PART 2 - WHAT IS " CLEAN SKY" ?

3. TECHNICAL CONTENT

3.1 Requirements for an efficient JTI performance

The greening of Aeronautics and Air Transport (A&AT) calls for a quantum leap in performance through a **consistent, coherent and holistic approach**.

Technologies allowing for the step change have to be concurrently developed, integrated and validated to maximise the benefit of **technology interaction** and **cross fertilisation** on the whole ATS.

The delivery of innovation can only be achievable through a new approach to RTD focusing on the integration of advanced technologies and validation of results in a **multidisciplinary approach** leading to full-scale ground and flight demonstrators.

“Clean Sky” will carry out the **R&T risk mitigation** activities, which are necessary to deliver the technology readiness level (TRL) for the future green aircraft developments.

Major areas of work have to cover the broad range of R&T work: aircraft (fixed wing and rotorcraft), engines, systems and eco-design concepts able to deliver more environmentally friendly aircraft production and operation.

“Clean Sky” JTI has to be **structured in the most efficient way** allowing both the full coverage of all areas of R&T work while ensuring a high degree of efficiency in the management of the technical activities

“Clean Sky” JTI must also be **visible and transparent** from the Aeronautics community and **flexible** in its adaptation to the global environment over the 7-year period. A mechanism should be set up to **steer the technical activities** by, and feed back to, the European Commission and ACARE.

3.2 Technological Domains addressed in "Clean Sky"

"Clean Sky" will address all the necessary technological domains that can contribute to meeting its objectives:

3.2.1 Reduction of fuel consumption (CO2) and NOx emissions

CO_2 emissions are directly linked to the fuel consumption cycle. CO_2 reduction can be achieved through a combination of solutions from complementary technological domains:

- More efficient engines, consuming less fuel whilst producing less NO_x at the different operational regimes
- Aerodynamics improvement: Improved lift / drag through new aerodynamics design and flow control technologies
- Aircraft weight reduction, through new structural design concepts, load control and new materials
- Mission management, through new mission profiles, from gate to gate, optimised with regard to the overall fuel consumption
- Energy management optimisation, through the "all electrical aircraft" concept, increased efficiency of all components in the power management and distribution system

These technological domains may bring other benefits; the reduced rate of use of fossil fuels will help reduce the current uncertainty in fuel availability and price.

3.2.2 Perceived external noise

Perceived noise can be reduced by:

- Reduction of noise emitted by the engine
- Reduction of noise generated by the air flow around the aircraft (including notably landing gears for aircraft, and rotor for helicopters)
- Definition of optimised take-off, approach and landing and taxiing profiles and procedures, allowing human population to be avoided in the airport vicinity.
- Low weight technologies

3.2.3 "Ecolonomic[12]" life cycle

The optimisation of **environmental impact** of aircraft for their **complete life cycle** will be achieved in considering the three phases of the aircraft life:

- Aircraft design
- Aircraft production
- Aircraft operations
- Aircraft withdrawal: dismantling, recycling, reuse, elimination, storage

3.2.4 Multi-disciplinary approach

These Technology Domains will be treated in the Clean Sky JTI in the concerned platforms (see definition of platforms below) in the most effective way and avoiding duplications.

[12] "ecolonomic" = ecological and economical/affordable

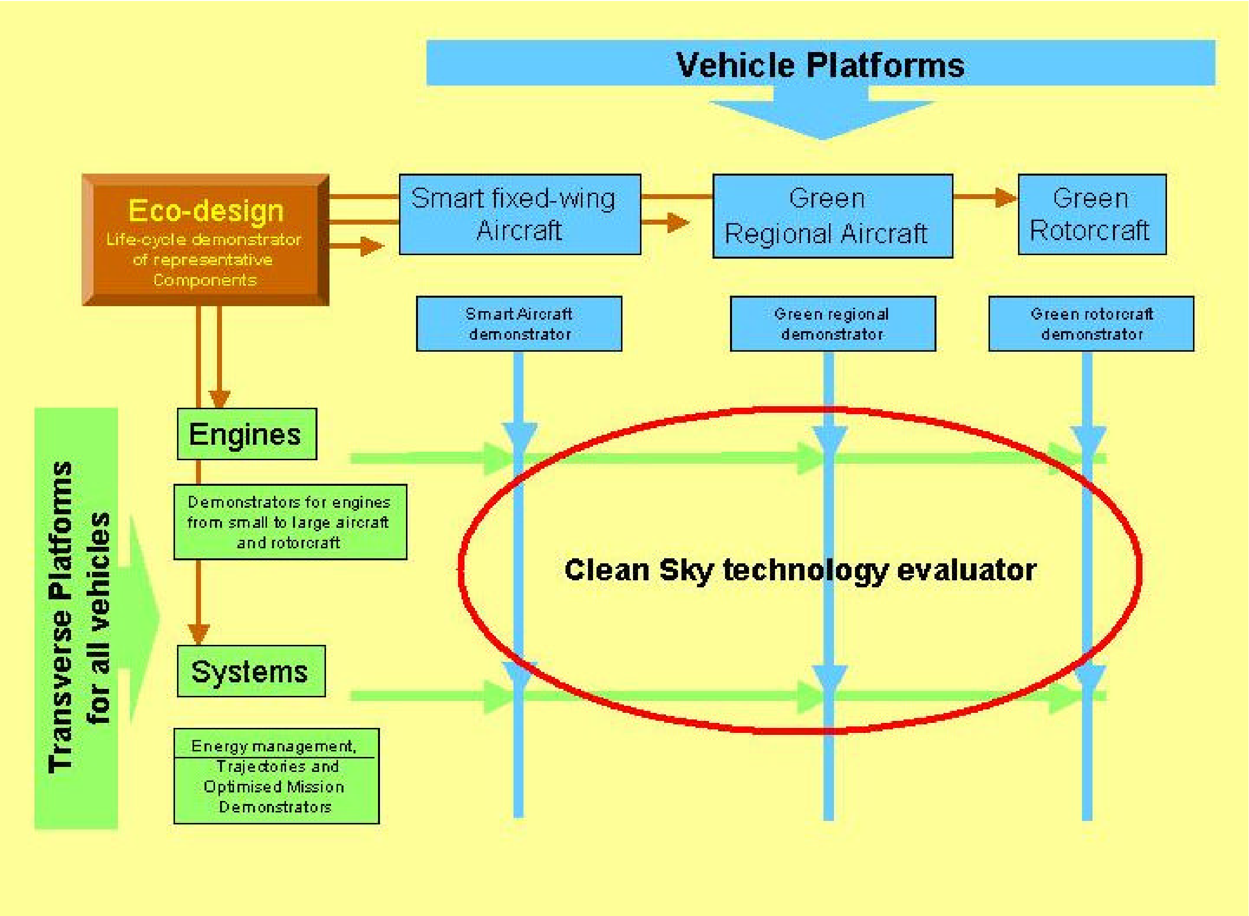
3.3 Work breakdown

The Clean Sky JTI is articulated around 6 platforms:

- 3 vehicle platforms (**SMART fixed-wing Aircraft**, **Green Regional Aircraft**, **Green Rotorcraft**) and **2 transverse platforms** (**Sustainable And Green Engine** and **Systems for Green operations**) that will deliver results to the vehicle platforms.

- An **Eco-design Platform** transverse to the other platforms that will support them in terms of the greening of design, manufacturing, production, maintenance and disposal.

-A **Clean Sky Technology Evaluator** to oversee the whole programme and allow for transparency and monitoring of the R&T activities.



3.3.1 Three vehicle platforms

- **SMART fixed-wing aircraft Platform** will deliver substantial reduction of fuel consumption and external noise by improving lift / drag and weight through flow and load control technologies and new innovative configurations.
- **The Green Regional Aircraft Platform** will substantially contribute to a greener environment reducing emissions and noise with technological solutions specifically tailored to regional aircraft (low weight low noise configurations).
- **The Green Rotorcraft Platform** will contribute to a reduction of perceived noise and to more efficient power use by using specific technologies tailored for Rotorcraft.

3.3.2 Two transverse platforms

These platforms will integrate and validate innovative technologies for engines and systems. These technology developments will have a potential of application across the vehicle platforms that will deliver the Requirements for the systems and their architectures.

- **The Sustainable and Green Engine Platform**
  There will be two lines of green engine platform activities, one focused on new propulsive concepts (including alternative fuels) and the other centred on requirements for next generation aircraft.
  The demonstrators will integrate, at full engine scale, technologies that contribute to step changes in propulsive efficiency and in thermal efficiency for the relevant thrust ranges.
- **The Systems for Green Operations Platform**
  It will focus on the critical aspects of the management of aircraft energy, the management of the missions and trajectories.
  A new way in the global management of aircraft energy will offer strong reduction in the overall aircraft energy consumption.. An innovative, environmentally efficient management of missions and trajectories will decrease fuel consumption and finally noise and emissions.

3.3.3 Eco-design platform

The Eco-Design platform is transverse to all the above platforms and will play two roles:

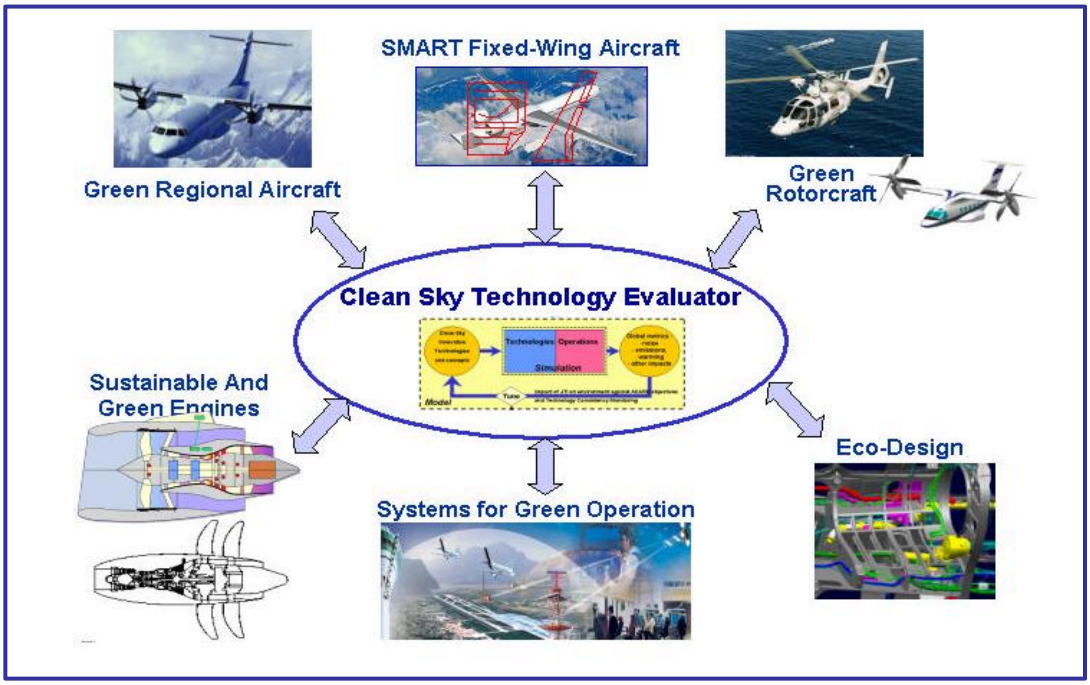
It will deliver common solutions for the greening of production, maintenance, disposal of the current products with known ecological requirements.

In addition the platform will observe the new technologies proposed by each of the platforms and will identify the associated ecologically sound design solutions.

The platform can also pro-actively deliver recommendations to the other platforms.

3.3.4 Clean Sky Technology Evaluator

The Clean Sky Technology Evaluator will provide the core activity of the project integrating the technical content across the JTI. The Clean Sky Technology Evaluator will be realised through a simulation suite that can **evaluate the merit of R&T** activities in the platforms in relation to ACARE targets. This simulation will forecast the benefits that can be expected when technologies to be delivered by "Clean Sky" will be integrated in future aircraft. It will provide elements of guidance and justification for decision-making within the JTI and for reporting to key stakeholders at critical "Clean Sky" milestones.



3.4 Clean Sky Integrated Approach

Figure 1 (following page) provides description of the "Clean Sky" integrated Approach. The WBS is structured by a vertical axis that represents the successive steps from the definition of requirements to the demonstrations and assessment of the results:

- Requirements and architecture
- Technologies development and adaptation
- Application studies up to demonstrations

Demonstrations and demonstrators:

- Definition of the demonstrations
- Selection of the demonstrators
- Preparation of demonstration, test
- Analysis and final report

On the horizontal axis, technology domains have been identified to ensure the delivery of step changes:

- Load and Flow Control
- New Configurations
- Low weight and low noise configuration
- Rotorcraft Noise reduction
- Rotorcraft Optimised Configurations
- Engines
- Energy Management
- Mission and Trajectory Management
- Aircraft life cycle

The selection of the technology domains has been carefully assessed to avoid duplication and overlap while ensuring all technical challenges are properly addressed.

These technology domains will be hosted by Platforms in charge of the development of the corresponding technologies.

The common definition of the high level requirements of the “Clean Sky” and design of the global architecture will ensure the technologies will benefit to all platforms.

Each technology domain will deliver technologies that will have a potential of application on a broad range of products.

In addition, the cross participation of the partners in several platforms will encourage the dissemination and assimilation of best practices and knowledge for any partner of “Clean Sky” and the supply chain.

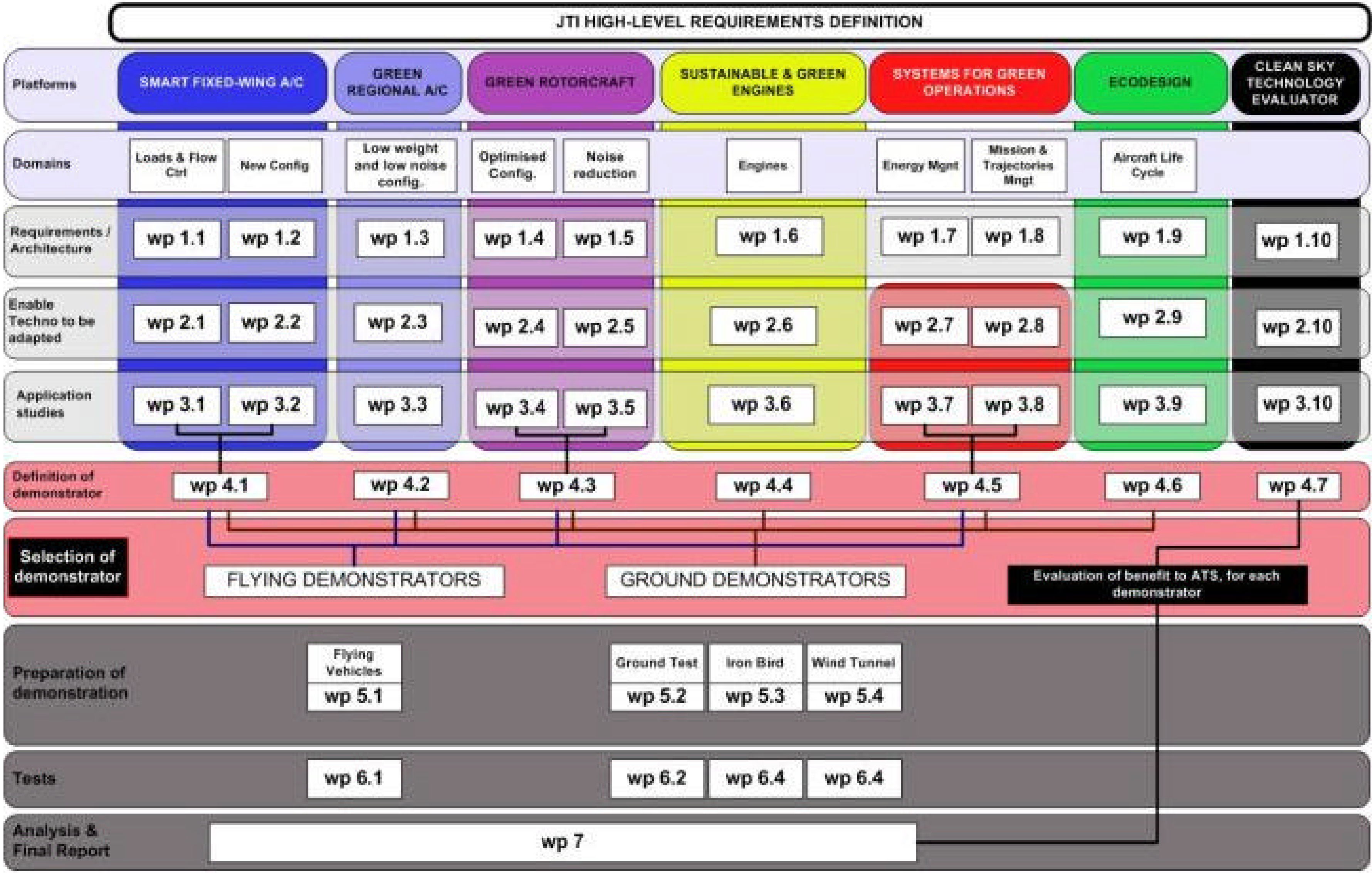
The demonstrators:

A key milestone in the integrated approach will be the definition and selection of the demonstrators. Based on the technology delivered by each platform a set of demonstrators will be selected. The selection will enable to run the appropriate demonstration maximising the benefit for a whole range of product while ensuring cost efficiency.

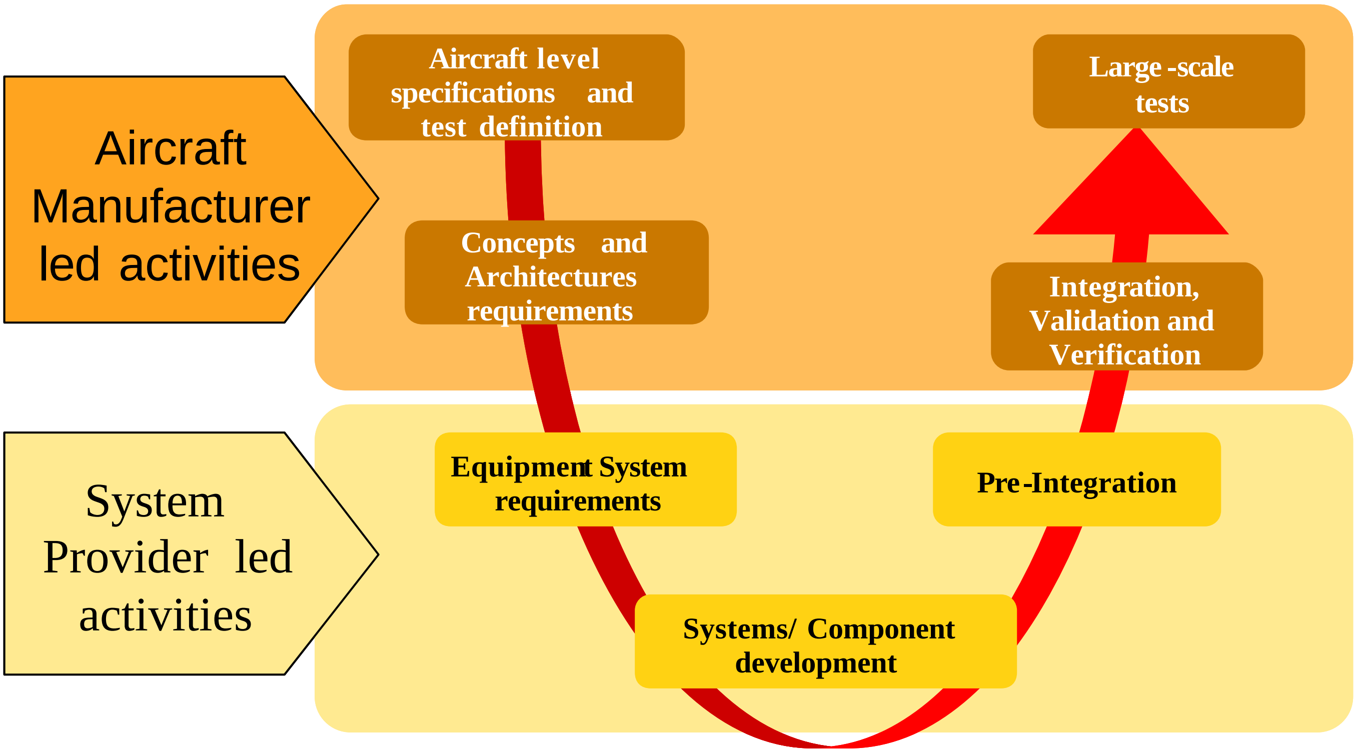
These demonstrators will be a combination of iron bird, ground testing and flying demonstrators.

The test plan will integrate the requirements of each platform in a coherent and exhaustive way. The results of the demonstration and their analysis will be potentially exploitable by any platform.

Figure 1


JTI HIGH-LEVEL REQUIREMENTS DEFINITION
Platforms
SMART FIXED-WING A/C
GREEN REGIONAL A/C
GREEN ROTORCRAFT
SUSTAINABLE & GREEN ENGINES
SYSTEMS FOR GREEN OPERATIONS
ECODESIGN
CLEAN SKY TECHNOLOGY EVALUATOR
Domains
Loads & Flow Ctrl
New Config
Low weight and low noise config.
Optimised Config.
Noise reduction
Engines
Energy Mgnt
Mission & Trajectories Mngt
Aircraft Life Cycle
Requirements / Architecture
wp 1.1
wp 1.2
wp 1.3
wp 1.4
wp 1.5
wp 1.6
wp 1.7
wp 1.8
wp 1.9
wp 1.10
Enable Techno to be adapted
wp 2.1
wp 2.2
wp 2.3
wp 2.4
wp 2.5
wp 2.6
wp 2.7
wp 2.8
wp 2.9
wp 2.10
Application studies
wp 3.1
wp 3.2
wp 3.3
wp 3.4
wp 3.5
wp 3.6
wp 3.7
wp 3.8
wp 3.9
wp 3.10
Definition of demonstrator
wp 4.1
wp 4.2
wp 4.3
wp 4.4
wp 4.5
wp 4.6
wp 4.7
Selection of demonstrator
FLYING DEMONSTRATORS
GROUND DEMONSTRATORS
Evaluation of benefit to ATS, for each demonstrator
Preparation of demonstration
Flying Vehicles
wp 5.1
Ground Test
wp 5.2
Iron Bird
wp 5.3
Wind Tunnel
wp 5.4
Tests
wp 6.1
wp 6.2
wp 6.4
wp 6.4
Analysis & Final Report
wp 7

The Integrated approach of “Clean Sky” will follow the well-known V cycle and enable a clear share of activities between the aircraft manufacturers and the systems providers.



The requirements in term of definition of innovative architectures will come from the aircraft manufacturers. Based on these requirements, technologies, systems and components will be developed by the system providers for further integration in the demonstrators.

The system providers will then pre-integrate systems and components for a future multidisciplinary integration in the selected demonstrators.

Under the responsibility of the aircraft manufacturers the demonstrators will be integrated, validated and verified. (Refer to chapter 7 - Demonstrators)

4. DETAILED TECHNICAL DESCRIPTIONS OF PLATFORMS

4.1 SMART Fixed Wing Aircraft Platform

4.1.1 Rationale

Over the last 50 years intensive research to optimise the configuration and aerodynamic profile of aircraft has delivered a steady improvement of the aircraft efficiency resulting in the reduction of fuel consumption and noise emission.

According to the ACARE goals, out of a target of 50% reduction in CO2, nearly half of the achievement should come from the airframe.

A Major reduction of weight will be achievable by the extensive utilization of composite material. But it will not be sufficient to reach the 2020 goals.

Major evolution in Aerodynamics and Flight Physics performance are required. A promising and still unexplored field of serious investigation in an operational environment is the concept of active wing and new configuration.

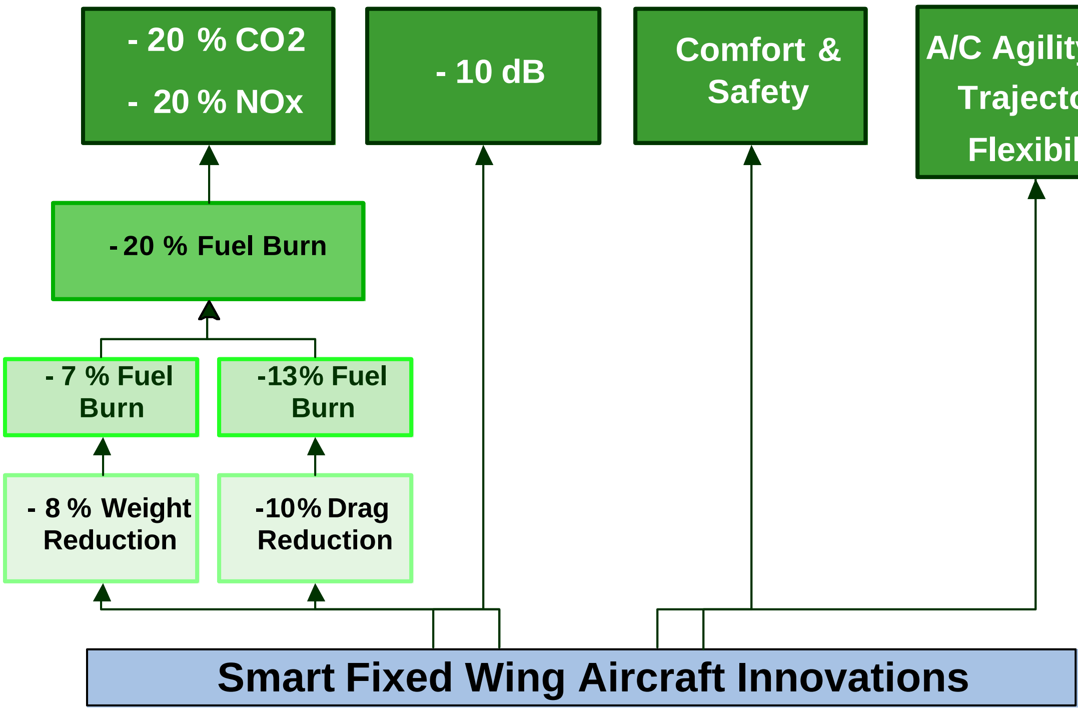
As a result of continuous incremental improvements the shape and configuration of large and small transport aircraft have converged to what has become an almost universal configuration: highly efficient passive wing with moveable surfaces, under-wing high by-pass ratio engines or rear fuselage engines, rear vertical and horizontal tails.

A step change in the performance can now only be achieved by rethinking the aircraft architecture and its components. The assessment of the benefits of such a radical change can only be validated on a representative flying vehicle via a multidisciplinary approach. This is the goal of the platform called SMART Fixed Wing Aircraft (SFWA).

4.1.2 Objectives and Impact of the Platform

The purpose of SMART Fixed Wing Aircraft flying demonstrator is to develop and validate up to TRL 6 innovative technologies, concepts and capabilities currently investigated at TRL 3 and showing the potential to demonstrate a step change in the critical areas of fuel consumption and noise emissions. To this end the SMART Fixed Wing Aircraft Platform will integrate an active wing and innovative airframe concept technologies. This integration will be largely based on the results of European projects (mainly AWIATOR and NACRE) performed within the previous framework programmes.

The merit of the active wing lies in its capacity to control loads and air flow and generate benefits in drag reduction and structural mass leading to a reduction of fuel consumption and gaseous emissions, noise, systems complexity and increasing ride comfort. Whereas a classical wing is passive with an optimised shape and high-lift devices, the active wing will sense the surrounding airflow, analyse and modify it to continuously seek optimum efficiency. This innovative approach and associated technologies will be integrated into a full-scale wing tested in a real operational environment on the flying demonstrator.



To integrate those breakthroughs at the overall Aircraft Level, some linked issues have to be studied. In this way, a set of innovative concept technologies (will be combined with the active wing solutions to further enable their integration to achieve the necessary step change in performance at the overall aircraft level:

The Platform will provide the most suitable means of drawing together current research activities at national and European level in a flagship project that will pave the way for the next generation of products.

The platform will have a leverage effect on the future R&T investments in the domain of Flight Physics. Outside "Clean Sky" R&T projects will be launched to complement the activities and reinforce the potential impact of the technology on new products.

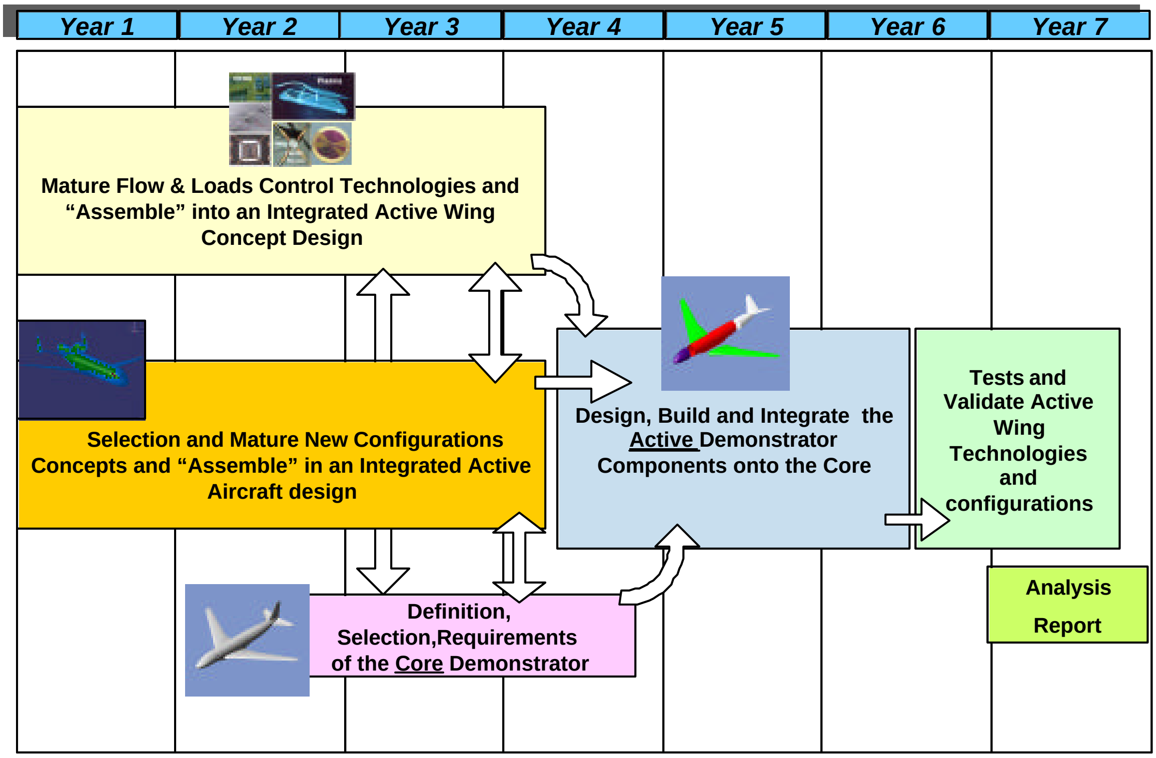
4.1.3 Potential Associates and Partners

To ensure that we will benefit from best skills and competences in Europe, first rank scientific and industrial partners will be integrated as associates in the SFWA Platform.

Cooperation with Universities Research Establishments and SME´s and from all over Europe will provide the network of skills, knowledge and competences needed to cover the development, subsequent testing, downselection and deployment of the SFWA technologies on a large demonstrator level.

In this way, in addition to other Platform Leaders, other industrials and large European Companies could be part of the SFWA Steering Committee. Especially for the design, manufacturing and certification of the demonstrator, European partners will deliver complete work packages to the SFWA Platform.

4.1.4 General Approach and Content



Definition, design and manufacturing of the core demonstrator could be shared with the Green Regional Aircraft platform.

Generic: The current high performance design tools and test methods are today optimized for a classical configuration and structure in order to ensure an efficient design. With the complete change envisaged in the aircraft architecture proposed by the platform, these tools and methods will need to be adapted and developed in order to design a SMART Aircraft.

In this perspective, we could consider that the red line of the SFWA Platform is to develop Active Wing technologies and to integrate them on large-scale demonstrator(s). The integration is not limited to the sensors and systems for flow and loads control. Consequences of that structural optimisation of the Wing should be anticipated at the overall aircraft level. To reach this target, two axes will be investigated:

4.1.4.1 Active Wing Technologies.

Active Loads Control (ALC) and Active Flow Control (AFC) technologies will be developed and validated in that Work-package, following those three steps:

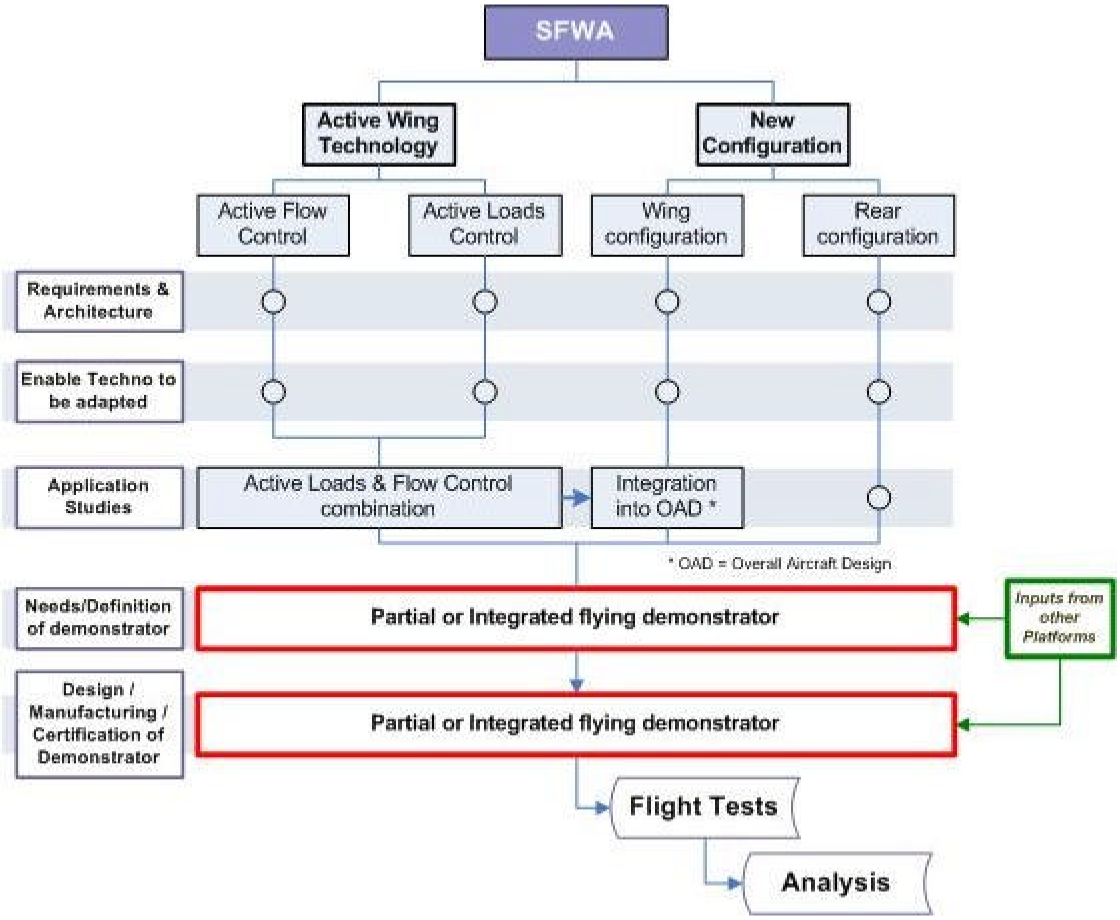
- Develop and validate the associated set of enabling technologies, in particular robust sensor-actuator architecture for combined active flow and load control. Set-up wind tunnel tests to develop flow-control solutions for noise reduction (wing high lifts, landing gears).
- Develop the tools necessary to integrate this sensor-actuator architecture in an optimized wing structure. Design and test new solutions for the integration of aircraft components, considering the presence of active flow and loads control systems.
- Achieve ultimate demonstration through flight test of the large potential benefits through evaluation and integration of Active Flow Control and Active Load Control wing combined with a set of innovative component concepts.

4.1.4.2 New components and configurations adapted to the integration of the Active Wing:

- New wing structure and components integration concepts taking into account the parameters of the Active Wing architecture. This chapter includes wing-fuselage interactions and innovative concepts for landing-gear integration.
- New aircraft configuration to accommodate the active wing. The major elements forward and rear fuselage /empennage and accommodation of innovative power plants will be reconsidered to give a new optimised aircraft suit embedding the active wing. Focus will be laid on a modified tail for innovative rear-engine installation or innovative tail with classic under-wing engine installation. The ultimate goal is to demonstrate in real flight conditions the adaptation of new rear configurations as well as related noise reduction to be obtained with overall Active Wing Aircraft design.

4.1.5 Technical Approach

The following WBS shows the global organisation of the SFWA work packages.



For the “Application Studies” step, both “Active Flow Control” (AFC) and “Active Loads Control” (ALC) will be associated and combined. Their integration into a new wing will be optimized and the sensors and actuator architectures rationalized. This step will require some validation loops with wind tunnel tests to secure that complex network into a classic wing first.

In parallel, the entire wing structure is adapted and optimised to anticipate the savings, allowed by AFC / ALC technology. At the “Application Studies” step, the overall “Active Wing” concept will be integrated into a new optimised wing, lighter and with a better Drag coefficient.

The global technical approach leading to flight demonstration is the following:

4.1.5.1 Active wing Technology:

a. In line with the top level requirement to provide the need in:

- Active and passive wall structure manipulation
- Low speed separation control

- Active laminar flow
- Innovative control surfaces and sensors for advanced loads alleviation functions and loads protection laws
- Active aeroelasticity (loads performance optimizations)
- Advanced methods applied to loads control
- Loads driven aircraft optimisation

b. To select, develop and adapt technologies:

- Sensors and actuators
- Distributed control and integrated tests capabilities
- Review and characterization of concepts and actuation design

c. To perform application studies and integrate the selected technologies:

- Development of methods and tools
- Development of integrated test capability
- Analyse and design the system architecture and test on grounds (wind tunnel tests, ..)
- Collect an extensive database for an integrated wing design on the flow field.

4.1.5.2 <u>New configuration /concepts adapted for Active Wing integration:</u>

a. In line with the top level requirement to provide the need in:

- Wing configuration and integration of the “Active Wing” into the overall Aircraft Design (OAD)
- New empennages
- Integration of innovative engine concepts (open Rotor, gear turbofan, counter rotating turbofan)/ noise shielding concepts
- Innovative integration methods for landing gears
- New nose and forward fuselage
- Alternative aero-brake systems/ no thrust reverser brake

b. To select, develop and adapt configurations/concepts

- Down selection of configurations solutions and concepts for components integration based on the requirements to provide most a beneficial aircraft environment for the Active Wing
- Architecture design

c. To perform application studies and integrate the selected configurations/ concepts:

- Numerical simulation and trade off studies
- Ground tests (wind tunnel) for promising concepts
- Major rig programmes
- Flight Clearance and safety issues

4.1.6 SFWA platform deliverables and Demonstration:

Active Wing:

- Mature and "ready-to-use" technologies and methods to implement AFC and ALC concepts.
- Flight proven integrated architecture for an Active Flow & Loads Control Wing

New configuration adapted to Active Wing technology:

- Flight proven integrated new Wing, including Active Flow / Loads Control
- Flight proven innovative components integration, regarding the Active Wing optimisations
- Flight proven confidence in an "Active Wing Aircraft Configurations suite", from down selected innovative configurations and adaptations to the new Active Wing.

These objectives are developed through the design, development, flight test and technology assessment of integrated active loads / flow control architectures and configurations.

4.2 The Green Regional Aircraft Platform

4.2.1 Rationale

Regional market is a large part of Air Transport System. Today, in the world, 45% of flights are operated with regional aircraft, and in 2020 the share is estimated to rise to around 50%.

Therefore regional aircraft are contributors to pollution mainly around regional airports (noise, CO_2 and NO_x), and to a large extent also globally.

A substantial contribution to the “Clean Sky” shall then come from the Regional Air Transport that, to drastically reduce the environmental impact all around, has to adopt innovative solutions in several technology domains.

Typical regional transport requirements of low exploitation cost will lead to products more optimised for the specific needs of this market segment. Environmental impact reduction will be a very important factor in shaping the technology content of future products, along with the fuel cost increase, that pushes towards more efficient aircraft solutions.

It is then paramount for the Industry to prepare for that by readying technologies for a better environment. The goals set by ACARE are far reaching compared to the present standing, and require a major effort in pulling together knowledge partly available but not yet at the necessary level of maturity.

According to ACARE goals, a large portion of the achievement should come from the airframe. Considering the fields directly under the responsibility of the aircraft manufacturer, step changes to improve the impact on the environment deriving from the operation of regional aircraft are expected mainly from weight and noise reduction technologies.

For the regional aircraft, the average mission range is very short, typically shorter than 500NM. The relatively small quantity of fuel on board makes the empty weight of the aircraft a larger fraction of the mission weight than for other types of aircraft. Consequently the aircraft empty weight counts significantly on mission fuel consumption, gaseous emissions and noise during all phases of the mission, and therefore technologies enabling to lower significantly this weight are basic to the GRA Platform.

Similarly, the high number of departures and landings of regional aircraft, requires maturing and integrating configurations for lower noise at the communities around airports.

Progress in these areas will have to be complemented by engines and systems having architectures and technical solutions providing the maximum benefit when properly integrated in this class of aircraft.

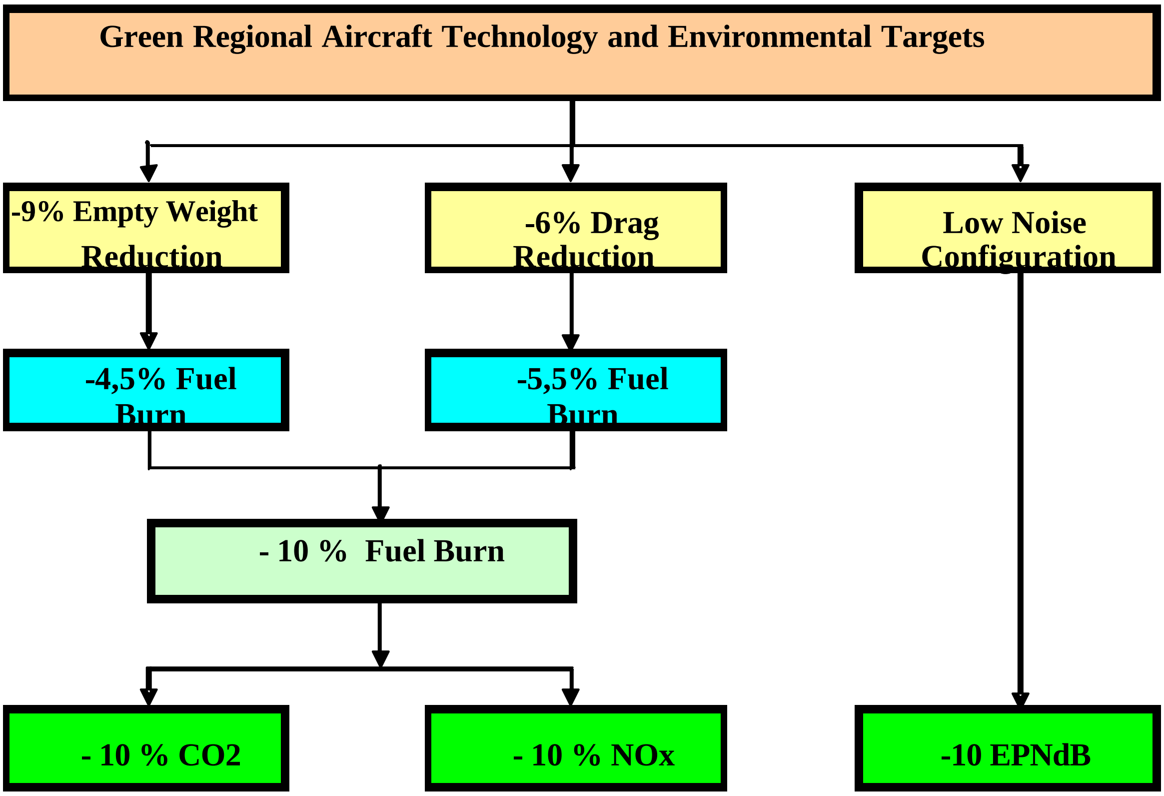
The resulting products for the regional market segment of the 2020’s will need to be substantially different from today offer, using a large share of technologies non conventional by today standards, and possibly with an overall configuration quite different from aircraft flying today.

Being able to integrate in a future advanced regional aircraft the key green technologies demonstrated in Clean Sky with other very competitive solutions will allow the full return of Europe as world leader also in the regional aircraft segment currently dominated by non-European actors, with the exception of turboprop ATR.

4.2.2 Objectives and expected impacts of the platform

The objective of the Green Regional Aircraft (GRA) Platform is to validate and demonstrate the technologies best fitting the environmental goals set for the regional aircraft entering the market in the years 2020.

The following table reports the level of achievement of the ACARE targets relative to the ACARE baseline (year 2000) expected once the various technologies applicable to the regional aircraft, to be developed by “Clean Sky”, will be integrated in an all new aircraft. The table reports also the expected benefits of on going research programs.



The Green Regional Aircraft Demonstration is the fundamental asset of the GRA Platform. It will constitute on one side the physical evidence of the degree of achievement of the ACARE environmental targets at aircraft level, and on the other will deliver the final assessment of the relevant technologies allowing the European industry to gather technical information that will be fundamental for the definition of environmental friendly future regional aircraft. It will be a cost effective mix of ground and flight tests covering the aspects of integration of airframe, systems and engines technical solutions at the aircraft level.

4.2.3 General approach and content

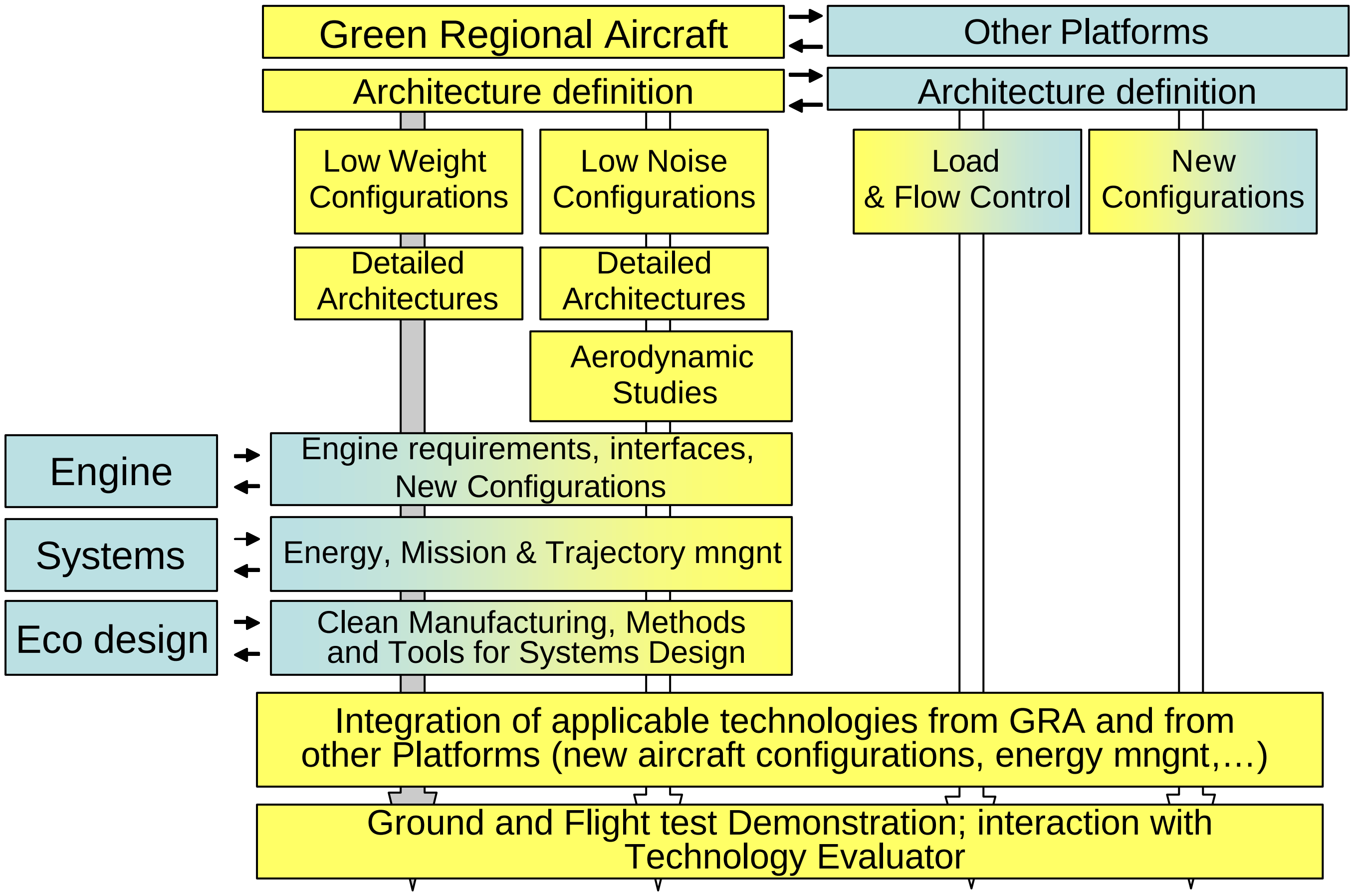
The general approach is functional to the step change in environmental impact that is sought for the regional products of the future.

It is necessary to concentrate on some very promising "mainstream" technologies, but also draw the benefits of other technologies in an integrated view of their cumulative and reciprocal effects.

This very productive new research approach is made possible by Clean Sky: take the benefit of multidisciplinary integration while gathering the results of several basic technologies.

The activities of the Platform are organised so as to:

1. develop the most promising "mainstream" technologies (Low Weight and Low Noise Configurations) best fitting the requirement of greening the regional aircraft;
2. integrate technical solutions from the mainstream technologies and from other technical domains of the Clean Sky (Energy Management, Mission & Trajectory Management, Engines, Eco Design, New Configurations, Flow & Load Control) in the Demonstrators of the Green Regional Aircraft, using a multidisciplinary approach.



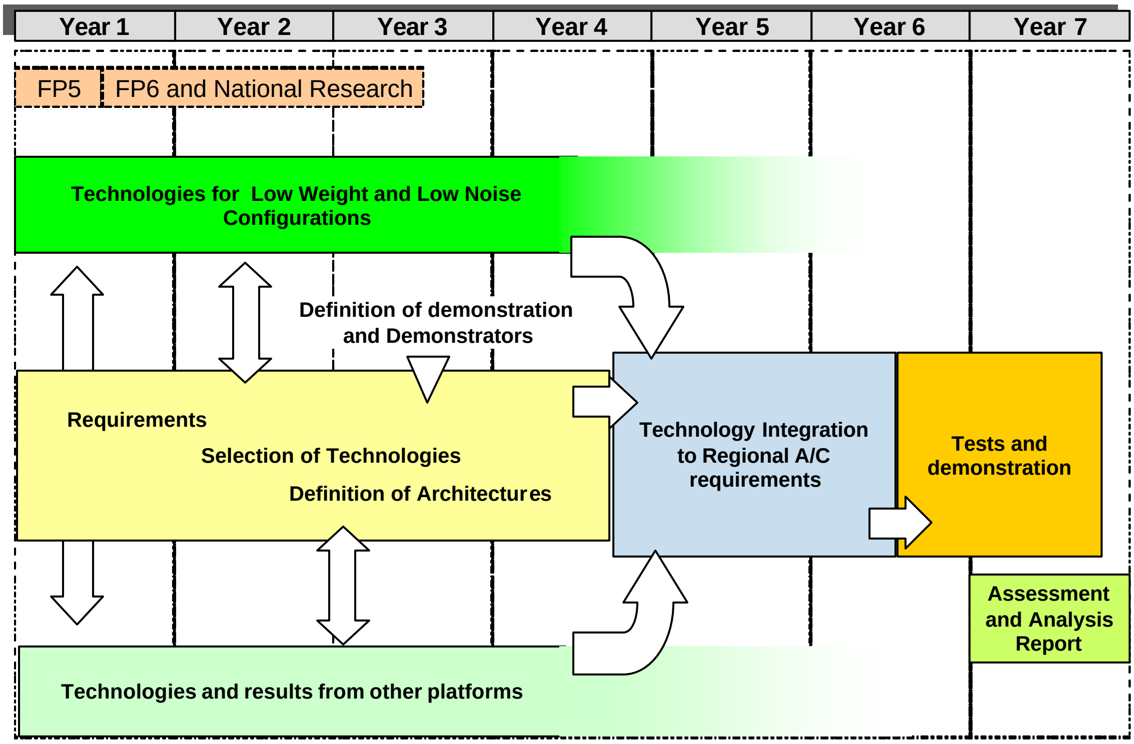
Technologies from several recent or on-going European research programs will constitute the significant background to the Green Regional Platform. The most relevant are:

TANGO	Validation and integration of design and manufacturing processes for composites
FUBACOMP	Developing and validation of manufacturing techniques, and structural design concepts to support the construction of a small integrated composite barrel fuselage structure.
ADMIRE	Developing a probabilistic foundation for the application of damage tolerant design of structures taking into account the innovative investigations on the initial flaw concept, crack growth evaluation improvements and residual strength in complex geometries.
SMIST	Implement Structural Health Monitoring (SHM) into aircraft structural design with respect to maintenance cost reduction, significant weight savings, respecting the critical capability to ensure the structural integrity of the aircraft to sustain structural safety at all times.
ALCAS	Reducing the fuel consumption of relevant European aerospace products through the cost effective full application of carbon fibre composites.
COMFORT	Multifunction composite structures (national research program)
RAIN	Addressing aerodynamic and aeroacoustic optimisation of aircraft concept to reduce the high lift and landing gear systems noise
SILENCER	addressing aerodynamic and aeroacoustic optimisation of aircraft concepts to reduce the noise impact relevant for airframe noise components, improved engine integration;
ROSAS	Radically different aircraft architectures
NACRA	New aircraft configurations relevant to noise reduction
POA	FP 5- Technologies for the all electric aircraft
MOET	FP 6- Technologies for the all electric aircraft
ADFCS/ADFCS2	Autopilot and flight control modes
VICTORIA	Integrated technologies and tools in advanced modular electronics
IFATS	Technologies for increasing on board aircraft autonomy

The basic needs of increasing flight safety, satisfying regional airlines requirements and improving cabin comfort and healthiness, and more in general competitiveness, will be considered during the program, to the purpose of defining merit factors to rank alternative solutions and assist technical choices.

The general workflow is illustrated below

GRA Platform - Flow of Activities



4.2.4 Technical approach and content

4.2.4.1 <u>Aircraft level Requirements and Architectures</u>

High level requirements and architectures for the GRA will be defined. They include:

- high level requirements for the regional aircraft, and their updating during Clean Sky
- aircraft advanced configurations for noise and pollution reduction
- high level requirements for engine and systems
- analysis of technologies alternatives from other domains, and their ranking
- requirements of the integration of technologies, at aircraft level
- requirements and criteria for the demonstration
- feedback from integration studies and from validation and demonstration results.

4.2.4.2 Low Weight Configurations (LWC)

4.2.4.2.1 Requirements and Architectures

In the current design approach of composite structures their sizing is based on material mechanical properties that are degraded to account for the negative effects of humidity and temperatures and for foreign objects impacts occurring during the aircraft operation. Monitoring of actual events occurring to each aircraft, which would be made feasible by sensors embedded in the structures, and the immediate maintenance action consequent to damage detection, will allow a different design methodology in which less degradation is to be considered, with a resulting lower weight.

The aircraft structures, beyond carrying structural loads, need to perform functions like lightning protection and electrical grounding. In metal conventional structures these functions are carried out by the base material itself. In composite structures these functions require the use of specialised elements, which add weight. This added weight will be minimised by multi-layer / multi-function architectures.

A classification of the different cases encountered in the aircraft design for different types of structural elements will be performed, for each of which the relevant applicable requirements and criteria will be developed.

Airworthiness criteria and requirements will be developed.

4.2.4.2.2 Enabling Technologies

- **Technologies**

The following technologies are envisaged for consideration:

Fibre Bragg-grating (FBG), sensitive coatings (SCS), environmental degradation monitoring sensors (EDMS), micro-wave sensors (µW), acoustic-ultrasonic (AU), comparative vacuum monitoring (CVM), acoustic emission (AE), imaging ultrasonic (IU). Conductive layers. Manufacturing technologies for integration of sensors and multifunctional layers in the composite structures.

- **Design Methodologies**

Computational tools which will assist in:

- o Defining optimal locations of sensors for effective detection of the level of damage
- o Analysing the multilayer configurations..

4.2.4.3 Maintenance Methodologies

New approaches for maintenance and repair needed for the presence of sensors and multifunction layers.

Advanced methodologies for definition of inspection intervals.

- ***Application studies***

Certification criteria definition.

Assessment and selection of the different updated sensors technologies available or under development.

Develop and validate design and maintenance methodologies for the multi-layer/multifunctional and for the sensorised structures.

Assessment of the expected weight savings for selected classes of structural elements.

Validation of sensors embedding and of multifunction layers structures using different manufacturing processes.

Definition of types of structures to be used for final validation and demonstration of the maturity achieved by these technologies.

Laboratory testing for validation

4.2.4.4 Low Noise Configurations

4.2.4.4.1 Requirements and Architectures

The requirements for the technologies to be developed will be set starting from the overall external noise requirements based on future airworthiness regulation and on trends of aircraft operation constraints at airports.

4.2.4.4.2 Enabling Technologies

Low noise high lift devices will be developed based on configurations including low noise kinematics fairing layouts and flaps optimised to obtain aerodynamic performance comparable to current systems but with a lower generation of aerodynamic noise.

Flap edge noise reduction by specific suppression devices will also be exploited for further noise reduction.

Noise produced by flow separation triggered by landing gear leg wirings and pipes, and by the wake generated by the wheel pack will be reduced by appropriate landing gear component design for low noise, to be pursued by System Platform, to which contribution in terms of requirements will be provided.

Flow separation noise contribution due to landing gear bay doors will be reduced by proper shaping. Shielding of the landing gear produced noise will be developed.

Solutions for other noise sources, such as the wing body fairing, antennae integration, drainage holes, ECS inlets, will be verified.

A large use of validated modelling made of advanced CFD/CAA tools is planned to support demonstrator design solutions and to analyse tests results. A comprehensive set of design data will be provided to support the demonstrator modification design.

4.2.4.4.3 Application Studies

The most promising features for lowering the aircraft aerodynamic noise will be validated through steps of analysis using computational tools and finally testing in wind tunnels.

Data will be developed concerning: physical configurations, noise performance, lift, drag and stability and control issues, weight, required actuation power, impact on platform general configuration. The impact on the aerodynamic design for low noise deriving from other requirements like enhanced lift, low drag, reduced wing loading, and intelligent aerodynamic surfaces actuation will be considered and integrated.

The most promising technical solutions will be brought up to the testing phase, for selection of the optimal ones and for validation of the technology.

4.2.4.5 Integration of applicable technologies from other domains

The other “Clean Sky” Domains of interest to the GRA Platform are:

- Load and Flow control
- New Configurations
- Engines
- Energy Management
- Mission and Trajectory management
- Aircraft Life Cycle

These technologies will be developed by the relevant Platforms together with the contribution of the Green Regional Aircraft Platform.

The demonstrations of the integration of these technologies will be focused on their relevance to the GRA Platform.

This activity will assure that the aircraft level view for these technology domains will be developed and demonstrated with the proper focus for the GRA.

4.2.5 GRA Platform Deliverables and Demonstration

Demonstration of the technical solutions integrated within the GRA platform with reference to the generic regional aircraft type is the means by which the following deliverables will be produced, at TRL 6:

a. Low noise aircraft configuration, consisting of the innovative solutions of the wing high lift devices and of the landing gear installation enabling the generation of less aerodynamic noise while performing their other basic functions at a high level of efficiency.

b. Low weight aircraft configuration, that is the advanced solutions of composite structures where sensors are embedded along with other materials so to obtain the load carrying capability plus the ancillary functions expected by the different elements of the structure at a weight significantly lower than using today technology.

c. The all electric architecture of the on-board systems best exploiting the advanced equipment technologies developed during the Clean Sky

d. The architecture of avionics utilising the technical solutions developed in the Clean Sky for the advanced flight guidance and flight management functions

All the advanced technologies that will be demonstrated will be optimised for the reduction of the environmental impact of the generic regional aircraft operation.

In fact, the general objective of Clean Sky is to mature the advanced technologies addressed to achieving the Vision 2020 goals up to the level required for their low risk application in future programs to be launched after the conclusion of this research. In the GRA Platform the specific integrated solutions stemming from the advanced technologies being investigated in the course of recent and on going European research projects as well as in the other Platforms and best tailored to the generic regional aircraft type will be demonstrated after application studies addressing also their integration at the aircraft level.

Demonstration will be performed in flight on appropriate test aircraft, preceded by ground tests. In specific cases, simulation on ground is deemed to be appropriate and cost effective; then demonstration will be stopped at this level.

There will be intermediate steps at which the results of the research will be monitored. They will be typically at the end of the application studies and tests, when projections on expected performance are possible.

4.3 Green Rotorcraft Platform

4.3.1 Rationale

The usage of helicopters in the Community has been until now concentrated in activities such as medical evacuation, rescue, civil protection, aerial work and law enforcement. These activities amount to about 1.500.000 flight hours per year to be compared with around 10.000.000 hours flown by the European commercial airlines. This volume of helicopter activity represents the pure minimum required to satisfy today’s primary needs of the population and, as such, it is commonly accepted.

Such rotorcraft operations are expected to grow sharply in the future to face the European citizen’s demand for a safer and more secure society. Considering only the case of medical services as an example, the number of flights will drastically increase as a result from the current development of advanced curing techniques and from the specialization of hospitals. The helicopter is definitely the most efficient vehicle to achieve safe and quick transport of patients between hospitals and to deliver living organs for transplantation.

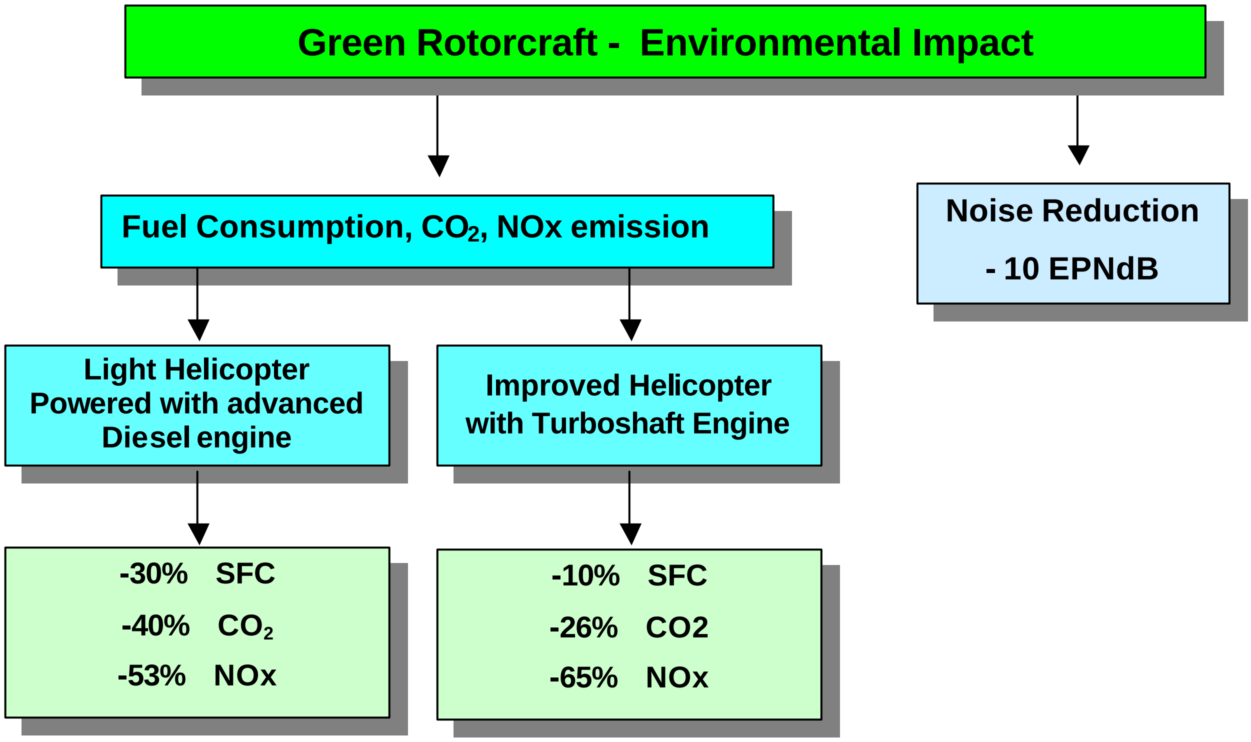
In addition, the rotorcraft traffic for passenger transport which is presently only a marginal activity is expected to develop rapidly as it is driven by the large growth in passenger air travel demand that is expected for the 2015 – 2020 period (2 to 3 fold increases). Helicopter shuttle operations carrying passengers from city heliports to airports, or even flights between cities without airports and for which efficient surface transport could not be efficiently developed (e.g. in mountainous areas, or for connection of islands to mainland where ground infrastructure is limited). In the meantime, thanks to their capability to operate independently from runways, tilt-rotors are expected to play a key role as complement of turboprop airplanes, to feed major airports with passengers starting from remote secondary airports. Whereas it can be estimated that the helicopter will ideally serve distances up to one hour of flight or 300 Km, the tilt-rotor aircraft will be able to double this distance thanks to its speed and to its capacity to cruise at flight levels similar to turboprops (pressurised cabin). The dependability and safety of rotorcraft services will simultaneously be enhanced thanks to the development rotorcraft-specific navigation based on satellite guidance (EGNOS, Galileo).

As a consequence of this expected growth of traffic, the rotorcraft contribution to the environmental impact of air transport which appears today as negligible would become more significant in next decade unless a major initiative is launched to make each rotorcraft flight definitely more environmentally friendly than today. The Rotorcraft Platform in the Clean Sky responds to the challenge of minimising the impact of sharply increasing rotorcraft traffic including the introduction of tilt-rotors through a much more efficient usage of energy and through a drastic reduction of greenhouse gas emission and noise footprints throughout the whole mission spectrum.

4.3.2 Objectives and expected impact of the platform

The present rotorcraft activities imply burning the equivalent of 400 000 tons of fuel per year in the Community. With the present technologies, this figure is expected at least to quadruplicate as a result of the traffic augmentation in the next 20 years . The final objective of all Research & Development performed at national and European levels is to come back within 20 years to the present global level of impact on the environment while sustaining the same expected growth of helicopter services.

The partial objective to be achieved within the next 10 years as resulting from Clean Sky i.e. outputs of the **Green Rotorcraft Platform** and contributions from other platforms mainly the **Sustainable and Green Engine** and **Eco-Design Platform**, along with outputs of other already launched technology programmes consists in halving the specific impact of any rotorcraft operation on the environment. In detail taking into account the year 2000 like baseline and consistent with the ACARE targets the objectives are reported in the diagram below.



4.3.3 General Approach and Content

Several recent or on-going European research programmes will bring significant background to the Green Rotorcraft Platform :

⇒ I.P. FRIENDCOPTER, addressing noise abatement procedures, improved engine integration, active rotor blades with distributed actuation for lower noise and reduced power loss ;

⇒ I.P. OPTIMAL, addressing airport approach procedures specific to rotorcraft which are compatible with noise abatement and with rotorcraft integration in the general ATM ;

⇒ TILTAERO and ADYN and part of the I.P. NICE-TRIP addressing aerodynamic and aero-acoustic optimisation of an innovative tilt-rotor aircraft concept to reduce the noise impact and minimise the power demand in take-off and cruise configurations ;

Although not included in the "Clean Sky" background, results of some National R & T programmes will also contribute to advancement toward the global impact reduction of helicopter operations, especially so for the major following ones :

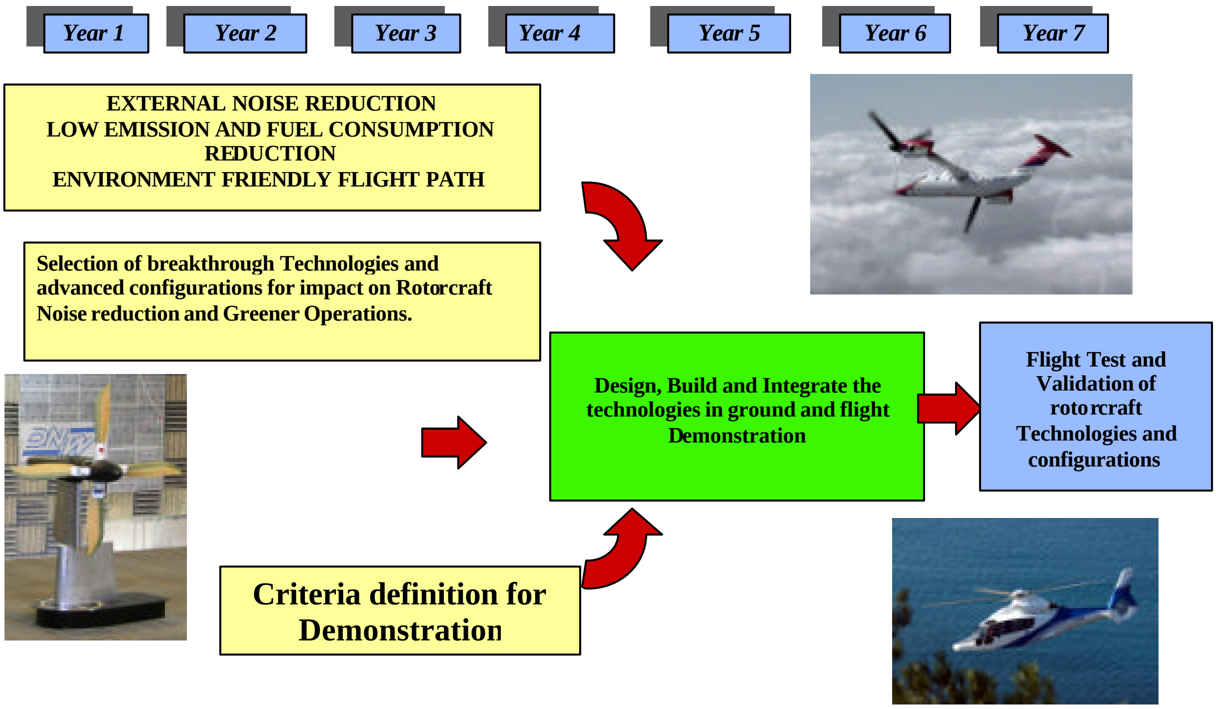
⇒ French programmes "Hélicoptère Silencieux" and "Pales 2005" addressing in-flight demonstration of technologies to reduce noise impact and reduce power demand of helicopters thanks to improved or optimized design ;

⇒ German programmes ATR, ADASYS and LARS addressing in-flight demonstration of improved design and individual blade control using trailing edge flaps to minimise simultaneously noise and vibration ;

⇒ British programme HEAT addressing elimination of hydraulic fluid thanks Electro-Magnetic Actuators (EMA) for main rotor control boosters ;

⇒ Italian ELIMAT project about introduction of advanced materials and manufacturing processes for a rotorcraft development.

Work Flowchart



The research actions will be conducted in three main areas described below.

4.3.3.1 External noise reduction

- Study and evaluation of innovative rotor blades: Rotorcraft noise being mainly due to impulsive and local airloads on rotor blades, this action engaged in the I.P. FRIENDCOPTER will be continued to reach a higher level of technology readiness.
- Engine noise reduction: A significant potential exists for reducing rotorcraft perceived noise in hover and low speed by acting on the turboshaft engines and their installation. The rotorcraft platform will provide the engine platform with relevant specification for engine noise minimisation.

4.3.3.2 Cleaner and more efficient power use

- Reduced drag of airframe and dynamic systems: technologies to reduce the aerodynamic drag and power loss of all helicopter components contributing to the shaft power demand in all flight configurations relevant for minimisation of gas emission and fuel burn will be further explored and demonstrated. A potential reduction of 10% shaft power averaged on a typical helicopter mission is foreseen.

- Reduced engine fuel consumption: based on two complementary activities:
  - Diesel engine installation for light helicopters and, in continuation with current I.P. FRIENDCOPTER activities, optimisation of turboshaft engine installation for other rotorcraft. The substitution of a turboshaft engine by an advanced Diesel engine on a light helicopter could cut down the fuel consumption by 30%. Since light helicopters account for 60% of the present turboshaft powered helicopter fleet, this study is expected to have important spin-offs for the global impact of helicopter operations. It will also be of interest for very light helicopters presently powered by gasoline piston engines.
  - The optimised installation of a turboshaft engine could reduce the fuel burn by typically 4%. Advanced turboshaft technologies developed within the engine platform and other programmes (esp. T.P. NEWAC) could further reduce the SFC by some 10%.
- Architecture and Integration for all electrical design: based on energy management optimisation, the more-electrical architectures will bring the concepts of "no bleed air" and "no power off-takes" on the engines to a higher maturity level, thereby also contributing to fuel burn reduction on future rotorcraft.

Some further activities linked with the Eco-Design platform will address the greening of the whole supply chain with elimination of toxic and non recyclable consumables and with environment oriented manufacturing processes including the selection of materials.

4.3.3.3 Environment-friendly flight paths

The expected fast growth of rotorcraft operations to and from airports (hub-feeder role), with an increasing fraction being performed under instrumented flight rules (IFR) could induce an excessive fuel burn with the helicopters or tilt-rotors following departure/approach routes designed for fixed wing aircraft. In order to allow a significant fuel economy, shorter IFR routes which do not interfere with aircraft traffic will be further developed and demonstrated taking advantage of the intrinsic agility of rotorcraft and integrating the requirements for noise abatement. This work will bring procedures developed in the OPTIMAL I.P. to a higher level of maturity.

Concerning operations to and from helipads, part of them being located within densely populated areas (hospitals, vertiports), the main goal will be the implementation of noise abatement flight paths, featuring multi-segmented and curved approach routes with variable speed profiles and with appropriate obstacle protection, to be developed and tested in a representative urban environment. This work will bring procedures developed in the FRIENDCOPTER I.P. to a higher level of maturity, allowing for a noise footprint reduction of 50% (impacted area) for most helicopter types flying throughout Europe.

Concerning specifically tilt-rotor aircraft, the possibility will be investigated to minimise the noise footprint during approach and departure using its ability to adapt the schedule of nacelle tilt and wing tilt angles within the conversion corridor.

Concerning low altitude navigation, mandatory for unpressurised helicopter cabins, the noise impact will be minimised thanks to 3D optimised VFR and IFR routes relying on accurate GNSS navigation (EGNOS, Galileo).

4.3.4 Technical Approach

4.3.4.1 Innovative rotor blades

The selected approach is to fully develop and mature the most innovative and promising technologies of active blade control using distributed actuation.

- Rotor Model: The rotor model with active blade twist which is developed and tested on the whirl tower as part of the FRIENDCOPTER project will be further tested in a wind tunnel in conditions representative of the actual flight envelope..
- Full Scale Rotor Blades: Full scale rotor blades with distributed twist actuation will be designed matching the requirements for flightworthiness and reliability. A prototype blade set and control system will be manufactured and tested in a laboratory and on the whirl tower. According results obtained during these ground tests, this active rotor might be finally tested on a helicopter in flight.

Specifications will be used for mature, flightworthy electric/electronic components suitable for supply, transfer and control of high voltage power needed for piezoelectric materials.

4.3.4.2 Drag Reduction on airframe and dynamic components

The following table indicates in the first column the components and problems to be addressed by order of decreasing priority while the second columns briefly describes the intended solutions or technologies to be investigated and implemented :

COMPONENT / SUBASSEMBLY	ENVISAGED SOLUTIONS
Main and tail rotor pylon, hub, swashplates, control rods and blade roots	Design of advanced fairings free from detrimental impact on maintenance
Blunt fuselage-tail junction	Reshaping without detrimental impact on weight ; passive boundary layer manipulators such as riblets, micro vortex generators, etc to minimise skin friction and prevent flow separation performance or overall operation

Turboshaft engine installation : inlet pressure loss and distortion, hot gas re-circulation, nozzle backpressure, external drag of inlets and nozzles	Optimisation of air inlet and nozzle configurations combining criteria for external drag, engine installation loss and noise absorption/shielding (further to current activities in the Friendcopter I.P.)
Rotor blades : profile drag and stall inception	Passive boundary layer manipulators such as riblets, micro vortex generators, etc ; active flow control techniques using synthetic jets, plasma actuators, etc to minimise skin friction and prevent flow separation
Tail unit and tail surfaces	New tail configurations such V-tail and active tail surfaces for fuselage incidence and sideslip control independent from rotor control

The tools necessary to develop these technologies include the numerical simulation of rotorcraft (Computational Fluid Dynamics, Computational Structural Dynamics, Multidisciplinary Coupling and Optimisation) and wind tunnel techniques which have to be adapted in parallel to technology development.

4.3.4.3 Integration of innovative electrical systems

Elimination of “non green” consumables esp. the hydraulic fluid is linked to Electro-Mechanical Actuators dedicated to flight controls, landing gears and braking devices. New architectures must be designed taking into account actuation technology development and new helicopter electrical architectures.

For each domain, the different technical topics and solutions are indicated here below :

PROBLEM / COMPONENT	SOLUTIONS/ACTIVITIES
Power Management : concurrent electrical power requirements ; short duration power demand ; emergency energy/power generation	Innovative electrical architectures; alternative power generation sources; use of auxiliary power as additional main power source; management principles for load requirements; flexible power availability.
Energy for piezoelectrical actuators : high voltage and high frequency switching are required to transfer in the rotating frame the energy sufficient to move the piezoelectrical actuators	Miniaturised, robust power supply, amplifiers & semiconductors
Electrical network : new requirements for modern rotorcraft, high voltage network	New electrical network architecture
Power electronics : need of weight reduction and extended life	Solid state components

Actuation : hydraulic fluid is a "non green" consumable	Electrical mechanical actuators for flight controls, landing gear, braking, hoist
Tail rotor : drive independent from main rotor could enable noise reduction ; electrical control actuation necessary to eliminate hydraulic fluid	Potential weight saving, fuel consumption reduction and "non green" consumables elimination to be explored

4.3.4.4 Installation of a Diesel engine on a light helicopter

A recent survey comparing different concepts of thermal engines suitable for reduction of helicopter fuel consumption allowed identifying the turbocharged Diesel engine as the most promising candidate. Its extremely low specific fuel consumption, good fuel tolerance and environmental-friendly exhausts led to the conclusion of an interesting implementation potential for lightweight helicopters.

The technical approach is the Green Rotorcraft Platform will comprise four steps :

- Investigation of the concept
- Integration study
- Engine specification
- Demonstration phase

Results of this activity will include a helicopter integration review, a performance simulation, emission status and conclusions regarding competitiveness: advantages and remaining problems.

4.3.4.5 Environment-friendly flight paths

The specific activities adapted to typical operational situations will be addressed as summarised in the table below.

OPERATIONAL SITUATION & PROBLEMS	SOLUTIONS/ACTIVITIES
IFR & VFR approach & departure: procedures & flight paths optimisation with respect to noise footprint minimisation (further respectively to OPTIMAL and FRIENDCOPTER)	Variable vertical and speed profiles for final IFR or VFR approach depending on rotorcraft class Optimised initial and intermediate IFR approach paths using high accuracy 3D or 4D satellite-based navigation Low noise IFR or VFR departures Specific low noise procedures for helipads / heliports in urban environment

Low level VFR & IFR en route navigation: autonomous and safe navigation ; minimisation of noise impact	3D optimisation of flight path for noise nuisance minimisation Narrowing of rotorcraft low level IFR flight routes thanks to the introduction of RNP-RNAV concept Separation and surveillance of rotorcraft low level traffic by Automatic De-pendent Surveillance Broadcast (ADS-B) technology
Specific Tilt-Rotor aspects: Noise and fuel consumption minimisation during the conversion phase	Tiltable wing and nacelle angle optimisation for noise minimisation during takeoff and final approach

The contribution of rotorcraft to the noise emission of the overall air transport will be assessed, taking into account the expected traffic growth and the proposed environment-friendly flight paths.

4.3.5 Links with others platforms

4.3.5.1 Links with the Eco-design Platform

The Rotorcraft platform will have benefits from the technologies developed into the Eco-design platform; four general issues can be identified:

- Materials
- Manufacturing
- Long life structure
- End of life management

4.3.5.2 Links with the Sustainable and Green Engine Platform

The Rotorcraft platform will actively contribute to the Engine platform by specifying rotorcraft needs and by contributing to the evaluation of specific rotorcraft engine.

4.3.5.3 Links with the Systems for Green Operations Platform

The Rotorcraft platform contribution will constitute in specifying rotorcraft needs for innovative electric equipment and integration of those on the rotorcraft, esp. high voltage power supply, control and transfer in the rotating frame for large scale piezoelectrical actuators embedded in the blades.

4.3.5.4 Links with the Technology Evaluator Platform

The Rotorcraft platform will synthetics its results and along with the relevant outputs of the horizontal platforms within the New Conceptual Rotorcraft numerical model which will be used to deliver the necessary set of representative parameters to feed the Parameterised Aircraft models in the Technology Evaluator Platform.

4.3.6 Deliverables and demonstration outputs for the Green Rotorcraft Platform

4.3.6.1 Wind tunnel tests

To validate the noise and drag reduction technologies, a dedicated tunnel experimental program will be established. This will allow collecting reliable acoustic data in anechoic wind tunnels, along with performance data (forces and moments, shaft power) and distribution of meaningful flow parameters (pressure, temperature, velocity).

For some advanced concepts involving insufficiently mature technology such as flow control using plasma actuators, synthetic jets or even actively twisted blades, the deliverable results will be obtained by integrating the wind tunnel results into a comprehensive rotorcraft simulation in order to identify the benefits in terms of noise impact and energy consumption before the flight tests activity.

4.3.6.2 Ground test articles

The validation of the novel electrical actuators and energy management systems selected during the first phase of Clean Sky will be conducted on an electrical integration bench.

The electrical tail rotor equipped with an electrical control booster and, possibly with an electrical drive, will be submitted to static and dynamic testing on a ground rig allowing measuring simultaneously its energetic and aerodynamic performance.

The innovative rotor blades will be tested on a main rotor whirl tower for demonstration of functionality and static/dynamic performance in the hovering configuration.

Test results will be incorporated into the comprehensive rotorcraft simulation (Iron Bird or Ground Test Vehicle) in order to derive conclusions regarding the benefits in terms of noise impact, energy consumption, possibility to proceed with the elimination of the hydraulic and bleed air systems on future helicopters.

4.3.6.3 Technology ground & flight demonstrations

The novel integration concepts regarding airframe and dynamic components aiming to reduce the parasitic drag and power demand which are considered feasible and successful after analytical studies and/or wind tunnel testing will be demonstrated in flight on at least two different helicopters, in order to represent the broad spectrum of rotorcraft size and configuration (tail rotor type, rotor hub architecture, fuselage volume, etc) and also depending on the possibility to combine the miscellaneous concepts on a given helicopter type. The innovative rotor blades could be incorporated to one of the configurations, depending on whirl tower test results.

At least one of the demonstration configurations will include an improved turboshaft engine installation (inlet, exhaust, fuel and control system) and possibly a modified engine.

Another demonstration configuration featuring a light helicopter will be powered by a Diesel engine specifically adapted for this installation.

On board measurements will be acquired for all relevant parameters (stress/strain, acceleration, fluid temperature and pressure, acoustic pressure, voltage or intensity, digital signals, etc) on airframe, rotor blades, engines, control systems, electrical and other energetic systems.

Specific noise data will be acquired on ground in order to establish footprints.

Before flights, the dynamic or active novel concepts will be submitted to a complete range of ground tests on the helicopter with and without rotation of engines and rotors, in order to perform final verification and tuning operations.

4.3.6.4 Operational flight demonstrations

The integration and further development of the ongoing projects will be finalised in dedicated experimental programmes with the use of helicopters of different types and size, to validate the actual benefits of standard and special noise abatement procedure, and related requirements for ground and on-board systems as a support to the pilots. Both quantitative and subjective assessment will be conducted, proving elements and data for the global evaluation to be performed in the Technical Evaluator platform.

In addition, regarding the environmentally friendly IFR navigation, approach and departures procedures, tests will be conducted in order to provide the flight data necessary to update ICAO criteria related to helicopter operations. In particular, the relevant test data will be submitted to the ICAO Obstacle Clearance Panel (OCP) in preparation for a future introduction the rotorcraft environmentally friendly IFR procedures in the PANS-OPS (ICAO Air Navigation Rules) regulatory material. Working in tight relation with ICAO bodies is expected to make these new procedures approved for operations relatively rapidly, i.e. within the 2010 – 2015 period, in parallel of the availability of Galileo “safety of life” service for aeronautics.

Tilt rotor specific integration aspects will be further approached using both advanced powered model developed in FP6 projects for wind tunnel testing, and evaluation of BA609 tilt rotor aircraft for specific flight testing to assess the noise impact.

4.4 Sustainable And Green Engine (SAGE)

4.4.1 Rationale

Propulsion is the major contributor to the environmental challenges set by the SRA: largest noise source, the only source of NOx and a major contributor to fuel burn. The engine sector has been responsible for 3/4 of the improvement in fuel burn efficiency over the last 30 years, as well as for noise improvements and pollution improvements.

This importance has been recognised by ACARE, which defined specific engine contribution to the environmental goals for 2020:

- 20 % CO_2 reduction
- 80 % NO_x reduction
- 50 % perceived noise reduction

The 2020 objective requires progress equivalent to that made in the past 30 years.

Engines that are flying today (CFM56 and TRENT families) represent the reference technology for the ACARE objectives. New engines are today under development for entry into service around 2007. This new generation of engines (SaM146, TRENT1000) represent the first step towards the ACARE goals. A new generation of engines, representing a second step, is foreseen around 2012. Last, a third generation, with a development starting in 2013 and entering into service around 2017, should approach the ACARE goals.

Based on market forecasts and more importantly dialogue with the major civil aircraft manufacturers, four opportunities stand out:

- The replacement of the entire narrow body fleet above 100 seats. This sector already contributes the majority of environmental pollution.
- Technologies developed above will naturally flow into the regional market. In this market, very low cost but high efficiency solutions are necessary to be competitive.
- Medium term, the helicopter market will need greened turbo-shaft engines with specific power increase.
- Although the timing is less clear, novel technology is required for the wide body market, drawing both on technology developed for narrow body applications, and specific technology for this sector where fuel consumption is at an absolute premium.

The engines of 2020 should be radically different from those in service today. Bypass ratios need to be much higher, engine nacelles may even disappear, power off takes will increase as the size of the core reduces and real time diagnostics will enable engine maintenance to be optimised. Clean Sky will enable all of these developments to be fully validated in a realistic operating environment.

As an example, the engine technology vehicle known as ANTLE performed this task for 2010 technology readiness using three European programmes (EEFAE, SILENCER and POA) and two national programmes.

If future demands push for more radical solutions to reduce even more aggressively the emissions and noise, the engine platforms demonstrators would be directed towards radical solutions as described under SAGE 2 and SAGE 3, closely linked to new vehicle concepts from the Smart Fixed Wing Aircraft platform and the Green Regional Aircraft platform.

Alternative fuels could lead to less polluting emissions and at the same time respond to the potential rise in fuel prices due to the decrease of fossil fuel availability, thus addressing both environmental and economical concerns. The major challenge in making the use of alternative fuels a viable solution lies in developing the production processes and the distribution infrastructure. However, the use of non-fossil fuels in aircraft engines has to be addressed in order for the air transport system to be ready when alternative fuels come into use.

4.4.2 Objectives and expected impact of the platforms

The purpose of the Sustainable and Green Engine (SAGE) platform is to assess, design, build and test up to five full scale engine demonstrators. The successful validation of these technologies will then facilitate the early introduction of innovative new products to significantly reduce the environmental impact of air transport. The impact on the achievement of the ACARE targets, relative to the ACARE baseline, in the context of ongoing major research programmes is shown in the Table below:

Engine Sector Environmental Targets and Achievements

	CO2	NOx	Noise (EPNdB) Cumulative
2000	**Baseline**	**Baseline**	**Baseline**
Clean Sky	**-14 % to –20 %** **TRL 6**	**-60 % to –80 %** **TRL 6**	**-16 to –20** **TRL 6**
ACARE	**-20 %**	**-80 %**	**-20**

*** NOx baseline is roughly consistent with 80% of CAEP2**

**** Noise baseline is roughly ICAO Stage3 – 10 EPNdB**

4.4.3 General approach and content

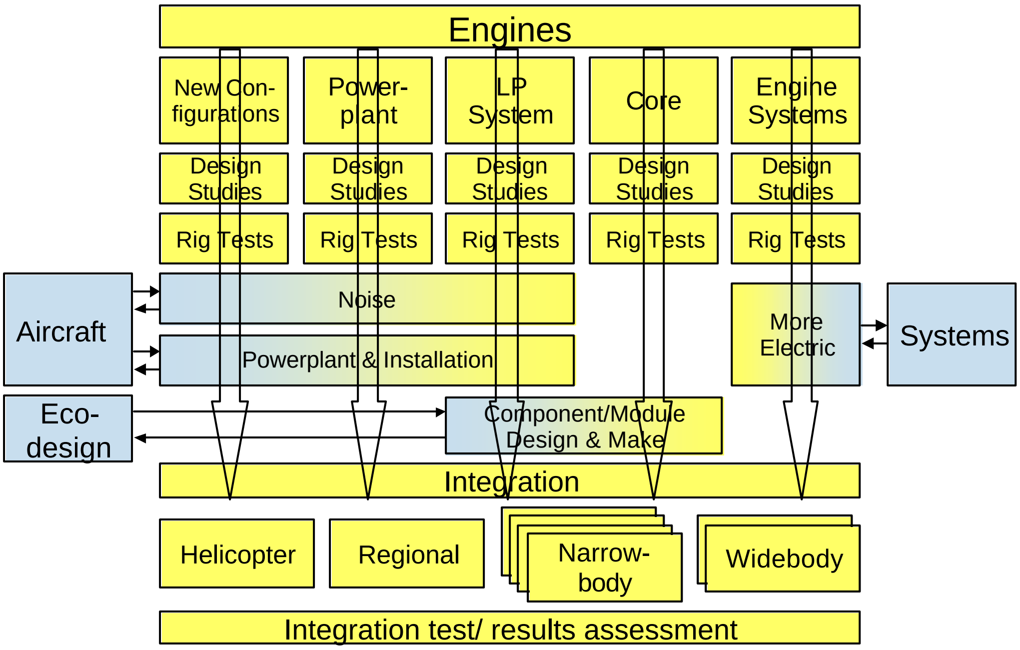
The proposed engine platform will contain a number of testing vehicles which will use the competencies and facilities of all the European aero-engine manufacturers complemented with those of related Research establishments, academia and SMEs. The proposed demonstrations will prepare new solutions for the complete range of the market, with engines for the narrow body fleet, high thrust engines for wide body aircraft, regional aircraft engines and helicopter engines. A focus will be put on narrow body aircraft engines where different configurations are possible. Step change technologies and the use of alternative fuels will be tested on the appropriate demonstration.

4.4.4 Technical Approach

4.4.4.1 Requirements and Concept Studies

The overall structure of the SAGE platform mirrors that of the entire Clean Sky programme. Studies will be done around the specific concept studies, conducted with airframe manufacturers and system suppliers, on aircraft/engine/system concepts in order to fully define the requirements for enabling technology and demonstration programmes. The principal focus of these studies will be upon radical architectures for aircraft, engine and systems, building on the output of programmes such as NACRE, POA and MOET.

4.4.4.2 Enabling Technology



The figure above illustrates the principal technology domains where sufficiently mature technology (typically validated to TRL 5 in large scale rigs) is required to support demonstration vehicles. The "New Configurations" technology domain (including concepts such as aft-mounted open rotor engines) forms part of the fixed-wing platforms, due to the close synergy between engine and airframe technology for such concepts. It is shown in the figure above for completeness, since it is a major element of the overall engine-related work-stream.

Much technology within these domains is being matured to TRL4-5 within Clean Sky timescales in FP6 IPs and in national programmes. Most notable amongst these is the LP systems technology in VITAL and the core technology in NEWAC. However, there are undoubtedly some gaps in the technology portfolio required to support the large-scale demonstration programmes, some of which are already known and some of which will be identified as the concept study and requirement capture activity proceeds in the early stages of Clean Sky. Further major rig programmes to validate enabling technology are therefore likely to be required during the early years of Clean Sky; these will include:

- Lightweight / low noise fan system and LP turbine rigs to augment and accelerate the technology validation within the VITAL programme.
- Powerplant technology validation, principally for noise and weight reduction, to build on the technology base established by the SILENCER programme and account for the fact that there is no successor to SILENCER within FP6.
- High efficiency / low Nox emission / low weight core turbomachinery rigs to augment the Technology Readiness level (TRL) which should be reached thanks to NEWAC and to other programmes, or where these are not addressed by existing programmes (for example, a next generation IP compressor, which is not covered within existing national and European programmes).
- Rigs to validate technology for architectural change, including open rotors, intercoolers (and associated ducting), power transfer technology and large gearboxes, depending upon the results of the joint airframe/engine "Novel Configurations" work-stream.

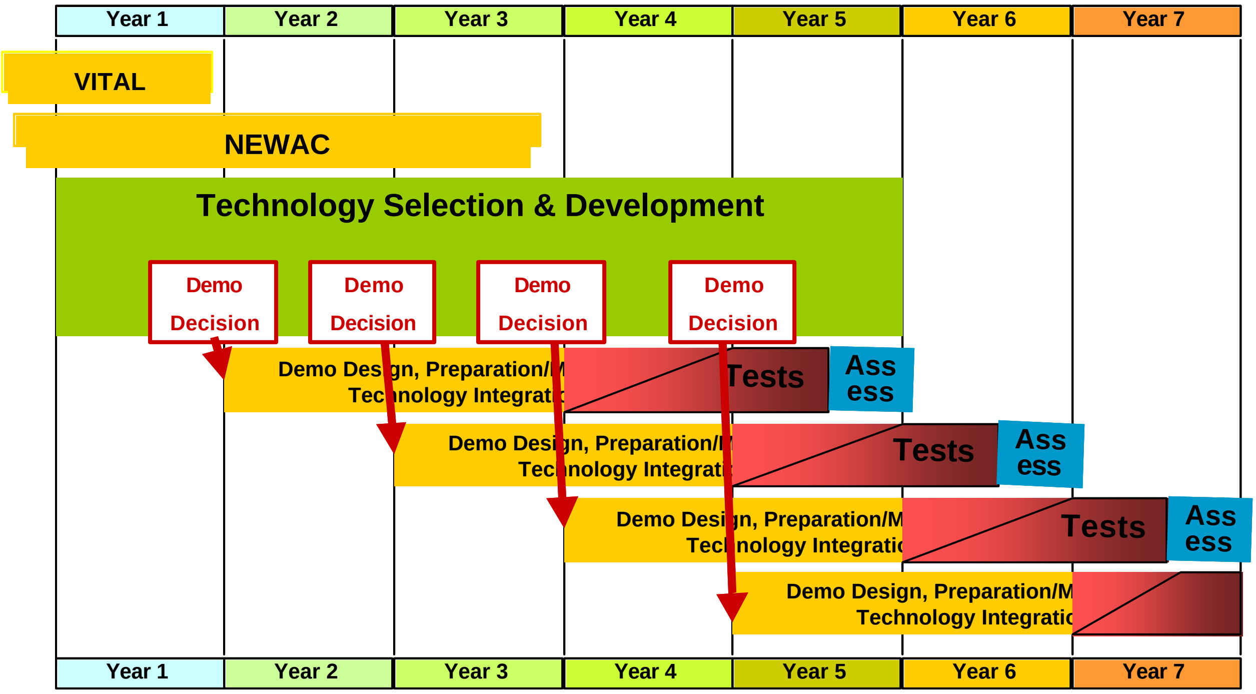
4.4.4.3 <u>Application Studies</u>

Before to definitely launch demonstrators incorporating the foreseen technologies it is necessary to design modules using these technologies in an actual engine environment and under constraints of integration within an actual engine, and to evaluate their real benefits.

This task will lead to the most promising technologies choice, taking in account an acceptable risk for the demonstrator behaviour. It will also permit to clarify ways and methods to design more surely the demonstrator within a given schedule.

Another output will be the need, or not, to partial tests, or complementary rig tests, dedicated to identified risks removal.

4.4.5 Platform Deliverables and Demonstration



The figure above illustrates the overall master plan for engine demonstration, and the timeline for definition and selection of demonstration vehicles. There is a wide range of candidate demonstration vehicles, distinguished by application (helicopter, regional, narrow-body and wide-body) and by engine architecture (2-shaft, 3-shaft, radical). It will be neither affordable nor efficient to define and execute demonstrator programmes covering this full suite; however, many technologies have the option of being validated in more than one demonstrator vehicle, and it is proposed to select demonstrator vehicles as Clean Sky proceeds. These will be selected based upon technology maturity and market requirement, and to maximise the technology validation opportunity (i.e. a suite of demonstrators will be chosen which maximises the set of technologies which are validated at TRL6). The figure below illustrates schematically the mapping between technology domains and potential demonstration vehicles.

4.5 Systems for Green Operations

4.5.1 Rationale

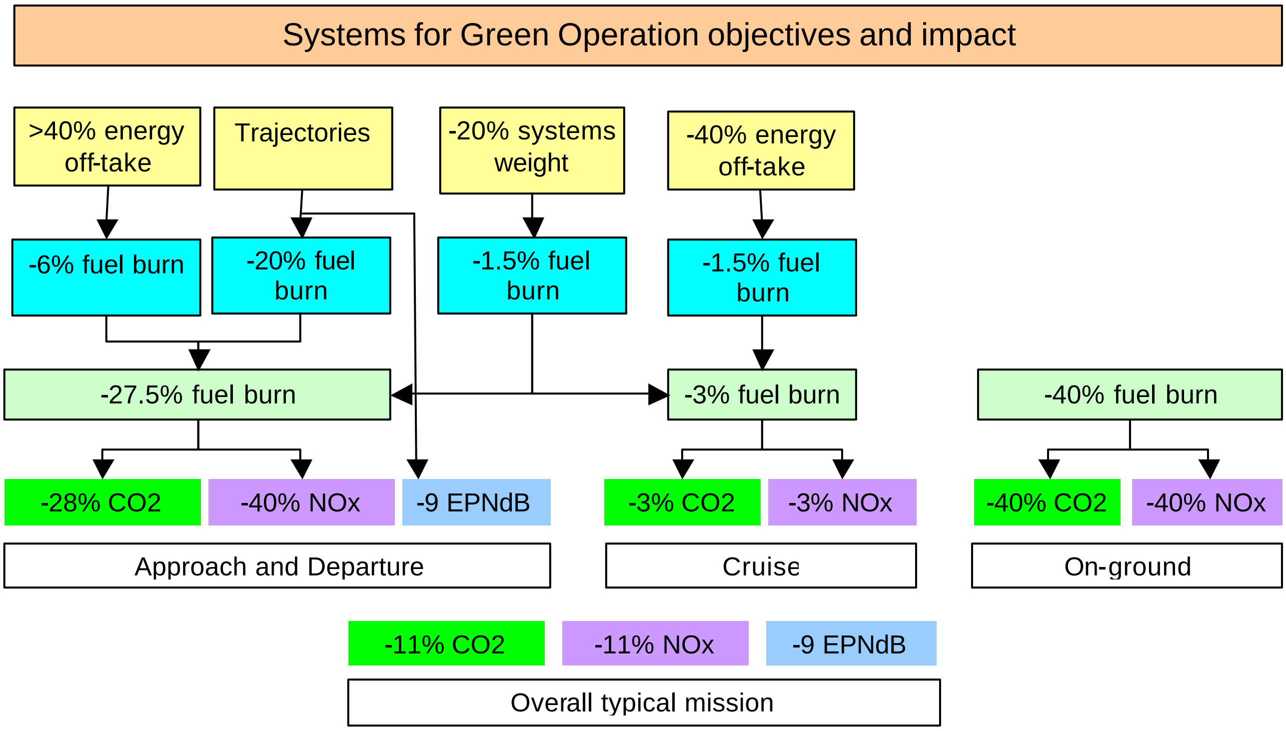
Up to now aircraft systems have been designed mainly from a safety, time efficiency and affordability view point. The increasing social demand to reduce fuel consumption, emissions and noise leads to the adoption of a new approach when designing systems. Two domains have been identified as major contributors to the achievement of the green challenges:

- The **Management of Aircraft Energy**, which includes the two focus areas of “All-Electric Aircraft Equipment Systems Architectures” and “Thermal Management”
- The **Management of** Aircraft **Trajectory and Mission**, which includes the four focus areas of “Green Trajectories”, “Quiet Landing Gear“, “Smart Ground Operations” and “Green Mission”.

The platform will deliver solutions that are integrated at aircraft level, fully demonstrated in realistic operational conditions and proven against the environmental challenges.

4.5.2 Objectives and Impact

This platform will create value for two phases of aircraft operation, the highest overall benefits being realised during the approach, on-ground and departure phases, where the environmental impact near built-up areas is directly affected. In addition, the technologies from this platform are enablers for further improvements in environmental impacts at the vehicle level. The impacts expected are:



In cruise:

- 3.5% less CO_2 and NOx emitted. This is due to reduced fuel consumption through improved energy management and mission management.

During approach and departure phases:

- 28% less CO_2 and 40% NOx in these flight phases, which corresponds to about 6% CO_2 and 6% of NOx globally. This is achieved through new trajectories, systems weight reduction and reduced fuel consumption.
- 3 dBA reduction during departure and 6 dBA during approach due to new trajectory and mission management and 4 dBA reduction due to landing gear technology improvement. A first estimate for a combination of these two is a reduction of 9 EPNdB

On-Ground:

- 40% CO_2 and 40% less NOx around the airport area on-ground, accounts on average for 2% less CO_2 and NOx over a flight. This is due to a reduction in fuel consumption.

Quantitative objectives have been set which will be pursued in the acquisition of each individual technology. Trade-offs at aircraft level will also be considered in the architecture activity.

These are:

- A reduction of systems related weight by 20%. This is based on keeping the functionality of the systems the same as the reference, but implementing the new technologies from this platform.
- A reduction of the systems related power extraction from the engine by 40%. Previous projects have shown that this is achievable, and will enable the engine to operate differently as well.
- A 20% reduction[13] of fuel usage due to improved trajectories around the airport, relevant to climb and descent phases.
- A 40% reduction in fuel usage on the ground (taxi and at the gate), due to smart ground operations.
- Noise reductions during approach 6 dBA[1] less (3 dBA on departure) related to new trajectories and 4 dBA less due to new landing gear technology.

4.5.3 General Approach

4.5.3.1 <u>Management of Aircraft Energy</u>

The **Management of Aircraft Energy** encompasses all aspects of on-board energy provision, storage, distribution and consumption. The goals are directly related to the overall Clean Sky objectives:

- Optimisation of power consumption as well as of the aircraft energy along the mission. This will be done through reduction of waste energy directly attributable to aircraft systems through better equipment system efficiency and through optimisation of energy transport and distribution systems. This leads to a direct reduction of fuel consumption and consequently of pollutant exhausts (CO_2, NO_x).
- Reduction of maintenance-related environmental impacts, such as elimination (or drastic reduction) of undesirable fluids like hydraulics or cooling fluids.

These challenges will be met by:

- The development and demonstration of **All-Electric Aircraft System Architectures** (power by wire), to be defined by airframers, including all energy users to facilitate the implementation of advanced energy management functions and architectures. This also entails the suppression of hydraulic fluids and related negative environmental impacts.
- Achievement of adapted and demonstrated control of heat exchanges (partly necessary due to the all electric concept) and reduction in heat waste within the whole aircraft through advanced **Thermal Management**.

[13] these targets have already been accounted in previous R&T projects, Clean Sky will demonstrate that they are actually feasible to TRL 6

These concepts will be complemented by solutions which envisage the eventual implementation of total aircraft energy management, such as resource management, health management and overall aircraft energy management (optimisation of exchange of energy between the engine and the energy generation and distribution system).

This work has very strong links to work done in the large-scale European FP5 *Power Optimised Aircraft* (POA) and FP6 *More Open Electrical Technologies* (MOET) projects. Technologies which have been functionally validated in POA and MOET will be proven in flight test or in large-scale integration ground tests in Clean Sky. Technologies which are required for Clean Sky but are not mature enough will be investigated in other collaborative research projects.

In addition, results from smaller projects (European and National) will be used:

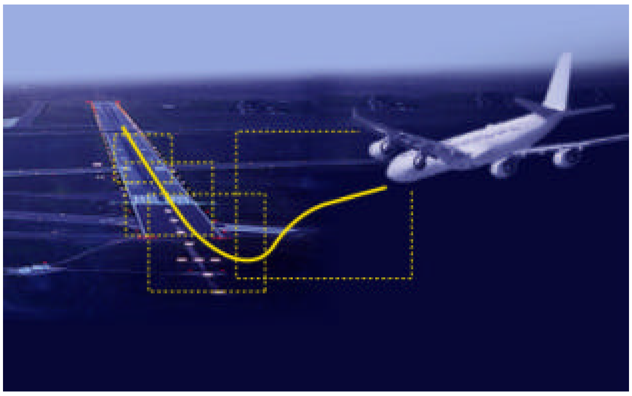
- EU, France and UK: the DRESS, MELANY and ELGEAR projects will provide inputs and equipment for the development of complete electrical actuation solutions for landing gear
- France: The MEGEVE and MODERNE projects will provide prototypes of electrical equipment that will be tested in Clean Sky.
- Sweden: NFFP4 program results are relevant to Clean Sky; Methods for conceptual design of vehicle systems for More Electric Aircraft, Autonomous flight control and decision making capabilities, Core Autonomy and On-board diagnostics and prognostics. There was also a demonstrator program on large aircraft systems.
- Germany: Lufo IV has a focus on the maturation of many electrical technologies for aircraft, and these technologies can be proven at TRL 6 towards the end of Clean Sky.

4.5.3.1 Management of Trajectory and Mission

New approaches for the **Management of Trajectory and Mission** have to be adopted for an overall optimisation of the aircraft and systems. This will be enabled by the following four concepts:

- **Green Trajectories**, based on more precise, reliable and predictable 3 dimensional flight path, optimised for minimum noise impact and low emission, including agile trajectory management, in response to meteorological hazard.
- **Quiet Landing Gear**, which addresses a major source of aerodynamic noise, and where environmental considerations need to be taken as part of the design.
- On the airfield itself, **Smart Ground Operations** uses new systems solutions and new ground procedures, so as to allow airplane engines to reduce fuel consumption and offer additional environmental benefits.
- A **Green Mission** from start to finish, with management of new climb, cruise and descent profiles, based on new aircraft performances database

which includes noise parameter and allows multi-criteria optimisation (noise, emissions, fuel, time), including management of weather conditions which could negatively impact the aircraft optimum route and results in additional fuel consumption.

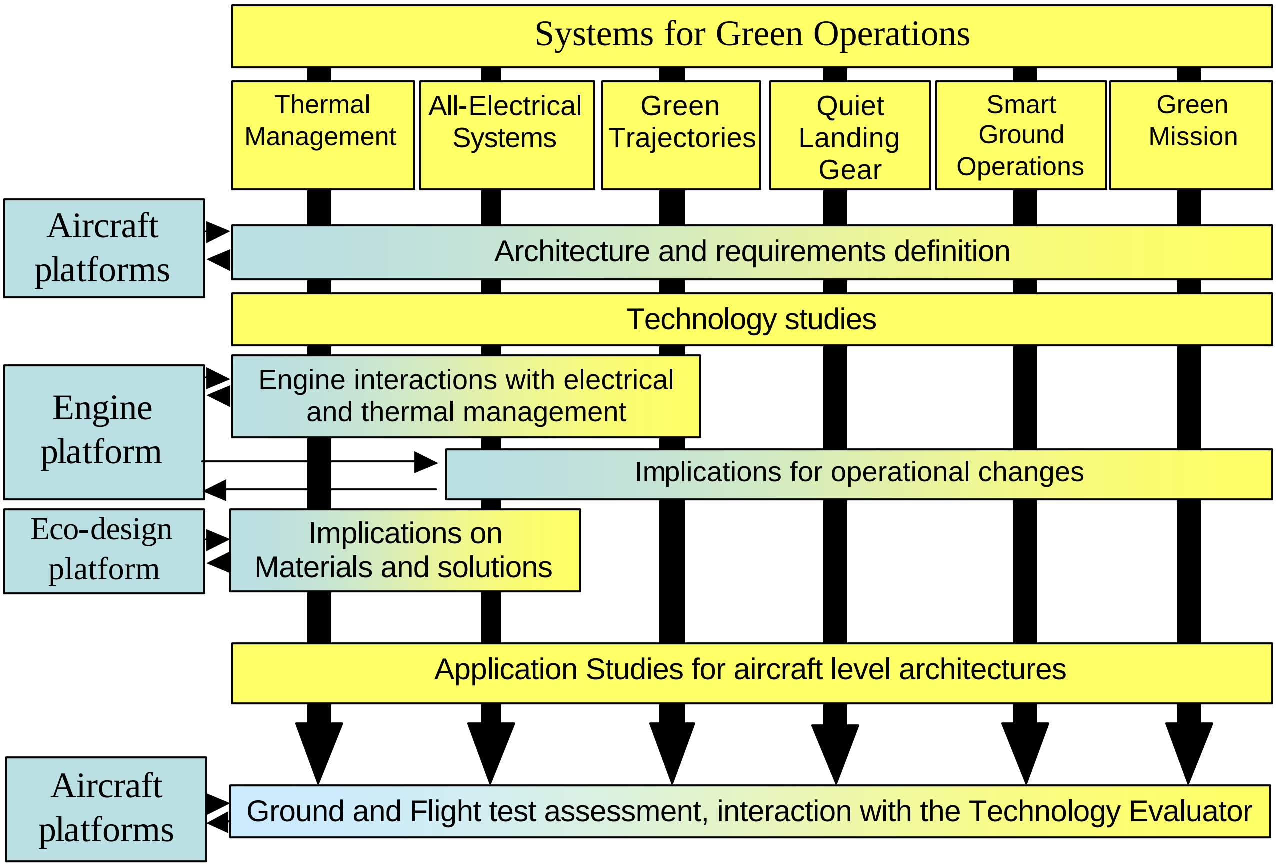


For all these items, Clean Sky will capitalise on the results of previous and on-going European studies, notably three FP6 Integrated Projects: OPTIMAL (new procedure for approaches and landing), FLYSAFE (management of meteorological hazard), EMMA (management of ground movement), ERAT (modelling of aircraft impact on the environment).

Coordination will be made to ensure compatibility and coherence with SESAR: SESAR will propose scenarios and roadmaps for the efficient evolution of the ATM in Europe. It will address solutions, including procedures, to optimise ATM system capacity, as well as flight efficiency and associated reduction in environmental impact, in a multi-aircraft context. Clean Sky will optimise on-board systems for environmental impact at the aircraft level only, taking into account SESAR outcomes in term of procedures and trajectories.

4.5.3.2 Interactions with other platforms

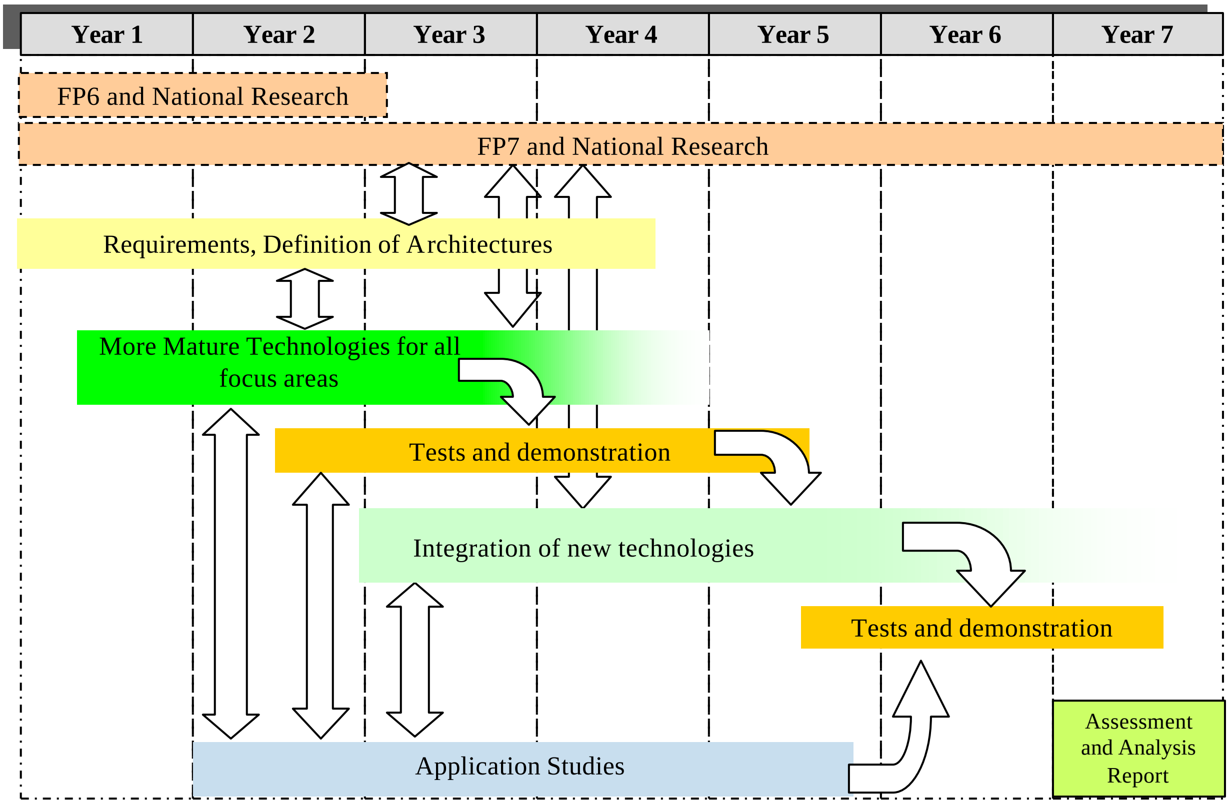
Figure: The general approach has many interactions with other platforms in Clean Sky.



This platform has a number of interactions with other platforms, as well as with the Technology Evaluator. Technologies in this platform could change airline and/or engine operation, and these will be evaluated together with the engine platform. Solutions for thermal management, as well as aspects of electrical systems (such as the removal of hydraulic fluids), will have ecological consequences, which must be assessed within the eco-design platform. Naturally, all architectural work will have strong links with the Smart Fixed Wing Aircraft, Green Regional Aircraft and Rotorcraft platforms.

On the above figure, Aircraft Platforms represent: Smart Fixed Wing Aircraft, Green Regional Aircraft, Rotorcraft and Eco-design for small aircraft systems.

Figure: The flow of activities within the platform



4.5.4 Technical Approach

The activity implemented in the platform will be multi-fold:

- High level activity will deliver operational scenarios in which the solutions will have to be demonstrated, shared aircraft level architecture references for the partners to elaborate solutions, as well as specific target breakdowns.
- Parallel activities will be implemented to define shared design environments, methods and tools to work in a collaborative way, verification and validation strategies, Technology Readiness Level monitoring tools.
- The major part of the activities will be dedicated to acquisition of technology and bricks of solutions. It is clear that the platform will exploit the maximum of technology bricks already under acquisition in other projects, as soon as they have reached a level of maturity that is worth large scale demonstration in the platform.
- A key activity will be the integration of technologies into systems and aircraft level solution, including when needed ground or flight demonstration.

- Specific application studies will ensure, for particular aircraft types, that an overall aircraft level assessment can be performed to give the theoretical validation of the designed architectures, as well as to provide validated inputs to the Technology Evaluator.

4.5.4.1 Requirements for Management of Aircraft Energy

The solutions defined in Clean Sky will meet the following requirements, with the right balance (electrical architectures and thermal management) to deliver to the specific environmental objectives, for different aircraft types (business, regional, large, rotorcraft), in order to achieve a global optimisation of the aircraft level energy efficiency :

- Reduction of peak demands and optimisation of the size of the power systems
- Modularity and standardisation for availability, reuse and scalability
- Total safety and easy certification

These requirements, as well as the architectures at aircraft level, will be defined in the aircraft Platforms: Regional, Rotorcraft, Eco-design for small aircraft, and in the Systems for Green Operations Platform for the large aircraft.
The development of the solutions to be studied in Clean Sky will all be carried out in the Systems for Green Operations Platform.

4.5.4.2 Requirements for Management of Trajectory and Mission

Requirements made to achieve high noise reduction will be two-fold: they will deal with the reduction of emitted noise on one hand, and the reduction of perceived noise on the other hand. Requirements will also be made for new functionalities with the primary goal of reducing pollution, i.e. fuel consumption, whilst preserving the high reduced-noise performance brought by the former capabilities. They will address:

  - Capability to perform high precision optimised trajectories and procedures, exploiting all characteristics of the aircraft performance, to minimise noise impact in the airport vicinity
  - Capability for permanent prediction of aircraft trajectories and their environmental impact
  - Capability to maintain the performance of the flight in any atmospheric perturbation
  - Equipment systems technology for quiet operation during approach, taxi and at the gate

- Multi-criteria flight management optimisation, including conventional and environmental constraints
- Planning, execution and control of complex trajectories that could include new climb, cruise and descent profiles.

4.5.4.3 <u>Enabling Technologies</u>

4.5.4.3.1 Technologies for "All-Electric Aircraft Equipment System Architectures"

The technology streams to be investigated in Clean Sky which will be the subject of dedicated development can be structured along the electrical energy supply chain breakdown ('bricks' of the architecture), which are:

- Power generation and storage technologies:
  - Starter/generators. As a consequence of the architectures, new high power generation is required for Clean Sky flight and large-scale ground tests.
  - Electrochemical power sources, such as fuel cells for emergency power provision will be flight tested in Clean Sky.
- Transport (Distribution), Conversion and Storage.
  - Commonality of power electronic conversion: a centralised power conversion centre architecture will be designed to make the systems architecture more complementary, efficient and light. Any flight test with electrical architectures will require these technologies.
  - New architecture and technologies for minimisation of weight and volume. This includes modular redundant standard components and novel combinations of conversion equipment to distribute electrical power most efficiently. Maximization of fibre optics use and simplified architecture for the wiring and the current return network will be tested.
- Electrical energy management architecture:
  - Global aircraft electrical power architecture, incorporating all possible power sources and consumers. This, together with dynamic load management, including reconfiguration of the network will be tested on large-scale ground based rigs.
  - Local electric network energy recycling. This will reduce the energy lost in heat in many users, even resulting in a weight reduction of components.
  - Thermal management of overall electrical layout.
- Electrical users:
  - The air system will be validated in flight, including the ability of this system to pressurise air for itself. Interfaces with thermal management technologies, and with ice and rain protection will be considered.
  - Electro-mechanical actuation (EMA) for flight control and landing gear will be addressed. Clean Sky focuses on the flight test of a new generation of smart EMAs, including mutualised power electronics architectures targeted to global simplification and weight reduction.

- o Electrical wing and nacelle ice protection are solutions to be tested in Clean Sky icing tunnel tests include electrical technologies and alternative ice protection strategies to save energy. This technology is also necessary in order to give green trajectory solutions the ability to move down to engine idle at any given time (not possible today with pneumatic ice protection).

4.5.4.3.2 Technologies for “Thermal Management”

In Clean Sky, the architectures for thermal management will be implemented, and necessary sub-architectures validated. The required technologies can be structured along the “cooling supply chain” breakdown, such as:

- ‘Cooling power’ generation and distribution. This includes integration with the air systems, as well as liquid loop technologies and distribution to and from power electronics, which can be flight tested.
- Overall thermal management solutions of aircraft/engine systems. Until now, these have been studied independently from one another.
- Optimisation of electrical drive system cooling, and interaction with the all-electric aircraft equipment systems technologies. Alternative cooling methods, such as using the aircraft structure, will be explored.
- Energy recovery/energy exchange systems, to reduce heat wastage. Building on earlier project work, these can be validated in flight.

4.5.4.3.3 Technologies for “Green Trajectories”

These technologies will concern mainly:

- o High accuracy & integrity localisation, such as GNSS hybridisation
- o High accuracy flight path prediction
- o Generation of green trajectories:
  - o Take-off and approach trajectories already studied in projects such as OPTIMAL: Noise abatement trajectories for departure and approach, Continuous Descent Approach, curved approach
  - o New flight trajectories, for example: In-trail climb, high speed take-off, idle mode final landing, 3 dimension RNP
- o Extended database including “pseudo-static” sensitive data (population, ozone…) for terminal and airport areas
- o Coupling between Flight Management and Surveillance
- o Management of robust performance in presence of any atmospheric perturbation

4.5.4.3.4 Technologies for “Quiet Landing Gear”

These technologies will concern mainly:

- o Solutions to reduce the intrinsic noise generation by the landing gear, which contributes up to half of airframe noise on approach (fairing technologies, extension/retraction procedures)
- o Advanced landing gear structural design to reduce noise

4.5.4.3.5 Technologies for “Smart Ground Operations”

These technologies will concern mainly:

- o Electrically driven wheels, using the landing gear and braking systems, for aircraft motion on the ground
- o New electrical generation on APU combined with this, to lead to overall fuel and noise reduction.
- o Coupling with airport navigation function and aircraft operational issues, including engine management

4.5.4.3.6 Technologies for “Green Mission”

These technologies will concern mainly:

- o Database with aircraft and engine performance modelling with environmental data
- o Characterisation and surveillance of the environment (atmosphere quality, weather conditions)
- o Capabilities to build complete flight profiles optimised for multi criteria including environmental impact, combining selected climb, cruise and descent trajectories (refer to Technologies for “Green Trajectories”)
- o Accurate real-time prediction of the complete flight profile and of its environmental impact

4.5.4.4 Application Studies

The aim of the application studies is twofold:

- To validate systems level solutions and technology bricks in the context of the given aircraft level architecture references and of operational scenarios for different aircraft types:

  Once the feasibility of the solutions is confirmed, they will be engineered to obtain demonstrators of equipment and subsystems. These demonstrators will then be used for the assessment of the solutions, using the most appropriate methodology (ground and/or flight tests).

- To validate the designed architectures through the performance of overall aircraft level assessments:

  Architecture references will be assessed at aircraft level, on simulators, iron birds and flight tests.

This work will be performed in a number of loops that will precede the flight tests and that will lead to validated architectures including advanced equipment and subsystems for the different aircraft types. Validated outputs will be provided to the Technology Evaluator in the course of these developments.

4.5.5 Deliverables and Demonstration

4.5.5.1 Management of Aircraft Energy

The main focus of demonstration in Clean Sky will be the validation and maturation of technologies and sub-architectures to TRL 6. This is needed to show that the technologies work in the relevant altitude, temperature, vibration and pressure environment. Thus, we intend to demonstrate:

- Proven large-scale ground-based architectural integration of electrical generation, distribution and loads, together with their management
- Proven large-scale ground-based architectural integration of thermal management technologies. Where maturity is shown, these will be integrated with the electrical equipment systems
- Flight proven electrical equipment systems, including environmental conditioning, actuation, ice protection
- Flight proven technologies, architectures and concepts for distribution and recycling of electrical energy through power electronics
- Flight proven technologies and sub-systems for thermal exchange and management, including liquid loops and large heat exchangers
- Flight testing of mature combinations of thermal and electrical technologies, to demonstrate aspects of total energy management.

4.5.5.2 Management of Trajectory and Mission

A comprehensive set of functions and architecture will be delivered in Management of Trajectory and Mission, notably:

- Solutions for low noise high precision trajectories, using Noise Abatement Procedures for Departure, Approach and Arrival, based on state of the art technology first, and second, with advanced solutions developed in the course of "Clean Sky".
- Solutions for autonomous aircraft motion on ground using electrical motors
- Noise reduction technologies for landing gear
- Solutions for Green Flight Management based on multi-criteria optimisation for minimal environmental impact mission

These functions will be based on a large set of on-board equipment and systems, notably:

- Localisation, Flight Management, including aircraft performance database, Surveillance, Coupling between Flight Management and Surveillance, Flight guidance, Data link, On-board airport navigation, Cockpit systems, Specific environmental performance database, Electrical motors for aircraft motion.

Models and computational means will be developed to test above functions and systems:

- Generic models and detailed databases for systematic aircraft and mission environmental performance characterisation
- Computational platform for the environmental characterisation and evaluation of mission management solutions
- Several low cost simulation platforms, in support to early prototyping, virtual integration at aircraft, system and component levels, demonstration of feasibility of the functional architecture, with maximum reuse of existing bricks

The demonstrations of the “Mission and Trajectory Management” concepts will include:

- In flight demonstrations, when validating at TRL 6 level, in real operating conditions (e.g. for weather condition) and feedback from operational pilots is required
- Ground demonstration based on a cockpit simulation:
  - To prepare the future flight test demonstrations for green trajectories
  - to demonstrate on ground, in a representative environment, the benefits of the green mission
- Demonstration of expected benefits on environment through “PC” simulation, in co-operation with the Clean Sky Technology Evaluator

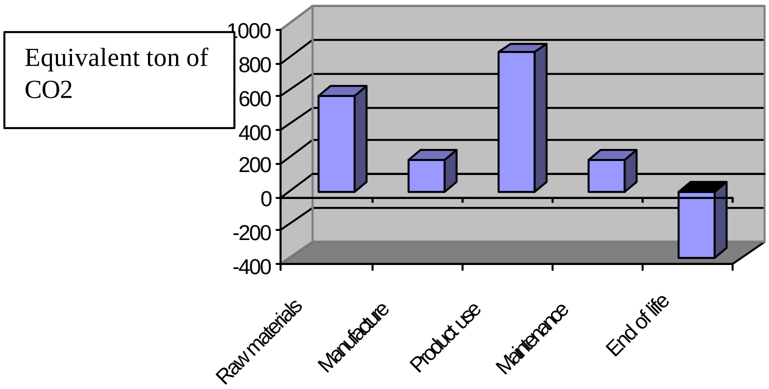
4.6 Eco-Design Platform

4.6.1 Rationale

The impact of an aircraft on the environment is generally considered as directly linked to its intensity of operation. A more global and accurate approach to evaluate this impact must take also into consideration the total Aircraft life cycle.

The product life cycle can be split within three distinctive phases: *aircraft design & production, aircraft use, aircraft withdrawal.* For each phase, there is a need to limit the quantity of natural resources (material, energy, water,…), to use harmless materials and find non-polluting substitutes and finally to design an Aircraft in a global perspective that addresses its dismantling and recyclability.

The result from the life cycle assessment of the metro in Oslo should be considered to give an understanding of what does it mean to develop an environmental perspective on an industrial product. Looking at the overall life cycle impact on green house effect (quantified in ton of CO2 equivalent) of the metro train one can see the expected dominance of the phases:



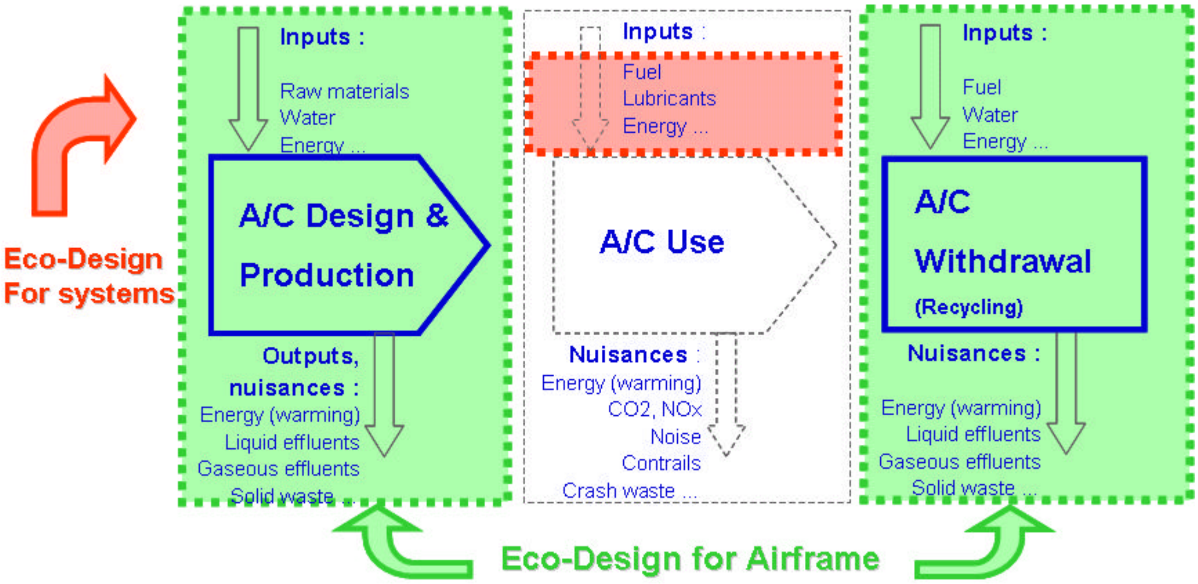
On this example close to aircraft, most critical phase regarding green house effect is the product use, mainly due to the energy consumption. However, it is very important to note that the other phases are not negligible at all.

Compared with others industries such as automotive, the aeronautic industry is late to consider the global life cycle design approach but it is now necessary to spend significant efforts to prepare the future:

- Aeronautics is quite a young industry but the problem of the aircraft withdrawal is really emerging today.
- The air transport impact on environment can be considered as small compared to the automotive one but it is continuously growing.

4.6.2 Objectives and impact of the platform

The global objective is to reduce the product environmental impact while keeping competitiveness of the aeronautic industry.



Overall logic

The **Eco-Design Platform** is focused on one hand on designing equipped airframe for decreasing inputs (raw materials, energy, water,…), outputs and nuisances (energy / warming, liquid effluents, gaseous effluents, solid waste, …) and on the other one suppressing the non-renewable and noxious fluids / materials (i.e. suppression of hydraulic) during operations and maintenance, while keeping the aircraft at the appropriate level quality and performances.

Then this platform is composed of two parts: the Eco-Design for equipped airframe and the Eco-Design for small aircraft systems.

4.6.3 Eco-Design for Equipped airframe

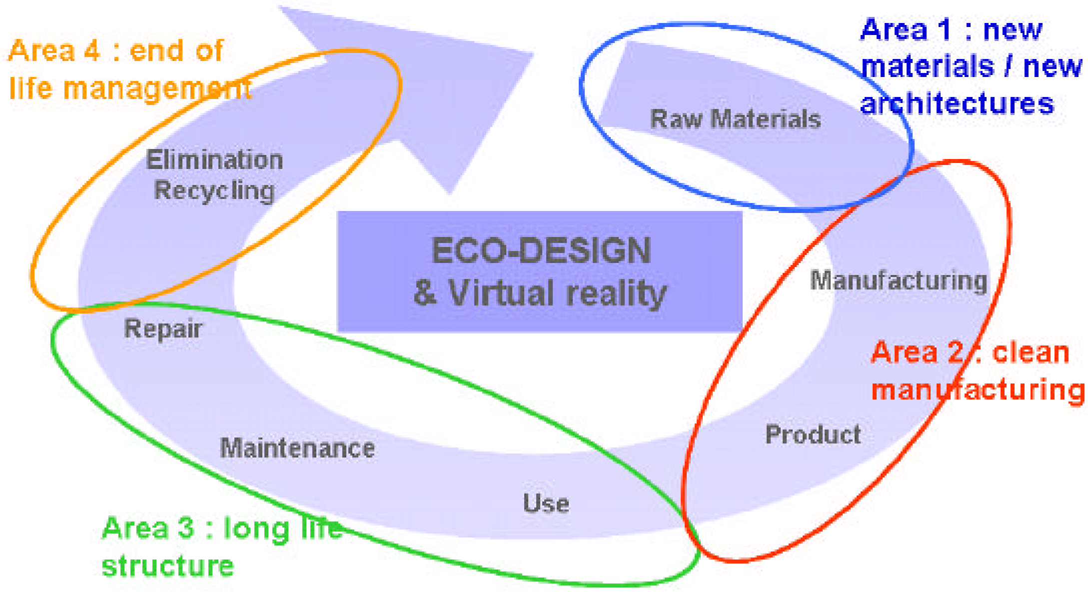
4.6.3.1 General approach and content

The Eco-Design Platform is meant to tackle the above issues by focusing on the following challenges:

- Optimal use of raw materials, decrease consumption of non renewable materials, natural resources, energy, emission of noxious effluents
- Avoidance of CMR (Carcirogenous, Mutagenous, Repro-toxic) compounds and application of future regulation such as the REACH regulation
- Green manufacturing and production processes

- Recyclability, storage, elimination of aircraft after several decades of operation.

Four main technical areas of progress will be considered to cover all the phases of the aircraft lifecycle as shown on the following figure:



These areas will be considered for significant parts of the aircraft: Structure, Cabin covering and furniture, Vehicle systems components / equipments, Engine components, Electronics.

4.6.3.1.1 Area 1 – Materials

Four main technical issues will be considered to cover all the phases of the aircraft lifecycle as shown on the following figure:

The overall aircraft lifecycle starts with extraction of raw materials the requirements of which will change to take into account future ecological constraints.

New structural materials will have to be as performing as current materials in order to avoid weight increase, more renewable and recyclable than current materials, especially considering carbon fibre materials. Furthermore, CMR[14] compounds will be avoided and future regulation such as REACH shall be taken into account.

The production processes will have to be optimised to reduce energy consumption and pollution while keeping low cost objectives.

New functions will be considered to improve benefits of new materials use. Examples of these functions are: self-healing, thermal and electrical conductivity, energy management, controlled released rate.

For composite materials, new technologies will be considered such as:

[14] *CMR=Carcinogenic, Mutagenous, Reprotoxic*

- New fibres and raw materials from agriculture
- New chemical processes to obtain existing materials but from agriculture
- Biotechnology: nano-materials, molecular design

For metallic materials new light alloys (e.g.: Al-Li) will be considered and particular effort will be spent on new surface treatment and protection.

A work package will be dedicated to modelling tools covering the design and the behaviour of new materials as well as the selection of materials through conception.

4.6.3.1.2 Area 2 – Manufacturing

The objective of this issue is to provide elements of definition of a “Green aircraft Production Factory”. The general industrial requirements of the future clean processes can be summarised as follows:

- Optimisation of the work flow and of transport of aircraft components
- Highly integrated processes
- Low energy, dry and clean processes
- Recyclability of ancillary manufacturing and integration tools
- Concept of “One shot process”

As becoming more and more critical with the worldwide economic development, societal requirements will be considered:

- Worker education and role
- Design of offices and workshops
- E-learning and virtual reality

The definition of the future “Green aircraft Production Factory” will take into account new concepts and technologies in the frame of composite, metallic structure, fitting and cabin interior:

- Waste management and energy management (including logistics and supply chain
- Virtual reality
- Direct manufacturing and storage reduction

As for the materials issue, a work package will be dedicated to modelling for the design of processes.

4.6.3.1.3 Area 3 – Long Life Structure

A way to reduce the materials and energy consumption to manufacture aircraft is to increase the lifetime. The objective of this issue is to investigate concepts and technologies to increase the structure lifetime. Three technical subjects will be considered:

Structural Diagnostic / Prognostic

The lifetime increase is obtained through the advanced Health and Usage Monitoring of the structure. Efforts will be spent on:

- In field feed back
- Real time monitoring
- Smart sensors
- Non destructive control

Long life materials

In addition to requirements of new materials dedicated to lifetime increase (resistance to interface, resistance to atmospheric pollutants), some topics will be considered:

- Failure mode and key criteria (damage tolerance)
- Smart repairs
- Mapping of pollutants

Test procedure

The objective is to improve ageing tests to reduce testing cycle and thus, progress on structural lifetime prognostic.

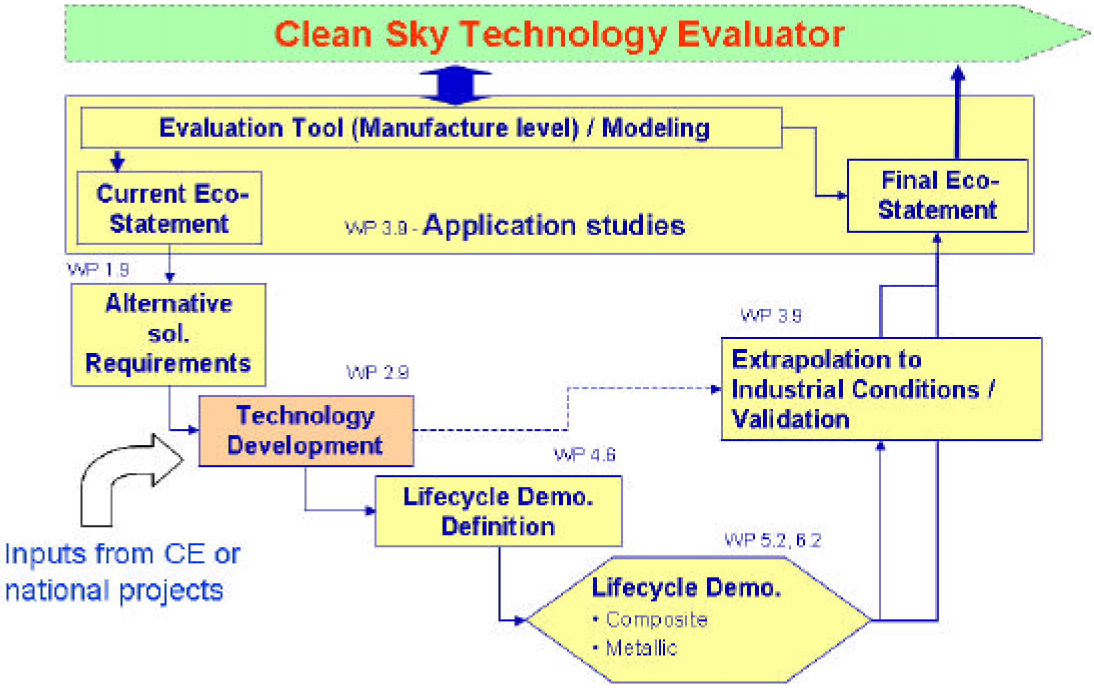
4.6.3.1.4 Area 4 – End of Life Management

At the end of life the aircraft must be dismantled and the resulting products are to be reused, eliminated or stored. The objective of this issue is the “cleaning” of these activities:

- Definition of a dismantling process reducing energy consumption, effluents and wastes
- For metallic, particular efforts will be spent on separation and purification in order to recycle materials into high quality metals
- For composite, physical, chemical and biological processing will be investigated to try to reach a real recyclability.

4.6.3.2 Technical approach

The work will be organised according to the following logic flow:



4.6.3.3 Application Studies

The general objectives of this Workpackage are:

- Development of tools for the quantitative evaluation of the environmental impacts of the production and withdrawal phases of the aircraft lifecycle.
- From the eco-statements as necessary along the study and especially at the start to elaborate alternative solutions requirements and at the end to produce data for the Clean Sky Technology Evaluator and the setting-up of final eco-statement.

4.6.3.4 Current Eco-statement

The first step will be to establish the current eco-statement in close relation with the "**Clean Sky Technology Evaluator**". It will produce a detailed assessment of the today environmental impacts of both the manufacturing and dismantling. This assessment shall take into account **E**nvironment issues and also **H**ealth and **S**afety impacts (HSE) on workers.

4.6.3.5 Final Eco-statement

Even if the demonstration is preformed under conditions as realistic as possible, it is on the basis of a single prototype. Consequently, it will be followed by a deep analysis to derive result data assuming a real industrial environment.

Then, a final “eco-statement” will be performed again in close relation with the "**Clean Sky Technology Evaluator**". This will produce quantified data assessing benefits from the platform activities. The data will be inputs to produce final overall assessment on benefits from “Clean Sky” activities.

4.6.3.6 Requirements

The analysis of the results from the current eco-statement will highlight critical issues and alternative solutions will be considered as answers. This Workpackage will produce an initial set of requirements for these solutions, covering the technical issues as described in above section: Materials, Manufacturing processes, Long life structure, End of life management.

4.6.3.7 Enabling Technologies

On the basis of the results of Application studies and taking into account the inputs from "**Clean Sky Technology Evaluator**", new innovative technological solutions will be developed and trade-off will be estimated. The most relevant technologies will be selected on the basis of their current maturity using the Technology Readiness Levels (see table in Annex).

Taking this scale it should be reasonable to consider technologies above TRL 4 in the frame of Clean Sky to reach TRL 6. For some very limited cases, technologies with TRL below will be used.

For technologies not mature enough recommendations will be produced according to their future benefit potential.

4.6.3.8 Deliverables

This part of the Eco-Design platform will provide a detailed eco-statement, a selection of the most relevant technologies and a comprehensive demonstration of an eco-design for composite and metallic structure as well as cabin covering and furniture through the realisation of complete lifecycle demonstration.

4.6.4 Eco-Design for Small Aircraft Systems

4.6.4.1 Rationale

The removal of hydraulics is the major incentive to consider the evolution of small aircraft towards an all electrical aircraft. The feasibility of such an aircraft has to be investigated through the study of innovative energy management architectures, requiring joining forces to provide appropriate requirements to Systems platform.

4.6.4.2 General approach and content

The general objective of this part of the Eco-Design platform is to make a significant step towards the concept of the all electric vehicle systems aircraft:

- *Removing of hydraulic fluid*

From the removing of hydraulic fluids we expect significant benefits in terms of **aircraft maintenance and disposal environmental impact**.

- *On board power by wire*

  On current aircraft the vehicle systems architecture is based on a federated approach and onboard power is generated and distributed though different media (electric, hydraulic, pneumatic).

  The use of electricity as only media offers a lot of possibility in terms of energy management (e.g.: Intelligent load shedding, power regeneration on actuators, sharing of Electrical Control Unit over actuators).

  From the on board power by wire concept we expect benefits in terms of greener **power efficiency** and subsequently in terms of **fuel consumption**.

Taking into account the power level required on actuators and the TRL of EMA, the deletion of hydraulic on large aircraft appears not possible within the time frame of Clean Sky. For example, the actuation of heavy landing gears of airliners requires high power peaks accessible reasonably only from the hydraulic technology.

Consequently, the first step towards the “oil-less power by wire” aircraft is to be considered for a small cabin aircraft such as business jet which would fit to other types of air vehicles

The objective of this part of the Eco-Design Platform is to demonstrate the feasibility and the benefits at aircraft level of the “oil-less power by wire” small cabin aircraft.

To demonstrate the feasibility and the benefits of the “oil-less power by wire” concept, it is necessary to point out two main ideas:

- **Trade-off and benefits analysis are to be performed at aircraft level**

  The comparison between a current technology aircraft and an aircraft based on the oil-less power by wire concept requests iterative loops at aircraft level to take into account the so called “snowball effect”.

  This compelling effect is due to the impact of the aircraft sizing around vehicle systems architecture. A given technology can be heavier than another but can be more efficient in terms of energy consumption. It will reduce the fuel consumption and so the mass of fuel requested for the same mission, then the size of the fuel tanks can be reduced, then the aircraft is smaller with a better aerodynamic. Finally, the heavier technology is much better than the lighter.

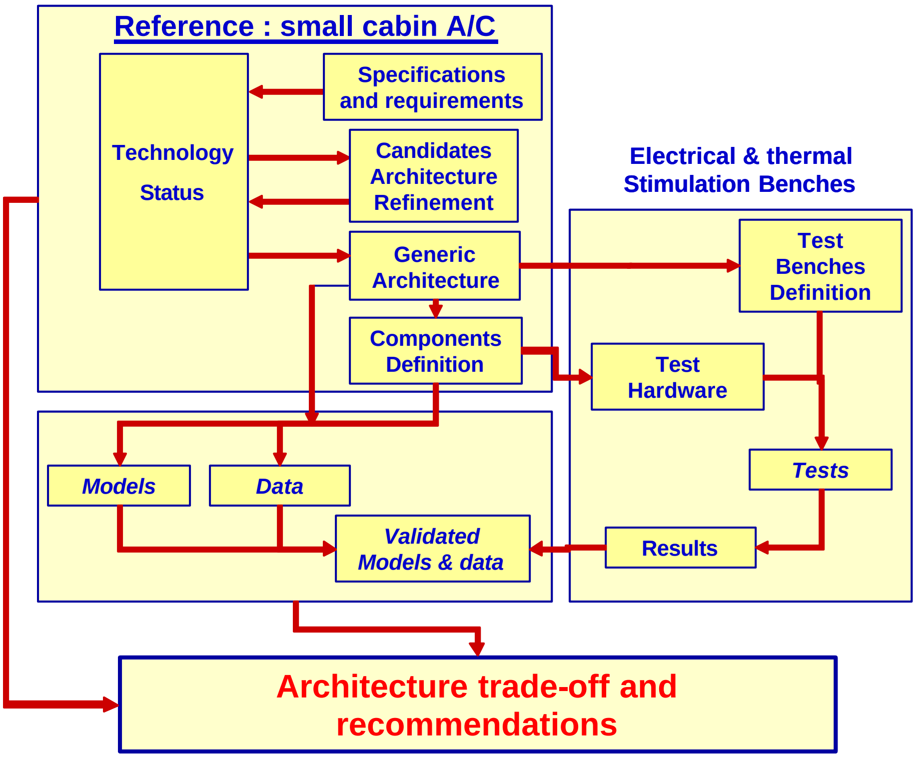
- **The all electric aircraft requests Thermal Management analysis**

  One advantage of the hydraulic systems is there is a fluid circulation which collects the power losses to a heat exchanger. The draining of heat is easy and the cooling is naturally centralised.

  On an electrical architecture the power losses (Joules effect) are not directly drained. In order to avoid temperature spots and over heating, it is necessary to elaborate new concept of the aircraft thermal management.

A part of activities is dedicated to aircraft level thermal management.

The global methodology is depicted on the following figure and the different steps can be summarised as follows:



Specifications and requirements

This step is to produce definition of the vehicle platforms and associated operational objectives (the generic missions to be performed). It produces basis and guidelines to identify required technologies.

Architecture down-selection

This step is to define architecture candidates from a pool of possible technologies. It produces a characterization of constitutive equipment and base components for all Architectures.

A generic "Multi-Functional" Architecture is defined as the basis for the demonstration.

Models and data collection

This step includes the creation of models for candidate architectures. The outputs are electrical and thermal power fluxes models.

Test activities

The tests are performed on ground electrical and thermal benches representing the generic "Multi-Functional" architecture as defined from the architecture down-selection. The purposes of the test are:

- "Real-Life" evaluation of key electrical and thermal technologies

- Capture both steady-state and dynamical behaviors of equipment based on these technologies
- Study in detail thermal and electrical transients
- Measure actual network quality and component thermal identification

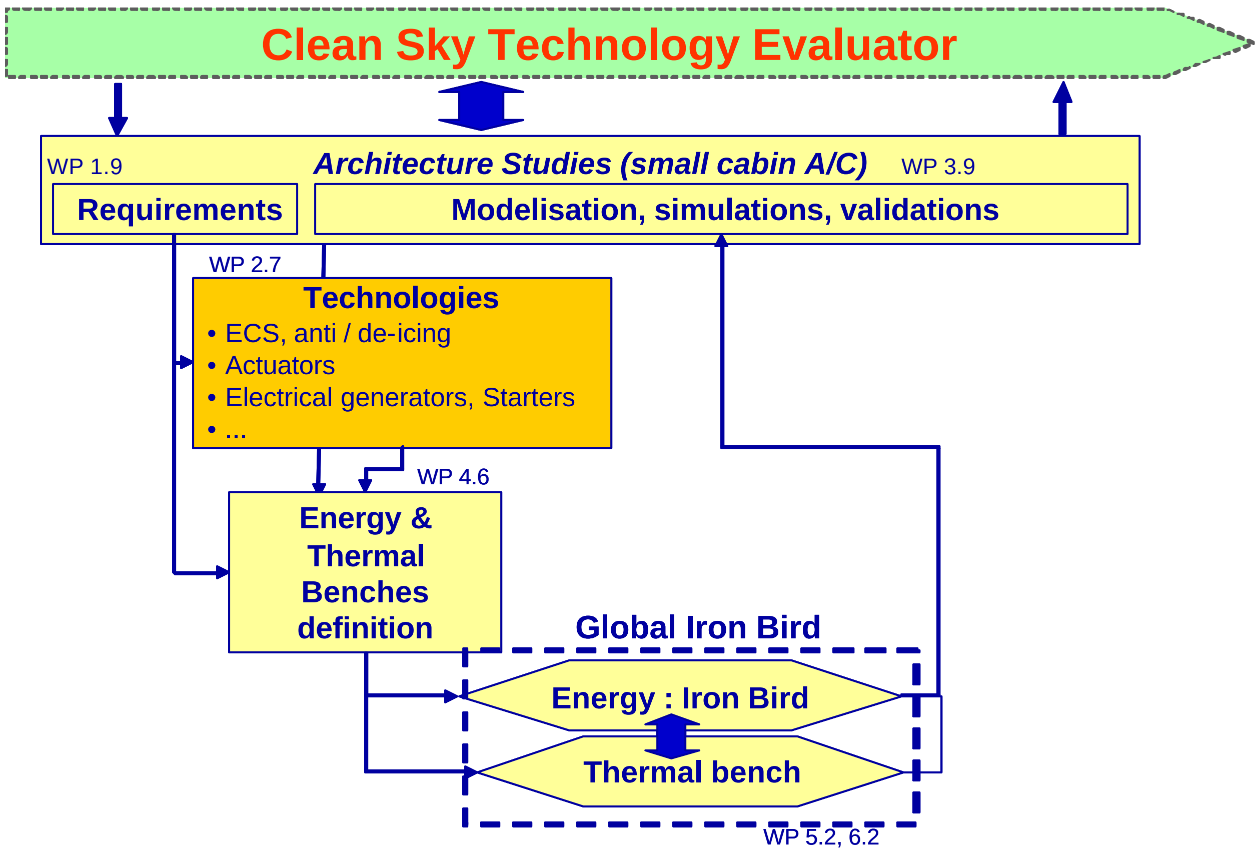
Validated models and data and architecture trade-off

The simulation results and test results are used as validation of models assumptions and results. This produces a set of updated / corrected models.

An extensive use of extrapolations from these models is conducted to investigate the architecture candidates and produce a trade-off analysis.

4.6.4.3 Technical approach

The work will be organised according to the following logic flow:



4.6.4.4 Application Studies

This Work Package covers the tasks defined in previous section as *"Architecture down-selection", "Models and data collection" and "Validated models and data and architecture trade-off".*

It will run all through Clean Sky in a close relation with the Clean Sky Technology Evaluator (TE):

- The TE will provide the Eco-Design platform models and criteria to take into account the environmental impacts through the trade-off analysis.
- The Eco-Design Platform will produce data to the TE for the final overall eco-statement at the end of activities.

This WP will exchange models and data for systems, sub-systems, components with the Systems for Green Operations platform.

4.6.4.5 Requirements

This corresponds to task “*Specifications and requirements”* defined previously.

It will produce requirements at systems, sub-systems and component levels to be transferred to the Systems for Green Operations Platform in charge of the technology.

4.6.4.6 Technology

The development and assessment of technologies, components and sub-systems activities will be performed within the Systems for Green Operation Platform. Two types of outputs are expected from this Platform: the production of realistic components for benches and the providing of models and data to feed the aircraft level models.

For technologies not mature enough at the start of “Clean Sky”, maturity activities will be conducted to allow integration of the technologies to the demonstration.

For the small cabin aircraft, examples of technologies candidates to be considered are:

Electrical technologies:

- Electrical generation / distribution (Starter / Generator, Smart converter / inverter, SSPC…)
- Electro-Mechanical Actuator for Flight Control, for utilities and landing gear,…
- Efficient Power supply (lithium-ion batteries, fuel cell, smart Auxiliary Power Unit)
- Anti-icing, de-icing technologies and concept.

Thermal management:

- Bleed-less ECS electrically driven
- Thermal cooling distribution technologies :
    - Heat pipe
    - Capillary cooling loop
    - Use of radiation for the homogenisation of temperature inside electronic compartment.

4.6.4.7 Energy & Thermal benches definition and Global Iron Bird

This activity is described in the Demonstrator/Demonstration paragraph.

The main purposes of these test activities based on an iron-bird are recalled:

- “Real-Life” Evaluation of Key Electrical and Thermal Technologies
- Capture Both Steady-State and Dynamical Behaviors of Equipment Based on These Technologies
- Study in Detail Thermal and Electrical Transients
- Measure Actual Network Quality and Component Thermal Identification

4.6.4.8 Deliverables

This activity will give a clear assessment of the feasibility of an all electrical small cabin aircraft and provide operational design tools (truly validated models and test benches) directly applicable for the development of a future aircraft since following outcomes will be carried out:

- Use of simulation results and test results to revise modeling assumptions
- Create a set of updated/corrected models
- Extensive use of extrapolations from these models to investigate reference platform architectures and application platform architectures