D5.2 Report Final Workshop

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Funding Scheme: Support Action
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<td>APU</td>
<td>Auxiliary Power Unit</td>
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<td>ATM</td>
<td>Air Traffic Management</td>
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<tr>
<td>CMS</td>
<td>Communication Management System</td>
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<td>CO2</td>
<td>Carbon dioxide</td>
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<td>CPDLC</td>
<td>Controller Pilot Data Link Communication</td>
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<td>DoW</td>
<td>Description of Work</td>
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<td>Flight Data Management / Monitoring</td>
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<td>(USA) Federal Aviation Authority</td>
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<td>FMS</td>
<td>Flight Management System</td>
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<td>IFE</td>
<td>In-Flight Entertainment</td>
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<td>HUMS</td>
<td>Health and Usage Monitoring System</td>
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<td>KERS</td>
<td>Kinetic Energy Retrieval System</td>
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<td>MTOW</td>
<td>Maximum Take-Off Weight</td>
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<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<td>RETROFIT</td>
<td>Reduced Emissions of TRansport aircraft Operations by Fleetwise Implementation of new Technology</td>
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<tr>
<td>ROI</td>
<td>Return On Investment</td>
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<tr>
<td>RTD</td>
<td>Research and Technology Development</td>
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<td>SESAR</td>
<td>Single European Sky ATM Research</td>
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<tr>
<td>TRL</td>
<td>Technology Readiness Level</td>
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1 Introduction

1.1 Context of the Retrofit Project

The RETROFIT project analyses the possibilities and attractiveness of retrofitting new technical solutions, which are being developed and which are available for new aircraft types, into the large existing fleet of commercial aircraft. A new generation of aircraft is only at the horizon. Existing aircraft still have a long life to serve, whereas the operational environment is changing. Airlines are confronted with emission trading, new noise rules, increasing fuel prices, new safety and security demands, and a new ATM environment where older aircraft generally do not comply with the new ATM standards without modifications, and passenger expectations to enjoy the highest levels of comfort possible.

The project first addressed the stakeholder requirements and investigated current and future technology options to retrofit into existing aircraft. Next, it addressed the need to perform additional research to make retrofits attractive as well as the question if specific research activities should be integrated in the EC framework programs. It addressed the certification issues related to retrofits and it investigated the industrial spin off. It also made a cost benefit analysis based on existing airline fleets and potential applications of new technical solutions. Finally, it assessed funding mechanisms for promising business cases. The results of the project will be widely disseminated. Promising cases can lead to a substantial economic activity in many European countries. Details on the project and the applied definition of “retrofit” are given in [D11].

1.2 Background

The European aeronautical industries and their supply chains, the research centres, and the universities are continuously developing, integrating and validating new technologies and processes in order to ensure industrial competitiveness answering the needs of its customers and of the European society. The aeronautical Research and Technology Development (RTD) mainly focuses on developments of technologies and processes that will finally be applied in new aircraft and engines or derivatives of existing aircraft and engines.

Aeronautical research and technology development is stimulated already for many years by the European Commission through Framework Programmes. The Transport Programme in the 7th Framework funds a large number of RTD projects addressing the need for more environmentally friendly, passenger friendly, and cost effective air transport, involving both small and targeted (i.e., level 1) projects and integrated (i.e., level 2) projects. In addition, the public-private joint technology initiatives Clean Sky and SESAR have started. Besides the European funded projects, national programmes in the EU Member States are also stimulating RTD of aeronautical technologies and processes.

However the development of new technologies and processes in RTD programmes is generally not focusing on retrofits. New technologies and processes are aimed at newly developed aircraft, whereas the fleet-wise application of these new technologies and processes through retrofits would allow obtaining societal and economic benefits earlier
and on a much larger scale, since a large portion of the future transport fleet will still consist of aircraft in service today.

The project, and in particular work package 5, is aimed at disseminating the information regarding the possible benefits of retrofit for Europe, by linking the benefits to European Union (EU) policy and identifying the possible roles that the European Commission (EC) together with the European Investment Bank (EIB) can fulfil. It is envisaged that EC and EIB will have a role in supporting and promoting retrofits in the form of facilitating earlier introduction of new technologies by financial stimulation.

The goals of the project are not limited to commercial interests and are expected to deliver many societal benefits by the reduction of CO₂ and other emissions as well as increasing safety.

1.3 Purpose of this document

This document contains the results of the project RETROFIT final workshop held at NLR in Amsterdam on February 14, 2012.

1.4 About this document

This document is a record of the day of the workshop and contains the comments and suggestions of the participants along with a definite list of participants.

1.5 Intended readership

This report was made under contract from the European Commission and serves to give recommendations on how to proceed on the topic of retrofits.
2 Workshop Report

2.1 Workshop at NLR facility

Coordinator of the RETROFIT project Martin Knegt welcomed all of the participants and thanked everyone for taking the time to attend.

Next, he provided a summary of the project dwelling on some of the highpoints and informing the workshop about the chronology of the project, from the initiation through to the request for extension submitted in September 2011 and honored by the EC.

The workshop proceeded with the following presentations by the various consortium partners:

1. Harry Tsahalis on “Investigation on Previous Retrofits”, about experience with previous retrofit programs, examples and criteria.

2. Erik Baalbergen on “Technology Inventory and Recommended RTD Topics”, followed by discussion on retrofit RTD topics recommended to the European Commission.

3. Dave Chilton on “RETROFIT possible future programs”, presenting a selection of potential retrofit technologies.

4. (intermezzo) Jan Vana from WheelTug about an onboard system that moves aircraft on the ground using electric motors, as an example of a retrofit for emission reduction.

5. Evert Jesse on “Cost-benefit studies”, analysing the cost / benefits of SESAR compatibility retrofits, Retrofitting existing A320 aircraft with GTF/nextgen Engines.

6. (intermezzo) Tom Milder from Fokker Services on “Modifications”, presenting examples in the areas of GNSS, seats, LED lighting, ADSB-out, and the iPad Class 2b electronic flight bag.

7. Ad de Graaff on “RTD funding and Technology take up”, discussing possible public funding support.

The workshop next continued with an open discussion on the three retrofit examples (used for the cost-benefit studies) and public funding, followed by the conclusions and round up.

2.2 Comments and Remarks during Q & A session

During the wrap up session at the end of the workshop the following comments and remarks were expressed by the participants:

- It is estimated that the retrofit market is now €1-2 billion.

- Have the top 5 technologies that were identified for RTD during the first workshop been considered in the course of the studies in the project?
  o Winglets
  o Biofuel for air transport
Fuel composition to reduce C content
Riblets in paint surface
New FMS and related systems

Of the abovementioned biofuel and fuel composition are not retrofit items as they do not entail any changes to the actual aeroplane, riblets in paint has a high TRL and is already being incorporated, and hence requires no RTD. The other two technologies were a part of the report on proposed future retrofit programs.

2.2.1 Wheeltug

- At what stage is the certification of the Wheeltug system?
  
  *In talks with FAA about certification since 2005 the expectation is fully certified in 2014.*

- System is leased for half of cost of savings that is agreed with them. 20-30 k$ per month.
- Has the workload for the pilot been analysed?
  
  *Yes; done as part of certification.*

- How do the cockpit controls work?
  
  *Similar to a cruise control in a car.*

- Is the power available from the APU sufficient?
  
  *95 kVA on APU 737/320 is available is more than sufficient.*

- Why has the RETROFIT consortium recommended RTD for main undercarriage?
  
  *The complications caused by the brakes, heat generated and the possible use of KERS technology RTD was considered by the consortium necessary.*

2.2.2 Engines

- In a presentation in the morning session it was shown that there have been successful engine retrofit projects in the past. Why were they successful then compared to now?
  
  *The costs related to the engines are now high and the relatively high write off costs of whole engines is high.*

- The workshop found that the total of 2000 tails for conversion/modification A320/B737 aircraft is low.
  
  *This is because the RETROFIT project only considered aircraft that were ten years old or younger.*

- One of the restricting factors for retrofitting on a huge scale is the availability of new engines and the cost of scaling up the production to meet (what is a one off action) the demand
- The timing of introduction of new engines is also important; companies would not do it just after overhaul.
- The workshop participants indicated that looking to improve existing engines by which 4-5% fuel saving may be possible and suggest investing RTD money because of the short time needed for implementation."

2.2.3 SESAR

- Air France was using EU subsidy to install Controller Pilot Data Link Communication (CPDLC), it suspended the implementation and paid back the subsidy as the ground equipment will not be available until 2019.
- The stand alone SESAR box is a non starter according to the financial institutions and the airlines are convinced it will not be possible due to the fact that many of the functionalities are embedded in the avionics suite.
- Cleansky/SESAR is regularly issuing calls for people having ideas. They are primarily focusing on new equipment. Some discussions on retrofits, but not addressed at the moment.
- SESAR has started to calculate the cost of retrofits but Cleansky does not address retrofits. OEMs look at future products rather than retrofits.
- Why is the SESAR group not represented at the Retrofit workshop? They were invited along with the Cleansky project but neither of them arrived at the workshop.

2.2.4 Winglets

- Why were winglets not considered for RTD by the consortium? It was considered to be only integration or engineering actions by the consortium.
- On the subject Winglets there is always RTD required in an effort to produce a more efficient one or more effective one.
- A330 winglet retrofit is an interesting action as there is reported load reduction and increased MTOW without changing the wing.
- It was suggested that you do not need to have the IP details of a wing to produce winglets.
Other workshop members insisted that there are analysis details that are required for development and the flutter analysis was given as an example.

2.2.5 Cabin

- In-Flight Entertainment and cabin refurbishment are carried out often by airlines, why was there no presentation in the workshop
- The Seats in the cabin are a source of much development; other aspects of cabin design deserve to be developed in a retrofit RTD proposal. One example is the star alliance modular cabin concept where members of the alliance use different configurations in the cabin.
Wireless internet technology is available but there is no common network available in Europe as opposed to the GoGo network in USA.

The workshop participants indicated that improvements in the cabin could be used for retrofit, i.e. use A350 cabin materials and apply to existing aircraft, whereas cabin are changed each 5-7 years and thus would present a good opportunity to apply these new materials.

If the retrofit is done only for the weight savings the cost will not be justifiable or deliver a return on investment, if the retrofit is planned for other functionalities, then you can use the extra weight savings as a bonus.

2.2.6 Maintenance

- What has a Health and Usage Monitoring System got to do with reduced emissions?
  
  By using advanced health monitoring systems, the integral weight of components can be reduced and that will reduce the emissions
  
- There are too few opportunities for retrofit that have a direct impact on maintenance even though the cost of maintenance is 2 or 3 times the initial purchase price of an aircraft.

2.2.7 Intellectual property

- IP, customer-driven (airlines-driven), resource and aircraft owners have to be involved.
- It was suggested that an OEM is not always needed as part of a retrofit consortium as long as you have access to source data (IP) from the OEM.
- OEMs are blocking improvements, many companies would be interested in developing retrofits, but need IP data, this is one of the biggest hurdles that blocks innovation in aeronautics.
- Glass Cockpit alternative fuels, have low TRLs
- Structures, air-ground communication have high TRLs for some applications.
3 Conclusions

The workshop commended the work done by the consortium and indicated that there was a need to further promote the whole retrofit culture.

It was felt that even though the work done was of a very high standard the choice of cost benefit analysis was not ideal as two of the three were high volume and high risk and the third was already engaged in creating good business by providing acceptable financial benefits for potential clients through a lease construction or a share of revenue generated.

In general the workshop considered that there was definitely a place for retrofit in the modern aviation market place but considered the relatively small PIP options as the most relevant in the present economic climate.

The equation of high volume retrofit programs being needed to produce a quick ROI was realistically described as a very high risk strategy and the consensus was that no individual company would be able to fund or provide enough security for a consortium and that the aircraft owners would not be willing to invest in high risk projects.

Intellectual property rights and the reluctance of OEMs to release the data to potential retrofit providers was seen as one of the major hindrances for independent providers with regards to retrofit.

The workshop expressed the view that there is reluctance by manufacturers (OEM) to divert resources into retrofit programs and are not prepared to divert them from the production capacity.
Appendix A – Workshop Agenda

Agenda
10.00 Welcome, coffee, Introductionary ‘Retrofit Speech’
10.30 Previous experience with retrofits: examples and criteria
10.50 Long list of technologies and likely topics for RTD, discussion on retrofit RTD topics for EC recommendation
11.35 Selection of potential retrofit Technologies
11.45 Wheeltug: retrofits for Emission reduction
12.00 lunch
13.00 Cost benefit analysis
   - Electric Taxiing
   - ‘SESAR’ retrofits
   - Fleet Re-engining
13.45 Fokker Services: Modifications
13.55 Possible public funding support
14.15 Discussion on the 3 examples and public funding
15.00 Round up, conclusions and recommendations
15.30 End of workshop
## Appendix B – Workshop Participants

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## Appendix C – Workshop Attendees Signature List

**RETROFIT**

**Final Workshop**

NLR - Amsterdam 14 Feb 2012

**Attendees List**

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# Attendees List

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Seventh Framework Programme
Grant Agreement No. 265867

Page 2 of 2
Appendix D – Presentations
**RETROFIT - Introduction**

Reduced Emissions of Transport Aircraft Operations by Fleetwise Implementation of new Technology

**RETROFIT Final Workshop**

Martin Krügel
Fachverband Flugwesen

Seventh Framework Programme
Grant Agreement No. 214587

**History and project review**

**2009**

- The Dutch Ministry of Economic Affairs invites the aerospace industry to draft a proposal for a research project under the 7th Framework Programme of the EC.
- Several members of the Dutch aerospace industry joined forces to work out a proposal called RETROFIT.
- Two members from other EU-states joined the consortium.

**2010**

- Jan 2010: the RETROFIT initial proposal was submitted to the EC.
- Oct 2010: the final RETROFIT Grant agreement was submitted to the EC.
- Nov 2010: the EC accepted the RETROFIT project and agreed on the budget.
- The RETROFIT consortium joined for a kick-off meeting.
- Establishment of Project Leader (Erich Koepp, DLR Services).

**Introduction**

**Definition of Retrofit**

To change the design of the construction, or to include, modify or substitute parts or equipment of aircraft already in operation, in order to incorporate improvements that were not existing, available or used at the time of original manufacture.

**RETROFIT**

**History and project review**

**2011**

- Execution of Work Packages by the consortium members
  - Issue of deliverables
- July 2011: Change of EC Project Officer
- Sep 2011: Consortium requests 4 months project extension
  - Data collection from third parties took more time than expected
  - Long list of potential technologies longer than anticipated
  - Processing of data for the final workshop and availability of stakeholders
- Oct 2011:
  - Amendment of Grant Agreement accepted by EC
  - Installation of new Project Leader, Aksel Mønsted (Falkirk Services)

**2012**

- Final Workshop
- Final report: dissemination of results and project accountability
Scope

- Project duration: 1 Year (initial planning)
  - Start: Nov 2010
  - End: Oct 2011 (initial planning)
  - Feb 2012 (revised planning)
- Project Coordination: Fokker Services
  - Project Leader
    - Emile Knoon (Nov 2010 – Oct 2011)
    - Aude Nouveau (Oct 2011 – Feb 2012)
  - Martin Knott – Coordinator
  - Peggy Favier / Benjamin Questier – Project management support
- 6 Work Packages

Work Packages

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Consortium

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Today's workshop

- Share project results with stakeholders
  - Recommendations on potential Retrofits
  - Cost benefit analysis for Retrofit technologies
- The need of EU support to facilitate Retrofit action
  - EU incentives for Retrofit
  - Funding mechanisms
- Collect the stakeholder opinions
  - Project results based on their experience
  - Formulate a common view on next steps to realize European Retrofit action for Emission reduction

Chatham House rules apply to stimulate an open discussion.
**Retrofit**

- **Scope**
  - Project duration: 1 Year (initial planning)
    - Start: Nov 2010
    - End: Oct 2011 (initial planning)
    - Feb 2012 (revised planning)
  - Project Coordination: Fokker Services
    - Project Leader
      - Emilie Krioss (Nov 2010 – Oct 2011)
      - Aude Nouvires (Oct 2011 – Feb 2012)
    - Martin Krug – Coordinator
    - Peggy Favier / Benjamin Questier – Project management support
  - 6 Work Packages

- **Consortium**

- **Work Packages**

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*Chatham House rules apply to stimulate an open discussion*
Engines: Re-Engining & Engine Upgrades

- Such programmes (but mainly engine upgrades) have and are applied to a range of aircraft of varying production status and/or age: such as: B787, DC-8, DC-10, MD-80 / MD-90, B737, A320, A340.
- Engine upgrades, developed in the form of Performance Improvement Packages (PIP), are applicable also to new engine developments (e.g., R-R Trent for B787, GE GE90 for B777, GE747-8).
- Findings into previous and current re-engining and Engine upgrade programmes for turbo-fan powered aircraft include CFM series engines, IAE series engines, Pratt and Whitney series engines, Rolls-Royce series engines, and General Electric series engines.
- Findings into previous or available programmes applicable to turbo-prop powered aircraft include the Dornier 228 NG, Fokker 50, Saab 2000, Embraer E120, Bombardier CL series, either through development of improved propeller designs and/or improved derivatives of older turboprop engines.

Airframe: Improvement Packages

- Short Field Performance (SFP) and Performance (PIP) Packages for the Boeing B777.
- Development programmed by Boeing back in 2006 by customer request.
- Allow access of B777 to B787 to exports with runways 4000 ft.
- Differences length with received permission.
- Dorsal fin alone (conical)
- Increased area of lift of the wing (measured approach speed reduction)
- Sealed in leading edge slot (provided increased lift during takeoff)
- Increased flight quality deflection of the ground (improvement of takeoff and landing performance).

Airframe: Performance Improvements

- Survey and findings include modifications, upgrades (available as Performance Improvement Packages) and other solutions applicable to the exterior of aircraft or changes to aircraft that may require subsequent revisions to aircraft exterior elements, covering items such as structures, components, and/or add-on solutions.
- Most cases address improvements of aerodynamic performance, hence benefits may include reductions in fuel burn and emissions, increase in operational range and MTOM, or even enabling aircraft operation to less accessible airports.
- Findings also include singular non-aerodynamic related improvements.
- Further than current improvements and programme applied to contemporary in-production aircraft, findings include programmes developed specifically to extend the life of out-of-production aircraft.

Airframe: Improvement Packages

- Super88 DC-9, MD-80, MD-90 and B717 Improvement Packages.
- Reduced drag due to modified wing leading edge configurations
- Enhanced fuel savings due to modified wing leading edge configurations
Airframe: Improvement Packages

- Super 98 DC-9, MD-80, MD-90 and B717 Improvement Packages.
  - Phase I Drag reduction package for the MD-80 is derivative of a project termed the CPIP (Cruise Performance Improvement Program) conducted in the past by McDonnell Douglas (prior to merger with Boeing).
  - With respect to tools and estimates made Super 98 estimates that the currently available MD-80/Phase I retrofit package:
    - could save up to US $283,000 per year
    - with an acquisition costs (including installation) break-even point at < 2 years
    - saving per annum is based on a fixed scenario (Fuel cost: US $3 per gallon, Stage length: 750nm, Trips per year: 1,375)
  - The developed retrofit offering by Super 98 for the MD-80 recently received an STC in September 2011, by the FAA (USA)

Airframe: Improvement Packages

- Super 98 DC-9, MD-80, MD-90 and B717 Improvement Packages.
  - Planned drag reduction retrofit kit.
  - Comprises of:
    - Increase of wingspan
    - Nacelle savings
    - Slats gap reduction
    - Vertical tip savings
    - Hinge cover and fairings.
  - The retrofit kit is estimated to become available in 2013.
  - The reported fuel burn reduction achieved with this drag reduction retrofit kit is 4%.

Airframe: Improvement Packages

- Super 98 DC-9, MD-80, MD-90 and B717 Improvement Packages.

Figure 11: SUPER 98 Boeing B717/MD-90 Drag Reduction Configuration and Annual Fuel Savings (fuel drag reduction retrofit) [91/95]

Airframe: Improvement Packages

- Bombardier CRJ-series Improvements.

Figure 14: Bombardier CRJ100 (left), CRJ900 (top right) and CRJ700 (bottom right) [98/99]

- Per introduction of the CRJ100 NextGen, it was communicated that some of the featured solutions will become available for retrofit by existing CRJ700/900 operators.

- Amongst the NextGen series features that may be probable retrofit options:
  - New Composite Flaps and Vories
  - Conical Engine Nacelle
  - New WingTip Extension and Winglets
  - Avionics update
  - New paint process and pre-paint anti-corrosion treatment (weight reduction benefit)
  - New seating and Seating configuration
  - New LED lighting options
  - Larger Overhead Manage bins.
Cabins: Upgrades & Modernization

- Retrofit of aircraft cabins, whether partial or complete, is one of the largest, long-running segments of the aircraft retrofit market.
- Cabin upgrades options may address a range of requirements from passenger appeal, comfort, and office environment facilities to aircraft cabin management, weight and energy reductions, safety and security features.
- Findings in this segment range from dedicated cabin upgrade solutions for retrofit, to whole cabin retrofit solutions, developed either by dedicated vendors, airline MRO branches and the airframe OEMs.
- Included in findings are retrofit solutions addressing:
  - Aircraft Security Monitoring
  - Aircraft Safety: decompression incidents, emergency power / lighting, fire detection-suppression, cabin monitoring, etc.
  - Aircraft Cabin Lighting, Cabin Environment Improvement, Cabin In-seat Power
  - Aircraft Cabin Modernisation Programmes - Airframe OEMs & Vendors

Avionics: Upgrades & Compatibility

- Retrofit of aircraft avionics, whether partial or complete, by choice or by aviation authorities mandate, is one of the largest, long-running segments of the aircraft retrofit market.
- Primarily due that aircraft must comply or be flexible to comply (flight deck technology) with constantly changing Air Traffic Control (ATC) requirements and future frameworks, i.e., Single European Sky ATM Research (SESAR) (EU) and Next Generation Air Transportation System - NextGen (USA).
- Numerous instances can be found concerning aircraft avionics retrofits (equipment changes) on ageing and out-of-production aircraft such as the B737-100/200/300/400/Classic, B757, etc.
Avionics: Flight deck Modernization

- In 2011, the FAA received an STC from Boeing for their Enhanced Takeoff/Approach (ETAP) project.
- 13 months development project (ETAP converted Boeing 737 to new architecture to upgrade analog flight deck to a digital flight deck compatible with upcoming NextGen requirements, using Commercial Off-The-Shelf equipment).
- FAA approved new retrofit package includes:
  - EICAS: Enhanced Indication and Crew Alerting System
  - Rood: Reconfigurable Open Display System
  - EFIS: Electronic Flight Instruments System
  - MFD: Multi Display Leaf
  - SDF: Switching Data Panel
  - TFD: Terrain Display
  - TMA: Traffic Management Advisor

Conclusions

- Further than expected fleet wide retrofit initiatives and programmes (cabin, avionics, security, etc.) reduce the need for more demanding and extensive programs such as those proposed by Airbus or Boeing.
- A range of performance improvement programs exist for ageing aircraft types, but also there is an emerging need for such programs to support and extend the service life of out-of-production aircraft.
- Large-scale upgrade and retrofit programmes (e.g., for engines, avionics, safety features) if not initiated by an OEM, need the participation of an OEM in particular for guidance and exchange of confidential information.
- Similar upgrade and retrofit programmes depending on scale (e.g., for cables, cockpits, etc.) may be initiated without OEM involvement, e.g., initiated and/or lead by Tier-level supplier, large MROs, Vendors, and Compete projects.
- The Performance Improvement Program/Performance Improvement Package scheme is seen as a successful model for large-scale fleet-wide retrofit initiatives as they encompass a wide range of changes.
Technology Inventory: how

- 175 candidate technologies for retrofitting to existing aircraft
- Steps taken:
  - Initial Long List of candidate technologies collected from ECP 5, 6, & 7 projects, national programmes, literature, web, stakeholder interviews, experts
  - Discussion at Reference Group Meeting with representatives from aircraft operators, aircraft builders, component suppliers, and lease companies:
    - which technologies are missing, potentially attractive in the timeframe from now up to 2050, and top 5 of most attractive technologies:
      - Wing tip devices
      - Weight reduction technologies in the cabin
      - In-flight entertainment (IFE) & communications
      - Avionics to improve flight efficiency & for ATM compatibility
      - Compatibility with alternative fuels
  - Updated and Finalised as Technology Inventory

Technology inventory: categories

- Re-engining
- Alternative fuels
- Aerodynamics
- Cabin
- Structures
- Avionics
- Equipment
- Security technology
- Safety technology
- Other
Identify RTD topics for the EU FP

- Further analysis of the "Required RTD for retrofit", thereby considering such issues as:
  - Does the topic involve RTD or, for example, is it engineering only?
  - Are the RTD contents clear?
  - Is the RTD specific for retrofit and is it not also covered by RTD for new aircraft?
  - Is the topic relevant for the market (cf. benefits)?
  - Is the technology technically feasible, also considering the costs (e.g. of certification)?

- Result: recommendations to the EC:
  - with respect to further research on technologies to increase their potential for retrofitting,
  - may be incorporated in FP7 and Horizon 2020,
  - including a short list of RTD topics specifically targeted to obtain the potential benefits of retrofitting for Europe.

General Recommendations to EC

- Promote research on retrofit applicability in developing new technologies for aircraft
- Any RTD proposal for the development of technology for new aircraft must address the potential for retrofit.
- Decrease the certification cost and time of retrofits by promoting RTD into virtual testing and virtual certification

This afternoon: do you agree with these recommendations?
Reduced Emissions of TRansport aircraft Operations by Fleetwise Implementation of new Technology

RETROFIT Workshop

Dave Chilton
Fielder Services

Seventh Framework Programme
Grant Agreement No. 200867

Identification of viable and feasible RETROFIT possibilities
- Initial list as starting point
- Refined by report on technology inventory
- First proposals for possibilities

Selected technologies
- Initial suggestions from IS
- Use of MCA method

Consultation with consortium members
- Choice of preferred technologies
- Input from consortium members
- Collection of comments
- Decision on trade off studies
RETROFIT possible future programs

- Selection of three cost benefit candidates
  - Avionics for SESAR compatibility
  - New high bypass ratio engines to existing A320 aircraft
  - Taxiing by internal power

SESAR
JOINT UNDERTAKING

Potential WheelTug Configuration
Objectives cost-benefit studies

- Understand typical economic factors for large scale conversions/retrofit programmes
- Quantify community benefits of retrofit programmes
- Quantify justified support means by the EU to support beneficial retrofit programmes

- Selected cases are samples with benefits in different dimensions. They are not intended to represent the most attractive retrofit programs.
- Much of required cost info is commercially confident, in those cases an estimated band width has been used.
- CR study based on Eurocontrol 2000 standard inputs for Cost benefit studies.

RETROFIT Workshop Cost-benefit studies
February 14 2012
E. Jesse A05E

Contents

- Objectives cost-benefit studies
- Retrofitting for SESAR compatibility
- Retrofitting existing A320 aircraft with GTP/next gen Engines
- Electric taxiing
- Conclusions

Retrofit for SESAR compatibility

- A large proportion of aircraft in EU airspace should be SESAR compatible to obtain system wide benefits
- Current newly delivered aircraft are very close to required capability
- They add to the system at a rate of ~300 units per year (3% of the fleet, covering 5% of the flights), allowing SESAR system wide benefits over 10 years??
- Retrofit of existing aircraft can speed this up when sufficiently large numbers are converted
- 2000 a/c converted provides an advance of ~5 to 10 years to critical mass
Currently a large number of aircraft types operate in EU airspace
- 729 types cover 70% of all flights
- But 2 types have by far the largest flight volume
  - A320 family, Boeing 737 NG and classic, together 44%
- Conversion costs are mostly non-recurring
  - dependent on functionality to be added, independent of aircraft size and fleet size
- Operator gains are per aircraft flight, hence proportional to number of flights and payload
- Only large scale conversion programs will be cost effective
  - A320 family plus Boeing 737
  - ~2000 aircraft are suitable (remaining life)

Assumptions
- 2 suppliers in competition
  - Each develops a "SESAR box"
- Development costs between 100 M€ and 250 M€
  - 2 types, 3 versions each
- Conversion costs (recurring per aircraft) 100 K€
- Complied unit sales price between 250 K€ and 1250 K€
- Planning for sales of 25% of the total market volume (500 units) puts limits on the allowable development costs and the minimum expected sales price
- Small scale programs seem unrealistic

SESAR compatibility Supplier cost-benefit

SESAR compatibility Operator cost-benefit

The ROI of the operator is via expected time benefits
- No additional costs assumed apart from capital related costs
- Expected time savings between 2.5 minutes and 9 minutes (fleet average)
  - Different sources quote different numbers
  - Most time saving potential rooms in approach/terminal area with ~50 km excess air distance (5 to 10 minutes)
  - Current delay times (average 2.5 minutes) are system related and not necessarily reduced for individual SESAR-equipped aircraft
- The time saving should be sufficiently reliable that fleets and schedules will be planned around this
**SESAR compatibility**

**Operator cost-benefit**

- Fuel burn per trip
- ETS charges
- Maintenance costs per trip
- Increased productivity
  - Crew
  - Aircraft

**Time value quantified (ref A320/377 ops)**

<table>
<thead>
<tr>
<th>Aircraft type</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
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</table>

**SESAR compatibility**

**Conclusions**

- Large scale retrofitting could bring the effective introduction of SESAR forward by 5 or 10 years
- Large scale retrofitting will only occur when suppliers and operators see a good business with acceptable risks
- The main benefit for the operators is a time saving
  - Direct benefit due to fuel savings
  - Productivity benefit (crew, aircraft utilisation) dependent on perceived reliability of time saving
- The benefits at community level are large enough to consider EU stimulation

**SESAR compatibility**

**Community benefits**

- Time value for the passengers
  - Will not result in higher fares, no additional income for the operators
- External costs of CO2 emissions

<table>
<thead>
<tr>
<th>Community benefit (€/year)</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
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<td>0.0</td>
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</tr>
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</table>

These represent the yearly value of 500 to 3000 aircraft converted to SESAR compatibility to the European Community as a whole.

The EC would be justified therefore to invest a proportionate amount to stimulate such a development.

But note that the values quoted are very inaccurate/barely.
Re-engining the A320 family introduction

- A large number of A320 type aircraft are in worldwide operation (~5000 units delivered)
  - Development costs of conversion can be amortised over a large potential market
- Reductions in fuel consumption significant on a global scale
- A320 NEO is in development, much of the development for a retrofit will already be done
  - Assumes that Airbus Industry will be a lead or major partner
- Re-engining only assumed, no winglets
  - Independent development with compatible characteristics
- Target fleet: all A320 aircraft less than 10 year old in 2015
  - Mix market 4000 units
  - CB analysis on 500, 1000 and 2000 units converted

Re-engining the A320 Cost benefit Supplier

Assumptions

- Development costs between 100 M€ and 500 M€
- Engine list price 10.5 M€ each including nacelle
  - Discounted subject to committed volume
  - Existing engines resisted
- Conversion costs estimated to be 800 k€ per unit for a 250 shipset conversion program. Learning curve 89% assumed for larger programs
- Downtime costs estimated to be equivalent to 3 weeks lease of replacement aircraft
- Investment payback and profit: the program will run about 10 years and generates 10% net profit over the total turnover (including engine purchasing costs)

Re-engining the A320 conversion scenario

- Re-engining entails hardware changes in wing and engine support structures, loads changes and systems modification
  - The modification must be certified as well as the new performance
- The main effort must come from the manufacturer, STC seems impossible
  - No indications yet that AI actually would pursue such an endeavour
- AI quotes a fuel burn benefit of 12% per trip due to PW GTF or GE leap-X
- No payload change is assumed
  - FQF increase could reduce payload on critical routes
  - Takeoff thrust increase could recover some of this
- No significant effect on maintenance costs assumed

Re-engining the A320 Cost benefit Supplier

Analysis

<table>
<thead>
<tr>
<th>Category</th>
<th>Unit Cost</th>
<th>500 Units</th>
<th>1000 Units</th>
<th>2000 Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial investment</td>
<td>M€</td>
<td>M€</td>
<td>M€</td>
<td>M€</td>
</tr>
<tr>
<td>Engine cost (10.5 M€ each including nacelle)</td>
<td>800</td>
<td>800</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>Conversion cost (250 shipsets)</td>
<td>200</td>
<td>200</td>
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<td>200</td>
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<tr>
<td>Total cost per aircraft</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Total revenue per aircraft</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
</tr>
</tbody>
</table>

The sales price of this conversion would be between 8.5 and 12.5 M€.
Powerplant purchasing costs are dominant.
The difference is largely driven by the total sales volume.
Re-engining the A320 Cost benefit operator

- Fuel saving 12% per trip average (Source: AI)
- Fuel price 1 €/kg (2015+)
- CO2 value 15 €/T
- Maintenance costs: no effect
- Capital costs:
  - Rate of return system depreciated in 15 years to 10% residual value
  - Reduced by depreciation of removed engines
  - Conversion costs depreciated in 8 years to 0%
  - Insurance costs increased by 2% over the total investment per aircraft
- 1500 trips per year (10% higher than EU average)

Re-engining the A320 Community benefits

- Reduction of external costs
  - CO2: 4.3 €/T
  - NOx: 5.2 €/kg
  - Noise: 25 €/trip (I0 + landing)

<table>
<thead>
<tr>
<th>Results</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 reduction per aircraft per year</td>
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<td>4.3</td>
<td>4.3</td>
<td>4.3</td>
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<tr>
<td>NOx reduction per aircraft per year</td>
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<tr>
<td>Noise reduction per aircraft per year</td>
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<td>25</td>
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<tr>
<td>Total external costs per aircraft per year</td>
<td>74.5</td>
<td>74.5</td>
<td>74.5</td>
<td>74.5</td>
</tr>
</tbody>
</table>

Total external external costs over 30 years (€) | 2235 | 2235 | 2235 | 2235 |

The community benefit is -1/3% of the direct benefits to the operator, investing a fraction of this will not make such a program profitable.

Re-engining the A320 Cost benefit operator

Results

<table>
<thead>
<tr>
<th>Description</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial cost of aircraft</td>
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<td>1500</td>
<td>1500</td>
<td>1500</td>
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<tr>
<td>CO2 emissions (Tons)</td>
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<td>4.3</td>
<td>4.3</td>
<td>4.3</td>
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<tr>
<td>Fuel price (€/kg)</td>
<td>1</td>
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<tr>
<td>Total external costs per aircraft per year</td>
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<tr>
<td>Total cost saving per year</td>
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<td>0.02</td>
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</tbody>
</table>

It proves that even under the most favourable assumptions such a program could not be profitable for both the operator and the supplier.

The benefit should be at least equivalent to 20% trip fuel saving.

Re-engining the A320 Conclusions

- Despite the potential of a very large retrofit programme re-engining the A320 will not lead to a sound business for the supplier and the operators unless the modification reduces the fuel costs by 20% (or equivalent)
- The best financial scenario entails a very large financial risk/exposure
- Financial stimulants proportional to the expected community benefits would lower the threshold, but not by a significant amount
- Airbus NEO engine offerings promise fuel savings of -12% per trip does not justify re-engining
Electric taxiing Introduction

- A system will be installed which drives the main wheels or the nosewheels electrically from energy provided by the APU.
- Such a system would reduce the running time of the main engines on the ground significantly over all operations.
- Engines operate very inefficiently in the idle settings, in fuel consumption and in specific emission quantities.
- Excess idle thrust on the ground leads to brake applications.
- The APU operates in a much more efficient regime.
- This study does not discuss technical problems and possibilities of electric taxiing.

Electric taxiing Assumptions

- The A320 family and Boeing 737 family cover close to 50% of all flights, is assumed to be representative of all narrow body ops.
- The A330 is taken representative of the typical wide body aircraft.
- With small volumes a retrofit is less likely to be cost-effective.
  - The effect per converted type is small at the community level.

<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>Percentage of Flights</th>
<th>Number of Flights</th>
<th>Estimated Number of Flights with Retardation</th>
</tr>
</thead>
<tbody>
<tr>
<td>340 series</td>
<td>340</td>
<td>3,000</td>
<td>3,500</td>
</tr>
<tr>
<td>320 series</td>
<td>320</td>
<td>1,500</td>
<td>1,700</td>
</tr>
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<td>319 series</td>
<td>319</td>
<td>700</td>
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<tr>
<td>317 series</td>
<td>317</td>
<td>3,000</td>
<td>3,300</td>
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<tr>
<td>A300/300</td>
<td>A300/300</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Other platforms, total, estimated</td>
<td>Other platforms, total, estimated</td>
<td>105</td>
<td>105</td>
</tr>
</tbody>
</table>

Investigated Potential

- The analysis is based on the standard ICAO LTO cycle and the ICAO emissions data base.
- Engine running during taxi reduced by 20 minutes.
- The mass of the system is comparable to the fuel mass saved during brief-in.
- Keeping aircraft mass in flight the same.
- No benefits yet from pushback costs.
- No effect on maintenance costs (Brake vs APU vs Engines vs taxiing system).

Electric taxiing Results

- Results Operator costs (per aircraft)

<table>
<thead>
<tr>
<th></th>
<th>B737 series</th>
<th>A320 series</th>
<th>A320 series</th>
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</thead>
<tbody>
<tr>
<td>Fuel quantity (kg)</td>
<td>240</td>
<td>215</td>
<td>201</td>
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<tr>
<td>CO2 quantity (kg)</td>
<td>777</td>
<td>678</td>
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<tr>
<td>Fuel cost (€/kg)</td>
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<tr>
<td>Emission cost (€/kg)</td>
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<td>9</td>
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<tr>
<td>Cost retardation (€)</td>
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<td>Taxipaid (€)</td>
<td>1249</td>
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<td>Cost saving (€/A320)</td>
<td>6429</td>
<td>5289</td>
<td>4989</td>
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</table>

- With a 3 year payback period such a system would be cost-effective with an installed price of ~3MK for narrow body aircraft and ~5MK for wide body aircraft.
Electric taxiing Results

<table>
<thead>
<tr>
<th>Narrow bodies</th>
<th>Wide bodies</th>
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<tbody>
<tr>
<td>Reduction cost (€/kN/km)</td>
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<td>58.2</td>
</tr>
<tr>
<td>Total cost</td>
<td>250.0</td>
</tr>
</tbody>
</table>

Community benefits

- External cost reduction potential between 250 and 300 kN/Year
  - See 2009-11 data
- This covers 63% of total ops in the EU
- Remaining 37% not taken into account (but conversions expected to be insignificant overall)

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Conclusions Cost-benefit studies

- SESAR
  - To bring community benefits of SESAR significantly forward in time a large number of aircraft should be retrofitted.
  - Development costs form the highest fraction of the sales price of such conversions; this limits application to the most numerous types in the EU transport fleet: the Airbus A320 and the Boeing 737 families
  - Such a program will entail a very high financial risk for the suppliers
  - If the EU wants to reap the benefits of such an enterprise it should find instruments to reduce this perceived risk

Electric taxiing conclusions

- If conversion costs are reasonable electric taxiing could well be cost effective for the operators
- Community benefits are significant, but not very large per converted aircraft
- If stimulation is considered it should lower the risk threshold for suppliers and operators

Conclusions Cost-benefit studies

A320 re-engineing

- Retrofitting for flight efficiency improvements requires a relatively large trip cost reduction and a large scale programme to realise a viable programme
- This is a high financial risk/exposure
- Community benefits are not large enough for meaningful stimulation

Electric taxiing

- This may well be cost effective on its prime economic merits
- Benefits for the airport environment are significant and could justify stimulation for earlier/more numerous introduction
Conclusions Cost-benefit studies

In summary:
- Large scale conversion programmes are essential to reduce development costs as part of the operator investments.
- The EU air transport fleet consists of a very large number of aircraft types, limiting the opportunity for large scale conversion programmes.
- The Airbus A320 and Boeing 737 families are sufficiently numerous, but for other types the returns diminish rapidly.
- The large scale plus high costs per converted aircraft renders these very high financial risk programs.

- Potential community benefits are large for all scenarios investigated, but generally much less than the total commercial value.
Retrofit

The Retrofit project was a study on behalf of the European Commission.
The first priority was to identify RTD topics for the EU Framework program.
The short list provides 10 RTD topics that may be incorporated in FP7 and Horizon 2020.
Recall:

<table>
<thead>
<tr>
<th>SESAR Box</th>
<th>Alternative tool</th>
<th>Kit for nacelle/composite fan casing</th>
<th>Exchange of secondary structures</th>
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<tr>
<td>Stand alone HUMS</td>
<td>Air-ground communication</td>
<td></td>
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<tr>
<td>Wireless on board communication</td>
<td>Engine retrofit tools</td>
<td>Rosetch into alt. fuel performance</td>
<td>Glass cockpit replacement</td>
</tr>
</tbody>
</table>

Why retrofits

- Retrofits can make aircraft more environmentally friendly, cost effective and safer.
- As third countries are developing their own aircraft, it will become more difficult to sell older aircraft outside Europe. Airlines may therefore decide to keep the older aircraft in the fleet longer to avoid a huge loss in depreciation. However, these aircraft need to stay cost effective, clean and appealing to passengers.

RTD in Framework program

- It is recommended in Level 1 projects to call for retrofit issues to mature technologies.
- It is also recommended to integrate these technologies with other systems in Level 2 projects.
- In the last call of FP7, the Commission intends to call for a level 2 project on cabin communications. Retrofit should be incorporated in the description of work.
- The Commission also will call for a level 2 project on integrated airline maintenance. Retrofits (HUMS) should be integrated in that call.
Level 3 demonstration projects

- The Commission is co-funding two level 3 demonstration projects:
  - **Clean Sky**: should be able to demonstrate the benefits of electric taxi as a retrofit.
  - **SESAR JU**: should be able to demonstrate the feasibility of retrofitting new ATM equipment in existing aircraft.
  - In the new ACARE SRIA the research into the performance of alternative fuels will be called for.

Retrofit funding issues

- The retrofit project made 3 case studies for retrofits and looked into the feasibility of funding:
  - The application of electric taxi
  - The re-engining of the A 320 fleet
  - The retrofitting of SESAR compatible on board equipment

The study looked at the possible funding opportunities for these retrofits and possible Commission actions. Interviews were held with the EU Commission (DG Move), SESAR JU, EIB and 2 financial institutions.

Retrofit implementation incentives

- The European Commission may incentivize the implementation of retrofits that support European policies in different areas:
  - Environmental protection: Reducing emissions and noise
  - Improve safety in air transport
  - Improve mobility within Europe by avoiding delays and unwanted en route extensions
  - Stimulate comfortable and intermodal transport
  - Create new jobs for the highly skilled workforce

Retrofit public funding issues

- Any involvement of the Commission should not be a stimulus for the manufacturing industry to avoid the most cost effective solution nor avoid competition.
- Any involvement of the Commission should not lead to market distortions and unfair global competition. If possible an equal public involvement on a global scale is wanted.
- Any involvement of the Commission should not discourage airline demands for integration of new technologies in new products (the forward fix).
Retrofit Electric taxi

- Seen by the financial market as an attractive option, although the payback period may be long.
- Experts demand that the system would be fail safe and malfunctions will not have detrimental effects on airport capacity.
- To bridge the long payback period some sort of incentive by the Commission may be needed based on the positive societal effects of aircraft emission reduction.
- Incentives could be soft loans or direct contributions paid from ETS revenues.

Retrofit of SESAR equipment

- This is by far the most difficult retrofit issue.
- Financial institutions are not interested as the benefits cannot be allocated at one specific entity and the risks are high as SESAR is depending on installation of new ground equipment as well.
- The financial institutions see SESAR primarily as a political program.
- External experts do not believe in the feasibility of the SESAR Box as proposed, since the equipment on board of aircraft will differ. Therefore a 2 year return on investment is not supported. (10-13 years mentioned)

Retrofit New engines on A 320

- The financial market believes that re-engineing only makes sense if a 20% improvement can be achieved and large quantities of aircraft would be involved.
- However due to a potential longer use of aircraft in combination with the intangible benefits, retrofitting could be interesting if some sort of support by public funds could be obtained.
- This could be a subsidy based on the revenues from the ETS system to bridge the cost and benefits.

Retrofit of SESAR equipment 2

- New on board equipment will be added gradually.
- This will be partially based on European regulation that will make equipage mandatory. The example is Data link CPOLC which is mandatory as from 2013 (whilst the ground infrastructure is not able to provide similar services).
- Respondents suggest that if the Commission would make retrofits mandatory, the Commission should offer compensations like paying for the certification and STC cost and offer “best equipped, best served” benefits like ATC at no cost and SWIM data for free.
## Retrofit SESAR equipment 3

- The Commission hopes that SESAR will be fully operational between 2020 and 2025. (the transition point).
- It is investigating ways to **co-fund the equipage** to stimulate airspace users to procure equipment early.
- An equipage fund as proposed in the US is seen as unrealistic: SESAR equipment cannot be leased to airlines as it will be integrated in the avionic systems.
- The Commission is proposing **soft EIB loans** for airlines to buy equipment, covering possibly 50% of the investment.

## Discussion issues

- Do you share our observations related to electric taxi?
- Do you agree on the conclusions regarding re-engineing?
- Do you share the same observations regarding SESAR? Do you think that SESAR will be implemented (Transition point) or will it be an incremental process of improving ATM?
- How do you see the funding of future ATM on board systems to evolve?

## SESAR 4

- As long as the transition point is not reached, the Commission would pay the **interest due** from TEN T funding in the period 2014-2018. After that, Member States would need to pay the interest due until the transition point is reached.
- However, EIB experts feel that it is **too early** to make any decision on equipage. First a better understanding of what is needed and the mass associated with it is to be gained. Second, the development of major elements of SESAR like the SWIM architecture needs to be completed before procuring equipment.