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## WORKING PAPER

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### ASSEMBLY — 36TH SESSION

#### EXECUTIVE COMMITTEE

#### Agenda Item 17: Environmental protection

#### DEVELOPMENTS IN ICAO RELATED TO CIVIL AVIATION AND THE ENVIRONMENT

(Presented by the Council of ICAO)

##### EXECUTIVE SUMMARY

This paper reports on progress made by ICAO since the 35th Session of the Assembly on aircraft noise and engine emissions, including activities related to civil aviation and the environment carried out by the Secretariat, CAEP-related activities and main developments in cooperation with other UN bodies, in particular, the developments emanating from the United Nations Framework Convention on Climate Change (UNFCCC) process and the recent release of the International Panel of Climate Change (IPCC) 4th Assessment Report – *Climate Change 2007*.

<i>Strategic Objectives:</i>	This working paper relates to Strategic Objective C ( <i>Environmental Protection - Minimize the adverse effect of global civil aviation on the environment</i> ).
<i>Financial implications:</i>	No additional financial resources required.
<i>References:</i>	A36-WP/35, <i>Consolidated statement of continuing ICAO policies and practices related to environmental protection (Appendices B through G)</i> A36-WP/39, <i>ICAO Policy on Aviation Emissions</i>

## 1. INTRODUCTION

1.1 The Council is presenting three papers to the Assembly on environmental protection. This paper provides a progress report on the Organization's activities in this area, including those of the Committee on Aviation Environmental Protection (CAEP) and ICAO's relationship with other United Nations (UN) bodies. The two other environment-related papers cover the ICAO policy on aviation emissions including developments in the field of market-based measures (A36-WP/39) and proposed revisions to Assembly Resolution A35-5: *Consolidated statement of continuing ICAO policies and practices related to environmental protection* (A36-WP/35).

1.2 The Organization's environment-related activities continue to be undertaken by the Council largely through CAEP.<sup>1 2</sup> CAEP assists the Council in formulating new policies, and developing new Standards and Recommended Practices (SARPs) on aircraft noise and aircraft engine emissions. CAEP has the mandate to undertake specific studies, as approved by the Council, related to control of aircraft noise and gaseous emissions from aircraft engines.

1.3 The Committee has held one meeting (CAEP/7 in February 2007) since the 35th Session of the Assembly (Doc 9886, *Report of the Seventh Meeting of the Committee on Aviation Environmental Protection*). CAEP has continued to pursue its work programme between formal meetings through working groups, focal points and annual meetings of its Steering Group to coordinate activities.

1.4 During the 14th and 15th meetings of its 180th session, in March 2007, the Council reviewed and approved with comments the recommendations from CAEP/7 including the proposals for amendments to Annex 16 — *Environmental Protection*, Volume I — *Aircraft Noise*, and Volume II — *Aircraft Engine Emissions*. The amendments were of a detailed technical nature aimed at updating and improving certification procedures. A State letter on the proposed amendments was sent on 25 May 2007 for comments by States and international organizations. Adoption of the new SARPs is expected by 20 November 2008.

1.5 Appendix A provides an overview of the technological developments in aircraft noise and aircraft engine emissions that have produced substantial environmental benefits during the last 40 years under the leadership of ICAO.

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<sup>1</sup> CAEP is currently composed of Members from 22 Contracting States and Observers from 12 Organizations and States.

**CAEP Members:** Argentina, Australia, Brazil, Canada, China, Egypt, France, Germany, India, Italy, Japan, Netherlands, Poland, Russian Federation, Singapore, South Africa, Spain, Sweden, Switzerland, Tunisia, United Kingdom and United States.

**CAEP Observers:** Greece, Norway, Arab Civil Aviation Commission (ACAC), Airports Council International (ACI), European Commission (EC), International Air Transport Association (IATA), International Business Aviation Council (IBAC), International Co-ordinating Council of Aerospace Industries Associations (ICCAIA), International Federation of Air Line Pilots Associations (IFALPA), International Coalition for Sustainable Aviation (ICSA), United Nations Framework Convention on Climate Change (UNFCCC) and World Meteorological Organization (WMO).

<sup>2</sup> China joined CAEP in June 2007.

## **2. AIRCRAFT NOISE**

### **2.1 The balanced approach to noise management**

2.1.1 The objective of the balanced approach is to reduce the impact of aircraft noise through a programme which takes into account the balance of four elements comprising: (1) the reduction of noise at source; (2) land-use planning and management; (3) noise abatement operational procedures; and (4) operating restrictions on aircraft use (see paragraph 2.6.1). The goal is to achieve maximum environmental benefits as cost-effectively as possible. The process of implementing such a programme and the balance between the elements would be the responsibility of Contracting States.

2.1.2 The 35th Session of the Assembly (A35-5, Appendix C) reinforced this concept and urged States to adopt a balanced approach to noise management, taking full account of ICAO guidance (*Guidance on the Balanced Approach to Aircraft Noise Management* (Doc 9829)) when addressing noise problems at their international airports. It had also been suggested that strategies for addressing “people issues”, airport case studies and encroachment analysis be incorporated into the Guidance Material on the Balanced Approach. All three of these actions have been addressed; however, further study related to the encroachment analysis was necessary and consequently the update only incorporates the first two issues. Information on the concept of the balanced approach has been made available for dissemination through a standard ICAO presentation.

### **2.2 Reduction of aircraft noise at source**

2.2.1 No new standards for aircraft noise were proposed at CAEP/7. Additional technical information for the *Environmental Technical Manual on the use of Procedures in the Noise Certification of Aircraft* (Doc 9501) was developed and the document will be updated accordingly [paragraph 1.4 refers].

2.2.2 During CAEP/7, an analysis of the correlation of noise levels around airports arising from day-to-day operations and noise certification levels was completed. This analysis was prepared based on data taken from various airports from different regions of the world. The study concludes that overall there was a reasonably high degree of correlation between noise certification levels and operational noise levels. The study also concluded there was no compelling need to change the current certification scheme.

2.2.3 Three Noise Certification Workshops were held in Montreal, Canada, 20-21 October 2004), Rio de Janeiro, Brazil (9 August 2005), and Bangkok, Thailand, (6-7 November 2006). These workshops were intended to enhance States’ certificating authorities awareness of current SARPs, associated guidance material related to aircraft noise certification, and re-certification of aircraft, promotion of harmonized noise certification procedures, etc.

### **2.3 Operational measures**

2.3.1 CAEP has developed guidance material providing general information on the assessment of noise and emissions (NO<sub>x</sub> and CO<sub>2</sub>) benefits accrued from the implementation of optimized noise abatement procedures that will be published as an ICAO circular.

## **2.4 Land-use planning and management**

2.4.1 An updated edition of the *Airport Planning Manual, Part 2 — Land Use and Environmental Control* (Doc 9184) will soon be published. The revised document provides recommended land-use planning guidelines and environmental protection practices applicable at airports, as well as examples of land-use planning techniques from various States.

## **2.5 Recommended methods for computing noise contours around airports manual**

2.5.1 A new guidance material on recommended methods for computing noise contours around airports has replaced Circular 205.

2.5.2 Overall, this new guidance represents a major advance in three important respects. Firstly, it provides much-needed guidance on the practical implementation of aircraft noise contour modelling, especially regarding the crucial importance of correctly representing aircraft types and their operating configurations and procedures. Secondly, it fully describes up-to-date algorithms that incorporate the latest internationally-agreed advances in modelling. Finally, the methodology was supported by an on-line, industry-backed, international aircraft noise and performance (ANP) database and could be applied to any airport scenario.

## **2.6 Operating restrictions: aircraft noise curfew study**

2.6.1 The issue of curfews was raised during the 35th Session of the ICAO Assembly. As a result, CAEP was charged with a remit to study the problem. CAEP prepared a study to address curfews focused on the scope and scale of the curfew problem. The study was limited to review of curfews, examining the types of curfew, the reasons for curfews and their global scope and scale.<sup>3</sup> In this context, the scale of the study had been understood as the number of airports that apply curfews, and the scope as the type of restriction (partial or total). A global curfew is one which bans all flights during a specific time period. A partial curfew prohibits the operation of specific aircraft types, or prevents the use of specific runways or only affects landings or take-offs. Curfews normally apply only at night, e.g. from 2300 hr to 0700 hr. The next step includes estimating the environmental impact of curfews on destination countries with a case-study for a major airport.

## **3. AIRCRAFT ENGINE EMISSIONS**

### **3.1 General**

3.1.1 The organization continued to address emissions under three approaches: the reduction of emissions at source (technology), operational measures and market-based measures to reduce emissions. The Organization also continued to cooperate with main technical and scientific bodies and organizations to advance its understanding of the impact of aviation on local air quality and global climate.

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<sup>3</sup> The study, which represented a “snapshot in time” of the curfew situation at the airports it covered, included an inventory of 227 airports with curfews, as extracted from the Boeing database at <http://www.boeing.com/commercial/noise/list.html>.

### **3.2 Relationships with other United Nations bodies concerning global effects of emissions**

3.2.1 Since the last Session of the Assembly, liaison has continued with other UN bodies, with a view to obtaining a better understanding of the environmental impact of aircraft engine emissions at a global level and to exploring policy options to limit or reduce emissions.

3.2.2 Liaison with UN policy-making bodies was primarily focussed on the UN Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC).

3.2.3 Regular reports have been made to the UNFCCC process regarding the work in progress within ICAO on limiting or reducing greenhouse gases (GHG) from aviation.<sup>4</sup> Since the last Session of the ICAO Assembly, the main development regarding the UNFCCC was the entering into force of the Kyoto Protocol (KP) in February 2005. Of main interest to aviation are the activities regarding its methodological issues, the implementation of the flexible mechanisms of the Protocol and the negotiations for the post Kyoto period in relation to Article 2.2 and the flexible mechanisms, in particular emissions trading and Clean Development Mechanisms (CDMs). These issues are addressed through the UNFCCC process under the Subsidiary Body for Scientific and Technological Advice (SBSTA). During CAEP/7, the UNFCCC provided assistance in the development of ICAO's new Guidance on Emissions Trading for Aviation, particularly in the areas of emissions inventory and geographic scope and more recently on the issue of CDMs.

3.2.4 Following a request from the UNFCCC, ICAO presented a report to the 22nd session of the SBSTA (SBSTA22), in May 2005, on the results of an aviation emissions and fuel consumption data comparison exercise, using data from aviation models made available to ICAO and inventory information from UNFCCC. Since ICAO presented its report at SBSTA22, there has been no further progress on the discussion in that forum regarding the methodological issues related to emissions from fuel used for international aviation. However, cooperative dialogue and exchange of information between the UNFCCC and ICAO continues.

3.2.5 Most of the cooperation activities with the IPCC, pertaining to limiting or reducing GHG, was related to the preparation of the Fourth Assessment Report (AR4) and of the 2006 Guidelines for National Greenhouse Gas Inventories (2006 Guidelines). ICAO requested that AR4 include an update of the main findings of the 1999 Special Report, in particular on the key areas of scientific uncertainty identified (e.g. the influence of contrails and aerosols on cirrus clouds). A summary of the findings of the IPCC AR4 related to aviation is shown in Appendix B to this paper.<sup>5</sup> Regarding the 2006 Guidelines, in 2002, the IPCC was invited to update its Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and the Good Practice Guidance. ICAO cooperated on this work with the IPCC - National Greenhouse Gas Inventory Programme (NGGIP) Secretariat by providing the necessary expertise and support for the development and refinement of a methodology for the calculation of aviation emissions.

3.2.6 ICAO has also worked with the World Meteorological Organization, World Health Organization and the Montreal Protocol on matters of interest and participated in meetings at the Commission on Sustainable Development.

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<sup>4</sup> Statements can be found at <http://www.icao.int/env/statements.htm>.

<sup>5</sup> Complete information on the 4AR, WG1 and WGIII, can be found at <http://www.ipcc.ch>.

### 3.3 Reduction of aircraft emissions at source

3.3.1 CAEP/7 did not make any recommended changes in the stringency of emissions Standards in Annex 16, Volume II — *Aircraft Engine Emissions* [paragraph 1.4 refers]. However, work is underway to determine the feasibility of lowering NO<sub>x</sub> Standards for aircraft engine emissions below the current levels. Nonetheless, work has been completed on establishing mid-term (MT, 2016) and long-term (LT, 2026) technology goals for NO<sub>x</sub> reduction to help CAEP in its future standard-setting activities and to assist engine manufacturers in their planning. The MT goal is – 45% (±2.5%) and LT goal is – 60% (±5%), respectively, of the CAEP/6 stringency level at pressure ratios of 30. The Committee is working to establish technology goals for noise and fuel-burn by 2010.

### 3.4 Operational measures

3.4.1 Operational measures and in particular ATM initiatives have the potential of saving substantial emissions.

3.4.2 In response to a request from the ALLPIRG 5 meeting in March 2006, CAEP experts produced an updated paper on issues concerning environmental benefits of CNS/ATM systems at the global and regional levels. It set out the possible development of simplified tools and associated guidance for estimating environmental benefits of CNS/ATM systems at the national level and provided initial “rules of thumb” for the conversion of savings in fuel into environmental benefits and estimates of savings accrued from the implementation of specific measures such as reduced vertical separation minimum (RVSM). Further development of models will continue to be necessary for the complete assessment of CNS/ATM environmental benefits. CAEP is currently analyzing these models and the environmental-related information contained in the *Global Air Navigation Plan for CNS/ATM* (Doc 9750) will be updated accordingly.

3.4.3 CAEP prepared a report on the assessment of noise and emissions reductions accrued from the use of Continuous Descent Approaches (CDAs). The report revealed that Global CDA assessment is difficult because of the variation in existing CDA concepts leading to the local proliferation of differing CDA practice. CDA trial results, however, generally showed significant noise, fuel-use and emissions benefits. The report recommends that a harmonised CDA concept and definition are now required to ensure best practice replication and to control proliferation of local CDA rules. CDA and other operational measures (such as CNS/ATM and NADP<sup>6</sup>) will undergo further refinement and testing during CAEP/8.

3.4.4 Since CAEP/7, a group in the ICAO Secretariat, with the support of CAEP and the PIRGs, has started to develop a programme to establish potential fuel-burn/emissions reduction objectives to be achieved in various ICAO regions in the upcoming years. ICAO was in the forefront of the implementation of RVSM in the NAT Region (March 1997), followed by the following: Asia/PAC (Feb. 2000), Australia/WATRS (Nov. 2001), EURSAM Corridor/Europe (Jan. 2002), Western Pacific/South China Sea (Feb. 2002), North of Canada (April 2002), Mid East/Asia/South of Himalayas (Nov. 2003), CARSAM/Domestic US/South of Canada (Jan. 2005) and Japan/Korea (Sept. 2005). ICAO is now coordinating plans for the implementation of RVSM in China (Nov. 2007), AFI Region (June 2009) and Russia (2010). The result will be the global implementation of RVSM in 2010, with all the benefits the application of the new separation minima can bring to the efficiency of operations and the environment.

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<sup>6</sup> Noise Abatement Departure Procedures (NADP)

3.4.5 The third Workshop on Aviation Operational Measures for Fuel and Emissions Reduction was co-organised by ICAO and Transport Canada on 20 and 21 September 2006 in Montreal.<sup>7</sup>

3.4.6 The ICAO Emissions Plan is currently in preparation by the Secretariat with assistance from CAEP. This plan will address a basket of options for limiting or reducing aircraft emissions.

### 3.5 Market-based measures

3.5.1 The Organization's activities related to market-based measures to limit or reduce emissions are described in detail in A36-WP/39, *ICAO Policy on Aviation Emissions*.

## 4. MODELLING ACTIVITIES

### 4.1 Activities since the last Assembly

4.1.1 The last Assembly requested that the Council regularly assess the present and future impact of aircraft noise and engine emissions and to continue to develop tools for this purpose. Regarding the assessment of aircraft noise, some experience existed and the appropriate tools had already been validated to that end. This work was presented to the 35th Session of the ICAO Assembly. However, there were no similar experiences with the assessment of the impact of aircraft emissions on local air quality and global climate or on the inter-dependencies between these parameters. Substantial work has been undertaken by CAEP to identify appropriate models made available by States for estimating emissions and related inter-dependencies. In consequence, what was feasible to be achieved by CAEP/7 was the development of trends using different models under the same assumptions. A more detailed discussion of the progress of noise and emissions trends and related models during CAEP/7 is shown in Appendix C.

## 5. ICAO ENVIRONMENTAL PUBLICATIONS

5.1 CAEP/7 has produced valuable studies and developed substantial guidance material in the field of aircraft noise and aircraft engine emissions. A detailed listing of ICAO's publications in this field is shown in Appendix D.

## 6. RECENT ICAO ENVIRONMENTAL DEVELOPMENTS

6.1 ICAO held a Colloquium on Aviation Emissions from 14 to 16 May 2007 in Montreal. The Colloquium provided a forum on aviation emissions, in particular on related developments emanating from CAEP/7. The Colloquium covered such areas of aviation emissions as "The Nature of the Problem, Assessing the Magnitude of the Problem, Local Air Quality Mitigation Measures, and Global Climate Mitigation Measures". This was a timely event that sought and shared information on the work on emissions with the view to facilitate environmental-related discussions and high-level decision making at this 36th Session of the ICAO Assembly in September 2007. The Colloquium attracted representatives of

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<sup>7</sup> More information on this workshop is available at <http://www.icao.int/icao/en/env/WorkshopFuelEmissions/Index.html>.

ICAO's Contracting States, aviation industries, international organizations and academic/research institutions.<sup>8</sup>

6.2 ICAO's first Environmental Report is expected by August/September 2007. This new document functions as ICAO's periodic status report and authoritative reference on aviation and the environment. It provides a comprehensive account of the work of CAEP, including synthesis of key developments that emerged from CAEP/7. In addition, it provides an effective mechanism to acknowledge and publicise the work of the CAEP experts, aviation industry and academia. The environmental report will be made available on the ICAO website.

## **7. ICAO ENVIRONMENTAL UNIT SUPPORT**

7.1 Environmental Protection is one of the strategic objectives of ICAO and one of the main challenges of the Organization for the upcoming years. The importance and complexity of aviation environmental issues have increased substantially in the last years.

7.2 In order to adequately staff the Environmental Unit of the ICAO Secretariat, States and international organizations were invited to nominate experts on an extra-budgetary basis to assist the Secretariat. Two officers are currently working through secondment to the Environmental Unit. The Secretariat extends its thanks to those States that have provided personnel support and extends an invitation to other States and International Organizations to provide further support.

## **8. CONCLUSION**

8.1 In order to attain the objective of minimizing the adverse effects of global civil aviation on the environment, ICAO and its stakeholders must find an appropriate balance between the future growth of air transport and the quality of the environment.

8.2 Information is key to meeting this environmental challenge. Agreed and accurately characterized scientific and technical data is essential to developing forward-looking solutions. Precise technical information on aviation emissions and their impact on local air quality and global climate must form the basis of all measures. ICAO, as the main source of information on aviation emissions and noise, will continue to cooperate with the IPCC, UNFCCC, UNEP, WMO and other relevant bodies to further develop its understanding of aviation emissions and the environmental impact of noise, and must disseminate this information accordingly.

8.3 As the global forum for pursuing aviation environmental issues, ICAO brings together the best technical expertise, viewpoints of Member States, representatives from the aviation and aerospace industries and environmental Non-Governmental Organizations (NGOs). This valuable process ensures that the latest developments (e.g. new fuels research and development), findings and trends are considered in ICAO's deliberations on how best to address aviation's environmental impacts. As we move forward into CAEP/8 (and beyond), ICAO must emphasize its role and provide wider information and guidance in order to facilitate actions by States and the aviation industry. Main challenges are

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<sup>8</sup> All documentation from the Colloquium (video with feature presentations and background material) is available at <http://www.icao.int/env/clq/clq07/>



expected to be in the area of global aviation emissions and the necessary mitigation measures need to be agreed with a view to addressing this issue.

8.4 Recognizing the many past environmental accomplishments of ICAO, there remains much more work ahead. As ICAO goes ahead in this new millennium, it will be confronted with many emerging environmental challenges from aviation. Effective actions must be taken by ICAO to ensure that adequate solutions are adopted to meet these new challenges in a timely and cost-effective manner.

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## APPENDIX A

### ICAO'S CAEP

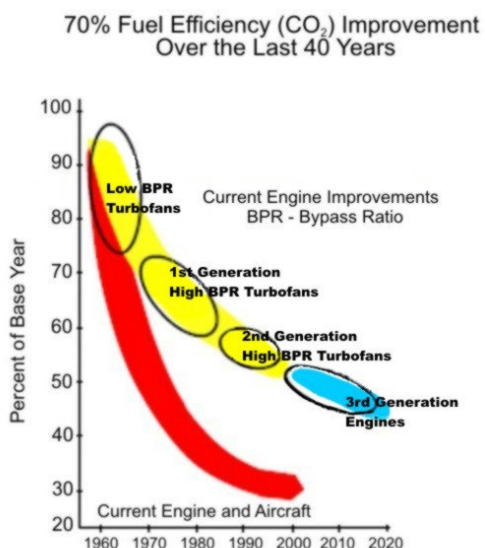
#### KEY ENVIRONMENTAL ACCOMPLISHMENTS

This Appendix addresses technological developments in aircraft noise and aircraft engine emissions under the leadership of ICAO.

#### Emissions Technology and Standards

With constant improvements in fuel efficiency from technological innovations, carbon dioxide emissions from aviation are growing at a slower rate than air traffic. Today's modern large transport aircraft are 70% more efficient than they were 40 years ago, as shown in Figure 1. Improvement in engine fuel efficiency has come mainly from the use of modern high-bypass engine technology that relies on increasing engine pressure ratios and higher temperature combustors as a means of increasing engine efficiency.

Figure 1 shows the fuel efficiency improvement trends in large commercial aircraft resulting from innovations in airframe and engine designs from the early 1960s until today. The lower line represents the efficiency of current engine and aircraft in service. The rings on the upper line represent incremental improvements in aircraft engine technology, starting with the low bypass ratio turbofans in the early 1960s (which included aircraft such as the B-707s, DC-8s, etc.) to the latest large commercial aircraft (such as the B-777s, B-787s and A-380s).

**Low BPR Turbofans:**

*Includes early B-707s, B-727s, DC-8s with JT3D and JT8D engine.*

**1st Generation High BPR Turbofans:**

*Includes early B-747s and DC-10s.*

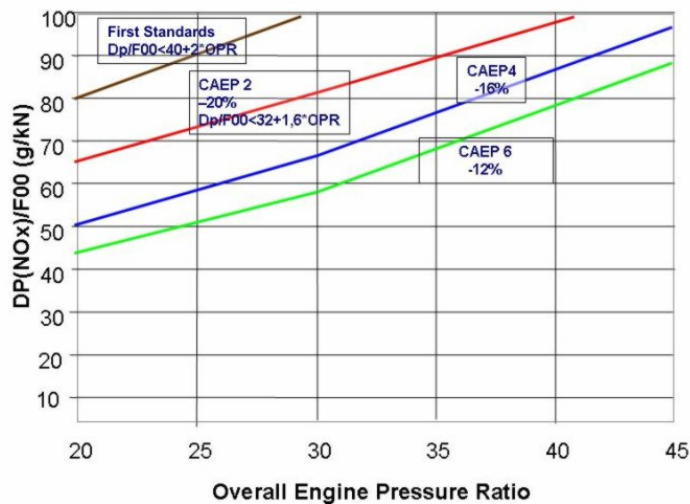
**2nd Generation High BPR Turbofans:**

*Includes late B-747s, all A-300s, 310s, and 320s, and nearly all A-330s and 340s.*

**3rd Generation Engines:**

*Includes late series of B-777s and the new A-380s and B-787s.*

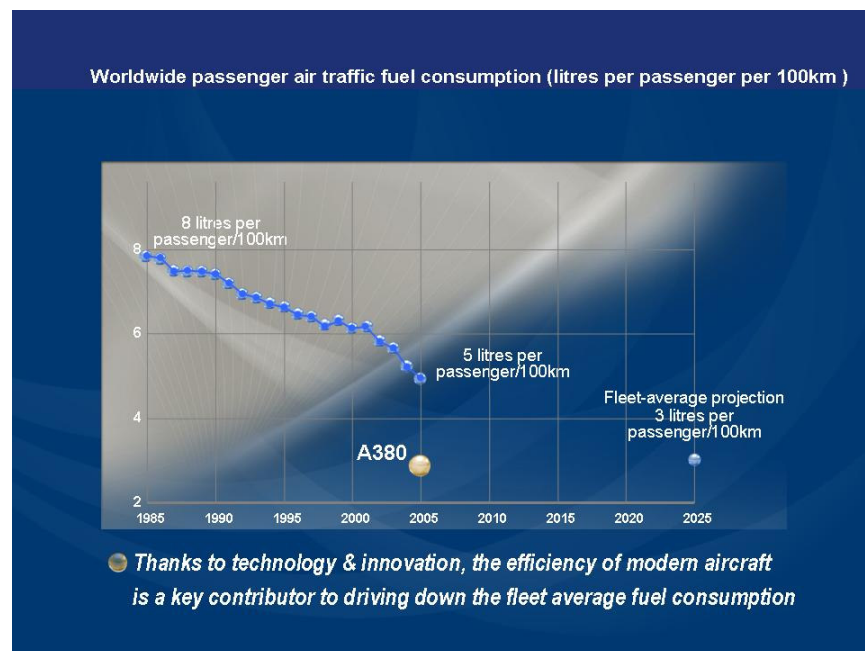
**Figure 1 – Fuel Efficiency Trends by Generation of Engine**  
Source: Boeing



There has been a notable reduction in NO<sub>x</sub> stringency of about 40 percent beyond the original ICAO standard for NO<sub>x</sub> adopted in 1981 (applicable in 1986), as shown in Figure 2. Although NO<sub>x</sub> Standards were initially intended to address local air quality, they also contribute to reduce the impact of aviation on climate, as NO<sub>x</sub> may be a precursor of ozone formation.

Figure 2 – ICAO NO<sub>x</sub> Emissions Stringency Trends Source: ICAO.

Successful initiatives have led to substantive reductions in terms of worldwide passenger air traffic fuel consumption (litres per passenger per 100 kms). Aircraft in the 1970s consumed about 12 litres of fuel to carry one passenger over a distance of 100 kilometres. Figure 3 illustrates technological improvements in the world passenger fleet. It averaged 8 litres per passenger/100km in 1985, 5 litres per passenger/100 km in 2005, and is projected to 3 litres per passenger/100km in 2025. The A-380 has a fuel efficiency of 2.9 litres in 2005 (20 years ahead of the projected fuel efficiency average for the world fleet).

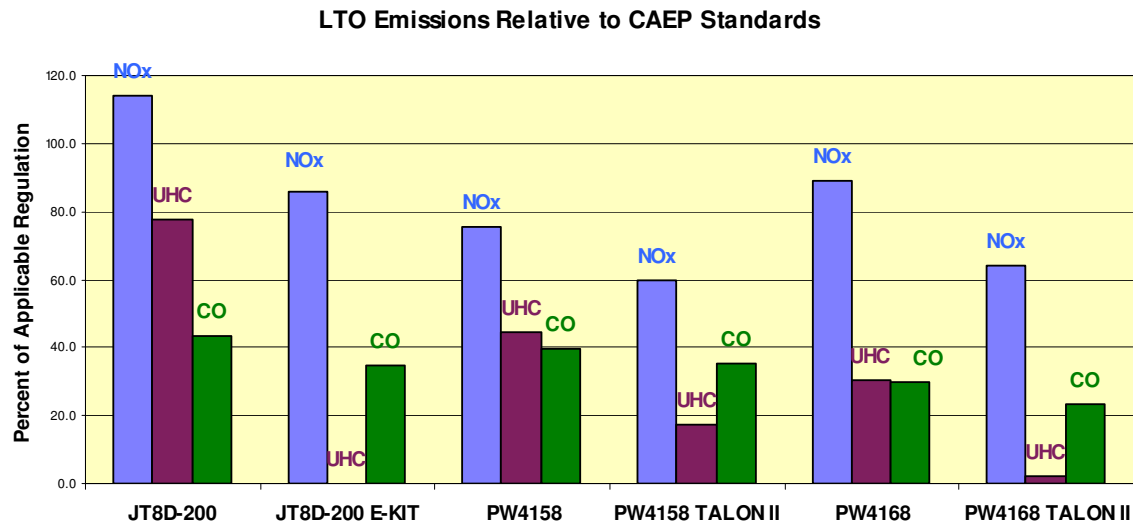


This is comparable to the level of fuel efficiency for a mid-sized diesel car. Further, as the result of its fuel efficiency, the A-380 generates CO<sub>2</sub> emissions as low as 80g per passenger kilometre. Current regulatory proposals for the car industry aim at 140g of CO<sub>2</sub> per kilometre in 2009 and 120g in 2012. Boeing's new B-787 Dreamliner aircraft is estimated to be 20 percent more fuel efficient than the B-767 and A330.

Figure 3 - Changes in Aircraft Fuel Efficiency Source: Airbus.

The introduction of ICAO Standards have contributed to the introduction of new technologies in the in-service fleet and to substantial reductions of NO<sub>x</sub>, HC and CO.

Figure 4 shows these examples of relative reductions in emissions levels from landings and take-off (LTO) before and after implementation of ICAO's CAEP Standards. For example, in the first comparison from left to right for the Pratt & Whitney JT8D-200 engines, emissions levels for NO<sub>x</sub>, UHC, and CO are at their highest. However, after compliance with ICAO's Standards from P & W JT8D-200 E-Kit, the overall levels of emissions dropped significantly. In fact, unburned hydrocarbons have been virtually eliminated. Similar examples exist for aircraft engines from other manufacturers.



**Figure 4 – Relative Reductions in Pollutants from Aviation by Engine Type** Source: Pratt & Whitney.

### Noise Technology and Standards

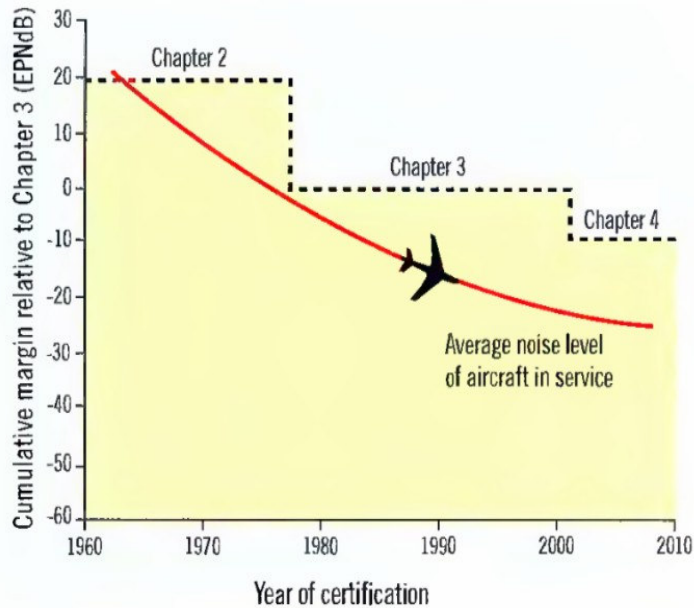
ICAO continues to develop ways to reach lower noise levels through collaboration with its stakeholders. This collaborative process, combined with emphasis on noise reduction technology and development of high bypass-ratio turbofan engines, have produced significantly quieter airplanes since the introduction of the jet age in the 1960s.

Noise produced by aircraft cannot be entirely avoided. Under the guidance of ICAO, the aviation industry was able to decouple the growth of aviation from its noise emissions thereby reducing the noise around airports to acceptable levels.

The noise levels of today's new technology airplanes are a total of 50 decibels (dB) quieter than those of the first generation of jet airplanes, as shown in Figure 5. This corresponds, in practice, to a reduction in noise annoyance of 75%, while air traffic has increased five-fold for the same period. Significantly greater improvements in noise technology were achieved by the new Airbus 380-series jumbo transport jet. Boeing's new Dreamliner aircraft (B-787) is also expected to deliver (see Figure 7) significant improvements in noise. The new B787 is about 15 to 20 dB below the Chapter 4 noise limits, and therefore at least 10dB better than the airplanes (e.g. B-767) it replaces.

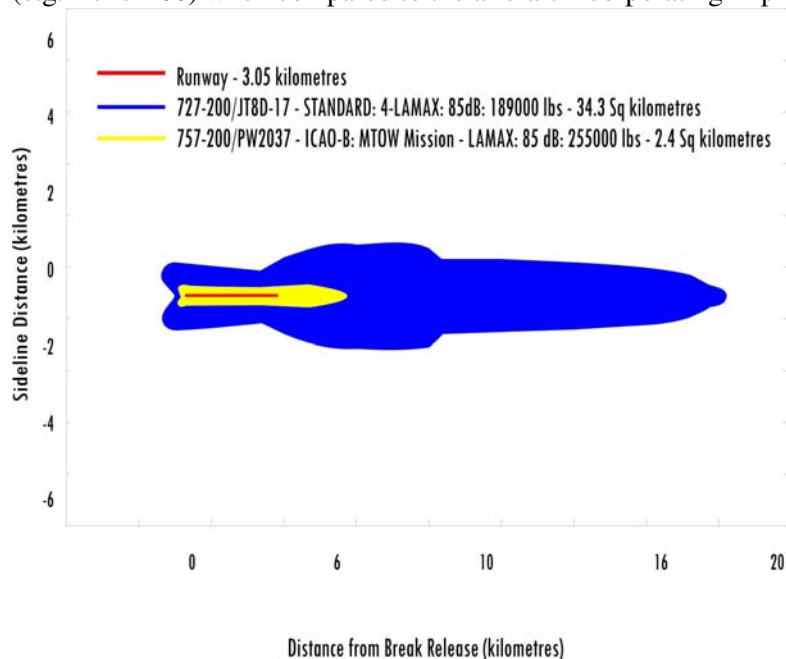
## Noise at Source

Figure 5 illustrates improvements in the average noise level of aircraft in service through technological innovations over the past 40 years from Chapter 2 to Chapter 4 aircraft noise standards.



**Figure 5 – An Illustration of Aircraft Noise Trends by Chapter**  
Source: ICAO.

Figure 6 shows the differences in departure noise footprints between older Chapter 2 (aircraft e.g. B727-200) when compared to the aircraft incorporating improved technology (B-757-200). Although these are not the most recent aircraft available on the market, this example clearly demonstrates the progress made with respect to aircraft noise over the past 20 years under ICAO's leadership and collaboration with the global aviation community.



**Figure 6 – Departure Noise Footprints Comparison** Source: ICAO.

Figure 7 shows capacity growth without aircraft noise increase. This figure compares two types of the A-340-series jets to the new A-380 jumbo transport. This comparison illustrates the significant

increases in carrying-capacity of the new A-380 (measured in tonnes), while registering reductions in aircraft noise. In fact, in one comparing example, the carrying-capacity doubled. Yet, the A-380 still generated reduced aircraft noise.

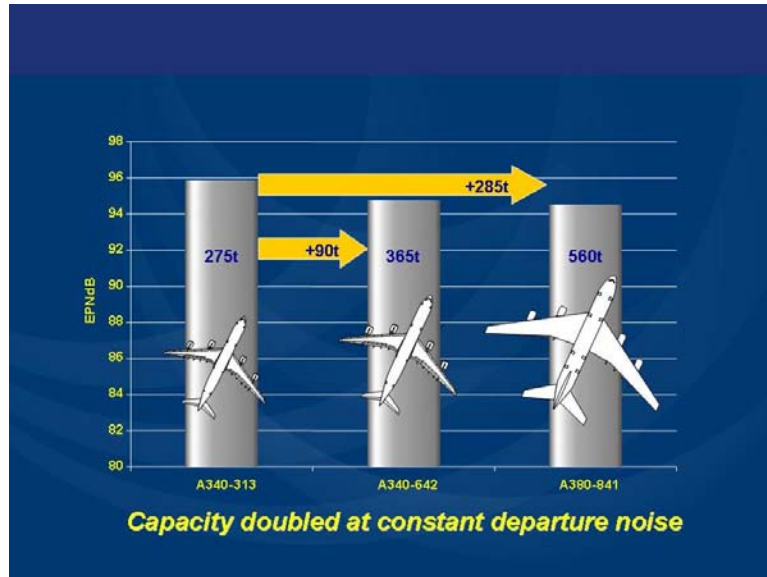


Figure 7 - Capacity growth without noise increase Source: Airbus.

## APPENDIX B

### SUMMARY OF THE FINDINGS OF THE IPCC AR4 RELATED TO AVIATION

#### 1. INTRODUCTION AND BACKGROUND

1.1 A comprehensive assessment of aviation's contribution to climate change is contained in the Special Report on Aviation and the Global Atmosphere, which was prepared at ICAO's request by the Intergovernmental Panel on Climate Change (IPCC) in collaboration with the Scientific Assessment Panel to the Montreal Protocol on Substances that Deplete the Ozone Layer and was published in 1999, and which reported *inter alia* that:

- Aircraft-emitted gases and particles which alter the atmosphere concentration of particles and gases, trigger the formation of condensation trails and may increase cirrus cloudiness, all of which contribute to climate change;
- Aircraft in 1992 were estimated to contribute about 3.5 percent of the total radiative forcing (a measure of change in climate) by all human activities and this percentage, which excludes the effects of possible changes in cirrus clouds, was projected to grow;
- Although improvements in aircraft and engine technology and the efficiency of the air traffic system will bring environmental benefits, they will not fully offset the effects of continued aviation emissions or the increases from the projected growth of aviation.

Although the IPCC special report recognized that the effects of some types of aircraft emissions are well understood, it reveals that the effects of others are not, and identifies a number of key areas of scientific uncertainty that limit the accuracy of projections of aviation impacts on climate and ozone.

#### 2. AR4 FINDINGS

2.1 Since publication of the IPCC special report, further work has been undertaken on some of the key areas of scientific uncertainty identified in the report, such as the influence of contrails and aerosols on cirrus clouds and the climate impact from oxides of nitrogen and methane. ICAO had requested that the IPCC include an update of the main findings of the special report in its Fourth Assessment Report (AR4) published in 2007. New findings related to aviation emissions<sup>1</sup> *inter alia* are the following:

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<sup>1</sup> More information on AR4 is available at <http://www.ipcc.ch>

- Due to developing scientific knowledge and more recent data, estimates of the climate effects of contrails have been lowered and aircraft in 2005 are now estimated to contribute about 3.0 percent of the total of the anthropogenic radiative forcing by all human activities;
- Total aviation CO<sub>2</sub> emissions is approximately 2 percent of Global Greenhouse Gases (GHG) emissions;
- The amount of CO<sub>2</sub> emissions from aviation is projected to grow around 3 to 4 percent per year; and
- Medium-term mitigation for CO<sub>2</sub> emissions from the aviation sector potentially can come from improved fuel efficiency. However, such improvements are expected to only partially offset the growth of aviation CO<sub>2</sub> emissions.

### 3. CONCLUSION

3.1 The IPCC international assessment process has significantly contributed to the evaluation of aviation effects. Increased cloudiness from persistent contrails and contrail cirrus is a consequence of global aviation operations and will remain so in the foreseeable future. The contrail contribution has been revised downward by about a factor of two from the 1999 IPCC assessment due to improved estimates of contrail cover and cloud radiative effects. Further work is underway to more fully characterise the climate forcing effects of aviation emissions. Contrail cirrus is an additional radiative forcing component, but currently has no best estimate and therefore has not been reliably quantified. Furthermore, aviation soot aerosol is expected to have increased the number of atmosphere particles in the upper atmosphere, which can potentially change cirrus cloud properties.

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## **APPENDIX C**

### **CAEP/7 MODELLING ACTIVITIES**

#### **1. INTRODUCTION**

1. The number of people exposed to significant noise levels is a consensual indicator for assessing the noise impact around airports. There is no accepted metric or modelling system for reporting the impact of aircraft on local air quality (LAQ) and global climate. For assessing trends to report on ICAO's environmental local air quality and global climate goals, CAEP/7 has carried out a model evaluation and used four models to make an initial evaluation of emission trends for greenhouse gases (GHG) and LAQ emissions. Work is still ongoing to evaluate these and other models, including multiple models for computing noise. This Appendix describes the main results of the initial trends assessment for noise and emissions based on the models currently under evaluation.

#### **2. COMMON ASSUMPTIONS IN DEVELOPING TRENDS**

2.1 In developing the trends, projections of future aircraft and CNS/ATM (communication navigation surveillance, air traffic management) technology developments, as well as any benefits resulting from other projected operational improvements were not considered to be sufficiently mature for inclusion in the assessment. As such, the assessment should be regarded as underestimating what aviation might be expected to achieve through continued technological and operational improvements. All trends were developed using the CAEP 2002 forecast.

#### **3. ASSESSMENT OF THE EVOLUTION OF AIRCRAFT NOISE**

3.1 Regarding the evolving concerns about noise exposure around airports, a revised noise trend was developed using the AEDT/MAGENTA model (Aviation Environmental Design Tool, Model for Assessing the Global Exposure to the Noise of Transport Aircraft). This model has been updated since the last Assembly, to reflect the latest international noise modelling standards.

3.2 Improvement in models (as used for the update to Circular 205) resulted in an increase in values presented. There is a change in the estimate of population affected by up to a 20% increase attributed to the updating of the AEDT/MAGENTA model in accordance with the latest international standards. This outcome becomes the new basis for comparison.

3.3 The results show an initial improvement in the situation with reduction in the size of the population affected by noise of about 30 percent in the short term (2006), relative to the 2000 level. This reduction in the noise exposure is generally consistent with those presented to the last session of the Assembly.

3.4 The global noise exposure levels were not forecast to reach the 2000 levels until 2020. In 2025, global noise exposure is projected to exceed the 2000 levels by up to 10 percent. Given the more

than doubling of traffic forecasted for this time period, this rather modest increase, can likely be attributed to the introduction of quieter, newer-technology aircraft into the future fleet combined with the retirement of older, noisier aircraft.

#### **4. ASSESSMENT OF THE EVOLUTION OF LOCAL EMISSIONS AND GREENHOUSE GASES**

4.1 The evolution of aircraft engine emissions were computed for CO<sub>2</sub> and NO<sub>x</sub> up to the year 2025. In order to fulfil the remit for assessing the progress towards the local air quality and greenhouse gas emissions goals, initial emissions trends were developed using four models: The AEDT/SAGE model (AEDT, System for Assessing Aviation's Global Emissions), AERO2k<sup>2</sup>, AEM (Advanced Emissions Model) and FAST (Future Aviation Scenario Tool).

4.2 Carbon dioxide (CO<sub>2</sub>) emissions are directly related to fuel burn. In 2002 the annual CO<sub>2</sub> emissions from aviation were close to 500 million tonnes, substantially lower than in 2000 due to the events of 9/11, the SARS epidemic and the economic downturn. Exact computed values were model-dependent. In the 3 years to the end of 2005, market recovery had resulted in an up to 13% rise in CO<sub>2</sub> emissions, exceeding the pre-9/11-SARS values by 2004. Year 2025 annual CO<sub>2</sub> emissions were estimated to be approximately 2.25 times higher than CO<sub>2</sub> emissions in 2005. Although the effect of future technology improvements has not been modelled, the overall aircraft efficiency in the fleet improves during this period due to replacement of older aircraft. The forecast also contains an increase in average fleet aircraft size. The result is a steady increase in annual CO<sub>2</sub> emissions from 2005 to 2025.

4.3 Regarding nitrogen oxide (NO<sub>x</sub>) emissions, annual emissions around 2.25 million tonnes were computed for 2002. For the three years to 2005, the modelling indicated a similar, perhaps slightly larger, percentage rise in NO<sub>x</sub> emissions than for CO<sub>2</sub>, probably resulting from the opposing influences of the replacement of older engines with more fuel efficient but higher NO<sub>x</sub> per unit thrust engines, resulting from the improved combustor technology in those newer engines. NO<sub>x</sub> emissions by 2025 were computed to be approximately 2.75 times the 2005 values, indicating how, for the current fleet, the absence of any improved technology beyond 2005 would be expected to result in the migration of the fleet to engines with higher NO<sub>x</sub> emissions per unit fuel. The benefit of the introduction of future improvements in technology has not been modelled. Regarding NO<sub>x</sub> emissions in the environs of airports, these emissions are sensitive to operational and other local assumptions for each airport which are not fully captured in the global scale modelling undertaken. Depending upon the operational assumptions used, NO<sub>x</sub> emissions below 3000 ft comprised between 7 and 12% of the total annual NO<sub>x</sub> emissions from aircraft. For the period from 2005 to 2025, computed future NO<sub>x</sub> emissions below 3000 ft, showed slightly smaller increases compared with the increases in total NO<sub>x</sub> emissions, likely due to fleet mix and stage length changes within the traffic and fleet forecast.

4.4 In contrast to CO<sub>2</sub> and NO<sub>x</sub>, a larger proportion of total flight carbon monoxide (CO) and hydrocarbons (HC) is emitted below 3000 ft. However, emissions of CO and HC generally remain at low levels relative to air quality concerns. All models show an increase from 2002 to 2005 although the individual modelled values varied significantly. Increases in HC and CO emissions below 3000 ft over the 20 year period from 2005 to 2025 were computed to be considerably less than the increase in traffic and fuel used. One important factor here is that more recent engines have significantly lower CO and HC

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<sup>2</sup> The AERO2K project, which was financed by the European Commission, is global 4D inventory of fuel usage and emissions of pollutants (NO<sub>x</sub>, CO, HCs, CO<sub>2</sub>, particles) relevant to aircraft impacts on the upper atmosphere. It was created to deliver data required for European and international policy development and future assessments of aircraft impacts on climate.

emissions levels per unit thrust and the retirement of older-technology engines during the period of the forecast can significantly reduce forecast CO and HC emissions.

4.5           It is re-emphasized that in the *initial* emissions trends indicated above, projections of future aircraft and CNS/ATM technology developments, as well as any benefits resulting from projected operational improvements were not considered to be sufficiently mature for inclusion in this assessment. As such, the assessment should be regarded as underestimating that which aviation might be expected to be able to achieve through continued technological and operational improvements over the forecast examined.

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## **APPENDIX D**

### **LISTING OF CAEP/7 STUDIES AND GUIDANCE MATERIAL**

This Appendix contains a listing of studies and guidance material on aircraft noise and aircraft engine emissions. ICAO's non-saleable publications developed by CAEP/7 are accessible on the ICAO public website.

#### **1. NOISE**

- Annex 16 to the Convention on International Civil Aviation — Environmental Protection, Volume I — Aircraft Noise
- Airport Planning Manual Part 2 — Land Use and Environmental Control (Doc 9184)
- Manual on Recommended Method for Computing Noise Contours around Airports (New)
- Environmental Technical Manual on the Use of Procedures in the Noise Certification of Aircraft (Doc 9501)
- Guidance on the Balanced Approach to Aircraft Noise Management (Doc 9829) (Revised edition)
- Balanced Approach Generic Presentation (New - web only)

#### **2. EMISSIONS**

- Annex 16 to the Convention on International Civil Aviation — Environmental Protection, Volume II — Aircraft Engine Emissions
- Guidance on Aircraft Emission Charges Related to Local Air Quality (Doc 9884) (New)
- Draft Guidance on the use of Emissions Trading for Aviation (Doc 9885) (New)
- Report on the Independent Experts NO<sub>x</sub> Review and the Establishment of Medium and Long Term Technology Goals for NO<sub>x</sub> (Doc 9887) (New)
- ICAO's Policies on Charges for Airports and Air Navigation Services (Doc 9082) (Revised edition)
- Long Term Technology Goals for NO<sub>x</sub> Presentation (New - web only)
- Airport Air Quality Guidance Manual. Preliminary edition 2007 (Doc 9889) (New - web only)
- Guidelines on the use of Procedures in the Emissions Certification of Aircraft Engines (New - web only)
- Report on Voluntary Emissions Trading for Aviation (VETS report) (New - web only)
- Collected Voluntary Activities Against Global Warming (New - web only)

#### **3. OPERATIONS**

- Global Air Navigation Plan for CNS/ATM Systems (Doc 9750)
- ICAO Circular on NADP Noise and Emissions Effects (New)

- Review of Noise Abatement Procedure Research and Development and Implementation Results (New - web only)

4. **OTHER**

- Report of the Seventh Meeting of the Committee on Aviation Environmental Protection (Doc 9886) (New)

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