# POLITECNICO DI MILANO

Facoltà di Ingegneria Industriale
Corso di Laurea in Ingegneria Aerospaziale

**Study about ATR prototype within the European Clean Sky Project with a focused analysis on low power bleed less de-icing systems.**

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Ringrazio mia moglie che in questi anni è stato il motore che mi ha spinto verso questo traguardo.
Ringrazio i miei genitori, senza di loro non sarei qui ora.
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# 1. Abbreviation list

| | |
|---|---|
| *A&AT* | *Aeronautics & Air Transport* |
| *ACARE* | *Advisory Council for Aeronautics Research in Europe* |
| *ACARS* | *Aircraft Communication Addressing and Reporting System* |
| *ACMS* | *Aircraft Centralized Maintenance System* |
| *ACW* | *Alternating current wild* |
| *AEA* | *All Electrical Aircraft* |
| *APM* | *Aircraft Performance Monitor* |
| *ATM* | *Air Traffic Management* |
| *ATR* | *Avions de Transport Regional* |
| *ATS* | *Air Transport System* |
| *BDRM* | *Banque de Donnéès Répercussions Modifications* |
| *BE* | *Bureao d'Étude* |
| *BPR* | *By-Pass Ratio* |
| *CAB* | *Change Approval Board* |
| *CCAS* | *Cabin Crew Alert System* |
| *CEO* | *Chief Executive Officer* |
| *CIAB* | *Change Instruction and Approval Board* |
| *CILL* | *Cockpit Integration Led Lighting System* |
| *CRI* | *Certification Review Item* |
| *DOA* | *Design Organisation Approval* |
| *DR&O* | *Design Requirements & Objectives* |
| *E-ECS* | *Electrical-Environmental Control System* |
| *EADS* | *European Aeronautical Defence and Space company* |
| *EASA* | *European Aviation Safety Agency* |
| *EDS* | *Eco-Design for System* |
| *EFB* | *Electronic Flight Bag* |
| *EIDS* | *Electrical Impulsive De-icing System* |
| *EIDS* | *Electric Impulse De-icing System* |
| *EM* | *Electrical Management* |
| *EMAS* | *Electro Mechanical Actuator* |
| *EMC* | *Electro Magnetic Compatibility* |
| *EMEDS* | *ElectroMechanical Expulsion De-icing System* |
| *EMEDS* | *Electrical Mechanical Expulsion De-icing System* |
| *EMI* | *Electro Magnetic Interference* |
| *EPGS* | *Electrical Power Generation System* |
| *EPNLdB* | *Effective Perceived Noise Level decibel* |
| *EU* | *European Union* |
| *FAA* | *Federal Aviation Administration* |
| *FAR* | *Federal Aviation Regulation* |
| *FOM* | *Flight Operation Manual* |
| *FTI* | *Flight Test Instruments* |
| *FTR* | *Flight Test Request* |
| *GDP* | *Gross Domestic Product* |
| *GRA* | *Green Regional Aircraft* |
| *GTR* | *Ground Test Request* |

| | |
|---|---|
| *HLTCs* | *High Level Target Concepts* |
| *ICAO* | *International Civil Aviation Organisation* |
| *ICR* | *Inter-Cooler Recuperator* |
| *IEP* | *Ice Evidence Probe* |
| *IEV* | *Installation d'Essai en Vol* |
| *IOS* | *Icing Onset Sensor* |
| *IPCC* | *Intergovernmental Panel on Climate Change* |
| *IPS* | *Ice Protection System* |
| *ITD* | *Integrated Technology Demonstrator* |
| *JTI* | *Join Technology Initiatives* |
| *JTI* | *Joint Technology Initiative* |
| *LCD* | *Liquid Crystal Display* |
| *LNC* | *Low Noise Configuration* |
| *LPDI* | *Low Power De-Icing* |
| *LWC* | *Low Weight Configuration* |
| *MAP* | *Mise Au Point* |
| *MC* | *Means of Compliance* |
| *ML* | *Modification Leader* |
| *MoC* | *Means of Compliance* |
| *MOD* | *Modification* |
| *MP* | *Modification Proposal* |
| *MPC* | *Multi Purpose computer* |
| *MSN* | *Manufacturer Serial Number* |
| *NAV* | *Navigation* |
| *OAT* | *Out Air Temperature* |
| *OPR* | *Overall Pressure Ratio* |
| *SB* | *Service Bulletin* |
| *SESAR* | *Single European Sky ATM Research* |
| *SGO* | *System for Green Operations* |
| *SMEs* | *Small and Medium Enterprises* |
| *SRA* | *Strategic Research Agenda* |
| *TAT* | *Total Air Temperature* |
| *TET* | *Turbine Entry Temperature* |
| *TMA* | *Terminal Management Area* |
| *TMEDS* | *Termo Mechanical Expulsion De-icing System* |
| *TRS* | *Technical Repercussion Sheet* |
| *TRS* | *Technical Repercussion Sheet* |
| *UMV* | *Unmanned Vehicles* |
| *UN* | *United Nation* |
| *V&V* | *Verification & Validation* |
| *VAC* | *Volt Alternating Current* |
| *VDC* | *Volt Direct Current* |
| *VSTOL* | *Vertical/Short Take-Off and Landing* |
| *WIPS* | *Wing Ice Protection System* |
| *WP* | *Work Package* |

# 2. Introduzione

Il seguente elaborato è stato redatto durante un periodo di tirocinio presso l'headquarter dell'ATR a Tolosa.

Lo studio riguarda uno specifico aspetto del coinvolgimento dell'azienda nel *Progetto Clean Sky*, una iniziativa europea promossa dall'ACARE e finanziata dalla Commissione Europea in partnership pubblico-privato con le aziende del settore aeronautico all'interno del più vasto progetto "*European Aeronautics: A vision for 2020*". I capitoli dal 1 al 4 sintetizzano i principali caratteri dell'ATR ed il contesto strategico in cui il Clean Sky si colloca. Il capitolo 5 comprende un'ampia panoramica sul ruolo di ACARE e sulla struttura del Clean Sky. I capitoli dal 6 all'8 approfondiscono alcuni aspetti tecnici del progetto come di seguito descritto:

cap. 6 – descrive i tre innovativi impianti elettrici che costituiscono i maggiori punti di rinnovamento nel prototipo al momento in preparazione, dedicando maggiore attenzione d'analisi alle soluzione di ice protection. In particolare viene presentato uno studio di trade-off sui sistemi di protezione dal ghiaccio bleedless a bassa potenza per velivoli regionali ad elica. Nello studio, svolto all'interno del dipartimento elettrico dell'ATR, sono stati considerati sia i sistemi di de-icing che quelli di anti-icing, analizzando vantaggi e svantaggi di differenti soluzioni, tra cui termica, ad impulsi e a glicolo. La mancanza di supporto all'interno dell'azienda ha impedito sia un eventuale accordo con le aziende esterne per ricevere un maggior dettaglio sui prodotti sia la possibilità, al termine dello studio, di operare una scelta fra le soluzioni trovate.

cap. 7 e cap. 8 – presenta una rassegna delle procedure interne di ATR con riferimento alle modifiche sperimentali sui velivoli, volta a definire il processo di qualificazione e certificazione dei sistemi, nel rispetto del DO/A di ATR, affinché i nuovi componenti studiati all'interno del Clean Sky possano essere testati in volo utilizzando il prototipo MSN 098, un velivolo ATR 72-500 messo a disposizione dall'azienda. La documentazione così prodotta è stata poi messa a disposizione di Alenia Aeronautica ni qualità di partner responsabile per tale parte del progetto.

Il paragrafo conclusivo del capitolo 8 insieme al capitolo 9 presentano le conclusioni dell'elaborato.

# 3. Preface

The following study was prepared within the *Clean Sky Project* (the Clean Sky from now on) - a Joint Technology Initiative promoted by the European Commission -, under the direct supervision of the electric department in the Green Regional Aircraft section of the Clean Sky.

The first section describe the framework in which the Clean Sky was promoted and summarize its main purposes. Subsequently two different specific section are developed:

- a review of ATR experimental modification procedures in order to define the qualification and certification process in the respect of ATR DO/A so that the systems studied in the Clean Sky could be tested on the demonstrator *ATR 72-500 MSN 098*. The documentation package developed was shared with *Alenia Aeronautica* as leading partner in the GRA so that all needed modifications could be designed
- a theoretical trade-off study focused on low power bleedless icing protection system for turboprop regional aircraft. The lack of an Non-disclosure Agreement  between ATR and the manufacturers of icing protection system has prevented to obtain detailed information.

# 4. Introduction

## 4.1. ATR

### 4.1.1. Company Profile

The *Avions de Transport Régional* was formed in 1982 as a joint venture between Aerospatiale (now EADS) and Aeritalia (now Alenia Aeronautica). During its almost thirty years of activity ATR establish itself as one of the world's leading aerospace company and the largest manufacturer of regional aircraft.
The success of ATR can be attributed to the combination of outstanding features, in terms of innovation, comfort and environment-friendliness. The latest generation of ATR turboprop aircraft with the state-of-the-art technology opens up new horizons to regional airlines worldwide by offering optimum performance, perfect reliability, exceptional passenger comfort, easy maintenance and high economic efficiency.
Having its headquarter in Toulouse, South of France, ATR employs more than 800 people across Europe. ATR is organised into several business units:

- commercial directorate,
- financial department,
- a customer service and some shared services unit which provides a broad range of services to ATR worldwide,
- engineering, operations and technology department, which helps develop, acquire, apply and protect innovative technologies and processes.

### 4.1.2. Milestone

| | |
|---|---|
| 1981 | Aerospatiale and Aeritalia merge their two separate, but similar, regional aircraft designs into a single effort. |
| 1984 | August 16<br>The ATR 42 makes its first flight.<br>The aircraft takes off for its maiden test flight from Toulouse, France, where the ATR final assembly line is located. |
| 1986 | The ATR family grows with the launch of the stretched-fuselage ATR 72 version. |
| 1988 | October 27<br>First flight of the ATR 72. The aircraft is flown from ATR's Toulouse facility. |
| 1997 | January<br>ATR 72-500 is certified by the French airworthiness authorities (DGAC France). |
| | September 5<br>This milestone makes ATR the first European program in its market segment |

to reach the 500-delivery mark in only 12 years.

2002 December
ATR obtains the DOA (Design Organization Approval).

2004 September
ATR obtains the Design Organization Approval (DOA) on the European level from the European Aviation Safety Agency (EASA).

2006 September 8
Air Deccan takes delivery of the 700th ATR aircraft, which is an ATR 72-500.

October 2007
ATR launches the '-600 series', the newest version of its family of aircraft.

### 4.1.3. Products

| January 2009 | Orders | Deliveries |
|---|---|---|
| ATR 42 | 418 | 409 |
| ATR 72 | 582 | 462 |
| *Total* | *1000* | *871* |

T 1: Products

The strong points of ATR's aircraft are versatility and capability to operate even in difficult environment and from short airfields. Those characteristics has made the company the most widespread regional aircraft provider with more aircraft in service with more operators than any competitor.
One of the most important competitive advantage of ATR products is the low fuel consumption associated with high tank capacity that ensures excellent range characteristics and the capability to fly multiple sectors without refuelling. These characteristics together with the low weights, an advanced aerodynamic design and the choice of state-of-the-art, highly efficient Pratt & Whitney of Canada PW100 series engines keep fuel burn to a minimum.
Furthermore, the excellent landing and take-off performance enable ATR aircraft to use the shorter runways set aside for commuter operations at many airport hubs. ATR aircraft thus:

1. reduce air traffic congestion,
2. decrease airline fuel consumption,
3. minimize environmental impacts.

The cornerstone of the latest generation ATR aircraft family is the 50-seater ATR 42-500, which entered into service in 1995, followed by the stretched 70-seater ATR 72-500 version in 1997.
The ATR 42 and ATR 72 have a high degree of commonality. They share the same fuselage cross-section, use the same basic systems, and are outfitted with a common cockpit that allows cross-crew qualification.
Following a strong market requirement, ATR 72-600 will soon introduce a new way of travelling. This new generation of aircraft will be offered with increased payload, mak-

ing the aircraft even more attractive, also in terms of operational range.
The models currently produced are:

- ATR 42-300/320
- ATR 72-200/210
- ATR 42-500
- ATR 72-500

The following paragraphs summarise ATR current production.

a. <u>First generation aircraft</u>

<u>ATR42-300/320</u>

F 1: ATR 42-300

Since its entry into service in December 1985, the ATR 42 has become a reference in the regional air transport industry.
The basic ATR 42-300 is fitted with two PW120 engines rated at 2,000 shp each. The ATR 42-320, fitted with two PW121 engines rated at 2,100 shp each, has been developed to offer increased performance in hot and high conditions and short runway operations.
The standard cabin layout is 48 seats at 30-inch pitch. The dimensions of the front cargo compartment can be adapted to accommodate 50-seat and 46-seat configurations at 30-inch pitch. The ATR 42 is remarkably easy to operate and maintain and is equipped with efficient, low-fuel-burn engines. Its operating costs are 15%-20% lower than those of its competitors.

<u>ATR72-200/210</u>

F 2: ATR 72 200

The ATR 72 is derived from the ATR 42 with a 4,5 m stretched fuselage. The two aircraft feature a high degree of commonality: the same cross section, simple systems, and cockpit for cross-crew qualification. The ATR 72-200 is equipped with two PW124B engines, rated at 2,400 shp each. The derivative version of the basic ATR 72, the ATR 72-210 is equipped with two higher power 2,750 shp PW127 engines.

The ATR 72-200/210 standard cabin layout is 66 seats at 31-inch pitch. The dimensions of the front cargo compartment can be adapted to accommodate 64 to 72 seats, assuring that every operator can find the solution to its needs. The main characteristics of the -210 version include excellent "hot & high" and short field capabilities.

The ATR 72-210 also features enhancements to cabin comfort especially advanced internal noise treatment and superior cabin air conditioning. A major advantage of the ATR 72-210 is its acoustic treatment, comprising stiffened frames, Dynamic Vibration Absorbers and skin damping material, all installed in the propeller area, ensuring a very high level of passenger comfort. The PW127 engine is also fitted with an Hamilton Standard/Ratier Figeac 247F propeller, characterized by advanced wide chord composite blades and a steel hub. The improved cooling capacity and air distribution of the air-conditioning system enhancements on the ATR 72-210 version ensure a high-level passenger comfort.

b. -500 series

ATR42-500


F 3: ATR 42-500

The ATR 42-500 is the latest development of the ATR 42. It draws from the in-service experience of about 700 ATR aircraft flying worldwide, with average dispatch reliability in excess of 99,6%.

The ATR 42-500 offers a combination of high overall performance and comfort unmatched in its class, while keeping the competitive cost-efficiency, which are the brand image of ATR aircraft. The ATR 42-500 provides passengers with an on-board comfort and services comparable to the jetliner ATR has always made optimal use of advanced technologies providing fuel-efficient aircraft to the airline industry. ATR aims at furthering its contribution to ensure a sustainable future for the aviation industry, and reconciling air transport growth while minimizing environmental impact. The ATR 42-500 has the lowest seat-mile costs in its market segment.

ATR72-500

F 4: ATR 72-500

The ATR 72-500 is the latest development of the ATR 72. It draws from the in-service experience of more than 700 ATR aircraft flying worldwide, with a proven average dispatch reliability of more than 99%. The ATR 72-500 is powered by PW127F engines and provides outstanding short field performance for an aircraft of this size, even on difficult hot and high airfields. The ATR 72-500 provides passengers with an on-board comfort and services comparable to the jetliner

ATR has always made optimal use of advanced technologies providing fuel-efficient aircraft to the airline industry. ATR aims at furthering its contribution to ensure a sustainable future for the aviation industry, and reconciling air transport growth while minimizing environmental impact. Since its introduction, ATR 72-500 has become the regional air transport industry reference for reliability and profitability, providing unmatched seat mile cost and unbeatable cost-efficiency.

c. -600 series

F 5: ATR -600 family

Engineered by enhanced technology, the -600 series is a large step forward in regional transportation market. Powered by PW127M engines, the -600 series provides outstanding short field performance. Significant product upgrades and innovative solutions at the service of low operating costs and high reliability.

The ATR -600 Series enjoys the latest innovations in the cockpit with simplified, integrated LCD advanced functions, enhancing safety, improved handling for pilots and maintenance cost saving.

Three main developments axis:

- Performance enhancement and expanded operational versatility
- Technology upgrade
- Improved passengers' comfort and appeal

Enhanced technology

- New Avionics Suite with Glass Cockpit
- Multi-Purpose Computer (MPC)
- ACARS
- Paperless cockpit (EFB)
- Integrated Aircraft Centralized Maintenance System (ACMS)

Superior Comfort

The new -600 series benefits from the widest cabin in the turboprop market, providing maximum passenger space and setting high standards of comfort. New style interiors offer more baggage room and feeling of space. The new smooth, soft lines of the ceiling and cabin side panels, re-shaped and re-designed to offer passengers more space and light, create an harmonious and balanced environment where traveling is a pleasure.

Enhanced Performance

- Increased ATR 72-600 operational weights
- Improved « hot & high » airport performance with PW127M engine
- PW127M multi-rated engine
- Short runways' takeoff performance

## 4.2. ATR environmental performance

ATR is all long committed to its environmental performance, both in the company and in the aircraft produced. In July 2008 ATR also received the ISO 140001 certification, an important goal in the environment performance. This environmental engagement is clearly remarked by Stéphane Mayer - company CEO at that time - in the following statement wrote in December 2008.

### 4.2.1. <u>Corporate statement of intent from the CEO on the Preservation of the Environment</u>

*Today, more than ever before, ATR's product development policy follows a set of criteria meticulously designed to respect the environment. It does so in full compliance with the sustainable development rules and requisites outlined by the World Commission for the Preservation of the Environment and the development of the United Nations Organisation.*

*In addition to be largely below the limits of the ICAO* noise nuisance regulations, and in comparison with other regional aircraft,- turboprops and jets alike -, our aircraft performances show an undeniable record of having the lowest gas emission levels. This is why ATR is regarded as the true "Green Player" of regional transport.*

*The "green" design properties of our aircraft, added to our environmental commitment have enabled ATR to reach a specific goal: to apply an Environmental Management system first to its production site activities and then throughout the workings of its entire organisation. The ISO 14001 certification received in July 2008 is an official recognition of our achievement.*

*To follow on from this initial certification stage, our intention is to extend our commitment to the respect of the following principles, throughout the life-long cycle of our products:*

- *To take preventive measures against any type of pollution*
- *To abide by legal environment friendly regulations*
- *To seek continuous improvement of our environmental performance*

*A pledge such as this involves a collective undertaking, from all ATR staff as well as from our "green" partners. We count on each and every one you to provide your on-going commitment and active participation in what is a crucial world citizen issue.*

*As and when the above is achieved, we shall be granted an extension of our ISO14001 certification to our product life cycle.*

*We will of course keep you informed on the progress of our project.*

*17.12.08*

*Stéphane MAYER*
*Chief Executive Officer*

#### 4.2.2. Rising to the challenges of environmentally-aware aviation

ATR purpose is to produce aircraft that combine cost-efficient performance with an environment-friendly approach minimizing the environmental impact. The high-tech engines and propeller efficiency of ATR aircraft ensure airlines a good fuel efficiency and a remarkably low noise signature.
ATR production is leading by three main environmental goals:

- lowest greenhouse gas emissions,
- $CO_2$ and fuel consumption reduced by 50% per passenger kilometre,
- full compliance with the *Chapter 4 Noise Regulations*.

ATR is set to participate in international research and project development, and in this context is also part of Clean Sky. This European initiative is part of the ACARE strategy in terms of lowering gaseous emissions and noise.

### 4.3. ACARE

#### 4.3.1. Vision 2020

In 2001, the report prepared by a group of European experts: "European Aeronautics: A vision for 2020" pictured an integrated vision of the European ATS for the next 20 years. It established the need to respond to society's needs and to secure European leadership in the aeronautics field.
More specifically, society's needs include the whole range of benefits that citizens expect of the air transport industry at that moment and in the near future. These benefits are direct, as in the quality and price of travel, and indirect, as in the preservation of security and safety in a more global world. This goal puts together the personal needs of travellers with the collective needs of non-travellers who want to live in quiet, pollution-free neighbourhoods.
The report also recommended the creation of both the ACARE, and the first European Technology Platform, which main scope was the preparation of a set of strategic research objectives initially collected in the SRA-1 released in 2002 and subsequently updated in the SRA-2 in 2004.

#### 4.3.2. SRA

a. SRA-1

This first document is built around five challenges for technology development: quality and affordability, environment, safety, air transportation system efficiency, security. It has been used as a reference guide for a number of national and institutional bodies for establishing their research programmes.

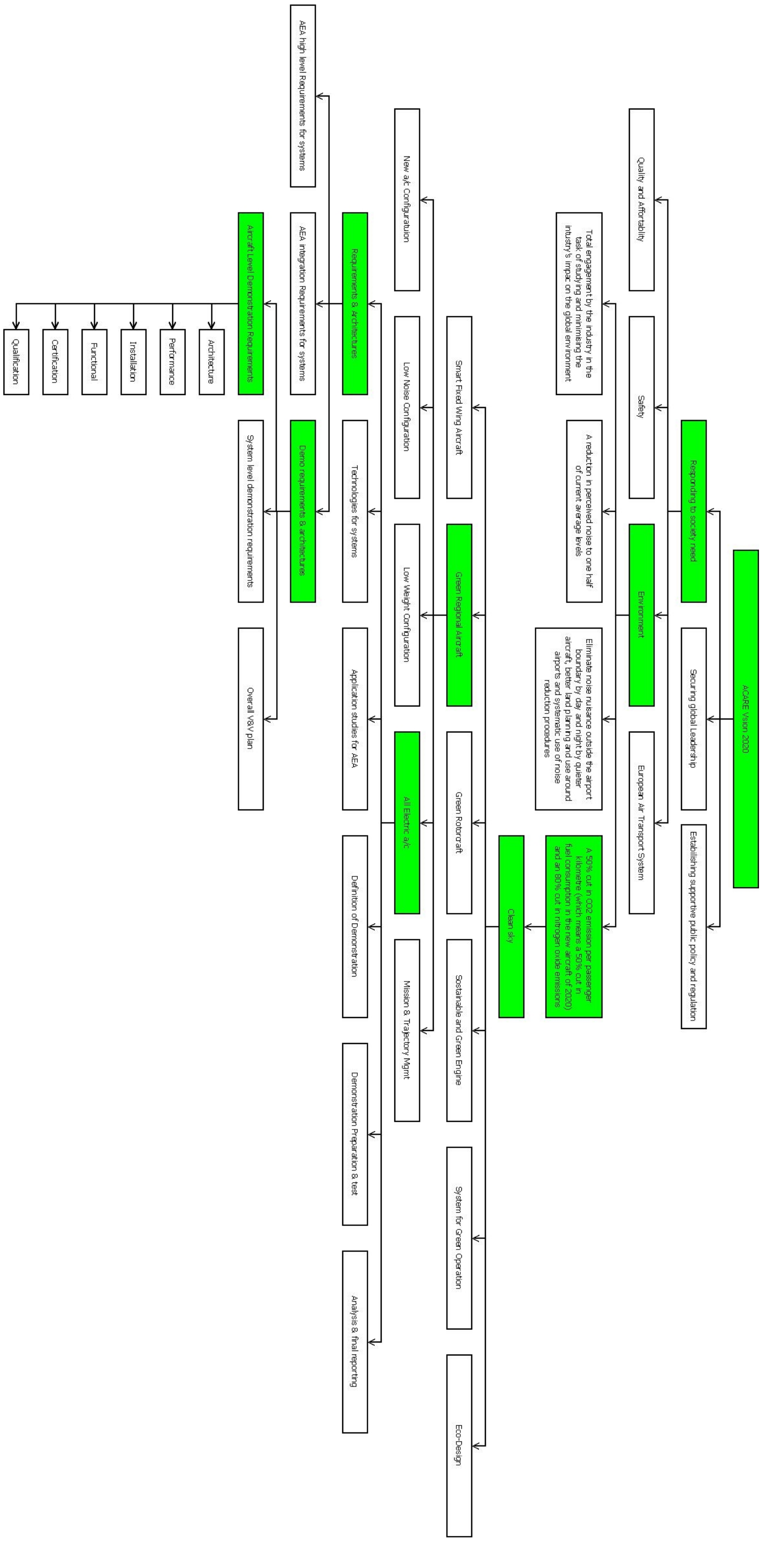
b. SRA-2

The updated version of Agenda describes six HLTCs and their associated technologies with respect to different socio-economic scenario: very low cost ATS, ultra-green ATS, highly customer oriented ATS, higly time-efficient ATS, ultra-secure ATS, 22nd century. Each HLTC focuses on a particular aspect of the ATS.

F 6: SDA 1 & 2 diagram

# 5. The project until today

## 5.1. Schematic resume




F 7: project flow chart

## 5.2. Advisory Council for Aeronautics Research in Europe

The January 2001 report "European Aeronautics: A Vision for 2020", stressed on the two European complementary goals of better serving societies needs while becoming a global leader in the field of aeronautics. The need of establish a strategical council - developing and maintaining a strategic agenda - was clearly express in the recommendation of create ACARE.

### 5.2.1. A vision for 2020

a. Introduction

History does not lack for examples of giant leaps forward in science and technology that subsequently transform human experience and possibilities. But few have touched more lives than the invention of the aeroplane at the beginning of the last century. It has shrunk the planet, destroyed distance and vastly expanded human mobility. The resulting economic and social benefits have been immense.

The rapid journey from the first tentative flights to the modern airliner is a testament to the restless search for technological improvement that has long characterized the aircraft business. Many aspects of technological evolution are shaped by a combination of changing social needs and competitive market forces. Today, these forces are still generating relentless pressures for change in the air transport system.

Europe can continue to meet the challenge of change by mobilizing all of those interests and actors behind the task of producing the competitive products and the air transport system that will be needed in the first decades of this new century.

Conscious of its responsibilities to society at large, the sector is well aware that it has to find an acceptable balance between public expectations and requirements, and the constant, fierce competitive pressures upon it. A generation ago, “Higher, Further, Faster” were the imperatives for any vision of the future for air transport. Now they are “More Affordable, Safer, Cleaner and Quieter”, reflecting the need to combine cost-effectiveness with an uncompromising attachment to safety and environmental objectives. The key to securing these objectives is investment in Research and Technology according to a strategy that can meet the demands of the market as well as the needs of the community.

b. A vision for European Aeronautics in 2020

The Council organized its work on the assumption that the aeronautics must satisfy constantly rising demands for lower travel costs, better service quality, the very highest safety and environmental standards and an air transport system that is seamlessly integrated with other transport networks. The following tables summarize these argument and show some examples.

| | |
|---|---|
| Quality and Affordability | Punctuality: 99% of all flights arriving and departing within 15 minutes of the published timetable, in all weather conditions. |
| | Time spent in airports: no more than 15 minutes in the airport before departure and after arrival for shorthaul flights, and 30 minutes for long haul. |
| | A steady and continuous fall in travel charges through substantial cuts in operating costs. |
| | Passenger choice: the same choice of facilities that are available on other forms of transport including leg room, flexible seating and office facilities incorporating state of the art communications. A greater choice of flights from regional locations. |
| | Air freight services: a larger percentage (by value) of cargo travels by air because it is more competitive with land and sea transport and it is fully integrated into a seamless intermodal freight transport system. |
| Safety | Aircraft will achieve a five-fold reduction in the average accident rate of global operators. |
| | Aircraft will drastically reduce the impact of human error. |
| | Higher standards of training for aircraft operations and maintenance and for air traffic management. |
| Environment | Total engagement by the industry in the task of studying and minimising the industry's impact on the global environmen |
| | A reduction in perceived noise to one half of current average levels. |
| | Eliminate noise nuisance outside the airport boundary by day and night by quieter aircraft, better land planning and use around airports and systematic use of noise reduction procedures. |
| | A 50% cut in CO2 emissions per passenger kilometre (which means a 50% cut in fuel consumption in the new aircraft of 2020) and an 80% cut in nitrogen oxide emissions. |
| European Air Transport System | An air traffic management system that can handle 16 million flights a year with 24-hour operation of airports and a more flexible and efficient use of European air space. |
| | An air traffic management system that can handle 16 million flights a year with 24-hour operation of airports and a more flexible and efficient use of European air space. |
| | A seamless European Air Traffic Management system mainly based on a civil global satellite system |
| | Integration of air transport into an efficient multimodal transport system. |

T 2: Guidelines for ACARE agenda

The Research Challenges (examples)

| Quality & Affordability | Safety | Environment | European Air Transport System | |
|---|---|---|---|---|
| Permanent trend monitoring | Flight hazard protection | Drag reduction through conventional and novel shapes | Innovative ATM operational concepts | |
| Flexible cabin environments | Advance avionics | Fuel additives | Advanced, intelligent and integrated ATM ground, airborne and space system | > |
| Passenger services | Probability and risk analysis | Noise reduction | Rotorcraft integration in ATM systems | |
| Anticipatory maintenance system | Computational methods | Propulsion concepts | High density traffic systems capability in all weather conditions | > |
| Integrated avionics | Human error checking systems | Emission reduction | Airport capacity and advanced management | |
| ATM related airborne systems | | Environmentally friendly production, maintenance and disposal | Increased use of airspace capacity | |
| Novel materials and structural concepts | | Better aircraft/engine integration | | > |
| Advanced design methods | | | | |
| System validation through modelling and simulation | | | | |
| Concurrent engineering | | | | |
| ^ | ^ | ^ | ^ | |

Global Leadership and competitiveness

The *regulatory* System

T 3: The Research Challenges

## 5.3. Strategic Research Agenda October 2002

The ACARE prepared its strategical document following the guidelines described in the previous chapter; the main contents of that document are subsequently summarized.

### 5.3.1. Scope of the SRA

a. Technical aspect

It embraces all technology necessary to ensure the continuous progress in aeronautics, and more widely in the air transport operations and air travel security. Potential benefits from advances made in other major fields (e.g space, IT, telecommunications, military "dual use" technologies and nanotechnology,) will be monitored and matched against the solutions proposed within the SRA.

b. Operational aspect

The baseline scenario leading the preparation of the SRA had, for the first edition, assumed that:

- the events of 11th September 2001 the mid/long term trend in air traffic growth identified in Vision 2020 will continue;
- social priorities will continue to be a balance between economic prosperity (supporting trade, commerce, employment, etc.) and an increasing desire to enjoy this prosperity within an overall quality of life and responsible management of the environment;
- in relation to the USA there will continue to be a healthy mixture of co-operation and competition against a backdrop of shared democratic values and sound economies.
- the first edition assumed no shocks to the international system by war or natural disaster.

### 5.3.2. The Technical Agenda

The technical agenda is the main section of the SRA, containing the body of research that will be needed in order to realise the objectives of the Vision 2020. The technical content of the SRA depended from the five major challenges and their interaction and addressing the top-level objectives. The elaborate purpose of provide more affordable, cleaner, safer and more secure air travel determines the major challenge areas.

These challenges, each of which has clearly identified goals, contributors and solutions, are:

- **Quality and Affordability** – the challenge of delivering products and services to airlines, passengers, freight and other customers whilst increasing quality, economy and performance for sustained international competitive success.
- **The Environment** – the challenge of meeting continually rising demand whilst demonstrating a sensitivity to society's needs by reducing the environmental impact of operating, maintaining, manufacturing and disposing of aircraft and associated systems.
- **Safety** – the challenge of sustaining the confidence of both the passenger and society that commercial flying will not only remain extremely safe, notwithstanding greatly increased traffic, but will reduce the incidence of accidents.
- **The Efficiency of the Air Transport System** – the economic needs of Europe's citizens, international competitiveness and the convenience of passenger and freight customers' demand that rising traffic shall not exacerbate the downsides of congestion, delay and lost opportunities. The challenge is therefore that the efficiency of the whole system taken together must be substantially increased. This will require radical new concepts to be introduced.
- **Security** – Recent events have underlined the reality that protected uninterrupted air services are a foundation for all the economic and social benefits of the air transport system. The challenge is to devise measures that will improve security, on a global basis, within a highly diverse and complex system and against a strong backdrop of increasing traffic.

### 5.3.3. The Challenge of the Environment

The environmental challenge is to accommodate the forecast increase in traffic whilst reducing the relative impact of aviation in respect of noise and emissions and the supporting systems of manufacture, maintenance and disposal.

a. Scope of the Environmental Challenge

The environmental scope embraces all the influences on people's lives caused by the ATS. The scope includes emissions at both the local and global scale throughout the life of the systems and noise where the impact is more local in its effect.
Four goals have been identified to address the Environmental challenge:

- To reduce fuel consumption and CO2 emissions by 50%
- To reduce perceived external noise by 50%
- To reduce NOx by 80%
- To make substantial progress in reducing the environmental impact of the manufacture, maintenance and disposal of aircraft and related products.

The goals recognise the contribution the Air Transport Industry needs to make to reduce environmental impact in the following areas:

- Global warming
- Community noise nuisance
- Airport pollution

More specifically, the $CO_2$ together with the other emissions of water vapour and $NO_x$ at altitude are considered to contribute to global warming, although the physical processes and the contribution from the constituent parts at different altitudes are still poorly understood. However with current fuels it is reasonable to assume that $CO_2$ production and hence fuel consumption is the primary contributor.
Within the current ATS, half of the $CO_2$ emitted is generated by flights below 1200nm, the sector of the market that operates the least fuel efficient aircraft for reasons of economics and passenger convenience whereas for longer range operation low fuel consumption is necessary to realise economic operation. However if $CO_2$ production were to become a primary design consideration, the choice of design speed, range and altitude would need to be re optimised. The most likely result would be to fly more slowly on short haul routes and to stop more frequently on long haul operations, There would however be economic penalties and passenger inconvenience to such an approach.

Whilst Air Transport is only a minority contributor (currently only 3% of $CO_2$ emissions derive from aircraft) as the demand for air transport increases its environmental impact must be minimised.
The goals and solutions are inter-related; in the framework of the SRA 10 contributors to the 4 goals were identified assuming that the environmental targets will not be fully met through straightforward evolutionary improvements of airframe, engine technology and further evolution of the Air Traffic Management System: full achievement of the targets will require the employment of novel concepts and breakthrough technologies into commercial service.

**Goal 1 - Reducing $CO_2$ Emissions**

The overall target of 50% reduction has been allocated between the airframe ,engine and

air traffic management, which could be achieve by changes to the aircraft size, design speed, range and operating procedures together with improvements in technology.
a. The target contribution by the airframe is 20-25% reduction in fuel burn therefore in CO2 reduction. The research will be along the paths of aerodynamics, weight reduction, configuration improvements as evolutionary developments on present technology. More radically, new aircraft concepts will be examined that will explore the prospects for step improvements in these areas.
b. The targeted contribution by the engines is 15-20% reduction in fuel consumption. Engine research will incorporate improvements to conventional engine concepts through increased thermal efficiency by increasing OPR and TET and increased propulsive efficiency by increasing BPR. Such improvements will be obtained by higher engine operating temperatures through the use of more advanced materials and designs, by a better efficiency in turbomachinery components and by new low speed fan design. Breakthrough technologies that may lead to new generation engines will be explored through developments of the Constant Volume Cycle and the Inter-Cooler Recuperator (ICR) cycle and by the use of un-ducted fans.
c. The role of an optimised air traffic management system is substantial with a target contribution of 5–10% lower fuel consumption through reducing in-flight delays, route inefficiencies and taxiing times.
In the long term, new fuels like hydrogen, methane or bio-kerosene may be potential solutions for $CO_2$ reduction however the impact of emitting additional water vapour and potentially higher $NO_x$, emissions would have to be evaluated.

**Goal 2 - Reducing external noise**

The "Quiet Aircraft" is a target concept designating a very quiet aircraft achieving, with noise abatement procedures, a 10 EPNDb reduction per operation and contributing significantly to lessening annoyance within airport boundaries. The evolutionary path will address the sources of noise generation and develop technologies for reduced airframe and engine noise by aeroacoustic design as well as novel noise reduction means, such as active systems. More radical solutions will emerge from new concepts of quiet aircraft.
The "Rotorcraft of the Future" is a strategic research route aimed at reducing noise footprints of rotorcraft by 50% and the noise by 10 EPNdB. It will include programmes relating to the design of low noise rotor and engine as an evolutionary programme as well as pilot aids to assist with low noise flying procedures. The radical approaches will be built around the introduction of advanced technologies such as smart materials on blades, but also advanced tilt rotor designs and low noise VSTOL concepts.
To support low noise impact by both fixed and rotary wing aircraft research will be conducted in new ATM approaches that will enable low noise flight profiles to be developed to minimise noise pollution around the TMA. Rotorcraft are part of the integrated air transport solution and have specific problems of noise and their integration into the ATM system that must be addressed.
Research will also support improved understanding of community impact, so that new environmental management tools and practices link appropriately with the introduction of new technology into the existing fleet whilst exploiting Noise Abatement Procedures.

**Goal 3 - Reducing NOx emissions**

The target is to reduce $NO_X$ emissions by 80% through a strategy based on improvements in combustor technology and design. Combustor design in the short-term will be directed at evolutionary advances to present generation designs but for the longer term work will be pursued to examine the potential of radical new designs of combustor and

injection systems when a better understanding of the combustion process has been obtained.
In the short term, fuel properties (sulphur content) as well as ATM (taxiing time reduction) will also have to be considered for other emissions reductions in addition to $NO_X$.

**Goal 4 - Environmentally Friendly Manufacturing, Maintenance and Disposal (MMD) Processes**

Although consumed fuel dominates emissions from aircraft the environmental impact of the manufacture of such large and complex systems is not inconsiderable and research is required to reduce this aspect still further.
The environmental impacts of the manufacture, overhaul, repair and disposal of products present many challenges for minimisation grouped under resources, emissions and hazardous materials and processes.The demand for all resources and the environmental impacts of their primary production can be minimised by research to improve yield during the whole of the manufacturing and use cycle including end-of-life disposal. Emissions occur from manufacturing processes. Research is required to develop alternative processes with low or zero emissions that will reduce their impact.

Achieving success in this environmental challenge is an extremely demanding objective. A wide range of fundamental technology developments will be required spanning the range from advanced ATM systems through to high temperature engine materials. Many technologies need to be employed and some of them will require technical “breakthrough” advances.
Meeting these environmental challenges will require a ‘system level approach’ where solutions developed for the ATM system, aircraft and engine are fully optimised. A full air transport system simulation that is capable of evaluating the capability of the ATM system and route structure, aircraft design options, the fleet mix, timetabling and level of passenger demand is recommended.
High performance computing will be a priority if a better understanding is to be generated on:

- noise generation and propagation
- aircraft and engine aerodynamics for performance improvement
- advanced structural design to reduce weight

In addition to the necessary search for novel concepts and breakthrough technologies, in order to determine the most promising longer term solutions, it is recommended that new concept studies be initiated to develop a range of potential solutions to the ‘environmental challenge’. These studies will enable the longer-term critical technology requirements to be identified and quantified.

## 5.4. 2008 Addendum to the Strategic Research Agenda

### 5.4.1. Foreword

In 2008 ACARE prepared an addendum to its SRA reinforcing the importance of a coherent roadmap for aeronautical technology development and recognising the inherent need to periodically update some of its forecasts and assumptions.
Two very large initiatives had been launched since the last SRA:

- Clean Sky, a research project with demonstrators aims to minimize the impact of aviation on the environment,
- SESAR, which will develop and deploy the future ATM system at a pan European level.

A number of large demonstration programmes and a range of applied research programmes have been launched through the EU Framework programme and national programmes.

### 5.4.2. The Environment

a. Changes, new, drivers and issues

In a few decades, the sustained impact of about 5% annual growth in air travel has greatly increased numbers of aircraft and the amount of air travel, bringing to society a tremendous increase in mobility and economic benefits.

During the UN Climate Change Conference in BALI in December 2007, the World's governments were acutely aware of the challenge ahead and the necessity to act and to put in place concrete measures to combat climate change.

These large scale climate influencing effects are not the only environmental concerns, although they may be the most serious. At the local level citizens are becoming less tolerant of noise and emissions associated with airports and these effects are also requiring increasing attention.

b. The image of Air Transport and Climate Change

The challenges to aviation are, however, not just in comparative terms. In absolute terms it is clear that aviation will be a significant contributor to global warming (a) because it is producing about 2% of man-made $CO_2$ emissions today (b) because it is growing at a rate of about 5% per annum and (c) because the IPCC indications are that emissions at altitude have an effect on climate change greater than that suggested by the industry's $CO_2$ emissions alone. The effect of aircraft emissions on the environment is complex and is not fully understood. For these reasons the present emphasis being given to the environment is justified even if some of the comparisons are not.

c. The medium-term objectives and progress

Both categories of environmental impact still need to be addressed and separately:

- Global impact (green house effect, climate change, $CO_2$ and $NO_x$ emissions, but also soot, particulate, water vapour, contrails, etc.): further work is needed to better understand the mechanisms of climate change, and the impact of aviation on it.
- Local impact: noise, and local air quality, $No_x$, unburned fuel in the vicinity of airports.

Clean Sky is a massive collaborative effort allowing the contributions of all members to be used across Europe. The public funds applied through the European Commission Framework and national programmes are always collaborative, and are carefully balanced against the priorities of the period.

d. In the Longer-term

The potential in the longer-term is for entirely new technologies that will take us much closer, or even to exceed, the target of neutrally sustainable growth. This will only come from public and private investment in carefully selected and controlled projects.

### 5.4.3. Conclusions and recommendations

The Addendum substantially change six main areas suggesting to:

1. increase intensity of work in the area of environmental impact.
2. consider the aviation aspects of new and alternative fuels.
3. increase attention in the security area to hassle-free operation dynamically adaptable security screening.
4. consider the airspace use and ATM aspects of the large scale introduction of the European air taxi and personal air transport business.
5. emphasise development of the mechanisms that support the deployment and exploitation of technology.
6. establish European positions, proper strengths and targets for strategic co-operation.

In order to avoid any damaging delay in research and testing, all needed funds have to be raise on time.

## 5.5. Clean Sky

### 5.5.1. Introduction

Clean Sky is a Joint Technology Initiative that will develop breakthrough technologies to reduce environmental impact. Aviation is an essential element of today's global society, bringing people and cultures together and creating economic growth.
Air transport is an important sector in the EU economy accounting for approximately 2.5% of GDP, and creating (directly and indirectly) over 3 million jobs. Moreover, the indirect economic and social impact of the sector is even greater and more widespread. Bases on projected growth, over the next twenty years, air transport could contribute an additional 1.8% of GDP to the EU.
The air transport industry is paying a lot of attention to growing public concern about the environmental issues of air pollution, noise and climate change. Although today air transport only produces 2% of man-made $CO_2$ emissions, this is expected to increase to 3% by 2050.
The Clean Sky was organised as a JTI in order to ensure it all needed funds to allow the implementation of this ambitious and complex project, including the validation of technologies at a high readiness level. The size and scale of the Clean Sky requires the mobilisation and management of substantial public and private investment and human resources. In this context the involvement of the European Commission was significant.

a. The Project

The Clean Sky JTI will be one of the largest European research projects ever, with a budget estimated at €1.6 billion, equally shared between the European Commission and industry, over the period 2008 - 2013. Clean Sky will encourage the participation of SMEs to ensure their full involvement in the programme, therefore offering opportunities to the entire aeronautic supply chain from all EU member states.
Speeding up new, greener design is essential to protect our environment: aircraft have a 30-year service life, and that new aviation design takes more than a decade to develop. Therefore the accelerated research process that Clean Sky offers represents an opportunity for rapid progress in the introduction of green technology into aviation.
Clean Sky will demonstrate and validate the technology breakthroughs that are necessary to make major steps towards the environmental goals sets by ACARE to be reached in 2020:

- 50% reduction of $CO_2$ emissions through drastic reduction of fuel consumption: 20 to 25% due to aircraft improvement, 15 to 20 % due to the reduction of engine Specific Fuel Consumption, 5 to 10 % due to operational improvements.
- 80% reduction of $NO_x$ (nitrogen oxide) emissions, combustor technology improvements represent the key research area in this respect.
- 50% reduction of external noise
- A green product life cycle: design, manufacturing, maintenance and disposal / recycling entailing a more comprehensive approach to evaluating the overall impact of the industry and taking in consideration the total aircraft life cycle from production to recycling. This also includes the development of non-toxic and non-polluting materials and processes.

### 5.5.2. Summarised content of Clean Sky

The Clean Sky JTI is made up of six major areas of work called ITD (fig. 8): Green Regional aircraft, SMART Fixed-Wing Aircraft, Green Rotorcraft, Sustainable and Green Engines, System for Green Operation, Eco-Design.


F 8: Clean Sky JTI

The ITDs have to cover the broad range of the research and testing work while ensuring a high degree of efficiency in the management of the technical activities. Additional details on each ITD are summarized in table 4.

| | |
|---|---|
| **System for Green Operation** | *Improvement of aircraft operation through the management of aircraft energy and the management of mission and trajectory*<br>The highest overall benefits will be 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 ITD are enablers for further improvements in environmental impacts at the vehicle level. |
| **SMART Fixed Wing Aircraft** | *Development of active wing technologies and new aircraft configuration for breakthrough, news products* |
| **Green Regional Aircraft** | *Release of low-weight aircraft using smart strutures, as well as low external noise configurations and the integration of technology developed in other ITDs, such as engines, energy management and new system architectures.* |
| **Green Rotorcraft** | *Release of innovative rotor blades and engine installation for noise reduction, lower airframe drag, integration of diesel engine technology and advanced electrical systems for elimination of noxious hydraulic fluids and fuel consumption reduction.* |
| **Sustainable and Green Engines** | *Design and preparation of five engine demonstrators to integrate technologies for low noise and lightweight low pressure systems, high efficiency, low NOx and low weight cores and novel configurations such as open rotors and intercoolers.*<br><br>Systems for Green Operations will focus on all-electrical aircraft equipment and systems architectures, thermal management, capabilities for "green" trajectories and mission and improved ground operations to give any aircraft the capability to fully exploit the benefits of Single European Sky |

| | |
|---|---|
| **Eco-Design** | *Focusing on green design and production, withdrawal, and recycling of aircraft, by optimal use of raw materials and energies thus improving the environmental impact of the whole products life cycle and accelerating compliance with the REACH directive.*<br>A simulation network called the Technology Evaluator will assess the performance of the technologies thus developed. |

T 4: Clean Sky ITD description

a. Clean Sky objectives and major benefits

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

Objective 1 - Reduction of fuel consumption ($CO_2$) and $NO_x$ 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.

Objective 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.

Objective 3 - "Ecolonomic" life cycle

The meaning of Ecolominc puts together ecological and economical/affordable. The optimisation of environmental impact of aircraft for their complete life cycle will be achieved in considering the four phases of the aircraft life:

- aircraft design;
- aircraft production;
- aircraft operations;
- aircraft withdrawal: dismantling, recycling, reuse, elimination, storage.

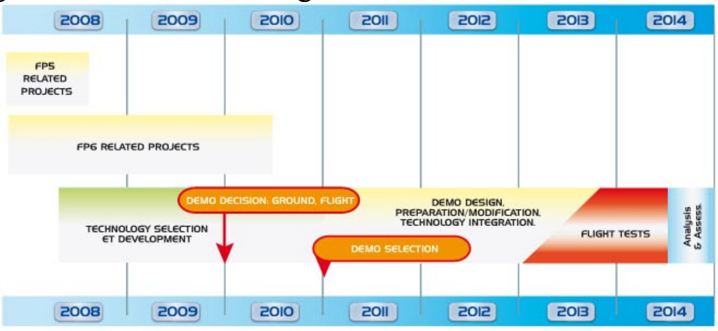
These objectives contribute of achieve three main benefits:

- accelerate the delivery of technologies for radically improving the

environmental impact of air transport;
- increase the completitiveness of European industry, thus contributing to the Lisbon Strategy objectives;
- encourage the rest of the aviation world to make greener products.

### 5.5.3. Planning

Clean Sky last for seven years as part of the European Commission's Seventh Research Framework Programme as showed in fig. 9.




F 9: Clean Sky planning

### 5.5.4. Participation

The members of Clean Sky represent 86 organisations in 16 countries, among which:
- 54 industries, including 20 SMEs
- 15 research centres
- 17 universities

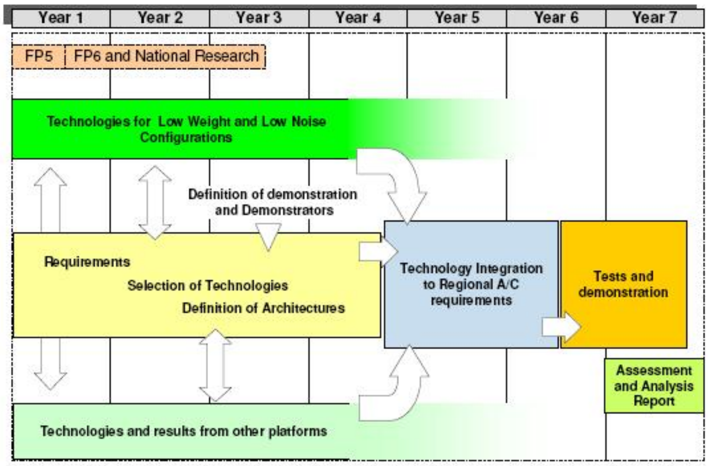
A significant part of the Clean Sky programme will be performed by partners selected through Calls for Proposals and Subcontractors selected through Calls for Tender.

## 5.6. Green Regional Aircraft

### 5.6.1. Introduction

On a global level, 45% of today's flights are operated with regional aircraft, and in 2020 this figure is estimated to rise to around 50%. A substantial contribution to the Clean Sky shall then come from the Regional Air Transport. Improvement of the environmental impact deriving from the operation of regional aircraft are expected mainly from weight and noise reduction technologies, as well as from the integration of advanced technologies belonging to other domains.

The study is planned for seven year and is complete by the demonstration in flight and on ground of the technology developed as explained in fig. 10.

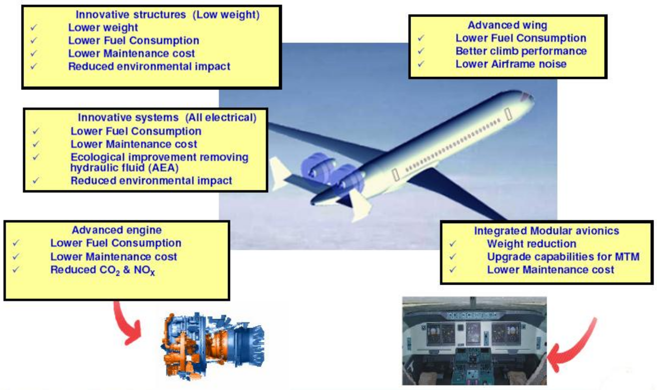



F 10: GRA General workflow of activities

### 5.6.2. The objective

The ambition for the GRA - ITD is to achieve a reduction in fuel consumption and noise emitted through a low weight, low noise, advance design and innovative system configuration. The GRA use a multidisciplinary approach for integrate technical solutions from the mainstream technologies ( Low Weight and Low noise Configurations) and from other technical domains of the Clean Sky (Energy Management, Mission & Trajectory Management, Engines, Eco Design) in the Demonstrators.

The technologies and their expected impact are illustrate in fig.11.



F 11: GRA Objectives and expected impacts

### 5.6.3. General approach and content

The GRA task is based on five different approaches developed at the same time:

- *Low weight configuration*
  This is the advanced solutions of composite structures where sensors are embedded in advanced materials in order to monitor the events occurring to each aircraft.
- *Low noise configuration*
  It consist 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.
- *New configuration*
  This approach aims at defining advanced regional aircraft general configurations integrating the innovative powerplants (including Open Rotors), Systems and Avionics best fitting the regional aircraft requirements, and the advanced aerodynamics and structures developed in GRA.
- *All electrical aircraft*
  Its main objective is to demonstrate the feasibility of on-board systems technologies and architectures: electrical powered air conditioning and pressurization, electrical and electronic technologies for generation, distribution and control, electrical ice protection and flight controls. Flight tests are planned.
- *Mission and trajectory management*
  Integration and validation of new optimised missions and trajectories by using of a flight simulator.

The GRA approach correspond to a WP:

WP1: Low Weight Configuration;
WP2: Low Noise Configuration;
WP3: All Electrical Aircraft;
WP4: Mission and Trajectory Management.

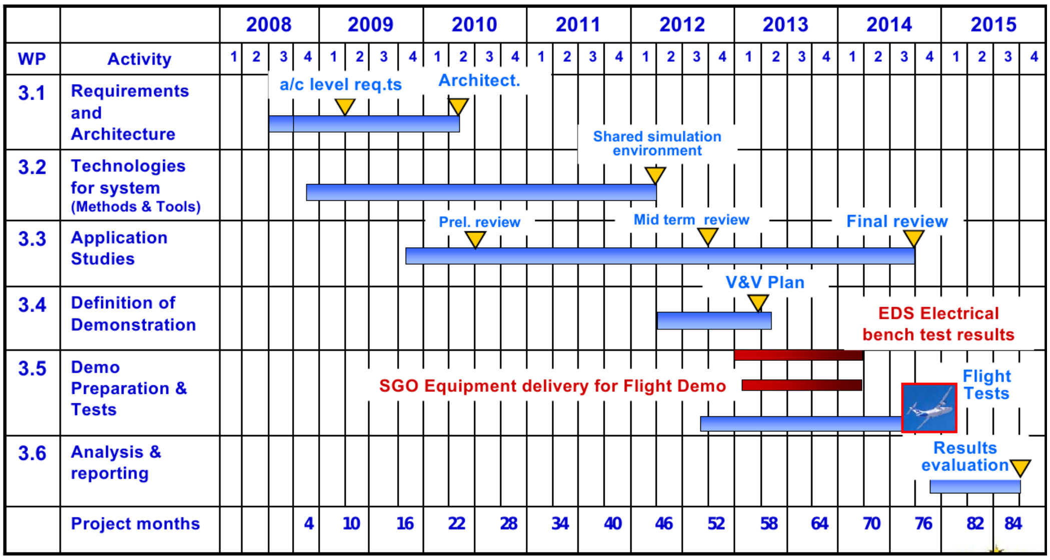
## 5.7. WP3 - All Electrical Aircraft

### 5.7.1. Introduction

The All Electrical Aircraft is a system configuration where the electric power replace all the pneumatic and hydraulic power. This architecture offers several important advantages like an easier control of the power quantity used during the different fly condition and a reduction of weight and maintenance due to the remove of hydraulic oil. This technology contribute for a 3/4% of all the gaseous pollution reduction in Clean Sky objectives. The planned activities for the AEA are showed in fig.12.
In order to create the conditions to realize these purposes, every on-board systems will be reviewed and reconsidered. Some of the system interested by this architecture are:

- electrical and electronic technologies for generation, distribution and control,
- air conditioning, pressurization, cooling/heating and compression,
- ice protection,
- actuation for aircraft control and manoeuvres.

The AEA want to demonstrate that this architecture permit a lower fuel consumption, lower maintenance cost, an ecological improvement by removing hydraulic fluid, a reduced environmental impact.




F 12: Work Plan AEA

### 5.7.2. Objectives

As integration domain of the GRA, the main objective of AEA is to demonstrate the feasibility of such type of on-board systems configuration for the next generation regional aircraft. To this extent, development of relevant data through dedicated studies, simulations and tests, including a meaningful in-flight demonstration of the key-factors related to the energy management solutions, are foreseen.
The principal advantage that the AEA will be demonstrate are:

a- Lower Fuel Consumption

The reduction of weight and the easier energy management system permit a significant reduction in fuel consumption during the fly.

b- Lower Maintenance cost

The exclusion of the non electrical power generation (removal of pipes,pump and fluid) significantly reduces the maintenance required.

c- Ecological improvement by removing hydraulic fluid

The exclusion of hydraulic fluid permit an important ecological improvement by remedying to the complex exhausted fluids disposal.

d- Low weight configuration

The All Electrical configuration will be lighter then the traditional due to the remove of the hydraulic system.

### 5.7.3. Energy management

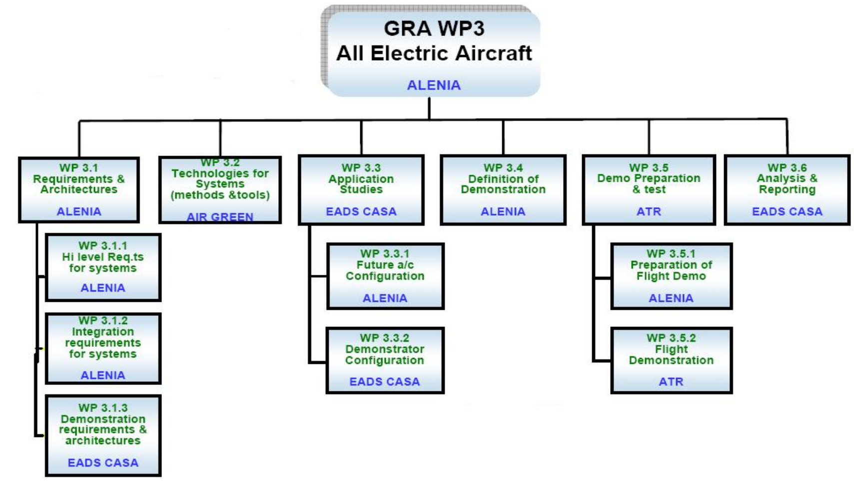
The Energy Management is the procedure leading the control of all aircraft power loads – electrical in a *all electrical* configuration. It permit the optimising of weight, volume and consumption, while taking care of power transients by *smoothing* non essential or non critical loads for that operative flight or operative phase.
Due to this high power request, such a management shall not rely as usual on the overload capacity of the generators (load management), but in order to keep weight and volume within acceptable limits for aeronautical applications, it shall be based on a new concept, that is to force global electrical power demand to decrease, even during an extra demand condition. To this aim, the network voltage applied to some selected power consumers shall be chopped and it shall result in power modulation. The electrical wiring and equipment installation shall be designed with a modular concept; for minimized the part numbers in use on the airplane the use of electrical components, such as relays and termination device, shall be controlled.
This technology is fundamental for the accomplishment of the Clean Sky goals. The reduction of the maximum load on the system trough the smoothing of non essential load allow smaller generators, with consequent reduction of the weight.
To achieve its objectives the AEA domain has organised its WP3 in to three major goals:

1. specification of the requirements for the design and integration of on-board systems;
2. identification of AEA architectures and configurations for the next generation regional aircraft
3. in-flight demonstration of the key elements of Energy Management in order to demonstrate that relevant solutions correctly perform in the real regional aircraft operative environment.

The WP3 is divided in six sub levels:

WP3.1 Requirements and architecture;
WP3.2 Technologies for system (methods and tools);
WP3.3 Application studies;
WP3.4 Definition of demonstration;
WP3.5 Demonstration preparation and test
WP3.6 Analysis and reporting.

Each sub level is in turn divided in other smaller activity package, as showed in fig. 13.




F 13: AEA Work packages organization

### 5.7.4. Demonstrator

The AEA demonstrator needs some of the different elements generated by other ITDs as summarised in table 5. The demonstrator will be also completed with specific element required for a corrected evaluation of the configuration:

- other simulated electrical loads,
- cockpit controls for new systems,
- I/F with existing systems and segregation devices.

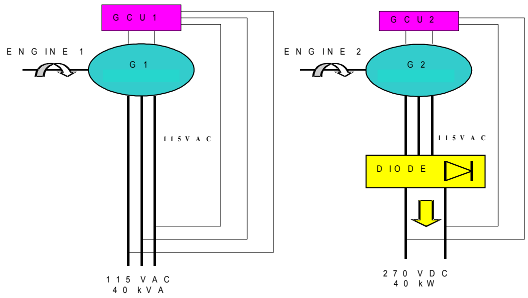
| | |
|---|---|
| System for Green Operations (SGO) | • Two electrical generators, with associated controls<br>• One innovative E-ECS<br>• One innovative Ice Protection System |
| Eco-Design for System (EDS) | • The energy management system hw and sw<br>• EMAs with counter loads |

T 5: Link between the AEA demonstrator and other ITDs elements

# 6. Electrical System in the AEA

The following chapter is a review of the three systems modified within the AEA that will be tested in flight on the ATR prototype.

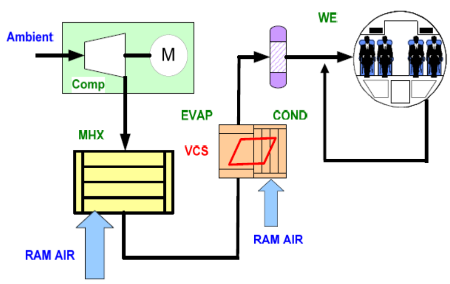
a. Electrical Power Generation System.



F 14: EPGS

The electrical power system shall provide electrical power as required to supply all aircraft electrical load utilization equipment during ground and in-flight operation.
In order to ensure the power request in a all electrical aircraft, the electrical power generation system must be boost. A possible way under studying is to change the generation to 270 VDC.
The increased amount of electrical power demand for the future all-electric regional aircraft would affect either the size and weight of cables and bundles, or the power losses throughout the network, should the voltage stay at low level. Therefore, the choice of rising the voltage is compulsory to a good design. An assessment on how power consumers currently brought into the market might change in case either of an high AC voltage power supply or of an high DC voltage has established that the high DC voltage would be the best solution for many reasons: a power converter saving, the possibility for more generators to work in parallel, the easier network harmonic content management and a reduced complexity in cabling distribution. The High Voltage DC (HVDC) network has been fixed to +270 Volt (being already a standard).
The first version of the new generator will be delivered in 2011, the final version is expected for 2013.

b. Electrical ECS



F 15: E-ECS

The removing of the pneumatic system from the aircraft could reduce the power bleed from the engine. A different ECS needs to be developed for the use in a bleed less turboprop. In the AEA is studying an electrical solution to this problem.
The E-ECS will be integrated as a "power sink" into the Electrical Energy Management framework. The flight demonstration includs the validation of both E-ECS integration and performances.
E-ECS Equipment for Flight Test Demonstrator will be released within the end of 2013.
The system will be composed from:

- motorized compressor/turbocompressor,
- motor and Inverter,
- power electronics,
- heat exchangers (MHX, heater/condenser),

- VCS.

This first draft of the equipment list will be frozen upon completion of architecture selection process.

c. WIPS

Introduction

As the recent history has showed the ice accretion is one of the most important problem for the regional aircraft. Some of the dangerous effect of the ice build up is:

- Destroys smooth flow of air over wing, leading to severe decrease in lift and increase in drag forces;
- Change in pitching moment;
- Damage to external equipment such as antennae and can clog inlets, and cause impact damage to fuselage and engines;
- Block probe and static port making it useless;
- Block the control surface.

The conditions at which start to be possible ice formation are called *ice condition*. This condition is described in *FAR 25 appendix C* and it exists when visible moisture is present in any form and the temperature is above a threshold. On ground the OAT is monitored and the threshold is 5°C or less; in flight the TAT need to be under 7°C. The visibility is then lower than 1 mile. During most of the normal operation a regional plane pass through ice condition.

The part of the aircraft that need to be protect against the ice is all the external part where the impact of supercooled air could form ice and where the ice formation could reduce the aircraft performance or the safety of fly. In particular the typical part protected from ice are: probes, static port, windows, control surfaces, leading edge, some engine part and, in turboprops, the propeller blades. Typically in regional aircraft only the de-icing of the leading edge use pneumatic source.

With the adoption of a bleed less engine the old ice protection system need to be changed. The actual technologies are already able to use electrical power instead of pneumatic for the ice protection, but this concept is still little used. A first level screening has been performed for underline the main feature of the existing technologies.

State of art of ATR aircraft

General description

The ice protection of ATR 72-500 permits aircraft operations in icing conditions, the protection is provided by a pneumatic and an electrical system. The ice accretion is monitored by:

- an ice detector provided below the left wing leading edge and connected to the CCAS,
- a visual indicator, or Ice Evidence Probe (IEP) located on the lower frame of the left side window,
- the APM, Aircraft Performance Monitor, function of MPC.

Three level of icing protection are provided. The level 1 is permanent, independent of the fly condition and it is ensure by electrical heating. The level 2 is an anti-icing, it will start when the aircraft enter in ice condition, before the ice formation and it ensure by electrical heating provide trough ACW. The level 3 is an de-icing, it will start when there is ice accretion on the aircraft, announce by CCAS, IEP or APM.

The level 1 ice protection is in charge to keep operational the instruments probes. A failure of these parts due to ice formation could reduce the capacity of detect ice formation. This parts are heated electrically but not ask a big amount of energy. Is protected at this level: windshields, pitot probes, static ports, TAT probes and alpha probes. It use both DC and ACW electrical network, for different part of the aircraft. The pilot start this ice protection level before the take off and stop after the lending.
The level 2 use ACW network for anti-ice components that use big amount of power. This components are: the aileron, elevator and rudder horns, the propeller blades and the side windows. The system will start from the crew when the plane enter in ice condition and stop when it came back in safe condition. As soon as the level 2 ice protection is selected on the stall warning angle of attack change and become lower.
The level 3 is a pneumatic system supplied by air bled from the engine HP conpressor and which operates on areas of the airframe. The zone de-iced pneumatically are the wing leading edges, the horizontal stabilizer leading edges and the engine air intakes and fas paths.

#### Ice detection

Three different systems are in charge to the ice detection. The Ice Detector Probe, the Ice Evidence Probe and the Aircraft Performance Monitoring. The Ice Detector Probe is install under the left wing, on the leading edge. It is a ultra sonic vibrating probe that detect the ice formation monitoring the variation of the vibration frequency.
The Ice Evidence Probe is provided close to the left side window and enables the cockpit crew members to visually detect the beginning of the ice formation and visual check that the aircraft is free of ice after icing encounter. The IEP is made up of a base secured to the fuselage and a mount which maintains the sensing element in the air stream. The sensing element consists of matt block cylinder, in ice condition, ice accumulation is shown on the profiled block to the cockpit crew member. During the night operation the ice accumulation masks a light source, controlled by the NAV lights switch.
The Aircraft Performance Monitoring is a function of the Multi Purpose Computer, it reinforces the knowledge and the awareness of the crew with regard to severe icing conditions during the flights. The theoretical and real drags of the plane, calculated through the real time acquisition of aircraft parameters, are compared and, if different, some alerts/warnings are delivered to the crew.
The APM analysis is conducted if the aircraft is in icing condition. It is possible only if the flap and landing gear are retracted and both engine operating.

#### Ice protection system

An ice protection system on exposed critical areas uses pneumatically inflated boots to shed ice accumulation. The system protected the leading edges of wing and horizontal tailplane and the engine air intakes and gas paths using HP bleed air.
Two type of boots are used: for the leading edges and the engine gas paths are used transversal boots which inflate alternate chambers, A & B; for engine air intake annular boots are used. For maximize the chances of ridge ice accretion and so reduces potential degradation in performances median and external boots have been extended on the upper surface of the wing. With this type of boot there is no need to wait for ice accumulation before selecting the system on.
When deflated, the boots are held to the structure thanks to a venturi supplied by bleed air for maintain unchanged the aerodynamic property of the wing. The system is protect against overtemperature, overpressure, engine fire, leaks and condensation.

#### Anti-icing system

The anti-icing system consists of electrical heating of: probes, windshields, side windows, propellers and flight controls horns. The power is supplied primarily by ACW current.

State of art of ice protection system

In the history of aviation many different systems to protected the plane from ice formation have been developed. These systems can be very different depending on the available power on the plane and its capability to withstand the accretion of ice.
The system for protected the leading edges are divisible in two main categories, de-icing solution and anti-icing solution.
The de-icing solution is reactive, it will used after there was been significant ice build up. The airfoil of the aircraft that mount this kind of system have to be design for withstand this layer on leading edge. Only some part of the aircraft can be de-iced, the external probe and other important part have to be heated for anti-iced.
The main vantage of this system is the low power request. Usually it use boots inflated cycling with the HP bleed air, this system break the ice layer that will be remove by aerodynamic effect. In rare cases an electrical system is used for break the ice, obtaining the same effect.
The low power request make this system the favourite for turboprop regional aircraft that can withstand easier the worsening of aerodynamics compare to turbofan aircraft.
There is five de-icing system actually used on aircraft:

- pneumatic;
- electro mechanical;
- electro impulse;
- electro-thermal;
- glycol;
- a combination of the above.

The anti-icing solution is pre-emptive, it should be turned on before the flight enters icing condition. Differently from de-icing, anti-icing system is in charge to maintain the wing completely clean. It is used when a small reduction of the aerodynamic capacity of the wing could be dangerous for the plane. Typically the anti-icing system heated the leading edge, where the slow speed of the supercooled water help the formation of the ice. For avoid ice formation on the rear of the wing due to the water produced on the leading edge, this water will be completely evaporates.
For obtain this the leading edge is heated at very high temperature using a big amount of power, electric or pneumatic.
This system keeps the leading edges clean for maintain unchanged the aerodynamic characteristics of the wing, but have two main disadvantage: the hight request of power and the difficult to control the downstream run-back.
It is typically used in turbofan aircraft because, due to the hight speed, the worsening of aerodynamic could be very dangerous. During the flight the anti-icing system must be switched on as soon as the aircraft enter into ice condition, before ice formation, and kept on until the complete cessation of hazardous conditions. For this reason energy consumption is considerably higher than the de-icing system.
A big problem of the anti-icing system is caused from his improper use. If it is start too late, when there is just ice on the wing, the system clean only the front part of the wing with the consequent creation of a step in the profile. The same situation could verify if the system don't work correctly and not all the water formed in the leading edge will be

evaporates.
There is three de-icing system actually used on aircraft:

- pneumatic;
- electro-thermal;
- glycol.

The following table 6 summarised the state-of-art.

| De-icing | |
|---|---|
| Pneumatic | It is compose from rubber boots and regulation valves and is manage by a computer. Typically the air was bleed from the hight pressure turbine of the motor and, through the pipes, it blows up the boots on wing, stabilizer and engine.<br>A computer manage the system, typically non all the boot are inflate at the same time but the system clean cyclically the different part. Each of these could be equipped with two boots, called A and B, that is inflate in sequence for improve the system's ability to remove ice. This system has some big vantage, it is light, use a small amount of power, simple to design, cheap to produce and don't stress the material of the wing. It also is the most used de-icing system, so it is largely tested and certified from the authority.<br>The disadvantage of the pneumatic system is prevalently the hight cost for the maintenance. The rubber parts are expose to the weather and need to be controlled often. Other minor problem is the bleed air take from the engine. |
| EIDS<br>EMEDS | EIDS and EMEDS are two similar system that use electrical power for produce a vibration of the skin of the leading edge, this motion is characterize from a small shift and a hight acceleration.<br>The big difference between the two systems is how this shift is generated, the EIDS, Electric Impulse De-icing System, is based upon a short-term electromagnetic field creating a high-speed acceleration pulse-wave on the surface; the EMEDS system use a particular electric actuator for imparts a strong force to the skin of the wing. This system don't use a new concept, but his application on the aircraft was, until today, limited to few Russian model. The vantage of this solution are numerous, it use a small amount of power, it is protected from the weather because it is installed inside the airfoil, it is light, it is easy to install and his lifetime is in the order of the aircraft lifetime, then the maintenance is almost nothing.<br>As all the other de-icing system this solution need a thin layer of ice for work correctly, for this reason exist some hybrid solution that solve partially this problem, but use a greater amount of power. |
| Electro-thermal | This system heated the surface of the wing using the electrical power at regular intervals, after the aerodynamic forces remove the ice detached from the wing.<br>This system start to replace the anti-icing system in many new aircraft. It is able to function both as de-icing and anti-icing. In de-icing mode |

| | |
|---|---|
| | reduce the power request to the aircraft.<br>Due to the absence of a system for remove the ice detached from the wing only the aerodynamic forces are in charge to do it. |
| Glycol | This system was studied for small aircraft, with short fly autonomy. It is based upon the freezing point depressant concept. An antifreeze solution is pumped from panels mounted on the landing edges. The solution mixes with the super cooled water in the cloud, depresses its freezing point, and allows the mixture to flow off of the aircraft without freezing.<br>The system is designed to anti-ice, but it is also capable of de-icing an aircraft as well. When the ice has accumulated on the leading edges, the antifreeze solution will chemically break down the bond between the ice and airframe, allowing the aerodynamic forces on the ice to carry it away. This capability allows the system to clear the airframe of accumulated ice before transitioning to anti-ice protection.<br>A valuable side effect of this system is the reduction of runback icing on the wings and tail.<br>The disadvantage of this system is prevalently the weight of the fluid needed to keep the plane clean for all the time that it could fly in ice condition. The maintenance of this system is a problem too due to the ease with which holes is obstructed, the panel skyd is perforated by laser drilling holes, 0.0025 inches in diameter. |
| **Anti-icing** | |
| Pneumatic | In the traditional architecture, hot bleed air is extracted from the airplane bleed system and distributed through the areas of the wing leading edge that need ice protection. For each wing, one valve controls the flow of the bleed air to the wing leading edge, while a "piccolo" duct distributes the heat evenly along the protected area of the wing leading edge. In addition, should ice protection on the leading edge slats be required, a telescoping duct supplies bleed air to the slats in the extended position. The spent bleed air is exhausted through holes in the lower surface of the wing or slat. |
| Electro-thermal | The electro thermal anti-icing use the electrical power for heat the leading edge. Several heating blankets are bonded to the interior of the protected slat leading edges and energized simultaneously.<br>This method improve the drag and noise reduction relative to the pneumatic system because there are no bleed exhaust holes. |

T 6: State-of-art in ice protection system

EIDS

There are two company that produce a EIDS de-icing system: PWD and IDI.

The PWD Electric Impulse De-Icing System (EIDS) is based upon a short-term electromagnetic field creating a high-speed acceleration pulse-wave on the surface. Minimum electric power consumption is needed. The idea of applying short-term pulse-waves on a surface was implemented for the first time in the aviation industry at the beginning of the sixties. Aircraft flying in icing conditions may develop serious problems, if ice is accumulated on the leading edges of the aircraft.

The short-term power stream from the source located inside the structure under the skin of the leading edges attacks the ice accumulated on the surface of the leading edges. An impulse wave field is created in the skin, and the micro amplitude of the skin wave deformation is sufficient to remove the ice, but is below the level that could cause metal fatigue. The consumed power of the system is less than 0,1 % compared to traditional thermal anti-ice systems.

The basic idea of EIDS system is:

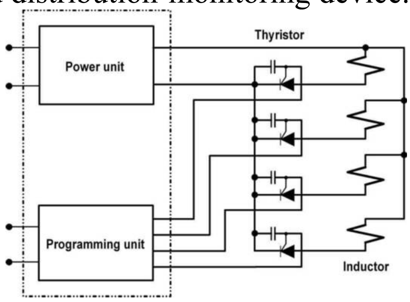
- short-term electromagnetic field creating a pulse-wave on surface.
- elastic deformation wave with micro amplitude.
- shock front propagates over the skin and cleans the surface.

F 16: PWD EIDS

EIDS systems consists of two mainparts:

- electric impulse generating unit,
- converter of electric impulses into mechanical impulses (inductor or impulse plate).

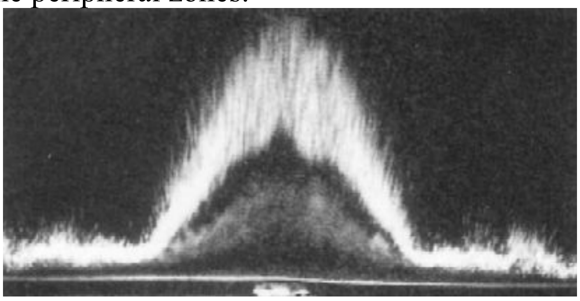
The electric impulse-generating unit contains a power-accumulating block (capacitor with charging elements) and distribution-monitoring device.




F 17: PWD EIDS system diagram

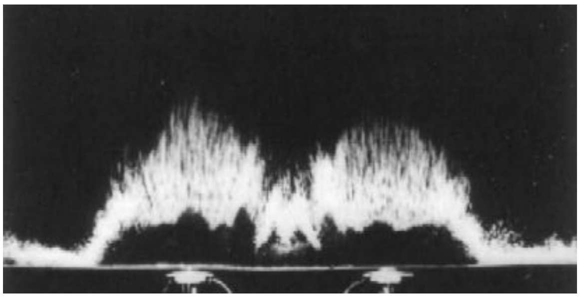
The electric impulse generating unit generates electric impulses with prescribed parameters, created through capacitor discharge, and in due time, in sequence, feeds the impulse plates. During the short intervals between the impulses required for charging the unit capacitors, the accumulation of energy takes place. The intermittent operation of the impulses and the sequential connection of the required number of impulse plates, according to the designed programme, ensure minimal power consumption rates by the

system.
The impulse plate represents a device converting the electric impulses from the generating unit into electromagnetic impulses (electromagnetic field). Practically, it is a coil with the windings embedded in the dielectric body. The impulse plates are arranged in the immediate vicinity of the surface to be cleaned and are the most critical elements of the system.
The principle of PWT operation consists of the following: an electric impulse from the impulse-generating unit passes through the winding of the impulse plate. The fast changing magnetic field created by the impulse plate establishes electromagnetic fields near the skin to be cleaned.
The electromagnetic field creates ultra short wave impulses in the skin. The resultant short-term elastic deformation wave, with a micro amplitude and shock front, propagates over the skin surface and clears it of the particles sticking to it.
The PWT systems of the 1$^{st}$ generation operated on the principle of local wave impulses cleaning the surface within quite limited areas of the impulse plate's action, and were not very efficient in the peripheral zones.



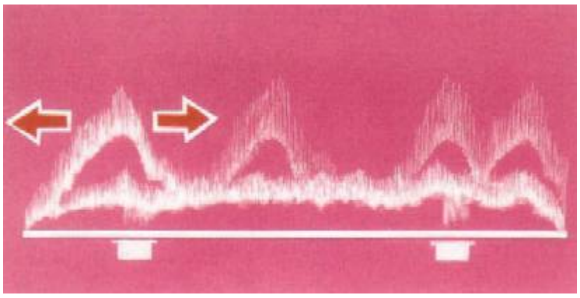
F 18: PWD EIDS 1st generation

In the PWT systems of the 2$^{nd}$ generation, widely used at present, the zone of action has significantly increased. This is due to the formation of wave contour made by two or more impulse plates. There is a more uniform wave spread over the surface, reducing significantly the power consumed.



F 19: PWD EIDS 2nd generation

The present development of the 3$^{rd}$ generation PWT system, where the wave contour is dynamically controllable, makes the process still more efficient.



F 20: PWD EIDS 3th generation

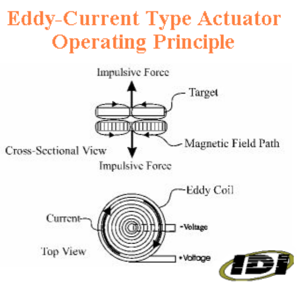
The basic aim of creating a new modified version of EIDS, the 3rd generation EIDS, was the desire to significantly expand the range of its application in aviation, including regional and light aircraft. Aircraft of these types are operated at much lower altitudes and are more frequently exposed to icing conditions.

However, the energy resources available and the take-off mass of such aircraft are limited. Therefore, the principal task when designing this system was to reduce its power consumption and weight. As a result of employment of the latest achievements in electronics and wave technology the new modified version, while preserving all the merits of the 2nd generation EIDS system, has the following advantages:

- Power consumption and the dimensions of the pulse generating unit and inductor were significantly decreased. Their performance parameters were improved, their efficiency increased.
- Small dimensions of the pulse-generating unit made it possible to install it in the thin wings near the surface to be protected against icing. This led to shortening of the length of electric wiring and low power consumption of the unit.
- Apart from the protection of the leading edges, the de-icing system can be used for ice removal on any aircraft surfaces, for example the helicopter fuselage during winter SAR operations. The system can also be used for rotor blades.
- Inspection takes minimum time and does not require special skilled labour.

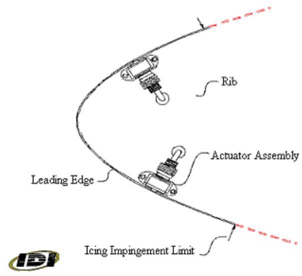
A $4^{th}$ generation is in study but there isn't information about it.

IDI system is quite similar to PWD, ISI EIDS is an acceleration based deicer for use on large aircraft, ship and bridge surfaces for general ice protection. The system was developed in collaboration with a NASA Glenn SBIR program. An electromagnetic coil is placed behind the surface skin that induces strong eddy currents in the metal surface. As a result, strong opposing forces are developed between the actuator coil and the metal skin. This results in a rapid acceleration that sheds and de-bonds ice into the air stream in a very efficient manner (ice layers can be shed as thin as .050").




F 21: EIDS IDI actuator

IDI's Icing Onset Sensor can be added to the basic system to provide an autonomous mode of operation. The IOS detects the initiation of ice accretion (icing onset) and continuously monitors the amount of accumulation. When the accumulation reaches a thickness threshold at which efficient clearing is possible, the sensor commands the deicer to fire. Because the sensor continuously monitors the accumulation, the sensor can determine if the ice was properly shed or if another clearing cycle is required. The sensor continues to monitor accretion and initiate de-icing cycles as required.



F 22: EIDS IDI actuator position

The Icing Onset Sensor is a thin film capacitive-based sensor that monitors airfoil icing. The sensor identifies two levels of icing conditions. A "Trace" light alerts the pilot when a trace of ice has formed on the airfoil. An "Ice" light warns that ice formation has grown to a thickness that can be verified by the pilot.

The system provides an indicator light test, a power-up self test, and a continuous built-in self-test to determine that the sensor element and detection circuits are working properly. The sensor element consists of a copper electrode pattern embedded in a polyimide laminate. This laminate is bonded to the host airfoil.

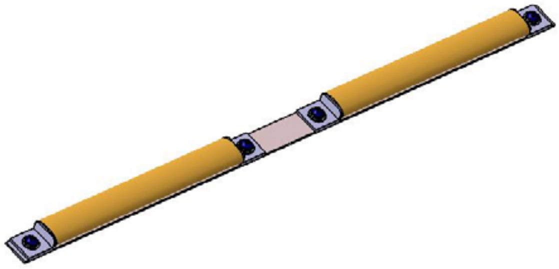
A small electric field is set up on the exposed surface of the sensor. The presence of ice on the sensor surface alters the field characteristics which are monitored by the sensor electrodes. The sensing region measures 1.5 inches chord-wise x 4.5 inches span-wise. In custom applications these dimensions are tailored in accordance with the leading edge curvature, angles of attack, and icing prone region.

The electronics package contains the circuitry that monitors and interprets the electric field signals. The 4 x 7 x 2 inch electronics package can be located remotely from the sensor element and is connected to the sensor element via small coaxial cables.

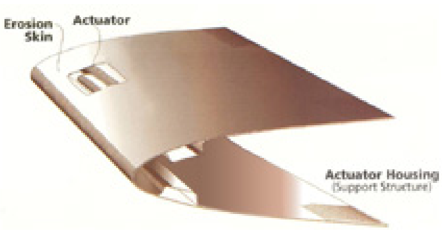
EMEDS

The principal company that produce EMEDS systems is COX. It design different systemss for respond to different request from the market. The standard EMEDS system is a typical de-icing that needs a thin layer of ice for work properly, the hybrid system and its evolution TMEDS, is placed in the middle between a de-ice and a anti-protection.

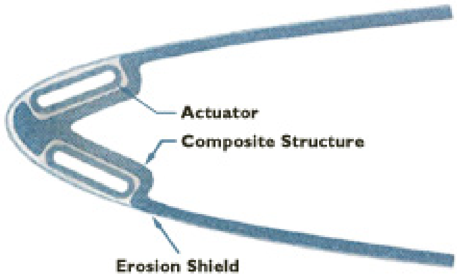
As presently configured, EMEDS consists of a Deicing Control Unit (DCU), an Energy Storage Bank (ESB) that contains capacitors, and the electromechanical actuators. An EMEDS actuator measures approximately 15” in length and consists of copper strips coiled into a tubular form with an elliptical cross section.


F 23: EMEDS COX actuator

The DCU charges the ESB's and controls the sequencing of actuator firings in a prescribed order, rate, and deicing cycle time. When an electrical charge is released from an ESB to an actuator, a magnetic field forces the actuator cross-section to change shape rapidly from elliptical to near circular. Because of its proximity to the inside of the aircraft skin, this action imparts a force that results in high acceleration, and low deflection of the aircraft skin. Subsequently, the accreted ice is shattered and removed.
Two rows of actuators are typically installed beneath the skin in rigid channels, and local actuators are fired alternately between the upper and lower surfaces.



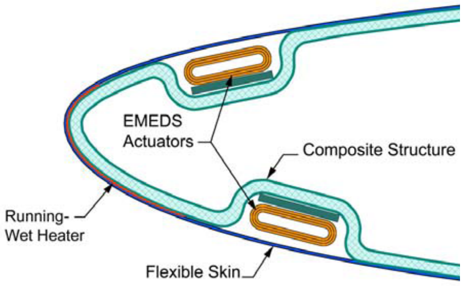
F 24: EMEDS COX actuator position



F 25: EMEDS COX actuator position

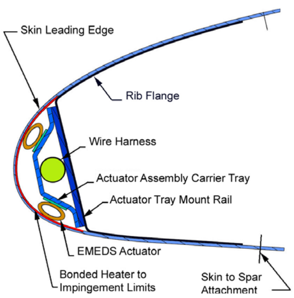
Energy discharged from the ESB each time an actuator is fired is about 45 joules (550 volts and 300μF capacitance). Power consumption can be less than 500 Watts for an entire aircraft. The skin accelerates and deflects approximately 0.025" to 0.040" in less than 0.005 sec. Typically, ice as thin as 0.060" can be shed.
The hybrid ice protection system was developed to provide an economical alternative to conventional anti-icing systems on roughness sensitive airfoils where high power is either impractical or unavailable 6,7. It consists of a thermal subsystem operating in a running-wet mode that partially or fully covers a roughness sensitive zone located within the impingement zone at the leading edge, and a low power deicing subsystem just downstream. The thermal system maintains a clean leading edge in the roughness sensitive zone by preventing the impinging supercooled water droplets from freezing. Minimal power is used because the surface temperature is held just above freezing. The goal is not to evaporate the impinging water since, in which case, substantially power is required due to the high latent heat of vaporization.
The water runs downstream beyond the heated zone and freezes there. This is the location at which EMEDS actuators are installed beneath the skin. Periodic actuation at these locations removes the frozen runback ice. The size of the accumulation is controlled by the frequency of actuation. Shorter deicing cycle times produce smaller accumulations. It should be noted that the LPDI requires some minimum ice thickness, typically of the order of 0.060" to properly deice the surface. Consequently, residual and inter-cycle ice will always exist at these downstream locations. However, because

EMEDS can remove small ice thicknesses without the creation of water, the possibility of downstream ice ridge formation is eliminated. One significant advantage is that no time limit is imposed on the aircraft's exposure to an icing environment since no ice ridge forms.

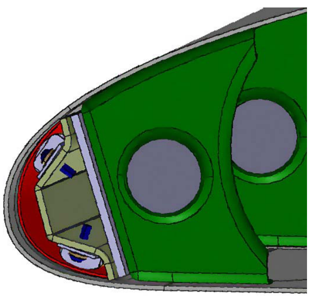


F 26: Hybrid system, COX, scheme

TMEDS use a strategic combination of electro-thermal and EMEDS deicing in much the same manner as the hybrid running-wet anti-icing system described earlier. However, instead of operating the heater continuously as a running-wet anti-icer, a very thin layer of ice is allowed to form within the direct impingement zone before it is removed by a coordinated sequencing of the thermal and EMEDS sub-systems. The result is a system that provides an ice protection system optimized for power and tailored to the allowable levels of ice accretion over the leading edge of the surface. TMEDS operates with substantially less power than an evaporative anti-icing system (hot air or electro-thermal), and also operates at significantly lower power than an electro-thermal de-icing system. This is because TMEDS eliminates the continuously operating parting strip along the entire span of a protected wing or tail. TMEDS also provides an improved level of surface cleanliness over that which is provided by conventional expulsive systems. As is the case of the anti-icing hybrid system, TMEDS also prevents the buildup of runback ice ridges, thereby allowing very long and unrestricted exposure to icing.
A heater is vulcanized directly to the non-breeze side of the leading edge skin. Generally, the extent of the heater covers the entire direct impingement zone. In some specific cases, the heater can be limited to regions of sensitivity for which adequate protection cannot be provided by the use of EMEDS alone. Alternatively, the heater can cover the stagnation region and the upper surface impingement zone, while protection of the lower surface could be accomplished by the use of EMEDS only.
In this construction, the EMEDS actuators are contained in a tray assembly mounted to chordwise ribs that are set back from the LE area to be protected. The composite substructure of the anti-icing hybrid system configuration could also be used.



F 27: TMEDS scheme


F 28: TMEDS scheme

Glycol

This system is mainly produced by TKS. It has the major advantage of providing anti--ice capability, as opposed to de-ice. The end result is an ice protection system that keeps ice off of the aircraft, maintaining aircraft performance in the icing environment.
The TKS ice protection method is based upon the freezing point depressant concept. An antifreeze solution is pumped from panels mounted on the leading edges of the wings, horizontal and vertical stabilizers. The solution mixes with the super-cooled water in the cloud, depresses its freezing point, and allows the mixture to flow off of the aircraft without freezing.
The system is designed to anti-ice, but it is also capable of de-icing an aircraft as well. When ice has accumulated on the leading edges, the antifreeze solution will chemically break down the bond between the ice and airframe, allowing the aerodynamic forces on the ice to carry it away. This capability allows the system to clear the airframe of accumulated ice before transitioning to anti-ice protection.
A valuable side effect of TKS ice protection is the reduction of runback icing on the wings and tail. Once fluid departs the panel on the leading edge of the surface, it flows aft over the upper and lower surfaces and departs the aircraft at the trailing edge. This runback effect keeps ice accumulation in check aft of the panels, from runback or from impact of larger water droplets. This side effect is a positive benefit in today's environment of concern for ice protection during large droplet encounters.
Fluid ice protection started in the 1930's as companies experimented with methods of introducing de-icing fluid at the leading edges of wings. TKS Ice Protection Systems were developed during World War II, as an ice protection measure compatible with armored leading edges. This compatibility was needed for aircraft to deal with the barrage balloon threat. With an armored leading edge, a balloon cable could strike the leading edge of the wing, slide down to an explosive cable cutter, and be severed. A rubber boot on the leading edge was not acceptable, allowing the cable to snag the leading edge of the wing and tear it off of the aircraft.
The first TKS systems developed were a relatively crude, porous channel system. Three sides of the channel or tube were solid, with the fourth side made from porous, powdered metal. These strips were placed on the leading edges of the wings and stabilizers as a mechanism to pump glycol solution onto those surfaces. Multiple strips were applied for more fluid coverage of the leading edges.
The concept evolved through the 50's, when the first stainless steel panels were developed. Panel porosity was achieved by using material formed from stainless steel mesh. In the early 80's, laser-drilled panels were developed.
Ice protection with a TKS system is achieved by mounting laser- drilled titanium panels to the leading edges of the wings, horizontal and vertical stabilizers. Secondary fairings or structures such as wing lift struts can be protected in a similar manner. Propellers are protected with fluid slinger rings, and windshields are provided with spraybars.
The outer skin of the ice protection panels are manufactured with titanium, typically 0.7 to 0.9mm thick. Titanium provides excellent strength, durability, light weight, and corrosion resistance. The panel skin is perforated by laser drilling holes, 0.0025 inches in diameter, 800 per square inch. The porous area of the titanium panels is designed to cover the stagnation point travel on the appropriate leading edge over a normal operatin g environment. This range is typically from best rate of climb at the low end to $V_{NO}$, maximum structural cruising speed. Conservative margins are added to this range.
The back plate of a typical panel is manufactured with stainless steel or titanium. It is formed to create a reservoir for the ice protection fluid, allowing fluid supply to the en-

tire porous area. a porous membrane between the outer skin and the reservoir assure even flow and distribution through the entire porous area of the panel.
The porous panels can be bonded or attached as a cuff over a leading edge (typical in STC installations) or built in as the leading edge. Most high performance general aviation singles and twins utilize the cuff method. Panels are bonded to the airframe with a two part, flexible adhesive.
Fluid is supplied to the panels and propeller by a positive displacement, constant volume metering pump. The two-speed pump provides two flow rates to the panels and propeller. The low speed supplies fluid for the design point of anti-icing during a maximum continuous icing condition. The high speed doubles the flow rate for removing accumulated ice or providing ice protection for more severe conditions. Flow rates are designed for this level of performance, regardless of the certification basis for the system.
For systems that are not certified for flight into known icing, one metering pump is provided. For systems certified for flight into known icing, two pumps are installed for redundancy. The pumps are individually selectable. Fluid for the windshield spray bar system is provided by an on-demand gear pump. The spray bar may be activated as needed to clear forward vision through the windshield. Similar to the metering pump, one or two pumps are provided depending on the certification basis.
The fluid passes through a micro filter prior to distribution to the porous panels and propeller(s). The filter assures all contaminants are removed from the fluid and prevents panel blockage.
A system of nylon tubing carries the fluid to proportioning units typically located in the wings and tail of the aircraft. The proportioning units divide the flow into the volumetric requirements of each panel or device supplied through the unit. Each panel and device is fed again with nylon tubing.
Each system is provided with a fluid reservoir that ensures a minimum ice protection endurance when filled. All systems are designed for a minimum anti-ice endurance of 2.5 hours. The endurance can be increased dependent on available volume for the reservoir and weight constraints on the amount of carried fluid. For the high performance single, the design fluid quantity typically falls in a range of 6 to 7.8 gallons.
The system is operated and monitored through a control panel in the cockpit. All modes of operation and selection for the metering and windshield pumps are controlled through the panel. Coupled to a float sensor in the reservoir, the remaining quantity of fluid is displayed. The operational state of the system may also be monitored with the panel.
One very important aspect of TKS ice protection is its inherent low power consumption. Little demand is placed on the aircraft electrical system by the TKS system. A 28 volt TKS system will typically draw 1.5 Amps of current during normal operation. Complete airframe ice protection is provided for a fraction of the power consumption of a resistance heating device on the airframe.
The active element of any TKS system is the antifreeze solution. In most instances, three fluids have been approved for use in TKS systems certified in the United States, but one is typically used. This fluid is commonly known as AL-5, manufactured to the British specification DTD 406B.
DTD 406B is a relatively simple mixture consisting of 3 parts: 85% ethylene glycol, 5% isopropyl alcohol, and 10% de-ionized water by volume. The fluid weighs 9.2 pounds per gallon. Simple as it is, the fluid is well filtered before distribution to remove even

the smallest contaminants that could adversely affect the operation of a TKS system. The fluid is available from a number of manufacturers in the U.S. And is readily available at a number of fixed-base operators throughout the country.

Conclusion

The study of an ice protection system started with the decision on how much power is available on the plane and what is the maximum thickness of ice layer that the plane could tolerate.

The table 7 below summarised advantages and disadvantages of all different options currently available.

| | Advantages | Disadvantages |
|---|---|---|
| Anti-icing full evaporative | Clean leading edge | High amount of power required<br>Downstream runback is difficult to control and cannot be remove |
| Pneumatic De-Icers | Low power required | Minimum ice thickness<br>High maintenance costs |
| Low power electrical De-Icing | Low power required<br>Low maintenance required | Minimum ice thickness |
| Glycol | Low power required<br>anti-icing capacity | High weight for long fly<br>High maintenance costs |

T 7: comparison between ice protection system

These review conducted to two antithetic solution: a- full evaporative anti-icing and b- de-icing. The first permits to keep the leading edge clean, but use a huge amount of power. The second, instead, use a small amount of power but need a thin layer of ice in order to properly work.

COX Company studied an intermediate solution that use less power than a full evaporative anti-icing and permit to keep the leading edge clean. This solution, called *hybrid solution*, has two main disadvantages: it creates a downstream accumulation of ice and it uses more power than a de-icing system.

The choose between anti-icing and de-icing depend on the capability of the profile to work safe with a thin layer of ice and on the power available in the plan. Typical a turbo prop regional aircraft have a modest amount of available power, for this reason a de-icing system is preferred.

The pneumatic system is currently the most widely used because it is widely tested, but it have high maintenance costs. However the electrical solution have the same life cycle of the aircraft, but is used only in a few number of aircraft, only 2 of this certified under FAA.

The following table 8 considers an hypothetical application of the different systems on a ATR 72-500 aircraft by considering only wing and horizontal stabilizer protection.

| Type of de-icing | | Weight kg | Power kW | Minimum ice thickness [mm] |
|---|---|---|---|---|
| PWT | EIDS | 10 | 0.1 | 2 |
| COX | EMEDS | 27 | <1 | 1.52 |
| | Hybrid | 27 | 100 | 0[1] |
| | TMEDS | 27 | 22 | <1.27 |
| IDI | EIDS | 36.6 | 0.77 | 1.58 |
| | EIDS | 58 | 1.54 | 0.8 |

T8: Comparison between low power electrical de-icing, weight power required and ice thickness

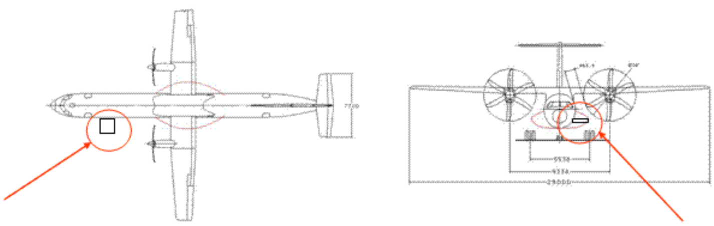
Using the available information the PWT system seems better than the other because in front of 0.5 mm more of minimum thickness it weight half and use 10% of power.
The most interesting system is the COX TMEDS. It have a good compromise between weight, power consumption and minimum ice thickness and some aircraft using it are near to certification under FAA.
Table 9 below compares the different options available in the current market.

| | | Advantages | Disadvantages |
|---|---|---|---|
| PWT | EIDS | Low weigh<br>Low power required | The study for employ on regional aircraft is just begun<br>High minimum ice thickness |
| COX | EMEDS | Low power required | High minimum ice thickness |
| | Hybrid | No minimum ice thickness on leading edge | High power required |
| | TMEDS | Low minimum ice thickness | At the moment no planes are certified with it |
| IDI | EIDS | Low minimum ice thickness<br>Low power required | High weight<br>Never been tested in flight.<br>Probably is not applicable to composite surfaces |

T 9: Comparison between low power electrical de-icing, advantages and disadvantages

<u>Fly demonstration</u>

The equipment will be release until the end of 2013. The flight demonstration includes the validation of both WIPS integration and performances. For safety reason the WIPS will be placed  in an external pod, as shown in fig. 29.



F 29: WIPS demo installation

1 0 mm on leading edge, 1.52 mm on profile

# 7. All Electric Aircraft requirements & architectures - WP3.1

## 7.1. Introduction

The first step of the AEA is the definition of the requirement and the architecture. For the purpose of this study is important to clearly define: requirement and architecture of system and demonstrator, together with the preparation and delivery of a *verification and validation plan* for energy management demonstration.
Under the WP3, the first sub level (Task 1 from now on) includes the analysis of all the on board systems relevant to the AEA and the systems affected by Energy Management. Specifically for each system will be define

- performance,
- architectures,
- integration,
- installation,
- certification.

## 7.2. Objectives

Task 1 has three main objectives:

1. hight level requirements for system;
2. integration requirements for system;
3. demonstration requirements and architecture.

This requirements influence all the development of the AEA configuration.
The collection, analysis and review of the aircraft level requirements for each on board systems and subsystems relevant to the AEA will be completed After that and using these requirements, the configuration and detail design requirements definition will be preliminary performed. With regard to the Energy Management demonstration, the main objective is a preliminary definition of the follows: a- aircraft level requirements, b- systems performance, architectures, installation, c- certification requirements. A third activity will assess the overall V&V plan for Energy Management demonstration into GRA.
Task 1 is organised as follow:

- WP3.1.1 Hight level requirements for systems (timeframe: September 2008 / May 2009)

  The main output is the Design Requirements and Objectives (DR&O) for the systems relevant for the AEA. The DR&O are based on AEA assumption for green aircraft definition, they are provided for four different reference aircraft configuration: 90 pax turboprop low and high speed, 130 pax turbofan and open rotor, taking into account the aircraft characteristics and top level aircraft requirements. The DR&O are provided for aircraft general systems, no avionic systems, and limited to those ones affected by the AEA design concept. All functional system requirements non affected by Energy Management/AEA issues are considered in principle non modified compared to the current offer.

- WP3.1.2 Integration requirements for systems (timeframe: April 2009 / foreseen in June 2010)

  The output will be the integration requirements for the on board systems and sub-systems relevant to the AEA. The requirements have to include architecture, performance, installation, functional, qualification and certification; the output will result from two in-parallel activities assessing the installation/integration and qualification/certification requirements, respectively.

- WP3.1.3 Demonstration requirements and architecture (timeframe: July 2009 / foreseen October 2010)

  The purpose is to define the aircraft and system level requirements for demonstration. The requirement have to comprise architecture, performance, installation, functional, qualification and certification suitable to demonstration solution. Two parallel activities will be performed assessing both the aircraft and the system/sub-system level. A third activity will assess the overall V&V plan for Energy Management demonstration into GRA.

## 7.3. WP 3.1.3 Demonstration Requirements and Architectures

### 7.3.1. Introduction

The WP 3.1.3 started in October 2009, with 3 month of delay.
This sub level of Task 1 deals with the demonstration and aims to define the requirements and architectures of the system/subsystem level and aircraft and to assess the overall verification and validation plan.

### 7.3.2. Objectives:

The overall objective of this sub level is to fully define the requirements of the demonstration both in aircraft and system level. This sub level also includes the preparation of the verification and validation plan.
The tangible output of the sub level consist in the preparation of three documents:

D3.1.3-01 – Aircraft level requirements for demonstration;
D3.1.3-02 – System level requirements for demonstration;
D3.1.3-03 – V&V plan for energy management in GRA.

Those documents have to include:

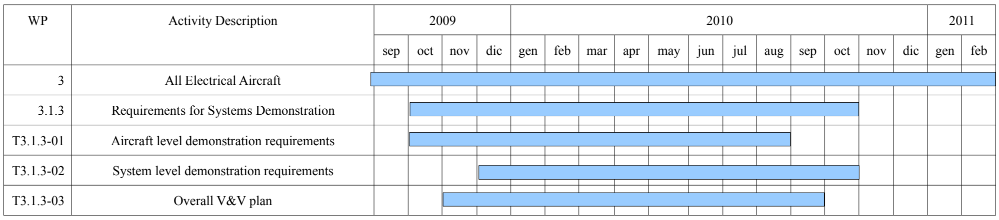
- a preliminary definition of the aircraft level requirements for Energy Management demonstration;
- a preliminary definition of requirement for on-board systems affected by Energy Management when actually tested in the demonstration either on ground and in flight;
- a preliminary assessment of the overall verification and validation plan for Energy Management demonstration into GRA.

Such requirements will comprise architectures, functional and performance, installation, qualification and permit to flight constraints applicable to demonstration solutions.

### 7.3.3. Tasks

The sub level is organised in three tasks, a detailed workplan is showed in fig. 10:

- T3.1.3-01 Aircraft level demonstration requirements
  (timeframe: October 2009 / foreseen August 2010) The task has as purpose to define the aircraft level requirements for Energy Management demonstration.
- T3.1.3-02 System level demonstration requirements
  (timeframe: December 2009 / foreseen October 2010) The task has as purpose to define the systems performance, architectures, installation and certification requirements for Energy Management Demonstration.
- T3.1.3-03 Overall Verification and Validation plan
  (timeframe: November 2009 / foreseen September 2010) The task has as purpose to assess the overall verification and validation plan for Energy Management demonstration into GRA.




T 10: WP3.1.3 updated planning

# 8. Task 3.1.3-01 Aircraft Level requirements for demonstration

### 8.1.1. <u>Introduction</u>

T3.1.3-01 defines the aircraft level requirements for demonstration. The requirements have to include: architecture, performance, installation, functional, certification, and qualification. This task as as source of information both the System for Green Operation ITD and other sub level (WP3.1.1 and 3.1.2).
ATR is involved in this task due to the choice of the ATR 72-500 prototype as testing aircraft. As described above, the ATR 72-500 is currently the most diffused regional aircraft; this justifies the choice of this aircraft as testing plane in the Clean Sky.
The demonstrations of AEA systems will be performed both in flight and on ground. During these tests all ATR's internal procedures should be followed.

## 8.2. Objectives

One of the main objectives of the task is to identify the best way to test the new architecture in flight and on ground. The findings of this research activity will be collected in a review that will be shared with all the project partner.
More specifically, ATR has to provide the following relevant existing requirements documents:

- Certification Basis and requirements
- General Environmental requirement for equipment
- EMI/EMC Requirements
- General Technical Requirement
- Electrical Power Requirements
- Configuration Control Document

Meaning with requirements:

- architecture;
- performance;
- installation;
- functional;
- qualification;
- certification.

## 8.3. Configuration Management Process

### 8.3.1. Introduction

The following paragraphs describe the overall procedure needed to apply the AEA architecture on the ATR prototype by opening an experimental modification.
An experimental modification allow ATR to obtain from EASA the permit to fly of the non certified aircraft in order to perform the in-fly test. All the modification of the aircraft must be removed at the end of the test.

### 8.3.2. Definition of *Modification*

Any change affecting a technical definition has to be considered a *Modification*. A document describing the change is associated to each *Modification*, including the threefold meaning of :

- technical modification - aiming to describe the technical content of the change;
- administrative modification - intended to manage the aircraft configuration, to provide the definition, accounting and traceability of the aircraft configuration and to show the evolutions of the program. It also authorizes the execution of the Design Office and Production activities (economical tool);
- legal modification - used to approve minor changes and repairs under DOA privileges and to submit major change to the airworthiness authorities in order to obtain their approval of the change to be embodied on aircraft.

The raising of a Modification Proposal (MP) controls the introduction of a modification. More than one MP can be included in one modification. All the MPs included in a modification will be identified and recorded in the modification database (RAMCS - BDRM) and the MP opening a modification shall never be included in another modification.

### 8.3.3. Experimental Modification

The sub category gathering the experimental modifications includes modification that intend to install, and later remove, any equipment/instrumentation required during the in-flight-test phase of a given aircraft.
Experimental modifications are numbered in a specific sequence (09xxx). They never are part of the delivery configuration of the A/C, and therefore they are not subject to Airworthiness Authorities approval; they are instead subject to Flight Conditions with Permit to Fly[i].
Any change to the standard definition needing for an experimental installations that cannot be removed from the aircraft, shall be covered by a specific modification "Provision for and/or Refurbishing".

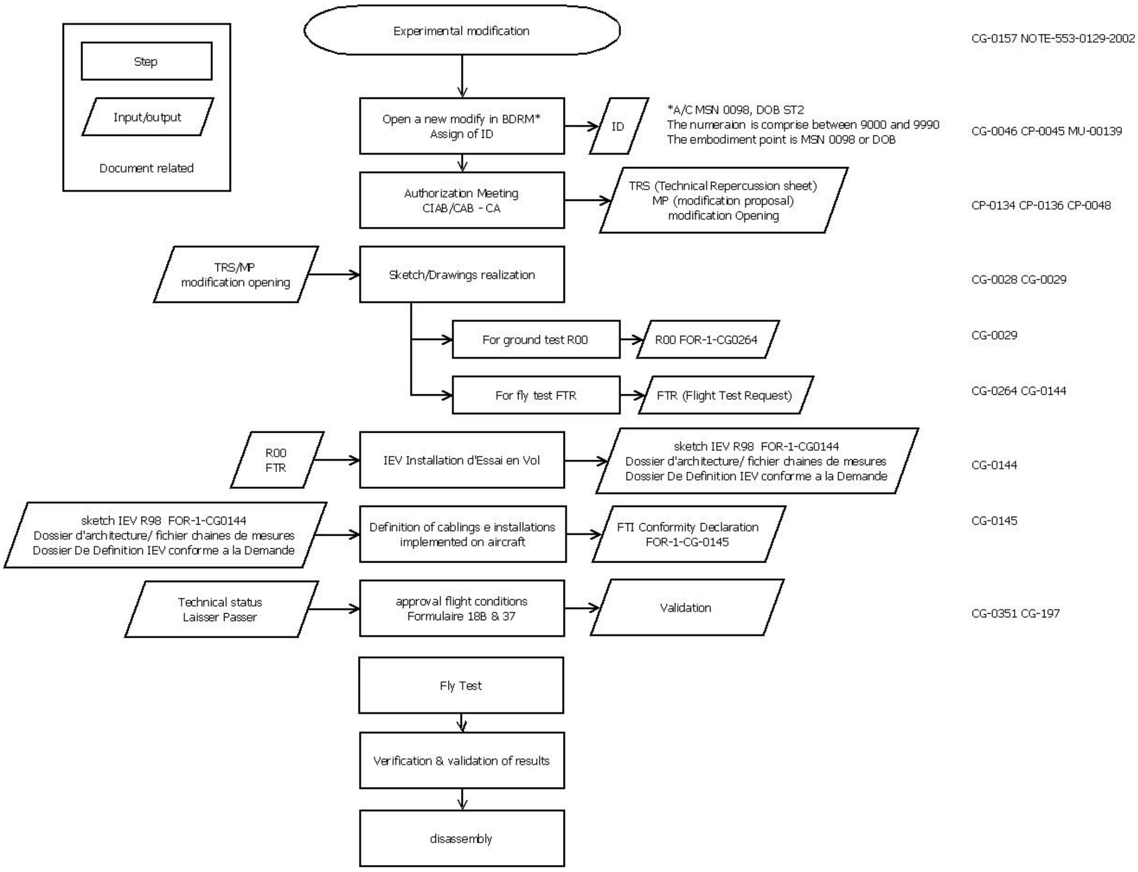
### 8.3.4. Role of modification leader

Every MP is assigned to a Modification Leader. The ML takes responsibility for the technical definition of the whole Technical Repercussion Sheet and for the detail design and drawing work.

The ML manages the full instruction of TRS with all the other specialists involved. The ML takes also the responsibility to check the whole TRS before closing on BDRM tool, on technical and “non recurring costs” as well.
The ML propose the modification classification as well (major or minor). In accordance with Part 21 section A and applicable GM/ACM criteria, a minor modification is one that has no appreciable effect on the mass, balance, structural strength, reliability, operational characteristics, noise, fuel venting, exhaust emission or other characteristics affecting the airworthiness of the product. A modification is classified as major when one or more of the criteria described in applicable regulation mentioned above are met.
Before starting the modification approval process the classification proposed by the Modification Leader will be confirmed by ATR Office of Certification & Airworthiness.
The ML issued the modification planning with ATR Office of Certification & Airworthiness , considering the certification target, the SB planning, the impacted regulations and MoC, the contingent modification of approved operational documents, the contingent equipment qualification, the commercial constraints, and the associated modification approval.

## 8.4. ATR Modification Procedure

### 8.4.1. Flow chart.



F 30: Modification Procedure, Flow chart

### 8.4.2. Opening of a modification

a. Preamble

The control of the instruction and the decision of the modification is implemented through the following actions:

- analysis of the request and decision to continue the instruction,
- creation the dossier (technical, industrial, economic),
- check of the dossier,
- launch of a feasibility study,
- opening the modification.

b. Analysis and creation ID

Upon receipt of the application, the DO/TM/T/C:

- Analyse the dossier and request additional information
- Create the ID in the software tool BDRM

Note: All IDs cannot be created without justification and without prior notice DO/TM/T/C for the GRA/AEA Modification CIAB committee opened ID 10005456 to cover all the modification.

c. Writing and control of MP and TRS

The electronic management tool BDRM used to create and maintain dossier PM and dossier FRT is a tool imported from Airbus France. Its use is widely described in manual referenced: MU-00139. This tool manages all information relating to an a modification proposal, from its initialization to the diffusion of the dossier.

d. Commissions for Modifications CIAB and CAB

Any change request is presented in Commissions for Modifications CIAB. This committee meets monthly and decides about the following actions:

- agreement for technical and economic instruction,
- agreement for opening,
- refusal, presentation in CAB or another decision.

e. Commissions d'affectations CA

All the Modifications that CIAB has authorised are presented in *Commissions d'affectations* for:

- confirm or define the target delay of end of instruction,
- confirm or define the embodiment point,
- follow the progress of the activities related to the instruction of the amendments,
- follow the progress of the activities related to the industrialisation and the certification of the amendments in progress

f. Opening of a Modification

After agreement for opening, service DO/TM/T/C:

- make sure that the technical file is enclosed by the person in charge,
- performs a second reading of the dossier and convenes the specialists if required,
- launches “feasibility” in order to define the embodiment points,
- number the modification via the “LGM”,
- assign the embodiment point to the amendment in IT tools “RAMCS”,

### 8.4.3. Writing sketches for experimental modification

For each experimental modification two kind of sketches have to be used: R00/xxxx for the modification and R29 for the experimental equipments.

a. Responsibilities of the sketch's author

The author is responsible for the technical content of the sketch as well as of the filing of the original of the sketch.

It belongs to him to define the conditions of annulment of the sketch, in particular:

- if it is a test configuration,
- if the sketch must be cancelled by a modification.
- if the request only concerns of the ground tests without modification of the A/C.

The author also manages the codes equipment items, in particular the change of the codes known as “50” (50 to 89: the last 2 digits of the CMS used for all the changes to test, compared to the CMS of origin).

b. Responsibilities of MAP BE

The manager of the MAP BE ensures:

- the validity of the modification bring to R00 by the author, for the A/C concerned,
- the right use of the sever of numbers used by the authors (not of redundancy of numbers in particular),
- the passage to the correct index of the sketches,
- the availability of the selected A/C in order to test this definition,
- the correct validation of the change mentioned for this sketch for the A/C chosen,

#### 8.4.4. Development test

a. Definition and operating envelope of ground or in-flight tests

Any ATR engineering specialist could ask for ground or in-flight tests, in the framework of the approval of a modification. These tests are call *Development Test*.

b. Ground and In-flight Test

The needed sketch for a ground test is the R00, the GTR is instead used only for certify a ground test.

The request for an in-flight-test is forwarded through a FTR[ii] form. This form has to be fill in every time a specialist design office needs either to perform a in-flight test (with or without test installation) or to simply mount a flight test installation on an A/C, even if it will not perform an in-flight test (case of the fix point or taxiing).

After the responsible person signed the FTR having check its technical contents, the form is transmitted to the MAP - IEV (DO/TM/TP).

c. MAP-IEV

The MAP - IEV is in charge of of:

- define the MSN of the aircraft which will be selected for the test,
- analyse the requirements out of specific equipment FTI (Test Flight Instruments) and to trigger the actions required to set up these means[iii],
- coordinate the commercial quotation and the availability of these equipment items,
- gather the documents necessary to the achievement of the test and to list them.

The MAP - IEV validates the FTR by signing it.

d. Drafting of “Design Flight Clearance”

For each request of an in-flight-test, a *Design flight clearance*[iv] has to be issued by the MAP – IEV. This document includes:

- a compliance statement of the aircraft compared to the definition dossier, by DO/Q,
- all the possible limitations associated with the aircraft configuration,
- the compliance of the aircraft for the ground or flight tests, by DO/T,
- the adoption without changes by DO/TV for flight test,

- the flight generic or specific conditions valid for aircraft[v].

If needed, a printed paper form *limitations* will be attached to the DFC. It belongs to the MAP - IEV to ensure that all the Engineering specialists concerned took part in the drafting of this document.
The reference of the flight approved conditions will figure on the DFC and will allow the delivery of a *laisser passer*[vi]

e. <u>In-flight-test installation</u>

The definition of in-flight-test installations is distributed following the structure below:

- measurement systems, sensors, measurement equipment items, recorders and, more generally, all systems independent from the A/C
  - engineering ATR (MAP - IEV, flight tests and specialists systems) which leads to the establishment of one or more sketch R98 or subcontracting with a qualified service provider IEV.
- pricking on the normal installation, furnishing of the cabinets and systems interfaces with of them the structure or the systems of the A/C
  - engineering ATR (MAP - IEV and specialists systems) which leads to the establishment of one or more R98 sketch

f. <u>Preparation of the flight</u>

The organisation of the flights is described in the FOM[vii]. This concerns, in particular, the choice of the crews, the classification of the flights, the flight procedures and the meteorological conditions minimal.

g. <u>Analyses and acceptance of the test results</u>

The results of the in-flight tests are the subject of a report crew or *Flight Crew Report*[viii]; this report is disseminated towards the authors of the FTR.
Moreover in the case of analysis of parameters (starting from a FTI or of a recorder aircraft), the results are transmitted through a document, the *Test Flight Result and Analysis*.
In order to validate the results, the specialist could request a new test if the first one was not performed, entirely or partly, in accordance with his request (FTR).
He could also ask for a new analysis if the one provided after the test was not exploitable because it doesn't respect the dynamic and sampling (in the case of the digital acquisitions) described in the paragraph *Instrumentation requirements*.
The specialist transmits the results together with a justification note which confirms the acceptance of tests and results. This justification note is presented with the CVE system in order to attest the compliance with the applicable rules.

## 8.5. ATR Certification

### 8.5.1. <u>Policy</u>

All the modifications will be categorized as minor or major.
In accordance with Part 21 section A and applicable GM/ACM criteria and as described in aragraph 8.3.4. , a minor modification is one that has no appreciable effect on the mass, balance, structural strength, reliability, operational characteristics, noise, fuel

venting, exhaust emission or other characteristics affecting the airworthiness of the product. A modification is classified as major when one or more of the criteria described in applicable regulation mentioned above are met.
If the modification is classified as minor it could be certified under ATR DO/A responsibility, otherwise it must be certified under EASA responsibility.
In any case in order to perform an in-flight-test is needed a permit to fly from EASA that must comply with CS25 and DO160 requirements, both in their latest version.

### 8.5.2. Certification Plan

After a deep analysis on the contents of the MOD, a certification plan has to be prepared according to the Mean of Compliance; the plan should then be used for drawing the *Flight Condition Document*.
After analysis of the certification plan, EASA an ask for additional requirements on a *Certification Review Item*.
The final goal of this process is obtain from the authority the Permit to Fly
A completed plan will be done as soon as modification proposal will be send by Alenia. A first draft is show here, basing on the information actually known. This first draft could undergo many change according to the information received from Alenia.

a. Draft certification plan
- CS25-831(a)-(c) ventilation MC 1/4/5/6
- CS 25-899 electrical bonding MC 1/4
- CS 25-1301 function installation MC 1/4/5/6
- CS 25-1309 equipment installation MC 1/4/5/6
- CS 25-581/1316 lightning protection MC 1/4
- CS25-1351 general MC 1/4/5/6
- CS25-1353 electrical equipment installation MC 1/4/5/6
- CS25-1355 distribution system MC 1
- CS25-1357 circuit protective device MC 1/4/5/6
- CS25-1360 precautions against injuries MC 1/4/5/6
- CS25-1363 electrical system tests MC 1/4/5
- CS25-1419 ice protection MC 1/4/5/6
- CS25-1431 electronic equipment MC 1/4/5/6
- CS25-1519 weight MC 1/2/6/8

b. Means of Compliance, explanation
- MC0 engineering evaluation/design documents/Technical Notes
- MC1-2-3 design/analysis/calculation/SSA/TN
- MC4/9 validation laboratory tests/reports/qualification tests DO160(last version)/DDP/QTR
- MC5 Ground tests of a/c-GTR-tests program/test procedures/tests report
- MC6 Flight tests and reports/FTR+FTI
- MC 8 Simulation

In order to obtain the Permit to Fly the system on board must be design in accord with the CS. 25 regulation.
A certification plan shall be issued and a compliance matrix will support it.

## 8.6. Qualification

In order to obtain the permit to fly for an experimental modification the equipments don't need to comply with all the chapter of DO160, the chapter involved will be define, as soon as modification proposal will be sent by Alenia, from the ATR specialists.
This first draft containing all the chapter that could be interested by the modify, most of then will not be put in the final qualification plan.
a. Qualification Draft

- 4 Temperature and Altitude
- 5 Temperature Variation
- 6 Humidity
- 7 Operational Shocks and Crash Safety
- 8 Vibration
- 10 Waterproofness
- 11 Fluids Susceptibility
- 12 Sand and Dust
- 13 Fungus Resistance
- 14 Salt Fog
- 15 Magnetic Effect
- 16 Power Input
- 17 Voltage Spike
- 18 Audio Frequency Conducted Susceptibility – Power Inputs
- 19 Induced Signal Susceptibility
- 20 Radio Frequency Susceptibility (Radiated and Conducted)
- 21 Emission of Radio Frequency Energy
- 22 Lightning Direct Effects
- 25 Electrostatic Discharge
- 26 Fire, Flammability

The chapter interested could be different for the each component installed on the aircraft. A more detailed list will be made as soon as modification proposal will be sent by Alenia

### 8.6.1. EMI/EMC Requirements

For the EMI/EMC requirements the reference document is DO160, the chapter involve is Magnetic Effect, 15. If needed other chapter will be considered.

### 8.6.2. Electrical power quality requirements

The quality requirement for the Electrical power is described in the document D00S3224001C. For obtain the permit to fly all the requirements must be respected.

## 8.7. The way forward

In order to use an ATR prototype as in fly demonstrator inside AEA contest is necessary to follow the ATR experimental modification procedure.
This procedure do not exempt the equipment from the certification and the qualification

process. All the systems that will be installed on aircraft must be certified and qualified. The definition of a certification and qualification plan will be done as soon as modification proposal will be sent by Alenia.
When Alenia will specify all System modification and ATR will analyse the feasibility on the MSN098 A/C demonstrator, the emergency will be to freeze the certification plan and to present it to EASA in order to obtain the permit to fly.
The qualification plan will be in accordance with contains of the modification (major or minor), some test could be done by similarity whit a safety to flight.
If the modification will be classified as minor the process of qualification and certification could be treated in the normal ATR DO/A process. If otherwise it will be classified as major, a special EASA permission shall be obtained.
With the information currently available is not possible to classify the modification, as soon as the modification proposal will be sent by Alenia ATR CIAB committee classify the modification.
In both cases, modification Minor or Major, the permit to flight will be given only by EASA authorities.

# 9. Conclusion

The new systems developed under the *Clean Sky GRA AEA* introduce a new concept for the aeronautical design: *the ability to manage power consumption during all the phases of flight*.

In order to obtain the maximum advantage from the Electrical Management the electrical network must be designed using modular concept. This new design consisting on the use of electrical components, such as relays and termination device, for minimize the numbers of active parts. The major modification introduced by Clean Sky regarding the electrical generation system. For change the actual systems, that use hydraulic and pneumatic power, with the new systems, based on electrical power source, the electrical power generation must be boost. All the components of the EPGS must be redesign for limit increase of weight and size consequent to increase of power and limit the dispersion. The best solution for the electrical power generation is the 270 VDC, that is becomes a standard. The reasons of this choice are several: the reduction of weight through the removal of a power converter, the possibility for more generators to work in parallel, the easier network harmonic content management and a reduced complexity in cabling distribution. Moreover, because the requirements for GRA AEA for flight control demand fly by wire configuration for both primary and secondary systems, the emergency system must be designed for ensured controllability even if all engine failed.

All the systems not affected by the electrical management are, in this preliminary phase, maintained at the current condition. The company involved in the Clean Sky project are now developing the different systems for give to ATR more information about their characteristics and the implementation on the demonstrator. After it ATR will define the modifications as minor or major and, based on this, produce a more detailed certification and qualification pans for the fly test. The screening study about electrical low power ice protection system showed how the state of art of these systems could be a viable alternative for the pneumatic system in a more electric configuration. A bigger study should be performed in order to underline the main advantage and disadvantage of the different system.

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GRA WP3.1.3 launch meeting 14-10-09 presentation
MoM GRA ALA ATR 15-12-09 presentation / minutes
WP3 2° PMC meeting minutes /presentation
WP3 3° PMC meeting minutes /presentation
WP3.1.3 call conference 16-04-10
ATR Quality Manual
ATR Design Organisation Manual
ATR internal documentation

- CG-0062-FR(A.8)
- CP-0045-FR(A.9)
- FOR-1-CG-0062-EN(A.4)
- FOR-2-CG-0062-EN(A.6)
- FOR-3-CG-0062-EN(A.0)
- CG-0028-R03-000-A2
- CG-0062-FR(A.8)
- CG-0157-R03-000-A0
- CG-0351-R03-000-A0
- CP-0045-FR(A.9)
- CP-0134-FR(A.4)
- NOTE-553-0129-2002-EN(A.5)
- CG-0029-R03-000-A2
- CG-0144-FR(A.3)

- CG-0197-R03-000-A1
- CP-0048-R04-000-A4
- CP-0136-R04-000-A1
- MU-00139
- NOTE-851-085-2001-R09-000-A2
- CG-0046-FR(A.6)
- CG-0145-FR(A.3)
- CG-0264-FR(A.5)
- CP-0050-FR(A.6)
- NOTE-540-0404-2002-R09-000-A4

i Refer to CG-0351 and GC-0197
ii FOR-1-CG-0264
iii Refer to CG-0144 and CG-0145
iv FOR-4-CG-0264
v Refer to CG-0351
vi Refer to CG-0197
vii Refer to NOTE-851-085-2001
viii Refer to NOTE-851-058-2001