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Final Study

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ABSTRACT

This report summarises policy options and provides background information relevant to the impact of aviation on the environment and on human health. The report focuses on the impacts judged to be most significant and has been carried out through a combination of literature survey (reviewed literature and available grey literature), interviews with individuals from key European organisations involved in aviation, environment, or aviation medicine, and internet research.

The impacts surveyed are aircraft noise, aircraft engine emissions (especially their impact on climate), resource use, and human health impacts from cosmic radiation, cabin air quality (pathogens, volatile organic compounds), and deep vein thrombosis. Policy options are identified where appropriate and the background information required to understand the options is provided and notes on broader issues are included.

The key issues currently relate to (1) the next round of agreements on aircraft noise ("chapter 4 aircraft"), (2) the steps to be taken to include aviation in the steps to stabilise emissions of carbon dioxide (because of their role in climate change), and (3) concerns about passenger health. Of these, the noise agreements are closest to being finalised, the climate change concerns are important but are further from agreement, and the current consensus is that there is little evidence to justify serious concern over passenger health although airlines could improve their practices.

The report includes an extensive list of sources which can be consulted for further information.

EXECUTIVE SUMMARY

Air travel is a growth industry. In terms of passenger kilometres travelled, world growth is projected at around 5 percent per year to 2015. As air traffic grows so then does aviation's overall impact upon the environment. These environmental and health effects have wide ranging implications at the local, regional, and global levels. This report identifies the main options for reducing these direct impacts, which are summarised and discussed below.

The impacts considered are those judged to be the most significant; specifically the environmental issues of noise, emissions and resource use and the health issues of deep vein thrombosis, cosmic radiation, and cabin air quality.

EU Aircraft Noise Policy Options

With the number of aircraft movements expected to increase for the foreseeable future, noise around airports will also continue to increase, unless quieter aircraft can be introduced and noisier ones phased out.

Noise standards for new aircraft have in the past been agreed through the International Civil Aviation Organisation (ICAO), but the most recent agreement (the so-called *Chapter 3*) standards were introduced over 23 years ago.

Chapter 2 aircraft will be phased out by the end of March 2002 in the EU, and by January 2001 in the USA, but these aircraft are now approaching 25-30 years old, are at the end of their economic life, and would in any case be phased out of most airline operations. Exemptions are agreed for some extension beyond these dates for, for example, airlines from developing countries. On the other hand, some EU airports are introducing total bans on *Chapter 2* aircraft, at least at night, before the dates shown above.

Proposals have recently been finalised by the fifth meeting of ICAO’s Committee on Aviation Environmental Protection (CAEP/5) steering group for stricter *Chapter 4* standards. CAEP/5 proposed a Chapter 4 standard which would require new aircraft to be 10dB quieter than existing standards from 2006. However, this still has to be agreed at the ICAO Assembly in September/October 2001. The recommendations would then need to be implemented by member states.

The airports association (ACI) has strongly criticised the proposals, largely because the majority of existing Chapter 3 aircraft will meet the new standards, and thus the onus will be on airports to introduce stricter limits themselves. In order to prevent a proliferation of local measures, CAEP/5 and the European Commission will try to develop guidelines for application globally or within the EU.

Airlines have also been encouraged to operate in such a way that fewer people are affected by noise, and fines have been imposed on aircraft deviating from track or exceeding prescribed noise levels. Continuous descent approaches can also be used to reduce noise at off-peak periods, while land use planning is also important to keep noise-sensitive uses well away from airports and flight paths.

Resource use

Air travel consumes a number of the earth's scarce resources. However, the most significant is aviation's use of fossil-based, non-renewable fuels. Over 130 terragrams of fuel was consumed by all forms of aviation in 1992 and this is projected to more than double to over 272 Tg by 2015[1]. The amount of fuel used by the aviation sector represents about 3 percent of the total global fossil fuels consumption[2]. In 1997 some 211 million tonnes of aviation fuels were produced[3] representing 6.3 percent of the total share of refinery products compared with 24.5 percent for automotive fuels. Impacts on land-use from air travel is considered applicable only to the start and end of the journey. Therefore, the provision of airport infrastructure can be considered a low demand for land, unlike surface transport systems.

Emissions

The effects from aircraft exhaust emissions are seen as a direct contribution to the mechanisms of climate change. The most significant pollutants are carbon dioxide, nitrous oxides, and water vapour. Although, the overall contribution from air transport is much less than other anthropogenic sources of pollution, significantly aircraft emissions are introduced to sensitive regions of the atmosphere at cruise altitude. The emissions contribute to climate change.

Economic or market based measures for ICAO to consider are:

- taxes on fuel collected through suppliers
- taxes on fuel collected together with existing en-route charges

These could be revenue neutral to avoid revenue distribution problems. Emissions trading is also an option that was proposed.

Regulatory action may also be necessary to prevent sales of new engines that do not meet the already agreed CAEP/4 emission standards. Work should also be intensified on developing new standards.

Inter-modal transport could also be encouraged, and replacing some short-haul flights by other, more environmentally friendly, modes of transport. In the longer term, research should be undertaken to reduce future aircraft engine emissions, for example through the use of biofuels, or non-carbon fuels.

The encouragement of tele- and video-conferencing would also help reduce air travel demand, but this might be left to market forces, as costs decline further.

<u>Health impact of aviation: Deep Vein Thrombosis (DVT)</u>

A recent case of the death of one passenger from DVT related causes (pulmonary embolism) soon after a flight from Australia to London has led to a large increase in press comment, especially in the UK. Much of this comment has been misleading with

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[1] IPCC (1999) 'Aviation and the global atmosphere', Cambridge University Press, UK., p303
[2] IATA/ATAG (1999) 'Aviation and the environment', Switzerland., p13
[3] International Energy Agency (1999) 'Key world energy statistics', IEA Publications, London.

regard to information on either the level of risk of death or even serious illness as a result of taking a long-haul flight.

While the risk has frequently been described as ‘economy class syndrome’, the UK House of Lords report referred to above stressed that DVT could also occur in business or first class cabins, and also in other modes of transport.

Given the lack of data which would allow the quantification of risks involved, the policy areas discussed focus on increasing research efforts, and encouraging airlines and tour operators to re-appraise the design of their cabins and their cabin service procedures. Any policy designed to introduce regulatory minima for seat pitch and width would need to be supported by cost benefits studies.

Health impact of aviation: radiation effects

Exposure to radiation at high altitude is a potential human health hazard, but the evidence from the UK House of Lords report suggested that ‘cosmic radiation exposure during flight represents an insignificantly small addition to the range of other factors that could lead to cancer or inheritable mutations’.

Health impact of aviation: VOCs and other pollutants inside aircraft

The UK House of Lords report stated that they received no evidence that chemical contaminants (including VOCs) are of either concern or significance to the flying public or to aircrew.

The most significant and recent case of this concerned Ansett Australia’s BAe 146 aircraft, where an incident was reported in 1997 a serious leak of oil into the air conditioning system, and the resulting loss of awareness and vertigo of the aircraft’s captain. Resulting investigation by the Australian authorities supposedly led to the engine defect being remedied.

Health impact of aviation: transmission of infection through air circulated in the cabin

This is another area where there is little data relating cabin air quality with adverse health effects. Until such links are established, policy should perhaps be directed towards voluntary industry action, rather than regulatory proscription. Thus, airlines should be advised to monitor continuously and review data on cabin air quality, as well as review and substantially improve in-service performance of monitoring of air filters (HEPA filters).

1. INTRODUCTION

The main purpose of this study is to identify a range of options which the European Parliament could consider and perhaps adopt as European Community strategy relating to the environmental and health impacts of aviation. The objective is not to conduct an exhaustive assessment of the prospective benefits of such options, but to provide a comprehensive inventory and review of the main issues and options involved in this field.

Part A of the study includes options concerning all the relevant existing legislative, administrative and policy instruments related to aviation. These will include a review of existing legislation on the operations of aircraft, including aspects connected with crew and passenger health and safety, as well as the environmental noise and pollution impacts.

Part B presents the arguments and evidence to the assessment of the various options. This will involve summarising and reviewing the work completed to date in this field, highlighting the major areas of uncertainty (for example upper atmospheric impacts of aviation). This part will focus on aircraft noise and engine emissions, as well as related energy use, since their impacts are the most significant and most researched to date. Impacts will be assessed on the ground and at various stages of flight, including very high altitude flights. They will include the effects on both passengers and crew in-flight, and those effected on the ground.

The following aspects are addressed (the relevant section numbers of this report are in parentheses):

1. Energy, environmental and health issues associated with aircraft

2. Land and energy use
   Comparison with other transport modes
   Consequences of energy use, including pollutants
   The impact of ATC routing and congestion on energy consumption

3. Direct environmental impacts from engine emissions (A2, B2 and C2)
   Emission of pollutants in the atmosphere and stratosphere
   Impact on ozone layer
   Ground level pollutant emissions
   Pathogen transmission
   Introduction of non-native wildlife species and general impact on wildlife

4. Climatic change
   The Greenhouse effect and cloud formation

5. Aircraft noise effects (A1, B1 and C1)

6. Environmental impact on passengers, air crew and ground staff
   Impact of reduced oxygen levels
   Distribution of pathogens
   Assessment of radiation effects
   Effects of VOCs and other pollutants inside aircraft

Part C provides a concise summary of the technical, economic and other issues, arguments and conclusions for non-specialists. This and the Annexes give Members of the European Parliament a comprehensive reference upon which to base debate and decisions in this field.

PART A: OPTIONS BRIEF

A1. Aircraft Noise

Council Directive 92/14 prohibits from 1 April 1995, with certain exemptions, operations of subsonic jet aircraft of over 34 tonnes with more than 19 seats fitted with engines of by-pass ratio of less than two (ie those that meet neither Chapter 2 (and those that do and are over 25 years old) nor Chapter 3 noise standards. The directive also prohibits the operations of Chapter 2 aircraft after 1 April 2002. Exemptions were included in an annex of specific aircraft (by serial number) registered in various developing countries. Since some of these aircraft were withdrawn or unserviceable and a number of aircraft had been inadvertently omitted, a number of amendments were subsequently introduced.

The most significant part of this directive is the phasing out of Chapter 2 aircraft after 1 April 2002. The same legislation was introduced in the US one year earlier. Developing country airlines were given exemptions. Quite a few aircraft which did not meet Chapter 3 standards were re-certificated to meet those standards both by acoustic treatment to the engines (hushkitting), and by re-engining.

Council Regulation 925/1999 prohibits the registration of those aircraft which have been modified and re-certificated to meet Chapter 3 standards (hushkitted) within the Community from 4 May 2000. This does not include those aircraft that have been completely re-engined with engines having a by-pass ratio of three or more. Re-certificated aircraft which are on the registry of member states may not be operated after 1 April 2002 unless they had already been operated in that state prior to this date.

Communication from the Commission to the Council, the European Parliament, the Economic & Social Committee and the Committee of the Regions, COM(1999)360final: Air Transport and the Environment – Towards meeting the Challenges of Sustainable Development.

Action points on noise from this Communication:

a) The endorsement by the 32nd ICAO Assembly of the work programme on noise implies that the Commission, in close co-operation with Member States, should participate actively in the CAEP work programme on the introduction of a new noise standard, and transitional rules for phasing out the noisiest of the current Chapter 3 aircraft. This standard should be significantly more stringent than current Chapter 3 standard. In line with the position taken by the Community and its Member States at the 32nd Assembly, the target date for a decision is the 33rd Assembly in 2001.

b) In addition, the European Commission will prepare policy measures aimed at advancing, on the basis of objective and non-discriminatory conditions, the introduction of more stringent measures at regional level, with particular emphasis on noise-sensitive airports.

c) Should ICAO fail to agree, in 2001, on more stringent noise certification standards and on transitional rules for phasing out the noisiest categories of current Chapter 3 aircraft in line with Community requirements, the Commission may have to propose European requirements, in close co-operation with other industrialised regions. Any such proposal would have to consider the need for an economic hardship clause for developing countries and take account of the impact on competitiveness.

EU and Global Aircraft Noise Policy Options: Noise standards applicable in EU member countries for new aircraft have in the past been agreed through the International Civil Aviation Organisation (ICAO), but the most recent agreement (the so-called *Chapter 3*) standards were introduced over 23 years ago. Proposals have recently been finalised by ICAO's Committee on Aviation Environmental Protection (CAEP/5) steering group for stricter *Chapter 4* standards. Their brief was to produce a new standard that would reduce the people of people impacted by noise levels of greater than 65dB. CAEP/5 proposed a Chapter 4 standard which would require new aircraft to be 10dB quieter than existing standards from 2006. However, this still has to be agreed at the ICAO Assembly in September/October 2001. The recommendations would then need to be implemented by member states.

These noise reductions are cumulative, or totalled across the three noise measuring points. No trade-offs are to be allowed between the three measures, and the sum of the differences at any two measurement points should be at least 2bB.

In addition to this new standard, CAEP also recommended:

- procedures for re-certification of existing aircraft meeting the new standard
- more stringent noise standards for helicopters
- publication of guidance material on land-use planning
- a proposal for new take-off noise abatement procedures

Community objectives to reduce noise and phasing out noisier aircraft have recently been published [COM(2000)821] for submission to next ICAO Assembly.

The Commission has indicated in both COM(1999) 360 and COM(2000)821 that, if agreement through ICAO does not result in stringent enough Chapter 4 standards or on transitional rules for phasing out Chapter 3 aircraft, it may have to propose European requirements, in consultation with other industrialised regions. It should be noted that the above CAEP proposal does not address the phasing out of Chapter 3 aircraft, and thus falls well short of what the EU was hoping to achieve.

A2. Aircraft engine emissions and resource use impact of aviation

1. No specific action should be taken and changes should be left to conventional market mechanisms ("business as usual"). As resources become more scarce their price will rise, discouraging low value uses. The advantage of this policy is that artificial distortions are not introduced and users are free to develop optimum solutions.

However, while such a policy might be effective for resource use, environmental costs or externalities are not imposed on polluters. Thus some mechanism needs to be introduced to ensure that "the polluter pays" and that these costs are effectively 'internalised'. This requires one or more of the policies described below.

2. Apply economic mechanisms to reduce adverse aircraft emissions. Purely economic measures could in principle be developed, based on the damage attributed to aviation; users are

then free to choose optimum solutions to minimise environmental and other costs. The complexity of the adverse effects of emissions (due mainly to water vapour, CO_2 and nitrogen oxides) means that well-founded economic mechanisms are not yet available. Issues of equity are raised by purely economic measures, and practical mechanisms for administering charges and distributing revenue are not yet identified.
Community objectives for ICAO to consider:

taxes on fuel collected through suppliers
taxes on fuel collected together with existing en-route charges

These could be revenue neutral to avoid the above mentioned revenue distribution problems. Emissions trading is also an option that is under active discussion, although there is a technical problem concerning charges related to the so-called "bunker fuels" used in aviation (and shipping) which currently fall outside the responsibility of any individual nation.

The aviation industry has a strong preference for charges to take the form of a levy rather than a tax, with proceeds used to alleviate / compensate directly any aviation-related environmental damage.

3. Apply regulatory mechanisms to reduce adverse aircraft emissions. Direct regulation of adverse emissions is in principle possible and ensures that users cannot avoid meeting required performance levels. Community objectives for consideration through ICAO suggest more stringent certification standards for new engines, and the possibility of an interim non-production rule on all engines that do not meet CAEP/4 NOx standards.

4. Sponsor research in specific technical and operational areas to reduce aircraft emissions. Research programmes such as Framework VI could emphasise topics which reduce uncertainties in knowledge of aviation's environmental or health impacts or which lead to reduced impact. Studies of operational aspects (e.g. air traffic management) should be covered as well as purely scientific or technical issues.

5. Encourage the use of biofuels in aviation. Biofuels are conventional fuels made from agricultural crops. They cause no net direct input of CO_2 to the atmosphere and require no major change in engine technology. The major problem with such fuel is the land area required to produce sufficient fuel - current technology could not produce enough fuel using available land.

6. Encourage the use of non-carbon fuels in aviation. Several non-carbon fuels are available, in principle, for aviation, eg hydrogen. Research followed by measures to encourage their use could reduce many unwanted emissions. Hydrogen fuel would entail major infrastructure changes and only removes the pollutant CO_2; nitrogen oxides and water vapour are still produced. Other technologies are still unproven.

7. Inter-modal transport could be encouraged. For journeys up to a few hundred km, surface travel can be competitive with air transport. Improved availability of convenient high quality surface transport would reduce demand for air transport. Experience suggests that successful integration of transport modes requires significant investment and only 10% of air journeys could be substituted with surface transport.

8. Encourage the development and application of teleworking and tele- and video-conferencing. Improvements in communication technology make teleworking increasingly practical. Teleworking is only relevant to business travel and is unlikely to reduce significantly the need for such travel; it is feasible that improved communications actually encourage travel.

A3. Health impact of aviation: Deep Vein Thrombosis (DVT)

DVT is a condition in which a small blood clot forms mainly in the deep veins of the leg. It is not life-threatening in itself, but can lead to complications, and in certain cases (pulmonary embolism) death.

DVT can occur as a result of long periods of inactivity, for example through travel in general and long-haul flights in particular. A recent UK House of Lords report[1] made a number of recommendations, which could be adopted as policy options for the EU:

Option 1: Airlines and/or their agents provide those intending to travel with them with information on precautionary and preventive measures relating to DVT, as well as perhaps predisposing factors.

Some airlines are already planning to do this through information printed on the ticket. However, with the growing use of electronic ticketing, this may have to be done using other means at the time of ticket purchase. Information at check-in, boarding or in-flight might be considered too late.

Option 2: Set up an epidemiological research programme of the case-control type in order to clarify the health risks for air passengers.

Option 3: Airlines and tour operators re-appraise the design of their cabins and their cabin service procedures.

Cabin service procedures are often used as a reason to restrict the mobility of passengers in the cabin. The design of cabins in terms of aisle width and seat pitch and design can be altered in the short-term, while the number of aisles and cabin lay-out would take longer to change. It was reported that only one country (UK) imposes minimum seat spacing on airlines (26 inches from the seat behind the base of the spine to the back of the seat in front). This is equivalent to a seat pitch of about 28 inches, where the seat back is two inches thick. This suggests a more stringent option to replace option 3 above:

Option 4: EU regulatory aviation authorities impose minimum seat spacing standards.

Where such a minimum is higher than competitive market requirements, care has to be taken to evaluate the loss of consumer travel benefits compared to the health benefits obtained. This option would thus have to be pursued in conjunction with option 2 above.

A4. Health impact of aviation: radiation effects

Air passengers are not in general at significant risk from cosmic radiation. What risk there is increases with altitude and proximity to the Earth's (geomagnetic) poles. Aircrew are exposed for long periods of time and may accumulate non-negligible, but still quite safe, doses. Regulations now exist to provide some protection for aircrew (at least for EU airlines), within, it is understood, Health and Safety legislation.

[1] House of Lords Select Committee on Science & Technology: Air Travel and Health, 15 November 2000

A5. Health impact of aviation: VOCs and other pollutants inside aircraft

The UK House of Lords report stated that they received no evidence that chemical contaminants (including VOCs) are of either concern or significance to the flying public or to aircrew.

A6. Health impact of aviation: cabin air quality and the transmission of infection

Option 1: Airlines review and substantially improve in-service performance of monitoring of air filters (HEPA filters), as well as upgrade filters to best-in-class.

Option 2: Airlines continuously monitor and review data on cabin air quality.

PART B: ARGUMENTS & EVIDENCE

B1. AIRCRAFT NOISE

Council Regulation 925/1999 prohibiting the registration of hushkitted aircraft within the Community as of January 2001 has been challenged in the Court of First Instance: Omega Air has requested that the regulation is annulled on the basis that it applies to re-engined aircraft having a by-pass ratio of less than three, and that this is not necessarily linked to noise emissions.

The US government has also complained to ICAO on this regulation, and a ruling is still awaited from ICAO. The EU might be willing to take a less rigorous stand on this issue if more progress is made on noise standards and phase-outs than evident to date. The table below explains the EU concerns that the large number of North American registered 'noisier' Chapter 3 aircraft might be exported to Europe to provide capacity for start-up or cargo airlines. This danger would be much reduced should the price of fuel remain high, in which case many of these aircraft would become uneconomic to operate.

Top world hushkitted fleet by region of registration

Region	*Number*	*Proportion %*
North America	1,486	77.8
EU	135	7.1
Africa	119	6.2
Latin America/Caribbean	103	5.4
Asia	49	2.6
Non-EU Europe	17	0.9
Total	1,909	100

Source: Airclaims CASE in Airline Business March 2001

The main driver behind the Chapter 4 proposals is the need to reduce the number of people impacted by noise emissions greater than 65dB.

The following options were under consideration by ICAO's CAEP steering group (out of an initial list of 26):

1. - 8dB Option

	New standard	*Phase-out*
2.1	- 8dB in 2002	
4.1	- 8dB in 2002	- 8dB in 2006
6.1	- 8dB in 2002	- 5dB in 2002
5.1	- 8dB in 2002	- 5dB in 2006 - 8dB in 2013

2. - 11dB Option

	New standard	*Phase-out*
2.2	- 11dB in 2002	
5.2	- 11dB in 2006	- 5dB in 2006
		- 11dB in 2013

3. - 14dB Option

	New standard	*Phase-out*
2.3	- 14dB in 2002	
5.2	- 14dB in 2006	- 5dB in 2006
		- 14dB in 2013

The working group evaluated the benefits from this reduction against the costs to the industry of stricter standards (an approach that was strongly supported by the US delegation).

The 14dB option was rejected on the grounds that, while being technically possible, the associated costs and development times to meet market needs might be unreasonable.

Of the above options, the **European Commission**, the Netherlands, Sweden, Germany, Norway all advocated the 11dB reduction, as did Australia. Spain, France and Italy supported an 8dB reduction, as did the US and Canada.

The European airport body, **ACI Europe**, called for a 14dB reduction, with at least a 4dB reduction at each of the three measuring points. Their view is that the limiting of aircraft noise by source through the design and introduction into service of quieter aircraft, and the phasing out of older models, is the most important and cost-effective measure to tackle the noise problem. They see the greatest losers from the CAEP/5 proposal as being the aircraft manufacturers, whose aircraft might not in the future be able to operate at some airports, as much stricter local measures become more widespread.

The UK airports group, **BAA** plc, has recently launched a number of medium to long-term objectives for airport noise:

A reduction in overall noise per passenger within the area of the 1998 57 Leq contour of 10% by March 2005

Year on year reductions in infringements of the night noise limits in force in April 2000 to zero by March 2005

A reduction in the number of Chapter 3 ‘high’ aircraft (those that just qualify for the most stringent international noise classification) to less than 1% of the level in April 2000, by March 2005

BAA also have short-term targets for each of its airports: the 2000/01 target for Heathrow was an increased use of Continuous Descent Approaches (see below) to achieve an average of 85% of all arrivals between 2300 and 0600 for January to March 2001.

The airline view, expressed by various trade and pressure groups, has been an emphasis on protecting their investments in Chapter 3 aircraft, which have been justified economically on the basis of a service life of at least 25 years. The Director General of **IATA** expressed support for the new CAEP/5 noise standards, saying that 'the future growth of our industry has been assured, whilst the global environment has been protected.' He added that it was 'a real win-win result for airlines, airports and for the surrounding communities.' This last view was totally at odds with the airport position presented above.

Individual airlines obviously prefer to reduce noise by the gradual introduction of quieter aircraft types, and by better operational procedures. **Air France** considered the best way to reduce noise nuisance is for manufacturers to continue to improve technology (acoustic certification). **British Airways** supports the introduction of a new noise standard, provided that it is 'technically feasible, environmentally beneficial, and environmentally reasonable.' Their preferred option is one that gives the best outcome in terms of expected costs and benefits.

A US aviation noise pressure group, the **Coalition for a Global Standard on Aviation Noise**, has renewed its support for the work of CAEP/5, commenting that without the recent agreements 'the international air transportation system would have been stymied in its ability to meet the expected increases in demand.' However, they urged CAEP/5 to resolve the remaining issues of noise abatement around airports, using such methods as land use planning, noise insulation, land acquisition and changes in operating procedures. This would allow actions in these areas to be taken within an internationally agreed framework.

Airbus Industrie see the best way to reduce noise nuisance as being through a balanced approach and joint efforts between aviation authorities, airframe and engine manufacturers, airlines, airports and municipalities. This would involve improved international standards, the application of new technology, phasing out of old aircraft, noise abatement procedures, land acquisition and land use planning, and noise insulation schemes.

The table below shows the percentage of each of the aircraft types meeting the various noise reductions proposed. Thus the 10dB reduction would mean that between 44% and 59% of existing aircraft would meet the standard. Of those that do not, many are nearing the end of their economic life, for example around 2,000 B727/737 and 1,000 DC8/DC9, or 3,000 aircraft in total (23% of the world fleet). This suggests that a large proportion of the current world fleet that are likely to be still operated in 2006 would meet the Chapter 4 standard.

World fleet meeting proposed Chapter 4 noise reduction

Aircraft type	*Active fleet (1999)*	*% meeting - 8bB*	*% meeting - 11dB*
Regional jets	1,156	100	100
Airbus single aisle	1,127	96	68
Boeing single aisle	5,209	46	38
MD/Boeing single aisle	2,121	38	10
Airbus widebody	870	74	46
Boeing widebody	1,983	71	59
MD/Boeing widebody	466	41	41
TOTAL*	12,932	59	44

Source: adapted from Airline Business, March 2001

* including L1011 and smaller jets not included in table

The EU situation differs from that in North America in that EU fleets are younger than in North America, and thus no action on noise standards would result in a significant increase in noise nuisance. On the other hand, in North America many aircraft are old and would be replaced by new quieter aircraft over the next 20 years, resulting in a noticeable reduction in noise, even if no action were taken on standards.

The US position is that noise restrictions should by applied on an airport-by-airport basis, whereas the EU believes that stricter standards should be set on a global basis.

In the **shorter term**, the Commission intends to apply transitional rules, especially in more affected regions, and apply their rule on the non-operation of re-certificated aircraft (those hush-kitted to meet Chapter 3 standards, but generally noisier than new Chapter 3 aircraft).

This shorter term policy is in line with the European Parliament's report on the Commission's Communication on Air Transport, and seeks to safeguard minimum aircraft life so as not to unduly increase airline costs, to meet the needs of densely populated areas, as well the needs of airlines from developing countries operating to and from the EU.

The **longer term** requirement is for a significant reduction in the noise of individual aircraft. In this respect, options 1 and 2 above do not meet the requirements of a genuine long-term design standard, or provide the necessary incentive for technical progress.

In the case of the agreement of reductions of the order of – 8dB to – 11dB, the policy paper stresses the need for a regular revision of this production standard in the future, as well as the need for unambiguous technical guidance for the re-certification or modification of existing aircraft.

Individual Airport Aircraft Noise Policy Options A growing number of EU airports have already introduced both operating procedures and surcharges/discounts on landing fees to discourage noisier aircraft, and reduce the impact of noise on communities living near airports.

Operating procedures already introduced include revised approach and departure routings. These give improvements in noise at minimal or no extra cost to operators, and no reduction in safety standards. Other measures are bans on the use of reverse thrust on landing and noise preferential runways, which either reduce the number of households affected by noise, or re-distribute peak noise impacts between communities. In Europe, the Joint Airworthiness Authority (JAA) is redefining the airworthiness rules to remove the requirement for reverse thrust for normal operations.

Re-designing the routes that aircraft take, especially departing from airports, can produce significant albeit very localised benefits. The benefits from Continuous Descent Approaches (CDA) are evident from the table below, but there are the disadvantages of some reduction in the volume of traffic that can be handled (increased separation between flights) and are more appropriate to off-peak periods:

Noise implications of Continuous Descent Approaches

Procedure	*Fuel consumption final 45km in kg*	*65dB(A) footprint area in square km*
2000 ft vectored to ILS	225	38
3000 ft vectored to ILS	213	25

Continuous Descent Approach	170	17

Source: era regional report, November 2000

Night curfews, or total bans on the operation of all jet aircraft, are in force at some EU airports (eg Frankfurt), while others have partial bans (eg on *Chapter 2* aircraft only). The period of ban for Chapter 2 aircraft varies from 14 hours at Amsterdam to 7 hours at Manchester. Some airports also have a night ban on certain heavier (and thus noisier) Chapter 3 aircraft.

Night noise quotas are in force at some airports (eg London airports and Manchester). The UK system classifies aircraft into seven bands, which are assigned quota counts from zero to 16. A cap is then placed on the total number of summer and winter season night movements, with a separate cap for noise quota calculated by summing the product of each flight and its quota count.

Night flights at London Heathrow have been the cause of particular annoyance, and the inspector for the Fifth Terminal Inquiry recommended that they should be banned. The UK government is facing a challenge to its night quota system in the European Court of Human Rights from a coalition of local authorities and noise pressure groups. Two articles of the Human Rights Convention are alleged to have been breached: that which guarantees 'respect for privacy' and that which provides for an 'effective remedy before a national authority'. The case could be resolved if the government approved the construction of Terminal 5 at Heathrow on the condition that night flights there are banned.

The UK DETR is also consulting the industry on alleviating night noise at Heathrow by changing the preferential use of the runways. Currently 89% of night movements are from the east, and switching some of these flights to approaches from the west would reduce noise, since the easterly approach has 5 times the population affected than the corresponding paths from the east.

Noise surcharges are applied at some airports (especially for *Chapter 2* aircraft), while at the same time offering discounts (incentives) to operators to introduce quieter *Chapter 3* aircraft. These are usually 'revenue neutral', which means that they do not result in any overall increase in airport revenues. Night surcharges are also applied at a number of airports in the EU. At some airports, it is impossible to separate the noise surcharge or discount from the total landing fee (eg German airports and London Gatwick).

The classification of aircraft for noise surcharge and discount purposes usually follows the ICAO *Chapter 2 and 3* standards. However, some airports have divided *Chapter 3* into a noisier and less noisy category. The introduction of a new *Chapter 4* will help airports apply economic incentives for newer quieter aircraft.

Money raised from noise surcharges is sometimes applied towards **noise insulation schemes** for householders in most affected areas. Even where there is no explicit noise charge, such a scheme might be funded from general landing fee revenue, in which case there would be an implicit noise charge (eg Copenhagen Airport). In extreme cases, airports acquire houses in close proximity to the airport for demolition.

Penalties are imposed on aircraft that either deviate from prescribed tracks (eg Madrid and Rome Fiumicino) or exceed prescribed threshold levels for each aircraft type (eg a number of UK airports), but this requires the installation of noise measuring equipment at various points on the flight paths.

Land use planning is also vital if the noise reductions already achieved are not lost through people and industry moving closer to airports. Further efforts need to be made to ensure that land in the area surrounding the airport is used only for non-noise sensitive purposes. The ICAO CAEP guidelines, which have yet be published, are obviously not binding on member states. A major problem in many countries is the separate planning requirements for airports and, for example, local housing.

There is obviously further scope for a wider application of the above across EU airports, as well as an increase in stringency at airports that already have such measures. Their advantage is that they are targeted at areas with particular problems. The disadvantage is that they often apply different standards, and thus might favour or penalise certain airlines operating in the single EU aviation market.

The **Greens / EFA** in the European Parliament have called for an EU-wide ban on night flights, with exceptions only allowed for the quietest aircraft. By 'quietest planes' they would presumably argue for a quieter category than the proposed Chapter 4 above. Some EU airports have based their charging on quieter aircraft categories, and the European Commission is investigating a common EU categorisation for airport noise charging and quota purposes, which would need to include a 'very quiet' category.

The Green MEP for the area adjacent to Amsterdam Schiphol Airport (Alexander de Roo) suggested an amendment to the European Commission's draft directive on the assessment and management of environmental noise. This would have effectively changed its focus to airport noise and required airport noise limits to be reduced to 'the noise found in a public library' within 18 months. This unrealistic amendment was rejected.

The **Aviation Environment Federation (AEF)**, the body that provides the focus for UK environmental concern in connection with aviation, favour the approach adopted by Amsterdam Schiphol Airport, as well as Luton and London City Airports in the UK. Its December 1998 paper, in conjunction with Airports Policy Consortium (APC), Friends of the Earth, the Council for the Preservation of Rural England and Transport 2000, propose the concept of *environmental capacity*, which defines a maximum noise exposure contour which should not be exceeded. This ensures that growth can only occur if the social noise cost is kept within a pre-defined limit. They also argue for a consistent approach to be applied to all airports.

The major problem with this approach is defining the contour and noise measurement and level. The Dutch use Kosten Units, which incorporate a significant night noise weighting, but other countries use measures which do not take into account night noise.

Finally, most of the discussions take as a starting point significant forecast growth of traffic, which implies more movements of aircraft and a larger average size of aircraft. AEF have argued that the removal of air transport's current tax and duty-free advantages, as well as the imposition of the various noise and emissions taxes, would mean substantially lower forecast growth rates, and less pressure on noise contours around airports (Sewill, 2000).

B2. Aircraft engine emissions and resource use impact of aviation

Background Information on Aircraft Emissions and the Atmosphere

There are three significant regions of the atmosphere as concerns aircraft engine emissions and their impact on the environment: the free troposphere, the stratosphere, and the planetary boundary layer. The troposphere is where almost all weather takes place (clouds, precipitation, etc.) and extends from the ground up to about 15 km at the equator and about 8 km at the poles. Because there is significant mixing in the troposphere due to weather systems, pollutants travel relatively freely once they are out of the layer of the atmosphere in contact with the ground (the planetary boundary layer, which is the part of the troposphere closest to the ground). Most ground emissions of air pollution stay in the boundary layer for several hours or days and are restricted to local or regional impacts. The troposphere above the boundary layer is the free troposphere. The stratosphere has much less mixing than the troposphere so once pollutants enter the stratosphere they generally remain there for long periods.

The significance of aircraft emissions is that they alone are directly injected into the free troposphere and even the stratosphere, as well as the planetary boundary layer. The main emissions of concern for climate are:

- Carbon dioxide (CO_2) - this has a long lifetime in the atmosphere and is the principal culprit of global warming.
- Nitrogen oxides (NO_x) - almost any combustion process in the atmosphere (which is 79% nitrogen) creates NO_x. NO_x is involved in atmospheric chemistry with ozone and is in some "acid rain" processes. Through the creation of ozone (O_3) in the troposphere NO_x contributes to global warming. In the stratosphere, NO_x is involved in chemistry which damages the ozone layer.
- Water vapour - Recent work has highlighted the potential climatic impact of clouds formed (partly) from the water vapour emissions (e.g. contrails) which are a normal by-product of fuel combustion. High thin cloud has an important role in climate and changes to its amount and geographical distribution may be significant.
- Soot and other particulates - Smoke and other particles and some sulphur compounds emitted by engines form effective nuclei for cloud droplets. At low altitudes, smoke contributes to local air pollution while higher in the atmosphere it may be involved in cloud formation, and thus in climate.

The climate impact of a gas is the product of its radiative greenhouse effect, i.e. how effectively it traps heat near the Earth's surface, and its lifetime. The radiative greenhouse effect of aircraft emissions of NO_x and CO_2 are roughly equal for current aircraft engine technology. However, NO_x and the O_3 it produces are relatively short-lived and so affect mainly the region in which they are emitted and have a smaller climate impact than the CO_2 which remains in the atmosphere for many decades.

In general terms, engine emissions are dealt with according to the part of the atmosphere they enter:

- Low-level emissions (below 3000', i.e. within the planetary boundary layer): These emissions contribute to local air pollution. Engine emission performance when used below 3000' (i.e. for take-off and landing) is regulated and is controlled by the engine certification process which has been in operation for some time. These regulations cover emissions of NO_x, carbon monoxide (CO) and unburnt hydrocarbons (UHC).
- Cruise-level emissions: These emissions are directly injected into the free troposphere and the lower stratosphere. Most of the fuel burn is during the cruise phase, and so these emissions represent the bulk of the CO_2, NO_x, etc., released. Engine

manufacturers have made significant improvements in engine efficiency, however there are so far no regulations targeted at the climate impact of aircraft emissions although this has become a significant area of discussion within the broader context of measures to reduce anthropogenic emissions of "greenhouse gases" (following the UNFCCC Kyoto meeting, 1997).

Studies have been made of the expected impact of a fleet of supersonic transport aircraft. These aircraft would fly high in the stratosphere (for fuel efficiency) and could have a significant environmental impact in their own right since their emissions are at a particularly sensitive part of the atmosphere (in the ozone layer).

Military aircraft are responsible for no more than a third of aircraft emissions and their contribution is expected to reduce over the next few decades as air force fleets are scaled down and as civil aviation grows.

The most authoritative recent report on aviation and the global atmosphere is that by the Intergovernmental Panel on Climate Change (IPCC, 1999). This is a comprehensive account of current knowledge of the key processes and issues. A summary of the IPCC report for policy makers (and the complete report) is available at http://www.grida.no/climate/ipcc/aviation/index.htm (or via the IPCC Web site http://www.ipcc.ch).

Discussion of Policy Options

The policy recommendations identified in Section of A of this report emphasise policies relevant to climate change because the near surface emissions are already largely covered by regulations for local air quality and the current engine certification process.

The aim of policies relating to the climate impact of aircraft engine emissions should be to integrate aviation into the general process of reducing emissions of CO_2 to stabilise its atmospheric concentration while recognising the particular characteristics of aviation. The generally accepted value for the pre-industrial concentration of CO_2 is 280 ppmv (parts per million by volume, i.e. on average each million air molecules contained 280 CO_2 molecules). The concentration has now risen to about 370 ppmv and is likely to stabilise at 2-3 times the pre-industrial level. The lower the level at which it stabilises, the lower we expect the degree of eventual climate change to be and, probably, the slower the rate at which it happens - both these make it easier for human society to adapt to the changing environment.

Aviation has several characteristics which should be recognised in considering how to manage its climate impact:

- Air transport is growing at 5-8% per year (measured in passenger-kilometres) and is expected to continue growing at this rate for the next 15-20 years (it doubles every 15 years currently).
- Air transport is an important part of international trade; it is part of the enabling infrastructure and is inherently international in character.
- Aircraft engines currently have very limited options for substituting the current fuels with non-fossil fuel derived products. All alternatives would have significant new costs associated with their use.

- Air transport accounts for 12% of fossil fuel use by the transport sector currently, and this proportion is likely to grow. In terms of total fossil fuel use, air transport is responsible for only 2-3 % currently.
- Projects to develop new aircraft or engines for air transport involve huge expenditure and timescales of a few decades - the aircraft now being designed (e.g. Airbus A380) are likely to be still in service in 2050, the Boeing 747 was designed in the 1960's.

Bearing in mind these points, it is likely that air transport will account for a growing proportion of fossil-fuel use over the next few decades - any attempt to cap fossil-fuel use by the aviation sector would bring severe problems.

Currently the favoured basis for any mechanism for limiting future CO_2 emissions is some form of emissions trading. Each country will have a quota of emissions it is allowed to make, and will only be able to emit more if it can buy CO_2 emission credits from another country which does not need its full quota. The current levels of CO_2 emission from non-renewable resources per capita (expressed as mass of carbon rather than CO_2) for selected countries are given in the following table.

Country	*Annual non-renewable C emissions per capita (1990, tonne C yr^{-1})*
Mozambique	0.01
China	0.85
UK	2.56
USA	5.99
Global average	~1.2

Source: CycleDigest, Winter 2000 (No. 28), Cycle Touring & Campaigning (data are quoted from UK DETR report).

Detailed mechanisms for emission trading have not been identified; some of the difficulties are:

- Developing countries fear that emissions trading could easily work to their disadvantage as rich countries buy up quotas globally leaving them little scope for development.
- If emission trading is not revenue-neutral then the issue of the just distribution of the proceeds should be addressed, but is complicated by the fact that many of those who suffer are likely to be in other countries and perhaps decades later.
- If emission trading is revenue-neutral, then no funds are set aside to compensate future victims of climate change and the costs of current action are therefore borne by future generations - this is not "sustainable development" as it is currently understood.
- Fuels for aviation and shipping fall outside any individual country's quota (these fuels are regarded as "bunker fuels"), and an agreed mechanism for attributing them to any nation has not yet been determined (this is a topic of current study within the UN Framework Convention on Climate Change). This international dimension also inhibits unilateral action that could be taken on a national or regional basis (airlines would buy their fuel wherever it is cheapest).

It seems likely that some form of emissions trading will be developed, largely because of its compatibility with the market economies of the most economically important nations. One possible implementation involves quotas for individual economic sectors such as aviation: this is termed a closed system, and is not widely supported because of the artificial distortions it is likely to create in the global economy.

The air transport industry clearly favours open market-based options ("open" implies that there is no sector-specific cap on emissions). For the market to work well it is important that all costs of any action are fully accounted for. In the case of environmental costs, these are very difficult to quantify since the "damage" may be apparent only some time later (decades or even centuries) and geographically distant from the initial activity (certainly beyond national boundaries in many cases).

The aviation industry would prefer any climate change related charges to be in the form of a levy, the proceeds of which could be directed to aviation-related environmental purposes. Charges in the form of taxation or duty which could not be earmarked for specific purposes are not favoured.

United Nations Involvement in Climate Change

Several UN organisations have responsibilities which include climate change, and the fact that these responsibilities tend to overlap causes complications. The organisations are UNFCCC (UN Framework Convention on Climate Change), ICAO (International Civil Aviation Organisation) and IMO (International Maritime Organisation). Aviation and shipping fall clearly within the remit of ICAO and IMO respectively, and so UNFCCC has to work with ICAO and IMO for these sectors whereas most other economic sectors fall wholly within UNFCCC's remit concerning climate change.

B3. Health impact of aviation: Deep Vein Thrombosis (DVT)

In December 2000, the Australian law firm, Slater & Gordon, announced that it would bring a class action suit against several international airlines over failing to warn passengers about the risks of developing DVT following a flight.

The airline trade association, IATA, has responded by suggesting that ‘at the present time, there is no conclusive medical evidence supporting the alleged connection of deep vein thrombosis (DVT) with long distance travel’. They add, however, that DVT needs further research, but in the meantime their members are very much aware of the need to minimise the potential risks. Such studies by the UK CAA, British Airways and others are reported to be already underway. Lufthansa added that they did not see any special risk for the normal passenger, even sitting in economy class.

IATA have developed practical precautionary guidelines for all carriers, which include informing travellers at the time of reservation of the risks of DVT and the research currently being conducted, and encouraging those with any family history of DVT or having any medical condition that might pose a risk when flying to seek medical advice before travelling.

IATA also encourage passengers prior to boarding and in-flight to drink sufficient fluids, wear loose-fitting clothing, avoid smoking and alcoholic beverages and perform physical exercises in their seats.

The Association of European Airlines (AEA) has formed a working group to examine DVT, and many of their members already inform their passengers on this subject through both inflight videos and magazines.

A recent meeting was convened for airlines, IATA, medical practitioners and other interested parties through the auspices of the World Health Organisation (WHO) in Geneva. There was unanimous agreement at the meeting that current research into DVT is inadequate. WHO will be working with scientists over the next two months to develop plans outlining current research, and identifying the areas where further work is needed.

B4. Health impact of aviation: radiation effects

Passengers and crew of aircraft receive a radiation dose due to energetic particles from space hitting the Earth's atmosphere ("cosmic radiation"). The dose inside an aircraft during cruise at altitude is much greater than at ground level due to the lack of the shielding effect of the lower atmosphere. The dose is also higher near the Earth's (geomagnetic) poles and in the South Atlantic off the coast of South America (the region referred to as the South Atlantic Anomaly by geophysicists). The longer a person is exposed to the radiation, the greater the dose received. The radiation level varies with time, in particular with the Sun's 11-year cycle of activity.

However, the level of cosmic radiation is low even at altitude; for example, a passenger on an average transatlantic flight receives a radiation dose equivalent to one chest X-ray. This is increased at times of high solar activity, but the exact relationship is still a subject of research.

Since May 2000, an EU directive has required member states' airlines to assess the radiation dose for flight crew.

B5. Health impact of aviation: VOCs and other pollutants inside aircraft

There is some concern that the air fed to the aircraft cabin during flight, which is drawn usually from the engines' air intake, sometimes contains high levels of volatile organic compounds (VOC's). A few anecdotal accounts have been reported of incidents of this type of cabin air pollution but on the evidence available there appears to be no systematic problem.

The most significant and recent case of this concerned Ansett Australia's BAe 146 aircraft, where an incident was reported in 1997 a serious leak of oil into the air conditioning system, and the resulting loss of awareness and vertigo of the aircraft's captain. Resulting investigation by the Australian authorities supposedly led to the engine defect being remedied.

The recent UK House of Lords report[1] stated that they received no evidence that chemical contaminants (including VOCs) are of either concern or significance to the flying public or to aircrew.

B6. Health impact of aviation: cabin air quality and the transmission of infection

There have been allegedly adverse effects on the health of both passengers and cabin crew from poor cabin air quality. This has resulted in specific cases of complaints by cabin crew and consumers

[1] House of Lords Select Committee on Science & Technology: Air Travel and Health, 15 November 2000

The European Commission, under its Fifth Framework research programme, is funding a three year research project involving 15 organisations from seven EU countries. This will address issues related to cabin air quality in commercial aircraft.

The US Federal Aviation Administration allows on-board levels of 5,000 parts per million (ppm) CO_2, versus a demand by the AFA for an improvement to 1,500 ppm.

New standards of air flow in cabins was introduced by the FAA in 1997, with any aircraft of up to two years old having to conform to ventilation standards of 10 cu.ft per minute per person. This is still below the standard demanded by the AFA of 20 cu.ft per minute per person.

Re-using blankets and headphones in the cabin has also been suspected as the cause of infections in the lungs and eyes. In November 2000, the US based Aviation Consumer Action Project (ACAP) joined with Unite (a union representing airline laundry workers) to demand improvements in on-board cleanliness and hygiene. Some US studies have identified contamination of blankets, pillow cases, tray tables and head rests. However, Unite were unsuccessful in persuading the US Department of Transportation to take any action, and they are now targeting passengers direct with the results of their tests.

B7. Biodiversity : Spread of organisms into foreign habitats.

The most direct issue relating to biodiversity is that air travel (deliberately or inadvertently) transports organisms (from microbes to mammals) from one ecosystem to another. In some cases, the migrant species has no natural predators in the new ecosystem and its population grows rapidly to a size which disturbs the local ecology; this can lead to the extinction of native species. This issue is not unique to or most severe for air transport and should be dealt with under more general transport regulations.

B8. Land and resource use

Air transport requires significantly less land than other modes of transport. In Germany, motorways and main national highways occupy around 660 square kilometres of land, compared to 338 sq.kms for the main railway lines, and only 40 sq.kms for the paved or concreted areas of Germany's airports (ADV, 1997).

Air transport operators in the EU used 15.5 teragrams (tg) of fuel in 1992, compared to a world total of 107.4 tg (European Commission, 1999). This is expected to increase by 90% and 111% in the EU and world respectively by 2015.

Some airlines have specific goals to reduce fuel consumption; for example, Lufthansa aims to reduce aircraft specific fuel consumption by 0.1 litre per 100 passenger-kms each year, and to reduce consumption by a further 10% by 2008 and a further 15% by 2012 (it had already reduced fuel consumption by 20% between 1991 and 1999).

B9. Other environmental impacts

Airline generate a large amount of waste materials, e.g. from the flight catering activities. Airports also generate waste, in the same way as railway and bus stations. Airlines operating at Heathrow Airport alone produced just over 15,000 tonnes of aircraft waste in 1999/2000, with a further 7,400 tonnes from the aircraft related waste from the airport. British Airways estimated that it produces over 70,000 tonnes a year of aircraft related waste.

In 1999/2000, Heathrow Airport incinerated 45% of its 27,000 tonnes of waste, 47% went to landfill sites and only 8% was recycled. British Airways has targets to reduce waste from in-flight catering through:

Better matching of catering to passenger numbers
Reducing the type and number of products placed on board
Increasing re-use and recycling of certain items
Product changes to reduce weight and wastage
Redistribution of obsolete products to charities

Improved measurement of the above will allow better monitoring systems.

PART C: TECHNICAL BRIEF

C1. Aircraft Noise

Commercial aircraft are classified for noise purposes according to the International Civil Aviation Organisations ICAO's Annex 16 noise standards, where jet aircraft are subdivided into 3 different Chapters according to their noise certification:

- **Chapter 1**: aircraft with type licence before 1970 (e.g. B707s)
- **Chapter 2**: aircraft with type licence between 1970 and 1978 (e.g. B747-100/200s, certain B737-200s with Pratt & Whitney JT8D engines)
- **Chapter 3**: aircraft with type licence after 1978 (e.g. A310, B757, B767, MD83)

This classification incorporates measurements at three specific points of a typical take-off and landing cycle:

Flyover (upon take-off): the measurement point is at a distance of 6,500 m from the start of the take-off roll, measuring along the extended centreline of the runway.

Sideline or lateral: measured at the point on a line parallel to, and at a distance of 450 m (or 700 m 3 or more engined aircraft for Chapter 2) from the runway centreline, where the aircraft's noise reaches a maximum during take-off.

Approach: the measurement point is 120 m vertically below the 3° descent path, on the extended centreline of the runway. At ground level, this would be at a distance of 2,000 m ahead of the runway threshold.

The approach limit under **Chapter 2** was a maximum of 108 EPNLdB for aircraft weights of 600,000 lb (272.7 tonnes) or more, declining according to a formula for aircraft of less than this maximum take-off weight. For **Chapter 3**, the approach limit was reduced to 105 EPNLdB for aircraft MTOW of 617,300 lb (280.6 tonnes) or more, also declining for lighter aircraft.

Examples of the noisier Chapter 2 aircraft are:

- B707s, DC-9s
- B727-100s and B727-200s
- B737-100s and certain older B737-200s
- certain older B747-100s

Chapter 3 aircraft are then all those jet aircraft (apart from supersonic aircraft) that are not included in Chapters 1 or 2.

Both hush-kits and re-engining is available to upgrade certain Chapter 2 aircraft to Chapter 3 standard. The B737-200 is certificated as a Chapter 3 aircraft with Nordam, Quiet Nacelle Corporation and Sound Solution hushkits, with a re-engining carried out by Tracor and others. The B727-200 has been re-engined by Valsan, while Fedex have fitted hushkits to these types. Hushkits are also available for longer haul B707 and DC8 aircraft, but not all these meet Chapter 2, and the economic viability of such retrofits is more questionable.

Under the Chapter 2 and Chapter 3 rules, trade-offs were allowed between the three measures, thus giving some aircraft types which were relatively worse on one measure and better on the other two to meet the standard. The prescribed noise levels may be exceeded at one or two of the measuring points if the sum of the two exceeding points is not greater than 3 EPNLdB, and no single exceeding point is greater than 2 EPNLdB.

Another criticism of the system was that certificated noise measures were used, rather than actual measurement of noise nuisance at a particular airport, under specific operating conditions. For example, a long-haul aircraft type operating a shorter haul sector (with a small fuel load) and with no cargo, would take-off light and could climb more rapidly and thus impose less noise on local communities. This was not taken into account in ICAO's classification system, which used specific guidelines on the use of maximum power settings.

Noise measurements:

dB : (decibel) basic unit of noise measurement.

dB(A): unit which uses the A-weighting curve. This unit has become an international standard for noise measurement especially for road noise. A sound level meter on the A-weighting curve functions as a filter discriminating against the lower frequencies in a manner similar to human hearing. This weighting curve is widely used for measuring surface noise.

PNdB: (perceived noise decibel) specially conceived to measure annoyance by jet aircraft noise. Basically, this level is measured for a single event, and divided in frequency bandwidths (1/3 octave) for each half-second increment of time. Each frequency bandwidth of the noise is then weighted according to its annoyance level. It is weighted more heavily at the higher frequency to represent the ear's sensitivity to aircraft noise.

EPNdB: (effective perceived noise decibel) a refinement of the PNdB. It introduces the duration of the event and a correction for frequency irregularities. The EPNdB is the unit of EPNL (effective perceived noise level) used by the FAA and ICAO as the standard measurement for aircraft certification. The relationship between dB(A) and EPNdB is simply EPNdB = dB(A) + 13.

Leq: (equivalent sound level) an energy-averaging measure for a stated period of time. This unit was generally used for road and railway noise measurement, but was adopted in the UK for noise measurement. The period of time considered by the UK government is the 16 hours between 0700 to 2300 hours (Leq_{7h-23h}).

Note: It is important to know that a noise reduction in the order of 3dB may look marginal at a first glance but in fact it represents cutting the noise intensity by half.

A limit of 55dB(A) is regarded as one that should not be exceeded to allow undisturbed sleep, while sound levels above 70 dB(A) make normal speech communication impossible (European Environment Agency). WHO guidelines state that sleep disturbance occurs as low as 30 dB(A) Leq, and that residential areas should be protected from noise above 45 dB(A) to ensure undisturbed sleep. UK legislation for the provision of secondary glazing for homes near airports originally specified levels in excess of 69 Leq, but more recent schemes at London Stansted and London City airports had a lower cut-off of 57 Leq for night time noise. Current DETR policy states that night-time noise of above 57 Leq should be taken into consideration in granting planning approvals. Germany limit new housing applications where the noise contour is 67 Leq and above, but with noise insulation. The French Government has similar limits, but using their

IP measure, and the Netherlands use Kosten Units. The cut-off points differ in terms of equivalent noise level, with the Dutch being the strictest.

Factors influencing irritation from noise:

Frequency range
Loudness
Repetition
Duration
Time of day
Activity of listener
Psychological factors

Noise comparisons of air with other transport modes depend on the distance of the measuring point from the vehicle. The following (from Airbus and INRETS) give some idea of the relative values:

High speed train (300 kph, 300m away):	92dB(A)
Express train (100kph, 100m away):	88dB(A)
Bus in town (8m away):	82dB(A)
Airbus A320 take-off (300m away):	80dB(A)
Airbus A320 take-off (700m away):	70dB(A)

A number of European airports publish their own sub-division of Chapter 3 aircraft into noisier and less noisy aircraft. These classifications, which vary from airport to airport, are used for charging, and occasionally night movement restriction purposes.

All German airports classify aircraft for noise charging purposes into the ICAO Chapter 2 and Chapter 3 categories, with Chapter 3 sub-divided into a bonus and non-bonus class. The basis of the Chapter 3 split is based on whether the noise levels are below a defined level. The bonus list includes all Airbus types, all Boeing 737s (apart from B737-100/200 and B727s which have not been retrofitted with Tay engines), BAe 146s, DC8-70s, DC10-30s, MD11s, MD90s and Fokker 70/100s.

Paris Orly, Charles de Gaulle and other French airports apply noise surcharges to a landing fee based on the widely used MTOW weight band system. However, the landing fee is first modified by a ratio that depends on aircraft acoustic group, the ratio varying from 0.85 for the lowest noise group to 1.30 for the highest (for day-time operations). For each take-off, a noise tax is then applied according the following formula:

$$\text{Tax} = b \times t \times \log_e (\text{MTOW})$$

where: t = a unit rate currently set at FRF 68
b = a coefficient which varies according to departure time and aircraft acoustic group

Whereas, Amsterdam, the German airports and the BAA use three noise groups (although the BAA refer to the seven group QC classification – see below), Paris use five groups. Their Group

1 covers essentially Chapter 2 aircraft, while their lowest noise Group 5 surprisingly include aircraft such as the A300 and A310 aircraft, which under the Amsterdam or German system would be in the middle category. Group 4 are mostly heavier B747 type aircraft, while many hushkitted short/medium haul aircraft are in Group 3.

A number of airports have restrictions on night operations, but only the BAA London airports and Manchester (and Brussels from the year 2000) have quota systems. Chapter 2 aircraft operations are usually banned between various night time periods (ranging from 1900-0500 at Frankfurt to 2300-0600 at Paris). In addition, some airports, such as London and Amsterdam ban some Chapter 3 widebodies between 2300 and 0600.

The UK government introduced the quota or QC system in October 1993 at London Heathrow, Gatwick and Stansted airports in order to provide protection for neighbouring communities from night noise disturbance, while at the same time give airlines clear guidelines for purposes of fleet planning. The system originally classified aircraft types into one of six bands, but this was subsequently increased to seven with the addition of a QC/0.5 band:

QC/0	exempt aircraft, which on the basis of noise certification data are classified as less than 87 EPNdB, but in the case of jet aircraft also have a maximum certificated take-off weight not exceeding 11,600 kg. They are not counted against the quotas or movement limits.
QC/0.5	less than 90 EPNdB
QC/1	90 - 92.9 EPNdB
QC/2	93 - 95.9 EPNdB
QC/4	96 - 98.9 EPNdB
QC/8	99 - 101.9 EPNdB
QC/16	greater than 101.9 EPNdB

Aircraft are classified under the above system separately for take-off and landing. There are two limits that should not be exceeded during the Summer and Winter periods respectively: a movement limit, and a quota count limit. The quota count limit is the product of the movement limit and the QC values of the expected aircraft types operating those movements.

In addition to noise surcharges, quotas and curfews, some EU airports apply penalties for aircraft that exceed certain noise levels at various measuring points, and in some cases when aircraft deviate from the prescribed track.

For example, Glasgow Airport imposes a penalty of 35% of landing charge for aircraft which exceed the following noise thresholds:

Day (0600-2330 hours): 97 dB (110 PNdB)
Night (2300-0600 hours): 89 dB (102 PNdB)

At Manchester Airport, aircraft exceeding the limits below have a surcharge of £500 (€710) plus £150 (€210) per full PNdB unit in excess of the limit:

100 PNdB (2300 ~ 0659 hours)
105 PNdB (0700 ~ 2259 hours)

The table below shows the area of 85dB(A) noise contours imposed by a take-off and approach of British Airways' main fleet. The B747-100 has since been retired, while the B747-400 shows a significant improvement over the B747-200 on long-haul services, the latter type being also phased out. British Airways' new strategy is based on the more heavy reliance of the B777 for long-haul services, with further significant noise improvements envisaged.

Aircraft Noise Contour Areas: 85dB(A)

Aircraft Fleet	*Take-off (85dB(A)*	*Approach 85dB(A)*
A319-131	0.49	0.08
A320-211	0.83	0.14
B737-200(Adv)	7.04	0.24
B737-300	0.70	0.24
B737-400	0.89	0.27
B767-336	1.41	0.30
B777-236	1.00	0.33
B747-136	5.15	1.10
B747-236	4.24	1.00*
B747-436	2.89	0.54

Source: British Airways, Social & Environmental Report, 2000
* estimated

On the short-haul routes, the replacement of Chapter 2 B737-200s by Chapter 3 B737-300s obviously results in a large reduction in noise impact, but these B737-300s are now being replaced by A319s on some routes, with further substantial improvements in noise footprint.

Population affected by Aircraft Noise* around Heathrow and Gatwick Airports

Aircraft Fleet	*London Heathrow Airport*	*London Gatwick Airport*
1988	538,000	50,000
1989	562,000	30,000
1990	488,000	30,100
1991	429,000	23,900
1992	372,000	23,000
1993	341,000	14,600
1994	319,000	14,600
1995	324,000	15,500
1996	299,000	14,900
1997	300,000	12,600
1998	311,500	9,400

Source: UK Civil Aviation Authority / DETRin British Airways Social & Environmental Report 2000
* based on 57 Leq, a level which has been described by DETR as 'the onset of disturbance'.

The above table for an airport which causes a significant noise nuisance and one that has less impact, which is not atypical in terms of range and trend in Europe, shows the very real progress that has been made since 1988 (even more so since 1974 when the numbers affected were just over 2 million). It also illustrates the levelling out of progress, as the Chapter 2 aircraft have been retired from service, and the need for a new, stricter standard.

Aircraft noise comes from two sources: engines and airframe. Considerable gains have been achieved from quieter engines, but the future potential for this source is much less. Airframe noise from air displacement is worst during the landing phase when flaps are deployed and the landing gear down. Attempts are being made to reduce landing gear noise through acoustic shields, and there is some scope for reductions from the other airframe noise sources (for example using winglets). But, in general, further noise reduction is technically more difficult and also more costly than previously.

C2 - Emissions:

Engine exhaust emissions from aircraft provide potential impacts to both the local and global environments. At ground level, emissions can effect the local air quality surrounding airports and at cruise altitude around 8 - 15km emissions can impact upon the lower stratosphere and upper tropospheric regions of the atmosphere. Chemical species emitted from aircraft engines identified as having potential for climate change and ozone depletion include carbon dioxide, nitrogen oxides, water, soot and particulates.

Carbon dioxide and water are produced during the combustion of fuel and are unavoidable products of the combustion process adding to natural concentrations and causing direct radiative warming in both the troposphere and stratosphere. Water also depletes ozone in the stratosphere. Nitrogen oxides
forms ozone in the upper troposphere and both forms and depletes ozone in the stratosphere. Soot and particulates can provide both radiative cooling and warming as well as modifying ozone chemistry.

Carbon dioxide emitted from aircraft is indistinguishable from that of other anthropogenic sources. Aviation contributes some 2 percent of emissions of carbon dioxide from fossil fuels and some 12 percent of all carbon dioxide from transport sources.

Reducing fuel burn is desirable both in terms of costs to the airline and emissions to atmosphere. Great improvements have been made in propulsion efficiency and Air France claim that carbon dioxide and water emissions per passenger kilometre (directly linked to the amount of fuel used) have decreased by 17 percent since 1991. Improved technology has also led to reductions in other pollutant constituents such as carbon monoxide and unburnt hydrocarbons (UHC's). Airbus claim reductions in carbon monoxide and UHC's by 98.4 percent and 89.5 percent respectively for the period 1960 to 1995.

C3 - Health impacts: DVT.

A great deal of uncertainty surrounds the issue of risks to passengers from deep vein thrombosis (DVT) and large scale epidemiological research programmes have been recommended by the UK House of Lords Select Committee on Science and Technology. Additionally, the Select Committee recommends that airlines take various to inform and make information available to the general public so that travellers can make preliminary decisions about their travel and the risk of DVT. This report recommends that issues surrounding DVT or so called 'traveller's thrombosis' or 'economy-class syndrome' should be considered on a wider-travel related basis, including all forms of forms passenger transport.

C4 - Health: Cosmic radiation.

Passengers and flight crew are exposed to, and receive a dose of, cosmic radiation during the cruise phase of flight. It is generally thought that levels of cosmic radiation are low even at altitude and that impacts to human health are minimal. Cosmic radiation dose is usually only considered significant for the flight crews of aircraft operating at extremely high altitudes. Both European and US airworthiness requirements dictate that

aircraft that operate above 49000ft are fitted with instruments to measure the cosmic radiation dose rate. However, more research is required in this area to and a recent EU directive requires airlines to assess radiation doses received by flight crew.

C5 - Health impacts: VOC's.

The UK House of Lords Select Committee found that under normal operating conditions, volatile organic compounds (VOC's) in cabin air were found to be either undetectable or at very low levels of up to 3 parts per million (ppm) - of which 80 percent were found to be alcohols from alcoholic drinks. These levels are well below the 1,000 ppm total workplace limit and below the workplace limit for any single component. It was concluded that cabin atmosphere levels of volatile organic compounds present no risk to cabin occupants under normal operating conditions. Fume odours experienced while manoeuvring on the ground is a matter of annoyance for some rather than a health hazard.

C6 - Health impacts: Cabin air quality.

C6.1 - Cabin pressure and health:

Pressurising the aircraft cabin involves applying a force to the fuselage structure that is directly proportional to the difference between cabin pressure and the external atmospheric pressure. Airworthiness requirements dictate that the cabin has an apparent altitude of 8000ft when the aircraft is at its maximum altitude. The minimum cabin pressure must be no less than the normal atmospheric pressure at an altitude of 8000ft. There is no clear evidence that an apparent cabin altitude lower than 8000ft is necessary and therefore aircraft manufacturers use this figure for the design of cabin pressurisation systems. Some Airbus aircraft have a slightly lower maximum cabin altitude (7350ft) but there is no clear evidence to suggest a cabin altitude significantly lower than 8000ft is necessary.

C6.2 - Reduced oxygen levels:

The aircraft air conditioning systems used by Airbus supply between 10 and 13 cubic feet per minute of fresh air for each occupant, assuming a full passenger load. Aircraft are sometimes fitted with a control device which enables the air flow to be reduced to around 80% of normal flow rate. The flow rate is reduced when the aircraft is carrying significantly fewer passengers than the maximum. Airbus provides clear guidance to flight crew on the number of passengers for which the reduced setting is appropriate. Claims have been made that airlines are inclined to reduce the flow settings as a cost cutting exercise. However, Airbus flight crew guidance ensures that each occupant receives the specified quantity of fresh air. Any reduction in flow rate when the aircraft has few passengers should not effect passengers but does provide a modest reduction in fuel consumption and therefore helps to reduce engine emissions to atmosphere.

C6.3 - Transmission of infections:

The UK House of Lords Select Committee on Science and Technology recommends that airlines make efforts to improve health information for passengers and dissuade intending passengers from flying while they are likely to infect others. It was also recommended that airlines and their agents retain all passenger information to ease the process of post-flight contact tracing. Additionally, it is thought that high efficiency particulate air filtration (HEPA) should be recommended as standard for re-circulatory systems.

C7 - Biodiversity.
It is generally thought that biodiversity impacts are less significant for air travel than for other forms of transport such as sea-borne freight. However, WHO/ICAO procedures for insect control in aircraft (known as "disinsection") govern the use of aerosols ("knock-down") before or during flight; and residual (surface cover) treatment for food preparation areas, closed spaces such as cabin lockers, and areas within the aircraft that are not accessible for aerosol treatment. These aerosols are used in three ways dependent on the national regulatory requirements of the destination country:

(a) "pre-flight" - sprayed into the cabin with lockers open before passengers and crew board;

(b) "blocks-away" - sprayed into holds, flight-deck and cabin prior to departure with doors closed and air-conditioning off; and

(c) "top-of-descent" - sprayed into the cabin about an hour before landing.

Perhaps of more concern than potential impacts to biodiversity are the potential impacts to human health from their use. However, the UK House of Lords Select Committee were unaware of any UK cases of ill health from exposure to pesticides in aircraft, and suggested that insect control procedures are not a significant health issue.

C8 - Other environmental and health impacts.
The processes of design and development, manufacture, use, and final disposal of civil aircraft all provide potential adverse environmental impacts to the local, regional, and global environments. However, an extensive strategic environmental assessment encompassing the entire life cycle of the civil airliner is beyond the scope of this exercise.

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UK House of Lords Select Committee on Science and Technology: Air Travel and Health, 15 November 2000.

Web sites

Intergovernmental Panel on Climate Change (IPCC): http://www.ipcc.ch
The IPCC works for UNFCCC and has prepared a series of authoritative reports on various aspects of climate change. One recent report (for ICAO) specifically considers the impact of aviation on the global atmosphere (see below).

IPCC report "Aviation and the global atmosphere":
http://www.grida.no/climate/ipcc/aviation/index.htm
This site has the full text of the report available as well as a summary for policy makers.

International Civil Aviation Organisation (ICAO): http://www.icao.org/
ICAO is a body of the United Nations. This site includes information on environment and aviation medicine topics.

United Nations Framework Convention on Climate Change (UNFCCC): http://www.unfccc.de/
This is the UN umbrella organisation for international work on climate change (science, impacts and policy areas).

Annex 2 : Contribution

The following organisations provided input to this report, either by interview, telephone conversation, e-mail, and internet searches:

International Civil Aviation Organisation
European Civil Aviation Conference
UK House of Commons Environment, Transport and Regional Affairs Committee
UK House of Lords Science and Technology Select Committee
Association of European Airlines
European Regions Airline Association
Air Transport Action Group
ACI - Europe
UK Civil Aviation Authority
The DGAC, Paris
Airbus Industrie
Air France
BAA
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