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Executive Summary

Clean Sky today epitomises a true Public Private Partnership (PPP). It represents a strategic and successful input to the Europe 2020 objectives: boosting private investments in research and innovation and making the best use of public research funding in a vital and growing sector. Five years into the Programme, the step-change improvement potential targeted, such as up to 30% reduction in CO₂ emissions and (depending on the aircraft segment) 60% reduction in noise footprint, are all within reach. Stakeholder participation is a huge success: first time participation from many SMEs and their success rate in the Calls for Proposals is over twice that of any other FP7 instrument. Industry is increasingly using Clean Sky as the centrepiece of their R&T programmes because of the flexibility of the instrument; and the JU has proven its efficiency as management body.

The aeronautical sector, in particular through Clean Sky 2, will be a critical player in contributing to one of the key Societal Challenge ‘smart, green and integrated transport’ defined in Horizon 2020. The Clean Sky 2 Programme included in the ‘Innovation Investment Package’ will serve society’s needs and strengthen global industry leadership. It will enable cutting edge solutions for further gains in decreasing fuel burn and CO₂ and reducing NOₓ and noise emissions. It will contribute strongly to the renewed ACARE SRIA¹.

Clean Sky 2 will build on the success of Clean Sky and will deliver full-scale in-flight demonstration of novel architectures and configurations. Advanced technology inserted and demonstrated at full systems level will enable step-changes in environmental and economic performance and bring crucial competitiveness benefits to European industry. By jointly pursuing this research on new breakthrough innovations and demonstrating new vehicle configurations in flight, the Programme will provide the proving grounds for concepts that would otherwise be beyond the manageable risk of the private sector. It will give the necessary funding stability to the private sector to develop and introduce game-changing innovations within timeframes that are otherwise unachievable. Compared to the best available aircraft in operation in 2014, up to a 30% reduction in fuel burn and related CO₂ emissions, similar or greater reductions in NOₓ emissions and up to a 75% reduction in noise affected communities will accrue from this focused and programmatic approach. These pace-setting gains will enable the European Aviation Sector to satisfy society’s needs for sustainable, competitive mobility towards 2050. By doing this, Clean Sky 2 will be the key European instrument to speed up technology development, overcome market failure and guarantee a sustainable advancement of aviation. Clean Sky 2 will significantly contribute to the Innovation Union, create high-skilled jobs, increase transport efficiency, sustain economic prosperity and drive environmental improvements in the global air transport system.

The proposed Clean Sky 2 Programme will be jointly funded by the European Commission and the major European aeronautics companies, and will involve an EU contribution from the Horizon 2020 Programme budget of €1.8 bn. It will be leveraged by further activities funded at national, regional and private levels leading to a total public and private investment of €4.05 bn. Clean Sky 2 will run for the full duration of Horizon 2020 actions, i.e. from 2014 to 2023. A phased approach will be taken to the start-up of Clean Sky 2 projects and align them closely and adequately with Clean Sky on-going projects (to be completed in the period 2014-2016). It will be endorsed and supported by the leading European aeronautical research organisations and academia. Small and medium-size enterprises and innovative sub-sector leaders will continue to shape promising new supply chains. In so doing, Clean Sky 2 will engage the best talent and resources throughout Europe and over 3,000 highly skilled staff (FTEs) will be consistently employed over a ten year period.

¹ Advisory Council on Aviation Research in Europe, Strategic Research and Innovation Agenda (2012)
1 The Strategic Context: Meeting the Challenges set in Horizon 2020

As underlined in the EC Communication of July 2013\(^2\), progress is slow towards the Europe 2020 objective of investing 3% of GDP in R&D, with particular weaknesses in private investments. **Clean Sky** as a Public-Private-Partnership (PPP) is noted as a proven instrument delivering innovations, by combining the efforts from both public and private stakeholders.

The European Aeronautics sector, as provider of almost half of the worldwide fleet, is of sovereign importance to the European Union and its Member States. It helps to meet society’s needs by:

- Ensuring competitive mobility solutions for passengers, freight and public services;
- Minimising aviation’s impact on the environment through key innovations in products and services;
- Providing highly skilled jobs, generating significant economic growth and creating wealth;
- Significantly contributing to the balance of trade and European competitiveness;
- Supporting Europe’s knowledge economy through substantial R&D efforts and deep supply chains.

Continued long-term public-private investment has made the European Aeronautics industry globally competitive, allowing it to drive the innovation agenda in many areas, including environmental performance. But the new challenges identified in ACARE SRIA highlight the need for more accelerated innovation and for more far-reaching solutions. A continuation of the existing **Clean Sky JTI** will ensure new concepts are fully validated in order to accelerate the market adoption of step-change solutions.

The **Horizon 2020 Programme** notes as one key **Societal Challenge: smart, green and integrated transport**. The aeronautical sector is a critical player in reaching the goals set out in Horizon 2020, and a continued PPP through **Clean Sky 2** can deliver key outcomes spanning two of the key pillars defined in Horizon 2020 - **Societal Challenges and Industrial Leadership**:

- **Creating resource efficient transport that respects the environment.** Aeronautical research and innovation in Horizon 2020 and **Clean Sky** in particular must **finish the job** of achieving the ACARE SRA goals as set for 2020;
- **Ensuring safe and seamless mobility.** New concepts will allow the air transport system meet the mobility needs of citizens: more efficient use of local airports, faster connections and reduced congestion;
- **Building industrial leadership in Europe.** **Clean Sky 2** will help protect and develop highly skilled jobs in Europe.

By pursuing joint European research on breakthrough innovations and demonstrating new vehicle configurations in flight, **Clean Sky 2** will enable investors to develop and introduce game-changing innovations in timeframes otherwise unachievable, and create an ‘**Innovation Urgency**’. In doing so, **Clean Sky 2** will significantly contribute to the **Innovation Union**, create high-skilled jobs, increase transport efficiency, sustain economic prosperity and drive environmental improvements worldwide, reinforcing Europe's role in leading the fight against Climate Change by positively contributing to lower emissions through technological advancement whilst enabling mobility to be sustained.

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2 The Clean Sky Joint Technology Initiative: Progress to Date

Progress to Date

The Clean Sky Joint Technology Initiative started in 2008, and constitutes an industry-wide, coherent programme totalling €1.6 bn, equally shared by the European Union and European Aeronautical Industry. It targets very significant environmental gains: 30% reduction in CO\(_2\), at least 6 dB less perceived noise per operation and 60% less NO\(_X\) emissions versus a 2000 reference. Clean Sky aims to mature and integrate technologies into system level architectures, such as (full) engines, electrical systems, structures and innovative wings, and validate these through large-scale demonstration.

Demonstrations in Clean Sky cover a wide array of application areas and scope. Around 20 important large-scale demonstrators are currently being readied for their test and evaluation, on ground or in flight. The first half of the Programme was dedicated to design, partial tests; and the start of manufacturing and key programme gates. By mid-2013, the two first demonstrators from SAGE (Sustainable and Green Engines), the large advanced turbofan engine and the turboshaft engine were undergoing ground tests. Other major demonstrators will be achieved by 2015/2016, like a low-drag wing on an A340 test aircraft, an electrical environmental control system on an ATR-72, low-noise helicopter trajectories and the ground test of a Counter-rotating Open Rotor (CROR). Clean Sky achieved 50% execution of the technical programme during 2012, corresponding with the mid-point of the programme. The annual budget execution rate and the rate of achievement of milestones and deliverables in Clean Sky are in line, and all demonstrator projects are under control.

Clean Sky’s environmental objectives can be considered achieved only when the demonstrators are run and the maturity of the technologies is confirmed. In the meantime, the technologies are selected and tested, allowing an increasingly precise forecast of the expected results. Data concerning efficiency, fuel consumption, weight, aerodynamic performance, etc. allow the Technology Evaluator (TE) to perform the assessments of Clean Sky’s progress towards its stated environmental goals, and simulate their impact at aircraft, airport and full air transport system levels. The first assessments performed early 2012 and early 2013 by the TE strongly underlined that Clean Sky was on the right track with respect to its objectives. These performance levels demonstrate that Clean Sky also forms the major contribution to the ACARE targets for the environment for 2020\(^3\) as formulated in the Strategic Research Agenda. These were formulated as the availability of technology available for use in development programmes in case of market needs that were capable of delivering the following reductions when compared to the relevant benchmark aircraft from 2000:

- 50% reduction in CO\(_2\) emissions per ton-km;
- 80% reduction in NO\(_X\) emissions per ton-km;
- 50% reduction in perceived noise;
- And a substantial improvement in the aircraft lifecycle impact on the environment.

Thus Clean Sky’s key goal of delivering ‘up to 75% of the vehicle technology gains’\(^4\) required is fully being met.

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\(^3\) The ACARE SRA targets include: 50% reduction in CO\(_2\), out of which 40% are expected from aircraft (vehicle) technologies and 10% from ATM and operations.

\(^4\) Clean Sky Programme Proposal 2007
The Clean Sky JTI is itself a successful demonstrator. It is successfully demonstrating the relevance of the instrument: pursuing integrated, high readiness technologies, connected to market needs, having the full European aeronautical sector working together to common objectives. Clean Sky successfully links major players of the European aeronautics industry and research organisations, SMEs and academia. The evidence is clear in respect to the leverage effect that Clean Sky has achieved within European aeronautics research and innovation. With Clean Sky as ‘flagship’, a significant number of topical research activities have spawned outside the Joint Undertaking, varying from national aeronautics programme projects to private-venture funded actions, further underlining the benefit of a programmatic approach with clear goals and metrics. In particular, several Member States and stakeholders from within ACARE have shown a deep interest in the Clean Sky approach to monitoring progress through its Technology Evaluator.

**Participation**

As of September 2013, more than 550 participants from 24 Member States are actively involved in the implementation of the Programme. Overall participation shows a very healthy mix of large industrial players, SMEs, academia and research organisations.
Partners (who represent 86% of the participants) are selected through Calls for Proposals. These calls are especially well suited to SMEs, due to the focused definition of work and to the fact that candidates can apply individually, via a simplified process – or build a small consortium. To date, 36% of the budget for Partners has been awarded to SMEs and over 60% of the SMEs participating in Clean Sky are first-time participants in the European Framework Programme. Through Clean Sky, many newcomers have found an easier entry point into the European Research Area, and created new links into “big industry”. This is an important enabler for the strengthening and deepening of European supply chains. Despite the “downstream research” nature of Clean Sky, academia is remarkably well represented. More than 80 academic institutions are engaged as participants.
3 The Rationale for Clean Sky 2

Beyond Clean Sky – the rationale for next steps in Clean Sky 2

Clean Sky 2 will be a natural continuation to progress achieved in Clean Sky, which will end upon completion of the 7th European Framework Programme (FP7). Close alignment in time and in content between projects of Clean Sky 2 to its predecessor will allow for a seamless transmission of technical progress. Depending on the technology readiness level (TRL) reached at the end of Clean Sky, and on the results of the demonstrators, several technologies will achieve sufficient maturity to become available for development activity towards future aeronautical products whereas others will need to be strengthened through a further step of maturation within a Research and Innovation environment. For some of the most innovative and promising technologies worked on in Clean Sky, the preparation of the associated demonstrators shows that a higher level of integration will be needed. This next step - demonstrating representative full-scale vehicle architectures - should give the required confidence to market players to invest in break-through innovation. This will also allow the Clean Sky 2 Programme to explore the interactions between Clean Sky technologies and those matured outside Clean Sky but still paramount for aircraft integration. The technological improvements instilled through Clean Sky 2 will underpin major advances in the next generation of aircraft by mastering the technologies and the risks, to meet the next market window to replace the current fleet.

Ensuring a continuation of the Aeronautical JTI with Clean Sky 2 will enable Europe to:

- Develop innovative energy efficient aircraft that operate worldwide and meet environmental and societal targets for more efficient, safer and environmentally friendly air transport;
- Achieve its strategic social priorities with sustainable growth, creation of wealth and stable employment in fields of high technology;
- Win global leadership for European aeronautics and its supply chain, including academia, ROs and SMEs.

The economic context

On average, 12% of aeronautic sector revenues, representing almost €7 bn per year for civil aeronautics alone, are reinvested in Research and Development (R&D) and support around 20% of aerospace jobs. The European aeronautics sector is a vital contributor to society and economy. The industry accounts for approximately 3% of EU workforce, generates roughly €220 bn of the European GDP per year and contributes positively to the EU’s trade balance with over 60% of its products exported. Every Euro invested in aeronautics R&D creates an equivalent additional value in the economy every year thereafter:

- The aeronautics sector is a key contributor to the European economy and the EU’s balance of trade;
- Continued growth in demand for air travel raises new environmental and socio-economic challenges;
- Research and innovation is core to EU competitiveness and drives sustainable value creation.

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5 ACARE SRIA for 2020-2050, p. 4.
6 ACARE SRIA for 2020-2050, p.7; export figure refers to 2009.
Meeting society’s requirements

Aviation is and will remain a vital enabler of our economy and society. Air traffic is forecast to grow by 4% to 5% per year in the next decades leading to a 4-7-fold increase in traffic by 2050\(^7\). This poses major environmental, societal and economic challenges that can only be tackled through an intense and sustained cooperation between public authorities, industry, research organisations, academia and SMEs.

The renewed ACARE SRIA was completed in 2012, with ambitious goals for a sustainable and competitive aviation sector. These include a 75% reduction in CO\(_2\) emissions, a 90% reduction in NO\(_X\) and 65% in perceived noise by 2050 compared to 2000 levels, and 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. Building on the substantial gains made in Clean Sky, Clean Sky 2 aims at meeting the overall high-level goals with respect to energy efficiency and environmental performance shown below\(^8\):

<table>
<thead>
<tr>
<th></th>
<th>Clean Sky 2 as proposed*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO(_2) and Fuel Burn</td>
<td>-20% to -30% (2025 / 2035)</td>
</tr>
<tr>
<td>NO(_X)</td>
<td>-20% to -40% (2025 / 2035)</td>
</tr>
<tr>
<td>Population exposed to noise / Noise footprint impact</td>
<td>Up to -75% (2035)</td>
</tr>
</tbody>
</table>

* Baseline for these figures is best available performance in 2014

The overall socio-economic and environmental benefits of Clean Sky 2 will go well beyond the impact of Clean Sky. With increasing demand for air travel, the market opportunity is larger and the environmental need is greater than when the original Clean Sky proposal was drafted. The Programme needs to build on the first phase of work but it also needs to be more ambitious 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.

\(^7\) European Commission, DG Transport and Mobility, http://ec.europa.eu/transport/modes/air/environment, 29.05.2012.

\(^8\) These figures represent the additionality of Clean Sky 2 versus the 2014 Horizon 2020 Start Date.
**Clean Sky 2 economic & environmental benefit**

The proposed 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 Bn. The direct economic benefit is estimated at ~€350-€400bn and the associated spill-over is of the order of €400bn. These figures are additive with respect to the Economic Value Added expected from Clean Sky, thus proving the compelling case for Clean Sky 2.

As a result of the higher growth forecast, the environmental case for continuing the Programme into a second phase is even more compelling with an estimate of the CO₂ saving potential of 4bn tonnes through Clean Sky 2. These 4bn tonnes of the CO₂ to be saved from 2020 to 2050 will be additive to the approximately 3 bn tonnes achievable as a consequence of the Clean Sky Programme.
Mastering the extended European Research and Innovation chain

The Horizon 2020 period will be decisive for delivering the innovations defining this century’s fleet and its environmental footprint. Clean Sky 2 results will be applicable to 75% of the world fleet needing replacement\(^9\) up to 2050, and Clean Sky 2 technology will be able to address aviation emissions totalling over 70% of the worldwide civil air fleet\(^10\).

Mastering the extended European research and innovation chain is a prerequisite to sustaining global competitiveness. In the past 5 years, Clean Sky has become the single most important instrument to address large research topics of advanced maturity up to the demonstration of integrated complex systems, in parallel with the ATM R&D in SESAR. The set-up as JTI has proven to be by far the most effective way to ensure that all relevant European stakeholders (including academia, research organisations and SMEs) cooperate in developing the most promising technologies towards future industrial application. With Clean Sky 2 building upon Clean Sky results it can uniquely further engage and align all the stakeholders in the European value chain and facilitate technology integration, up to vehicle test beds. Clean Sky 2 will trigger research investments from both public and private sector players, and permit the pooling and aligning of the required capacities and capabilities from across Europe so as to deliver the innovation and growth needed and thereby be a driving force for further investment well beyond its own technical scope.

Spill-over effects of aeronautical industry

Aeronautical technologies are a proven catalyst for innovation and spill-over into many other sectors\(^11\). The main reasons are the severe performance, environmental, weight, 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, historically after an aeronautical application, with the contribution of large investments, skills and efforts to meet the severe requirements, a technology is extended to another field allowing it to achieve a competitive advantage and stay on the technology leading edge. Aeronautics has been the first-user promoter of many new technologies or processes which later spread over many other application fields. A well-known example relates to high-performance cars. Many parts, components, design techniques, manufacturing processes, project management principles, are directly derived from the aeronautical experience.

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\(^9\) Based on the proportion of the short to medium range aircraft in the global that will need to be replaced. Data derived from the Airbus Global market Forecast 2011-2030.


4 Clean Sky 2 Set-up

Building on Clean Sky: the structure of Clean Sky 2

Clean Sky has demonstrated clear benefits in terms of accelerating technology development. Major developments are being made possible in different systems such as optimized wing designs, new fuselage construction concepts, energy efficient engine architectures, new flight guidance systems and ‘more electric’ on-board systems. These technological advances need to be integrated into complete aircraft to render the next generation of air vehicles more efficient and reduce emissions and noise. In addition, new vehicle configurations will have to be evaluated with flight demonstrators as they will be essential to fulfil the ambitious objectives of renewed ACARE SRIA.

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. Clean Sky 2 will continue to use the Integrated Technology Demonstrators (ITDs) mechanism when appropriate. Its objective-driven agenda to support real market requirements providing the necessary flexibility is well suited to the needs of the major integrator companies. The new Programme will also focus on reinforcing interactions between demonstrations of improved systems for a better integration into viable full vehicle architectures. The Clean Sky 2 structure will involve demonstrations and simulations of several systems jointly at the full vehicle level through Innovative Aircraft Demonstrator Platforms (IADPs).

As in Clean Sky, a dedicated monitoring function - the Technology Evaluator (TE) - spanning all technology development and demonstration will be incorporated in Clean Sky 2.

Finally, a small number of key areas will be co-ordinated 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.

• Innovative Aircraft Demonstrator Platforms (IADPs)

IADPs will 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 proposed 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 “integrated approach” that a JTI-based research programme can provide is not feasible using other instruments typical of the former Framework Programmes (e.g., Level 1 / Level 2 projects). 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 Call for Proposals;
• Feedback to ITDs on experiences, challenges and barriers to be resolved in the longer term;
• A long-term view to innovation and appropriate solutions for a wide range of issues.
• **Integrated Technology Demonstrators (ITDs)**

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 maturing 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 comprising topics affecting the global vehicle-level design;
- Engines for all propulsion and power plant solutions;
- Systems comprising on all board systems, equipment and the interaction with the ATS.

• **The Technology Evaluator (TE)**

A Technology and Impact Evaluation infrastructure is an essential element within the Clean Sky PPP and will be continued. Impact Assessments such as at Airport and ATS level currently focused on noise and emissions will be expanded where relevant for the evaluation of the Programme’s delivered value. Where applicable they can include the other impacts, such as the mobility or increased productivity benefits of Clean Sky 2 concepts. The TE will also perform evaluations on aircraft “Mission Level” to assess innovative long term aircraft configurations.

• **Transverse Activities**

Some activities can be relevant for various IADPs and ITDs. These “Transverse Activities” do not form a separate IADP or ITD, but are an integral part of the other IADPs and ITDs. A dedicated budget will be reserved inside the concerned IADPs and ITDs to perform these activities. Leaders will be nominated for each Transverse Activity. So far, two Transverse Activities are agreed for Clean Sky 2:

- ECO-Design: looking at the whole life cycle of the developed technologies, components and vehicles;
- Small Air Transport (SAT): looking at airframe, engines and systems technologies for small aircraft, with a dedicated attention brought to synergies with the other segments.
Membership and Governance of **Clean Sky 2**

Membership of *Clean Sky JU* will enable participation in the Governance of the Programme. The governance will be ensured through a Governing Board composed of Members and two advisory bodies providing further input and recommendations, and playing a coordinating role, namely the States Representatives Group (SRG) and the Scientific Committee.

Membership of the *Clean Sky 2* JTI will be formed by:

- The European Commission representing the Union and ensuring EU public policy;
- Leaders of IADPs and ITDs who will commit to achieve the demonstrator programmes and manage these throughout their full duration;
- Core-Partners who will make a substantial long term commitment towards a demonstrator programme with key competences and technical contributions aligned towards IADP and/or ITD high-level objectives.

Core-Partners will be chosen through open and competitive call mechanisms, guaranteeing a transparent selection of the best membership and strategic participation.

In addition, Partners will be invited to participate in specific topics and projects in the scope of a well-defined limited commitment. These partners will be selected in a transparent and competitive manner and chosen as a result of open calls for proposals (CfP).

With 60% of funding open to competition, *Clean Sky 2* will rely on a broad and wide participation where SMEs, research organisations and academia interact directly with key industry stakeholders. Up to half of this 60% competed part will be awarded to selected participants who will join the JU as Members, ensuring the long term Programme stability and coherent approach to meeting the relevant ACARE Goals. *Clean Sky 2* is expected to involve at least 800 participants from the European aeronautics players and also new entrants in this field. It is expected to strengthen the involvement of participants to *Clean Sky* so far, when selected again for future activities.
From *Clean Sky* to *Clean Sky 2*: principles of transition

A phased approach will be taken to the start-up of *Clean Sky* 2 projects. In very broad terms, in the first 4 years *Clean Sky* developed and demonstrated technologies up to TRL4-5. From approximately 2012 a selection of the most promising and mutually additive technologies are now being subsequently taken to TRL6 system level demonstration, by 2016 at the very latest. In specific cases, *Clean Sky* ITDs will bring a small number of high-potential - but less mature - technologies up to TRL4 through a focused effort during the 2014-17 period. These will not be validated at TRL6 within *Clean Sky* but can be good candidates for continuation in *Clean Sky* 2.

*Clean Sky* 2 IADPs will use the TRL validation from *Clean Sky* as a start to perform the necessary integration studies in the 2014-2017 timeframe. *Clean Sky* or *Clean Sky* 2 ITD level outputs will form a key input into the configuration and content of demonstrations. The ultimate down-select decision will however often involve other factors depending on maturity achieved in specific technologies and the risks associated to the actual TRL of a sub-system or system.

The activities within *Clean Sky* will be pursued until completion according to plan. Then the technology integration may be launched in a *Clean Sky* 2 IADP or, if the maturity at this point is deemed not sufficient for integration, the technology development will be continued as part of the relevant ITD. An IADP may start in *Clean Sky* 2 while some of the integrated technologies have not yet passed the final validation tests. The architecture and configuration trade-off studies can be launched in an IADP as soon as the specifications and interfaces of the components and subsystems to be integrated can be frozen. Consequently, the activities within *Clean Sky* ITDs can be completed according to their own work plan at the latest in 2016 while new activities are launched within *Clean Sky* 2 ITDs and IADPs according to a staggered schedule starting in 2014, the start of Horizon 2020, at the earliest.

In the figure below, the principles of transition management from *Clean Sky* to the proposed *Clean Sky* 2 Programme are shown. However, it must be noted that in *Clean Sky* 2 each ITD and IADP may develop a tailored approach and adopt its own timing because technology details, TRL maturity achieved in *Clean Sky* or specific needs require modifying the general approach.
5 **Clean Sky 2 – Introduction to the Programme Technical Content**

**Structure of the Clean Sky 2 Programme**

The *Clean Sky 2* Programme consists of four different elements, as shown in the picture below:

- Three Innovative Aircraft Demonstrator Platforms (IADPs), for Large Passenger Aircraft, Regional Aircraft and Fast Rotorcraft, operating demonstrators at vehicle level;
- Three Integrated Technology Demonstrators (ITDs), looking at Airframe, Engines and Systems, using demonstrators at system level;
- The Technology Evaluator (TE), assessing the environmental and societal impact of the technologies developed in the IADPs and ITDs;
- Two Transverse Activities (Eco-Design, Small Air Transport), integrating the knowledge of different ITDs and IADPs for specific applications.

An overview of the distribution of the requested funding is given for the different IADPs, ITDs, TE and the Transverse Activities. The funding distribution is based on the 1.8 bn € of EU funding anticipated in the European Commission’s Legislative Proposal of 10th July 2013.

The overall estimated budget is €4.05 bn. In addition to the EU contribution (from the Horizon 2020 programme budget), the private members will contribute with €2.25 bn. This includes some additional activities which are not formally part of the *Clean Sky 2* Programme as described here, but which are contributing to the objectives – enablers for the demonstrators or parallel research work necessary to develop an operational product in due time.

The structure of the proposed *Clean Sky 2* Programme can be summarized as set out below.
Large Passenger Aircraft IADP (Leader: Airbus)

The Large Passenger Aircraft IADP approach builds on the positive experience in Smart Fixed Wing Aircraft (SFWA) in Clean Sky. The BLADE laminar wing flight test demonstrator, the CROR demo engine flying test-bed and two different low speed and load control flight tests under preparation will provide unique contributions towards maturing technologies for application in the next generations of aircraft. For Clean Sky 2, the Large Passenger Aircraft goal is high-TRL demonstration of the best candidates to accomplish the combined key ACARE goals with respect to the environment, fulfilling future market needs and improving the competitiveness of future products. The setup of the main programme objectives is to further push the value of technologies tackled in Clean Sky. The focus is on large-scale demonstration of technologies integrated at aircraft level in 3 distinct ‘Platforms’:

- **Platform 1:** “Advanced Engine and Aircraft Configurations” will provide the environment to explore and validate the integration of the most fuel efficient propulsion concept for next generation short and medium range aircraft, the CROR engine;
- **Platform 2:** “Innovative Physical Integration Cabin – System – Structure” is targeting to develop, mature, and demonstrate an entirely new, advanced fuselage structural concept developed in full alignment towards a next generation of cabin-cargo architecture, including all relevant principle aircraft systems;
- **Platform 3:** “Next Generation Electrical Aircraft System, Cockpit and Avionics” has a clear focus to develop and demonstrate a next generation cockpit and navigation suite. Based on the results of a number of research programs which are currently on-going or to be started shortly, platform 3 shall provide the program to integrate and validate all functions and features which are emerging from individual developments into a disruptive new concept in a major demonstrator suite.

Regional Aircraft IADP (Leader: Alenia Aermacchi)

In Clean Sky, a dedicated ITD - Green Regional Aircraft (GRA) - provides essential building blocks towards an air transport system that respects the environment, ensures safe and seamless mobility and builds industrial leadership in Europe. In Clean Sky 2 the Regional Aircraft IADP will bring the integration of technologies to a further level of complexity and maturity than currently pursued in Clean Sky. The goal is to integrate and validate, at aircraft level, advanced technologies for regional aircraft so as to drastically de-risk their integration on future products. The proposed IADP demonstration programmes are:

- **2 Flying Test-beds** (to minimize the technical and programme risks) using modified existing regional turbo-prop aircraft with under-wing mounted engines, for demonstration campaigns;
- **5 large integrated Ground Demonstrators:** full-scale wing, full-scale cockpit, full-scale fuselage and cabin, flight simulator and iron bird.

Full scale demonstrations, with acceptable risk and complexity but still providing the requested integration, are essential to allow the insertion of breakthrough technologies on regional aircraft entering into service from 2025. The Flight Demonstration Programme will be divided into technologically compatible demonstrations sub-programmes:

- **Innovative Wing and Flight Controls:** integration and flight testing of technologies for a new generation wing and advanced flight control systems;
- **Flight Demonstration of a highly efficient and low noise wing including structural aspects;**
- **Full scale innovative fuselage and passenger cabin for increased passenger comfort and safety;**
- **Flight Simulator demonstrating new cockpit interaction concepts as well as advanced avionics;**
- **Virtual and Physical “Iron Birds” as part of the Regional A/C Ground Demonstration Programme.**
Fast Rotorcraft IADP (Leaders: Agusta Westland – Eurocopter)

The Fast Rotorcraft IADP of Clean Sky 2 consists of two separate demonstrators, the NextGenCTR tilt-rotor and the LifeRCraft compound helicopter. These two fast rotorcraft concepts aim to deliver superior vehicle productivity and performance, and through this economic advantage to users.

NextGenCTR will be dedicated to design, build and fly an innovative next generation civil tiltrotor technology demonstrator, the configuration of which will go beyond current architectures of this type of aircraft. This tilt-rotor concept will involve a rotating wing complemented with two propellers mounted on short wings for horizontal cruise. Demonstration activities will aim at validating its architecture, technologies/systems and operational concepts. They will show significant improvement with respect to current Tiltrotors. NextGenCTR will continue to develop what has been initiated in Green Rotorcraft ITD in Clean Sky. New specific activities will also be launched in Clean Sky 2 in particular concerning drag reduction of the prop-rotor, airframe fuselage and wing. The new prop-rotor will require substantial research to reduce noise emissions. In Clean Sky, noise reduction is mainly addressed through the optimisation of flight trajectories. In Clean Sky 2 transversal subjects will cover new research areas, validating them at full scale and in real operational conditions.

The LifeRCraft project aims at demonstrating the compound rotorcraft configuration, implementing and combining cutting-edge technologies from the current Clean Sky programme, and opening up new mobility roles that neither conventional helicopters nor fixed wing aircraft can currently cover. The compound concept will involve the use of forward propulsion through turbo-shaft driven propellers on short wings, complementing the main rotor providing vertical lift and hover capability. A large scale flightworthy demonstrator, embodying the new European compound rotorcraft architecture, will be designed, integrated and flight tested. This demonstrator will allow reaching the TRL 6 at full-aircraft level in 2020. The individual technologies of the Clean Sky Programme (Green Rotorcraft, Systems for Green Operations and Eco-Design ITDs) will be further matured and integrated in this LifeRCraft demonstration.

Airframe ITD (Leaders: Dassault Aviation – EADS-CASA – Saab)

In the Smart Fixed Wing project in Clean Sky, a more efficient wing with natural laminar flow, optimised control surfaces and control systems will be demonstrated. Also, novel engine integration strategies will have been derived and tested, and innovative fuselage structures investigated. Progress towards the 2020 targets will be significant but efforts remain necessary - in particular for the most complex and challenging requirement on new vehicle integration – to reach these objectives and start towards the 2050 SRIA goals. The Airframe ITD will target significant gains in the following areas:

- Introducing innovative/disruptive configurations enabling a step-change in terms of efficiency;
- Developing more efficient wings: Further important gains can be obtained combining:
  - Weight-optimized use of composites on very high aspect ratio wings,
  - Cost effective production of laminar wings and use of hybrid laminar flow technology,
  - Full scale demonstration of the aero efficiency of low cost wings and of high-lift wing concepts;
- Developing fuselages with optimized usage of volume and minimized weight, cost and environmental impact. Step changes in efficiency and environmental impact are expected from:
  - Optimized shapes of fuselage and cockpit,
  - Optimized use of metallic and composite materials,
  - New integration of components and systems, as well as advanced integrated structures;
Overview of the Clean Sky 2 Proposed Programme

- Developing an enhanced technology base in a transverse approach towards airframe efficiency to feed the demonstrators on synergetic domains such as:
  - Efficient wing technologies,
  - Hybrid laminar flow technologies,
  - New production and recycling techniques,
  - Progress on certification processes and associated modelling capacities which will be key to facilitate the market access of future step changes.

**Engines ITD (Leaders: Safran, Rolls-Royce, MTU Aero Engines)**

As defined in Clean Sky, the objective of the Sustainable and Green Engines (SAGE) is to build and test five engine ground demonstrators covering all the civil market. The goals aim at validating to TRL 6 a 15% reduction in CO₂ compared to 2000 baseline, a 60% reduction in NOₓ and a 6dB noise reduction. This is roughly 75% of the ACARE objectives. Whereas some activities were delayed for the Open Rotor programme for example, the bulk of SAGE objectives remain on track.

*Clean Sky 2 will* 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 can be summarized as below:

- **Open Rotor Flight Test, 2014-2019:** a second version of a Geared Open Rotor demonstrator carrying on Clean Sky SAGE 2 achievements and aimed at validating TRL 6;
- **Ultra High Propulsive Efficiency (UHPE) demonstrator addressing Short / Medium Range aircraft market, 2016-2022:** design, development and ground test of a propulsion system demonstrator to validate the low pressure modules and nacelle technology bricks;
- **Business aviation / short-range regional Turboprop Demonstrator, 2014-2019:** design, development and ground testing of a new turboprop engine demonstrator in the 1800-2000 shp class;
- **Advanced Geared Engine Configuration, 2015-2020:** design, development and ground testing of a new demonstrator to validate key enablers to reduce CO₂ emissions and noise as well as engine mass;
- **Ultra-High Bypass Ratio (UHBR) Large Turbofan demonstrator, 2015-2023:** design, development, ground and flight test of an engine to demonstrate key technologies at a scale suitable for large engines;
- **UHBR Middle of Market demonstrator, 2014-2019:** development and demonstration of technologies in each area to deliver validated powerplant systems matured for implementation in full engine systems;
- **The Small Aero-Engine Demonstration projects related to SAT [Small air Transport] will** focus on small fixed-wing aircraft in the general aviation domain and their power-plant solutions, spanning from piston/diesel engines to small turboprop engines.
Overview of the Clean Sky 2 Proposed Programme

**Systems ITD (Leaders: Thales- Liebherr Aerospace)**

Systems and equipment play a central role in aircraft operation, flight optimisation and air transport safety:

- Direct contributions to environmental objectives: for example optimized green trajectories or electrical taxiing have a direct impact on CO₂ emissions, fuel consumption and perceived noise;
- Enablers for other innovations: in particular for innovative engines or new aircraft configurations;
- Enablers for air transport system optimization: improving greening aviation, mobility or ATS efficiency can only be reached through the development and the integration of on-board systems;
- 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.

Starting from the Clean Sky developments through Systems for Green Operations (SGO), further maturation, demonstration and new developments are needed to accommodate the needs of the next generation aircraft. In addition, the systemic improvements initiated by SESAR and NextGen will call for new functions and capabilities geared towards environmental or performance objectives, and for flight optimisation in all conditions, flight safety, crew awareness and efficiency, better maintenance, reduced cost of operations and higher efficiency. The Systems ITD in Clean Sky 2 will address this 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 TRL5). The main domains to be addressed are cockpit environment and mission management, computing platform and networks, innovative wing systems, landing gears and electrical systems.
- Customization, integration and maturation of these individual systems and equipment in IADP demonstrators. This will enable full integrated demonstrations and assessment of benefits in representative conditions.
- Transverse actions will also be defined to mature processes and technologies with potential impact on all systems, either during development or operational use.

**Eco-Design Transverse Activity (Leader: Fraunhofer Gesellschaft)**

Eco-Design will co-ordinate research geared toward high (European) eco-compliance in air vehicles¹², over their product life. Eco Design is based on two domain concepts, namely:

- The Eco-Design Analysis (EDAS) activity. All pillars of life value are addressed, beyond the conventional “cradle to grave” philosophy, to stimulate better re-use options and new, best practice service options, embracing all the supply chain and OEM players. Eco-Design Analysis is a knowledge and responsibility empowerment approach, addressing widened stakeholder interests and enabling a better grasp of the full domain of ground pollution issues.
- The Vehicle Ecological Economic Synergy (VEES) activity is driven from Materials, Processes & Resources (MPR) innovations, from the assimilation of cooperative modules from the ITD/IADP demonstrators with an adaptive Eco Hybrid Platform (EHP). This is “LCA+” (Life Cycle Analysis-plus) design driven, and is an open platform on the level of complete vehicles. LCA+ is used as a receiving-end methodology from the developing Design for Environment (DfE) vision.

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¹² Includes also Engine and Systems, and regardless of aircraft, rotorcraft frame definition.
Small Air Transport (SAT) Transverse Activity (Leader: Evektor – Piaggio Aerospace)

The SAT Initiative proposed in Clean Sky 2 represents the R&T interests of European manufacturers of small aircraft used for passenger transport (up to 19 passengers) and for cargo transport, belonging to EASA’s CS-23 regulatory base. This will include dozens of industrial companies (many of which SMEs), research centres and universities. The New Member States industries feature strongly in this market sector. The community covers the full supply chain, i.e. aircraft integrators, engine and systems manufacturers and research organisations. The approach builds on accomplished or running FP6/FP7 projects. Key areas of societal benefit that will be addressed are:

- Multimodality and passenger choice;
- More safe and more efficient small aircraft operations;
- Lower environmental impact (noise, fuel, energy);
- Revitalization of the European small aircraft industry.

To date, most key technologies for the future small aircraft have reached an intermediate level of maturity (TRL3-4). They need further research and experimental demonstration to reach a maturity level of TRL5 or TRL6. The aircraft and systems manufacturers involved in SAT propose to develop, validate and integrate key technologies on dedicated ground demonstrators and flying aircraft demonstrators at an ITD level up to TRL6. The activity will be performed within the Clean Sky 2 ITDs for Airframe, Engines and Systems with an aim to making the best use of synergies with the other segments of aeronautical design, with strong co-ordinating and transversally integrating leadership from within a major WP in Airframe ITD.

Technology Evaluator (Leader: German Aerospace Center DLR)

A Technology and Impact Evaluation infrastructure is and remains an essential element within the Clean Sky JTI. Impact assessments evaluating the performance potential of the Clean Sky 2 technologies both at vehicle level and at relevant aggregate levels such as at Airport and ATS level, and currently focused on noise and emissions, will be retained. Where appropriate they will be expanded to other relevant environmental or societal impacts (e.g. mobility benefits or increased productivity).

For vehicle concepts arising from the IADPs, the core aircraft performance characteristics (at the so-called ‘mission level’) will be reported by the IADP and TE impact assessment will focus on aggregate levels. For those Clean Sky 2 ITDs technologies not feeding into an IADP aircraft model, the TE will build up its own Mission Level assessment capability, also to assess innovative long term aircraft configurations. Thus, an aircraft-level synthesis of these results via ‘concept aircraft’ is possible and the respective ITD results can be shown at aircraft level and evaluated within the Airport and Air Transport System alongside the IADP results. In summary, the Technology Evaluator consists of three major tasks:

- Monitoring of Clean Sky 2 achievements vs. defined environmental and societal objectives;
- Evaluation at Mission Level by integrating selected ITD outputs into concept aircraft / rotorcraft;
- Impact Assessments at Airport and ATS Level using IADPs and TEs concept aircraft / rotorcraft.
Conclusion

Horizon 2020 aims to inject renewed vigour in implementing the Innovation Union. Creating and sustaining the skills-base and investment climate to drive innovation forward are vital, if Europe is to build and maintain industry leadership. Innovative new approaches instilled through Clean Sky 2 will underpin step-change advances in the performance of the next generations of aircraft expected to be required from 2025, by mastering the technologies and the development risks. The global fleet will require replacement of up to 75% of aircraft now flying or on order by 2050 with new models, where technology developed and/or matured in Clean Sky and Clean Sky 2 is eligible for application. Jointly, these Programmes will as such largely determine the aircraft and fleet performance and its environmental footprint over the course of this century. The Horizon 2020 Programme covers a critical period in which to accelerate the pace of aviation’s innovation potential, and reinforce Europe’s leading role in shaping the future of aviation.

Securing the global industrial leadership the European aeronautics sector has fiercely fought to achieve over the last 5 decades will strongly contribute to a sustainable, safe and efficient air transport system – a proven driver of growth and prosperity through the connections it enables between people, and the mobility and access to goods it provides. Beyond the immediate benefits in European competitiveness in the broader aviation sector, significant spillover effects into the wider economy are therefore evident.

Clean Sky 2 will offer unsurpassed opportunities for wide stakeholder participation from the EU and Associated States. Significantly, when compared to Clean Sky: beyond the 100% growth of programme activity performed by the established aeronautical industry, approximately 150% growth is foreseen for academia & research organisations and some 200% growth for SME activity is expected within the Programme. With 60% of funding open to competition, Clean Sky 2 will rely on a broad and wide participation where these SMEs, research organisations and academia interact directly with key industry stakeholders. Up to half of this 60% competed part will be awarded to selected participants who will join the JU as Members, ensuring the long term Programme stability and a coherent and synergistic approach to meeting the relevant ACARE Goals. Clean Sky 2 is expected to involve around 800 participants from the European aeronautics players and also new entrants in this high tech and growing sector. Together, some 3000 full-time equivalent resources will work towards the Programme’s goals and a significant ‘pull’ mechanism will attract new talent into the science, technology engineering and mathematics domains: a powerful investment in Europe’s scientific and technological excellence and its competitiveness.