PARE preliminary analysis of ACARE Challenge 3 environmental impact goals (towards quieter and cleaner environment in aviation sector)

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PARE - Perspectives for the Aeronautical Research in Europe

- Assess the rate of progress relative to the 23 Flightpath 2050 goals and those which need greater support, as well as make recommendations relevant to achieve those goals;
- Compare with the progress outside the EU to assess the competitive/collaborative status;
- To identify and foster the participation of aviation and aviation-related stakeholders in EU research and innovation activities considering, among other aspects, the potential for further contributions from the acceding, candidate and associated countries;
- Include technologies outside the aeronautical sector that could have benefit in aeronautics;
- Focus on the significant potential to increase the participation of women, not only increasing the number of engineers but also bringing additional complementary skills.
# PARE

## List of participants

<table>
<thead>
<tr>
<th>#</th>
<th>Participant Legal Name</th>
<th>Country</th>
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<tr>
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<td>2</td>
<td>INOVAMAISS - SERVICIOS DE CONSULTADORIA EM INOVAÇÃO TECNOLOGICA S.A.</td>
<td>Portugal</td>
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<td>3</td>
<td>ZAPOROZHIE MACHINE-BUILDING DESIGN BUREAU PROGRESS STATE ENTERPRISE NAMED AFTER ACADEMICIAN A.G. IVCHENKO</td>
<td>Ukraine</td>
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<td>France</td>
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<tr>
<td>5</td>
<td>UNIVERSIDAD POLITÉCNICA DE MADRID</td>
<td>Spain</td>
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<td>6</td>
<td>VARTA MICRO INNOVATION GMB</td>
<td>Austria</td>
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<td>7</td>
<td>UNIVERSITATEA POLITÉHNICA DIN BUCURESTI</td>
<td>Romania</td>
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<td>Ukraine</td>
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<td>INNIPULS SPOŁKA ZOGRANICZONA ODPOWIEDZIALNOSCIA</td>
<td>Poland</td>
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<td>12</td>
<td>İzmir Katip Çelebi Üniversitesi</td>
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<td>13</td>
<td>QUASAR HUMAN CAPITAL, Unipessoal Lda</td>
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<td>VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS VIESOJI ISTAIGA</td>
<td>Lithuania</td>
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<td>15</td>
<td>SATA Internacional</td>
<td>Portugal</td>
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Key challenges of a strategic research and innovation agenda *Flightpath 2050*
Comparison of long-term goals for environmental impact factors of aviation between ICAO Policy, EU and USA Research and Development agenda

<table>
<thead>
<tr>
<th>Environmental impact factor from aviation</th>
<th>ICAO Policy Goals (A39-Resolutions)</th>
<th>EU ACARE Goals 9 (FP2050 till 2050)</th>
<th>US FAA and NASA Goals (NSTC2010 and CLEEN II till 2035)</th>
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<tbody>
<tr>
<td>Noise</td>
<td>Limit or reduce the number of people affected by significant aircraft noise</td>
<td>perceived noise emission of flying aircraft is reduced by 65%</td>
<td>52 dB reduction relative to cumulative margin of ICAO/FAA Stage 4 noise limit (a 25-year goal, by enabling N+3 aircraft and engines)</td>
</tr>
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<td>NO\textsubscript{x} emissions</td>
<td>Limit or reduce the impact of aviation emissions on local air quality</td>
<td>90% reduction in NO\textsubscript{x} emissions</td>
<td>80% reduction in NO\textsubscript{x} emissions (for cruise relative to 2005 best in class and for LTO relative to ICAO CAEP/6 standard)</td>
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<tr>
<td>Greenhouse gas emissions and fuel/energy consumption</td>
<td>Limit or reduce the impact of aviation greenhouse gas emissions on the global climate: a reduction in net aviation CO\textsubscript{2} emissions of 50% by 2050, relative to 2005 levels</td>
<td>75% reduction in CO\textsubscript{2} emissions per passenger kilometre</td>
<td>60% reduction in Aircraft Fuel/Energy Consumption (CO\textsubscript{2} emissions per passenger kilometre?) relative to 2000 best in class</td>
</tr>
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The goals and action areas for Challenge 3 of the ACARE perspectives

In principle for Goal 9 the vehicle design improvements are considered mostly (plus biofuels)
• In 2017, strong growth saw traffic back on the most-likely scenario from the 2013 forecast of Eurocontrol
Predictions of fleet transition from current aircraft to imminent/future aircraft 2010-2050

Evolutinary approach

Revolutinary approach?
The EU Framework Program, with its three levels and the intended research objective

- TRL scale was introduced into the EU funded projects arena in 2014 as part of the Horizon 2020 framework program
Maturation Timeline for Technology Readiness Level

Future technology improvements could stabilize overall aircraft noise exposure in the 2035 timeframe.

For each traffic forecast, 'advanced' and 'low' technology improvements rates are applied to new aircraft deliveries from 2015 onwards. The upper bound of the range reflects the 'low' technology improvement rate, and the lower bound is the 'advanced' technology improvement rate.
The CAEP Panel had previously concluded that the two primary paths to aircraft noise reduction were increasing Bypass Ratio (BPR) of the propulsion system cycle, and component noise reduction technologies (NRT).
BPR beyond the demonstrated level of 9 (Environmental trade-offs)

- Nacelle weight and drag as fan diameter increases
- Engine-out drag and consequent effect on tail control surface size
- Landing gear length for nacelle ground clearance
- Core size limitations and auxiliary bleed requirements
- Fan stall and stability control during extreme shifts in operating line from sea level to cruise.
Comparison of US and EU research goals

Limited visibility on funding commitments beyond this point.
IEP2 predicted noise reduction target versus US and EU research goals
• The MT goal for 2016 was agreed at 45% ± 2.5% below CAEP/6 at OPR 30, and the LT goal for 2026 at 60% ± 5% below CAEP/6 also at OPR 30.
2009 Review data with RQL (rich-quench-lean concept) combustors in grey and new mid-OPR engines.
Controlling temperature with Lean-Burn is key to minimizing NOx: the TAPS combustor will provide even more significant reductions as shown in Figure during high altitude climb and cruise conditions, where approximately 90% of NOx emissions are emitted.
• It is important to recall that the ACARE objectives should be achieved through: a) aircraft technology, b) engine and combustion technology, c) ATM and flight optimisation.
Aero-engine optimisation trades for new engine design

- Figure demonstrates the trades driving new engine design with respect to optimum fuel burn (CO2), minimum noise (by minimum fan pressure ratio FPR) and minimum NOx (by minimum OPR). The difference in LTO NOx levels between the best design for low NOx and best design for low CO2 can be up to 30%. Also, noise reduction obligations for new aircraft as introduced at some airports can lead to a divergence from the optimum engine design for lowest CO2.
CO₂ & Fuel Burn Trends from International Aviation, 2005 to 2050

**CO₂ Emissions = 3.16 × Fuel (Combustion Only)**

Extrapolation beyond 2040

Minimum CO₂ Gap = 1,039 Mt

1.39% per year fuel efficiency improvement

2% per year fuel efficiency improvement

*Actual carbon neutral line is within this range. Dashed line in technology contribution silver represents the "Low Aircraft Technology Scenario." Note: Results were modelled for 2005, 2006, 2010, 2020, 2025, and 2030, and then extrapolated to 2050.
### Clean Sky concept aircraft

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<tr>
<th>Clean Sky concept aircraft</th>
<th>CO₂</th>
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<tr>
<td>High Sweep bizjet aircraft, HSBJ 2020</td>
<td>-19%</td>
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<tr>
<td>Regional Turboprop aircraft, TP90 2020</td>
<td>-30%</td>
</tr>
<tr>
<td>Regional Geared Turbofan aircraft, GTF130 2020</td>
<td>-21%</td>
</tr>
<tr>
<td>Short-Medium Range aircraft (CROR engine), APL 2 2020</td>
<td>-34%</td>
</tr>
<tr>
<td>Long Range aircraft (Advanced Turbofan), APL3 20 20</td>
<td>-18%</td>
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<tr>
<td>Twin Engine Heavy rotorcraft, TEH 2020</td>
<td>-22%</td>
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FORUM-AE 2015 assessment of progress towards ACARE 2020 goal

Completion level for CO2 & NOx Goals

- TRL6 to be covered by new projects
- TRL6 foreseen by ongoing projects
- TR6 achieved

CO2: 28% TRL6 to be covered, 50% TRL6 foreseen, 48% TR6 achieved
LTO NOx: 40% TRL6 to be covered, 10% TRL6 foreseen, 50% TR6 achieved
Cruise NOx: ?% TRL6 to be covered, ?% TRL6 foreseen, ?% TR6 achieved
Aircraft CO$_2$ emissions reduction

- Estimated excess CO$_2$ emissions per flight are decreasing in taxi, take-off, climb/descent and en route phases

ACARE CO$_2$ & NOx goals calendar (using CAEP6 margin for NOx)
Global aviation CO$_2$ forecast with ACARE assumption
Preliminary TRL assessment for Goal 9 of Challenge 3

- NYSERDA (TRL/CRL) Calculator results for analysis and assessment of ACARE Challenge 3 Goal 9 “Reduction of Noise and Emissions” (mid-term goals)
Preliminary recommendations from PARE project

- **9.1:** Support a broad research effort to reduce aircraft noise (a) at the source (b) through operating procedures and (c) taking into account psychoacoustic effects.

- **9.2:** Besides struggling with short term solutions to an increasingly pressing noise problem a modest effort should be made towards a long-term definitive solution: aircraft in audible outside airport boundaries.
Preliminary recommendations from PARE project

• 9.3: Formulate a set of trade-offs between (a) different types of emissions (CO$_2$, NO$_x$, particles and water vapor) in (b) local airports and global cruise flights.

• 9.4: Besides struggling with short-term emissions problems put a modest effort towards a long-term definitive solution: the hydrogen and electric powered aircraft.
Preliminary recommendations from PARE project

• 9.5. To renovate coordination efforts for all specific subjects of the dominant environmental problems:
  - X-Noise
  - FORUM-AE
  - CORE jet fuel

• 9.6. PM-emission should be included in goals like $\text{NO}_x$ and $\text{CO}_2$
Develop air vehicles of the future

Key element

Airframes
Propulsion
A/C level integration

Key element performance improvement

Drag reduction
Weight reduction
Noise Reduction

Key element improvement

High Aspect Ratio wings
Extended robust laminarity
Active adaptive wing
External noise management technologies

Optimized composite structures
Innovative structural architectures

Next gen materials

Technology
TRL5-TRL6

2020

TRL6
TRL8
TRL8

2030

TRL6
TRL8
TRL8

2040

TRL6

2050