle structure.
RACER activities were focused on the definition of new flagship demonstrators focusing on additive manufacturing applications on gear boxes, and on thermoplastic interior linings related to the RACER fuselage.

Technology Evaluator (WP4)

Close collaboration and engagement between the Fast RotorCraft IADP and the Technology Evaluator (TE) led to agreement on the methodologies chosen for assessing the conceptual vehicles towards the TE 2nd Assessment. New reference helicopters were added for comparison to the performance of RACER and NGCTR. The impact, in terms of CS2 goals, of each enabling technology was calculated, presented and delivered in the Technology Impact document.

Implementation of complementary grants awarded through call for proposals

During 2021, 35 Grant Agreements for Partners awarded from Call 1 to Call 11 were active, while 8 have been closed.
All these projects complement the activities implemented in the FRC IADP Grant Agreement for Members and contribute to the results described above.

➔ AIR – Airframe ITD

Summary of activities and progress of work in 2021

A summary of the activities that progressed in 2021 is presented here below, with a focus on the main demonstrators impacted (references in the Development Plan). Details are provided in the next section.

With respect to innovative aircraft architecture, noise reduction due to an optimised scarfed nozzle concept was assessed (D3-2). In addition, concerning virtual modelling for certification, additional testing activities were carried out for the cabin thermal modelling with a human thermal model. The concrete involvement of EASA was discussed and their involvement has been organised for each task over the course of 2021 (D3-5). For advanced laminarity, the exploitation of the wind tunnel test (WTT) carried out in 2019 on a business jet (BJ) mock-up incorporating the natural laminar flow nacelle and horizontal tail plane has been completed. In addition, activities are ongoing on the "Natural Laminar Flow laminar wing" with the continuation of BLADE flight test data exploitation (D3-7) with a targeted closure in 2022. Referring to high speed airframe, the manufacturing activities including tooling have started for the composite flaperon demonstrator (D2-3). In addition, the assembly of three structural door demonstrators has been performed for installation on LPA Platform2 multifunctional fuselage demonstrator (D1-1). With respect to novel control, the electrical wing icing protection system (EWIPS) BJ slats was manufactured for future testing at CIRA icing wind tunnel (D3-13). For novel travel experience, the acceptance review of all of the scale one BJ office centred cabin demonstrator items was completed and manufacturing started (D2-12).
Regarding the next generation optimised wing, the critical actions of the RACER's wing critical design review (CDR) were closed; manufacturing and assembly of the elementary parts started (D1-3). In addition, SAT optimised composite CDR was passed and four small-scale integral demonstrators were manufactured, inspected and assessed (D2-15), and the Flight Test Bench 2 (FTB#2) Morphing Winglet flyable components were delivered to REG IADP and installed on the aircraft (D1-4). With respect to the optimised high lift configuration, the wind tunnel test with ice conditions was completed for the loop heat pipe ice protection system technologies (D2-16). In addition, a 4m-length lower skin with integrated spars and stringers was manufactured in liquid resin infusion and validated the tooling manufacturability technology (D1-6). For advanced integrated structures, the embedded SATCOM antenna was delivered to REG IADP FTB#2 for flight (D1-8). The first four flight trials on M28 aircraft for SAT were flown for nacelle components with more affordable manufacturing technologies for small aircraft (D3-24), and manufacturing in automated fibre placement technologies of side-shells for RACER was completed (D1-2). In

relation to advanced fuselage, the CDR for Next Generation Civil Tilt Rotor (NGCTR) subsystems and vertical tail was passed (D1-13,14,15) and RACER Rotorless Tail delivered (D1-12). Finally, for Eco-Design, five flagship demonstrators were defined and more than 25 Eco-Statements performed by ECO TA for Airframe technologies. The end of the technology development phase was reached and technologies were down-selected for inclusion in Eco-Design demonstrators. Finally, the TRL 6 assessment for Collaborative Robot (COBOT) for cockpit technology TRL6 was successfully passed.

Main achievements and progress of work in 2021

Innovative Aircraft Architecture: With respect to "Optimal engine integration on rear fuselage", boundary layer injection (BLI) activities continued with the use of low fidelity up to high fidelity tools. The final assessment of the scarfed nozzle concept was performed in mid-2021. In addition, activities related to "Contra Rotating Open Rotor (CROR) and Ultra High Bypass Ratio (UHBR) configuration" were completed at the end of 2021. With regards to "Novel high performance configuration", activities have continued for BJ missions on the large fuselage configuration to prepare low-speed WTTs expected to take place mid-2022. The aerodynamic design of a blended wing body (BWB)-BLI configuration started for the SMR mission. Cross-checks and results of sensitivity studies are still on-going, and a final workshop is planned for early 2022. With respect to "Virtual Modelling for Certification", the activities continued to develop the tools for various topics. Tasks on "external acoustic loads modelling", "safety for composite fuel tank for lightning", and "aerolic study" were completed in 2021.

Advanced Laminarity: Activities related to "Laminar nacelle" were completed in 2021. With regards to "Natural Laminar Flow (NLF) smart integrated wing", activities are ongoing on the "NLF laminar wing" with the continuation of the BLADE flight test (FT) data exploitation, as well as on the WTT performed at the end of 2021 on the impact of surface defects on transition onset and detection of transition onset in unsteady configurations. Additionally, a WTT in low speed velocity and high Reynolds number conditions for evaluation of a NLF BJ wing is in preparation to be carried out in 2022. Activities on the NLF leading edge ground based demonstrator (GBD) were completed by the end of 2021. The activities under "Extended Laminarity" have continued on a Hybrid Laminar Flow Control (HLFC) leading edge segment including a chamberless design concept i.e. taylored skin single duct (TSSD) for wind tunnel (WT) validation to be carried out in 2022.

High Speed Airframe: With respect to "Multidisciplinary wing for high and low speed", a first full scale flaperon demonstrator was successfully injected in resin transfer moulding (RTM) by the end of 2021. With regards to the spars of the composite wing root box (WRB) demonstrator, 2021 was dedicated to the preparation of test articles and associated tooling (tests planned by mid-2022). The manufacturing of the composite stiffened wing lower panel for BJ was completed mid-2021, as well as the associated activities on curing simulation by end 2021. The activities related to "Tailored Front Fuselage" progressed towards the definition of a power-optimised BJ windshields demonstration that will take place in 2023 (ground/flight test); the definition of an innovative heating device (combining anti-icing and anti-fogging) to lower power demand from windshields is still ongoing. With respect to "Innovative shapes and structure", the manufacturing activities associated to the cargo door demonstrator continued in coordination with the LPA Multi-Functional Fuselage Demonstrator (MFFD). Work for the metallic cargo door demonstrators was completed, including testing, and the composite cargo door detailed design is ongoing.

Novel Control: With respect to "Smart mobile control surfaces", the icing wind tunnel test (IWTT) was completed mid-2021 for ultra-low-power ice protection, and heating tests of the composite fixed leading were performed in preparation for future impact testing on test articles. In parallel, mechanical testing of heater mats was initiated. The development of the electro-thermal simulation code is continuing as well. With respect to innovative movable concepts, the CDR for the multi-functional flap mechanism was passed, as well as the winglet morphing tab (WMT) preliminary design review (PDR). Pressure cells demo design is progressing in parallel. Activities on "Active load control" and more particularly on gust load alleviation (GLA) progressed towards a WTT in a transonic facility with the attainment of PDR and CDR in 2021; the test readiness review (TRR) is planned for end 2022, and the test campaign will follow. With regards to flutter control, the modifications for the existing model of the BJ Horizontal Tail Plane (HTP) were launched and the test is planned for mid-2022. Flutter and load control laws design is progressing as well.

Novel Travel Experience: With respect to the "Ergonomic Flexible Cabin", operational concepts for more efficient cabin operations (smart galley/crew operations) were defined, and functional and operational requirements for supportive devices were identified. For the multi-functional cabin rest area (activities completed), tests were performed on the versatile crew rest area and the results show overall positive feedback from the cabin crew. TRL6 was achieved in early 2021 for in-seat ventilation and those activities are now completed. The activities related to "Office Centred Cabin" have been focused on the manufacturing and assembly of the BJ cabin scale 1 mock-up. Testing of the mock-up will be performed in 2022 based on the test matrix previously defined to evaluate the new concepts in terms of comfort and well-being.

Next Generation Optimised Wing Boxes: With respect to "Wing for lift and incremental mission shaft integration", 2021 was dedicated to the finalisation of the RACER wing design and manufacturing. The upper and lower wings assembly were completed and the first priority items, i.e. the lower and upper wings and the cradles, were delivered to the RACER prototype assembly line and the design of the second priority items such as the flaps and the fairings were completed. In parallel, the structural tests necessary for the permit to fly were prepared and the manufacturing of the tests items started (about 70% completed). Under "Optimised composite structures", the main achievements of 2021 were related to the preparations for the full scale 7 meter wing manufacture which will be taking place in 2022. The full scale integral manufacturing tools were in the final stages in 2021. In addition, significant progress was made regarding the SHM (structural health monitoring) algorithm development activities. With respect to "More efficient wing technologies", no major activities were done, apart from minor support to the FTB#2 Step1 permit to fly works and preparation of the aircraft for the flight test campaign. Under "Flow and shape control", the PDR for the loads alleviation system step 2 scope was achieved, focused on validation at rig level.

Optimised high lift configurations: With respect to the "High wing / large turboprop nacelle configuration", the preliminary detail design of the biphasic capillary heat transport system within the nacelle and the intake of an aircraft power-plant was completed. Under "High Lift Wing", the test campaign was completed up to subcomponents level for the thermoplastic out-of-autoclave *in-situ* consolidated upper cover with stringers. The composite outer wing box CDR was approved, and the design of all the parts was released for manufacturing. The manufacturing of the liquid resin infused wing box lower covers integrated with spars final part, already started, being all the preforms laminates formed ready to infuse the part at the beginning of 2022. In addition, the manufacture of the aluminium hot stamped rib demonstrators was achieved. In "High-Lift for SAT", the blown flap WTT was successfully performed and concluded.

Advanced Integrated Structures*:* With respect to "Advanced Integrated Empennages for Regional Aircraft", the activities focused mainly on the manufacturing of the integrated demonstrators relating to the torque box of the vertical stabiliser in multi-rib configurations and to the multi-spar box of the horizontal stabilizer with integrated leading and trailing edge.
Under "All electrical wing", the PDRs for the high voltage direct current (HVDC) and electro-mechanical actuators (EMAs) for spoilers and ailerons at system level were achieved, focused on validation at rig level of the REG FTB#2 Step 2 scope. For the structure embedded antenna SATCOM, the antenna's system was accepted, integrated and validated on the FTB#2 aircraft on ground. The flight test campaign is planned to start early 2022.
With respect to "Advanced Integrated Cockpit", completion of the last stages of the development of the multi-functional structures (focused on transport aircraft cockpit demonstrators) was achieved. In the field of multi-functional acoustic isolation technologies, a full scale noise test on a full composite cockpit demonstrator with a specifically developed acoustic interior lining was prepared for testing. The CDR of the acoustic lining configuration was achieved, the lining was supplied and installed and TRR was completed by the end of 2021. The activity on impact protection functionality has been focused on designing impact protection panels, bird strike simulation completion for CDR and preparation for a full scale bird strike test on a composite cockpit demonstrator. The structural health monitoring integration into the structure, panel level testing activity for both single and multi-impact events, impact location, required hardware, software and algorithms required for CDR were performed after PDR was achieved in early 2021. Finally, for electromagnetic compatibility and lightning strike protection activities, electromagnetic compatibility simulations were performed. Lightning stroked panels were repaired and retested according to test plan.
Under "More affordable small aircraft manufacturing", the design and all necessary moulds and tools for manufacturing of the reference and innovative composite nose part demonstrators were delivered and made available for manufacturing of demonstrators and ongoing electro-magnetic compatibility tests. Optimised jigless technology (hole-to-hole manufacture and assembly method) were successfully assessed and fatigue tests of riveted joints completed. In addition, activities on ground tests of crucial elements of the pilot's cabin and especially on the flight tests of totally new engine nacelles (metallic design replaced by composite structure) were successfully conducted.
With respect to "Assembly of Fast Rotorcraft airframe', activities were mainly focused on the manufacture of the RACER flightworthy items. First, to allow the completion of the Rotorless Tail, all complex metallic items were delivered and accepted. Then, the fuel system was delivered, installed and tested on the flight demonstrator. Finally, the windshield and windows were delivered, as well as the upper cowlings and the cockpit/passenger doors.

Advanced Fuselage*:* Under "Rotorless Tail for Fast Rotorcraft" (RACER), the following activities were carried out: full rotorless tail drawing released; finalisation of rotorless tail single part manufacturing; flyable item assembly conclusion and delivery; assembly and delivery of the tail

boom for ground test campaign, and release of permit to fly documentation advanced draft. With respect to "Pressurised Fuselage for Fast Rotorcraft" (NGCTR), donor structure was manufactured and released to allow for the start of modifications to accommodate revised major structural attachments. The design aspects for the tail section were completed. Manufacturing trials were undertaken to demonstrated technology development and de-risk test specimen and flight component manufacture.
Under "More Affordable Composite Fuselage", four full-scale fuselage stiffened panels were manufactured with automated fibre placement and one stiffened panel of the passengers cabin demonstrator was assembled. The results assessments of the fatigue and shear static tests executed on flat panels were delivered. On Design-Against-Distortion, progress was made predicting residual stress and distortion of additive manufacturing parts made out of reinforced polymers, and integrating these models in a novel design optimisation tool. For smarter fuselage development, activities focused on: testing of the first sub-component panel; sensorising and impact of a curved fuselage panel; the development and assembly of the large triaxial machine, ready for testing; the validation of the non-linear numerical platform for residual life assessment of flat stiffened panels and development of cost module for composite structures, including integration of structure health monitoring system.
With respect to "low weight, low cost cabin", activities focused on: the final definition of the human centred response model; design of the mechanical integration / installation of the major cabin items into the REG-IADP On-Ground Pax Cabin Demonstrator; CDR closure in relation to the implementation of the Environmental Control System into the demonstrator; and on the definition of location of shakers, speakers and subwoofer.

Eco-Design: Under "Eco-Design Management and ECO TA Link", regular participation in the ECO-TA meetings and participation in the reviews were performed by the members. The management activities are related to supporting vehicle economic ecological synergy / eco-design analysis (VEES/EDAS) mapping, simplified life-cycle inventory (LCI) data delivery descriptions and setting up of LCI data collection teams, as well as to writing synthesis reports and outputs for ECO TA, and strengthening the common dissemination activities. With respect to "Eco-Design for Airframe", after finalisation of the technology development in 2020, the most promising and relevant demonstrators (defined as "Flagship Demonstrators") per each technology stream (thermosets, thermoplastics, metals, and bio-materials) have been designed in detail, and the CDRs took place in 2021. The next step consists of manufacturing and testing activities in 2022 and 2023. In parallel, life-cycle assessment (LCA) data collection continued for technologies with respect to the flagship demonstrators, and this activity will further continue; resulting "International Reference Life Cycle Data System (ILCD)" data will be stored in the ECO TA Eco-Hybrid Platform (EHP). Based on this database, eco-statements will be performed for the Eco-Design demonstrators and their reference parts.
In relation to "New materials and manufacturing", the final validation of the planned activities has been performed with eco-design related benefits identified. The activities are completed.

Implementation of Complementary Grants awarded through Call for proposals

During 2021, 75 Grant Agreements for Partners awarded from Call 1 to Call 11 were active, 30 have been technically closed.
All these projects are complementing the activities implemented in the AIR ITD Grant Agreement for Members and contributing to results described above.

➔ ENG – Engines ITD

Summary of activities and progress of work in 2021

For the **Ultra-High Propulsive Efficiency (UHPE) Demonstrator** (WP2), the technology maturation plan has progressed well, completing several rig test campaigns on dedicated key enabling technologies for the Engine Ground Test Demonstrator (GTD). The maturation plan achieved TRL4 with technologies dedicated to the transmission system. A comprehensive maturation plan on the low pressure turbine, including contributions from several complementary grants, delivered results to enhance integration and performance. The manufacturing readiness level has increased for several components of the future propulsive system as turbine rear frame, shaft, acoustic inlet, large front blades. The open fan engine architecture has been selected as an option for preparing the engine ground test demonstrator (GTD).

For the **Business Aviation / Short Range Regional Turboprop Demonstrator** (WP3), the activity focused on the Tech TP demonstrator, which was modified to integrate an electrical machine from a complementary grant in the power and accessory gear box (PAGB). This enabled Tech TP to start a hybridised test campaign in 2021. PAGB test rig dynamic commissioning was completed by the end of 2021 with the resolution of the torque oscillation issue. Several rig testing activities were completed to support the demonstration, such as the mixed flow compressor and drained bearings. Turbine blade-off module test rig components manufacturing was almost completed, and air inlet pressure probes calibration performed. Optimised compressor parts manufacturing and instrumentation were completed for robustness and performance tests demonstration. Compressor module (named Turbocel) components are almost manufactured to complete test module repair for IGV compressor tests.

For the **Advanced Geared Engine Configuration** (WP4), compression system activities focused on completion of the conceptual design of the two-spool rig. This has been concluded by passing the preliminary design review (DR3) and the test concept review. The expansion system demonstrator detail design activities have been completed. Hardware procurement for the finished parts has started to support module assembly and instrumentation.

For the **Very High Bypass Ratio (VHBR) Middle of Market Turbofan technology** (WP5) the intermediate pressure turbine rig design and manufacture of the VT4-4 high Mach rig progressed with testing planned in 2022. The power gear box integration work has been completed supporting integration into the demonstrator ground test engine in WP6. The fluid systems modelling capability as defined in a complementary grant continues to progress to plan with an enhanced three-way coupled predictive model completed with the model progressing to be validated against a representative engine bearing chamber. The high pressure turbine rig facility progression is continuing with the strut casing preliminary design review completed and critical design review activity started, supporting progression to rig testing in 2022.

For the **Very High Bypass Ratio** (**VHBR) Large Turbofan demonstrator** (WP6), the intermediate pressure (IP) turbine hardware has progressed through to final manufacture and assembly for engine 1, with supporting assembly instructions and tooling manufactured. The hardware from a complementary grant providing turbine casing manufactured by advanced net-shape methods has been characterised supporting use in the engine test campaign. Intermediate compressor case manufacture has progressed with hardware delivery of the first and second intermediate compressor cases completed in 2021 supporting the demonstrator build programme.

For **Reliable and more efficient operation of small turbine engines** (WP8), the activities related to the hybrid electric architecture allowed the finalisation of the concept of the hybrid electric engine, focusing on the most promising architecture for the SAT application. For this configuration, component and sub-system modelling enabled the achievement of a preliminary aircraft integration. Combustor investigation has been carried on within a test campaign. For the compressor activities, assessment of the distortion impact has been completed, moreover the team is focusing on the optimisation opportunities for hybrid configuration.

For **Engine Eco Design** (WP9), the manufacture of parts has allowed the collection of detailed life cycle inventory (LCI) data in all three different selected technologies (additive manufacturing, carbon fibre recycling, advanced engine manufacturing processes). In addition to the parts already in scope such as heat exchanger, blisk, inlet guide vane, new parts were introduced such as the fan case, brackets, high pressure turbine nozzle to increase the engine coverage. A first complete set of data has been provided to Eco-design Transverse Activity to contribute to the CS2 LCI database.

Main achievements and progress of work in 2021

For the **Ultra-High Propulsive Efficiency (UHPE) Demonstrator** (WP2), following multiple maturation studies, a review was performed to assess the path for the engine demonstrator. The Open Fan engine architecture has been selected to be further matured and the activities focused on consolidating data to design the engine demonstrator.
As part of the maturation on nacelle, the acoustic inlet demonstrator met Manufacturing Readiness Level (MRL) 6. Several rig test campaigns of supporting technologies for the transmission system were completed, preparing the TRL4. As far as the high speed low pressure turbine is concerned, the maturation activities delivered results contributing to the de-risking of the full design, contributing to the preparation of TRL4. The assembly of the advanced turbine rear frame (TRF) was made. The rig test campaign for the HP compressor component was completed to validate TRL4 on the dedicated technologies.
Technical requirements documents have been issued for the engine demonstrator to prepare for the preliminary design phase. It is worth noting that WP2 UHPE tests are now planned in 2024 to align with the evolution of the engine concept architecture and the intergartion with the airframer anticipated in the Clean Aviation programme to maximise the results. A careful monitoring is in place to ensure achievement of the objectives by the Programme end by the members.

For the **Business Aviation / Short Range Regional Turboprop Demonstrator** (WP3), the milestone ground test with more electric PAGB Tech TP demonstration was achieved.
Main activities performed in 2021 are:

- disassembly and teardown inspection of the PAGB of Tech TP demonstrator after an extensive test campaign (including performance assessment, control system, oil interruption tests);
- manufacturing of specific parts and assembly of a hybridised PAGB integrating the serial/parallel electrical machine from a complementary grant for hybridisation demonstration;
- start of more-electric / hybridised TechTP demonstrator test campaign;

- several partial ground demo tests of gas turbine components and modules have been launched and/or completed to demonstrate technology performance and maturity, such as the mixed flow compressor performance rig test, the drained bearings partial test, and the tri-sector combustor injectors flame-out and relight partial test;
- PAGB partial test bench debugging and dynamic commissioning for endurance test;
- manufacturing and instrumentation of optimised compressors for robustness and performance tests is completed;
- manufacturing of almost all turbine blade out partial test rig components is completed.

For the **Advanced Geared Engine Configuration** (WP4), in the compression system significant progress was made in the design and preparation of the two spool compressor rig. The conceptual design was completed, including full definition of the aerodynamic design, structural and rotor dynamic assessment, definition of secondary air system and corresponding thermals. The preliminary design review was passed. Correspondingly, the test setup, intrumentation requirements, and measurement systems concept were defined and reviewed in the test concept review which was also passed.
The expansion system engine demonstrator passed the critical design review DR5 mid-year and the finished parts for machining were released. Finished parts drawings have been aligned with suppliers and completed. Trial parts have been evaluated in the first article inspections and the machining of engine parts has been released. The technology development has continued and acceptance tests for the casted blade and the ceramic matrix composites (CMC) segments have been defined and prepared. Based on the Covid-19 situation schedule impacts have been evaluated and communicated to the JU. The project plan has been adjusted with the test campaign now starting early in 2022.

For the **Very High Bypass Ratio (VHBR) Middle of Market Turbofan technology** (WP5), the final report on the alternative aluminium alloy for ICC (Intermediate Compressor Casing) confirmed the TRL4 achievement. The VT-2 data analysis and comparison outlet guide vane measurements were completed.

For the **VHBR Large Turbofan demonstrator** (WP6), a Flight Test Bed is planned to test the next generation of cutting-edge technologies regarding the UltraFan® demonstrator. The pylon design preliminary design review (PDR) component maturity gate was successfully completed and the pylon integration PDR was also completed. The flight test instrumentation progressed to plan with the master parameter instrumentation list for the nacelle agreed between the airframer and engine maker. The nacelle component PDRs are launched and will complete through to the start of 2022. The Test Readiness Review (TRR) of the IP Turbine has been completed, while key components have been manufactured and are being built into the first IPT module supporting the first ground test engine. The UltraFan® programme successfully passed the overall engine Test Readiness Review (TRR) and will complete the first assembly in time for testing early in 2022.

For the **Reliable and more efficient operation of small turbine engines** (WP8), 2021 has been focused on the hybrid electric activities. Starting from the downselected series hybrid architecture, the studies were focused on the engine components to allow a preliminary integration on the aircraft. The design and sizing of the sub-system was completed. An evaluation of compressor sensitivity to blockage and distortion was completed. Moreover, a focus on hybrid electric customisation of the compressor was carried out, enabling the definition of the optimisation opportunity of the compressor in this configuration. Based on the test results achieved within the previous tests on all additive combustors, a series of additional activities have been carried out to better investigate improvement opportunities. A test campaign on the cooling technique has been carried out.

In **ECO DESIGN** (WP9), different kinds of samples have been manufactured and tested through a complementary grant to define the boundary limits in additive manufacturing for new heat exchangers to define the design of a whole heat exchanger to be optimised in terms of weight and heat transfer. Another complementary grant has produced first recycled semi-products from carbon fibre wastes. Regarding engine parts advanced manufacturing, a blisk at full scale has been manufactured in three scenarios covering one titanium-based scenario and two nickel-based scenarios with individual manufacturing routes. The inlet guide vane (IGV) has been manufactured as a preliminary mock-up. The IGV final design freeze is expected in January 2022. In parallel, the activities have provided new or more detailed LCI data, which will feed the CS2 database to allow further environmental impact assessment.

Implementation of Complementary Grants awarded through Call for proposals

During 2021, 74 Grant Agreements for Partners awarded from Call 1 to Call 09 were active, 18 were closed.
All these projects complement the activities implemented in the ENG ITD Grant Agreement for Members and contribute to the results described above.

➔ SYS – Systems ITD

Summary of activities and progress of work in 2021

The integrated modular communications technologies progressed beyond TRL4 with the ground test achieved to support end-to-end demonstration. The connected cabin concept progressed by passing TRL4 and the connected galley achieved TRL5.
For the Integrated Electrical Wing the hydraulic power pack (HPP) equipment reached TRL5. Flight control models for the improved test platform were adapted and the HPP assembly on SIW completed.
The manufacturing of smart active inceptors hardware for demonstration was completed and electronic unit tests are progressing. EMA's flight test demonstration has been completed and the flight clearance documentation for FTB#2 Step 1 provided.
In the area of Landing Gear Systems, the direct drive system achieved TRL5+ (green taxiing) and the equipment electric actuation system for NLG achieved TRL6.
Electrical generator channels for SAT were delivered for integration. The digital generator control unit (DGCU) acceptance tests have been performed on the PROVEN rig-enabling Airbus generation test campaign. First tests on the Disconnect mock-up for principle validation have been performed. Development of the automatic reversibility is in progress, the FirmWare has been developed and needs to be fully validated. The analysis of electrical tests performed on generation channels have started.
The Electrical Environmental Control system (EECS) Critical Design Review (CDR) was fully closed and the design of air cycle turbomachine rotor tests bench have been finalised. Concerning the next generation cooling, the software was developed for protection against centrifugal compressor surge events. Activity also progressed to support eco-design. In the area of primary

flight ice detection, the system achieved TRL4.
In the area of Small Air Transportation, progress on all demonstrators was made. The SAT Landing Gear EMA and electrical braking achieved CDR. Avionics for small SAT TRL5 verifications were completed with 1st Flight Demonstration for SAT affordable future avionics execution. The CDR for SAT Fly-by-Wire Demonstrator passed and the actuator and air data probe mechanical integration into the FbW demo was executed. The manufacturing of the de-icing model was completed. Seat manufacturing and the crash test campaign of the improved seat has been postponed to the beginning of 2022. Partner projects progressed and high voltage (HV) tests started. The Monte Carlo-based large-scale simulation validation was finished successfully.
Transversal activities on disruptive electronics progressed and the work on three level compact AC/DC power converter was completed as well as the work on the high voltage DC secondary power distribution network. Research activities continued on the topics as surface treatment and de-treatment processes. Meanwhile for the transversal activity regarding an integrated simulation framework, updates have been made to the software core environment incorporating extended TRL5 capabilities.

Main achievements and progress of work in 2021

WP1 Extended Cockpit

In the field of communications, the Clean Sky 2 objective is an end-to-end demonstration of integrated modular communications at TRL5 on representative avionics trial hardware. In 2021, related technologies progressed beyond TRL4, and research on low-profile/drag electronically steerable antennas for in-flight connectivity was also carried out.
In 2021, low TRL research continued on the disruptive flight management solutions as extended strategic navigation functions using e.g. Artificial Intelligence technologies and on the new generation of head-up displays based on high brightness and compact micro displays.
Regarding enhanced vision and awareness, new efficient production methods for 94 GHz W-band waveguide antennas were investigated.

WP2 Cabin & Cargo Systems

For the connected seat, a sensor module box has been validated and seats and partial parts of the seat have been tested according to the demonstration test plan. For the seat power converter and power management, the demonstrators' development and individual testing have been finalised. For the connected trolleys and galleys, the galley content detection started. The camera detection to optimise the installed solution is still ongoing.
For the Halon-Free Fire Suppression System, the activities were completed at TRL4 to allow further developments in the future regarding on board inert gas generation system (OBBIGS) use.
Newly developed equipment of the waste-water-system which reuses grey water have been tested and the selected system approach was verified.
In parallel the continuous standardisation activities were carried out and the overall demonstration activities have been started. Finally, the cabin and cargo demonstration campaigns have been started and will be completed Q2 2022.

WP3 Innovative Electrical Wing

Flap Tab EMA and ECU validation tests were accomplished and the documentation for flight clearance made available to the airframer by end of 2021. Phase 3 of the Smart Integrated Wing Demonstrator with new hydraulic supply components (hydraulic power package) were completed. Wing architecture studies with comparisons on all achieved results on short range

and long range architectures are closed. Partner projects have been supported and even closed. Based on the results of TRL5 demonstration, the hydraulic power package including the required sub-system components were improved where needed and complementary elements such as health monitoring and electrical supplies will be added in national projects. Additional testing will be done on the Smart Integrated Wing in 2022.
After completion of step 2 electromechanical design and the manufacturing of major sub-assemblies, the Smart Active Inceptor is ready for integration. Stand-alone electronic testing was partially completed. Performance evaluation and qualification tests of the full configuration will be performed during 2022 in order to reach TRL5.

WP4 Landing Gear System
The Green Autonomous Taxiing System achieved TRL5 mid 2021. The short turn-around-time (TAT) system was optimised using a new integrated digital model in order to reduce the weight. A third part will be finished in 2022.
The Nose Landing Gear Local Electro-Hydraulic system and its components will be integrated in airframer landing gear rig to support clearance for flight test in 2022. This will enable subsequent system installation on an aircraft and demonstration of function and performance to reach TRL6, which is postponed to 2022 due to aircraft availability.
In 2021 braking technology progressed for sensing technology, modelling of high-fidelity and reduced-order artefacts for analysis purposes, design, and development of controls and prognostic and health monitoring (PHM) algorithms, as well as definition and design of suitable communication architectures. Preliminary laboratory testing activities were carried out.
Manufacturing of test articles and test rig for the composite main landing gear structure were completed in 2021. Results evaluation and TRL5 level assessment is planned in 2022. Works on landing gear sensor systems completed environmental and system testing, system integration on flight test aircraft, flight testing, and final reporting.

WP5 Electrical Chain
The demonstrator under preparation is based on three pillars: the high voltage direct current technologies, the innovative ways to install and distribute electricity to the consumers and the capability to feed the electrical network with parallelised or hybridised electrical sources. In 2021, the description of the unitary electrical products, with their expected performance, was shared and agreed. This allowed the freeze of the design of the global demonstrator where these bricks will be integrated.
In the starter-generator area, Generator Control Unit (GCU) activities were completed. The test report of the analysis of the performance on PROVEN test bench was postponed to Q1 2022. The test campaign on the disconnect system was performed, the report will be accomplished beginning of 2022. The paralleling of the power electronic module was successfully tested, the activity on energy storage was continued and different sub-systems were tested.
The work on Innovative Electrical Network harnesses including wiring and interconnection systems continued. TRL 3 level was achieved in 2021, TRL4 of high voltage AC and high voltage DC electrical networks will be reached at the end of 2022.
The Perimeter of High Voltage Direct Current activities was revised to focus on component demonstrators' preliminary design. Expected performance of the demonstrators were defined.
Definition of the required content and functionalities of the eECS power electronic module demonstrator has progressed well and will enable demonstrator delivery to D10 in 2022.

WP6 Major Loads

The Adaptive Environmental Control System was validated at TRL4 in 2021. A critical design review of the approach proposed in the adaptative ECS project was held at the end of 2021.
For the electrical Environmental Control System and Vapour-Cycle System demonstrators, the system and components have been performed to validate the technologies up to TRL 4.
The test matrix has been matured and agreed between the partners for full-scale icing wind tunnel testing in 2022.
TRL5 for primary-flight-ice-detection system, and more precisely at ice accretion rate and crystals level, was postponed to Q2 2022 due to difficulties in booking icing wind tunnel test campaign in 2021.
The Airborne Interferometric Ice Sensor demonstrator was matured up to TRL3 mid of 2021.
Virtual demonstration of Air Systems initiated in 2021.

WP7 Small Air Transport Activities

Technologies are maturing towards TRL5, through the manufacturing/assembly of technology demonstrators and the execution of test campaigns. In particular, the more electric landing gear rig test was prepared. In this test both the electric brake and actuation will be mounted on a P180 landing gear test rig to verify system functionality and to validate high level requirements.
On affordable future avionics solution, the first flight demonstration has been accomplished integrating enabling technologies.
Modified passenger seats have been crash-tested in order to validate the developed methodology. Documentation for the crash test second campaign was prepared.
In the field of passenger comfort, ground heat loss measurement methodology has been finalised for acoustic and thermal insulation and for acclimatisation comfort.

WP 100.1 Power Electronics and Electrical Drives

The work on 3 level compact AC/DC power converter is completed as well as the work on the high voltage direct current secondary power distribution network. The simulation activities with respect to advanced models for decision making on centralised/decentralised architectures was completed. This is providing a foundation for future work on integrating a number of technologies into an electrical power train demonstration including electro-magnetic compatibility and stability optimisation.

WP 100.2 Product Life Cycle Optimization: ECO Design

Research activities continued on surface treatment and de-treatment processes reducing the use of CrVI, functionalised thermoplastics and composites, high temperature electro-mechanical systems.

WP 100.3 Model Tools and Simulation

In 2021, yearly updates to the software core environment incorporating extended TRL5 capabilities based on stakeholder and user feedback were completed. The underlying framework was deployed with significant extensions towards wider workflow management capabilities for customised process support.
The thermal aircraft platform and integrated thermal architecture modelling was extended to include a dedicated parallel hybrid propulsion use case to demonstrate flexibility. In addition, the testing and integration of the aircraft operations library was completed in 2021. The final onsite commissioning of the HiL test bench was delayed as a result of the global Covid-19 crisis. Commissioning of the system took place in early 2021 and, although it was impacted by Covid-

19 travelling restrictions, it was followed by the HiL test campaign in the second half of 2021 with the final deliverable completed.

Implementation of Complementary Grants awarded through Call for proposals

During the period, 76 Grant Agreements for Partners awarded from Call 1 to Call 11 were active, 10 were closed. Due to the Covid-19 impact, 22 GAPs were extended with no major impact on ITD results.

All these projects complement the activities implemented in the SYS ITD Grant Agreement for Members and contribute to results described above.

➔ ECO – Eco-design transverse activity

Summary of activities and progress of work in 2021

Building on the 2020 achievements, concrete applications have been further developed in 2021 and defined as flagship demonstrators (FSD) in each IADP/ITD to showcase ecological and economical improvements with regard to Design for Environment DfE2020+.

A procedure for dealing with LCA Indicators referencing (yet) state-of-the-art implementation analysis of EU Reference PEF Methods was conducted on the basis of aviation-relevant parts and technologies. An agreement on the consolidated list of indicators used to assess the eco performance at technology level will be reached in Q1 2022 and will be implemented into the LCA results.

The procedure also reflects the management of the interpretation and the evolution of background aeronautical materials processes and resources and thus adaption of particular indicator sets, midpoint/ endpoint methodology correctness.

The set out FSD Demonstration and contributing products and pilot/stage technology references are being managed and a process has been established to exploit the results in the form of best available technology footprints (in the FSDs) and make out EPD Environmental Product Declarations Type III. Eco TA has established an overall relative commendation level of 40% environmental improvement in the final results.

Delivery of life cycle data from SPDs to Eco TA still remains a challenge of the programme. As these life cycle data build the foundation for the life cycle assessment and for the collation of global key performance indicators, coordination measures have been increased to ensure and enforce the delivery of life cycle data from SPDs to Eco TA.

The Eco Hybrid Platform has been released as a version for user elaboration.

Due to the Covid-19 pandemic situation meetings were limited to online sessions. Physical workshops and conference events have been postponed to the 2022/23 period.

Main achievements in year 2021

During 2021 the major achievements are:

- Two LCA/Eco Statement Report Outputs, including indicator set
- Eco Hybrid Platform Version 0.1
- Design for Environment DfE2020+, initial version
- Procedure in dealing with LCA Indicators
- Flagship demonstrators enforced in IADPs/ITDs for evaluation of ecolonomic impacts

Implementation of call for proposals and thematic topic in the period 2021

The linking of 20 Grant Agreements for Partners or Thematic Topic Projects to the Eco-design Transversal Activity has been refurbished and made fit for integration. The partner projects are complementary to the SPDs GAMs and their Topic Managers are responsible to ensure delivery of validated life cycle inventory data via SPD to Eco TA according to Eco-design standards.

➔ SAT – Small Air Transport Transverse

Summary of activities and progress of work in 2021

Within the Small Air Transport Transverse Activity (SAT TA), the second loop of design of the green 19-seat small commuter was completed with integration of technologies matured at critical design review (CDR) level. The E-STOL (Electric/Hybrid Short Take-Off and Landing) conceptual design further matured in 2021 with the definition of the hybrid-electric power train architecture and preliminary integration studies performed.

Main achievements and progress of work in 2021

In 2021, the three SAT Work Packages progressed almost in line with the objectives.

WP1 – The programme was monitored on a continuous basis, ensuring timely reporting and alignment with usage of resources. Deliverables and milestones delayed in 2020 due to both Covid-19 and technical issues have been recovered.

WP2 – Two Small Aircraft Commuter Green Aircraft configurations have been analysed in 2021:

- o 19-seater green and more affordable small commuter EIS2025 (entry into service in 2025): the second design loop of EIS2025 commuter integrating TRL5/6 technologies based on subsystem technology CDRs has been finalised and preliminary assessment of performance done. The preliminary results show that targets fixed at Programme beginning (-20% CO_2 and NO_X emissions) are met for the design mission (800 nm, 230 KTAS).
- o Conceptual studies on the E-STOL Green 19-seats Commuter A/C configuration EIS2032 (entry into service in 2032) have started, including preliminary allocation studies of hybrid power-plant.

WP3 – In order to further mature the most promising airframe, engine and system technologies and assess related benefits at aicraft level, preparatory activities started in 2021 towards the integration into the SAT integrated demonstrators:

- o SAT-D1 – Iron Bird Demonstrator
  - CDR of the “Fly-by-Wire for SAT” demonstrator passed in September 2021.

- High voltage lab tests of “Electrical Power Generation and Distribution for SAT” started in November 2021.
- CDR of “Electrical Landing Gear for SAT” achieved in July 2021.

o SAT-D3 – Safe and Comfortable Cabin

- Affordable Future Avionic Solution for SAT – the first batch of technologies were flight tested in June 2021 as planned. Preparation of the second flight test campaign (Phase 1) is scheduled for September 2022 and is progressing according to plan.
- Lab tests of “Comfortable and Safe Cabin for SAT” were completed in March 2021.

➔ TE – Technology Evaluator

Summary of activities and progress of work in 2021

In 2021, progress was made in the six remaining Work Packages, in line with the objectives:

WP0 contributed to the elaboration of requirements to launch TE activities such as: the socio-economic effects of the Clean Sky 2 Programme (incl. competitiveness & additionality of CS2 and COVID-19 impacts on aviation), vehicle-specific forecasts updates to 2050 in relation to rotorcraft, SAT and BizJet; and climate impact and local air quality assessments.

WP2 contributed to strengthening the interfaces between the TE and IADPs, ITDs and TAs. The series of regular monthly conference calls between the TE and the Clean Sky 2 partners continued in this respect. Four TE-SPD workshops were held: the design of additional TE concept aircraft (February), overall “vehicle models” (March), the impact of the Covid-19 pandemic (September) and exchange on structure, methodology and content of the planned activity.

In WP3 – Mission Level Assessment, workshops were organised in relation to the SPD aircraft models and aircraft modelling of the TE itself (people mover and LR++ aircraft concept). Inputs and information from the TE workshop on “vehicle models” and from the CSJU hosted “techno mapping” workshop in February 2021 was used for the preparation of the 2nd global assessment. In addition, another task included the contribution to two TE projects. The first one deals with the elaboration of roadmaps for alternative energy sources and novel propulsion technologies, with a special focus on H_2. The second project deals with reduction of the environmental impact through the optimisation of air traffic system in terms of aircraft size/range, missions and flight network.

In WP4 – Airport Level Assessment, the activities concentrated on the preparation of the 2nd assessment and the planning of the consideration of updated SMR and LR aircraft from LPA in the airport modelling process as well as the TE concept aircraft LR++ and “people mover”. In addition, new reference vehicles were discussed and agreed upon for the Next Generation Civil Tilt Rotor and the compound configurations, respectively.

In WP5 – ATS Level Assessment, enhanced activities on the level of scenarios and forecasts were conducted to consider especially the impact of the Covid-19 pandemic but also the potential influence of policy changes in form of potential sub-scenarios based on assumptions regarding the European Green Deal. In addition, connectivity and economic impact modelling have been carried out. Support was provided to the project dealing with the elaboration of roadmaps for alternative energy sources and novel propulsion technologies, which proposed H_2 propulsion in a regional aircraft, as well as in a short/medium range aircraft. Additionally, support was provided to the CS2JU study on the socio-economic impact started in November 2021. Reflecting the need which arose from the evaluators' recommendations to consider climate related policies, an investigation of future Sustainable Aviation Fuel (SAF) prices to be considered in the demand modelling and related forecast scenarios was also performed.

In **WP7** the TE Dissemination and Exploitation activities were updated. Due to the impact of Covid-19, on-site presentations at conferences remained limited. However, the virtual participation of TE to conferences was possible and many TE-related topics were presented (e.g. EASN conference special session and others). The release of two posters, update of the TE teamsite, the contribution to the update of the Clean Sky 2 website and the preparation of the TE Impact Chapter in relation to the Work Plan 2022/2023 were performed.

Implementation of Complementary Grants awarded through Call for proposals in 2021

During 2021, 7 Grant Agreements for Partners awarded from Call 1 to Call 11 were active, 3 have been technically closed. All these projects are complementing the activities implemented in the Technology Evaluator 2 TA Grant Agreement for Members and contributing to results described above.

1.5. Calls for tender

Due to operational reasons, two initially planned operational calls for tenders in 2021 were merged into one open procedure with slightly modified scope. The operational call for tender resulted in award of a direct service contract for which the details can be found below:

Call for tenders 2021				
REF NUMBER AND SUBJECT OF THE CONTRACT	TYPE OF PROCEDURE	CONTRACT AWARD NOTICE	CONTRACT VALUE IN EUR	CONTRACTOR
DC/CSJU.2021.OP.02- Provision of an independent study on the socio-economic impact of CS2 Programme	Open Call for tenders	2021/S 199-517887	1.484.250,00	Roland Berger GMBH

1.6. Dissemination and information about project results

In 2021, a series of actions were implemented aimed at raising awareness among the beneficiaries about the importance of dissemination and exploitation (D&E) of the projects' results.

Since the last Call of the Programme was evaluated in 2020, the activities carried out by the JU were consecrated primarily to the monitoring of the D&E activities of the projects in course of implementation.

The main activities carried out in 2021 are the following:

Organisation of a workshop for beneficiaries of the projects, with an attendance of more than 100 participants, providing information on D&E rules on H2020 and useful tips to increase the visibility of project results;

Organisation of a workshop for project officers, to recall the main rules and main obligations of participants under H2020 and tips to better help beneficiaries to increase their visibility;

Participation to the periodic Programme Coordinators' meetings, to monitor D&E continuous results and provide assistance where needed;

Assistance on a daily basis to projects concerning any of the D&E requests.

To notice, in all the events above important information has been provided on publications of technical and scientific articles, open access and other publishing rules such as green and/or gold access; how to build a solid plan for dissemination and exploitation (PEDR) submitted as a deliverable in the project and to be continuously updated depending on the state of advancement; the extent of open data and data management plan; H2020 exploitation booster and H2020 results platform. Finally, some words on the open Research Europe publishing platform has been provided, to familiarise with the publishing platform of the EC.

Concerning the main performance, in 2021 there is a net increase in all the dissemination and exploitation activities.

In 2021, the number of reported peer-reviewed and technical papers increased by more than 30% compared to 2020; the number of theses by 59% and book chapters by 18% and participation in conferences by 30% notwithstanding the limitations due to Covid-19. In addition, a spectacular increase in other dissemination activities such as the publication of press releases or articles in magazines has been registered for 79.4%.

Exploitation activities register a good increase at JU level, although more effort is needed for some SPDs, and especially for patents. More specific information per SPD is provided in Annex 4.

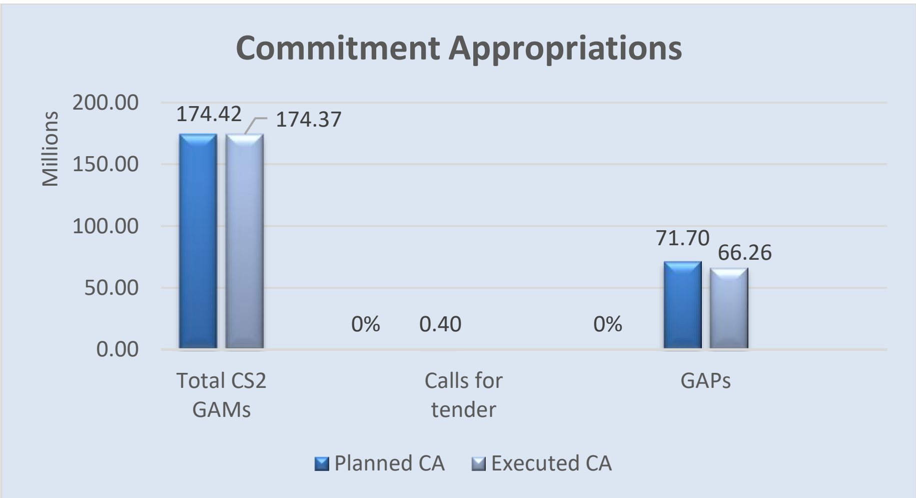
1.7. Operational budget execution

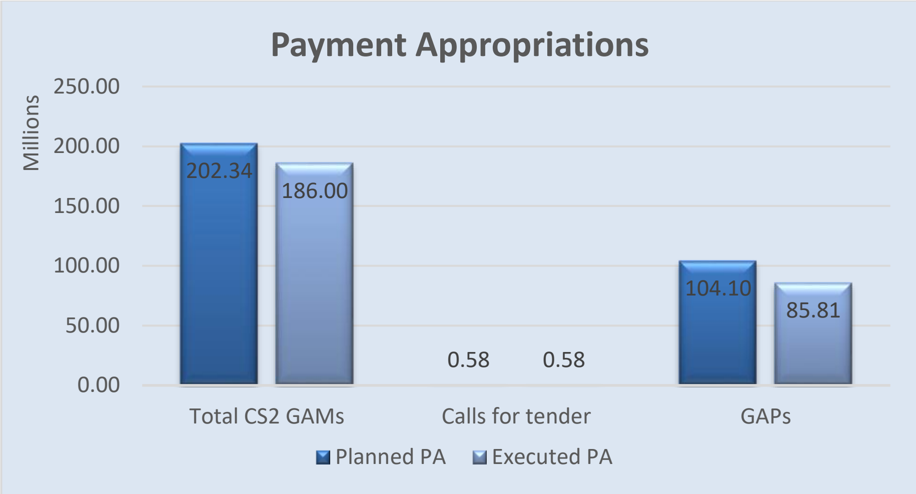
The execution rate for commitment appropriations consumption reached 100% in 2021 (97,6% in 2020) while for payment appropriations reached 82.9% (compared to 88.7% in 2020) with 69.8% for GAMs and 98.2% for GAPs respectively. This is explained by the delays in implementing the technical activities for the following main reasons:

- the under execution in the GAMs 2020-2021 (-17% budget, ~-19,5 million €);
- the slow-down of activities in the GAPs due to Covid-19 pandemic leading to a high number of requests for extension (>80% of a total of 148 amendments processed in 2021) resulting in a lower level of costs submitted.

Title IV CS2 Budget execution	Executed CA	Executed PA
LPA	63.934.220,52	16.003.215,85
REG	9.140.558,00	3.124.335,02
FRC	14.424.291,15	6.159.294,31
AIR	20.903.451,34	9.599.833,61
ENG	24.205.624,70	4.274.362,51
SYS	16.599.089,52	4.802.926,95
TE	2.672.878,80	295.470,37
ECO	1.136.175,76	357.281,25
SAT	762.207,27	421.147,87
Total CS2 GAMs	153,778,497,06	45,037,867.74
	100.0%	82.9%
Calls for tenders	1.484.250,00	0
	100.0%	0,0%
GAPs	0,00	54.042.671,20
	0%	99%
Total CS2 Operational	155.262.747,06	99,080,538.94
	100%	82.9%

The above payment execution rates resulted in €22.9 million of unused funds in 2021 (compared to €16.2 million in 2020).





Budget evolution

On 18 December 2020 the Governing Board (GB) adopted the second amendment to budget 2020-2021 for a global amount of €70.4 million in commitment appropriations and €89.3 million in payment appropriations (*Initial Budget 2021*).

In April 2021, the GB adopted an amendment *('3rd amendment to the 2020-2021 budget')* to re-inscribe the carry-over related to the financial year 2020 (unused commitment and payment appropriations from closed GAMs and GAPs). This was used to cover the GAM 2020-2021 extension to years 2022 and 2023 as well as the payment credits needed for the carried forward administrative commitments.

In October 2021, a fourth budget amendment *('4th amendment to the 2020-2021 budget')* was adopted to further increase the available credits needed for the GAMs amendments to extend the period until 2023.

Lastly, a few internal transfers (as decided by the Executive Director in accordance with the financial rules) were required to ensure an efficient resource allocation for the running costs and operational activities implementation.

The final budget adopted by the Governing Board on 26 October 2021 for implementation amounted to €182.1 million in commitment appropriations and €189.4 million in payment appropriations.

1.8. In-kind contributions

In-kind contributions (IKC) are provided by the private members throughout the lifetime of the programmes.

For Clean Aviation programme the IKC targets will be defined based on the members participation into the programme. Due to the late entry into force of the SBA on 30 November 2022, no IKC under Horizon Europe were reported for 2021.

For Clean Sky 2 programme thetarget amounts are set out in the Clean Sky 2 JU Regulation, reppelled and relaced by the SBA:

	H2020 (m €)
Max. Union contribution for operational expenditure	1.716
Max. total EU contribution to operational cost of private members (leaders/core partners)	1.201
Min. expected in kind contribution from private members to the Joint Undertaking (IKOP + IKAA)	2.193
Minimum private members in kind contribution for additional activities – in-kind (IKAA)	965

H2020 programme:

The private members can provide their in-kind contributions in two ways under the H2020 programme: in-kind contributions from operational (JU funded) projects, i.e. unfunded share of costs on JU projects (IKOP) and in-kind contributions from implementing the so-called additional activities (IKAA).

IKOP certification and validation

According to the Clean Sky 2 JU regulation, all costs to be taken into account as IKOP must be certified. The IKOP values mentioned in the table below show both the reported and the certified and validated amounts to date. As of the cut-off date of the Final Accounts 2021, the JU has validated certified contributions to the value of €581.336 million. A breakdown by area of the projects is provided below.
The difference between the reported and certified values is linked to the grant reporting cycle, for 2020 the IKOP values are not validated[5] yet, while for 2021 only the reported values are available. The verification of the received cost claims is on-going and the validation of the certifified amounts will take place in the second half of 2022.

[5] The certification will be done together with the 2021 values reported with the GAM costs claims 2021.

ITDs/IAPDs	GAM 2014 – 2021 JU contribution*	Reported IKOP by private members 2014-2021*	Certified and validated by JU IKOP 2014-2021	Still to be certified IKOP
AIRFRAME	192,945,928	122,747,644	103,719,688	19,027,957
ECO-DESIGN TA	4,241,823	21,652,766	2,895,987	18,756,779
ENGINES	204,270,181	161,204,126	144,226,644	16,977,482
FAST ROTORCRAFT	118,436,776	112,427,872	69,873,600	42,554,273
LARGE PASSENGER AIRCRAFT	261,762,647	192,764,817	132,114,967	60,649,851
REGIONAL AIRCRAFT	64,937,727	96,310,583	41,112,202	55,198,381
SMALL AIR TRANSPORT	1,486,209	8,978,110	408,096	8,570,013
SYSTEMS	141,084,923	106,272,318	86,021,854	20,250,463
TE	3,608,534	1,448,244	962,844	485,400
TOTAL	**992,774,748**	**823,806,482**	**581,335,883**	**242,470,599**

**including the reported amounts by private members for 2020 + the estimated amounts for 2021*

IKAA certification and validation

The IKAA value of €1.27 billion reported includes a total amount of €1.03 billion fully certified by the members' external auditors and validated by the Governing Board (GB) for the period 2014-2021[6]. This value has also been provided to the GB for its opinion.
The additional activities underlying the values validated by JU management to date and reported for the period 2014-2021 consist of:

- preparation of test aircraft/platforms including infrastructure for flight testing;
- development and testing of advanced component technologies, modelling, control systems and materials systems for the engine demonstrator programme;
- development of accompanying manufacturing methods and techniques, e.g. for laminar wings;
- development of supporting technologies, e.g. research and technology development of architectures, technology bricks and other enablers for systems and airframe;
- aircraft architecture design process;
- new manufacturing and assembly techniques;
- composite manufacturing processes;
- activities concerning the innovative passenger cabin;
- configuration optimisation tools;
- development of various technologies/materials lowering operating and life cycle cost;
- Counter-Rotating Open Rotor related complementary activities;
- Landing Gears complementary activities;

[6] Decision ref. CA-GB-2022-06-24 Opinion on IKAA 2014-2021

- preparation of simulated environment for integration of early developments.

At the end of 2021, at programme implementation level, the JU incurred 83% of the total programme expenditure[7], whereas the members already provided 97% of the expected total in kind contribution, with the IKAA rate of 132%. Assuming that the current trend will be constant for the remaining years of H2020 programme, the private members will exceed the overall €2,155.00 million IKC obligation as required by the Council Regulation.

	Targets CS2 Regulation m€	Actual 2014-20 m€	Achieved %
Max. Union contribution for operational expenditure	1,716.00	1,429.81	83%
Max. total EU contribution to operational cost of private members (leaders/core partners/associates)	1,201.00	995.72	81%
Min. expected in kind contribution from private members to the Joint Undertaking (IKOP + IKAA)	2,155.00	2,088.10	97%
Min.private members in kind contribution from additional activities (IKAA)	965.00	1,289.99	132%

1.9. Synergies with the European Structural and Investment Funds (ESIF)

The Clean Sky 2 Joint Undertaking had been called upon by its founding Council Regulation (EU) no. 558/2014 of 6 May 2014[8] to develop close interactions with European Structural Investment Funds (ESIF) and to underpin smart specialisation efforts in the field of activities covered by the CS2 JU.

In this context, the JU strongly supported synergies with ESIF by allowing complementary activities to be proposed by applicants to CS2 calls and by amplifying the scope, adding parallel activities or continuing CS2 co-funded projects/activities through ESIF in synergy with the Clean Sky 2 Programme and its technology roadmap. The JU also promoted the use of ESIF to build and enhance local capabilities and skills in fields related to the programme, in order to enhance the level of European competitiveness of stakeholders in this area.

Action plan and synergies with Member States and regions

To foster the participation of the European countries and regions, Clean Sky 2 had launched a pilot strategic plan for synergies with Member States and regions that was successfully completed in 2021 and resulted in 18 MoU at a national or regional level, representing 33 EU regions (including the regions that are geographically placed in 4 Member States with a MoU at national level) out of the 155 regions that participated in Clean Sky calls.

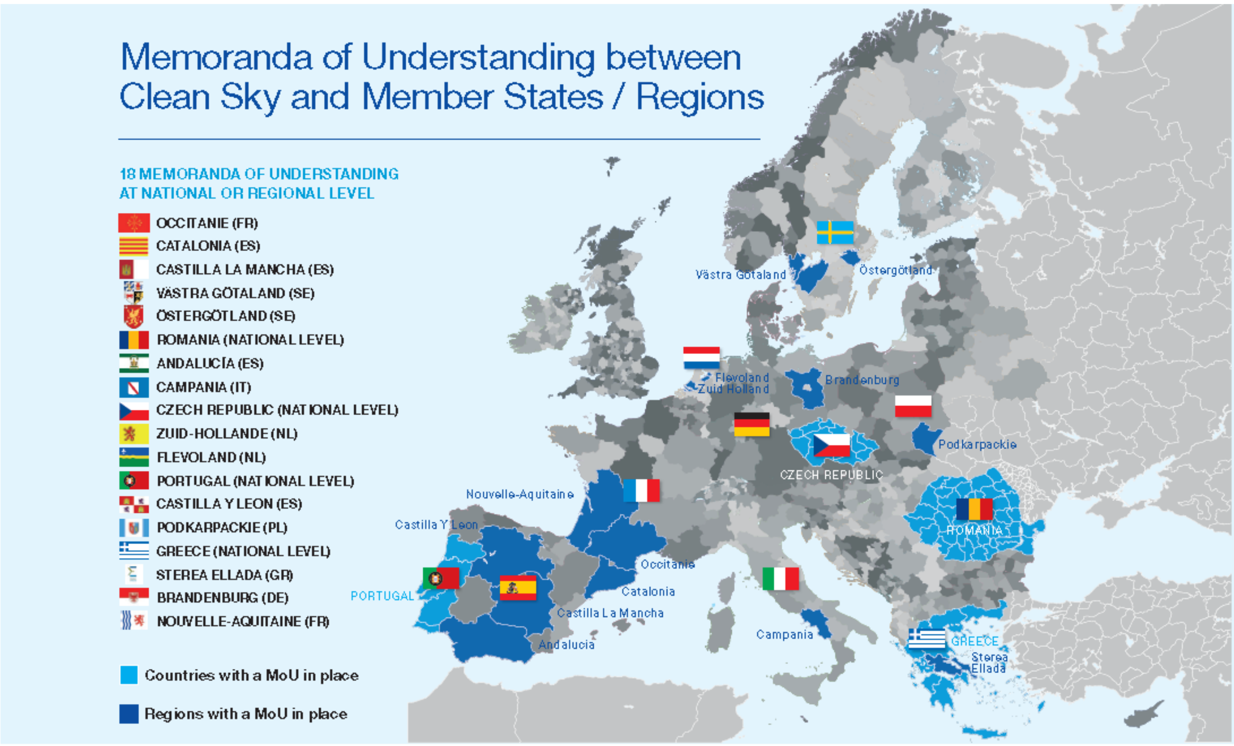
By the end of 2021, the following figures show the progress in the action undertaken by the JU:

[7] 2014-17 are validated and certified figures, the 2018-19 figures are based on reported values provided by the Members.

[8] See in particular Recital 21: “the CS2 JU should seek to develop close interactions with the ESIF, which can specifically help to strengthen local, regional and national research and innovation capabilities in the area of the Clean Sky 2 Joint Undertaking and underpin smart specialisation efforts.”

At strategic level, and despite the consequences of the Covid-19 crisis since 2020, the JU was continuing the implementation of the action plan on synergies, and the support to Member States and regions that were interested in using the ESIF or other national/regional funds for the aeronautics area and other related technologies in this domain. In 2021, the CS2JU also continued its bilateral contacts and strategic discussions with interested Member States and regions, preparing the ground for synergies within the Clean Aviation context.

The countries and regions with a MoU in place are depicted in the following map.



MoU implementation in 2021

In the framework of the MoU implementation, some Member States / regions under a MoU had launched calls and funding schemes in 2020, that either included topics dedicated to aeronautics that are synergetic to the JU or else incentivised the submission of proposals complementary to JU activities and objectives. During 2021, these countries (Greece, Portugal) and regions (Campania, Occitanie, Västra Götaland, Castilla La Mancha) supported the projects that had been selected by their national or regional calls. The JU had been called in the provision of advice and technical expertise in the context of the MoU cooperation.

Additionally, within the context of activities dedicated to synergies, the JU organised several virtual meetings with countries and regions of its MoU network and outside, as well as with clusters, to discuss about the challenges for synergies and strategic cooperation within the Clean Aviation programme.

2. SUPPORT TO OPERATIONS

2.1. Communication Strategy and activities

2021 was a truly challenging year. The Covid-19 pandemic, which hit the aviation industry particularly hard in 2020, continued to have an impact on the world with cancelled flights, lockdowns, and travel restrictions. In turn, the effect was felt on Clean Sky's projects, with consequences for team mobility and technical timelines. We were forced to adapt Clean Sky's communications actions according to the situation, to ensure continuity in our news and key messages while preparing the foundations for the new Clean Aviation programme.

Our overall communication goal – to showcase the progress and results of the many European projects working towards our environmental goals to reduce emissions and noise levels from aircraft – in principle remained the same. In practice, however, the new situation deeply affected some communications areas such as public relations and institutional affairs, events and publications. A particular challenge was to anticipate and prepare for the new Clean Aviation programme on top of the regular remit.

Consequently, the creative strategy focusing on brand-new digital/online actions and media partnerships initiated already at the start of the pandemic in 2020 was fine-tuned and perfected, with the aims of sharing and disseminating Clean Sky messages, reaching new audiences, and building our positive reputation as a European partnership that delivers results.

In addition, the Clean Aviation communications strategy for 2021-2022 was discussed and endorsed by the preparatory group for Clean Aviation (CS3 PG) at its October meeting, paving the way for strong strategic communications to help get the new programme off to a flying start.

Communications actions took place in 2021 in four main strands: 1) impactful content creation; 2) enhanced digital projects; 3) digital events; and 4) wide-reaching press work and press partnerships.

Impactful content creation to reach wide audiences

Clean Sky worked closely with members and partners to produce new and updated impactful content to showcase key facts and figures and technology results to date.

A key piece of content in 2021 was the design, production and publication of the report *Highlights 2020*. This brochure focused specifically on achievements of the CS2 programme in the previous year, and included up-to-date facts and figures as well as sections on synergies with regions and the future programme. Although it was also disseminated by post, the brochure performed well online in a digital format, helped by an attractive design.

A special edition of Skyline magazine was also published in 2021, focusing on research organisations in Clean Sky. This magazine included pieces from project participants from Europe's leading research centres, industry associations, and the European Commission.

Another action was the creation and publication of 30 stories on Clean Sky 2 results, covering all technology platforms, which built on the successful batch of stories produced in the previous two years. The stories were published on Clean Sky's website and a dedicated promotion campaign on social media took place throughout 2021 to share them more widely.

Regular news articles on the website continued throughout 2021, with more inputs from Clean Sky's programme unit to produce short, catchy pieces of news. Altogether, 52 news articles were published.

The Executive Director's blog became established in 2021. Thought leadership pieces were developed, which were then published on EurActiv, LinkedIn and on the website. A total of seven blog posts were published over the course of 2021, and content relating to the new Clean Aviation partnership performed best. The highest-performing blog post for 2021 was entitled "Clean Aviation is gearing up for take-off". On EurActiv, it was read 2,319 times. Two weeks after publication on LinkedIn, it had been read 288 times, received 212 reactions and the 'short post' which led to the article had been read 12,070 times.

In connection with the launch of Clean Aviation, a huge amount of effort went into the creation of communications material supporting the new identity: logo, corporate identity guidelines, fact sheets, opinion articles and FAQs produced in alignment with EU impactful research & innovation narrative and visual identity, and widely communicated among the Clean Sky/Clean Aviation membership.

Enhanced digital projects

With the cancellation of physical events and airshows in 2021 (particularly the Paris Air Show - Le Bourget), digital communications took centre stage as a way to share Clean Sky's messages and reach new audiences, and Clean Sky continued to invest in this area throughout 2021.

The major digital highlight in 2021 was the creation and launch of www.clean-aviation.eu in connection with the launch of the new programme on 1 December. New features included a refreshed homepage, a completely rewritten Clean Sky section, and a brand-new Clean Aviation area to cater for the high level of interest in the new programme. Traffic to the website almost doubled in December 2021 compared to December 2020 (from 12 671 in December 2020 to 21 223 in December 2021). Overall traffic figures show that the number of visitors increased throughout 2021 as a whole compared to 2020 – from 154 790 in 2020 up to 169 625 in 2021, with 21 223 visitors arriving in December 2021. This means that December alone accounted for 12.5% of the total website traffic for 2021, a significant figure given that December is usually a month with less traffic due to the holiday period.

Clean Sky's first-ever online stand, which was launched in November 2020 with the aim to replicate an airshow experience in a virtual format, was updated in 2021 with two new technologies. The promotion of the online stand continued in the first half of 2021 with a dedicated action with Politico in several Member States, as well as social media campaigns. These actions resulted in over 8000 visitors to the stand in 2021.

Clean Sky's monthly digital newsletter *E-News* greatly increased its subscriber list, from 4187 in January 2021 to 5192 by 1 January 2022, in part due to the Clean Sky spring event in April. Following the launch of Clean Aviation, the *E-News* format was enhanced accordingly. This increase in subscribers was observed even taking into account a campaign launched in September 2021 that removed "zombie subscribers" who never engage with E-news. Such campaigns ensure that our list remains active and up-to-date.

In 2021 our social media strategy led to more frequent posts and greater coordination with the European Commission and Clean Sky Members, which notably increased traffic by amplifying each other's messages. On Twitter, 185 Tweets were posted, with 505K impressions and 434 new followers. On LinkedIn, 170 posts were made, with 520K impressions and 3249 new followers – bringing Clean Sky's total social media following to over 12 000 people.

Digital events

As digital events continued to remain the norm for much of 2021 due to the Covid situation, Clean Sky continued to organise and participate in online conferences and panels to share key messages.

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

Additionally, Clean Sky participated in external high-profile aviation events to raise awareness of our goals and achievements while expanding our community. These included, in virtual formats: special Clean Sky sessions at the US's AIAA SciTech forum; the green aviation summit organised by ATAG and Cranfield University; EU Industry Days; France's AAE conference; a joint webinar between the EU and the US FAA on sustainable aviation; EASN's annual conference; Clean Sky sessions at ICAS Shanghai; Portugal's AED Days; a talk for TU Delft alumni; ADM Torino; and a lunch talk for USAIRE Aerospace Business Club.

Actions around these events included promotion through the Clean Sky website, E-News and social media; coordinating with the organisers on practical and technical aspects; preparing briefings and presentations for the Executive Director; and writing news articles and social media posts covering key messages afterwards.

Wide-reaching press work and press partnerships

To continue to reach new audiences, share our messages and to prepare for the launch and promotion of Clean Aviation in late 2021, Clean Sky agreed on several media partnerships with key media outlets.

In a bid to engage a new audience, Clean Sky invested in a media partnership with the Brussels Times for two campaigns over the course of 2021. The audience is made up of Brussels residents, including EU policymakers and influencers. Clean Sky's first campaign with the Brussels Times launched in June 2021 and resulted in 1 962 322 impressions on Brussels Times' homepage; 8 529 clicks into the article and an average reading time of 3 minutes 16 seconds. After this result, it was decided to engage with Brussels Times for other articles – on 1 December 2021, an article was published on the Brussels Times website to celebrate the launch of Clean Aviation which resulted in 1 858 584 impressions on the homepage; 7 515 clicks into the article and an average reading time of 2.05 minutes. A banner campaign was also launched which resulted in 219 157 impressions and 411 clicks in total.

Clean Sky continued to engage with EurActiv for the policy topic sponsorship of the topic Sustainable Aviation, and will continue this engagement for 2022. Overall the initiative resulted in 22 289 reads of 22 sustainable aviation articles, of which 19 815 were unique visitors. 1 840 shares on social media (Facebook and Twitter) of these articles were recorded. A banner campaign also received 17 678 impressions, and 1 510 clicks were recorded on all visual elements on the page. The launch of Clean Aviation was also celebrated on the Sustainable Aviation page with the publication of an op-ed by Axel Krein on 6 December 2021.

An article was also published in the European Files on 1 December 2021 to mark the launch of the new Joint Undertaking, and several paid media partnerships were also set up for 2022 to highlight the new programme.

In addition to that, specific press briefings between key journalists and the Executive Director were organised in connection with the Clean Sky spring event in April and the launch of Clean Aviation, leading to positive press coverage.

Finally, the Communications team suggested and organised a press training to optimise the team's capabilities to deal with press queries and public speaking, in preparation for the launch of Clean Aviation.

Clean Sky continued implementing the large Communications Framework Contract in four different lots, which run from 2018-2021. At the same time, a joint Framework Contract for communications services with four lots for Clean Sky, SESAR and Shift2Rail Joint Undertakings was published, assessed, and granted in 2021. The Communications team led the work on drafting specifications work and was part of the assessment committee.

In 2021 the Head of Communications was supported by an assistant Contract Agent, an interim, and an in-house consultant writer/editor.

2.2. Legal and financial framework

The JUs Single Basic Act

In the course of 2021, the JU provided legal support to the preparation of Clean Aviation Joint Undertaking including the inter-institutional legislative process related to the Single Basic Act and to the preparation and early design of a number of preparatory actions related to the establishment of Clean Aviation JU and its operating framework. The JU legal team coordinated over the year 2021 a "WG3" on governance and operating principles established in the framework of the Clean Sky 3 Preparatory Group (CS3PG) in order to ensure, discuss and negotiate with the private side appropriate necessary preparatory measures for the timely establishment of the Clean Aviation JU including its private Membership, commitment letter process, design and organisation of the new governance bodies in particular Governing Board and Technical Committee and other operational aspects.

The Council Regulation (EU) 2021/2085 of 19 November 2021[9] establishing the Joint Undertakings under Horizon Europe (the "Single Basic Act") was adopted by the Council on 30

[9] 30.11.2021 EN Official Journal of the European Union L 427/109

November 2021 and entered into force the same day. The Clean Aviation Joint Undertaking established under the Single Basic Act was therefore legally established on 30 November 2021 pursuant to Article 174 as the legal universal successor of the Clean Sky 2 Joint Undertaking in respect of all contracts, including employment contracts and grant agreements, liabilities and acquired property of the Clean Sky 2 Joint Undertaking.

Under the new legal framework, the ongoing Clean Sky 2/H2020 programme activities and actions and the financial obligations related to those actions will continue to be governed under those applicable rules until their completion, thus allowing the continuation of the ongoing CS2 programme and its technical activities until its completion foreseen by 31 December 2024.

From the entry into force of the Single Basic Act and the end of the year 2021, the CAJU has contributed to the establishment of the private Membership of the CAJU and of the formalisation of its acceptance of the Single Basic Act and of its commitment process (Letter of Commitment), to the preparatory work and establishment of the new governance framework and bodies of the CAJU and of its operating framework set under the Single Basic Act via a number of Governing Board decisions on 16 December 2021 (including an "omnibus decision" confirming the application to the CAJU of a list of Governing Board Decisions and legal acts adopted under CS2JU), the acknowledgment of the private membership agreement and the collective letter of commitment required under the Single Basic Act.

The JU actively cooperated with the Commission also on the legal design and preparation of the Horizon Europe model grant agreement and JU specific provisions and on a number of legal and operational aspects and procedures to be put in place in early 2022 to ensure a timely launch of the CAJU programme and implementation of the Single Basic Act provisions.

Financial Regulation

The Regulation (EU, Euratom) 2018/1046 on the financial rules applicable to the general budget of the Union, repealing Regulation (EU, Euratom) No 966/2012 (2012 Financial Regulation) was adopted in 2018. By decision of 4 November 2019, DG BUDG accepted certain CS2JU derogations and rejected other derogations. The revised Financial Rules were adopted on 27 January 2020 following a Governing Board written procedure.

In the year 2021, by Decision of the CAJU Governing Board of 16 December 2021 ("omnibus decision"), the Financial Rules were included in the list of Governing Board decisions and other legal acts which shall remain applicable under the newly established Clean Aviation JU.

Governance decisions

A set of Governing Board decisions related to the establishment of the new governance and functioning of the CAJU were adopted by the first Governing Board of CAJU of 16 December 2021 as listed under subchapter 3.1 of this document.

Court cases – litigations

The EU General Court had delivered its judgement on 25 November 2020 in the Case T-71/19 "BMC vs CS2JU." In the year 2021, no appeal was lodged by "BMC" thus the judgement became "res judicata" and directly applicable. In view of ensuring the follow-up of the judgment and the condemnation of "BMC" by the General Court to the reimbursement to the JU of the legal costs of the proceeding, the JU calculated and issued the request for reimbursement of those costs.

The General Court issued on 27 October 2021 its judgement on the five joint cases (T-268/17, T-269/17, T-270/17, T-271/17, T-318/17) lodged in 2017 by the JU against the JU grant beneficiary "Revoind" legally transformed in the course of the application to the Court to "Revoind di Pindaru Gelu." The General Court accepted the claims raised by the JU in all cases and condemned "Revoind" to the payment of the outstanding amounts as requested by the JU under the proceeding. No appeal was lodged by the end of 2021 thus the JU has started analysing its enforcement avenues at national level also considering the specificities of the case and the conclusions of the OLAF final report issued on the same case.

Still in the year 2021, the proceeding continued in relation to the three ongoing cases (T-649/20, T-721/20, T-767/20) lodged by the JU against the JU beneficiary "Alpha Consulting" and its legal representative for the enforcement of debt recoveries in the framework of the respective Grant Agreements. In the course of the year, the General Court rejected a plea of inadmissibility raised by the defendant after inviting the JU to provide its written observations and invited the parties to submit an additional set of written observations. Developments and a possible judgement in merit is expected in the course of 2022.

2.3. Budgetary and financial management

Title 1 & 2	Budget (€ m)	Executed (€ m)	% rate
CA	8.7	8.1	92,6%
PA	10.1	7.6	74.7%

Titles 1 & 2 – Administrative expenditure

For commitments, the execution rate was 92.6%, slightly above 91.99% in 2020. For payments, the rate achieved reached 74.7% in 2021 showing some improvement compared to 68.5% in 2020 (mainly in Title 2). The under-execution is mostly due to activities not performed (e.g. face-to-face meetings and trainings, physical events and travel missions cancelled due to Covid-19 restrictions), services delivered but not invoiced yet (e.g. invoices for services rendered in December) and frontloading for 2022 activities (e.g. booking of exhibition stands for 2022 events).

Staff expenditure budget (Chapter 11) was used for the statutory staff of the JU (42 posts filled in as of 31.12.2021), although other external support was also hired in by the JU to cope with the increased workload (Chapter 15). The other main budget items are allocated to IT expenditures (Chapter 21) and communication activities (Chapter 27).

2.4. Procurement and contracts

In 2021 the following contracts with value > 15.000 EUR were awarded and signed:

	Doc. Reference	Subject	Type of procedure	Contractor	Amount (€)
1	OF No 2020/106 implementing FWC No. CSJU.2017.OP.01-Lot 3-01 as amended by Amendment no 1	High-level Clean Sky online event on the 20th April 2021	Order Form	TMAB Business Events NV	62,440
2	OF 2020/58 implementing FWC n° HR/R1/PO/2018/004 as amended by Amendment no 1 and 2	Second phase of Deloitte HR study on CS2JU and future program consisting of three streams	AMD-Order Form	Deloitte	179,850
3	DC/CSJU.2021.NP.01	Web enhancement	Direct Contract	European Service Network	45,740
4	PO-No 2021/01 - CSJU.2020.NP.06	Provision of interim staff services related to missions outside Brussels	Negotiated Procedure	Randstad Belgium	69,480
5	Amendment no 1 to SC No SC-03/FWC-CS2JU.OP.01-LOT4-01 implementing FWC/CSJU.2017.OP.01-LOT4-01	Web maintenance	AMD-Specific Contract	European Service Network	126,000
6	OF No 2021/26 implementing FWC No. CSJU.2017.OP.01-Lot 1-01	30 Articles	Order Form	EU Turn	54,600
7	OF No 2021/28 implementing FWC No. CSJU.2017.OP.01-Lot 1-01	Brand refresh	Order Form	EU Turn	19,800
8	OF No 2021/33 implementing FWC No. CSJU.2017.OP.01-Lot 1-01	Event materials	Order Form	EU Turn	49,975.40
9	OF No 2021/37 implementing FWC No. CSJU.2017.OP.01-Lot 3-01	Hybrid event 2022	Order Form	TEMAB Business Events NV	184,394
10	OF No 2021/40 implementing FWC No. CSJU.2017.OP.01-Lot 2-01	Corporate Video	Order Form	20STM	30,250

11	EC/CSJU.2021.CEI.01-01	Professional writing/editing expertise	CEI	Science Unscrambled SRL - Ms Catherine Collins	138,800
12	OF n1 2021/62 implementing FWC No CSJU.2017.OP.01-Lot 301	Stand and Conference	Order Form	TMAB Business Events NV	54,955
13	DC/CSJU.2021.OP.02	Independent study on the socio-economic impact of CS2 Programme	Open Tender	Roland Berger	1,484.25
14	Amendment N.2 to SC-03.FWC.CSJU.2017.OP.01.LOT 4.01	Communication works	Specific Contract	European Service Network	50,400
15	Purchase Order 97/2021	Event Berlin	Direct Contract	ILA	61,072
16	CSJU.2021.NP.06	Media Partnership	Negotiated procedure	Euractiv	20,000
17	CSJU.2021.NP.07	Media Partnership	Negotiated procedure	Politico	18,500

2.5. IT and logistics

In 2021 the new year began, as usual, with a maintenance and upgrade window over the holiday period. During 2021 the Covid-19 pandemic continued to dictate the working pattern of the JU and ICT was central to supporting this new way of working.

All the new ICT developments were aimed at providing more flexible, remote and secure working solutions. Of the many highlights during the year the most notable were:

- Microsoft Teams was deployed as the new remote meeting and collaboration tool (replacing CISCO WebEx). MS Teams offers more options, is less expensive and better integrated with other office applications.
- The classical telephone landlines for the office were replaced with virtual lines which are integrated with MS Teams on both computers and smartphones (via an app). The landline numbers were retained as was the telephone provider thereby providing a seamless transition. Now the JU staff are able to use their single contact number on multiple devices at all locations and in a fully integrated way with Outlook contacts. This is a state-of-the-art “Unified Communications” solution.
- Cybersecurity was also improved. The JU switched from McAfee to MS Windows Defender which offers more options. There was cybersecurity training for the staff and a clandestine test organised with the Computer Emergency Response Team of the EU to check the alertness of the staff to phishing attempts.
- SharePoint and OneDrive were deployed and basic training for all staff provided. The first use cases for these new tools is developed.

- In common with the other Joint Undertakings, a 120K project was launched to convert one of the common JU meeting rooms to a high standard “Board Room” format teleconference room.
- In addition, five Audio Visual Meeting Units were purchased and installed in 2021 by Clean Sky and these have proven to be very useful.
- A new framework contract was signed for the provision of mobile telephony with better pricing and service compared with the previous contract.
- On the software side, a high level design phase for the new programme, knowledge and relationship management tools was completed. This project with continue to the detailed phase in 2022.
- On logistics, the biggest initiative in 2021 was a study done with an architect about the future of the office building and options to make it more suitable for the new hybrid way of working.

However, one of the most complicated changes for ICT in 2021 was the transition from Clean Sky to Clean Aviation. This involved creating new e-mail addresses and system profiles for all the staff in as seamless a way as possible. The change had an impact on all ICT systems as associated workflows, login protocols etc. Nevertheless, it was successfully managed.

Overall 2021 was a busy and successful year for ICT in the JU, building on previous developments and laying the foundations for future changes.

2.6. Human Resources

The JU establishment plan for 2021 contained a total of 42 statutory staff (TA and CA) and two SNEs with 42 posts filled at the end of the 2021. In 2021 the JU launched the recruitment process of two positions (Team Leader and Project Officer).

In addition to the statutory posts, the JU relies on external service providers such as the webmaster, the IT services firm shared with the other JUs, nine interims and one consultant in communications (English Writer) to provide extra support to the JU.

The JU also further implemented together with the other JUs, the use of Systal, an online HR tool to perform secure selection processes. In accordance with the decision of the Governing Board regarding the reclassification system, in 2021 the JU has performed the reclassification exercise and as a result, eleven TA end three CA staff members were reclassified.

3. GOVERNANCE

3.1. Governing Board

In 2021, for the first eleven months of the year the Governing Board was composed of 23 members: the Commission, with 50% of the voting rights; the 16 founding members of Clean Sky 2 Joint Undertaking, and six core partner representatives of the ITDs/IADPs in the Clean Sky 2 programme. The Chairman of the CS2 JU Governing Board was Stephane Cueille (Safran) and the Deputy Chairman Marco Protti (Leonardo Aircraft). Due to the Covid-19 pandemic, the Governing Board could not meet physically and instead heldthree meetings in 2021 organised via MS Teams facilities on:

- 17 March 2021
- 17 June 2021
- 26 October 2021

In 2021 the CS2 JU Governing Board adopted the following key documents via written procedure:

- Written Procedure 2021-01 Adoption of the TE2 Synopsis report
- Written Procedure 2021-02 Internal Audit Capability Plan 2021
- Written Procedure 2021-03 Second Amended Work Plan and Budget 2020-2021
- Written Procedure 2021-04 IKOP Opinion 2014-2019
- Written Procedure 2021-05 Opinion on the Final Accounts 2020
- Written Procedure 2021-06 Approval of the AAR 2020
- Written Procedure 2021-07 IKAA Opinion 2014-2020
- Written Procedure 2021-08 Work Plan and Budget 2022-2023
- Written Procedure 2021-09 Adoption of the CS2DP update
- Written Procedure 2021-10 Adoption Additional Activities Plan 2022
- Written Procedure 2021-11 Renewal of the Executive Director contract

Most of the decisions were adopted unanimously or almost unanimously, showing a smooth and efficient decision-making process. Each Governing Board (GB) was prepared by a Sherpa Group meeting, chaired by the JU. The GB acted according to its adopted Rules of Procedures.

As of 30 November 2021, when the SBA establishing the Joint Undertaking under Horizon Europe was adopted, the newly formed Clean Aviation JU Governing Board consists of two representatives of the Commission on behalf of the European Union (holding 50 % of the voting rights) and fifteen representatives of the private members chosen by and from the founding members and associated members ensuring a balanced representation of the aeronautical value chain, such as aircraft integrators, engine manufacturers and equipment manufacturers, research and technology organisations, universities and higher education establishments, and small-medium sized enterprise [SMEs] (holding collectively the other 50 % of the voting rights). The Chair of the Clean Aviation Governing Board is Rosalinde van der Vlies (Director of the Clean Planet Directorate in the European Commission's DG for Research and Innovation) and the Co-Chair from the private members elected during the first governing board meeting of 16 December is Sabine Kauke (Chief Technical Officer at Airbus).

During its first meeting of 16 December 2021, the Governing Board of Clean Aviation adopted the following:

- Decision adopting the Governing Board Rules of Procedure;
- Decision of the Governing Board on the selection of Associated Members of the Clean Aviation Joint Undertaking under the procedure laid down in Article 59(2) of the Single Basic Act;
- Decision of the Governing Board adopting the 'Light' Work Programme and Budget 2022-2023;
- Decision adopting the Rules of Procedure of the Technical Committee;
- Decision of the Governing Board adopting the Strategic Research and Innovation Agenda (SRIA);
- Decision on the selection process and specific criteria for the composition of the "European Clean Aviation Scientific Advisory Body" of the Clean Aviation Joint Undertaking;
- Decision adopting the list of Governing Board decisions of the Clean Sky 2 Joint Undertaking to be transferred and continue to apply to the Clean Aviation Joint Undertaking.

3.2. Executive Director

The Executive Director is the legal representative and the Chief Executive for the day-to-day management of the JU, in accordance with the decisions of the Governing Board, in line with Article 19 and 67 of the SBA.

The coordination role of the Executive Director is supported by the organisational structure of the JU programme office, providing for dedicated responsibilities in all units. The JU's management acts on the basis of its quality system, which is described in the JU's Quality Manual. Interactions with the SPDs are mainly governed by the Management Manual. All grant management processes applied by the JU are designed to a large extent by the Commission through the H2020, Horizon Europe tools and other EC systems.

3.3. Scientific Committee

The Scientific Committee (SciCom) is an advisory body to the Governing Board. In 2021, the Scientific Committee met four times: March 15, June 14, October and October 15.
The Scientific Committee is consulted on various key documents, mainly providing opinions and recommendations regarding the CS2JU Work Plan priorities and the Calls for Proposals launched, but also advising on the technical, scientific and programmatic relevance of the Clean Sky 2 programme's research and innovation actions with respect to the achievement of the environmental Clean Sky. However, in 2021, there was no new call to be launched. There has been a substantial revision of the CS2DP, for which the SciCom was consulted and which has been summarised in a report delivered late October 2021.
CS2 has continued to involve the SciCom members as reviewers in the Annual Reviews and the Interim Progress Reviews of the CS2 programme. The SciCom delivered individual reports about each SPD review meeting and a consolidated summary report concerning the main outcomes and recommendations of all Annual and Interim Reviews meetings for Governing Board information.

The term of the SciCom members was supposed to end in December 2020 after a 3-year mandate. Following the decision No. 304 of the Executive Director of 24 November 2020, their appointment was extended until the end of 2021 or, if the Clean Aviation partnership was established sooner, until the new regulation enters into force.
The Council Regulation 2021/2085[10] establishing the Joint Undertakings under Horizon Europe was published on 19 November 2021, which officially concluded the term of the current SciCom members.
The Council Regulation states under Article 21, the need for each Joint Undertaking to establish a Scientific Advisory Body (SAB), for which the specific provisions are described in Article 70.
Consequently, a call for expression of interest was launched on 23 November 202111, in accordance with the selection process and criteria set out in the Governing Board Decision of 16 December 2021.
Following the outcome of the selection process based on 81 applications received after closure of the call on 5 January 2022, the 15 members of the Scientific Advisory Body of the Clean Aviation Joint Undertaking (including one member representative of EASA and six additional members on the reserve list) were appointed by GB decision on 1 February 2022.
The role and tasks of the Scientific Advisory Body are laid out in Article 21.7 of the Council Regulation and the first meeting of the SAB was held on 4 February 2022.

3.4. States Representatives Group

The States Representative Group (SRG) is an advisory body to the Clean Aviation JU, established in accordance with Article 20 of the SBA.

The SRG consists of one representative of each EU Member State and of countries associated with the Horizon Europe programme. It is chaired by one of these representatives and two co-chair representatives.

To ensure that the activities are integrated, the Executive Director attends the SRG meetings and the Chair of the SRG attends as an observer at the Governing Board. The secretariat is ensured by the JU.

During 2021 prior to the adoption of the SBA, the CS2 JU SRG met virtually three times:

- 4 March
- 4 June
- 6 October

The SRG was informed regularly and consulted on the ongoing activities of the CS2 programme, including the CfP11, the Work Plan 2020-2021 and the Bi-Annual Work Plan 2022-23. The opinions provided by the SRG were duly taken into consideration by the JU as part of its review. The SRG was informed on the development of the different ITDs/IADPs/TAs, on the milestones of major demonstrators and the assessment of the Technology Evaluator. The representatives

[10] Council Regulation (EU) No 2085 2021 of 19 November 2021 establishing the Joint Undertakings under Horizon Europe (hereinafter "Single Basic Act" or "SBA") OJ L 42717
[11] https://clean-aviation.eu/sites/default/files/2021-12/Clean%20Aviation%20SAB%20Call.pdf

were also regularly updated about the preparation of the Clean Aviation Partnership and the Call for Ideas for potential Clean Aviation members.

Key actions:

- the SRG's representatives participated in CS3PG and in the configurations WG3 *Operating Principle*s and WG4 *Innovation Architecture,* and thus kept aware the SRG members about the progress on the Clean Aviation Partnership;
- since March 2021, the vice-chair Juan Francisco Reyes took over the chair of SRG, due to Herben's departure in another post outside the Netherlands. The representatives agreed on a temporary Chair role in terms of "allowing continuity/transitioning" towards the Clean Aviation JU;
- following an internal consultation, the SRG acted as an informal shadow SRG (informal discussions) until the Clean Aviation Partnership enter into force and the official nominations of the new SRG representatives;
- a small group of SRG members in collaboration with Clean Sky and the European Commission, prepared the Rules of Procedures for the new Clean Aviation SRG. This group also provided comments in the draft Call for Expression of Interest for synergies with Member States and regions.

3.5. Technical Committee

The Technical Committee (TC) is an executive body to the Governing Board. In 2021, no (virtual) meetings of the Technical Committee took place.
On 16 December 2021, the Governing Board established the TC and adopted the the TC Rules of Procedure (TC RoP). According the TC RoP:

- The TC shall be composed by up to four European Commission representatives and Union bodies, one representative from each member other than the Union, and one representative of the European Union Aviation Safety Agency (EASA).
- The TC shall be co-Chaired by a representative of the European Commission and a representative of the Founding Members other than the Union.
- The Executive Director shall be a permanent observer in the Technical Committee. The Executive Director may delegate his or her function to a senior staff member of the CAJU programme office.
- Representatives of the States' Representatives Group and the European Clean Aviation Scientific Advisory Body may attend as observers upon invitation of the Chair team, or on their own request, in agreement with the Chair team.
- A Governing Board Member may be delegated by the Governing Board to follow the activities of the Technical Committee and may attend the meetings as an observer of the Technical Committee.
- The outcome of the TC tasks (as described in article 69(5) and (6) of the SBA) shall be delivered to the Governing Board in an annual report, including the following chapters:
    - presentation of technical developments in a technological roadmap and strategy of the programme, including proposals for amending the Strategic Research and Innovation Agenda;
    - presentation of the proposals for the technical priorities and research actions to be included in the work programme and the research topics for open calls for proposals;

    - in coordination with the State Representative Group, presentation of the research actions planned or in progress at national, regional or other non-Union levels, including recommendations on the actions necessary to maximise possible synergies of the Clean Aviation Joint Undertaking's programme;
    - proposed revisions or optimisation of the technical scope of the programme to align it to the overall Horizon Europe and other European partnerships' related work programmes;
    - recommendations on maximising the impact in line with the European Green Deal and the potential market uptake of the programme's results;
    - propose priorities for certification and standardisation activities linked with upcoming Clean Aviation Work Programmes;
- Other tasks of the TC shall be performed and be provided in the form deemed most appropriate, following the request from the Governing Board. Ad-hoc reports may be prepared and provided to the Governing Board as required in response to specific questions raised by the Governing Board

Key actions:
In agreement with the European Commission's co-Chair, the TC secretariat:

- o invited Governing Board members to nominate their TC representatives and express candidatures as co-Chair representative of the Founding Members;
- o asked the nominated TC members to provide the 'Declaration of confidentiality and non-conflict of interest' duly compiled and signed;
- o scheduled the first TC meeting (via MS Teams) on 14 January 2022.

4. INTERNAL CONTROL FRAMEWORK

4.1. Financial Procedures

The JU Financial Rules are aligned with the model Financial Regulation for public-private partnership bodies[12]. In December 2021 the Governing Board of CAJU confirmed the continuous applicability of the JU Financial Rules through an omnibus decision[13].

All internal financial workflows of the JU are described in the Manual of Financial Procedures, which presents the financial circuits for the implementation of the JU budget. The financial circuits concern all financial operations taking into account the lean structure of the JU, any risks associated with the management environment and the nature of the financing operation. The financial procedures are established on the basis of the following risk considerations:

- the administrative budget of the JU (represents only about 4% of its total budget);
- for the management of the H2020 grants, the JU uses the EC tools and aligns its processes

[12] Commission Delegated Regulation (EU) 2019/887 of 13 March 2019 on the model Financial Regulation for public-private partnership bodies referred to in Article 71 of Regulation (EU, Euratom) 2018/1046 of the European Parliament and of the Council, OJ L 142, 29.5.2019, p. 16–42.

[13] Ref. CS-GB-Writ proc-2019-07 Revised Financial Rules and CAJU GB Decision omnibus of 16th December 2021.

with the agreed workflows for the entire H2020 user community;

- in order to ensure the accounting data quality, the JU applies an extra layer of control on all payments and recovery orders by opting for the manual validation by the accounting officer in the recovery and payment processes.

Financial procedures in the JU are also based on the controls embedded in the accounting system ABAC and the EC H2020 tools for grant management (SyGMa/Compass).

Hence, the whole grant management is operated via SyGMa/Compass, including GAM signature, pre-financing, GAM amendments, costs validation and payment.

Awareness of the JU's Members about the main financial rules of grant management was raised during the annual Financial Workshop (see also futher below).

As a consequence of the migration to the EC tools, the reporting on IKOP had to be adapted. The IKOP guidance has been revised taking into account the new approach of reporting total project costs and has been communicated to all Members. This new procedure applies to the reporting of IKOP for the period 2018-2019. A local Microsoft Access based tool has been created by the JU to ensure a robust IKOP validation process, which provides the basis for a reliable recognition in the JU's Annual Accounts.

4.2. Ex-ante controls on operational expenditure

A key element of the ex-ante controls applicable to H2020 grants of the JU is the related guidance issued by the Commission and applicable to all H2020 stakeholders.
The simplified ex-ante control approach allows only limited checks when assessing the periodic reports and cost claims. Therefore, considering the complexity of the GAMs and their high budget values, the JU has implemented more detailed checks for the validation of the GAMs costs claims since the beginning of the programme (detailed reporting and validation of use of resources for costs claimed, interactions between coordinators and Project and Financial Officers, reinforced internal review through internal meetings until final validation).
Regarding the Certificates of Financial Statements (CFS), the JU has established an individual approach with its Members, which provides for a biannual certification even if not required according to H2020 rules.

Due to Covid-19 the annual financial workshop was organised remotely achieving a high participation of more than 150 JU members in the CS2 programme. The event combined general sessions and thematic workshops dealing with a wide range of topics which are essential in the context of GAM reporting (financial rules, eligibility criteria, most common errors, in-kind contributions, legal aspects of the grant agreements, ex-post audits).

4.3. Ex-post control of operational expenditure and error rates identified

I. Introduction

CAJU has taken over the CS2 JU processes pertaining to the execution of the H2020 programme, including the ex-post audit activities for H2020 projects until the finalisation of the H2020 programme. For the Clean Aviation programme, the audit strategy will be developed in the year 2022.

The results of the EPA process represent a significant element of the Internal Control System of CAJU. Besides the summary in this report, further details regarding scope and results of the audits will be provided in the Annual Ex-post Audit Report 2021, which will be available in its final version on the website of Clean Aviation JU.

The main objectives of the ex-post audits are:

1) To assess the legality and regularity of the validation of cost claims performed by the JU's management through the achievement of a number of quantitative targets,
2) To provide an adequate indication on the effectiveness of the related ex-ante controls
3) To provide the basis for corrective and recovery activities, if necessary

The scope of the audits performed during the year 2021 comprised H2020 grant agreements funded by the former Clean Sky 2 JU.
The audit activities for all H2020 grants are fully centralised in the Common Audit Service (CAS) of DG R&I. This contributes to a consistent harmonised audit approach for the totality of the H2020 projects and aims at reducing the audit burden for beneficiaries, who participate in projects with several granting authorities of the H2020 research family[14]. The implementation of the audit results remains under the responsibility of the individual granting authorities.

In line with the H2020 Audit Strategy and the related JU implementing procedure, CAJU is establishing its specific audit results for the H2020 programme on the basis of its individual samples drawn from the population of Clean Sky 2 grants.

In addition, cost claims pertaining to Clean Sky 2 projects also form part of the Common Representative Sample (CRS) of the Common Audit Service of DG R&I (CAS), which is the basis for calculating the results of the ex-post audits for the entire H2020 research family.
Furthermore, cost claims of Clean Sky 2 projects are included in various samples of corrective (risk based) audits established by the CAS.

Whilst the CRS is a basic indicator of legality and regularity for the Framework Programme as a whole, Clean Aviation JU aims to assess its particular population to provide specific assurance on the legality and regularity regarding the JU's individual operational expenditure.
Due to the specific samples taken for the population of Clean Sky 2 grants, as described in the

[14] Group of Commission services, Agencies and Joint Undertakings implementing the H2020 programme

following sections, explicit evidence has been made available to draw conclusions on the error rate prevailing in the expenditure incurred by the former Clean Sky 2 JU.

Taking into account the above mentioned audit layers, the following samples are considered relevant for the assurance of the Executive Director of Clean Aviation JU for the year 2021:

(A) *Specific sample of Clean Sky 2 projects* (including only representative audits)

(B) *Sample of corrective (risk based) audits of the Common Audit Service of DG R&I (CAS) covering Clean Sky 2 projects*

(C) *Common Representative Sample (CRS)* of the CAS covering H2020 projects for all H2020 stakeholders, including Clean Aviation JU.

Scope of the audit exercise 2021 and coverage

<u>(A) Specific Clean Aviation JU sample</u>

The audit sample for 2021 was established in line with the methodology provided in the H2020 Audit Strategy and the JU implementing procedure. It comprises the following elements:

- Representative sample
    - Most significant cost claims selected at random (the population was stratified to achieve a certain coverage of the most significant cost claims).
    - Cost claims from previous representative samples[15]

- Risk based sample
    - Cost claims selected following a specific risk assessment

The scope of the audits covers CS2 projects from the years 2016 to 2020 from both partners and members:

45 new audits for H2020 projects stemming from the 2021 JU representative sample, covering 70 cost claims, were launched until November 2021, out of which 25 provided final results until the closure of the final accounts 2021.

Two additional beneficiaries were selected in the year 2021 on a risk-based approach comprising three cost claims and amounting to € 2,707,348. These audits will be launched and finalised in the year 2022.

Additionally, the results of nine final audits stemming from the 2019 and 2020 representative samples are included in the 2021 reporting.

The total audited value of the JU specific sample reported in 2021 was € 52,557,025.46 (reported validated project costs).

[15] The audit of some participations of earlier selections had to be postponed, as the concerned beneficiaries had been subject to audit shortly before, either by CAJU or other granting authorities of the H2020 program.

Table 1: H2020 Audit exercise 2021

Audit exercise 2021 H2020 programme	Total	GAMs & GAPs				
		2016	2017	2018	2019	2020
audited value	52 557 025	252 543	15 340 993	31 857 195	4 259 801	846 493
number of cost claims	52	1	9	24	14	4
number of audits	34	1	5	12	12	4

Table 2: Audit coverage

Accumulated audit coverage until end of 2021	
	Euro
Total audited value from EPA exercises 2016 to 2021 (a)	257 666 947
Total amount of validated cost claims (b)	1 533 162 809
Coverage (a) / (b)	16.81%

(B) Sample of corrective (risk based) audits of the Common Audit Service of DG R&I (CAS) covering Clean Sky 2 projects

In addition to the Clean Aviation JU representative sample, cost claims pertaining to Clean Sky 2 projects have also been audited as part of the corrective (risk based) samples selected by the CAS.
The JU does not consider them as representative for the specific Clean Aviation JU error rate calculation.

In 2021, 9 audits were launched by the CAS on Clean Sky 2 projects, covering 13 validated cost claims stemming from GAMs and GAPs from year 2015 to 2019. Additionally, 4 audits on CS2 GAMs stemming from the 2019 and 2020 corrective samples of the CAS are included in the 2021 reporting.
The total accumulated value of audits stemming from the corrective CAS samples on CS2 projects since the beginning of the H2020 programme audits until 2021 was € 71,344,785.

Through these samples, an additional coverage for the Clean Sky 2 projects related operational payments of 4.65% could be achieved.

Status of audits and results (error rates) of the specific samples

Because of the Covid-19 pandemic crisis and related travel limitations during 2021, the Common Audit Service had to postpone a number of on-the-spot missions during the years 2020 and 2021. This has delayed the delivery of final results.

Audit results received at present and used for the error rate calculation include final results for 34 audits.

Table 3: Status of current H2020 audits

Status of audits included in H2020 audit exercise 2021	number
Total number launched and results not yet reported	55
Immature results	21
Preliminary reports received	34
Final reports received	34
Audits included in the final audit results 2021	34

Error rates:
The representative error rate is an indicator of the quality of the ex-ante controls as it gives an estimate of errors that remain undetected after the ex-ante controls have been performed.

As no results of risk based audits have been available for the EPA results 2021, the representative error is identical to the detected error. Based on the results of the final audit reports, detected errors are corrected and extension of systematic errors is calculated and implemented following the related rules of the Clean Sky 2 grant agreements. Under the assumption of a full implementation of the audit results, the residual error rate is calculated. This indicator is relevant for the assurance on the legality and regularity of the Clean Aviation JU's operations.

The residual error rate indicates the 'net-errors' that remain in the total population after implementing corrective actions resulting from the ex-post controls including extension of systematic errors to non-audited cost claims.
The **accumulated representative error** rate for the CS2 programme expenditure, identified in the audited cost claims of the audit exercises of the years 2016 to 2021, amounts to 1.79%[16] while the corresponding accumulated residual error rate is 0.96%.

Table 4: Error rates

Summary of H2020 error rates for the H2020 programme (accumulated results of 2016 to 2021):	
Representative error rate (RepER%) =	-1.79%
Systematic error rate (RepERsys%) =	-1.34%
Residual error rate (ResER%)=	-0.96%

The corresponding results for the annual exercise 2021 are 2.52% for the representative error and 1.10% for the residual error.
The accumulated error rates reported for the year 2021 confirm the level of error as identified in the previous years for the CS2 projects. On the level of the programme and the actual year 2021,

[16] As no risk based audits have been performed the detected error is representative.

the residual error stays well below the targeted threshold of 2%.

Extension of audit findings

The extension of audit findings stemming from H2020 audits is performed according to common criteria for the entire H2020 Research Family. This means that systematic errors identified in individual cost claims of H2020 projects will be corrected in all projects of the concerned beneficiaries including those funded by other granting authorities. For efficiency reasons, the minimum threshold for the audit extension is an average systematic error of 2% identified in the individual audits.

In the EPA exercises performed from the beginning of the H2020 programme until end of 2020 concerning beneficiaries of the Clean Sky 2 programme, extension of systematic audit findings has been launched in 44 cases out of 198 finalised audits. 89% of these cases have been successfully closed until the date of this report.

Table 5: Extension of audit findings until EPA 2021

	Finalised Audits	Value of audited cost claims	Extension of audit findings launched (numbers of cases)	Value of corrected unaudited cost claims after extension	Extension of audit findings Implemented[17] (% of numbers of cases)
EPA 2016	6	13 067 875	-	-	-
EPA 2017	16	27 132 196	4	3 720 391	100%
EPA 2018	28	21 112 705	6	5 455 076	100%
EPA 2019	72	46 038 348	18	18 354 067	100%
EPA 2020	42	97 758 797	7	5 965 956	100%
EPA 2021	34	52 557 025	9	61 487 535	44%
Total	**198**	**257 666 947**	**44**	**94 983 025**	**89%**

The audit extension for the EPA exercise of 2021 is ongoing, 5 cases are in the implementation phase. In addition, the extension exercise covers also seven beneficiaries, who have been audited for other than Clean Sky 2 projects.

Implementation of audit results

Overpayments identified in the EPA exercise 2020 for H2020 projects have been corrected until the the date of this report to 94%.
For overpayments detected in H2020 audits of the ex-post audit exercise 2021, the correction

[17] The implementation of the correction is done by CAJU, in the case of on-going projects, through withholding the overpaid amounts from the next payment to the coordinator and, in the case of closed projects, through recovery orders directly sent to the beneficiary.

rate is currently at 77% and is targeted to arrive at 100% until the end of 2022, when the extension of audit finding cases will have been assessed and closed by the dedicated unit in the Common Audit Service.

On programme level, the accumulated corrections implemented so far for the H2020 programme until the date of this report represent 87% of the total impact of detected errors and extension of audit findings.

Table 6: Correction achieved

ACCUMULATED Total corrective action for H2020 EPA exercise 2016-2021 - implementation achieved				
Audited value	Adjustments in favour of CSJU (detected error and extension of findings)	related overpayment	recovered overpayment [18] (€)	recovery rate (%)
850 997 577	-8 508 552	-6 084 548	-5 322 193	87.47%

Materiality applied for specific audit exercises

The control objective is to ensure for the Clean Sky 2 programme that the residual error rate, which represents the level of errors which remains undetected and uncorrected, does not exceed 2% of the total expense recognised until the end of the programme. 2% is therefore the materiality level set for the JU. A detailed description of the materiality criteria applied for the assessment of the audit results with a view to the assurance declaration of the Executive Director of the JU is provided in Annex 9 of this report.

Results of non-representative ex-post audits pertaining to the sample of corrective (risk based) audits of the CAS covering Clean Sky 2 projects

In the year 2021, a detected error rate resulting from the sample of corrective (risk based) audits selected by the CAS covering Clean Sky 2 projects has been established and amounts to 2.97%. The accumulated detected error for the years 2016 to 2021 of this type of sample currently amounts to 2.49%.

The representativeness of this error rate is limited as the selection of the samples has not been based on a consistent methodology for random sampling and the coverage achieved is only at 4.65% (see related section above). Nevertheless, the results contribute to the cleaning of the JU expenditure from detected errors and thus add to the assurance obtained from the audits.

[18] i.e. adjustments booked in the JU accounting system for offsetting with next payment

Results of the Common Representative Sample (CRS) of the CAS covering H2020 projects for all H2020 stakeholders, including the former Clean Sky 2 JU.

The **main indicators** used by the European Commission on legality and regularity of EU Framework Programmes for Research and Innovation are:

Representative detected error rate, based on errors detected by ex-post audits on a Common Representative Sample of cost claims across the R&I Family.

Cumulative residual error rate, which is the extrapolated level of error after corrective measures have been implemented by the Commission services following the audits, accumulated on a multi-annual basis

The **targets** set by the Commission for the Horizon 2020 programme are to ensure that the cumulative residual error rate remains within a range of 2-5 % aiming to be as close as possible to 2%.

Progress against Horizon 2020 targets is assessed annually, based on the results of the implementation of the ex-post audit strategy and taking into account the frequency and importance of the detected errors along with cost-benefit considerations regarding the effort and resources needed to detect and correct the errors.

The Commission points out, that due to its multi-annual nature, the effectiveness of the control strategy of the R&I Family can only be measured and assessed fully in the final stages of the EU Framework Programme, once the ex-post control strategy has been fully implemented, and errors, including those of a systematic nature, have been detected and corrected.

In the context of the annual reporting, this assessment needs to check in particular whether the scope and results of the ex-post audits carried out until the end of the reporting period are sufficient and adequate to meet the multiannual control strategy goals in the future as foreseen.

Due to the COVID-19 pandemic crisis and related travel limitations during 2021, the Common Audit Service (CAS) – in line with the instructions of the Commission – could not carry out the necessary on-the-spot missions and had to postpone some of them.

The following table presents the error rates calculated by the Commission for the H2020 Framework programme by the end of 2021:

	HORIZON 2020 EX-POST AUDITS
REPRESENTATIVE DETECTED ERROR RATE[19]	2.29%
CUMULATIVE RESIDUAL ERROR RATE	1.60%

Despite the above-cited caveats, the Commission considers the 2021 cumulative residual error rate for Horizon 2020 to fall within the target range (2-5%), and therefore a reservation is not

[19] In 2020 the Commission re-defined its methodology for calculating the Horizon 2020 error rates in line with the European Court of Auditors' observations in its 2018 and 2019 Annual Reports19. As of January 2020, the application of the revised methodology resulted in an error rate higher, on average, by 0,37 % in comparison to the error rate calculated by applying the methodology used in the past.
Consequently, the detected error rate for 2020 and 2021, cumulative, calculated according to the methodology used in the past has been corrected by adding 0.37%.

necessary for the Horizon 2020 expenditure.

Since Horizon 2020 is a multi-annual programme, the error rates, and the residual error rate in particular, should be considered within a time perspective. Specifically, the cleaning effect of audits will tend to increase the difference between the representative detected error rate and the cumulative values of the residual error rate, with the latter finishing at a lower value.

These error rates are calculated on the basis of the audit results available when drafting the Annual Activity Report. They should be treated with caution as they may change subject to the availability of additional data from audit results.
The decrease of the error rates in year 2021 could be due, among other reasons, to the beneficiaries' increased knowledge of the eligibility rules and its inherent learning curve, as well as to the results of the communication campaigns, targeted webinars and trainings, addressed in particular to newcomers and SMEs.
With the objective of further reducing the error rates, the Commission will focus on enhancing risk based ex-ante controls in dedicated grant management tools.

Assessment of the ex-post audit results

As described in the materiality criteria in the annex 9 of this report, the control objective of the JU is to ensure that the residual error rate, which represents the remaining level of errors in payments made after corrective measures, does not exceed 2% of the total expense incurred until the end of the H2020 programme.

The audit approach for H2020 grants is based on the H2020 Audit Strategy and the related implementing procedure of CAJU[20].

The present final results of the ex-post audit exercises 2016 to 2021 pertain to validated cost claims for GAMs and GAPs of the years 2014 to 2020 for the CS2 programme. As such, the results of the EPA process 2021 provide information on the legality and regularity of the validation process for GAM and GAP execution 2014 to 2020 for the CS2 programme and do not directly relate to the entire expenditure incurred by the JU until the end of 2021. However, the JU's annual EPA strategies are implemented through an on-going process, which produces accumulated results applicable to the entire expense incurred for the Clean Sky 2 programme.

The cumulative audit coverage achieved in the EPA exercises until 2020 represents 17% of the validated financial statements pertaining to GAMs and GAPs of the years 2014 to 2020.
The additional coverage achieved through corrective audits launched by the CAS on Clean Sky 2 grants is 5%.

The accumulated results established in the CS2 samples until the end of 2021 reflect a representative error in favour of Clean Aviation JU in the validated operational expense -before correction measures are taken- of 1.79%, compared to 1.60% for the accumulated audit exercises until 2020.

[20] Clean Sky 2 JU Procedure for implementing the H2020 Ex-post Audit Strategy, dated 01.12.2016

The CS2 **accumulated residual error rate** stemming from the six annual audit exercises until 2021 amounts to **0.96%**, maintaining the same level as in the previous year.

In view of the moderate errors detected, the level of assurance provided through these audit results is considered adequate for the reporting of the year 2021.
The results from audits pertaining to the specific samples carried out on the Clean Sky 2 projects as well as the samples of the CAS (CRS and other corrective audits), indicate, that over the multiannual period, and especially considering the envisaged level of the overall audit coverage, the residual error rate will stay below 2% on programme level.
In conclusion, with a view to the achieved ex-post audit results, no reserve is considered necessary for the legality of the Horizon 2020 related expenditure of Clean Aviation JU for the year 2021.

4.4. Control efficiency and cost-effectiveness

In 2021 the cost of ex-ante control as a percentage of annual expenditure was 1.61%. The benefit of controls in 2021 includes the ex-post recoveries and the rejected costs in both GAMs and GAPs. The total cost is calculated in terms of FTEs performing the control activities and details per sector of control are provided in the second table.

The ratio of average cost/average benefit for one running project in 2021 is 1:10 and this is mainly due to the relatively high level of rejected costs.

Budget 2021 (Payments in EUR)		% in total budget	Total estimated costs of ex-ante control	Cost of ex-ante control as % of annual expenditure
Administrative expenditure	7,567,187	7.1%	354,737	4.7%
Operational expenditure	99,080,539	92.9%	1,361,126	1.4%
Total	**106,647,726**	**100.0%**	**1,715,863**	**1.6%**

Benefits of controls (in EUR)	18,636,166
Total cost of controls (in EUR)	1,715,863
Average cost (in EUR) of control for one running Grant Agreement (Total costs / no. 330 projects running as at 31.12.2021)	5,200
Average benefit (in EUR) of control for one running Grant Agreement (Benefit / running projects)	56,473

Sector	Estimated FTEs allocated to controls	Cost (EUR)	Total
Grant management	15.24	1,361,126	

Procurements	3.1	233,009	
Other general controls	0.9	121,729	
Total cost of ex-ante controls	**19.24**	**1,715,863**	**1,715,863**
Ex-post control	1.6	149,711	
Total	**20.84**		**1,865,574**

4.5. Audit of the European Court of Auditors

In 2021, the JU was audited on its annual accounts 2020 by the European Court of Auditors as set out in the Statutes. The results of these audits were published in the Court's Annual Report on the EU Joint Undertakings for the financial year 2020. As in previous years, the Court issued a positive opinion to the JU on the reliability of the annual accounts and on the legality and regularity of the underlying transactions.

The scope of the Court's annual audit for the year 2021 comprises also a review and analysis of several horizontal topics common to all JUs (staff management, business continuity during the Covid-19 pandemic and cyber security).

For the audit of the 2021 operational expenditure, the Court has continued the audit approach introduced in 2019 and undertook audits directly at beneficiaries' level for all Joint Undertakings in the H2020 programme. The results of these audits are presented in the annual report of the Court for the year 2021.

Follow up of observations made by the Court of Auditors in its audit of the year 2020:

Description of observation	JU comments and/or corrective actions taken
"Regarding the JU's 2020 payment budget available for Horizon 2020 projects, the Covid-19 pandemic resulted in a slowdown of the grant agreements for partners (GAPs), and in addition, an under-execution of the 2018-2019 grant agreements for members (GAMs). The latter led to significant recoveries of overpaid pre-financing that increased the operational payment appropriations (internal assigned revenue funds) to €22.6 million in 2020. This situation adversely affected the implementation rate of the operational payment budget, which was 82.6% at the end of 2020 (2019: 97.2%). Finally, contrary to the JU's financial rules, it did not fully use the previous years' appropriation of €13.3 million, which was re-entered into the operational budget 2020, before using the payment appropriations of	In the year 2021, the JU has put in place additional monitoring measures to ensure that the reactivated funds are consumed first. As the EC grant management tool does not prioritise the use of CS2 funds without manual intervention for each payment, the financial team has been instructed to always check the availability of previous year's appropriations before consuming fresh funds from the current year. The CS2 2021 budget execution has been impacted by the Covid-19 pandemic situation, in particular concerning payment appropriations for administrative expenditure. In 2021, the JU has had a 99.6% rate[21] of implementation for the commitment appropriations in 2021. The payment appropriations were executed to 82.3% of the

[21] This rate is calculated excluding Title 5 which was foreseen not to be used in 2021 although within the overall budget available commitment appropriations of the year.

Description of observation	JU comments and/or corrective actions taken
the year."	available funds[22]. For a comparison, in 2020 the JU executed its commitment appropriations with a rate of 97.4% of the available funds and with 88.1% of payment appropriations. The JU has thus maintained very good performance in commitment appropriations, which have increased 2.2% with respect to 2020 execution. However, payment appropriations show a decrease of 5.8% with respect to the previous year mainly due to the negative impact of Covid-19.
"Although the JU's statutory staff remained static at 42 from 2017 to 2020, during the same period, the JU significantly increased its use of interim staff from three to ten full-time equivalents (FTE), that is, from 8% to 24% of the JU's statutory staff. The tasks performed by the interim staff are however, not of a one-off or temporary nature, arising from an exceptional increase in workload or the performance of a one-off activity, but rather are permanent in nature (e.g. legal service assistant, secretarial support, communication assistant, and project officer assistant). The JU's practice creates de-facto permanent posts, in excess of those foreseen in the staff establishment plans. This indicates that the JU's level of statutory staffing is not sufficient to implement the JU's research and innovation agenda and related work plans. This situation also presents significant risks for the JU, concerning the retention of key competences, unclear accountability channels, and lower staff efficiency that could negatively affect the JU's overall performance."	The JU has been obliged to constantly enlarge the use of interim staff during the past years due to the limitations of the rigid staff establishment plan under the condition of increasing tasks and workload. At present, two programmes – Clean Sky 2 and Clean Aviation – are running in parallel, resulting in an even higher volume of work. Efforts have been made in 2021 through a dedicated project to enhance staff efficiency, but the use of interim and intra-muros will continue to cope with the increasing workload. With regards to the risks noted by the Court, the JU has put in place mitigation measures, such as appropriate supervision mechanisms, limiting tasks for interims to non-core tasks and ensuring appropriate training and mentoring support.
"The JU more than doubled the payment budget of its infrastructure and communication expenditure (representing around 1.5% of the JU's total available payment budget) for the financial year 2020. This doubling of the payment budget, together with the impact of the Covid-19 pandemic on planned costs for IT, communication, events and other external services, resulted in the low implementation rate of 42.7% at the end of 2020 (2019: 98.7%)."	For payments, the rate achieved reached 74.7% in 2021, showing some improvement compared to 68.5% in 2020 (mainly in Title 2 - 53% in 2021). The 2021 under-execution is mostly due to activities not performed (e.g. face-to-face meetings and trainings, physical events and travel missions cancelled due to Covid-19 restrictions), services delivered but not invoiced yet (e.g. invoices for services rendered in December) and frontloading for 2022 activities (e.g. booking of exhibition stands for 2022 events). The JU has taken a more conservative approach

[22] Excluding the unused appropriations 2021 of 22,9 million € (56,3% of execution rate if the unused appropriations are included as total payment budget).

Description of observation	JU comments and/or corrective actions taken
	while forecasting the infrastructure and communication expenditures for the year 2021.
In the context of the JUs' in-kind contribution provided by the private members, the Court sees the risk "...that IKAA might not be fully aligned with the JU's objectives. Where the founding regulation does not define a minimum level for IKOP but only for IKAA (CS, FCH, and BBI), the JUs take the view that private members can fulfil their obligation for in-kind contributions with IKAA."	In the opinion of the JUs, there is no such risk, since the JUs have implemented a validation process specifically for the IKAA, which comprises of ensuring the contribution of the additional activities to the objectives of the individual JUs as well as the certification of the reported values by independent auditors in line with the JUs' Regulations.

4.6. Internal Audit

The internal audit functions of Clean Aviation JU were carried out in 2021 by the Internal Audit Service of the Commission (IAS) and by the Internal Audit Officer of Clean Aviation JU (IAO) according to Art. 28 and Art 29 of the Financial Rules[23].

<u>Internal Audit Service (IAS):</u>

- *Audit in 2021*

In 2021 the IAS did not carry out a new assurance audit. Several follow-up audits have been performed on previous recommendations:

<u>*Follow-up Audit on Horizon 2020 grant implementation*</u> (final report of 22 October 2020), started in April 2021:
The IAS concluded in June 2021 that the three recommendations had been adequately and effectively implemented by the JU and were therefore considered closed. Details were reported already in the AAR 2020.

<u>*Follow-up Audit on Performance Management*</u> (final report of 20 November 2017), started in July 2021:
The concerned recommendation related to Monitoring and Reporting on the Performance of H2020 Projects. The action plan consisted of three sub-actions which addressed weaknesses in the JU's monitoring process regarding the contribution of the CS2 projects of partners to the High Level Objectives of the CS2 programme. Following the implementation process of the actions, the JU has proposed the recommendations to the IAS in several steps as ready for closure, the last update being provided in May 2021. In a specific note for the CAJU concerning the year 2021[24], the IAS concluded that the recommendations are considered implemented.

[23] Ref. CS-GB-Writ proc-2019-07 Revised Financial Rules and CAJU GB Decision omnibus of 16th December 2021
24 Internal Audit Service contribution to the 2021 Consolidated Annual Activity Report process of Clean Aviation Joint Undertaking, Ares (2022) 1465746 – 28/02/2022

Follow-up Audit on Performance Management (final report issued on 20 November 2017) and on the *H2020 Grant Process* (from the identification of the call topics to the signature of the grant agreement) (final report issued on 15 November 2016), started in January 2022.

Two recommendations concerning the update of the JU's internal procedure descriptions, like the Management Manual and the Quality Manual, according to the actual H2020 processes have been implemented by the JU in several steps and have been proposed to the IAS for final closure in November 2021. In its annual report for the CAJU concerning the year 2021, the IAS concluded that the recommendations are considered implemented,

- Significantly delayed recommendations

One recommendation stemming from the audit on *Performance Management* (final report of 20 November 2017) is still pending implementation. The issue is related to completing the JU's performance framework by defining criteria and related indicators, as well as quantifying targets for the competitiveness/industrial leadership objectives (mobility/connectivity, employment, GDP impact, etc.), and develop the methodology for measuring progress under the CS2 Programme towards achievement of these objectives. A new deadline for implementing the required action has been agreed with the IAS for July 2022.

In September 2021, the contract for a socio-economic study on the CS2 programme was signed with Roland Berger. The scope of the contract comprises:

- analysis of the socio-economic impact of the Clean Sky 2 programme, and more specifically, the real and projected attainments of the Clean Sky 2 programme (Task 1);
- assessment of the impact of the Covid-19 pandemic and providing an updated outlook for how the landscape may evolve in the post-Covid-19 period (Task 2);
- development of an outlook for the aviation sector, taking into account any scenarios and developing models for the evolution of the aviation system, and create a risk-adjusted future-ready investment strategy for the Clean Aviation Joint Undertaking (Task 3).

An inception report was issued by the contractor in December 2021, providing a first review on the above three tasks of the contract and developing the required frameworks for the assessment. Concepts and models for measuring competitiveness and innovation have been drafted; likewise, the frame for the impact assessment of Covid-19 on the structure of industry, sustainability and additionality of the CS2 programme under socio-economic aspects; finally, the outlook for developing the CA vision until 2050.
The recommendation will be fully implemented within the revised deadline.

Internal Audit Officer (IAO):

Under the responsibility of the Governing Board, the IAO carries out the function of the Internal Audit Capability as described in the CS2 Financial Rules[25]. The IAO's Annual Report 2021[26]

[25] Ref. CS-GB-Writ proc-2019-07 Revised Financial Rules and CAJU GB Decision omnibus of 16th December 2021
[26] Annual Report 2021 of the Internal Audit Officer, dated 31.01.2022

summarises the activities performed during the year 2021 with reference to the approved annual audit plan[27]. The audit plan has been fully implemented with a minor adaptation: the limited review of the actions taken by the JU management to mitigate several control deficiencies identified by the Internal Control Coordinator in February 2021, has been integrated in the IAO risk assessment without establishing a separate report.

For the year 2021, the IAO confirmed to the GB her organisational independence according to the IIA standards. For some specific activities and processes of the JU, for which the IAO took over direct operational responsibility, the IAO highlighted to the GB a potential lack of objectivity. However, these processes of the JU were fully covered by other auditors, like the European Court of Auditors (ECA) and the Internal Audit Service of the Commission (IAS), either through assurance audits or through risk assessment.

As in previous years, in 2021 the IAO coordinated the JU's ex-post audit process. The entire activity and results for the year 2021 are presented in subchapter 4.3 of this report. Throughout the year, the IAO ensured the proper coordination of the JU's audit process with the Common Audit Service (CAS).
Changes in the future audit strategy of CAJU are expected following a change in the audit approach of the Court of Auditors and given the new Control Strategy for the HE grant management of the Commission, which provides for enhancing the ex-ante controls within the framework of a risk-based project monitoring strategy.

Other main areas of the IAO activities have been:

- coordination of JU risk management;
- advice on the JU's self-assessment of the Internal Control Principles;
- fraud risk assessment and implementation of the anti-fraud action plan;
- support for revising the quality system for CAJU and contributing to the JU's improvement programme.

With a view to the antifraud measures of the JU, the IAO holds the function of the Antifraud Correspondent of CA JU and liaises with OLAF and the FAIR committee. The latter deals with the global Antifraud Strategy and related activities in the entire research sector of the Commission. Regarding the status of cases reported to OLAF, refer to sections 2.2 and 4.7.

In the field of assurance audit, the IAO has contributed to the implementation of recommendations from other auditors, in particular from the Internal Audit Service of the Commission, and provided support to the JU management for developing the appropriate actions.

At the end of 2021, the IAO had updated her risk assessment of the JU's internal control system and identified some risk areas, which were not specifically monitored by the JU management. All the risks provided for a medium or low risk level and are therefore not described in this report in detail. They will be considered in the JU's self-assessment of the internal control system and in the global JU risk assessment. Detailed information on the IAO risk assessment is provided to the JU management in the annual IAO report 2021.

[27] Annual Audit Plan of the CS2 JU Internal Audit Capability, approved by the GB on 19.04.2021

4.7. Risk management, conflict of interest, fraud prevention and detection

Risk Management

As one major element of its Internal Control Framework, the JU assesses and manages, through a dedicated process, the potential risks which may be detrimental to achieving its objectives.

The complexity of the JU activities, with the involvement of many stakeholders participating in the execution of the programmes with a variety of often interconnected activities, calls for assessing and managing risks at the different levels of activity of all actors:

- Joint Undertaking organisation level
- CS2 programme level
- ITD/IADP/TA level (risks pertaining to the WP objectives and performances)

The responsibility for risk management in the JU including the identification and implementation of mitigating actions is with the Executive Director and the Programme Office, supported by the CS2 Programme Coordination Committee. Risks to be considered in the year 2021 were described in the CS2 Development Plan and in the Grant Agreements for Members and Partners, in individual risk registers of the SPD Leaders reported regularly to the JU's Programme Office and in the Steering Committees. All risks, including the SPDs' risks, which had an impact on the objectives of the programme, were captured in the global JU Risk Register, which provides for an evaluation of the risk level and description of the mitigating activities.

The JU had provided an analysis of the relevant risks in the work plan 2020-21 to which the following assessment refers (see the table further down in this section).
The main risks for the JU relate to the operational objectives of the programme and to some core management processes, which in turn could have an impact on the operational and financial implementation of the overall programme.

With respect to the methodology used, the JU follows the Impact/Likelihood concept:

	Impact			
high	4	4	8	12
medium	3	3	6	9
low	2	2	4	6
very low	1	1	2	3
		1 low	2 medium	3 high
				Likelihood

Risk level

1 - 2	Low
3 - 4	Medium
5 - 9	High
> 9	Critical

Risk rating = Impact x Likelihood

The impact is the potential consequence should the event materialise. The likelihood reflects the probability and remaining impact of the event, taking into account the mitigating actions which are planned or have been taken.

The different types of risks are assessed according to the following criteria:

Impact level	Financial *(measured in % of annual budget; depending on the risk, the reference could be the total JU budget or subcategories [titles, lines])*	Reputational	Operational
4 - Critical	Impact > 10%	Strong reputation or political impact with key stakeholder	Failure would create major disruption to critical activities
3 - High	2% < Impact < 10%	Major reputation or political impact with key stakeholder	Failure would create major disruption to very important activities
2 - Medium	1% < Impact < 2%	Some reputation or political impact with key stakeholder	Failure would create some disruption to important activities
1 - Low	0% < Impact 1%	Impact primarily internal	Failure would disrupt minor activities
0 - Very Low	Impact > 0%	Impact primarily internal	Failure would disrupt very minor activities

Risk Description	Likelihood (H/M/L/VL)	Impact (H/M/L)	Impact Category*	Mitigating actions	Residual Risk
Achievement of high-level goals **Execution of the technical activities in Clean Sky 2 may not result in the achievement of the High-Level Objectives as stated in the Regulation.**	VL	H	*Operational* *Reputational*	Mitigation achieved as per RA 10/2021: The residual risk is lowered from High to Medium as compared to last year based on the confirmation of the achievements of HLGs as reported in the 1st TE assessment. Good progress from IADPs/ITDs/Tas has been made in quantifying environmental contributions from the different aircraft concepts to perform a 2nd TE assessment contributing to meet the Clean Sky 2 High Level Objectives. Mitigating actions: Define objectives for the IADPs/ITDs in all areas of qualitative goals of the Regulation [e.g. competitiveness and mobility and monitor progress towards these goals through periodic assessments with the TE and by the JU directly via supporting studies and coordination and support actions, where necessary.	M
Implementation of the Clean Sky 2 Development plan may be hampered due to: • Changed priorities of private Members and reduction of leverage effect of EU funding: Strategic or technical priorities within industrial companies may result in a lack of resources available for Clean Sky 2, delays in the completion of the activities and/or a need to revise programme content.	M	H	Operational Reputational	The residual risk is unchanged as compared to last year based on the 2021 CS2DP revision. Mitigation plan as per Risk Assessment 10 - 2021 Early warning capability was maintained through Quarterly Reports, Annual and Intermediate Progress Reviews and ad hoc meetings with regular updates to the Governing Board.	H

Risk Description	Likelihood (H/M/L/VL)	Impact (H/M/L)	Impact Category*	Mitigating actions	Residual Risk
• Delays in execution of grants: Technical setbacks, delays in execution of grants and business continuity risk in one or several IADPs / ITDs / TAs may result in under-achievement of milestones and deliverables and/or a significant over/ under-spending of annual budget. • Lack of funding linked to technical difficulties or lack of robustness of resources/financial planning vs demonstration objectives: Planning for cost and effort for complex, large ground and flight demonstrators (10-year programme) may lack maturity and/or accuracy, leading to delayed completion of technical activities or reduced scope of activities. Covid-19 impact: The economic crisis may cause significant delays in research activities of all SPDs, due to the breakdown of companies and/or their supply chains. The economic crisis in aviation industry may enhance the described risk as research activities may temporarily lose priority due to lack of funds in industry. As an immediate effect of the restrictions on mobility, organisations may not be able to ensure the execution of research work as proposed in the CS2DP.				Technical execution was closely monitored through timely execution of milestones and deliverables, phase and gate process in particular for flight demonstrators, with some limited reorientations to confirm the ambition of the programme as reflected in the CS2DP, WP and prepared GAM Amendments to ensure CS2 HLGs. Each IADP / ITD deployed an updated risk management and "through to completion" plan with critical path management, budgets and risks. Seek for funding opportunities through other instruments (national level or other EU initiatives) or increase the level of additional activities required to meet the programme objectives.	
Multi-annual budget planning and execution Lack of adequate plans on the ITDs' side at the level	M	M	Financial	*Mitigation achieved as per RA 10/2021:* The residual risk is lowered from High to Medium as compared to last year based on the confirmation of	M

Risk Description	Likelihood (H/M/L/VL)	Impact (H/M/L)	Impact Category*	Mitigating actions	Residual Risk
of CA and PA during the execution of the multi-annual budget may hamper the execution of the full operational budget (re-inscription of the credits to ensure maximised programme execution).				achievements from the JU Members. Detailed assessment: The CS2DP revision has been finalised in October 2021; this will be the final baseline against which GAMs will report up to the end of the programme. The level of consumption of planned resources is higher than the rate of deliverables and milestones achieved. The JU Members have confirmed that nevertheless the contribution to the demonstrators will be achieved as planned until the end of the programme. For some technical reasons, the EC global budget for CS will be lower than foreseen in the multi-annual planning (€6.9m less), this difference will have to be managed.	
Loss of funding due to bankruptcies in Covid19 aftermath **The increase in the bankruptcy rate amongst the JU's beneficiaries may cause high loss of pre-financing.**	VL	H	Financial	Mitigation achieved as per Risk Assessment 10/2021: The residual risk is lowered from High to Medium as compared to last year based on the limited number of actual cases incurred during the year Mitigating actions performed: The instrument of reinforced monitoring has been used in order to monitor the financial risk linked to bankruptcies and to limit the financial losses to the extent possible. Evidence for distribution of funds to the consortium by the coordinators of projects has been requested with the aim of monitoring high amounts of pre-financing. The effect of Covid-19 pandemic will be known in	M

Risk Description	Likelihood (H/M/L/VL)	Impact (H/M/L)	Impact Category*	Mitigating actions	Residual Risk
				2022. For the moment the risk has not materialised.	
Market uptake of research results **The maturity of certain demonstrators at programme completion may be lower than expected (due to Covid-19 or technical difficulties) hampering the timely exploitation of results.**	M	H	Operational	Maintaining an early warning capability through quarterly reports, the Annual and Intermediate Progress Reviews and where necessary alerting the Governing Board. Assessing the impact of timely delays of Covid-19 on market forecast (socio-economic impact study to launch) and proposing the re-alignment of acitvities where required to maximise the timely exploitation of results. Proposing a revision of the CS2DP and the WP and using the GAM Amendment process to officiate.	H

Impact category: Reputational; Operational; Financial

Conflict of interest

In 2021 the JU continued to apply the decisions adopted by the Governing Board regarding the rules on the prevention and management of conflicts of interest applicable to the bodies of the Joint Undertaking[28] and to the JU staff members[29]. The related processes, for instance concerning Members of the JU's Governing Board, experts of evaluation procedures, panels for procurement and recruitment, applied consistently the required precautionary measures to identify potential conflicts. A JU policy on sensitive functions has been drafted based on a dedicated risk assessment and will be finalised in the year 2022.

To enhance awareness, a training was performed for all JU staff in the beginning of 2021 regarding the building blocks of fraud, the role of OLAF, the Antifraud Strategies applicable for the JU, Clean Sky's fraud risk assessment and the major measures to be taken to prevent and detect fraud in the different phases of the grant management cycle.

In addition, a workshop has been carried out in June 2021 to streamline the internal processes and clarify the roles and responsibilities for anti-fraud controls of the entire JU team. The workshop focused on the newly established JU Guidance for combatting fraud, the action plan for the implementation of the Antifraud Strategies, the IAS recommendations regarding antifraud controls in grant management and on the new Compendium of Conflict-of-Interest Procedures of the JU. Subsequent to the workshop, the JU staff has worked on defining a manageable set of red flags and related actions to prevent and detect fraud based on the list of warning signs established by the Common Implementation Centre for the Research Family[30].

Fraud prevention and detection

The Clean Sky 2 programme and JU has been covered by the Common Antifraud Strategy for the Research Family (CAFS)[31], which addressed the fraud risks of the entire sector of research in the European Commission. An action plan for detective and preventive measures is linked to this global antifraud strategy, which all stakeholders implement in close coordination with the Commission. One of the major issues addressed is the detection and prevention of double funding and plagiarism, for which the Commission has developed IT tools, which enable the JU to perform similarity checks for individual projects during the entire grant management phase.
In addition to the common approach for the research sector, a specific Clean Sky 2 Antifraud Strategy has been implemented. It is based on a dedicated fraud risk assessment, which is revisited every year. In the mid-year review of the fraud risk assessment 202132, the risk levels for individual budget areas and types of activity have been evaluated and remained unchanged as compared to the assessment 2020, see the table on the next page.

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[28] Ref. CS-GB-Writ Proc 2016-15Rules on CoI_JU Bodies and CAJU GB Decision omnibus_16th December 2021
[29] Ref. CS-GB-2017-10-19 CoI decision JU staff.
[30] Published in the new Antifraud section on the homepage of the Common Implementatin Centre (CIC)
[31] Issued by the Common Implementation Centre (CIC) and latest version adopted by the Executive Committee in November 2019
[32] Dated 30.06.2021

Type of expenditure / non-expenditure area	Total amount (Mill Euro)	Fraud risk - likelihood	Fraud risk - Impact[33]	FRAUD RISK - OVERALL
Grants	1 716	*Low*	*High*	*Medium*
Research integrity	-	*Low/Medium*	*Medium*	*Medium*
Experts management	6	*Very Low*	*Medium*	*Low*
Procurement	50	*Very Low*	*Medium*	*Low*
Administrative and other	22	*Very Low*	*Medium*	*Low*
Internal fraud	-	*Low*	*Medium*	*Low/Medium*
In-kind contribution	2 155	*Low*	*Medium*	*Low/Medium*
GRAND TOTAL (M€)	3 949			

Covid-19 pandemic - impact on fraud risks

According to an assessment of the European Court of Auditors, the risk of fraudulent bankruptcies or other fraudulent behaviours, to escape the financial problems and supply restrictions, needs to be considered in the context of the Covid-19 pandemic as additional threat for legality and regularity.
The JU has therefore established a specific risk-based sample of ex-post audits to cover the stratum in the JU population of GAP projects, which indicate a certain exposure to Covid-19 constraints as described by the Court of Auditors, like financial weaknesses, operational delays, high personal costs as compared to average.
Depending on the results of the audit exercise, the JU will develop mitigating actions to avoid the types of errors identified in the audits before authorising payments.

OLAF recommendations

In the year 2021, OLAF issued the final conclusions and its reports regarding two cases pertaining to grants of CS and CS2JU. The alleged fraud was confirmed in both cases:

Entity	Result of investigation	Financial impact	Prevention measures to avoid cases in future	Country
Case 1	Irregularity confirmed: - Non-execution of the grant agreement - Embezzlement of EU funding by legal representative of the entity for personal interests	€2.04 million; (FP7 projects, not covered by EC guarantee fund; therefore the JU will bear the loss)	Monitor more rigidly underperformance of participants through **risk-based project monitoring process** (in place) Definition of warning signs for fraud risks (red flags)	Italy
Case 2	Irregularity confirmed: - Fraudulent	€500.1 K; (H2020 project, covered	This type and size of fraud is difficult to prevent:	Belgium

[33] Materiality and/or reputational impact.

Entity	Result of investigation	Financial impact	Prevention measures to avoid cases in future	Country
	bankruptcy - Embezzlement of EU funding by legal representative of the entity	by EC guarantee fund; therefore, financial loss is limited to litigation fees)	Fraud has been committed by Coordinator Financial capacity checks are performed by REA Beneficiary had provided a declaration of honor regarding its financial capability	

The recommendations of OLAF in both cases focus on measures to be taken by the JU to recover the funding and to consider flagging the entity and the person in the EC systems (Exclusion Database). The JU has completed the litigation case before the EU General Court pertaining to the case in Italy (lodged in 2018) and will try to execute the General Court judgement at national level. With regard to the Belgian case, the JU had registered its financial claims with the liquidator already in 2017, based on the OLAF report and confirmation of fraud, the JU is analysing what judicial action may be taken at national level.

4.8. Compliance and effectiveness of Internal Control

The Executive Director, together with the Internal Control Coordinator and the JU staff at all levels, ensured the implementation of the internal control framework according to the JU's principles and rules.
As input for the assurance on the functioning of the JU's internal control system, a global assessment has been performed taking into consideration the application of the JU's agreed internal control principles, results of controls throughout the reporting year, exception reports, specific control weaknesses or risks identified and recommendations received from the JU's auditors.

An assessment of the Internal Control Principles (ICPs) is ongoing on the basis of the following elements:

- a review of the compliance documents available in the JU for each internal control principle according to the EC list of reference documents related to the ICPs as far as applicable for Clean Aviation JU
- the analysis of the set of 80 internal control monitoring indicators and their results for the year 2020
- the review of the functioning of the 17 ICPs as well as the identification of the improvements needed

The results of the internal control monitoring indicators are complemented by other sources of information stemming in particular from audits of the ECA, the IAS and the IAC of Clean Aviation JU, but taking into consideration also the results of internal surveys, studies from external consultants, self-assessment and consultation with responsible staff members.

5. MANAGEMENT ASSURANCE

5.1. Assessment of the Annual Activity Report by the Governing Board

GOVERNING BOARD OF CLEAN AVIATION JOINT UNDERTAKING

ASSESSMENT OF THE ANNUAL ACTIVITY REPORT 2021

The Governing Board of the Clean Aviation Joint Undertaking has taken note of the Annual Activity Report 2021 (Authorising Officer's report), which was made available on 26 May 2021.

The Board is of the opinion that the Annual Activity Report accurately reflects the implementation of the 2021 activities of the Joint Undertaking from both an operational and administrative point of view.

The Board is pleased to note the successful launch of the Clean Aviation Joint Undertaking under Horizon Europe and the continuation of a steady implementation of the Clean Sky 2, the legacy Horizon 2020 programme.
The Board takes note that the JU has fulfilled its monitoring tasks through the implementation and usage of dedicated key performance indicators for the achievement of strategic research and management objectives.

The Board acknowledges the peak effort in the CS2 programme execution performed in parallel with the launch of the renewed Clean Aviation partnership and programme start, the high workloads resulting from this for the JU programme office, as well as for the private members, and states its appreciation for the efforts and progress made.

The Board takes note of the effects of the Covid-19 crisis and its impact on the programme implementation. It expresses its appreciation for the outlook that its effects on the programme's progress were contained, and although several demonstrators experienced delays, overall the programme implementation remains on track and geared at reaching the set objectives.
Despite the challenging year, the Board appreciates the good rate of budget execution achieved in 2021 and encourages the members to maintain it further. It encourages all participants to the programmes to continue to meet the targets set out in the Clean Sky 2 Development Plan and the Strategic Research and Innovation Agenda, and to meet the objectives as set out in the relevant the grant agreements in terms of the achievement of milestones, deliverables and the optimum use of resources assigned.

The Board takes note that the in-kind contributions of the private members are brought in at a satisfactory level to meet the commitments made by the private members, in particular with reference to the additional activities provided. It encourages the members to continue to make and to ensure the timely reporting of in-kind contributions.

The Board is pleased to note the continued efforts applied to creating synergies and the growing number of strategic Memoranda of Understanding put in place with the various regions in Europe, promoting synergies with European Structural & Investment Funds. The implementation of these projects has a visible impact in strengthening the R&I innovation capacity of the European aeronautics regions, while complementing the programme and supporting its overall objectives.

The Board takes note of the good dissemination and exploitation results, with Clean Sky programmes having obtained 279 patents and published 1.157 technical and peer-reviewed papers and encourages the members and the Programme Office to continue the dissemination efforts by highlighting the programme's achievements and impact.

The Board also takes note of the significant external communications efforts and successful reach out to new audiences and building a positive reputation of the Clean Aviation European partnership.

The Board notes that no critical risks have been identified regarding the achievement of the CS2 programme objectives, the implementation of the JU's main business processes and its internal control framework. The GB is pleased to note a strong risk management process in the JU, including the systematic monitoring of technical and financial risks in the projects.

The Board takes note that the H2020 audits are duly implemented and processed and that the ex-post audits results in 2021 audit exercise meet the target of achieving a residual error rate below 2%. Further actions to maintain the applied preventive and remedial measures as well as to continue a robust audit process for the H2020 programme will be supported by the Board.

Done in Brussels, June 2022

Rosalinde van der Vlies

(Signed)
Chair of the Governing Board

5.2. Elements supporting assurance

Besides the dedicated supervisory activities of the Executive Director, the main elements supporting the assurance are:

- the reporting of the Head of Administration and Finance (who is also the internal control coordinator of the JU);
- the assessment of the Internal Control System by the Internal Control Coordinator of the JU
- the reporting of the Head of Unit for Programmes;
- the reporting of the Head of Unit for Strategic Development;
- the reporting of the Head of Legal;
- the reporting on the accumulated results of the ex-post audit processes from 2011 to 2021 and the related implementation;
- the information received from the Data Protection Officer;
- the results of audits of the European Court of Auditors to date;
- the reporting of the Internal Audit Officer and the Internal Audit Service of the Commission;
- the overall risk management performed in 2021 as supervised by the Executive Director;
- the key performance indicators in place;
- the dedicated ex-ante controls of the JU's operational expenditure;
- the private members' reporting of in-kind contributions.

5.3. Reservations

No reservation is entered for 2021.

5.4. Overall conclusion

Not applicable.

5.5. Declaration of assurance

I, the undersigned, Axel Krein, Executive Director of Clean Aviation Joint Undertaking

In my capacity as authorising officer by delegation

Declare that the information contained in this report gives a true and fair view[1]*.*

I state that I have reasonable assurance that the resources assigned to the activities described in this report have been used for their intended purpose and in accordance with the principles of sound financial management, and that the control procedures put in place give the necessary guarantees concerning the legality and regularity of the underlying transactions.

This reasonable assurance is based on my own judgement and on the information at my disposal, such as the results of the self-assessment, ex-ante and ex-post controls, the work of the internal audit capability, the observations of the Internal Audit Service and the lessons learnt from the reports of the European Court of Auditors for years prior to the year of this declaration.

I confirm that I am not aware of anything not reported here which could harm the interests of the Joint Undertaking.

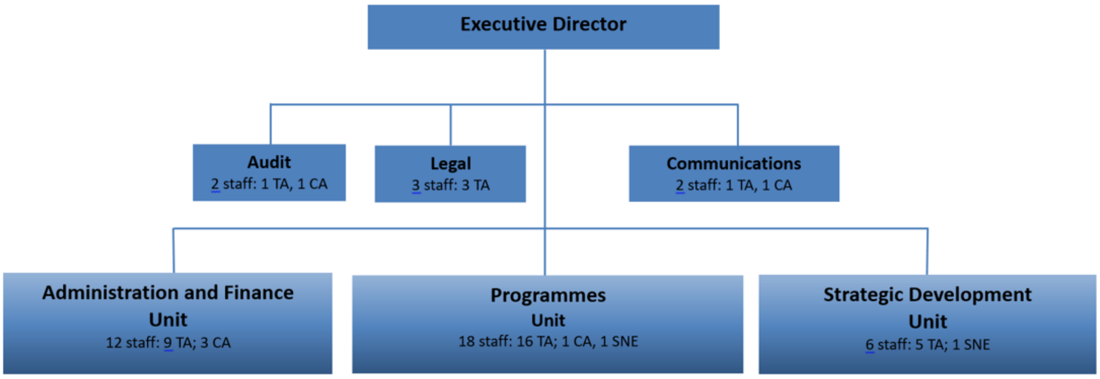
Brussels, 1 April 2022

(signed)

[1] True and fair in this context means a reliable, complete and correct view of the state of affairs in the Joint Undertaking.

ANNEXES

1. Organisational chart



The Establishment Plan foresees 44 staff in total, out of which 42 staff members
[36 Temporary Agents (TA) + 6 Contractual Agents (CA)] and 2 Seconded National Experts (SNE).

2. Staff establishment plan

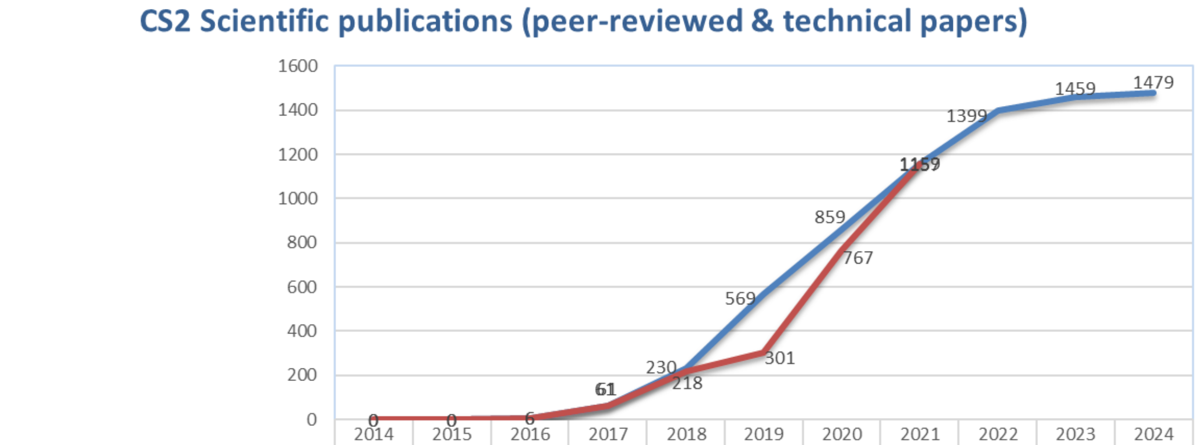
Category and grade	Establishment Plan 2021		Staff population actually filled at 31.12.2021	
	Off.	TA	Off.	
AD 16				
AD 15				
AD 14		1		1
AD 13				
AD 12		2		2
AD 11		1		1
AD 10		3		3
AD 9		10		10
AD 8		3		3
AD 7		3		2
AD 6		9		9
AD 5				
Total AD		*32*		*31*
AST 9				
AST 8		1		1
AST 7		0		0
AST 6		2		2
AST 5		1		0
AST 4				
AST 3				1
AST 2				
AST 1				
Total AST		*4*		*4*
TOTAL TA		36		35
CA FG IV		1		1
CA FG III		5		5
CA FG II				
CA FG I				
Total CA		*6*		*6*
TA+CA		*42*		*41*
SNE		*2*		*1*
TOTAL (TA+CA+SNE)		44		42

3. Publications from projects

The table below presents the status of the dissemination as reported by 31 December 2021.

Publications	GAM	GAP	Tot Dec 2020	Total Dec 2021	Delta	Comparison with 2020 in %
Peer Reviewed Paper	319	515	550	834	284	51.63%
Technical Paper	139	184	217	323	106	48.85%
Book	9	18	22	27	5	22.72%
Thesis	8	31	16	39	23	143.75%
Participation in conferences	375	505	608	880	272	44.74%
Other	150	190	70	340	270	385.70%
Total	1000	1443	1483	2443	960	64.73%

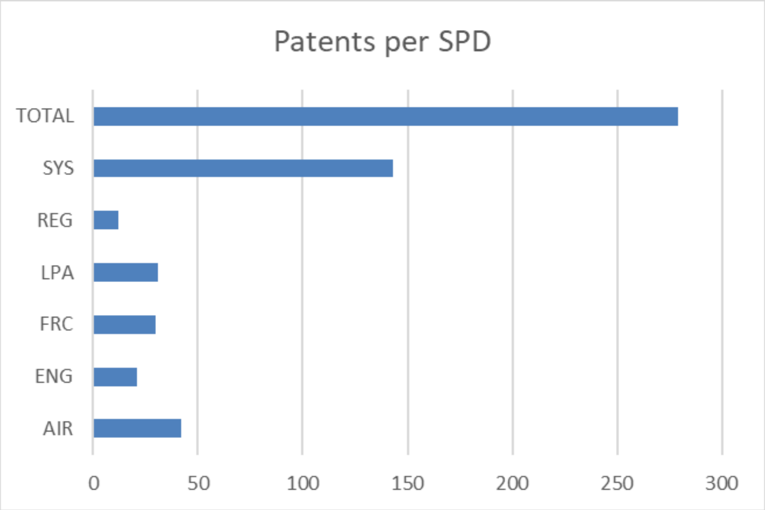
The graph here below presents the progress against the JU yearly KPI targets in terms of scientific publications (only peer-reviewed and technical papers).



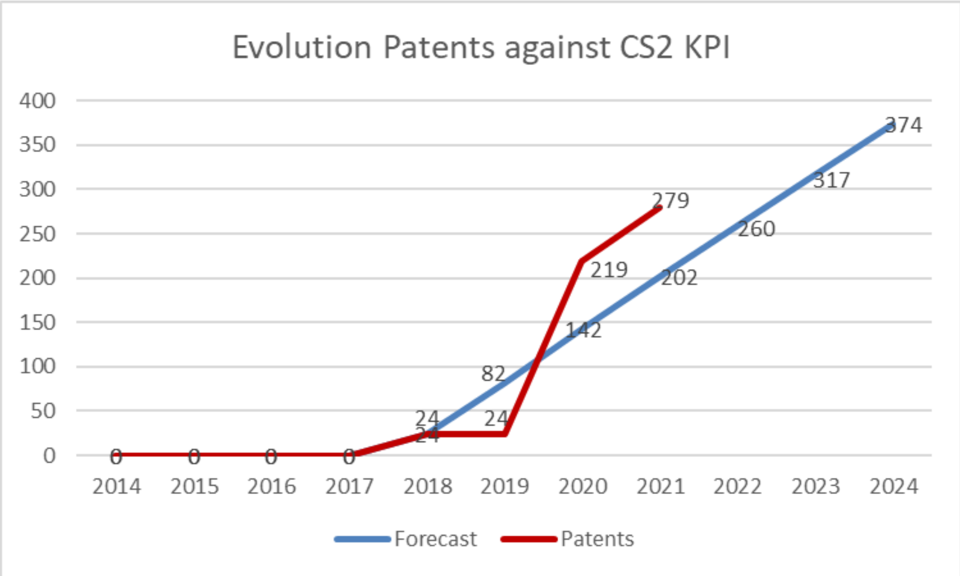
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
CS2 JU KPI targets	0	0	6	61	230	569	859	1159	1399	1459	1479
Achieved publications (peer+tech)	0	0	6	61	218	301	767	1157			

Graph: 'JU KPI: Scientific publications (peer-reviewed papers & technical papers)'

4. Patents from projects



SPD	PATENTS
AIR	42
ENG	21
FRC	30
LPA	31
REG	12
SYS	143
TOT	279



Year	Forecast	Patents
2014	0	0
2015	0	0
2016	0	0
2017	0	0
2018	24	24
2019	82	24
2020	142	219
2021	202	279
2022	260	
2023	317	
2024	374	

5. Scoreboard of Horizon 2020 and common KPIs

Description	Targets	2021 Results	2020 Results	Comments
	H2020 Results			
SME - introducing innovations of participating SMEs	No target set	Not reported	Not reported	Information not yet available; will be addressed in the tender "socio economic impact"
SME - Growth and job creation in participating SMEs	No target set	Not reported	Not reported	Information not yet available; will be addressed in the tender "socio economic impact"
Patent applications and patents	> 366 patents	Patent applications: 60	Patent applications: 87	The target is established on programme level by 2024.
Demonstration activities (number of demonstrators and technology streams)	35	34: L1 demonstrator 107: L1-L2 demonstrator	34: L1 demonstrator 106: L1-L2 demonstrator	
Redress after evaluations	<2% of proposals (excluding PP submission related redress requests)	No CfP in 2021	2.61% 5 out of 191 proposals	
Time to grant (TTG)	80%	No CfP in 2021	CFP10 = 86,21 CFP 11 = 100%	
Time to pay (TTP) Operational budget	95%	99%	99%	
Vacancy rate (%)	0%	4.55%	2%	

Description	Targets	2021 Results	2020 Results	Comments
Budget implementation/ execution	95% in PA	Total CA: 99.6% Total PA: 82.3% Oper. CA: 100% Oper. PA: 82.9% Admin CA: 92.6% Admn PA: 74.7%	Total CA:97.4% Total PA: 88.1% Oper. CA: 97.6% Oper. PA: 88.7% Admin CA: 92% Admn PA: 68.5%	
Time to pay (TTP) Administrative budget	> 95%	97%	99%	

6. Indicators for monitoring cross-cutting issues

Description	Targets	2021 Results	2020 Results	Comments
	H2020 Results			
Country distribution (EU Member States and Associated countries) - ***numbers***[34]	EU 28: 95% Associated: 5%	GAPS : (CFPs 1 to 11) EU: 96.38% Associated : 3.62 % --------------- GAMS 2014-2023 EU: 332(97.79%) AC: 7(2.21%)	GAPS : (CFPs 1 to 11) EU : 94.33% Associated : 4.77% Others: 0.90%	GAMs signed GAPs applications/ participations
Country distribution (EU Member States and Associated countries) - ***financial contribution***[35]	No target set	GAPS : (CFPs 1 to 11) EU: 96,83% - 519 million euro AC : 3,17% - 17 million euro ---------------- GAMS 2014-23 EU=99,41% - 1.134 million Euro AC=0.59%- 6,7 million euro	GAPs: (CFPs 1 to 11) EU: 97,19% - 865 million euro AC: 2,81% : 25 million euro	GAMs signed GAPs applications/ participations
SME participation - financial contribution	At least 13%	GAPS CFP 1-11: SMEs 26.09 % ------------ GAMS 2014-23: 3.87%	GAPS - CFPs 1 to 11 : 25.87%	

[34] Targets and results 21 still treat the UK as EU Member State
[35] Targets and results 21 still treat the UK as EU Member State

Description	Targets	2021 Results	2020 Results	Comments
Gender balance - Programme participation	No target set	Female participation rate :26.57%	Female participation rate: 31%	
Gender balance - Project coordinators	no target	Female rate of coordinators 16,51%	Female rate of coordinators 17%	
Gender balance - Advisors and experts	No target set	Female Participation Rates*: 9% in Annual Reviews and Technical Reviews (IPR) 10% in the SciCom *No CfP performed in 2021, therefore no relevant data	Female Participation Rates: 19% in Evaluations (CfP11) 12% in Annual Reviews and Technical Reviews (IPR) 10% in the SciCom	
Third-country participation[36]	No target set	GAPS : 0,54%	GAPs : 0.54%	
Innovation Actions (IAs): Share of projects and EU financial contribution allocated to Innovation Actions (IAs)	Leaders: 100% Core partners: 100% partners: 70%	Leaders: 100% Core Partners: 100% Partners = In numbers: 53,86% In funding: 53,46%	Leaders: 100% Core Partners: 100% Partners = in number 53,7% in funding: 53,5%	
Demonstration activities within IAs	70%	Not reported	Not reported	
Scale of impact of projects (High Technology Readiness Level)		*Result only at end of programme*	*Result only at end of programme*	Based on CS2DP the maturity plan per demos at programme completion: • TRL3: 9 • TRL4: 11 • TRL5: 46 • TRL6: 36

[36] Targets and results 21 still treat the UK as EU Member State

Description	Targets	2021 Results	2020 Results	Comments
Horizon 2020 beneficiaries from the private for profit sector - number of participants	not more than 60%	GAMs: 80.53 % GAPs : 49,34 %	GAMs: 80% GAPs : 47%	
Horizon 2020 beneficiaries from the private for profit sector - financial contribution	not more than 80%	GAMs: 81,39% GAPS : 47,85%	GAMs: 83% GAPS : 44%	
EU financial contribution for PPP	Not specified	CA: 182.1 M€ PA: 189.5 M€	CA: 311.4 M€ PA: 311.4 M€	
Private sector contribution including leverage effect	On programme level: 125%[37]	IKOP reported: 819.11 million IKOP certified: 581.34 million IKAA reported: €1,119 million IKAA certified: € 1.030 million The executed EU contribution by the private Members represents 83% of the total envelope while the reported IKC is equal to 90% of the overall target *(declared, not fully certified figures)*	IKOP reported: 717.65 million IKOP certified: 581.34 million IKAA reported: €1,144 million IKAA certified: €838,13 million The executed EU contribution by the private Members represents 71% of the total envelope while the reported IKC is equal to 82% of the overall target *(declared, not fully certified figures)*	The IKC certification for 2020-21 will be provided in 2022
Dissemination activities	At least 100 per year (papers, thesis, book chapters,	948	Peer Reviewed papers : 157 Technical papers : 43 Thesis : 3	

[37] Not applicable as annual target.

Description	Targets	2021 Results	2020 Results	Comments
	conferences and other dissemination activities)		Book : 5 Conference participation : 115 Other Dissemination Activities : 3	
Distribution of proposal evaluators by country	<25% from one country	No CfP and/or evaluation exercise in 2021, indicator not applicable	CfP11 Italy 20.0% France 12.6% Spain 9.5% UK 9.5% Germany 8.4% Greece 8.4% Belgium 6.3% Netherlands 4.2% Romania 4.2% Ireland 3.2% Others 13.7%	
Distribution of proposal evaluators by type of organisation	<66% from one sector	No CfP and/or evaluation exercise in 2021, indicator not applicable	CfP11 Private for profit organisation = 36% Higher or secondary education establishment = 36% Research Organisation = 12% Public Organisation = 2% Other = 14%	

Description	Targets	2021 Results	2020 Results	Comments
Participation of Research and Technology Organisations and Universities in PPPs (Art 187 initiatives)	At least 25%	Gaps : share of participants: RES: 25.97% UNI : 26,39% Share of contrib. : RES : 31,59% UNI:24.91% ------------------------------ GAMs: share of participants : RES:15,38% UNI :3.27% Share of contrib. : RES : 13,16% UNI: 2,83%	GAPs : share of participants : RES: 25.69% UNI : 27.02% Share of contrib. : RES : 31,29 UNI:25.28% ----------------------- GAMs: share of participants : RES:11.98% UNI : 6.96% Share of contrib. : RES : 14.62% UNI: 3.13%	
Ethics efficiency: % of proposals not granted because of non-compliance with ethical rules Time to ethics clearance for proposals invited to grant	<2% 45 days	No CfP and/or evaluation exercise in 2021, indicator not applicable	0% clearance time < 45 days	
Residual error rate	<2%	0.96%	0.91%	

7. Scoreboard of KPIs specific to Clean Sky 2 Joint Undertaking

Description	Targets	2021 Results	2020 Results	Comments
	H2020 Results			
Call topics success rate	> 90%	No CfP in 2021, indicator not applicable	97%	

Description	Targets	2021 Results	2020 Results	Comments
WP execution deliverables versus plan	100%	> 75%	77%	These are based on Q4 Reports (Q1-Q4 Cumul) from the different SPDs and coherent with the level of resources spent.
Ex-post audit coverage	20%	16.8%	16.9%	As our audit results do not imply a risk, that the error rate of maximum 2% is exceeded, we keep the audit burden for our beneficiaries as low as possible and reduce the coverage as compared to the target.

8. Final accounts

The main tables of the Final Accounts 2021 of the CAJU are comprised of the Balance Sheet, the Statement on Financial Performance, the Statement of Changes in Net Assets and the Cash Flow Analysis. A detailed explanation to assets and liabilities of the JU and to the economic result of the year 2021 is provided in the *Notes to the Final Accounts*, which form part of the Final Accounts document itself.

Economic Outturn

The Statement on Financial Performance presents the economic result of the CAJU in the reporting period (1 January 2021 – 31 December 2021).

The most substantial components are the operational expenses incurred in-cash and in-kind for implementing the aeronautical research programmes funded by the JU. The operating expenses (administrative expenses) cover the running costs of the JU.

As a result of the specific accounting rules applied by CAJU, the funds received from the Commission and from the other members of the JU are shown as contributions received from Members in the net assets of the balance sheet and not as revenue in the economic outturn.

The non-exchange revenues represent adjustments for contributions from Members previously recognised in the net assets due to subsequent changes in already validated cost claims (e.g. through ex-post audits) and miscellaneous administrative revenues.

Balance Sheet

The balance sheet reflects the financial position of the CAJU at 31 December 2021. Assets are comprised mainly of the fixed assets, pre-financing incurred for the execution of the grant agreements and balances with the central treasury[38]; liabilities include the *Net Assets* on one side and current liabilities such as amounts payable, accruals and provisions on the other.

The available funds at the year-end increased compared to 2020 mainly due to the underexecution of the GAM 2020-2021 and the effects of the Covid-19 pandemic (2020: €76.97 million, 2021: €81.74 million).

The main fixed asset items are the IT and audiovisual equipment.

The balance of the net assets at the end of the reporting period presents the accumulated contribution received by the JU from its Members (the Commission, industry and research organisations), which has not yet been received for funding the research programme.

The net assets in the balance sheet of the JU's final accounts 2021 show a negative balance of € 147.46 million.

The two main elements are the outstanding and the non-validated Members' in-kind contribution. The declared in-kind contributions related to 2020 and 2021 have not been certified at the date of the preparation of the Final Accounts which are recognised as oprational expenditure in the EOA but not yet in the Net Assets. The in-kind contributions from operational activities are planned to be approved by the Governing Board in the second half of 2022.

The negative Net Assets do not indicate any risk of solvency, but are the consequence of the accounting method applied according to the specific accounting rules and guidance provided by the European Commission for the Joint Undertakings.

Main tables:

BALANCE SHEET			
ASSETS		31/12/2021	31/12/2020
A. NON CURRENT ASSETS	4.1.1		
Property, plant and equipment (net)		114,516.00	128,982.00
Intangible assets (net)		0.00	3,133.00
TOTAL NON-CURRENT ASSETS		**114,516.00**	**132,115.00**
B. CURRENT ASSETS			
Short-term pre-financing	4.1.2	**42,520,213.76**	**161,767,195.85**
Short-term pre-financing Clean Sky JU		42,520,213.76	161,767,195.85
Short-term receivables		**84,146,221.02**	**79,688,330.36**

[38] Since 2017 the treasury of CJU is integrated into the Commission's treasury system. Because of this, the JU does not have any bank accounts of its own. All payments and receipts are processed via the Commission's treasury system and registered on intercompany accounts which are presented under the heading 'exchange receivables'.

BALANCE SHEET			
Short term receivables - recoveries from members and partners		2,282,497.95	2,660,150.26
Deferred charges and accrued income		119,204.59	55,251.12
Central treasury liaison accounts		81,744,518.48	76,972,928.98
Cash and cash equivalents		0.00	0.00
TOTAL CURRENT ASSETS		**126,666,434.78**	**241,455,526.21**
TOTAL ASSETS		126,780,950.78	241,587,641.21

LIABILITIES		31/12/2021	31/12/2020
C. NET ASSETS			
Contributions received from Members (EU & industry)	4.2.1	2,377,576,696.81	2,289,001,136.24
Contributions in kind received from Members (Industry)		1,174,301,658.01	1,174,301,658.01
Contributions used during previous years		(3,378,400,187.50)	(2,984,870,261.18)
Contributions used during the year (EOA)		(320,939,899.73)	(393,529,926.32)
TOTAL NET ASSETS		**(147,461,732.41)**	**84,902,606.75**

D. CURRENT LIABILITIES			
Members contribution to be validated	4.2.2	**242,470,599.18**	**136,310,007.19**
Accounts payable and accrued charges		**31,772,084.01**	**20,375,027.27**
Amounts payable - consolidated entities		0.00	0.00
Amounts payable - beneficiaries and suppliers		5,667,983.18	12,186,443.85
Amounts payable - other		125,332.74	53,788.38
Accrued charges		25,978,768.09	8,134,795.04
Provision for risks and charges - short term		**0.00**	**0.00**
Provision for risks and charges - short term		0.00	0.00
TOTAL CURRENT LIABILITIES		**274,242,683.19**	**156,685,034.46**
TOTAL LIABILITIES		126,780,950.78	241,587,641.21

STATEMENT OF FINANCIAL PERFORMANCE			
	Ref.	2021	2020
REVENUES			
NON-EXCHANGE REVENUES	4.3.1		
Recovery of expenses		1,432,706.22	1,835,086.57
Exchange gains		274.15	2,855.53
TOTAL NON-EXCHANGE REVENUES		**1,432,980.37**	**1,837,942.10**
OPERATIONAL EXPENSES	4.3.2		
Operational expenses funded by CSJU in cash		208,717,085.49	264,371,536.43
Operational expenses contributed in kind by members		106,160,591.99	123,674,114.98
TOTAL OPERATIONAL EXPENSES		**314,877,677.48**	**388,045,651.41**
OPERATING EXPENSES	4.3.3		

STATEMENT OF FINANCIAL PERFORMANCE			
Staff expenses		4,700,157.41	4,569,157.76
Administrative expenses		2,795,715.54	2,750,817.23
Total administrative expenses		**7,495,872.95**	**7,319,974.99**
Other operating expenses			
Exchange losses		395.21	2,973.67
Total other operating expenses		**395.21**	**2,973.67**
TOTAL OPERATING EXPENSES		7,496,268.16	7,322,948.66
OPERATING RESULT		(320,940,965.27)	(393,530,657.97)
FINANCIAL INCOME	4.3.4		
Interest on late payment (income)		2,247.95	1,121.93
Total financial income		**2,247.95**	**1,121.93**
FINANCIAL EXPENSES			
Financial expenses		1,182.41	390.28
Total financial expenses		**1,182.41**	**390.28**
FINANCIAL RESULT		1,065.54	731.65
ECONOMIC RESULT OF THE YEAR		(320,939,899.73)	(393,529,926.32)

Changes in Net Assets and Liabilities	EURO	EURO
Net Assets		
Balance as of 31 December 2020		**84,902,606.75**
Contributions received from members during the year 2021:		
Private members	3,609,095.57	
European Commission	84,966,465.00	
Private members contributions in kind from 2008-2020 validated in 2021	0.00	
Total contributions in 2021		**88,575,560.57**
Economic Outturn for 2021		**(320,939,899.73)**
Balance as of 31st December 2021		(147,461,732.41)

CASH-FLOW - 31.12.2021	
	2021
Economic result of the year	(320,939,899.73)
Operating activities	
Amortisation and depreciation	63,974.90
Non-cash expenses in-kind	106,160,591.99
Cash contributions from Members (EC & Industry)	88,575,560.57
Increase/(decrease) in provisions for risks and liabilities	0.00
(Increase)/decrease in pre-financing	119,246,982.09
(Increase)/decrease in exchange receivables and non-exchange recoverables	(4,457,890.66)
Increase/(decrease) in payables and accruals	11,397,056.74

Other non-cash movements	0.00
Net Cash Flow from operating activities	**46,375.90**
Investing activities	
(Increase)/decrease in intangible assets and property, plant and equipment	(46,375.90)
Net Cash Flow from investing activities	**(46,375.90)**
Net increase/(decrease) in cash and cash equivalents	(0.00)
Cash and cash equivalents at the beginning of the period	0.00
Cash and cash equivalents at the end of the period	**(0.00)**

9. Materiality criteria

The assessment of the effectiveness of the CAJU control system for H2020 grants is based mainly, but not exclusively, on ex-post audits' results. The effectiveness is expressed in terms of detected and residual error rate, calculated on a representative sample.

This chapter provides a detailed explanation on how the Clean Aviation JU defines the materiality threshold as a basis for determining significant weaknesses that should be subject to a reservation to the annual declaration of assurance of the Executive Director.

Deficiencies leading to reservations should fall within the scope of the declaration of assurance, which confirms:
- A true and fair view provided in the AAR and including the Annual Accounts
- Sound financial management applied
- Legality and regularity of underlying transactions

Multiannual approach

As a result of its multiannual nature, the effectiveness of the CAJU's controls can only be fully measured and assessed at the final stages of the programme's lifetime once the ex-post audit strategy has been fully implemented and systematic errors have been detected and corrected.
The control objective is to ensure for the CS H2020 programme, that the residual error rate, which represents the level of errors that remain undetected and uncorrected, does not exceed 2% of the total expense recognised until the end of the programme (see explanations to the weighted average residual error rate underneath).

This objective is to be (re)assessed annually, in view of the results of indicators for the ex-ante controls and of the results of the implementation of the ex-post audit strategy, taking into account both the frequency and importance of the errors found, as well as a cost-benefit analysis of the effort needed to detect and correct them.

Notwithstanding the multiannual span of the control strategy, the Executive Director is required to sign a statement of assurance for each financial year. In order to determine whether to qualify this statement of assurance with a reservation, the effectiveness of the control systems in place needs to be assessed not only for the year of reference but also with a multiannual perspective, to determine whether it is possible to reasonably conclude that the control objectives will be met in the future as foreseen. In view of the crucial role of ex-post audits, this assessment needs to check, in particular, whether the scope and results of the ex-post audits carried out until the end of the reporting period are sufficient and adequate to meet the multiannual control strategy goals.

Effectiveness of controls

The basis to determine the effectiveness of the controls in place is the cumulative level of error expressed as a percentage of errors in favour of the CAJU, detected by ex-post audits measured with respect to the amounts accepted after ex-ante controls.

However, to take into account the impact of the ex-post audit controls (corrective measures of audits), this error level is to be adjusted by subtracting:

- Errors detected and corrected as a result of the implementation of audit conclusions in audited financial statements;
- Errors corrected as a result of the extension of systematic audit results to non-audited cost claims issued by audited beneficiary.

This results in a residual error rate, which is calculated in accordance with the following method:

1) REPRESENTATIVE ERROR RATE

As a starting point for the calculation of the residual error rate, the representative error rate will be established as a weighted average error rate identified for an audited representative sample.

The weighted average error rate (WAER) will be calculated according to the following formula:

$$\text{WAER\%} = \frac{\sum (er)}{A} = \text{RepER\%}$$

Where:

∑ (er) = sum of all individual errors of the sample (in value). Only the errors in favour of the JU will be taken into consideration.

n = sample size.

A = total amount of the audited sample expressed in €.[39]

2) RESIDUAL ERROR RATE

The formula for the residual error rate below shows how much error is left in the auditable population after implementing the outcome of ex-post controls. Indeed, the outcome of ex-post controls will allow for the

[39] In 2020 the Commission re-defined its methodology for calculating the Horizon 2020 error rate for all audits closed as from 01 January 2020. The main change in the methodology is that in cases of systemic errors, the denominator used in the error calculation is the sum of costs actually audited and not the sum of all accepted costs. The audits performed within the samples selected by CAJU are not affected by this methodological change.

correction of (1) all errors in audited amounts, and (2) systematic errors on the non-audited amounts of audited beneficiaries (i.e. extension of systematic audit findings).

$$ResER\% = \frac{(RepER\% * (P-A) - (RepERsys\% * E)}{P}$$

Where:

ResER% = residual error rate, expressed as a percentage.

RepER% = representative error rate, or error rate detected in the representative sample, in the form of the Weighted Average Error Rate, expressed as a percentage and calculated as described above (WAER%).

RepERsys% = systematic portion of the RepER% (the RepER% is composed of complementary portions reflecting the proportion of systematic and non-systematic errors detected) expressed as a percentage.

P = total amount of the auditable population of cost claims in €.
A = total amount of the audited sample expressed in €.
E = total non-audited amounts of all audited beneficiaries. This will consist of all non-audited cost statements for all audited beneficiaries (whether extrapolation has been launched or not).

This calculation will be performed on a point-in-time basis, i.e. all the figures will be provided as of a certain date for the specific annual audit exercise actually performed.

The control objective is to ensure that the residual error rate of the overall population (recognised operational expense) is below 2% at the end of each of the Clean Sky programme.

If the residual error rate is less than 2%, no reservation would be made.

If the residual error rate is between 2 and 5% an additional evaluation needs to be made of both quantitative and qualitative elements in order to make a judgment of the significance of these results. An assessment needs to be made with reference to the achievement of the overall control objective considering the mitigating measures in place.

An additional correction effect may be considered in the assessment of the legality and regularity of the transactions of Clean Aviation JU through implementation of audit results outside of the specific JU samples.
The Common Representative Audit Sample (CRAS) or risk-based samples of the CAS may cover additional CS cost claims, which are not part of the specific sample of the JU.
Furthermore, errors could be corrected through extension of systematic audit findings on unaudited JU cost claims, which do not stem from JU representative audits.

$$AddErCorr\% = \frac{\sum (AddErDet) + \sum (AddErSyst)}{P}$$

∑ (AddErDet) = error detected outside of the specific JU sample (samples of the CAS).

∑ (AddErSyst) = financial effect of extension of systematic audit findings on unaudited JU cost claims, which do not stem from JU representative audits.

In case the residual error rate is higher than 5%, a reservation needs to be made and an additional action plan should be drawn up.

These thresholds are consistent with those retained by the Commission and the Court of Auditors for their annual assessment of the effectiveness of the control systems operated by the Commission.

Adequacy of the scope

The quantity and adequacy of the (cumulative) audit effort carried out until the end of each year is to be measured by comparing the planned with the actual volume of audits completed.

The data is to be shown per year and cumulated, in line with the current AAR presentation of error rates.

The Executive Director should form a qualitative opinion to determine whether deviations from the plan are of such significance that they seriously endanger the achievement of the control objective for the programmes. In such case, he would be expected to qualify his annual statement of assurance with a reservation.

A multiannual control strategy requires a multiannual perspective to assurance

It is not sufficient to assess the effectiveness of controls only during the period of reference to decide whether the statement of assurance should be qualified with a reservation, because the control objective is set in the future. The analysis must also include an assessment of the likely performance of the controls in subsequent years and give adequate consideration to the risks identified and the preventive and remedial measures in place. This would then result in an assessment of the likelihood that the control objective will be met in the future.

10. Summary of recommendations issued by the IAS significantly delayed

Content and significance of recommendation	Audit title	Deadline for implementation (original target date)	Status
Recommendation No 1 *(very important):* The performance framework: objective setting and linking all stages of the programme	Performance management[40]	31/03/2019	The recommendation has been downgraded by the IAS to *important.* In May 2021 the JU has requested an extension of the delay for implementation until June 2022.

[40] IAS Audit Report IAS.A2-2017-W CLEANSKY-001 - Performance management of the Clean Sky 2 Joint Undertaking activities, audit report dated 20.11. 2017

11. List of Major Deliverables and Milestones achieved in 2021

LPA - Large Passenger Aircraft IADP

Demonstrators/Techno Streams (as shown in CS2DP)	Major Deliverables 2021
LPA-01-D2 Advanced Rear-end	Report on manufacturing selection of CFRP out of autoclave thermoplastic technology
LPA-01-D3 Scaled Flight Testing	Overall assessment of Scaled Flight Testing
LPA-01-D4 HLFC on tails large scale ground-based demonstrator	Report on HLFC on Tails TRL5 review
LPA-01-D6 Ground-based demonstrator HLFC wing	Report on HLFC on Wing wind tunnel test
LPA-01-D8 Radical Configuration Flight Test Demonstrator	Comparison of radical aircraft flight / wind tunnel test results to predictions
LPA-01-D9 Hybrid Electric Ground Test Bench	Battery Powered System Test Report
LPA-01-D10 UltraFan Flight Test Demonstration	Report on UHBR ice protection technology wind tunnel test
LPA-01-D11 Active flow control Flight Test Demonstration	Report on full scale testing of a new type of sensors for the AFC flight test instrumentation
LPA-01-D12 Flight test demonstration of active vibration control technologies/noise prediction methods for rear-mounted engines	Aircraft demonstration report on active technologies for vibration control/noise reduction
LPA-01-D13 UHBR SR Integration	Delivery of the SA²FIR fan stage
LPA-01-D15 Non Propulsive Energy	NPE demo debug status report
LPA-01-D16 Common Technology Bricks for Future Engines	LPS demonstrator rig test plan
LPA-01-XD Cross Demonstrator Capabilities WP1.1	Enhanced prediction of fan broadband noise with improved aerodynamic models in PropNoise
LPA-02-D1:Next Generation Fuselage, Cabin and Systems Integration	• Multifunctional Fuselage demonstrator shells manufactured and delivered • Thermoplastic components welding qualification tests completed, results available • CfPs Status evaluation about benefits and applications- Airbus • Report on evaluation of sensing solutions applied on structural test similar to what will be needed for future Platform 2 Demonstrators testing. • Validation Report on fatigue prediction tool ONERA Material characteristic data
LPA-02-D2: Next Generation Cabin & Cargo Functions	• Delivery of a fully integrated and validated new crown module incl. all enabler technologies Delivery of a process qualified Printed Electrics technology
LPA-03-D2 Regional Active Cockpit	Final Review Report of global operational validation
LPA-03-D3 Business jets Demonstrator	Report on the Demonstration tests on the physical RDPC for business jet

REG - Regional Aircraft IADP

Demonstrators / Techno Streams (as shown in CS2DP)	Major Deliverables 2021
REG WP1 - TP90 Pax Configuration	Conventional configuration definition - Loop 3.
REG D3 - Full scale innovative Fuselage & Pax Cabin demonstrator (Structural demonstration); REG D4 - Iron Bird	Description of IVHM framework validation outcomes
REG D4 - Iron Bird	Iron Bird GTRR report

FRC - Fast Rotorcraft IADP

Demonstrators/Techno Streams (as shown in CS2DP)	Major Deliverables 2021
D01 –Wind Tunnel Model	WT test article – WP1
ET1.5 - D05 – Wing-NPS Assembly	Wing structural test articles – WP1
ET1.2 - D02 - Tie Down TiltRotor (TDT) Demo	Ground and flight test matrix – WP1
ET1.8 - D08 - D08 - Flight Control & Actuation Systems & Comp	Electro-Avionics Test Rig Technical Spec – WP1
ET1.2 - D02 - Tie Down TiltRotor (TDT) Demo	TD harness manufacturing – WP1
ET2.1 - RACER Flight Demonstrator Integration	Assembly of the RACER Demonstrator.
ET2.1 - RACER Flight Demonstrator Integration	PtF and ground test status – summary note
ET2.3 - RACER Dynamic Assembly Demonstrator Integration	Main Gear box CDR – summary note
Eco Design Concept Implementation	Life-Cycle Assessment of FRC green technologies – WP3
Technology Evaluator Methodology	Data Pack for technologies contribution to CS2 objectives – WP4

AIR - Airframe ITD

Demonstrators / Techno Streams (as shown in CS2DP)	Major Deliverables 2021
Technology Stream A-1 Innovative Aircraft Architecture / AIR-D3-2 "Optimised integration of rear fuselage"	Synthesis Report of BLI exploration at configuration level
Technology Stream A-3: High Speed Airframe / Demonstrator AIR-D1-1 "Metallic cargo door"	Synthesis Report for TRL5 Gate Review
Technology Stream B-1: Next generation optimized wing / Demonstrator D2-15 "Composite Wing for SAT"	Small scale demonstrator, Wing assembly and bonding tooling, lower skin tooling, 7M wing integral preform
Technology Stream B-2: Optimized high lift configurations/ Demonstrator D2-16 "Loop Heat Pipe Anti Ice Nacelle"	• Turbo prop nacelle demonstrator Loop Heat Pipe project Ice Wind Tunnel Test results conclusions. • Preliminary detail design of the biphasic capillary heat transport system within the nacelle and the intake of an aircraft power-plant.
Technology Stream B-2: Optimized high lift configurations / Demonstrator D1-6 "Advanced	• Composite Outer External Wing Box Out of Autoclave detail design definition and Critical

Composite External Wing Box”	Design Review report. • Composite Outer Wing full scale test definition specification. • Thermoplastic skin panels and stringer run out subcomponent test completion. • Delivery of Ribs in hot stamping technology.
Technology Stream B-2: Optimized high lift configurations / Demonstrator D2-17 “High Lift Device for SAT”	Blown Flap for SAT Wind Tunnel Test results assessment report
Technology Stream B-3: Advanced Integrated Structures / Demonstrator D2-20 “Cocured Multirib full scale box for VTP”	Mid-scale fabrication and characterization of thermoset co-cured multirib for an integrated torque box
Technology Stream B-3: Advanced Integrated Structures / Demonstrator D2-21 “Cocured multispar box for HTP”	Mid-scale thermoset co-cured multispar for main torque box with integrated leading edge and trailing edge
Technology Stream B-3: Advanced Integrated Structures / Demonstrator D1-8 “All Electrical Wing: HVDC, SATCOM, Spoiler & Aileron driven by EMAs Ice Protection”	PDR Step 2 for HVDC, EMA’s for validation at Rig level achieved
Technology Stream B-3: Advanced Integrated Structures / Demonstrator D1-2 “Door for RACER Rotorcraft”	All Doors Hardware delivery for Fast RotorCraft RACER demonstrator.
Technology Stream B-3: Advanced Integrated Structures / Demonstrator D1-11 “Pre-assembled RACER airframe to FRC”	Acceptance Trimming System for Rotorless parts for Fast RotorCraft RACER demonstrator.
Technology Stream B-4: Advanced Integrated Structures/Demonstrator D1-12 “Rotorless Tail”	PtF documentation advanced draft released

ENG - Engines ITD

Demonstrators / Techno Streams	Major Deliverables 2021
WP2 – Ultra High Propulsive Efficiency (UHPE) Demonstrator for Short / Medium Range aircraft	Review outcome for Engine GTD design substantiation plan
WP5 – VHBR – Middle of Market Technology (Enabler)	Delivery of test reports for key enabling IP Turbine technologies supporting TRL 6 completed
WP6 – VHBR – Large Turbofan Demonstrator	UltraFan® Intermediate Compressor Case for Ground Test engine 2 completed

SYS - Systems ITD

Demonstrators / Techno Streams (as shown in Work Plan)	Major Deliverables
D25: Integrated Modular Communications demonstrations – WP1	Ground test platform delivery (Q4 2021)
D2: Equipment and systems for Cabin & Cargo applications – WP2	• Water waste system development report (Q3 2021) • Halon-free fire suppression systems development report
D3: Smart Integrated Wing – WP3	HPP Test Result Summary (Q4 2021)
D4: Innovative Electrical Wing – WP3	Test report for Safety of Flight of Aileron/Spoiler EMA (Q4 2021) and delivered to REG FTB#2

D5: Advanced Landing Gears Systems – WP4	TRL5 reports on Green Autonomous Taxiing System
D10: High Voltage DC Power Management Centre – WP5	Innovative distribution preliminary demonstrator test results
D18: Fly by Wire – WP7 [SAT]	Fly by Wire Iron Bird Lab Tests (Q2 2021)
D22: Comfortable and safe cabin for small aircraft – WP7 [SAT]	New Interior Materials Flight Test (Q1 2021)
T3: Modelling and Simulation Tools for System Integration on Aircraft – WP100.3	Results of hardware-in-the-loop versus full virtual tests (Q1 2021)

ECO - Eco-design transverse activity

Demonstrators / Techno Streams (as shown in CS2DP)	Major Deliverables 2021
ecoDesign Transversal Activity	• Two LCA/Eco Statement Report Outputs • Eco Hybrid Platform Version 0.1 • Progress report on Eco Design Transversal Activity • Design for Environment DfE2020+, initial version

SAT - Small Air Transport Transverse

Demonstrators / Techno Streams (as shown in CS2DP)	Major Deliverables 2021
SAT WP1 (SAT D1, SAT D2, SAT D3)	Dissemination, Communication and Exploitation Report.
SAT WP3 (SAT D1)	Feasibility study for the integration of All-electric technologies.

TE - Technology Evaluator

Demonstrators / Techno Streams (as shown in CS2DP) - NA	Major Deliverables 2021
Dissemination Material (Posters, Globe, Conference Presentations, i.e. EASN) - WP3	Delivered

__Major Milestones achieved in 2021__

LPA - Large Passenger Aircraft IADP

Demonstrators/Techno Streams (as shown in CS2DP)	Major Milestones 2021
LPA-01-D2 Advanced Rear-end	Specimen manufacturing for Advanced Rear-end test pyramid
LPA-01-D4 HLFC on tails large scale ground-based demonstrator	HLFC on Tails TRL5
LPA-01-D6 Ground-based demonstrator HLFC wing	HLFC on Wing critical design review with particular reference to S1Ma WTT
LPA-01-D9 Hybrid Electric Ground Test Bench	Battery Powered System Test completed

LPA-01-D11 Active flow control Flight Test Demonstration	Test of the new type of sensors for the AFC flight test instrumentation completed
LPA-01-D12 Flight test demonstration of active vibration control technologies/noise prediction methods for rear-mounted engines	Aircraft demonstration with active technologies for vibration control/noise reduction
LPA-01-D16 Common Technology Bricks for Future Engines	LPS demo - rig assembly and commissioning completed
LPA-01-XD Cross Demonstrator Capabilities WP1.1	Review of the Enhanced prediction of fan broadband noise with improved aerodynamic models in PropNoise
LPA-02-D1:Next Generation Fuselage, Cabin and Systems Integration	Lower skin manufactured and delivered Evaluations for LPA Platform 2 demonstrator contexts of a delamination detection solution for large surface monitoring, and an inspection system for damage detection at structural interface between complex composite structure and assembled metallic components Butt Strap Integration - Proof of Feasibility
LPA-02-D2: Next Generation Cabin & Cargo Functions	Validated Module Demonstrators & Full functional Crown Module in FIL Start of Production Trials Evaluation Single Materials Prototype inspection of redesigned and designed selected enabler
LPA-03-D2 Regional Active Cockpit	Technologies operational validation (TRL 5) for Pilot Workload Reduction Technologies
LPA-03-D2 Regional Active Cockpit	REACTOR Assessment of global operational validation
LPA-03-D3 Business jets Demonstrator	Demonstration tests on the physical RDPC for the Business jet

REG - Regional Aircraft IADP

Demonstrators / Techno Streams (as shown in CS2DP)	Major Milestones 2021
REG WP1 - TP90 Pax Configuration validation through WTT demonstrator	Provision of Conventional configuration definition - Loop 3.
REG WP2.1 - WTTs demonstrators for Innovative AirVehicle Technologies REG D1 - Adaptive Wing Integrated Demonstrator – Flying Test Bed#1 (FTB1)	Morphing devices wind tunnel tests (WTT2 and Droop Nose functionality) completion
REG D3 - Full scale innovative Fuselage & Pax Cabin demonstrator (Structural demonstration); REG D4 - Iron Bird	IVHM framework validation
REG D4 - Iron Bird	GTRR progress

FRC - Fast Rotorcraft IADP

Demonstrators/Techno Streams (as shown in CS2DP)	Major Milestones 2021
ET1.1 - D01 –Wind Tunnel Model	WTT's for TD 1st flight – WP1
ET1.2 - D02 - Tie Down TiltRotor (TDT) Demo	TD major components build start – WP1
ET1.5 - D05 – Wing-NPS Assembly	Start of Structural tests of the Wing – WP1
ET1.8 - D08 - D08 - Flight Control & Actuation Systems & Comp	Electro-Avionics Test Rig components build– WP1
ET1.2 - D02 - Tie Down TiltRotor (TDT) Demo	TD harness manufacture – WP1
ET1.2 - D02 - Tie Down TiltRotor (TDT) Demo	TD Final Assembly start – WP1
ET2.1 - RACER Flight Demonstrator Integration	Front, Central and Rear Fuselage Assembly – Summary–WP2
ET2.1 - RACER Flight Demonstrator Integration	Permit to fly documentation status - Engineering
ET2.3 - RACER Dynamic Assembly Demonstrator Integration	Main Gear box CDR closed
Eco Design Concept Implementation	FRC green technologies assessment– WP3
Technology Evaluator Methodology	Definition of tools and metrics for technologies contribution assessment – WP4

AIR - Airframe ITD

Demonstrators / Techno Streams (as shown in CS2DP)	Major Milestones 2021
Technology Stream A-3 High Speed Airframe / Demonstrator D2-3 "Flaperon"	TRL5 reached
Technology Stream A-3 High Speed Airframe / Demonstrator D1-1 "Cargo door"	TRL5 reached
Technology Stream B-1: Next generation optimized wing / Demonstrator D2-15 "Composite Wing for SAT"	Major tooling and preforms for full scale 7M wing demo
Technology Stream B-2: Optimized high lift configurations/ Demonstrator D2-16 "Loop Heat Pipe Anti Ice Nacelle"	• Tprop nacelle TRL 5 review of the Ice Protection System based on Loop Heat Pipe after WTT results. • PDR for System to cool down engine oil by including ice protection in a composite intake.
Technology Stream B-2: Optimized high lift configurations / Demonstrator D1-6 "Advanced Composite External Wing Box"	• OoA Composite Wing Box CDR closure. • Delivery of Hot Stamped Ribs.
Technology Stream B-2: Optimized high lift configurations / Demonstrator D2-17 "High Lift Device for SAT"	High Lift for SAT correlation of numerical models with Wind Tunnel Tests results data.
Technology Stream B-3: Advanced Integrated Structures / Demonstrator D3-23 "Jigless assembling for SAT structure"	"Verification of the second experimental assembly" was fulfilled together with the release of key-output report dedicated for evaluation of production of the second experimental assembly.
Technology Stream B-3 Advanced Integrated Structures/Demonstrator D1-12 "Rotorless Tail"	Rotorless Tail Delivery to RACER FAL.

ENG - Engines ITD

Demonstrators / Techno Streams	Major Milestones 2021
WP2 – Ultra High Propulsive Efficiency (UHPE) Demonstrator for Short / Medium Range aircraft	Review on design substantiation plan performed for GTD
WP5 – VHBR – Middle of Market Technology (Enabler)	Key underlying IP Turbine technologies for UltraFan® demo engine test #1 completed
WP6 – VHBR – Large Turbofan Demonstrator	UltraFan® Multi-Stage IP Turbine TRR for engine demo successfully completed

SYS - Systems ITD

Demonstrators / Techno Streams (as shown in CS2DP)	Major Milestones for 2021
D3: Smart Integrated Wing – WP3	TRL5 for HPP (Q4 2021)
D4: Innovative Electrical Wing – WP3	Flight Clearance for Aileron/Spoiler EMA (Q2 2021) and delivered to REG FTB#2
D10: High Voltage DC Power Management Centre – WP5	• Design Review to freeze the definition of integrated demonstrator for innovative distribution architecture at PROVEN (D10) • High Voltage DC components (Solid State Power Controller / Remote Control Circuit Breaker) CDR (Q3 2021)
D11: Next Generation EECS Demonstrator for Large A/C – WP6	Motorized Turbo Compressor TRL4 Review (Q4 2021)
D13: Next Generation Cooling systems Demonstrators – WP6	Centrifugal Compressor TRL4 Review (Q4 2021)
D16: Thermal Management demonstration Test rig – WP6	• TRL5 on Adaptive Environmental-Control-System (Q3 2021) achieved AVANT system infrastructure operational (Q4 2021) achieved
D22: Comfortable and safe cabin for small aircraft – WP7 [SAT]	New Interior Materials Flight Test (Q1 2021)

ECO - Eco-design transverse activity

Demonstrators / Techno Streams (as shown in CS2DP)	Major Milestones 2021
ecoDesign Transversal Activity	• SPDs demonstrations: quarterly progress meetings monitoring for delivery of Life Cycle Inventories SPDs to EcoTA • Flagship Demonstrator Masterplan Implementation • Workshops on Eco Hybrid Platform • GPP Indicator Communication Sessions • ecoDESIGN conference session at EASN

SAT - Small Air Transport Transverse

Demonstrators / Techno Streams (as shown in CS2DP)	Major Milestones 2021
SAT WP1 (SAT D1, SAT D2, SAT D3)	Annual Review Meeting – Activities performed on 2021 are positively assessed.
SAT WP3 (SAT D1)	Feasibility study for the integration of All-electric technologies – Feasibility studies and requirements definition for the integration of all electric technologies developed into the SYS ITD are performed.
SAT WP3 (SAT D3)	Demonstration of safe and more comfortable cabin on EV-55 platform (TRL 6).

TE - Technology Evaluator

Demonstrators / Techno Streams (as shown in CS2DP) - NA	Major Milestones 2021
Delivery and update of SPD models (WP3)	Delivered

12. List of abbreviations and project acronyms

Abbreviations

AAR	Annual activity report
A/C	Aircraft
ATM	Air Traffic Management
CA	Commitment Appropriations
CDR	Critical design review
CfP	Call for Proposals
CfT	Call for Tender
CS2DP	Clean Sky 2 Development Plan
EASA	European Aviation Safety Agency
EC	European Commission
GAM	Grant Agreement for Members
GAP	Grant Agreement for Partners
GB	Governing Board
IAO	Internal Audit Officer
IKOP	In Kind contributions from Operational Projects
ITD	Integrative Technology Demonstrator
IADP	Innovative Aircraft Demonstrator Platform
JU	Joint Undertaking
JTP	Joint Technical Programme
PA	Payment Appropriations
PDR	Preliminary design review
QPR	Quarterly Progress Report
SPD	System & Platform Demonstrator
SRG	States Representative Group
TA	Transversal Activity
TE	Technology Evaluator
ToP	Type of Action
TP	Technology Products
TRL	Technology readiness level
TTG	Time To Grant
WP	Work Package

Project Acronyms

ACD	Anti-Contamination Device
ACCV	Axial Centrifugal Compressor Vehicle
ADVANCE	Advanced Value and Service driven Architectures for Maintenance
aECS	adaptive Environmental Control System
AFC	Active Flutter Control
AFP	Automatic Fibre Placement
AFT	Afterward
AM	Additive Manufacturing
ATN/IPSIMA	Aeronautical Telecommunication Network/Internet Protocol Suite Integrated Modular Avionics
ATP	Acceptance Test Procedure
AWL	Advanced WingLet
BBCU	Broad band control unit
BJ	Business Jet BLI Boundary Layer Ingestion
BoM	Bill of Materials
BWB	Blended Wing Body
CAA	Computational Aero-Acoustics
CAE	Computer Aided Design

CDR	Critical design review
CFD	Computational Fluid Dynamics
CFRP	Carbon Fibre Reinforced Polymer
CG	Centre of Gravity
CMC	Composite Matrix Ceramic
CNT	Carbon Nano Tube
CROR	Contra-Rotating Open Rotor
CWB	Central Wing Box
DEP	Distributed Electrical Propulsion
DfE	Design for Environment
DGCU	Digital Generator Control Unit
DMC	Demonstrator Management Committees
DMU	Digital Mock-Up
EACU	Electromechanical Actuators Control Unit
ECS	Environmental Control System
ECU	Electronic Control Unit
EDAS	Eco-Design Analysis
eECS	electrical Environment Control System
EHA	Electro-Hydraulic Actuation
EHP	Eco Hybrid Platform
ELG	Electrical Landing Gear
EPDS	Electrical Power Distribution System
EGDS	Electrical Generation and Distribution System
EMA	Electro-Mechanical Actuation/Actuator
EMC	Electro-Magnetic Compatibility
EWIPS / eWIPS	Electrical Wing Ice Protection System
EoL	End-of-Life
EPGDS	Electrical Power Generation and Distribution System
FAL	Final Assembly Line
FbW	Fly by Wire
FCS	Flight Control System
FT	Flight Test
FTB1	Flying Test-Bed no. 1
FTB2	Flying Test-Bed no. 2
FWD	Forward
GBD	Ground Based Demonstrator
GCU	Generator Control Unit
GLA	Gust Load Alleviation
GTD	Ground Test Demonstrator
GTRR	Ground Test Readiness Review
HLFC	Hybrid Laminar Flow
HiL	Hardware in the loop
HMI	Human Machine Interface
HV	High Voltage
HVC	High Versatility Costs efficiency
HPE	High Performance and Energy Efficiency
HPP	Hydraulic Power Pack
HTP	Horizontal Tail Plane
HVDC	High Voltage Direct Current
ICS	Interface Control Drawings
IGV	Inlet Guide Vane
ILCD	International Reference Life Cycle Data System
IHMM	Integrated Health Monitoring Management
IPS	Ice Protection System
IVHM	Integrated Vehicle Health Management
IWT	Innovative Wing Tip
IWTT	Icing Wind Tunnel Test

LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LG	Landing Gear
LRI	Liquid Resin Infusion
MFFD	Multi-Functional Fuselage Demonstrator
MFFM	Multi-Functional Flap Mechanism
MRL	Manufacturing Readiness Level
MTE	MultiFunction Trailing Edge
NDI	Non Destructive Inspection
NGCTR-TD	Next Generation Civil Tilt Rotor related Technology Demonstrator
NLF	Natural Laminar Flow
OBIGGS	On Board Inert Gas Generator System
OoA	Out-of-Autoclave
OWB	Outer Wing Box
PAGB	Power & Accessory Gear Box
PDR	Preliminary design review
PED	Personal Electronic Device
PHM	Prognostics and Health Management
PtF	Permit to Fly
RACER	Rapid And Cost-Effective Rotorcraft
RTM	Resin Transfer Moulding
SAT	Small Air Transport
SHM	Structural Health Monitoring
SIW	Smart Integrated Wing
SoF	Safety of Flight
TAT	Turn Around Time
TD	Technology Demonstrator
TE	Trailing Edge Or Technology Evaluator
TP90	Turboprop 90 Pax
TRF	Turbine Rear Frame
TRL	Technology Readiness Level
TRR	Test Readiness Review
TSSD	Tailored Skin Single Duct
UHBR	Ultra-High Bypass Ratio
UHPE	Ultra-High Propulsive Efficiency
VEES	Vehicle Ecological Economic Synergy
VTP	Vertical Tail Plane
WIPS	Wing Icing Protection System
WMT	Winglet Morphing Tab
WP	Work Package
WRB	Wing Root Box
WT	Wind Tunnel
WTT	Wind Tunnel Test