



Clean Sky 2 Joint Undertaking

DEVELOPMENT PLAN

28 October 2021



PAGE INTENTIONALLY LEFT BLANK

Table of Contents

1.	SCOPE OF THIS DOCUMENT	4
2.	CLEAN SKY 2 RATIONALE	5
3.	THE EU AND GLOBAL POLICY CONTEXT – AVIATION AND ENVIRONMENT	8
4.	CLEAN SKY 2 PROGRAMME: OVERVIEW, STRUCTURE AND CONTRIBUTORS	10
5.	PROGRAMME KEY ENVIRONMENTAL OBJECTIVES	17
6.	CLEAN SKY 2 KEY TECHNOLOGY AND DEMONSTRATION AREAS	18
7.	OUTLINE OF THE CLEAN SKY 2 IADPS, ITDS AND TAS	19
7.1.	LARGE PASSENGER AIRCRAFT IADP [LPA]	20
7.2.	REGIONAL AIRCRAFT IADP [REG]	22
7.3.	FAST ROTORCRAFT IADP [FRC]	23
7.4.	AIRFRAME ITD [AIR]	25
7.5.	ENGINES ITD [ENG]	27
7.6.	SYSTEMS ITD [SYS]	28
7.7.	SMALL AIR TRANSPORT TRANSVERSE ACTIVITY [SAT]	29
7.8.	ECO-DESIGN TRANSVERSE ACTIVITY [ECO]	30
7.9.	TECHNOLOGY EVALUATOR [TE]	31
8.	MASTER PLAN	33
9.	OVERVIEW OF MAJOR RISKS	39
10.	FUNDING RESOURCES ESTIMATES	41
11.	CLEAN SKY 2 PROGRAMME IMPLEMENTATION TO DATE	46
12.	CS2 LINKS TO OTHER PROGRAMMES	48
	ANNEXES	51
A.	ABBREVIATIONS	51
B.	DETAILED OVERVIEW OF CLEAN SKY 2 TECHNOLOGY AND DEMONSTRATION AREAS	53

1. Scope of this document

This document defines the Clean Sky 2 Programme's [CS2] main objectives and key performance targets towards environmental impact and energy efficiency, industrial leadership and Europe's need for sustainable and competitive air transport. As such, it provides the direction of technological research and demonstration activities within Clean Sky 2 as set in the context of the European Union's overall aviation strategy¹, and in line with the relevant institutional policy documents and framework (such as Horizon 2020). As the policy goals target the evolution of the air transport system up to 2050, the same time window is considered of relevance for the priorities in, and impact of, the Clean Sky 2 Joint Undertaking's activities.

The primary purpose of this Development Plan is to lay out the high-level structure of the CS2 technical programme, the main activities and their schedule (including milestones), key risks and their mitigation, its forecast budget to completion and the way this will be managed.

It aggregates the detailed plan prepared in the different technical areas (e.g IADPs/ITDs/TAs) and it provides a high-level summary and a consolidated view across the Clean Sky 2 Programme.

In particular, it defines:

- The key technology streams and their maturity to be reached at the end of the Programme.
- The relevant demonstrators and the associated development and cost schedules.
- The benefits projected in terms of mobility, competitiveness and environmental impact.
- Technical interrelationships and interdependencies between Programme elements.

The Clean Sky 2 Development Plan (CS2DP) is linked to the following other documents:

- Council Regulation (EC) No 558/2014 of 6 May 2014, setting up the Clean Sky 2 JU;
- The Clean Sky 2 Joint Technical Proposal (JTP V5).

The CS2DP provides the strategic framework for following documents:

- Clean Sky 2 JU (Bi-annual) Work Plan;
- Annual Budget Plans (ABP);
- Grant Agreements for Members (GAM) for each IADP, ITD and TA;
- Grant Agreements for Partners (GAP).

¹https://ec.europa.eu/transport/modes/air/aviation-strategy_en

2. Clean Sky 2 Rationale

Clean Sky 2 is a Public-Private Partnership (PPP) between the European Commission and the EU aviation industry, aiming to reduce aviation's environmental impact by accelerating development and deployment of cleaner air transport technologies and in particular the integration, demonstration and validation of these technologies. The initiative builds upon the Clean Sky Programme (FP7) achievements and continues addressing integrated technology demonstrations at large system level, including new configurations and new vehicle demonstrations at the integrated vehicle level. In addition, Clean Sky 2 enlarges the scope of demonstration to a wider set of technologies and introduces further integrated demonstrations and simulations of several aircraft systems at the aircraft platform level.

The environmentally-friendly and resource-efficient technologies developed in the Clean Sky initiative will support the EU aeronautical industry, including the supply chain, to maintain and further develop its global leadership in this sector, which is important for our society.

The environmental impact of aviation

Aviation contributes to climate change predominantly through the release of carbon dioxide (CO₂) and nitrogen oxides (NO_x) through the burning of fuels. Aircraft noise is also an important environmental issue, in particular for the population close to airport areas and under the main arrival and departure tracks. Currently, the aviation sector is responsible for about 12% of transport emissions and 2% of all human-induced CO₂ emissions, with the risk of significantly higher percentages as air transport develops further and other sectors find easier routes to low-emission or emissions-free solutions such as electrification.

Despite all the improvements in reducing the environmental impact of aviation achieved over the last 40 years, the impact is still growing due to the growth of air traffic. According to the EUROCONTROL forecast, the number of flights in Europe in 2035 will be 1.5 times more than in 2012, with an average growth of 1.8% per year in the 'most-likely' scenario. This growth will be even stronger outside Europe, with the global expected traffic growth estimated to be 4.3% annually over the next 20 years. As depicted in Figure 1, targeted and timely action is crucial to achieve a greener air transport system.

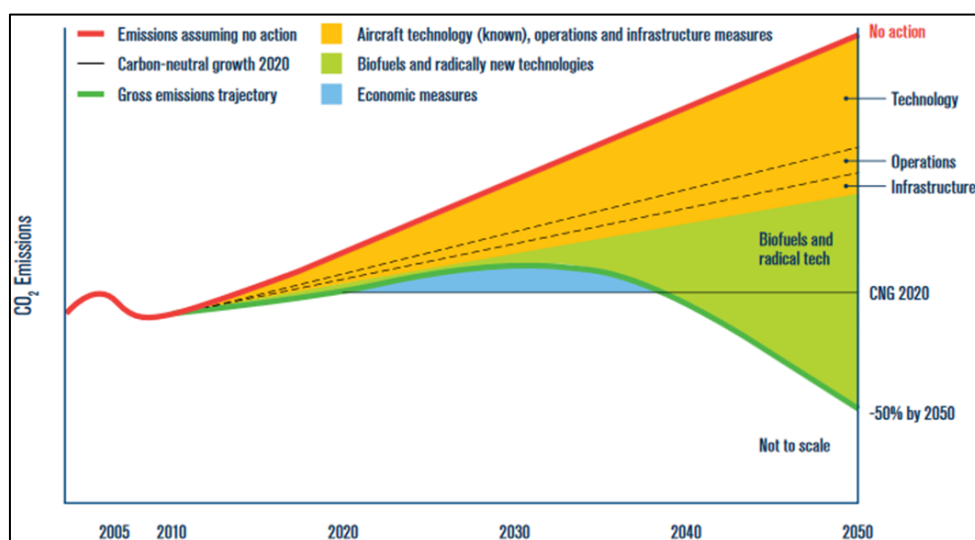


Figure 1: Schematic CO₂ emissions reduction roadmap [Source IATA]

The renewed ACARE Strategic Research and Innovation Agenda (SRIA)¹ was completed in 2012 and updated in 2017, with ambitious goals for a sustainable and competitive aviation sector through to 2050. These include a 75% reduction in CO₂ emissions, a 90% reduction in NO_x and 65% reduction in perceived noise by 2050 compared to year 2000 levels, and a 4 hour door-to-door journey for 90% of European travellers. These substantial emissions reductions and mobility goals require radically new aircraft technology inserted into new aircraft configurations.

The economic context of aviation

Aviation helps to meet societal needs by ensuring suitable and sustainable mobility of passengers and freight and significantly contributing to the European economy and to the competitiveness of Europe as a region. The sector has a strong social impact as it facilitates European integration and contributes to sustainable development by providing essential transport links. It also affects the efficiency of business operations by stimulating development, opening new markets, boosting international trade, encouraging investment and allowing effective communication between regions and companies. While a strong effort is being made to address transport inter-modality to increase its servicing capability, there is no alternative to aviation on long and intercontinental routing.

Worldwide, aviation transported nearly 3.6 billion passengers and nearly 51.2 million tonnes of cargo² through more than 100 000 flights daily³ in 2013. The current forecast, in line with the yearly air traffic growth of 4.3%, is for a doubling of these values within the next two decades.

In economic terms, in 2014 the EU aviation sector contributed €707 billion⁴ to the EU GDP: a total of 5.0%, including direct, indirect, induced, and tourism catalytic impact. €350 billion of this contribution or ca. 2.5% of the GDP is direct and indirect only impact from aviation. The sector is also a catalyst for growth and skilled employment. The number of jobs created directly by the industry is estimated to have reached 2.5 million in 2014, of which 395 000 are highly skilled and sustainable jobs. In total (direct, indirect and induced impact), aviation supported 6.9 million jobs in EU and represented around 26% of the jobs in the sector worldwide. For comparison, the automotive sector in EU represented approx. 12.6 million jobs⁵ directly and indirectly (2015).

Strengthening the competitiveness of the European aviation industry

In the current strategic context and in the face of increasing global competition, the future international competitiveness of the EU aviation sector will depend largely on the environmental and energy efficiency performance of its product portfolio. In particular, results on fuel efficiency (and/or carbon footprint) and noise reduction directly drive the expansion capability, or “license to grow”, of air transport. Capacity positively increases the impact on jobs at roughly twice the rate of GDP growth. Achieving reduced impacts on the environment, in particular of CO₂, NO_x and noise, contribute strongly to an improved societal impact of the sector.

To ensure the development and deployment of new and radical technologies, the relevant industrial players need to collaborate at an early stage, and a sizeable and stable multi-annual R&D budget is required to reduce the risks related to this research. For these reasons, public intervention at EU level through traditional collaborative research is not enough and a Joint Technology Initiative (JTI) with a Joint Undertaking is needed (large scale demonstration, validation, potentially faster market access, etc.). Collaboration within a JTI is an effective means to provide the necessary

¹ <http://www.acare4europe.org>

² Aviation: Benefits beyond borders – Air Transport Action Group, July 2016

³ <http://www.iata.org/pressroom/pr/Pages/2014-08-12-01.aspx>

⁴ Aviation: Benefits beyond borders – Air Transport Action Group, July 2016

⁵ <http://www.acea.be/statistics/tag/category/employment-trends>



framework for the European industry to develop and demonstrate new and efficient (breakthrough) technologies, and to address the different sources of market failures discouraging aeronautics research.

Setting up the Clean Sky 2 Programme

In July 2013, the European Commission launched an Innovation Investment package¹ that paved the way for the continuation of the Clean Sky JTI within the EU Horizon 2020 Framework Programme. In May 2014, the Council of the European Union agreed to extend the Clean Sky JTI within the EU Horizon 2020 Framework Programme, followed by the entry into force of the Clean Sky 2 Regulation in June 2014.

Clean Sky 2 follows the 10 priorities of the Juncker Commission, the Transport White Paper, and Flightpath 2050 and is fully in line with the Horizon 2020 objectives. It helps to overcome the so-called "market failure" by using public support to reduce the development risk of non-conventional technologies to a level that is considered to be financially viable by the aviation industry.

The spill-over effects of the aeronautical industry

Aeronautical technologies are a proven catalyst for innovation and spill over into many other sectors. The main reasons are the strict performance, environmental, weight, and safety requirements any aeronautical products must comply with, as well as the necessity of a "system" vision and the management of complexity. As a consequence, an aeronautical technology is often extended to another field allowing it to achieve a competitive advantage and stay on the technological leading edge. Aeronautics has been one of the first-users and promoters of many new technologies or processes such as carbon-fibre reinforced composites, Computer-Aided-Design, Computational-Fluid-Dynamics, automation, satellite-based navigation or turbine technology, which later spread over many other application fields.

¹ <http://ec.europa.eu/programmes/horizon2020/en/area/partnerships-industry-and-member-states>

3. The EU and Global Policy Context – Aviation and Environment

Governments and international bodies are increasingly raising awareness and advocating policy measures to mitigate climate change and the environmental impact of aviation. Reaching an effective political consensus at the EU and global level in qualitative and quantitative terms is a difficult process. However, the relevance of R&D including strong and long-term investments in environmental technologies is acknowledged by all parties. Notwithstanding the recent signs of retrograde action from the US government, increasingly global industrial sectors are themselves considering providing contributions to sustainable development, and aviation is no exception.

Aviation has delivered strong gains in fuel efficiency and noise emissions in the past decades, but overall growth in air transport dwarfs these improvements per Revenue Passenger Kilometres (RPK), and total emissions from the aviation industry will continue to rise over the next decades unless trend-breaking action is taken to introduce game-changing technologies. The past years have seen important actions taken and agreements reached that will have a bearing on the aviation sector's future perspective, among others:

- the signature of the COP21 Paris climate change agreement in 2015;
- the adoption of the European Commission's new Aviation Strategy in December 2015;
- the agreement on the ICAO CO₂ standard for new aircraft in February 2016;
- the adoption of the European Commission's European Strategy for low-emission mobility in July 2016;
- the ICAO agreement on global market-based measures for control of CO₂ emissions from international aviation in October 2016, often referred to as CORSIA;
- the ratification of the Paris agreement in November 2016;
- the European Commission's adoption of the Accelerating Clean Energy Innovation Communication as part of the Energy Union initiative in November 2016.

The European Union has shown leadership in the global context in terms of setting clear and effective policy objectives toward the mitigation of environmental and climate-related impacts. The European aviation community has developed its environmental industrial strategy in parallel with the developing policies of the Union, often preceding directives and their implementation, as the development cycles for new engines and aircraft span decades and involve a rigorous validation and certification process.

Aviation and its supporting aeronautics sector must accelerate the development and introduction of environmentally-friendly products and services. While the push for action is clear, this state of affairs confirms:

- the objectives and goals set out already by the European Commission and stakeholders through the Vision 2020 and Flightpath 2050 documents and through the Strategic Research and Innovation Agenda (SRIA) of the Advisory Council for Aeronautics Research in Europe (ACARE);
- the subsequent setting up of the first ever European Public-Private Partnership (PPP) in aeronautics - Clean Sky - in 2008 under FP7;
- the decision to continue this undertaking with an even higher commitment in 2014 under Horizon 2020.

These are steps in the right direction and are more important today than ever before.

This focusing of efforts on the political and strategic side has been matched by the achievements of the Clean Sky and Clean Sky 2 technical programmes to date. The independent internal Technology Evaluator assessment confirmed that the technologies developed since 2008 through Clean Sky match the initial objectives set and have high potential to reduce emissions significantly once on the market. Even if the economic and production viability of many of these technologies still needs assessing beyond the research perimeter, it has been crucial to demonstrate that 600



organisations across Europe are pooling knowledge and resources together in a partnership and have been able to successfully carry out a complex joint technology development programme. This progress is continuing. Its effectiveness is contributed to by the central role that Clean Sky 2 has developed in Europe with regard to coordination with national and regional efforts in aeronautics. Clean Sky 2 continued in 2019 to actively engage with Member States and European regions seeking and building synergies with their investments through the national/regional funds, in particular through the European Structural and Investment Fund. Please refer to chapter 12.1. Aviation is the result of the confluence of four main areas: aeronautics, airports, air traffic management and airlines, each with its own specificities in terms of economy, time scales and societal impacts. These sectors are strongly bound together as technology deployment, economic and societal fall-outs depend critically on their convergence. Furthermore, Clean Sky has continued to engage with other European organisations involved or linked with aeronautics research. While cooperation with SESAR and Fuel Cells and Hydrogen JUs was already established, the possibility of synergies with the ECSEL JU started in 2016. Even more importantly, a strong and effective cooperation was setup and a MoU signed with the European Aviation Safety Agency (EASA), which is responsible for the future certification of Clean Sky technologies. Clean Sky contributed to the first European Aviation Environmental Report released by EASA in January 2016. More details are given in chapters 12.2 and 12.3.

4. Clean Sky 2 Programme: Overview, Structure and Contributors

4.1. Clean Sky 2 overview

Clean Sky 2 builds on the work of Clean Sky. Close alignment between the two ensures a seamless transition and anchors the gains that can be reached in impacts and societal benefit. Based on the technology readiness level (TRL) demonstrated at the end of Clean Sky, several technologies will be ready for potential development and deployment. Others will need to be matured further within a research environment, and will require a higher level of system integration and further validation under Clean Sky 2. More importantly, given the extremely long development and product life-cycles in aeronautics, and the levels of investment and financial risk going well beyond the private sector's autonomous capability, the long-term stability in research agenda and funding through an instrument such as CS2 is essential in addressing long-term goals as set out in the renewed SRIA where it has been patently stated that evolutionary technology development and incremental performance improvements will no longer suffice. The PPP approach creates the best conditions to give the required confidence to market players to invest in breakthrough innovation. The inclusive approach coupled with the active pursuit of synergies will also allow the CS2 Programme to exploit synergies between its technologies and those matured outside with potential complementarity. Innovations from CS2 will drive major advances in the next generation of aircraft by mastering the technologies and the risks, in time to meet the market window to replace the current fleet.

High Level Objectives for Clean Sky 2

The Clean Sky 2 Programme builds on its predecessor, but will also drive towards more ambitious objectives and extend its reach [including longer-term and lower-TRL actions] in order to:

- Accelerate the progress towards the ACARE SRIA goals for 2020-2050;
- Enable a technological leap in the face of emerging competitors;
- Justify the early replacement of aircraft that have yet to enter service and accelerate the adoption of new technology into the global fleet.

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 CO₂ emissions by 20 to 30 % compared to 'state-of-the-art' aircraft entering into service as from 2014;
- (ii) reducing aircraft NO_x and noise emissions by 20 to 30 % compared to 'state-of-the-art' aircraft entering into service as from 2014.

Figure 1: High Level Objectives for Clean Sky 2 as set out in the Regulation [see also Figure 2]

The Programme aims to accelerate the introduction of new technology in the 2025-2035 timeframe. By 2050, 75% of the world's fleet now in service (or on order) will be replaced by aircraft that can deploy Clean Sky 2 technologies. Based on the same methodology as applied in the Clean Sky economic case in 2007 the market opportunity related to these programmes is estimated at ~€2000 billion. The direct economic benefit is estimated at ~€350-€400billion and the associated spill-over is of the order of €400billion. These figures are additive with respect to the Economic Value Added expected from Clean Sky. As a result of the higher growth now forecast, the environmental case for continuing Clean Sky with the CS2 Programme is even more compelling. CS2 technologies will bring a potential saving of 4 billion tonnes of CO₂ from roughly 2025 through to 2050 in addition to approximately 3 billion tonnes achievable as a consequence of Clean Sky.

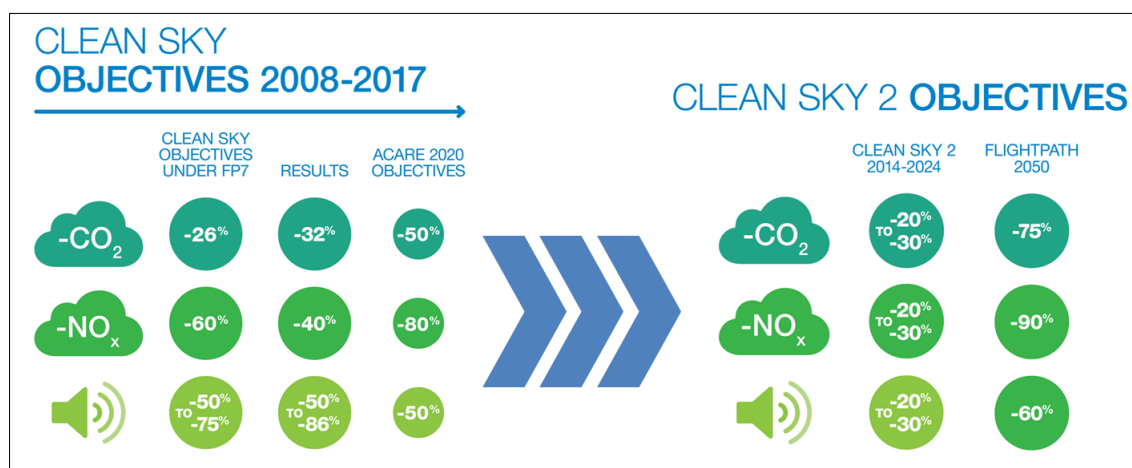


Figure 2: Transition from Clean Sky (FP7) to Clean Sky 2 (Horizon 2020)

The importance of the Clean Sky 2 JU Public-Private Partnership

Clean Sky 2 focuses and allows the coordination of aviation stakeholders' initiatives and investments at a European scale. It gives the necessary stability and stimulus to the aviation sector stakeholders to introduce game-changing innovations at a scale and in a timeframe otherwise unachievable. Clean Sky 2 reduces the high commercial risk that is associated with research activity in the aeronautics sector and which is beyond the capacity of private industry. As a Public-Private Partnership it attracts strong private investment on the pre-requisite that this is complemented with a comparable "seed" amount of public funding.

The Clean Sky and Clean Sky 2 set-ups are leading to greater industrial and international integration within the Union. It has started to correct the distortions that exist as a result of the provision of public support outside Europe whilst focusing the stimulus on socially desirable environmental improvements.

Their settings mirror the business model of the aeronautical sector production supply chain, which keeps the major integrators in charge of the development of the final product (e.g. an aircraft, an engine, a flight system). In the specific case, an EU innovation/know-how chain was set within the R&T perimeter and involved all actors capable of contributing at different levels to the successful assembly and testing of final demonstrators. The concentration under a single coordinated programme of the activities aiming to meet clear environmental objectives speeds up the pace of technology progress, and consequently the market introduction of new products, providing a competitive boost to the EU manufacturing industry.

The results of Clean Sky and Clean Sky 2 to date show clearly that the formula is successful, with realistic perspectives of competitiveness and growth of the industry across the Union leading to strong socio-economic benefits through the development of advanced technologies meeting the set environmental targets.

The technological advances made and demonstrated in Clean Sky under the FP7 Programme, complemented with progress to be made in the Clean Sky 2 Programme and under parallel and complementary research and technology development, in part resulting in the Clean Sky 2 JU Regulation's *Additional Activities* undertaken by the Members, only “crystallize” into tangible benefits in the aviation [air transport] system when absorbed in complete aircraft configurations and new aircraft designs and programmes. Clean Sky 2 aims to lay the groundwork for such new innovations to be prepared for the aviation system by systematically selecting successful technologies and integrating these into major system level and, ultimately, full aircraft level demonstration and de-risking efforts. This will render the next generation of air vehicles more efficient and reduce emissions and noise more than an evolutionary trajectory in terms of aircraft development would allow, and thus – importantly – accelerate the route to market for new solutions by de-risking and maturing the new approaches. New vehicle configurations incorporating advances that will help the sector fundamentally shift gears in terms of performance gains will have to be evaluated with flight demonstrators as they will be essential to fulfil the ambitious objectives of the renewed ACARE SRIA. Put simply, the goal of a large-scale Public-Private Partnership approach at the scale of Clean Sky 2 will be to pull forward adoption and ultimately market readiness of technologies that enable a doubling of the “evolutionary” rate of performance improvement, and set a trend-breaking development that will lead to aircraft “skipping a generation” in comparative terms to the business-as-usual development trend.

Evidence is mounting that conventional aircraft configurations are approaching intrinsic performance limits, as the integration of the most recent technologies are showing diminishing returns. Therefore, the need today is even greater for industry to develop materially different, substantially more environmentally-friendly vehicles to meet market needs, and ensure their efficient integration at the air transport system level.

4.2. Clean Sky 2 overall programme structure

The set-up of the Clean Sky 2 Programme is based on the notion of building on and extending the successful formula trialled in the Clean Sky Programme under FP7. As such, Clean Sky 2 continues to use the Integrated Technology Demonstrators (ITDs) mechanism. The ITD instrument's objective-driven agenda to support real market requirements providing the necessary flexibility is well-suited to the needs of the major integrator companies. The new Programme also focuses on reinforcing interactions between demonstrations of improved systems for a better integration into viable full vehicle architectures. The Clean Sky 2 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 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 incorporated in Clean Sky 2.

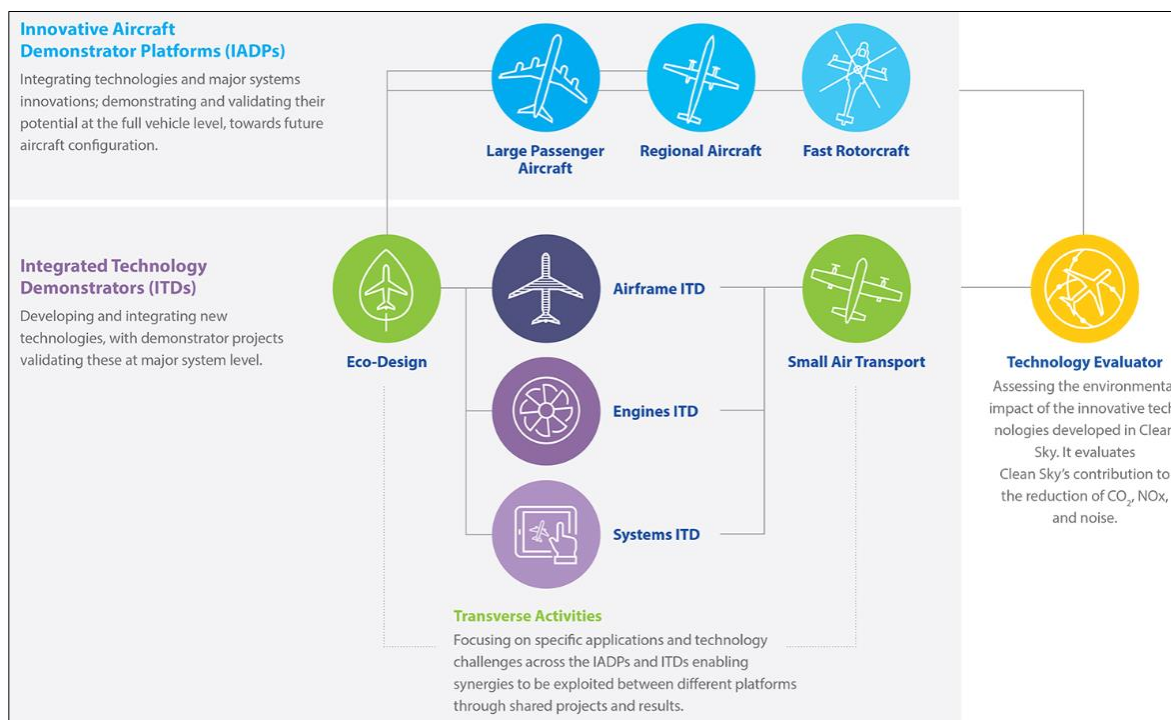


Figure 3: Clean Sky 2 Programme Logic and Set-up

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 and close to real operational conditions. To simulate and test the interaction and impact of the various systems in the different aircraft types, vehicle demonstration platforms are covering 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 of project Partners;
- An “integrated” approach to R&T 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 to 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 new configurations 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 the maturation of verified and validated technologies from their basic levels to the integration of entire

functional systems. They have the ability to cover quite a wide range of technology readiness levels. Each of the three ITDs orientates 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 the innovative flight vehicle configurations:

- **Airframe ITD [AIR]** comprising topics affecting the global vehicle-level design;
- **Engines ITD [ENG]** for all propulsion and power plant solutions;
- **Systems ITD [SYS]** comprising on-board systems, equipment and flight management.

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 common technical challenges. 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, mainly addressed to technology development, and driven by excellence toward the TA objectives, while simultaneously supporting the industrial, competitiveness and societal leadership of the Programme Participants in the actions of the SPDs, is reserved for these activities to be performed inside the concerned IADPs and ITDs. Transverse Leaders are nominated and coordinate each TA. Three Transverse Activities are agreed for Clean Sky 2 and are specified in the Statutes for the JTI:

- **Eco-Design TA [ECO]:** addressing materials, processes and resources impact considering the life cycle optimisation of technologies, components and vehicles - their design, manufacturing, operation, maintenance and disposal; and addressing the ever-increasing pressure to reduce harmful impacts on the Earth's resources and the impact related to scarce elements and resources;
- **Small Air Transport TA [SAT]:** airframe, engines and systems technologies for small aircraft, extracting synergies where feasible with the other segments;
- The **Technology Evaluator [TE]** will enable an independent Technology and Socio-Economic Impact Evaluation which is an essential task within the CS2JU. Environmental Impact Assessments currently focused on noise and emissions will be continued and expanded where relevant for the evaluation of the Programme's progress. Other impacts, such as on Mobility or on Industrial Leadership of Clean Sky 2 concepts, will be assessed. The TE may also perform evaluations on innovative *long-term* [low TRL] aircraft configurations where beneficial to the Programme's content.

4.3. Clean Sky 2 members and contributors

The Clean Sky 2 Joint Undertaking is built on a membership, complemented by activities performed by Partners. The membership of the Clean Sky 2 JU is comprised of:

- The European Commission representing the Union and ensuring EU public policy;
- Leaders and their Affiliates as defined in the Statutes and committed to achieving the full research and demonstrator activity of the Programme;
- Core Partners (and their Affiliates) as selected through the Calls for Core Partners and duly accepted by the Governing Board of the CS2JU upon successful selection and negotiation, who bring a further substantial long-term commitment towards the Programme.

The different roles and tasks are defined as follows:

As **Members**, *Leaders* and *Core Partners* are jointly responsible for the execution of the overall Programme, meeting the High-Level Objectives, and providing the in-kind contributions in order to meet the minimum level to be brought to the Programme by the Members as set in the Regulation.

Core Partners were selected through open and competitive calls planned over the first years of the Programme, guaranteeing a transparent selection of the best membership and strategic participation. As Members of the JU in the meaning of the Clean Sky 2 Regulation, Core Partners make long-term commitments and contribute to the implementation of the Programme over its lifetime: bringing key competences and technical contributions, and significant in-kind resources and investment.

Core Partners contribute to the global management of the technology streams and demonstrators and as such may also manage activities of Partners selected via Calls for Proposals.

Core Partners join the ITD/IADP Steering Committees in which they are active, contributing to its governance. Core Partners are also represented at Governing Board level via a process of co-opting and rotation at ITD/IADP level.

Leaders' and Core Partners' participation and contributions are governed ' by the Regulation and in addition through the Grant Agreements for Members [GAMs] managed by the JU which set out actions over the full period of the Programme, via extendable and renewable multi-annual GAMs that closely align with the CS2JU's Work Plans.

Partners participate in the Programme in specific projects with a well-defined and limited scope and commitment defined in topics launched in Calls for Proposals [CfP]. Partners are selected through these calls which are launched in a regular and phased approach over the Horizon 2020 funding period [2014–2020]. Partners' participation is 'governed' by the Regulation and in addition through dedicated Grant Agreements for Partners [GAPs]: complementary grants structured to complement the Members' contributions and activities and jointly managed by the JU and *Topic Managers* appointed by the Members. Partners' activities are monitored and managed by the JU in close collaboration with the Topic Manager in order to ensure the alignment of actions and the convergence of technical activity towards the Programme's goals.

The funding repartition of the CS2 Programme is set out in the Regulation and is as follows:

- Up to 40% of the Union's available funding of €1 716 million [net of administrative costs] is ring-fenced for its 16 leaders and their Affiliates;
- Up to 30% of the Union's funding is available for Core Partners; and
- At least 30% will be awarded via competitive Calls for Proposals and Calls for Tenders.

The 60% to be awarded via the Calls for Core Partners and Calls for Proposals represents over €1 billion, making it alone over 25% greater than the total budget of the first Clean Sky Programme and just over five times the call funding volume of Clean Sky. With this substantial amount of funding open to competition, Clean Sky 2 will foster wide participation where SMEs, research organisations and academia interact directly with key industry stakeholders. The different call mechanisms and the related breadth of the call topics and technical scope of the CS2 programme will provide opportunity for the vast bulk of the aeronautics industry in the European Research Area to participate, and also allow for space for newcomers, including important opportunities for "cross-over" participants from outside the sector. Getting capable new firms involved in the aeronautics sector can make an important contribution to the competitiveness of the sector and to the European economy.



Taking into account that there are roughly 600 participants in the original Clean Sky Programme, we expect 800-1000 for Clean Sky 2. That is ample evidence of a dynamic and open system operating in the JU and with all stakeholders.



5. Programme Key Environmental Objectives

The translation of the Programme's high-level environmental objectives into targeted vehicle performance levels is shown below. These are in line with the approach to be taken in the CS2 TE impact and technology evaluation cycles. Each conceptual aircraft summarises the key enabling technologies, including engines, developed in Clean Sky 2, contributing to the achievement of the Programme objectives. The target TRL for key technologies at closure of the Programme indicates the level of maturity and the level of challenge in maturing towards potential uptake into marketable innovations:

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	N/A	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.

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

²Key enabling technologies at major system level

³There 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

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



6. Clean Sky 2 Key Technology and Demonstration Areas

The CS2 technology and demonstration activity is structured in nine key (technology) themes further subdivided in a number of demonstration areas, as depicted below. Inside each area, the aim is to integrate, demonstrate and validate the most promising technologies capable of contributing to the CS2 high-level and programme specific objectives. A demonstration area may contribute to one or more objectives and also may involve more than one ITD/IADP. The funding values in the table are all indicative.

Theme	Demonstration area	Demonstrator / Technology stream in Programme Area							Contribution*			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

Notes:

(1) Enabling Technologies are aligned with the major thematic research and technology development areas as shown but are considered as standalone; they are contributing to enhance the environmental performance of future A/C without resulting into a demonstrator as part of an ITD/IADP.

(2) The total funding of these different demonstration areas is of 1628 M€. The difference with the CS2 funding Programme of 1716 M€ relates to the effort required to manage the different activities, to run the Technology Evaluator and the coordination activities of Transverse Areas (Eco & SAT) and all contributing activities that are implemented through Thematic topics.

It is worth noting that the evolution of the funding across the different Themes is marginal since the last revision of the plan in 2020. Evolutions are mainly due to financial adjustments e.g. increased or reduced effort at demonstrator level that have been performed by some parties, with almost no impact on the funding allocated per Demonstration Themes. Further details on these evolutions is given in the part 8 of the document.

DEMONSTRATION THEME	EC FUNDING (M€)	EVOLUTION COMPARED TO 2020 (M€)	EVOLUTION COMPARED TO 2020 (%)
Advances in Wings, Aerodynamics and Flight Dynamics	190.6	2.5	1.3%
Aircraft Non-Propulsive Energy and Control Systems	184.8	-1.7	-0.9%
Breakthroughs in Propulsion Efficiency (incl. Propulsion-Airframe Integration)	478.5	0.6	0.1%
Enabling Technologies	51.7	-1.4	-2.6%
Innovative Structural / Functional Design - and Production System	217.5	-2.1	-1.0%
Next Generation Cockpit Systems and Aircraft Operations	146.2	-1.3	-0.9%
Novel Aircraft Configurations and Capabilities	265.9	-2.6	-1.0%
Optimal Cabin and Passenger Environment	54.0	0.3	0.5%
Eco-Design	39.3	-0.2	-0.4%

7. Outline of the Clean Sky 2 IADPs, ITDs and TAs

7.1. Large Passenger Aircraft IADP [LPA]



The large commercial aircraft market (generally seen as civil aircraft with a capacity exceeding 100 seats and covering short/medium and long range mission) remains highly competitive, with several new entrants having the means to reach a technology level comparable to legacy US and European manufacturers. Their ambition is often coupled with strong government support, expectations for a captive “home” market and low costs and pricing. To stay ahead, the LPA programme objectives are to further mature technologies tackled in Clean Sky, e.g. the integration of innovative propulsion systems; to validate other key enabling technologies like hybrid laminar flow control strategies for the wing, horizontal and vertical tail plane as well as an all-new next generation fuselage/cabin and cockpit-navigation.

The Large Passenger Aircraft goal is development and demonstration of the best technologies to accomplish the key goals of the Clean Sky 2 Regulation with respect to energy efficiency and impact on the environment, thereby fulfilling future market needs and improving the competitiveness of future products. The set-up allows to push the value of technologies tackled in Clean Sky, and to add the validation of additional key technologies at integrated level with large scale demonstrators in operational conditions.

Three distinct ‘Platforms’ will be managed in parallel and develop the abovementioned technologies and demonstrators:

- **Platform 1 “Advanced Engine and Aircraft Configurations”**

One major part of the scope of the Platform 1 “Advanced Engine and Aircraft Configurations” is to provide the development environment for the integration of the most fuel-efficient propulsion concepts into compatible airframe configurations and concepts targeting next generation short and medium range aircraft. The considered propulsion concepts range from the novel open rotor engine architecture to advanced Ultra-High Bypass Ratio (UHBR) turbofan to hybrid [and/or distributed] propulsion concepts, exploring the potential configurations that exploit the potential of Boundary Layer Ingestion (BLI). In parallel with these new engine and system architectures, studies for Non-Propulsive Energy (NPE) generation will be performed.

Another major part of the scope of Platform 1 is the development of integrated flow control techniques for advanced aircraft performance for the whole operational envelope. The major technologies with respect to this are the Hybrid Laminar Flow Control technology (HLFC) for skin-friction drag reduction and fluidic actuators for high-lift performance improvement. Finally the opportunities and the limits of scaled flight-testing will be investigated. This includes the “Radical Configuration Scaled Flight Test Demonstrator” that will demonstrate a radical configuration for an Advanced Small/Medium Range (SMR) airliner for the 2035 timeframe. The radical configuration should surpass the CleanSky2 environment objective of a 20% reduction in Block Fuel through the application of a radical configuration. The configuration was selected from a design space exploration and features Distributed Propulsion.

The overall set-up of Platform 1 aims to ensure that all technologies being developed and demonstrated are following consistent target aircraft configurations and concepts, which means that the compatibility between airframe and propulsion technologies is assured.

The validation will be performed through the most appropriate means (e.g. flight test, ground test, wind tunnel test or simulation) depending on the maturity level and TRL targeted after integration of a given technology at A/C level.

- **Platform 2 “Innovative Physical Integration Cabin – System – Structure”** aims to develop, mature, and demonstrate an entirely new, advanced fuselage structural concept in alignment towards next-generation cabin-cargo architectures, including relevant aircraft systems. To account for the substantially different test requirements, the large scale demonstration will be based on two individual major demonstrators. A Multi Functional Fuselage Demonstrator will be developed, manufactured and tested with focus on innovative thermoplastic materials and industrial manufacturing including novel joining technologies and robotic assembly. This demonstrator will integrate Cabin/Cargo and System modules/components to validate Multi ATA¹ technologies and their industrial processes. A Cabin and Cargo demonstrator will be dedicated to integrating and testing a next generation of large passenger aircraft cabin and cargo. A number of smaller test rigs and component demonstrators are part of the programme. The target is to accomplish technology readiness level up to 6, for a certain number of technologies. The demonstrators are supported by a work-package on cross-functional activities dealing with development of multifunctional technologies for elementary, automated structural testing and prediction tools for structural components under applied loads.
- **Platform 3 “Next Generation Aircraft Systems, Cockpit and Avionics”** has a clear focus to develop and demonstrate a next generation cockpit and navigation suite, addressing large aircraft, regional aircraft and business jets. Based on the results of a number of projects which are currently ongoing, Platform 3 should allow functions and enabling technologies which are emerging from individual developments, aimed to aircraft safety enhancement and robust operations, to be integrated and validated into enhanced cockpits and new disruptive cockpit concepts in several demonstrators.

The Regional Aircraft and Business Jet aircraft enhanced cockpit demonstrators will integrate functions targeting flight crew workload reduction, mainly through advanced pilot’s interfaces such as innovative pilot’s displays and multimodal devices, Pilot monitoring system, as well as enhanced navigation means and support to aircraft status management, enabled by appropriate optimized avionics technology.

The Large Aircraft disruptive cockpit operations concept demonstrator will implement a “Human Centric” approach to operate the aircraft and integrate innovative functions and Human-Machine interface technologies to reduce crew workload, improve situational awareness and support increased navigation functions availability, robustness and autonomy, in line with relevant SESAR enabling functions and technologies.

Corresponding functions to be integrated in the demonstrators will be developed in LPA Platform 3 with leaders and Core Partners and as well in ITD Systems and in other national R&T framework. With the core of Platform 3 demonstrators being ground-based demonstrators, selected functions and technologies will be brought to flight test demonstration when justified, either on Large Aircraft or on business jet.

In addition the development of value-driven end-to-end maintenance service architectures and applications suite has been defined and demonstrated, enabling the replacement of scheduled maintenance by efficient value driven on-condition maintenance. With strong contributions from CfP-projects, main parts of this project were completed successfully as planned in 2020, with the project closure to be completed in 2021.

¹Air Transport Association (ATA)

7.2. Regional Aircraft IADP [REG]

Regional aircraft provides essential building blocks towards an air transport system that respects the environment, ensures safe and seamless mobility, and builds industrial leadership in Europe. The Regional Aircraft IADP will bring technologies to a further level of integration and maturity than achieved in CS1 GRA. The goal is to integrate and validate, at aircraft level, advanced technologies for regional aircraft so as to meet the CS2 Regulation's objectives and simultaneously drastically de-risk their integration on future products.



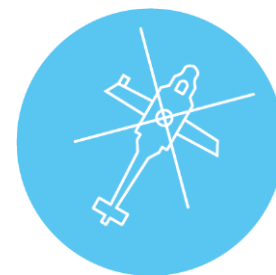
Full-scale demonstrations, with acceptable risk and complexity but still providing the requested integration, are essential to enable the insertion of breakthrough technologies on regional aircraft entering into service beyond 2025. The Technology Development is arranged along “Waves” and developed through roadmaps defined to satisfy the high-level requirements of the future Highly-Efficient Next Generation Regional Aircraft, the configuration of which are developed at conceptual level in a dedicated work package. Such work package includes also preliminary conceptual studies and experimental activities aimed to explore hybrid-electrical regional aircraft configurations.

To increase synergies and cross-fertilisation across the different ITDs and IADPs, some of the above technological roadmaps will be shared with the “streams” of the Airframe ITD and with the developments of sub-systems and systems planned inside the Systems and Engines ITDs. The Demonstration Programme will be divided into technologically compatible and “scope close” demonstrations, including two flying test-beds [FTBs] and several ground demonstrators, some of which will be managed in and performed through the Airframe ITD:

- **Flying Test Bed 1 - Innovative Wing and Flight Controls (Regional IADP):** Integration and flight testing of technologies suitable for regional aircraft applications for a new generation wing and advanced flight control systems. Innovative wing related systems aerodynamic enhancements and LC&A features will be demonstrated complementing FTB2, such as: high A/R by means of adaptive/innovative winglets.
- **Flying Test Bed 2 - Flight Demonstration of a high efficient and low noise Wing with Integrated Structural and related Systems solution (Regional IADP):** A new wing will be designed, manufactured and equipped with new structural solutions strongly integrated with advanced new control surfaces, flaps and composite winglets. Control of the innovative system will be done through the affordable flight control system of actuators (hydraulically and electro-mechanical EMAs). The Flight Test Bed 2 is complemented with on ground rigs in Airframe ITD of structural and system technologies like composite materials (ISC thermoplastics and LRI), HVDC (High Voltage and Direct Current electrical system) and Electromechanical (EMAs) actuation.
- **Outer Wing Box** On-ground demonstrator dedicated to validation of design and of innovative low cost and low weight structural technologies integration at full scale/full size through structural static and fatigue tests.
- **Full-scale innovative fuselage and passenger cabin (Regional IADP):** Integration and on-ground testing of a full-scale innovative fuselage and passenger cabin including all the on-board systems and advanced solutions for increasing passenger comfort and safety. The fuselage will be a full-scale demonstration of technologies for composite material, structures and manufacturing aimed at weight and cost reduction and to minimise the environmental impact through eco-design and energy consumption optimisation all along the life-cycle (towards a zero-impact).
- **Iron Bird (Regional IADP):** Virtual and Physical “Iron Birds” will also be an important part of the Regional A/C Ground Demonstration Programme. These will also be used to integrate, optimise and validate the systems modification of the Flying Test Bed and the results of their simulations and ground testing will be essential to achieve the permit-to-fly.
- **Ground Demonstration of the wing (Airframe ITD),** including the airframe and related systems.
- **Ground Demonstration of the Cockpit (Airframe ITD),** including the structure and related system.

7.3. Fast Rotorcraft IADP [FRC]

The Fast Rotorcraft IADP consists of two concurrent demonstrators - the Tiltrotor demonstrator and the Compound Rotorcraft demonstrator - along with transversal activities relevant for both fast rotorcraft concepts.



- **Joint activities:**

These activities cover the methodology for technology evaluation of fast rotorcraft demonstrations and the Eco-Design concept implementation, along with the programme management activities for the Fast Rotorcraft IADP. Concerning the methodology for technology evaluation, the activities will allow for the defining of SMART objectives and criteria adapted to the fast rotorcraft missions in line with the general TE approach for Clean Sky 2.

Concerning Eco-Design concept implementation, the activities will allow coordinating approaches and work plans in the two demonstration projects regarding the greening of rotorcraft production processes and ensuring complementarity of case studies. The general Life Cycle Assessment approach will be coordinated with the participants of the Eco-Design TA.

- **The Next-Generation Civil Tiltrotor demonstrator (NGCTR):**

The aim of NGCTR is to design, install and demonstrate in flight innovative Civil Tiltrotor technologies enabling future prototype development, and show significant improvement with respect to the current state of the art Tiltrotors. The project will also allow the development of R&T activities which will increase the know-how needed for future Tiltrotor aircraft and their operation through a volume of research and innovation activities not available today within the EU, and equivalent to that of conventional helicopter platforms.

The primary objectives are to demonstrate the potential to reduce the CO₂ and noise footprint, reduce the cost of ownership, and achieve high speed, high efficiency, and high productivity. The technology demonstrator will utilise an existing platform into which innovative technologies will be incorporated, which are scalable to different sizes of aircraft in the future as market requirements demand. The primary focus will be on:

- Advanced wing architecture;
- Tail structure and configuration;
- Non-tilting engine installation with efficient nacelle architecture and split gearbox drivetrain;
- Advanced Flight Control with a modular, distributed and scalable flight control system.

This approach allows the project to capitalise on existing assets for those elements necessary for flight but not intrinsic to the technologies being matured and demonstrated. However, in addition to these key technologies to be flown on the demonstrator, advancement of other technologies that will support a highly efficient state of the art product in the future will be developed in parallel and subject to ground-based demonstration. If the opportunity arises, they may be incorporated into the technology demonstrator later in the validation programme.

NGCTR will further develop technologies initiated in Clean Sky and launch new activities specific to Clean Sky 2 and the NGCTR project. In the area of CO₂ emissions reduction, NGCTR will continue/develop engine installation and flight trajectories optimisation (this is now done by analytical models and with scaled model tests, whereas Clean Sky 2 will validate it at full scale), while specific new Clean Sky 2 activities on drag reduction will be necessary due to modified fuselage-wing architecture. This specific Clean Sky 2 topic will also be related to operating cost reduction, in order to address competitiveness of the architecture and solutions adopted. A new prop-rotor blade (developed outside of Clean Sky 2) will support reduced noise emissions. In Clean Sky noise reduction was mainly addressed through trajectory optimisation. This will continue in Clean Sky 2 and will be linked to SESAR concepts where necessary. Clean Sky 2 transversal subjects will cover new material (e.g. thermoplastics, surface treatments, less hydraulics and more electrical systems), validating them at full scale and in real operational conditions where possible.

In close collaboration with the Technology Evaluator, key parameters will be defined to show Clean Sky 2's achieved progress according to a specific Tiltrotor roadmap. Today, certified Tiltrotors are not available in the civil sector although this should be the case during the lifetime of Clean Sky 2 (while only one product is available in the military); hence, a database from which baseline information can be extracted for the current state of the art is not available. Therefore, 'key performance parameters' (KPI) will be introduced to show NGCTR's progress with respect to reference data taken as baseline (mainly referring to technologies which have been tested or conceptually designed in the period 2005-2012). Objectives will be defined considering Tiltrotor specificities and in line with the main pillars of Clean Sky 2, as well as Horizon 2020, towards a Smart, Green and Integrated Transport and addressing environmental compatibility (Greening Objectives), competitiveness (Industrial Leadership) and mobility. Considerable attention will be paid to the project's impact on the EU's economy and job creation, to confirm and further sustain a steady growth of the sector with regard to revenues, workforce productivity, high rate of new employment (in particular of higher educated personnel) and R&D expenditure.

- **The Compound Rotorcraft demonstrator (RACER):**

With the unveiling at Paris Air Show 2017, the Compound Rotorcraft demonstrator has been renamed as the RACER demonstrator. The RACER high speed research helicopter aims to demonstrate in flight that the compound rotorcraft configuration, implementing and combining cutting-edge technologies from the current Clean Sky 2 Programme, can open up new mobility roles that neither conventional helicopters nor fixed wing aircraft can currently cover in a way sustainable for both the operators and the industry. The project will ultimately demonstrate the capability to combine the following capabilities: payload capacity, high manoeuvrability, agility in vertical flight including capability to land on unprepared surfaces near obstacles and to load/unload rescue personnel and victims while hovering; long range, high cruise speed, low fuel consumption and emissions, low community noise impact, and high productivity for operators.

A large scale flight-worthy demonstrator embodying the new European compound rotorcraft architecture will be designed, integrated and flight tested. With a first flight planned for the end of 2022, this demonstrator will allow Technology Readiness Level 6 to be reached at whole aircraft level in a basic configuration in 2023. The project is based on:

- identified mobility requirements and environmental protection objectives;
- lessons learnt from earlier experimentation with the low scale exploratory aircraft X₃;
- a new compound helicopter formula, based on box wings, with pusher propellers at their tips;
- technology progress achieved for rotorcraft subsystems on one side through participation in Clean Sky projects and other research activities at EU, national or local level.

The individual technologies from the first Clean Sky Programme (Green Rotorcraft ITD, Smart Green Operations ITD, Eco-Design ITD) that will be further matured and integrated in this RACER demonstration concern:

- A new compound helicopter formula, based on box wings with pusher propellers at their tips;
- New rotor blade concepts aiming to improve high speed efficiency and minimise noise.
- Airframe drag reduction through shape modifications and aerodynamic interactions reduction;
- Innovative electrical systems e.g. brushless generators, high voltage network, efficient energy storage and conversion, electrical actuation;
- Eco-Design approach, to study how to substitute harmful materials and favour green production techniques;
- *Fly-neighbourly* demonstration of new flight guidance functions and approach.

The RACER project essentially consists of the following main activities and deliveries:

- Airframe structure and landing system: Advanced composite or hybrid metallic/composite construction, featuring low weight and aerodynamic efficiency. This airframe structure is a key enabler of the new box-wing/pusher propellers configuration;

- Lifting rotor and propellers: Low drag hub, pylon and nacelles, flight test of 3D-optimised blade design;
- Drive train and power plant: New drive-train architecture and engine installation optimised for the RACER configuration. In particular, new Main Gear Box, Propeller Gear Boxes, and supercritical shafts will be developed and flight-tested. Through National Additional Activity projects, In-Flight demonstration of the “Eco-Mode”, i.e. flying in cruise on one engine only, with the second engine in idle mode, is planned;
- **On board energy, cabin and mission systems:** Implementation of the more electrical rotorcraft concept to minimise power off-takes from the engines and drive system. Key electrical systems will be key enablers of the Eco-Mode demonstration;
- **Flight control, guidance and navigation:** Smart flight control exploiting additional control degrees of freedom inherent to RACER configuration for best fuel economy and quieter flight;
- **RACER Demonstrator overall design, integration and testing:** All coordination and cross-cutting activities relevant to the whole vehicle delivering a full range of ground & flight test results and final conclusion.

7.4. Airframe ITD [AIR]

Aircraft level objectives on energy and environmental efficiency, industrial leadership and enhanced mobility, and the fulfilment of future market requirements and contribution to growth cannot be met without strong progress on the airframe. Strong progress towards the 2020 targets has been made through Clean Sky (estimated at 75% of the relevant part of the initial ACARE goals for 2020). However, further progress is required on the most complex and challenging requirement on new vehicle integration to achieve the high-level goals set in the CS2 Regulation, to fully meet the 2020 objective, and to progress towards the ACARE SRIA’s 2050 goals. This progress will be enabled through the foreseen execution of 9 major Technology Streams:



- **Innovative Aircraft Architecture**, to investigate radical transformations of the aircraft architecture. The aim of this Technology Stream is to demonstrate the viability of some most-promising advanced aircraft concepts (identifying the key potential showstoppers & exploring relevant solutions, elaborating candidate concepts) and assessing their potential.
- **Advanced Laminar Flow** as a key technological path to further progress on drag reduction, to be applied to major drag contributors (nacelle and wings); this Technology Stream aims to increase nacelle and wing efficiencies by the mean of Extended Laminar Flow technologies. Fuselage related laminar flow is also targeted.
- **High Speed Airframe**, to focus on step changes in the fuselage and wing, enabling better aircraft performance, with reduced fuel consumption and no compromise on overall aircraft capabilities (such as low speed abilities & versatility).
- **Novel Control**, to introduce innovative control systems and strategies to improve overall aircraft efficiency. The new challenges that could bring step change gains do not lie in the optimisation of the flight control system component performing its duty of controlling the flight, but in opening the perspective of the flight control system as a system contributing to the global architecture optimisation. It could contribute to sizing requirements alleviations thanks to a smart control of the flight dynamics.
- **Novel Travel Experience**, to investigate new cabins including layout and passenger-oriented equipment and systems as a key enabler of product differentiation, having an immediate and direct physical impact on the traveller, and with a great potential in terms of weight saving and eco-compliance.

- **Next Generation Optimised Wing**, to progress the aerodynamic and structural efficiency, including ground testing of innovative wing structures. The challenge is to develop and demonstrate new wing concepts (including architecture) that will bring significant performance improvements (in drag and weight) while improving affordability and enforcing stringent environmental constraints. New concepts of wing must be explored for the efficient application on future medium/small regional aircraft and rotorcraft.
- **Optimised High Lift Configurations**, to progress on the aerodynamic efficiency of wing, engine mounting and nacelle integration for aircraft serving small, local airports by enabling excellent field performance, and increasing aircraft versatility.
- **Advanced Integrated Structures**, to optimise the integration of systems in the airframe along with the validation of important structural advances and to make progress on the eco-production efficiency and manufacturing of structures.
- **Advanced Fuselage** to introduce innovation in fuselage shapes and structures, including cockpit and cabins. New concepts for the fuselage are to be introduced to support future aircraft and rotorcraft designs. More global structural optimisation will provide further improvements in drag and weight, in the context of a growing cost and environmental pressure, including emergence of new competitors.
- **Eco-Design management and Eco TA Link**, to ensure the link between the Airframe ITD and the Eco Transversal Activity (Eco TA) by supporting the Coordination Committee Meeting (CCM) Delegate, to continue performing VEES/EDAS mapping, to set up LCI data collection teams, to write the synthesis reports and to perform the management of the outputs to ECO TA
- **Eco-Design for Airframe**, to apply the most interesting technologies developed between 2018 and 2020 to demonstrators (to reach TRL 5-6 at the end of the demonstration phase in 2023), and to provide necessary inputs to Eco TA to perform Eco-Statements on A/C parts i.e. demonstrators and associated reference parts.
- **New Materials and Manufacturing**, to make available to the aerospace industry and its supply chain a set of new technologies increasing the manufacturing efficiency and reducing the environmental footprint of the aircraft production including new testing and verification methods and providing necessary inputs to ECO TA to perform Eco-Statements on new efficient manufacturing and testing technologies.

Due to the large scope of technologies undertaken by the Airframe ITD, addressing the full range of aeronautical portfolio (Large Passenger Aircraft, Regional Aircraft, Rotorcraft, Business Jet and Small Air Transport) and the diversity of technology paths and application objectives, the above technological developments and demonstrations are structured around 3 major Activity Lines, allowing for better focus on the synergies of the integrated demonstrations in a technically consistent core set of user requirements, and, when appropriate, better serve the respective IADPs:

- **Activity Line A: Demonstration of airframe technologies focused on High Performance & Energy Efficiency (HPE);** this Activity Line is devoted to technology demonstrations on reference aircraft operating at high speed and high altitude flight conditions with longer range, and turbofan power plant.
- **Activity Line B: Demonstration of airframe technologies focused on High Versatility and Cost Efficiency (HVC);** this Activity Line is devoted to technology demonstrations on reference aircraft operating at lower speed and lower altitude flight conditions, with shorter range, and turbo-propeller power plant.
- **Activity Line C: Demonstration of airframe technologies focused on Eco-Design (ECO);** this Activity Line is devoted to the development and maturation of technologies to reduce the environmental impact for the non-operational phases of the aircraft lifecycle. Technologies will be developed to TRL 4/5 and ground demonstrators incorporating the most promising ones will then be manufactured and tested, thus allowing a maturation of technologies to TRL 5-6.

7.5. Engines ITD [ENG]



The European engine sector currently has about 40% of the global market and H2020/Clean Sky 2 will allow it to at least maintain that share. At this scope, Safran, MTU and Rolls-Royce have secured corporate commitment to build on the success of SAGE to validate more radical engine architectures to a position where their market acceptability is not determined by technology readiness. The platforms or demonstrators of these engines architectures are summarized below:

- **Ultra-High Propulsive Efficiency (UHPE) demonstrator addressing Short / Medium Range aircraft market, 2014-2023:** Technology maturation through modules & rigs ground demonstrations to prepare the design, development and ground test of a scale 1 integrated propulsion system demonstrator to validate the new engine architecture, the Low Pressure Modules & Systems and associated Nacelle Technologies.
- **Business aviation / Short range regional Turboprop Demonstrator, 2015-2022:** Design, development and ground testing of a new turboprop engine demonstrator.
- **Advanced Geared Engine Configuration (HPC and LPT technology demonstration), 2015-2023:** Design, development and ground testing of a new demonstrator to reduce CO₂ emissions and noise as well as engine weight.
- **VHBR Large Turbofan demonstrator, 2014-2023:** The trend to very high Bypass Ratio engines requires technology development across a broad range of complex gas turbine systems, from fan inlet through the complete compression, combustion and turbine to exhaust. Rolls-Royce will lead the development and demonstration of technologies in low-speed low pressure-ratio fan, aerodynamic and structural design of high efficiency multi-stage Intermediate Pressure turbines, integration of novel accessory and power gearbox.
- **Very High Bypass Ratio (VHBR) Middle of Market Turbofan technology, 2014-2023:** Design, development, build and ground test of an engine to demonstrate key technologies at a scale suitable for large engines. The Rolls-Royce Advance 3 engine core will be demonstrated and provide the core gas generator used for the demonstrator.
- **Light weight and efficient jet-fuel reciprocating engine, 2014-2019:** For the small aero-engine demonstration projects related to SAT [Small Air Transport]: Development of an alternative 6-cylinder engine architecture, integration and optimization of aircraft installation for such an engine and technologies improvements on core engine (power density), turbocharger, propeller and engine control system. Ground test of engine demonstrator up to permit-to-fly.
- **Reliable and more efficient operation of small turbine engines:** for the small aero-engine demonstration projects related to SAT [Small Air Transport]: Development and demonstration of technologies in each area to deliver validated compression, combustion and power turbine systems for small turboprop engines, as well as optimized propeller. A new stream on hybrid electric application has started.
- **ECO design (2018-2023):** four areas of interest have been identified: additive manufacturing, composite recycling, Engine parts manufacturing and Repair solutions. The activities will aim at providing Life Cycle Inventories, on selected Flagship Demonstrators, to Eco TA for Life Cycle Analysis. Based on the generated database, the ECO activity will aim at quantifying and potentially optimizing the actual eco-benefit and Life Cycle Impact of these technologies.

Engines ITD has the objective to deliver substantial improvements in engine technology; in particular the following challenges will be addressed:

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

with their implementation. The ultimate goal of the project is to achieve TRL6 on some of the architectures.

- Rolls-Royce, Safran and MTU ensure the leadership and the participation in the programme has been extended to encompass both large tier 1 suppliers and more specialized companies as well as academia and research organizations.

7.6. Systems ITD [SYS]

While systems and equipment account for only a small part of the aircraft weight, they play a central role in aircraft operation, flight optimisation, and air transport safety, cost and environmental performance at different levels:

- Direct contributions to environmental objectives: optimised green trajectories, electrical taxiing, more electrical aircraft architectures, which have a direct impact on CO₂ emissions, fuel consumption, perceived noise, air quality, and weight.
- Enablers for other innovations, for example “bleedless” power generation and actuators, which are necessary steps for the implementation of innovative engines or new aircraft configurations.
- Enablers for air transport system optimisation: many of the major improvements identified in SESAR, NextGen and Clean Sky for greening, improved mobility or ATS efficiency can only be reached through the development and the integration of on-board systems such as data link, advanced weather systems, trajectory negotiation, and flight management predictive capabilities.
- Smart answers to market demands: systems and equipment have to increase their intrinsic performance to meet new aircraft needs without a corresponding increase in weight and volume: kW/kg, flux/dm³ are key indicators of systems innovation.



In Clean Sky, the Systems for Green Operations ITD developed solutions for more efficient aircraft operation. Further maturation and demonstration as well as new developments are needed to accommodate the needs of the next generations of aircraft. In addition, the systemic improvements initiated by SESAR and NextGen will call for new functions and capabilities for environmental or performance objectives, but also for flight optimisation in all conditions, flight safety, crew awareness and efficiency, better maintenance, reduced cost of operations and higher efficiency. Finally, framework improvements will be needed to allow for more efficient, faster and easier-to-certify development and implementation of features and functions.

The Systems ITD in Clean Sky 2 will address these challenges through the following actions:

- Work on specific topics and technologies to design and develop individual equipment and systems and demonstrate them in local test benches and integrated demonstrators (up to TRL 5). The main technological domains to be addressed are [1] cockpit environment and mission management, [2] aircraft communication platform and networks, [3] innovative wing systems (WIPS, sensors, and actuators), [4] landing gears, [5] the full chain of electrical power generation, distribution and usage, and [6] Cabin and Cargo systems technologies. The outcomes will be demonstrated system architectures ready to be customised and integrated into larger settings. An important part of this work will be to identify potential synergies between future aircraft at an early stage to reduce duplication.
- Hand-over of individual technologies or systems to the IADPs for customisation, integration and maturation in large scale (flying) demonstrators. This will enable fully integrated demonstrations in IADPs and the assessment of benefits in representative conditions, including the progress towards the Clean Sky 2 high-level goals to be monitored through the Technology Evaluator.

- Transverse actions are also defined to mature processes and technologies with potential impact on all systems, either during development or operational use. Examples of these transverse actions are development tools and simulation, eco-design etc.

A link with LPA Platform 3 and SAT is established to ensure the alignment do respective demonstrators.

7.7. Small Air Transport Transverse Activity [SAT]



The Small Air Transport (SAT) is a Transversal Activity (TA) in the frame of Clean Sky 2 research project. SAT deals with small general aviation and commuter/feeder aircraft and their technology needs: 'fixed wing' aircraft between 4 and 19 seats.

The SAT Initiative proposed in Clean Sky 2 represents the R&D (Research & Development) interests of European manufacturers of small aircraft used for passenger transport and for cargo transport, belonging to EASA's CS-23 (European Aviation Safety Agency Certification Specifications-23) regulatory

base. This will include dozens of industrial companies (many of which are SMEs, i.e. Small or Medium size Enterprises), research centres and universities. The community covers the full supply chain, i.e. aircraft integrators, engine and systems manufacturers and research organizations.

SAT main goal is to meet the Flightpath 2050 target whereby "90% of travellers within Europe are able to complete their journey, door-to-door within 4 hours", improving overall European air mobility.

Mobility, in fact, is a key to answer many societal needs, being essential to connect people, to provide additional business opportunities, to increase society's health and to ease trans-national employment. Focusing on small aircraft, SAT will be able to guarantee a smarter use of the available ground infrastructures, making the operation of small aircraft economically viable.

In fact, today there is a big need for connecting small airports in remote areas which do not have an affordable solution due to high cost per seats of available small aircraft. A reduction of operating cost of Small Aircraft transport will open the market, contributing to improve mobility in Europe, connecting small cities and helping to reduce flight time, offloading surface transport, thus increasing the overall mobility of European society.

SAT focuses on market innovations to reduce operational cost and environmental impact, ensuring good operational safety levels as well, to unlock the potential offered by small regional airports, which are closer and more accessible to the travelling society.

Since the operation of small aircraft need only little or no additional infrastructural investments, it opens many opportunities for regional growth and employment, especially in remote areas far from big airports or with limited or absent road and railway connections to bigger cities.

To reach its main goals, two different platforms have been designed inside SAT TA: a Reference and a Green aircraft.

The Reference aircraft is a virtual aircraft designed considering 2014 technologies with an existing engine assuring the requested take-off power.

To enhance convergence towards an optimal and consistent Green aircraft, three different design loops will be performed by integrating key technologies developed in the frame of Clean Sky 2 Integrated Technology Demonstrators (ITDs):

- AIRFRAME ITD - Low cost composite wing box and engine nacelle using Out of Autoclave (OoA) technology, Liquid Resin Infusion (LRI) and advanced automation process.
- AIRFRAME ITD - Innovative high lift devices, allowing aircraft operations from short airfields (<800m).
- AIRFRAME ITD - Affordable small aircraft manufacturing of metallic fuselage by means of Friction Stir Welding (FSW) and Laser Metal Deposition (LMD).
- SYSTEM ITD - Affordable fly-by-wire architecture for small aircraft (CS23 certification rules).

- SYSTEM ITD - More electric systems replacing pneumatic and hydraulic aircraft systems (high voltage Electrical Power Generation and Distribution System, low power de-ice system, landing gear and brakes).
- SYSTEM ITD - Advanced avionics for small aircraft, to reduce pilot workload, paving the way for single pilot operations for 19 seats.
- SYSTEM ITD - Advanced cabin comfort with new interiors materials and more comfortable seats.
- ENGINE ITD - New generation of turboprop engine with reduced fuel consumption, emissions, noise and maintenance costs for 19 seats aircraft.
- ENGINE ITD - Alternative diesel engine option for small 9 seats commuter aircraft.

As final step of the design validation process, the integration studies of relevant technologies into the 19-seats Green aircraft configuration will be carried out through three relevant SAT ground and flight demonstrators in order to validate and assess benefit at aircraft level.

7.8. Eco-Design Transverse Activity [ECO]



The Eco Design (ECO) is a Transversal Activity (TA) in the frame of Clean Sky 2 project.

The Eco Design approach consists of integrating environmental criteria over the different phases of a product's lifecycle. Environmental protection is and will be more and more a key driver for the aviation industry as a whole. The challenge is to reduce the environmental impact in the face of continuing expansion in demand for aviation.

ECO is the only contributor to meet the Flightpath 2050 target whereby "Air vehicles are designed and manufactured to be recyclable", improving overall European aircraft industry environmental compliance. Environmental compliance, in fact, is key to answer also societal needs, being people more conscious of environmental aspects, to provide additional business opportunities, to increase society's health and to ease the compliance to emerging regulations.



Figure: Closed Life Cycle Approach provided through the Clean Sky Programme circular economy model

The Eco-Design Transverse Activity (TA) aims to coordinate and support valuable projects in ITDs/IADPs contributing to a significantly reduced ecological impact of future air vehicles.

Several demonstrators at different TRL were assessed in CS1 through Eco-Statements implementing Life Cycle Assessment. In CS2 Eco-Design TA aims to broaden the assessment methodology to include more environmental indicators providing a framework for technology guidance including future social impacts to enhance the competitiveness of the European aviation sector.

Eco-Design TA will mainly focus on materials, processes and resources sustainability, efficient manufacturing and production, lifetime service, and end-of-life, and shall also consider emerging

aspects coming from future requirements to be met. This will be based on a modern developed Life Cycle Impact Analysis (LCIA) for the integrated Clean Sky 2 portfolio of technologies and their inventories along eight defined eco-themes¹ including eco-statements and socio-economic statements on a micro-economic build-up.

Eco-Design TA will be coordinated in cooperation with ITDs/IADPs with the core of technology development and demonstration residing in the ITDs/IADPs. Eco-Design activity, including the launch of complementary grants, will be screened and assessed through a methodology determining the relevance, benefit and impact for the transversal action. Selected projects started to be implemented with the TA supporting members and partners in monitoring and measuring their progress toward the economic goals. The Life Cycle Analysis will provide results in terms of Global Key Performance Indicators (GKPI) being:

- Re-use Recycling Quota (RRQ),
- Step forward Ground Pollution Potential (GPP) improvement made out of consolidated and modernized indicators from Primary Energy Demand (PED), Global Warming Potential (GWP) of the product life; relevant substance monitoring beyond CO₂-equivalent, bio-diversity as well as health risk parameters etc.
- Socio-economic derivative (SED) and eco statement process indications

Selected flagship demonstrators (FSDs) have been defined in each ITD/IADP to be assessed for the final eco-statement using the Eco-Design approach, in order to provide tangible cases helping industry to demonstrate the Eco design benefits with the respective LCA, GKPI outcomes.

Workshops on specific themes of interest (i.e. chrome VI free processes, composites recycling, additive manufacturing) aim to foster joint collaborative approaches and to ensure synergies.

Eco-Design analysis will then support the assessment of the Eco-Design technologies. The principles of an extended aeronautical database and novel life-cycle assessment [LCA] methodologies will be developed with a design for environment vision to help quantify the environmental benefits of the most promising technologies and orientate the research in the Eco-Design theme. Data base management principles and interfaces are under discussion and agreement for a proper cooperation.

The Eco Hybrid Platform virtual demonstrator, as a key delivery of the action, offers an integrated visualisation of “economic” improvements of aircraft products and production. This allows the representation of all Eco-Design activities in CS2 and a single point of access to the Eco-Design toolbox for eco-statements and socio-economic assessment. Dissemination of Eco-Design results represents crucial support to the European aircraft industry and will be implemented accordingly.

The Eco-Design Coordination Committee steers the Eco-Design activities performed in the different SPDs toward the action objectives ensuring the proper level of interaction between the involved parties.

7.9. Technology Evaluator [TE]

The Technology Evaluator (TE) will monitor and assess the environmental and socio-economic impact of the technological results arising from all CS2 activities across all the CS2 instruments. The TE will specifically quantify the expected improvements of the aviation sector in future scenarios in comparison to baseline scenarios.



¹ Eight eco-themes:

[A] LIFT, Identification Strategy, Life Scoping; [B] Materials, Processes & Resources (MPR); [C] Manufacture/ Production; [D] Service to Component & System; [REUP] Re-Use / Recycling; [EoL] End of Life; [ADS] Integration / Field Assembly-Disassembly-Separation; [ASA] Alternative Sectorial Applications; & [UP] Use Phase Reference for exchange with TE

The TE will provide feedback to the CS2 instruments to enable the optimisation of their performance. Technology impact assessments as part of CS2 cover environmental as well as socio-economic impacts with a particular focus on reducing aircraft CO₂, NO_x and noise emissions by 20-30% compared to 'state-of-the-art' aircraft entering into service as from 2014. Where applicable, the benefits brought about by CS2 demonstrators and technologies will be monitored against well-defined environmental targets and socio-economic targets of the ACARE Flightpath 2050 and the corresponding goals outlined in the Strategic Research and Innovation Agenda (SRIA).

CS2 results will be considered in the form of 'concept aircraft models' where related impacts will be assessed on three levels: mission level, airport level, and air transport system (ATS) level. All three levels are strongly interconnected and build on one another. Technology assessments/mappings will be performed on all IADP, ITD, and SAT TA results, for potential input to the concept vehicle models including mainliners, regional aircraft, business jets, small air transport vehicles, and fast rotorcraft, as well as on TE concept aircraft models. All the assessments will be based on comparisons between newly-developed and 2014 reference technologies covering the 2025, 2035, and 2050 time horizon. Technologies developed in the SPD's but not included in the concept vehicles will be assessed within their native ITD/IADP.

To ensure sufficient flexibility and to reduce the need for coordination between the instruments and the TE, mission level assessments are mainly conducted by the IADPs, ITDs, and the SAT TA. As one of the lessons learned from CS, assessments of individual technologies at vehicle level can be expedited by assigning mission level assessments to the CS2 instruments doing the synthesis of a concept model. On the mission level, the instruments' results will be complemented by a limited number of TE concept models both for those parts of the global fleet not under consideration in or going beyond the scope of CS2, and for CS2 technologies without dedication for one of the instrument's concept models.

With regard to the mission level, the TE ensures harmonisation of methods, metrics, and reporting. The TE will conduct airport and air transport system level assessments with the CS2 instruments' concept models as input. The TE will also conduct the socio-economic assessments on micro- and macroscopic level and it will establish a link to the ECO TA for life-cycle analysis types of evaluation.

The monitoring and information capacities are established by an efficient and effective interfacing between TE and the CS2 instruments.

The TE has constantly refining metrics and methods, which have been agreed with the CS2 instruments and considered in all assessments; the need for updates will be monitored. The TE has elaborated possible extensions of its scope, for example with regard to global warming and local air quality assessments; the TE will continue to support such extensions. The TE forecast modelling is recognised as a globally accepted methodology. This results from coordination and close cooperation with EU and international institutions in the aviation field (e.g. EASA, SESAR, CAEP). The ATS fleet forecast and scenarios of the 2nd general assessment will consider COVID19 impact and will endeavour to incorporate at the global level the effects of the climate policy measures newly introduced by the EU (such as FitFor55 or ReFuelEU).

8. Master Plan

8.1. Summary of the evolutions compared to 2020

The CS2JU and its Members have revised the strategic planning of the Programme, with the evolutions as summarised below.

Overall, the plan remains stable in terms of the number of demonstrators as their overall number is roughly unchanged. The detailed planning of every demonstrator is given in the next section.

The plan now includes 107 demonstrators (compared to 106 in the last CS2DP revision), resulting from one additional demonstrator in the AIRFRAME ITD to improve visibility of ECO activities within the ITD.

Nevertheless, a certain number of evolutions is proposed in the current revision of the CS2DP. They can be categorised as follows, depending on their impact on the maturity at completion and the associated financial impact:

- 1) TRL unchanged: the maturity at completion is unchanged compared to 2020. It may be accompanied by a reduction or an increase of effort to seize funding opportunities or mitigate technical risks;
- 2) Increased TRL: the maturity at completion is increased compared to 2020, maximising the benefits towards the HLGs;
- 3) Scope reduction: due to technical difficulties, delayed decision gate or financial limitation: the maturity at completion is reduced while some activities will deliver results in 2024 and beyond thanks to other financial support (e.g. national programme, self-investment, etc.).

The evolution of the master plan is summarised in the table below:

Type of changes		Funding evolution			
		Reduced effort	Same effort	Increased effort	<u>TOTAL</u>
Maturity evolution	TRL unchanged	10	79	10	99 (92%) (*)
	Increased TRL	-	2	-	2 (3%)
	Scope reduction by 2023 (reduced TRL)	2	3	1	6 (5%)
	<u>TOTAL</u>	12	84	11	107

(*) of which 23% have reported delays.

The scope of work for the vast majority of demonstrators (95%) is unchanged confirming the ambition at Program end. A scope reduction or delay beyond 2023 has been reported on 5% of the demonstrators and is a consequence of prioritisation exercise within SPD to maximise the results at completion.

Demonstrators experiencing a scope reduction are the following:

- Morphing Leading Edge Demo (AIR ITD): due to funding issues, ambition is reduced from TRL5 to TRL4 after prioritisation within the ITD.

- Innovative Movables (AIR ITD): ambition is reduced from TRL 5 to TRL4 following change in a Member's strategy.
- Boundary Layer Ingestion (LPA IADP): after inconclusive assessment of benefits related to BLI, Members decided to ramp down this activity so that TRL3 is no more at stake.
- Advanced Electrothermal Wing Ice Protection (SYS ITD): cancellation of FT following Member's prioritisation and leading to reducing TRL from 6 to 5.

The following demonstrators are postponed in order to better align their contribution with the future Clean Aviation Programme (CAP):

- UHPE Demo (ENG ITD): TRL5 likely to be delayed to 2024 as compared to last CS2DP revision (end 2023). This is due to a delay of 6 months in the down selection of the engine architecture proposed for the new aircraft concept. The proposed architecture for demonstration will aim at a significant increase of expected benefits from the engine performance (CO₂ reduction could be as high as 15%, far above the 9% targeted in Clean Sky 2) thanks to the validation of low pressure technologies used for the future unducted engine concept. Members have confirmed their commitment to secure TRL5 achievement in 2024.
- Enablers for Integrated Open Rotor design (LPA IADP): maturity at completion reduced to TRL3 as a consequence of the delay of 6 months in the down selection of the engine architecture proposed for the new aircraft concept. Members confirmed that full TRL4 achievement is not at reach. Activities are planned to prepare the decision gate on the new aircraft concept (targeted on the new EPCA) & to de-risk noise and blade out topics.

Besides those evolutions, delays have been reported on approximately one-fourth of demonstrators. Those demonstrators are delayed by 6.5 months on average. Nonetheless these demonstrators' goals will still be achievable within the timeframe of the Programme (i.e. TRL at completion unchanged) except for two demonstrators that will be completed beyond 2023 (LPA UltraFan FT & ENG UHPE). Delays are mostly due to technical difficulties that occurred during the year or external dependencies (unavailability of Wind Tunnel slot), with only 4 demonstrators being delayed due to Covid-19 as a main reason. This shows that, despite the Covid-19 pandemic is still affecting the Program on some specific activities involving hardware, its impact has been mostly mitigated by the Members. The JU and Members are nevertheless continuously monitoring the situation.

Compared to 2020, the number of demonstrators expected to complete their work within the last two years of the Programme has increased by 10% at more than 70%. This comes as a consequence of technical difficulties linked to a certain level of uncertainty inherent to R&I activities. Although the contribution to the High-Level Goals is not affected since the overall Programme content remains mostly unchanged, the timely exploitation of results may be impacted. Close monitoring measures are in place to avoid any further delays and trigger specific actions where necessary.

To mitigate the potential risk of funding shortages for some demonstrators, transfers of funding across IADPs/ITDs and an increase in funding have been proposed for some demonstration areas.

8.2. Planning per demonstrators

The planning is available in the next pages.

State of play as of September 2021					<div><div><div>CDR</div><div>PDR</div><div>CoR</div></div><div><div>FT</div><div>Testing/GT</div></div><div>ET = Enabling Technology</div></div>												
Theme	Demonstration Area	Demonstrator /Technology Streams	Number of ETs	TRL at End	Demonstrator /Technology Streams Maturing Over Time												2024 2025
Breakthroughs in Propulsion Efficiency (incl. Propulsion-Airframe Integration)	Advanced Engine/Airframe Architectures	AIR-D3-2 Optimised integration of rear fuselage [WP A-1.1, A-1.3]	3	4/5													
			TRL Maturity		TRL2			TRL3		TRL4		TRL4/5					
		LPA-01-D10: UltraFan Flight Test Demonstration	4	6					TRL3					TRL4	TRL5	TRL6	
			TRL Maturity					TRL3					TRL4	TRL5	TRL6		
		LPA-01-D13: UHBR Short Range Integration	6	6													
			TRL Maturity				TRL2		TRL3				TRL4/5	TRL6			
	Ultra-high Bypass and High Propulsive Geared Fans	LPA-01-D1: Enabler for Integrated Open Rotor Design	4	4													
			TRL Maturity												TRL3		
		LPA-01-D16: Common Technology Bricks for Future Engines	4	5												TRL5	
			TRL Maturity							TRL3	TRL4				TRL5		
	Hybrid Electric Propulsion	AIR-D3-3 UHBR integration [WP A-1.2]	1	6													
			TRL Maturity				TRL2		TRL3		TRL4	TRL5	TRL6				
		ENG 5 - VHBR - Middle of Market Technology	5	5													
			TRL Maturity												TRL5		
	Small Aircraft, Regional and Business Aviation Turboprop	ENG 6 - VHBR - Large Turbofan Demonstrator UltraFan™	5	5													
			TRL Maturity												TRL5		
		ENG 2 - UHPE	5	5													
			TRL Maturity												TRL5		
	Boundary Layer Ingestion	ENG 4 - Adv. Geared Engine Configuration (HPC-LPT)	5	0													
			TRL Maturity														
LPA-01-D9: Hybrid Electric Ground Test Bench		4	4														
		TRL Maturity															
Hybrid Electric Propulsion	REG WP1 - Hybrid/Electrical Regional Aircraft Configuration	3	3														
		TRL Maturity															
	LPA-01-D14: Boundary Layer Ingestion	1	2														
		TRL Maturity															
Small Aircraft, Regional and Business Aviation Turboprop	ENG 3 - Business aviation / short range Regional TP Demonstrator	5	5														
		TRL Maturity															
	ENG 7 - Small Aircraft Engine Demonstrator	5	5														
		TRL Maturity															
Small Aircraft, Regional and Business Aviation Turboprop	ENG 8 - Reliable and more efficient operation of small turbine engines	5	4														
		TRL Maturity															
	REG WP2.3 - WTT Demonstrator for the Innovative Propeller	8	8														
		TRL Maturity															
Advances in Wings Aerodynamics and Flight Dynamics	Advanced Laminar Flow Technologies	AIR-D3-7 NLF smart integrated wing [WP A-2.2]	1	6													
			TRL Maturity														
		AIR-D3-10/11/12 - Extended laminarity [WP A-2.3]	1	4													
			TRL Maturity														
		LPA-01-D11: Active flow control flight test demonstrator	2	3													
			TRL Maturity														
		LPA-01-D4: HLFC on tails large scale ground-based demonstrator	5	6													
			TRL Maturity														
	Advanced Laminar Flow Technologies	LPA-01-D5: Natural Laminar Flow demonstrator for HTP bizjets	4	4													
			TRL Maturity														
		LPA-01-D6: Ground-based demonstrator HLFC wing	7	4													
			TRL Maturity														
		AIR-D3-6/8/27 - NLF BJ Nacelle / HTP & nacelle access doors demonstrator [WP A-2.1/A-2.2]	1	5													
			TRL Maturity														
		AIR-D3-9 NLF Leading Edge GBD [WP A-2.2]	1	5													
			TRL Maturity														
	Aircraft Wing Optimization	REG WP2.1 - WTTs demonstrators for Innovative AirVehicle Technologies (DN, Morphing Flap, NLF, ...)	5	5													
			TRL Maturity														
		REG D1 - Adaptive Wing Integrated Demonstrator – Flying Test Bed#1 (FTB1)	6	6													
			TRL Maturity														
REG D1 - Adaptive Wing Integrated Demonstrator – Outer Wing Box Ground Test		2	5														
		TRL Maturity															
REG D2 - Integrated Technologies Demonstrator – Flying Test Bed#2 (FTB2)		5	6														
		TRL Maturity															
Aircraft Wing Optimization	AIR-D2-7 Innovative movables [WP A-4.1.2]	1	4														
		TRL Maturity															
	AIR-D1-7 Multifunctional Flap [WP B-2.2]	1	6														
		TRL Maturity															
	AIR-D2-18 Morphing Leading Edge Demonstrator [WP B-1.4]	3	4														
		TRL Maturity															
	AIR-D3-17/18/19 - Novel Control [A-4.2]	1	6														
		TRL Maturity															
Aircraft Wing Optimization	AIR-D1-5/8 - ON-GROUND ACTUATION RIG FTB#2 WING [WP B1.4, B3.2]	7	6														
		TRL Maturity															
	AIR-D1-4/6 - ON-GROUND STRUCTURAL RIG FTB#2 WING [WP B-1.3, B2.2]	13	6														
		TRL Maturity															
Aircraft Wing Optimization	AIR-D2-17 SAT high lift demonstrator [WP B-2.2]	1	6														
		TRL Maturity															

State of play as of September 2021					<div><div><div>CDR</div><div>PDR</div><div>CoR</div></div><div><div>FT</div><div>Testing/GT</div><div>ET = Enabling Technology</div></div></div>												
Theme	Demonstration Area	Demonstrator /Technology Streams	Number of ETs	TRL at End	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024-2025		
Innovative Structural / Functional Design - and Production System	Advanced Manufacturing	AIR-D2-15 Composite Wing for SAT [WP B-1.2]	4	6													
			TRL Maturity														
		AIR-D3-21/23 - Aileron, fuselage panel jigless assembly for SAT [WP B-3.4]	1	6													
			TRL Maturity														
		AIR-D3-22 Joints Metal/Composite Structures for SAT [WP B-3.4]	1	6													
			TRL Maturity														
		AIR-D2-20/21/22 - Empennage for Regional A/C (VTP, HTP, LE) [WP B-3.1]	1	5													
			TRL Maturity														
	AIR-D2-3 Flaperon [WP-A-3.1]	1	6														
		TRL Maturity															
	AIR-D1-9/10 & D3-20 - ON-GROUND STRUCTURAL COCKPIT FTB#2 [WP B-3.3]	4	5														
		TRL Maturity															
	SAT D2 - Wing Smart Health Monitoring: "smart" composite wing integrating technologies for health monitoring	2	5														
		TRL Maturity															
	LPA-01-D2: Advanced Rear-end	6	6														
		TRL Maturity															
	Cabin & Fuselage	REG D3 - Full scale innovative Fuselage & Pax Cabin demonstrator (Structural demonstration)	3	6													
			TRL Maturity														
AIR-D3-24 Cabin Parts for SAT structure [WP B-3.4]		1	6														
		TRL Maturity															
AIR-D1-1 Cargo Door [WP-A-3.3]		1	6														
		TRL Maturity															
Innovative Solutions for Business Jets	LPA-02-D1: Next Generation Fuselage, Cabin and Systems Integration	8	5														
		TRL Maturity															
	AIR-D1-16 & D3-26 - Regional Aircraft Fuselage and Cabin Major Components Demonstrator [WP B-4.3, B-4.4]	4	6														
		TRL Maturity															
	LPA-02-D3: Next Generation Lower Center Fuselage	8	2														
		TRL Maturity															
	AIR-D2-1/2 - BJ Composite Wing Root Box [WP-A-3.1]	1	5														
		TRL Maturity															
Cockpit & Avionics	AIR-D2-4 Power-optimized BJ windshields (anti-icing) (WP A-3.2)	3	5														
		TRL Maturity															
	AIR-D2-6 BJ Composite Central Wing Box Panel [WP-A-3.3]	1	3														
		TRL Maturity															
Next Generation Cockpit Systems and Aircraft Operations	Cockpit & Avionics	AIR-D2-5 BJ Composite Half Central Wing Box [WP-A-3.3]	1	3													
			TRL Maturity														
		D23. Affordable future avionics solution for SAT	1	5													
			TRL Maturity														
		D24 Enhanced vision & awareness	1	4													
			TRL Maturity														
		D25 Integrated modular communications	1	5													
		TRL Maturity															
	Advanced MRO	LPA-03-D1: Disruptive Cockpit Large Aircraft	10	5													
			TRL Maturity														
LPA-03-D2: Regional Active Cockpit		5	5														
	TRL Maturity																
Cockpit & Avionics	LPA-03-D3: Enhanced functions and technologies ground and flight tests on business jet	7	5														
		TRL Maturity															
	D1 Extended Cockpit	9	5														
		TRL Maturity															
Advanced MRO	LPA-03-D4: Maintenance service operations enhancement demonstrator	14	4														
			TRL Maturity														



State of play as of September 2021					<div><div><div>CDR</div><div>PDR</div><div>CoR</div></div><div><div>ET = Enabling Technology</div><div>Testing/GT</div></div></div>												
Theme	Demonstration Area	Demonstrator /Technology Streams	Number of ETs	TRL at End	Demonstrator /Technology Streams Maturing Over Time												
Novel Aircraft Configurations and Capabilities	Next-Generation Civil TILTROTOR	Next-Generation Civil TILTROTOR	11	6													
		AIR-D1-13/14/15 NGCTR Fuselage Components	3	6							TRL3	TRL4		TRL5	TRL6		
	RACER Compound Helicopter	RACER Compound Helicopter	8	6													
		AIR-D1-2/3/11/12 RACER Airframe Components	4	6							TRL3	TRL4		TRL5	TRL6	TRL6	
	Aircraft Innovative Configuration	REG WP1 - TP90 Pax Configuration	All REG ETs for TP90	5													
		REG - Long Term (TP130 pax Configuration)	All REG ETs for TP130 pax	3							TRL3	TRL4		TRL5			
		AIR-D3-1 Noise shielding tail plane (WP A-1.1)	1	5													
		AIR-D3-4 Novel high performance BJ configuration (WP A-1.3)	1	4													
		LPA-01-D3: Validation of scaled flight testing	1	5													
		LPA-01-D8: Radical Configuration Flight Test Demonstrator	1	5													
	Aircraft Non-Propulsive Energy and Control Systems	Electrical Systems	REG D4 - Iron Bird	3	5												
			D18. Fly-by-Wire for SAT	2	5												
D3. Smart Wing Actuation Demonstrator			1	5													
D4. Innovative Electrical Wing Demonstrator			2	6													
D10. HVDC Power Management Centre for large A/C - Demonstration			2	5													
D16. Thermal Management demonstration			2	5													
D9. Innovative Electrical and control/Command Networks for distribution systems - Demonstration			3	5													
D19. Electrical power generation and distribution for SAT			2	5													
D13. Next Generation Cooling systems			1	6													
D8. Innovative Power Generation and Conversion			4	5													
Landing Systems		SAT D1 - Aircraft Level 0: More electric systems for small air transport	3	5													
		D17. Advanced Landing Gear Sensing & Monitoring System	1	5													
		D21. Electrical landing gear for SAT	1	5													
		D5. Advanced Landing Gear Systems	6	5													
		D6. Electrical Nose Landing Gear System	2	6													
Non-Propulsive Energy Optimization		LPA-01-D15: Non-Propulsive Energy Optimization for Large Aircraft	4	5													
		D11. Next Generation EECS Demonstrator for large A/C	1	6													
		D12. Next Generation EECS Demonstrator for Regional A/C	1	4													
		REG WP2.3 - IWT Demonstrator for the Low Power WIPS	1	5													
		D20. Low power de-ice for SAT	1	5													
	D15. Primary In-Flight Ice Detection Systems	2	6														
	D14. Advanced Electrothermal Wing Ice Protection	1	5														
	AIR-D3-15 Icing code for de-icing [WP A-4.1.1.3]	1	5														
	AIR-D2-16/19, D3-16 Ultra low power ice protection [WP A-4.1.1.6, B-2.1, B-3.2]	1	5														
	AIR-D3-13 /14 - EWIPS Integration on BJ Flap & Slat [WP A-4.1]	1	5/6														

State of play as of September 2021					<div><div><div>CDR</div><div>PDR</div><div>CoR</div></div><div><div>▲</div><div>▲</div><div>ET = Enabling Technology</div></div><div>FT</div><div>Testing/GT</div></div>												
Theme	Demonstration Area	Demonstrator /Technology Streams	Number of ETs	TRL at End	Demonstrator /Technology Streams Maturing Over Time												2024 2025
Optimal Cabin and Passenger Environment	Passenger Comfort	D22. Comfortable & Safe Cabin for SAT	3	4													
			TRL Maturity														
		REG D3 - Full scale innovative Fuselage & Pax Cabin demonstrator (Comfort/Thermal demonstrations)	1	6													
			TRL Maturity														
	Innovative Cabin Passenger/Payload systems	SAT D3 - Safe and comfortable cabin	2	5													
			TRL Maturity														
		LPA-01-D12: Flight test demonstration of active vibration control technologies/noise prediction methods for rear-mounted engines	2	6													
			TRL Maturity														
		AIR-D2-8/9/10/11 - Ergonomic flexible cabin [WP 5.1]	1	6													
			TRL Maturity														
	AIR-D2-12/13/14 - BJ office centered cabin [WP A-5.2]	3	5														
		TRL Maturity															
	D2. Equipment and systems for Cabin & Cargo applications	1	5														
		TRL Maturity															
	LPA-02-D2: Next Generation Cabin & Cargo Functions	7	5-6														
		TRL Maturity															
Eco Design	Eco Design	AIR-ECO Flagship Demonstrator	11	6													
				TRL Maturity													

9. Overview of Major Risks

#	Risk Description	Likelihood (H/M/L)	Impact (H/M/L)	Impact Category†	Mitigation Plan	Residual Risk
1	Achievement of high-level goals Execution of the technical activities in Clean Sky 2 may not result in the achievement of the High-Level Goals [HLGs] as stated in the Regulation.	L	H	R/T/S	<p>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.</p> <p>Confirm the contribution of every IADPs/ITDs/TAs to the Clean Sky 2 High Level Objectives and quantify their environmental contribution to the different A/C concepts in view of the 2nd TE assessment as defined in the Technology Evaluator.</p> <p>Elaborate and maintain for key demonstrators/ technologies an estimate of the expected environmental improvements and monitor the progress towards the fulfilment of the objectives.</p> <p>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 & Support actions, where necessary.</p>	M
2	Implementation of the Clean Sky 2 Development plan may be hampered due to: <ul style="list-style-type: none"> • Change 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. • 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. 	M	H	T/S/C	<p>The residual risk is unchanged as compared to last year based on the 2021 CS2DP revision.</p> <p>Maintain an early warning capability through quarterly reports, the Annual and Intermediate Progress Reviews and where necessary alert the Governing Board.</p> <p>Monitor technical execution through timely execution of milestones and deliverables. Assess technical difficulties during ad-hoc or regular reviews and propose a mitigation plan to fix the technical issues.</p> <p>Each IADP / ITD to reinforce a detailed risk management and “through to completion” plan with critical path management, budgets and risks, allowing due assessment and revision opportunities.</p> <p>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.</p>	H

#	Risk Description	Likelihood (H/M/L)	Impact (H/M/L)	Impact Category†	Mitigation Plan	Residual Risk
3	Competences and Skills availability Competences and resources to successfully enable the completion and test on ground and flight demonstrators might not be available as needed (prioritisation of resources within organisations or additional difficulties).	M	M	S/T/C	The residual risk is lowered from Medium to Low as compared to last year, based on recent progress reported showing only limited risk about resource availability (mainly related to Wind Tunnel Test). Closely monitor ground and flight demonstrators through monitoring of critical milestones. Enforce consistent and robust risk management; implement early-warning system to avoid late discovery of critical path related risks.	L
4	Dissemination and Exploitation The number of scientific papers produced at completion of Clean Sky 2 (100 per year) might be lower than anticipated, causing insufficient dissemination of the CS2 Programme results to the research community. Likewise, the number of applications for patents may fail to reach the target of 366 in total, indicating a lack of exploitation activities triggered through the CS Programmes.	L	M	R/S	The residual risk is unchanged as compared to last year. More than 2000 dissemination activities were performed including 1000 technical and scientific papers. Nevertheless, only 277 patents have filed to date as compared to an objective of 366. The JU will continue to monitor the dissemination activities at conferences, symposia, and the production of papers disseminated on a yearly basis. The JU also monitors applications for patents. Dedicated action plans are established per ITDs/IADPs/TAs on D&E with quantified figures until completion of the programme.	L
5	SPDs interdependencies causing delays The strong interdependencies between IADPs (as providers of requirements and as integrators) and ITDs (as providers of a/c components, systems and solutions) can cause delays in the overall programme in case of (technical/scheduling) problems.	M	L	T/S/C	Improve coordination and create well defined interfaces between IADPs and ITDs. Introduce programme management tools and techniques in parallel with the Grant Management systems supporting the individual grants in financial/legal aspects.	M
6	Partners' contribution to GAMs Partners contribution to GAM could not be fully in line with demonstration objectives	M	M	T/S/C	Implementation phase: Implement specific monitoring and management measures on case-by-case basis.	M
7	Market uptake of Research results delayed The maturity of certain Demonstrators at programme completion maybe lower than expected (delays, Covid-19 impact, technical or financial difficulties) hampering the timely exploitation of results. <u>Covid-19 impact on market demand:</u> The Covid-19 crisis has delayed the scenarii for new products introduction, due to its impacts onto the airlines and the adverse consequences on the passenger's demand. The situation is not expected to be fully recovered before 2024-25. Consequently, the situation has delayed the introduction of new technologies onto new aircraft to enter into service by 2025-2030.	M	H	T/S	Maintain an early warning capability through quarterly reports, the Annual and Intermediate Progress Reviews and where necessary alert the Governing Board. Assess the impact of COVID-19 on market forecast (socio-economic impact study to launch) and propose the re-alignment of activities where required to maximise the timely exploitation of results. Propose a revision of the CS2DP and the WP and use GAM Amendment process to officiate.	H
†Impact category: R (Reputational for JU); T (Technical Targets), S (Schedule Targets) or C (Cost Targets)						

10. Funding Resources Estimates

The maximum funding available as defined in the Regulation is €1 755 million, of which a maximum of €39 million corresponds to the contribution towards the Joint Undertaking administrative costs. This leads to an estimated net funding available for the Clean Sky 2 R&I operations of €1 716 million. In accordance with the Statutes of Clean Sky 2, Annex I Art. 16 which defines indicative funding shares, the Union contribution dedicated to operational costs (€1 716 million) is quantified in € amounts as set out below in the following tables.

In Table 1 the net indicative allocation to IADPs, ITDs and TAs is shown. Column (1) in the table shows the original indicative IADP and ITD funding estimates from which 1%, 2% and 4% for the TE, ECO and SAT TAs respectively are subtracted (see columns (2), (3) and (4)). Column (5) represents the indicative funding for the IADPs/ITDs and TAs up to Programme completion as set at the start of the Programme.

	(1)		(2)	(3)	(4)	(5) = (1) - (2) - (3) - (4)
IADPs / ITDs	Indicative Allocation Regulation - % (Annex III Clean Sky JU Council Regulation)	Indicative Allocation Regulation - M€	TE 1% IADPs/ITDs values - M€	ECO 2% IADPs/ITDs values - M€	SAT 4% IADPs/ITDs values - M€	Resulting Indicative Allocation - M€
			Transverse activities			
			[1% = 17.16]	[2% = 34.32]	[4% = 68.64]	
LPA	32%	548.17	5.48	12.48	21.71	508.50
REG	6%	109.63	1.10	2.50	4.34	101.70
FRC	12%	200.20	2.00	4.56	7.93	185.71
AIR	19%	333.67	3.34	7.60	13.21	309.52
ENG	17%	286.00	2.86	6.51	11.33	265.30
SYS	14%	238.33	2.38	5.43	9.44	221.09
TE						17.16
ECO						39.06
SAT						67.95
TOTAL*	100%	1,716.00	17.16	39.06	67.95	1,716.00
				124.18		

*Total Values for Transverse Activities as agreed in the June 2016 CS2DP and approved by the GB

Table 1 - Original distribution of Funding in € million: operational budget to completion per CS2 Programme.

Since the beginning of the Programme, several financial evolutions took place, leading to budget transfer from one ITD/IADP to another, in order to ensure the implementation of the work with a maximum efficiency. These evolutions across the programme areas led to the following funding breakdown per IADP/ITD/TAs (2014-2020):

State of Play: November 2020

	(1)	(2)	(3)	(4)	(5)=(1)+(2)+(3)+(4)
IADPs / ITDs / TAs	Allocation	Reapplication ECO	Reapplication SAT	TE	Allocation incl. TA Redistribution
LPA	486.29	8.00			492.29
REG	102.77	2.00			104.77
FRC	190.39	1.50			191.89
AIR	290.25	6.50	24.45		321.20
ENG	282.05	6.50	17.25		305.80
SYS	224.01	3.50	22.65		250.16
TE GAM	-	-	-	14.11	14.11
ECO GAM	-	6.06	-		6.06
ECO funding for re-distribution	-	3.40	-		3.40
SAT GAM	-	-	3.00		3.00
Thematic Topic	30.90	1.60	-	0.92	33.42
TOTAL	1604.66	39.06	67.35	15.03	1726.10
Deviation wrt max. funding value of 1,716 M€ (over commitment)					-10.10

Table 2 - Indicative Distribution of Funding in € million: operational budget to completion per IADP/ITD/TA.

In 2021, the different evolutions in Programme content and related funding estimates are summarised as follows:

a) Transfer of funding across SPDs (with neutral variation of funding)

- Transfer of technical activities for a total of €2.70 million from AIR to REG;
- Transfer of technical activities for a total of €0.67 million from LPA to AIR;
- Transfer of technical activities for a total of €0.50 million from SYS to LPA;
- Transfer from ECO (Central Cooperation) to REG for a total of €0.40 million.

b) Funding reduction per area

- A reduction of the funding budget dedicated to Partners (CfP) of €0.75 million due to a lower execution rate. This was reflected in the Thematic funding envelope. This trend is set to continue as the Programme is approaching its closure and delivery phase (based on Clean Sky experience).
- A reduction of the funding budget dedicated to tenders of €0.67 million in TE (CfT cancellation);
- A reduction of the funding budget dedicated to Leaders of €0.09 million in TE (minor adjustment).

In addition, the SYS ITD has reduced its overall funding by €5.36 million (due to the cancellation of activities and scope reduction in members' activities), without reducing its ambition in the field of ECO TA.

c) ECO Central Coordination

Finally, €3 million for implementation for ECO Central Cooperation (ECO CC) are proposed for implementation across the different SPDs.

These projects will contribute to securing the ECO TA objectives as defined in the CS2DP. Out of the four projects proposed, two are selected for full implementation in the following areas:

- 1.5 M€ in FRC in relation to manufacturing process for main gearbox and interior thermoformed linings;
- 1 M€ in ENG in relation to the Repair of Fan Blade, High Pressure Turbine nozzle and Blisk;

One project is selected for partial implementation in the field of AIR with 0.5 M€ for activities related to Liquid Resin Infusion and/or In Situ Consolidation of thermoplastic for the outer wingbox).

Error! Reference source not found. shows the provisional allocation of funding per IADP/ITD and TA (in M€), following the different evolutions recorded in 2021 and as depicted above.

State of play as of October 2021

IADPs / ITDs / TAs	Allocation	Reapplication ECO	Reapplication SAT	TE	Allocation incl. TA Redistribution
LPA	484.12	8.00			492.12
REG	105.47	2.40			107.87
FRC	190.39	3.00			193.39
AIR	288.22	7.00	24.45		319.67
ENG	282.15	7.50	17.15		306.80
SYS	216.97	3.50	23.83		244.30
TE GAM		-	-	13.34	13.34
ECO GAM		6.06	-		6.06
SAT GAM		-	3.00		3.00
Thematic Topic	30.15	1.60	-	0.92	32.67
TOTAL	1597.48	39.06	68.43	14.26	1719.23
Deviation wrt max. funding value of 1,716 M€ (over commitment)					- 3.23

Table 2 - Indicative Distribution of Funding (in M€): Operational budget to completion per IADP/ITD/TA (25 October 2021)

Notes:

- (1) TE: activities are performed within the TE and not within the IADPs/ITDs.
- (2) ECO: €6.06 million estimated funding for the ECO TA coordination and monitoring through its GAM. The remaining ECO TA funding will fund technical activities in the IADPs/ITDs and/or be re-assigned to technology development.
- (3) SAT: €3.0 million estimated funding for coordinating and monitoring within the TA through its GAM. The estimated balance (€68.43 million) is redistributed to the AIR/ENG/SYS ITDs in accordance with the information received from SAT Leaders and confirmed by Leaders in September 2021).

As depicted in Table 2 (2021) above, the ECO and SAT transverse areas (i.e. implemented across ITDs/IADPs with a specific funding assigned within each area of the Programme) remain stable with the following funding envelope:

- a total funding envelope of 68.43 M€ assigned to SAT (67.95 M€ last year);
- a maximum total funding envelope of 39.06 M€ assigned to ECO-TA

In absence of confirmation mid-2018 of all planned topics until the last call for proposals and in light of the Programme funding execution available at the end of 2017, the JU has mitigated the risk of non-execution of the CfP envelope - as set out in the Regulation, a minimum value of 30% of the Programme funding shall be assigned to Partners through competitive calls - via the inclusion of a new type of topic called “Thematic Topic” from the eighth call for proposals onwards. This new mechanism was partially funded by the reduction of Partners activities in the different areas of the Programme.

Over the last four calls for proposals (CfP08-CfP11), 14 thematic topics were launched in total, representing 25 proposals with a total funding request of approx. €34 million (incl. contribution to ECO TA and TE), exceeding the maximum funding available at Programme level by approx. 3.3 M€ at the end of 2021. As compared to 2020, this “over-commitment” value is reduced by 6.8 M€ as a result of adjustments made in the funding initially forecasted for calls and variations observed in the members’ activities.

Together, these topics successfully contributed to widen the participation in the CS2 Programme, allowing for innovative solutions proposed outside a strict “pull” from the Members’ technology development and demonstration activities.

The current distribution of the Programme funding between the different category of participants (Leaders, Core Partners and Partners) is given in the following table:

State of play as of October 2021

Funding envelope to completion (in M€)	Allocation according to CS2 Regulation		2021 CS2DP	
	in %	in M€	in %	in M€
Leaders	<40%	<686.4	39.1%	673.06
		LPA	38.9%	191.57
		REG	43.1%	46.53
		FRC	37.2%	71.93
	IADPs/ ITDs/ TAs	AIR	36.6%	117.13
		ENG	40.2%	123.45
		SYS	43.6%	106.62
		TE	50.7%	6.77
		ECO	100.0%	6.06
		SAT	100.0%	3.00
Core Partners	<30%	<514.8	29.5%	506.67
		LPA	30.0%	147.73
		REG	29.0%	31.26
	IADPs/ ITDs/ TAs	FRC	29.9%	57.86
		AIR	32.9%	105.28
		ENG	33.6%	102.98
		SYS	25.2%	61.57
Calls for Proposals / Tender	>30%	>514.8	31.4%	539.50
TOTAL	<u>1716.00</u>		<u>1719.23</u> <u>(max. funding of 1716.00)</u>	
Of which Thematic Topics in CfPs			32.67	
Of which over commitment			3.23	

Table 3 - Distribution of estimated funding between Leaders, Core Partners and Partners/Tenders

Notes:

(1) Leader and Core Partner shares may evolve over the Programme lifetime.

(2) Figure for Calls for Proposals/Tenders shows the balancing figure to €1 716 million and is subject to change.

As depicted in **Error! Reference source not found.:**

- the budget assigned to Leaders and Core Partners has not yet reached the maximum value as defined in the regulation and this complies with the obligations as set by the regulation i.e. not to exceed 30% for CP/L;
- the funding value of activities proposed for implementation in the Programme currently exceeds the maximum funding available for operational activities in Clean Sky 2 by

approximately 3.3 M€. This “over-commitment” (corresponding to less than 0.1% of the Programme funding) should be reduced at Programme end in light of the lesson learnt from the Clean Sky Programme experience and is deemed necessary in the ongoing implementation phase of the Programme to meet the minimum funding of 30% assigned to Partners activities. Over the next two years (end 2023), there is a need for the JU to anticipate any project failure, delays in execution of projects or rejection of costs claimed on ineligibility grounds, leading to a lower execution rate than expected for Grant Agreement for Partners (GAP projects from CfPs). The overall situation is therefore mitigated by means of an “over-commitment” of activities to be funded without offsetting the current Programme content and will be monitored on a yearly basis by the JU. This “over-commitment” should be compensated at Programme end from GAP under-execution (~2% observed on projects already closed);

- where necessary, adjustment to the funding is planned in the final years with a view to ensure alignment with maximum funding available of 1716 M€ allocated to the overall Programme.

11. Clean Sky 2 Programme Implementation to date

11.1. Summary of Call results to date – Calls for Core Partners

With Clean Sky 2 now operating for over six years, all four Core Partner Calls that were foreseen for the Programme have been successfully launched and closed. The conclusion of the negotiations for the fourth and final Call for Core Partners took place at the end of 2017. This completed the selection process for the Clean Sky 2 Core Partners and for the membership, on time with respect to the planning made at the start of the Programme.

On the basis of the four calls launched, and the successful grant implementation with the candidate Core Partners resulting from these calls, the JU has established a preliminary planned allocation over the Programme's life of approximately 98% of the foreseen Core Partner funding (which is up to €514.8 million according to the Regulation). The remaining "unallocated" Core Partner funding, included in their funding budget, provides a healthy contingency margin and will allow for flexibility in the downstream management of the Programme in bi- or multi-annual Work Plans and GAMs.

When disregarding multiple winning applications leading to participation as Core Partner via more than one call and/or in more than one IADP/ITD, the net number of Core Partners incl. their affiliates and linked third parties acceding to the Programme on the basis of Calls for Core Partners is over 190 with roughly 50 SMEs participating (disregarding those applications that led to participation as Core Partners via more than one call and/or in more than one IADP/ITD). The Members originate from 22 different countries: 18 Member States and four countries associated to Horizon 2020 [Israel, Norway, Switzerland and Turkey].

A detailed list with the Members participating in the CS2 programme is available on the CS2 website¹ and is updated on a regular basis.

11.2. Summary of Call results to date – Calls for Proposals

In the six years since the Programme's start, a total of eleven Calls for Proposals (CfPs) were successfully launched, with the last one closing at the end of 2020 with the grant preparation completed. Call eleventh therefore completes the Partners' Cycle foreseen for the Clean Sky 2 Programme.

Since 2018, the JU has included Thematic Topics in the planning of the Calls for Proposals. These topics contribute to the progress towards the high-level goals in the CS2 JU Basic Act and are not specifically linked to one IADP/ITD [demonstration activities/strategy], meaning they are not "inside" one of the current IADPs/ITDs. When including the eleventh call, the JU successfully launched 14 thematic topics (100% success rate), representing 25 proposals with a total funding request of approx. €34 million.

Overall, these eleven calls are engaging more than 806 partners from 28 different countries with a strong SME involvement in terms of participation and grants awarded: SMEs make up 40% of the partners selected, requesting 25% of nearly €537 million in EU funding launched via the eleven calls for proposals. Altogether, these CfP calls represent 543 projects, of which 372 are still running as of today. Most of them (70%) will be completed by November 2022 whereas 30% are expected to close at the end of December or beyond 2022.

¹ <http://cleansky.eu/members-0>

As mentioned under Chapter 10, the “over-commitment” at programme level is reduced in 2021 to €3.22 million (€10.10 million last year). The difference will be compensated by the end of the Programme with the under-execution expected in the implementation of GAPs (98% of execution is observed after the closure 171 GAP projects). It is thus of critical importance that GAP projects are executed as per initial planning with no extension beyond November 2022.

11.3. Programme execution to date (Leaders and Core Partners)

The below graph provides the funding execution profile until Programme completion for the Members’ activities (considering that Partners’ activities follow the same trend) and shows the evolution in comparison to CS2DP 2020. The funding percentage mentioned for a given year corresponds to the cumulative level of funding achieved at the end of the given year.

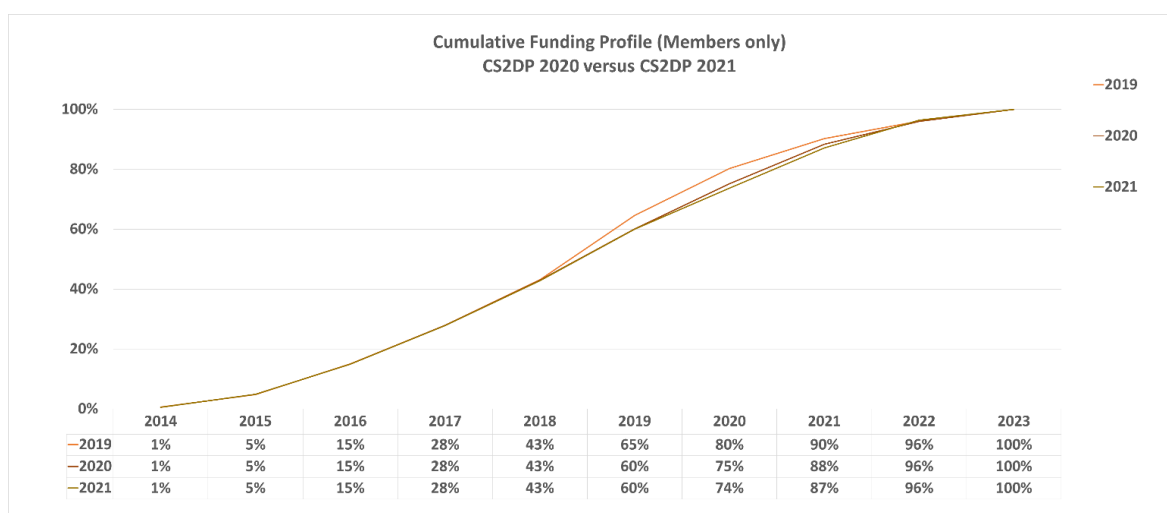


Figure: Funding profile for Members’ activities (GAMs) - State of play: October 2021

The overall picture can be summarised as follows:

- 75% of programme effort and funding reached early 2021;
- Manufacturing phase initiated together with testing and delivery of results;
- 30% of demonstrators to be completed by end 2021 after recovery of COVID-19 impact

12. CS2 Links to Other Programmes

12.1. Synergies with other European, national and regional programmes

In accordance to its founding Council Regulation of May 2014, Clean Sky 2 has been called to develop synergies with the European Structural Investment Funds (ESIF). To meet this target, Clean Sky 2 has implemented a coherent and comprehensive policy strategy and an action plan on synergies with Member States and Regions which are interested in investing ESIF within the aeronautics R&I area and other related technologies. In this regard, Clean Sky 2 has developed a closer interaction with interested Member States (MS) and Regions in Europe by discussing strategies and possible cooperation via a tailor-made approach as well as designing modalities of cooperation - depending on the level of interest, the regional stakeholders' base, and the commitment which a Member State/Region may decide to engage with.

To support and implement such synergies with ESIF, Clean Sky 2 has encouraged the applicants to the calls to submit complementary activities during either the submission or the implementation of a project. While in the context of the cooperation with Member States/Regions, Clean Sky 2 has promoted the signing of a Memorandum of Understanding (MoU)¹, which is an important and effective instrument and provides a strategic approach and the opportunity to discuss in advance with MS and regional authorities ways to stimulate synergies. The MoU follows the regional strategy/RIS3 and the applicable ESIF regional funding instruments that can identify thematic objectives or align the regional funding instruments to support possible pilot projects². A quality label has also been awarded to the complementary activities via an independent evaluation process. This "Clean Sky Synergy Label" can provide an incentive effect and a guarantee of success for Member States/Regions to invest in the projects, support actions, local capabilities and infrastructures of national and/or regional importance.

By October 2021, eighteen MoU have been signed with Member States/Regions and more than sixty Member States/Regions have been identified to include aeronautics or areas which correlate to the Clean Sky 2 Programme as thematic areas/priorities for ESIF funding within their RIS3. Additionally, twelve Clean Sky Synergy Labels have been awarded to complementary activities, related to Clean Sky Programme, while more than fifty-two pilot projects have been supported by ESIF with a budget of more than €50 million.

The coherence and complementarity with National Programmes in the Member States is also considered by the States Representatives Group and, when appropriate, directly with Agencies in charge of any programme which may provide inputs for the execution of the Clean Sky activities.

Clean Sky 2 currently continues to monitor, support and encourage the implementation of the current MoU. The effective and operational implementation of some MoU has resulted in the increase of the submitted pilot projects and the expectations for more in Horizon Europe. In addition, Clean Sky 2 is exploring and planning how the EPCA will enable strategic cooperation with Member States' and associated countries' national and regional programmes. These initiatives will not only leverage efforts and create synergies and multiplier effects across technology domains, but also across European, national and regional boundaries. Combining resources and funding will produce a substantial leverage effect, and help reach the challenging objective of deep

¹ <http://cleansky.eu/structural-funds-and-regions>

² Article 37 of the H2020 RfP provides that, in case of cumulative funding, the grants may not cover the same cost items.

decarbonisation. In this context, the EPCA will review the MoU policy procedure in order to ensure more effective synergies and investments in the sector. Shared roadmaps and alignment of programmes will be considered at both national and regional level. The interested MS and regions should ensure their intention to invest in aeronautics activities related to Clean Aviation Programme and objectives and should provide long-term financial commitments.

Based on the lessons learnt and the best practises by Clean Sky 2, the new Clean Aviation partnership will continue to promote and implement a strategy for more effective and efficient synergies, as well as a strengthened cooperation with the 'aeronautics' Member States and Regions. These synergies can be also built on the significant efforts and results stemming from national programmes in the EU Member States, and can stimulate a smart use of structural funds directed via the Research & Innovation Smart Specialisation Strategies in the next framework programme.

The new framework programme Horizon Europe¹ encourages synergies not only with ESIF but also with other EU programmes and funding schemes. In this context, Clean Sky 2 is currently also exploring and planning how the EPCA will enable synergies with other European Partnerships and EU Research Programmes.

12.2. Clean Sky 2 - SESAR & SESAR 2020 coordination

Clean Sky 2 is focused on aircraft-based and aircraft performance-driving technology development culminating in demonstration-based validation. Yet it is obvious that the full benefit of these technologies will only be achieved if they are compliant with and can be fully integrated in overall future air transport system defined by SESAR/SESAR 2020, NextGen and similar initiatives. The compatibility of Clean Sky 2's work with the overall principles and concepts of operations of SESAR/SESAR 2020 (and through these European initiatives with the overall global air transport system) is a key objective to be met in Clean Sky 2. Cooperation, compatibility and consistency between activities and developments in Clean Sky 2 (especially for flight procedures and Extended Cockpit where direct implementation of SESAR/SESAR2020 regulations will be performed) and the objectives of SESAR/SESAR 2020 (in terms of Concepts of Operation and ATM rules) is crucial for the success of both programmes.

Clean Sky 2 has implemented an effective interface with SESAR 2020 at executive, programme and technical levels with regular meetings and involving the Systems ITD and the Regional and Large Passenger Aircraft IADPs. A Memorandum of Cooperation (MoC) was signed between the two Joint Undertakings in December 2015.

The purpose of this MoC is to establish a cooperative framework between the Parties that contributes to the sustainable development of the European air transport system through an effective implementation and integration of some areas of their respective Programmes. The scope of this framework includes the following objectives:

- Sharing the scope of activities at WP level and coordinating where relevant between each JU's development, validation and demonstration activities, while mitigating gaps or overlaps between the work programmes;
- Exchanging information about the calls to be launched by each Party and topics related to avionics/ATM/environmental aspects, including agreement on sharing information during the grant implementation and technical activities (e.g. via the periodic reviews);
- Pursuing consistency between work programmes with regard to the definition of the performance targets, in particular regarding environmental targets;
- Exchanging periodically on the progress achieved in their respective work programmes;

¹ Any action within the context of Horizon Europe will depend on the proposed European Partnership on Clean Aviation being confirmed.

- Coordinating and implementing relevant activities at the aviation, aeronautics and air transport level and agreeing joint communication actions where relevant and feasible.

Upon the request of either JU, dedicated common reviews may be jointly implemented, and common meetings with the participation of respective industries organised. The respective JUs may also establish coordination on possible cooperation with other EU bodies.

12.3. Clean Sky 2 - EASA coordination

Based on the MoC, monthly meetings between Directors / Heads of Units are held, while Technical Coordination meetings and dedicated workshops on different areas are regularly organised. The scope of the collaboration is to understand the potential impact of technological development on the evolution of standards and the certification of components and systems for the application in future aircraft or equipment. The focus herein is on :

- the Clean Sky 2 R&I activities under preparation or underway and related demonstrators and achievements and their potential impact on future safety management system and certification processes and requirements;
- shared understanding of the results of other EC collaborative and coordination programmes;
- the topics in the EASA research plan, as basis for consideration of the CS2JU members;
- supporting the preparation of EASA's role in the environmental monitoring and reporting, such as but not limited to the European Aviation Environmental Report.

Share and make use of established approaches achieved in Horizon 2020, in Aviation Safety projects as an option for the engagement of EASA in Clean Sky 2 projects.

For the JU private members, the possibility to use EASA resources through a direct route in terms of technical expertise to the projects (against cost recovery as defined in EASA's procedures) allows Clean Sky 2 members to contract directly for supporting activities and for these to be eligible costs.

As with SESAR, a regular exchange of information exists between the JU and EASA on the projects and actions underway in order to identify topics of potential interest. In several topics launched by the CS2JU, EASA have expressed an interest in participating in the monitoring of progress and/or the results of the R&I actions; and agreements between the JU, EASA and the Beneficiaries are in place to adequately cover this.

The CS2JU contributes significantly to the EASA mandate to monitor and report on European aviation's environmental impact through the working groups and steering bodies related to inter alia the European Aviation Environmental Report, the next edition of which is planned for mid-2022.

Further exchange of information and regular coordination is done with respect to activities of common relevance, like CAEP working groups and other EU interests at ICAO level.

Annexes

A. Abbreviations

A/C:	Aircraft
ACARE:	Advisory Council for Aviation Research and Innovation in Europe
AIR:	Airframe (ITD)
ATA:	Air Transport Association of America
ATM:	Air Traffic Management
CAEP:	Committee on Aviation Environmental Protection
CS:	Clean Sky Programme
CS2:	Clean Sky 2 Programme
CS2DP:	Clean Sky 2 Development Plan
CSMM:	Clean Sky Management Manual
CDR:	Critical Design Review
CfP:	Call for Proposal
CfT:	Call for Tender
CNS:	Communication, Navigation and Surveillance
CoR:	Concept Design Review
CROR:	Counter Rotating Open Rotor
CS2JU (JU):	Clean Sky 2 Joint Undertaking
D&E:	Dissemination and exploitation
EASA:	European Union Aviation Safety Agency
EC:	European Commission
ECO:	Eco-Design TA
ENG:	Engines (ITD)
EPCA:	European Partnership for Clean Aviation
ESIF:	European Structural and Investment Funds
FRC:	Fast Rotorcraft (IADP)
FT:	Flight Test/Testing
GAM:	Grant Agreement for Members
GAP:	Grant Agreement for Partners
GB:	Governing Board
GRA:	Green Regional Aircraft (ITD)
GRC:	Green Rotor Craft (ITD)
GT:	Ground Test/Testing
ITD:	Integrated Technology Demonstrator
IADP:	Innovative Aircraft Demonstrator Platform
ICAO:	International Civil Aviation Organization
JTI:	Joint Technology Initiative
JTP:	Joint Technical Programme
LPA:	Large Passenger Aircraft (IADP)
MoU:	Memorandum of Understanding
MoC:	Memorandum of Cooperation
OoO:	Out of Autoclave
PDR:	Preliminary Design Review
PPP:	Public-Private Partnership
RIS3:	Regional Research and Innovation Strategies for Smart Specialisation
R&I:	Research & Innovation
SAGE:	Sustainable and Green Engines (ITD)
SAT:	Small Air Transport Transverse Activity
SESAR:	Single European Sky Air Traffic Management Research



SFWA:	Smart Fixed Wing Aircraft (ITD)
SGO:	Systems for Green Operations (ITD)
SPD:	Systems & Platform Demonstrators
SYS:	Systems (ITD)
TA:	Transversal Activity
TAC:	Technical Advisory Contract
TE:	Technology Evaluator
TP:	Turboprop

B. Detailed Overview of Clean Sky 2 Technology and Demonstration Areas

Detailed overview with the Demonstrator / Technology Streams (state of play September 2021 and all figures are indicative):

Theme	Demonstration area	Programme Area [IADP/ITD/TA]							Demonstrator / Technology Stream	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	→			→				AIR-D3-2 Optimised integration of rear fuselage (WP A-1.1, A-1.3)	→		→	478.5	146.5
									AIR-D3-3 UHBR integration [WP A-1.2]					
									LPA-01-D1: Enablers for Integrated Open Rotor Design					
									LPA-01-D10: UltraFan Flight Test Demonstration					
									LPA-01-D13: UHBR Short Range Integration					
									LPA-01-D16: Common Technology Bricks for Future Engines					
	Ultra-high Bypass and High Propulsive Geared Fans					→			ENG D4 Adv. Geared Engine Configuration (HPC-LPT)	→		→		257.6
									ENG D2 UHPE demonstrator for SMR Aircraft					
									ENG D6 VHBR – Large Turbofan Demonstrator UltraFan™					
									ENG D5 VHBR – Middle of Market Technology					
	Hybrid Electric Propulsion	→	→						REG Hybrid-Electrical Regional Aircraft Configurations Studies	→	→	→		24.0
									LPA-01-D9: Hybrid Electric Ground Test Bench					
	Boundary Layer Ingestion	→							LPA-01-D14: Boundary Layer Ingestion	→		→		8.3
	Small Aircraft, Regional and Business Aviation Turboprop	→							ENG D3 Business aviation / short range Regional TP Demonstrator	→	→	→		42.2
									ENG D8 Reliable and more efficient operation of small turbine engines					
									ENG D7 Small Aircraft Engine Demonstrator					
REG WTT Demonstrator for the innovative Propeller														

Theme	Demonstration area	Programme Area [IADP/ITD/TA]							Demonstrator / Technology Stream	Contribution *			Funding	Funding
		LPA	REG	FRC	AIR	ENG	SYS	SAT		E	M	C	RoM m€	RoM m€
Advances in Wings, Aerodynamics and Flight Dynamics	Advanced Laminar Flow Technologies	→			→				AIR-D3-10/11/12 - Extended laminarity [WP A-2.3]	→		→	190.6	86.1
									AIR-D3-6/8/27 - NLF BJ Nacelle / HTP & nacelle access doors demonstrator [WP A-2.1/A-2.2]					
									AIR-D3-7 NLF smart integrated wing [WP A-2.2]					
									AIR-D3-9 NLF Leading Edge GBD [WP A-2.2]					
									LPA-01-D11: Active flow control flight test demonstrator					
									LPA-01-D4: HLFC on tails large scale ground-based demonstrator					
									LPA-01-D5: Natural Laminar Flow demonstrator for HTP bizjets					
	Aircraft Wing Optimization	→			→				LPA-01-D6: Ground-based demonstrator HLFC wing	→	→	→	190.6	104.6
									AIR-D1-4/6 - ON-GROUND STRUCTURAL RIG FTB#2 WING [WP B-1.3, B2.2]					
									AIR-D1-5/8 - ON-GROUND ACTUATION RIG FTB#2 WING [WP B1.4, B3.2]					
									AIR-D1-7 Multifunctional Flap [WP B-2.2]					
									AIR-D2-17 SAT high lift demonstrator [WP B-2.2]					
									AIR-D2-18 Morphing Leading Edge Demonstrator [WP B-1.4]					
									AIR-D2-7 Innovative movables [WP A-4.1.2]					
									AIR-D3-17/18/19 - Novel Control [A-4.2]					
									REG D1 - Adaptive Wing Integrated Demonstrator – Flying Test Bed#1 (FTB1)					
									REG D1 - Adaptive Wing Integrated Demonstrator – OWB					
									REG D2 - High Lift Advanced Turboprop – Flying Test Bed#2 (FTB2)					
									REG WTTs demo for Innov. AirVehicle Technologies (DN, Morphing Flap, NLF, ...) (2B)					
Innovative Structural / Functional Design and Production System	Advanced Manufacturing	→	→		→			→	AIR-D1-9/10 & D3-20 - ON-GROUND STRUCTURAL COCKPIT FTB#2 [WP B-3.3]	→		→	217.5	68.3
									AIR-D2-15 Composite Wing for SAT [WP B-1.2]					
									AIR-D2-20/21/22 Empennage for Regional A/C (VTP, HTP, LE) [WP B-3.1]					
									AIR-D2-3 Flaperon [WP-A-3.1]					
									AIR-D3-21/23 - Aileron, fuselage panel jigless assembly for SAT [WP B-3.4]					
									AIR-D3-22 Joints Metal/Composite Structures for SAT [WP B-3.4]					
									SAT D2 Wing Smart Health Monitoring					
	Cabin & Fuselage	→	→		→				LPA-01-D2: Advanced Rear-end	→		→	217.5	138.1
									AIR-D1-1 Metallic Cargo Door [WP-A-3.3]					
									AIR-D1-16 & D3-26 Regional Aircraft Fuselage and Cabin Major Components Demonstrator [WP B-4.3, B-4.4]					
									AIR-D3-24 Cabin Parts for SAT structure [WP B-3.4]					
									D3 - Full scale innovative Fuselage & Pax Cabin demonstrator (Structural demonstration)					
	Innovative Solutions for Business Jets				→				LPA-02-D1: Multi Functional Fuselage Demonstrator			→		11.2
									LPA-02-D3: Lower Center Fuselage next generation					
									AIR-D2-1/2 - BJ Composite Wing Root Box [WP-A-3.1]					
									AIR-D2-4 Optimized BJ cockpit structure with load-bearing windshields (WP A-3.2)					
									AIR-D2-5 BJ Composite Half Central Wing Box [WP-A-3.3]					
									AIR-D2-6 BJ Composite Central Wing Box Panel [WP-A-3.3]					

Theme	Demonstration area	Programme Area [IADP/ITD/TA]							Demonstrator / Technology Stream	Contribution *			Funding	Funding
		LPA	REG	FRC	AIR	ENG	SYS	SAT		E	M	C	RoM m€	RoM m€
Novel Aircraft Configurations and Capabilities	Next-Generation Civil Tiltrotor			→	→				NGCTR Tiltrotor		→	→	265.9	111.1
				→	→				AIR-D1-13/14/15 NGCTR Fuselage Components		→	→		117.4
	RACER Compound Helicopter			→	→				RACER Compound Rotorcraft		→	→		117.4
				→	→				AIR-D1-2/3/11/12 RACER Airframe Components		→	→		117.4
	Aircraft Innovative Configuration	→	→		→				AIR-D3-1 Noise shielding tail plane (WP A-1.1)	→	→	→	265.9	37.3
									AIR-D3-4 Novel high performance BJ configuration (WP A-1.3)					
									REG Long Term (TP130 pax)					
									REG TP90 Pax Configuration (5C)					
									LPA-01-D3: Scaled flight testing					
									LPA-01-D8: Radical Configuration Flight Test Demonstrator					
Aircraft Non-Propulsive Energy and Control Systems	Electrical Systems						→		SYS D1 Aircraft Level 0 – Iron Bird integrated demo	→		→	184.8	102.8
									SYS D10. HVDC Power Management Centre Demonstrator for large A/C on PROVEN test rig					
									SYS D16. Thermal Management demonstration on AVANT Test rig					
									SYS D13. Next Generation Cooling systems					
									SYS D18. Fly by Wire for SAT					
									SYS D19. Electrical power generation and distribution for SAT	→		→		
									SYS D4 - Iron Bird					
									SYS D4. Innovative Electrical Wing					
									SYS D8. Innovative Power Generation and Conversion					
									SYS D9. Innovative Electrical and control/Command Networks for distribution systems - COPPER Bird®					
									SYS D3. Smart Wing Actuation Demonstrator					
									SYS D17. Advanced Landing Gear Sensing & Monitoring System	→		→		
	Landing Systems						→		SYS D21. Electrical landing gear for SAT	→		→	184.8	31.8
									SYS D5. Advanced Landing Gear Systems					
									SYS D6. Electrical Nose Landing Gear System					
									SYS D7. Electrical Rotorcraft Landing Gear System					
	Non-Propulsive Energy Optimization for Large Aircraft	→							LPA-01-D15: Non-Propulsive Energy	→		→		13.4
	Environmental Control System & Ice Protection System	→			→		→		AIR-D2-16/19 & D3-16 - Ultra low power ice protection [WP A-4.1.1.6, B-2.1, B-3.2]	→	→		36.8	
									AIR-D3-13 /14 EWIPS Integration on BJ Flap & Slat [WP A-4.1]					
									AIR-D3-15 Icing code for de-icing [WP A-4.1.1.3]					
									SYS D11. Next Generation EECS Demonstrator for Large A/C					
									SYS D12. Next Generation EECS Demonstrator for Regional A/C					
									SYS D14. Advanced Electrothermal Wing Ice Protection					
									SYS D15. Primary In-Flight Ice Detection Systems					
									SYS D20. Low power de-ice for SAT					
									REG IWT Demonstrator for the Low Power WIPS					

Theme	Demonstration area	Programme Area [IADP/ITD/TA]							Demonstrator / Technology Stream	Contribution *			Funding	Funding
		LPA	REG	FRC	AIR	ENG	SYS	SAT		E	M	C		
Next Generation Cockpit Systems and Aircraft Operations	Cockpit & Avionics	→					→		SYS D1. Extended Cockpit	→	→		146.2	134.5
									SYS D23. Affordable future avionic solution for SAT					
									SYS D24. Enhanced vision and awareness					
									SYS D25. Integrated Modular Communications					
									LPA-03-D1: Disruptive Cockpit Large Aircraft					
									LPA-03-D2: Regional Active Cockpit					
									LPA-03-D3: Business Jet Demonstrator					
	Advanced MRO	→							LPA-03-D4: Maintenance service operations enhancement demonstrator					11.7
Optimal Cabin and Passenger Environment	Passenger Comfort	→	→				→	→	SYS D22. Comfortable and safe cabin for SAT	→	→		54.0	16.0
									REG D3 - Full scale innovative Fuselage & Pax Cabin demonstrator (Comfort/Thermal demonstrations)					
									SAT D3 Safe and comfortable cabin					
									LPA-01-D12: Flight test demonstration of active vibration control technologies/noise prediction methods for rear-mounted engines					
	Innovative Cabin Passenger/Payload systems	→			→		→		SYS D2. Equipment and systems for Cabin & Cargo Applications	→	→			38.0
									LPA-02-D2: Next Generation Cabin & Cargo Functions					
									AIR-D2-8/9/10/11 Ergonomic flexible cabin [WP 5.1]					
									AIR-D2-12/13/14 BJ office centered cabin [WP A-5.2]					