OPENAIR

Optimisation for low Environmental Noise impact AIRcraft

LONDON

20 - 23 October 2015
Outline

• Scope
• Validated Technologies
• Evaluation results
• Progress towards ACARE.
OPENAIR Scope

Project Coordinator: Snecma
No. Of Partners: 47
Objectives:

- 2,5 dB Noise reduction per operation
- Validation of Generation 2 Noise Technologies up to TRL5
- Integration and trade-off studies.
- Identification of applicability over the product range

Project Duration: 5,5 year (2009-2014)

Total Budget: 30 M€
Environmental Goals Definition: The EU 2020 Vision Targets

**2020 Vision Targets**

- Reduce CO2 by 50%
- Reduce NOx by 80%
- Reduce perceived noise by half
- Eliminate noise nuisance outside airport boundaries
- Substantial cuts in operating costs
- Five-fold reduction in accident rate
- Drastic reduction in the impact of human error
- 99% of flights within 15 minutes of timetable
- New standards of quality and effectiveness
- Halve the time to market
- Improve synergies between civil and military research

**ACARE SRA1**

-10 EPNdB / Operation
65 LDEN at Airport Boundaries

**Contributors** (based on ICAO Balanced Approach)

- Source Noise Reduction (The Quiet Aircraft)
- Noise Abatement Procedures
- Community Impact Management

**Goals**
Steps to the 2020 ACARE Aircraft Noise Target

EC Mid-Term Goal

Phase 1: 2010 Solutions
- Generation 1 Noise Technologies
- Noise Abatement Procedures

Based on FP4 to FP6 Projects (1998 - 2010)

Phase 2: 2020 Solutions
- Generation 2 Noise Technologies
- Novel Architectures

Based on FP5 to FP8 Projects (2004 - 2020)

ACARE Goal (TRL 6 Technology, also includes benefit from NAPs)

2020 VISION

Technology Breakthrough

Average Decibels per Aircraft Operation

Base (2000) + 4 + 8 + 12 + 16 + 20 Years
European Research Effort aimed at Aviation Noise Reduction – Phase 1

ACARE Contributors

Enablers

Noise Abatement Procedures

Management of Noise Impact

Years

Source Understanding, Basic Tools & Technology Elements (Enablers)

Ramp Noise
Core
Jet and Active Techs.
Turbomachinery
Liners & Propagation
Airframe
Installation Effects

Noise Reduction Technologies (NRT) Generation 1

Noise Reduction Technologies (NRT) Generation 2

Novel Architectures

Exhaust Noise Reduction Technology

Turbomachinery Noise Reduction Technology

Nozzle Design
Liner Technology

Airframe noise Reduction Techniques

High Lift Devices & Landing Gear

Operational Practices

Noise Abatement Procedures

National Programs

SILIENCE(R)

RESOUND

DUCAT

RAIN

National / Industry Research

SOURDINE

RAIN

SOURDINE II

X-Noise
Steps to the 2020 ACARE Aircraft Noise Target

**Phase 1: 2010 Solutions**
- Generation 1 Noise Technologies
- Noise Abatement Procedures

*Based on FP4 to FP6 Projects (1998 - 2010)*

**Phase 2: 2020 Solutions**
- Generation 2 Noise Technologies
- Novel Architectures

*Based on FP5 to FP8 Projects (2004 - 2020)*

**2020 VISION**
- Technology Breakthrough
- ACARE Goal (TRL 6 Technology, also includes benefit from NAPs)
SILENCE(R) Results

- 10 Technologies validated
  - 1. Compressor for UHBR engine
  - 2. Fan design
  - 3. Exhaust Nozzle
  - 4. Negatively Scarfed Inlet (NSI)
  - 5. Lip liner
  - 6. Zero Splice Inlet (ZSI)
  - 7. Low Freq. liners (plugs)
  - 8. High freq. liner (in exhaust)
  - 9. Landing gear fairings
  - 10. Wing hole treatment
Steps to the 2020 ACARE Aircraft Noise Target

**Phase 1: 2010 Solutions**
- Generation 1 Noise Technologies
- Noise Abatement Procedures

*Based on FP4 to FP6 Projects (1998 - 2010)*

**Phase 2: 2020 Solutions**
- Generation 2 Noise Technologies
- Novel Architectures

*Based on FP5 to FP8 Projects (2004 - 2020)*

**OPENAIR**
- Average Decibels per Aircraft Operation
  - SILENCE(R)
  - -2.5 dB

**2020 VISION**
- Technology Breakthrough

**ACARE Goal**
- TRL 6 Technology, also includes benefit from NAPs
European Research Effort aimed at Aviation Noise Reduction – Phase 2

**ACARE Contributors**

**Enablers**
- Noise Reduction Technologies (NRT) Generation 1
- Noise Reduction Technologies (NRT) Generation 2
- Novel Architectures

**Management of Noise Impact**
- Noise Abatement Procedures

**Years**
- 02 03 04 05 06 07 08 09 10 11 12 13 14

**Source Understanding, Basic Tools & Technology Elements (Enablers)**
- Ramp Noise
  - Core
  - Jet and Active Techs.
  - Turbomachinery
- Liners & Propagation
- Airframe
- Installation Effects

**Advanced Configurations**
- Aircraft Architectures
- Engine Architectures

**Turbomachinery Noise Reduction Technology**
- Noise Reduction at Source
- Nacelle Technologies

**Exhaust Noise Reduction Technology**
- Nozzle Design
- Liner Technology

**Airframe noise Reduction Techniques**
- High Lift Devices & Landing Gear

**Operational Practices**
- Noise Abatement Procedures

**Noise Impact Management: Tools & Understanding**
- Perception / Annoyance
- Open Rotors En-Route Noise
- Noise / Emissions Interdependencies Modelling
- Noise Mapping Models

**Descriptions at www.xnoise.eu**

**X-Noise**

**IDEALVENT**
**RECORD**
**ORINOCO**
**JERONIMO**
**CLEANSKY**
**OPENAIR**
**CLEANSKY**
**CLEANSKY**
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**CLEANSKY**
**FLOCON**
**NINHA**
**TEAMPLAY**

**Enablers**
- JEAN
- COJEN
- PROBAND
- MESSIAEN
- TURNEX
- TELENI
- VALIANT
- DREAM
- OPTIMAL IP
- SEFA
- COSMA

**Advanced Configurations**
- ROSAS
- NACRE
- VITAL
- DREAM

**Turbo machinery Noise Reduction Technology**
- SILENCE(R)

**Exhaust Noise Reduction Technology**
- ERAT

**Airframe noise Reduction Techniques**
- SOURDINE II

**Operational Practices**
- SILENCE(R)
- SOURDINE II

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**Operational Practices**
- SILENCE(R)
- SOURDINE II

**Noise Impact Management: Tools & Understanding**
- SILENCE(R)
- SOURDINE II
OPENAIR Partnership at kick-off

- 47 partners:
  - 20 Industries
  - 21 Research Institutes
  - 6 SMEs

- 15 countries
  - 12 EU states
  - 3 non-EU states (Swiss, Russia & Egypt)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Research Institutes</th>
<th>SME</th>
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<tbody>
<tr>
<td>AEROSTAR</td>
<td>Andreev Acous. Inst.</td>
<td>INASCO GR</td>
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<tr>
<td>Airbus Deutschland</td>
<td>ASU Cairo</td>
<td>ARTTTIC FR</td>
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<td>Airbus France</td>
<td>CEPr</td>
<td>NASTECH IT</td>
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<td>Airbus UK</td>
<td>Chalmers</td>
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<td>Aircelle</td>
<td>CIRA</td>
<td>FFT BE</td>
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<td>ATMOSTAT</td>
<td>CNRS</td>
<td>Microtech PL</td>
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<td>Avio</td>
<td>COMOTI</td>
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<td>Bombardier</td>
<td>DLR</td>
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<td>Dassault</td>
<td>EPFL</td>
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<td>EADS</td>
<td>Imperial College London</td>
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<tr>
<td>GKN Aerospace</td>
<td>IVTAN</td>
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<td>ITP</td>
<td>KTH Stockholm</td>
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<td>Messier-Dowty</td>
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<td>PFW Aerospace</td>
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<td>QinetiQ</td>
<td>Tsagi</td>
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<td>Rolls-Royce DE</td>
<td>Univ. of Patras</td>
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<td>Rolls-Royce UK</td>
<td>Univ. of Madrid</td>
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<tr>
<td>Snecma</td>
<td>Univ. of Roma Tre</td>
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<td>Snecma Propulsion Solide</td>
<td>Univ. of Southampton</td>
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<tr>
<td>Volvo Aero</td>
<td>Univ. of Cambridge</td>
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<td>VTT</td>
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</tr>
</tbody>
</table>
Engine Technologies

- Optimised & lined stators
- Lined bifurcations, struts and splitters
- Lined core stators
- Scarfed nozzle
- Micro jet
- Optimised bypass duct liners
- Active stators
- Variable impedance inlet liners
- Low-frequency liners
- Virtual scarfed inlet
Airframe noise:

- Adaptive Slat gap
- Optimised Slat settings
- Slat chevrons
- Flap side edge treatment
- Perforated trailing edge
- Downstream body
- Spoiler with folding fences
- Fractal spoiler
- Low noise LG design
- Splitter plate
- Airframe noise:
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15 Technologies validated to TRL 4/5

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<th>Technology</th>
<th>Validation Level</th>
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<tbody>
<tr>
<td>Variable impedance liner</td>
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<tr>
<td>Lined radial Splitters</td>
<td>Low Noise Slat setting</td>
</tr>
<tr>
<td>Lined fins</td>
<td>Porous flap side edge</td>
</tr>
<tr>
<td>Highly curved bypass duct</td>
<td>Low Noise landing gear design</td>
</tr>
<tr>
<td>Scarfed nozzles</td>
<td>Deceleration Plate</td>
</tr>
</tbody>
</table>
Segmented inlet liner

Segmented liner with 80mm deep liner

UoS, GKN

25% Low-frequency DDOF liner (80mm deep)

75%
Baseline DDOF liner

SMR AP2-EP2 Forward Fan noise source:
Segmented liner: -1.5 EPNdB Cumulative

Significant Buzz-saw noise reduction in the cabin not achievable by any reasonable amount of acoustic treatment in the fuselage
Folded Cavity Inlet Liner
liner impedance model

• Folded cavity behaves as deep liner at low frequency
• Primarily direct reflection at high frequency

SMR /BPR12 Forward Fan noise source;
Folded Cavity (Deep Liner) : -4 EPNdB Cumulative

Significant Buzz-saw noise reduction in the cabin not achievable by any reasonable amount of acoustic treatment in the fuselage
MDO OGVs (Stators)  
Multi Disciplinary Optimized

- Ultra low vane count design (44 -> 10 OGVs) for reduced fan system broadband noise
- Performance/Acoustic design process defined optimum leading edge shape of fan OGVs.
- 7dB (1 BPF) noise reduction demonstrated at AneCom fan rig.

MDO OGVs (RR, Cambridge, DLR)

Lined OGVs (Stators)

- Reduce broadband noise due to lower number of OGVs (10 off)
- Reduce /minimize increase of tone noise with Vane lining while fan performance remain unchanged

Acoustically treated OGVs - GKN, CHALMERS, PFW

SMR/BPR12 Forward Fan noise source;
-0.5 EPNdB Cumulative

SMR/BPR12 Rear Fan noise source;
-2.1 EPNdB Cumulative

Liner Concept
Radial Splitters

Bifurcation + Radial Splitter

FRONT VIEW SHOWING 2 SPLITTERS

Radial splitters
Aerodynamic  Airbus
Acoustics  Airbus/FFT
Manufacturing  Aircelle/RR

radial splitters
hardware (Aircelle)
Lined Fins

Bifurcation + Lined Fins (OA12)

FRONT VIEW SHOWING 4 FINS

Fins
Aerodynamics Snecma
Acoustics Snecma
Manufacturing Aircelle/RR

lined fin hardware - Aircelle
The highly curved bypass duct (BPD) seeks to push out the duct earlier to higher radius. As the BPD cross sectional area is conserved this results in a reduced height duct with a greater liner area per unit length. Reduced height ducts are more effective at noise absorption. These attributes allow a shorter nacelle to be used giving significant reductions in weight and drag.

Bombardier, Snecma, RR, Airbus, DLR, NLR
Scarfed nozzle

- Broadband noise reduction with scarfed nozzle for angles between 60 and 120° (ref nozzle axis) on the flyover arc
- 3 dB average reduction of rearward fan noise component

Test results: Far-field directivity of broadband modal content at CB/FL condition: Baseline and scarfed nozzles

S. Lemaire “Identification and reduction of the noise produced by Falcon business jets”, AIAA Aeroacoustics 2013, Berlin, Germany. Keynote
Active Stator system

- Large scale demonstration of controlling both forward as well as rearward radiated fan noise
- TRL maturation on all system components

One-shot manufacture concept
Piezoelectric actuator
Mechanical testing of full scale hardware

Snecma, CTTM, VTT, Microtech, EADS IW, COMOTI, INASCO, DLR
Active Nozzle – Pulsed Microjets

- Large scale acoustic tests
  - Isolated and installed under-wing tests
- Integration Studies
  - Engine performance, weight, SFC, geometrical compatibility (reverse, liner), …
  - -1 EPNdB cumulated jet noise (SMR/BPR9)
  - CMC core nozzle sector prototype manufactured and tested

Validated

Snecma, Aircelle, Herakles, CNRS
Low noise slat setting

When slat deployed find out the best gap/overlap settings ensuring $C_{l_{\text{max}}}$ and aeroacoustic performance

Slat settings (gap /overlap)

Numerical process CFD/CAA simulations (DLR) for the slat settings optimisation

- CFD
- RANS
- 4D-Stochastic Sound Sources (RPM)
- CAA-Code PIANO with stochastic source models (F)RPM

Validated
Adaptive Slat

when $C_{l_{\text{max}}}$ is required at high angle of attack of the A/C open the slat gap for normal landing procedures close the slat gap
Porous Flap Side Edge

- Large scale acoustic testing
- Foam and Mesh configurations tested
- Integration studies on airworthiness requirements.
- -1 EPNdB reduction on flap noise source

S. Lemaire "Identification and reduction of the noise produced by Falcon business jets", AIAA Aeroacoustics 2013, Berlin, Germany. Keynote
Low Noise Landing Gear design

Extract of the test matrix deployed in DNW-LLF for Wing Gear addressing:

- the efficiency of Low Noise technologies on the large scale Gear
- The parametric effect related to the position or design of components

<table>
<thead>
<tr>
<th>Components Tested</th>
<th>Effects tested</th>
</tr>
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<tbody>
<tr>
<td>Baseline Wing gear</td>
<td>reference</td>
</tr>
<tr>
<td>Dressing</td>
<td>low noise dressing routing</td>
</tr>
<tr>
<td>Cardan pin</td>
<td>cardan pin location changes from side of the leg to the front of the leg</td>
</tr>
<tr>
<td>Dressing fairing</td>
<td>Noise efficiency of add-on</td>
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<tr>
<td>Torque link fairing</td>
<td>Noise efficiency of add-on</td>
</tr>
<tr>
<td>Spring fairing and joint fairing</td>
<td>Noise efficiency of add-on</td>
</tr>
<tr>
<td>Drag stay/leg cover</td>
<td>Noise efficiency of add-on</td>
</tr>
<tr>
<td>Ramp fairing</td>
<td>Noise efficiency of add-on</td>
</tr>
<tr>
<td>Main door</td>
<td>door - wind direction angle changes</td>
</tr>
<tr>
<td></td>
<td>door to leg spacing changes</td>
</tr>
<tr>
<td>Lower side stay new design</td>
<td>lower side stay cylinder shape vs. H-shape (reference)</td>
</tr>
</tbody>
</table>

Validated
Landing Gears: Deceleration plate

when attached downstream of complex gear structures are assumed to reduce the local inflow velocity to such structures and thus reduce related noise generation without negative flow displacement effects.

-1,5 -2 EPNdB reduction of Main Landing gear noise

Deceleration Plate with different surfaces were tested and assessment are provided at landing gear model level.
• **ANTE: Aircraft Noise Technology Evaluation** process developed from 2001 to 2005 under SILENCE(R) funding.
  - Single event comparison
  - Airport Impact assessment

• **Configuration matrix OPENAIR**, using a wide range of aircraft products
Technology Evaluation

Environmental impact assessment on Amsterdam Airport

- Simulation through fleet replacement by
  - OPENAIR baseline aircraft (already incorporating noise technologies validated by earlier projects)
  - OPENAIR LNT (Low noise technology) fleet incorporated by the best performing technologies of the OPENAIR project:

<table>
<thead>
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<th>No. of Operations</th>
<th>Day</th>
<th>Evening</th>
<th>Night</th>
<th>Total</th>
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<tbody>
<tr>
<td></td>
<td>300000</td>
<td>90000</td>
<td>30000</td>
<td>420000</td>
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Baseline scenario (Schiphol 2011):

<table>
<thead>
<tr>
<th>Business jet</th>
<th>AP2 (SMR)</th>
<th>AP3 (LR)</th>
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<tr>
<td>3%</td>
<td>80%</td>
<td>17%</td>
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Project Results

→ Conclusion

- OPENAIR technologies allow a noise reduction of 2.3 dB per average operation (at LDEN contour level).
- 49% reduction of noise impacted people
- OPENAIR has validated 15 noise technologies to TRL 4/5:

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ACARE Noise Technology & Operational Goals (Fixed Wing Aircraft) – SRA1 + SRIA

Noise Reduction Technologies (NRT) Generation 1 + Noise Abatement Procedures (NAPs)

SRA1 Target including NAPs

NRT Generation 2
Openair → -2.3dB / TRL4-5

Possible Gap In New Aircraft Configurations Development

2035 Target + Step Change in aircraft configurations

NRT Generation 3

Further Step change in vehicle configurations

2050 Target including NAPs
Thank You for Your Attention

This work was funded by European Commission Framework 7 under the OPENAIR project (Grant agreement 234313)