EUROPEAN COMMUNITY

COMPETITIVE AND SUSTAINABLE
GROWTH PROGRAMME

SOURDINE II WP1

D1-1
Identification

Project acronym:	SOURDINE II
Project full title:	“Study of Optimisation procedURes for Decreasing the Impact of NoisE II”
Project number:	GRD2-2000-30105
Contract number:	G4RD-CT-2000-00394
Start date:	12 November, 2001
Duration:	45 months

Sourdine II Consortium:

NLR	*Stichting Nationaal Lucht- en Ruimtevaartlaboratorium*	*NL*
AENA	Aeropuertos Españoles y Navegación Aérea	*ESP*
AIRBUS F	*Airbus France SAS*	*F*
EUROCONTROL	*European Organisation for the safety of Air Navigation*	*INT*
ISDEFE	*Ingenieria de Sistemas para la Defensa de España S.A.*	*ESP*
INECO	*Ingenieria y Economia del Transporte*	*ESP*
SICTA	*Sistemi Innovativi per il Controllo del Traffico Aereo*	*IT*

Document Change Log

Release	Author	Affected Sections / Comments	Document Nature	Date
0.1	SICTA	All, Creation	Confidential	30/07/02
0.2	SICTA	All	Confidential	24/08/02
0.3	SICTA/ NLR	All	Confidential	24/09/02
0.4	SICTA/ NLR	Review SICTA, INECO and AIF	Confidential	28/10/02
0.5	SICTA	All / Final internal review	Confidential	05/11/02
0.6	SICTA	All / AENA review Update by SICTA: projects linked to SII, Amendments to Annex 16 of ICAO, on board technology and ATC technology.	Confidential	10/12/02
0.7	SICTA	NLR comments SICTA quality review	Confidential	13/01/03
0.8	SICTA	EC comments	Confidential	03/03/03
1.0	SICTA	Final version	Public	03/03/03

Document Distribution

Partner	Distribution list
AENA	Monica G. Medina
Airbus France	Michel van Boven
Eurocontrol Experimental Centre	Peter Hullah Cristiana Cafiero
Ineco	Peter Lubrani
Isdefe	Marcos E. Medina
NLR	Ruud Den Boer Collin Beers
SICTA	Claudio Vaccaro Mariacarmela Supino

Review and Approval of the Document

Organisation Responsible for Review	Reference of comment documents	Date
NLR. AIF	E-mail	29/10/02
Organisation Responsible for Approval	**Name of person approving the document**	**Date**
Project Manager	Ruud den Boer	03/03/03
Work Package Leader	Claudio Vaccaro	03/03/03
EC Official	Chris North	03/03/03

Document Information	
Document title	D1-1 Identification
Version	V1.0
Date	03-03-2003
Classification	Public
Work package	WP1
Document identification	SII_WP1_D1-1_v10

Contributing Partners	Authors
-	-

Contact Information
Advanced Systems for Air Traffic Control, SICTA
Attn. Ms. Mariacarmela Supino
Viale Fulco Ruffo di Calabria, Aeroporto di Capodichino c/o ENAV
80144 Napoli
Italy
Tel.: +39-081-5999437
Fax: +39-081-5999445
e-mail: mcsupino@sicta.it

1 Summary

This deliverable provides an initial inventory of the «State-of-the-art» in the field of Noise and Emission assessment, including the principal results from relevant completed/on-going projects (e.g. Sourdine I) and working groups (e.g. ICAO CAEP).

Successfully implemented practices, noise abatement procedures already in place, as well as future CNS/ATM technology, air traffic forecasts and noise legislation in force in some European countries are also provided in the document.

Table of Contents

1 Summary 5
2 Introduction 9
2.1 Purpose 9
2.2 Document Structure 9
2.3 Acronyms 9
2.4 Reference documents 11
3 Sourdine I results and recommendations 13
3.1 Achieved objectives 14
3.2 Conclusions re noise abatement procedures 14
3.3 Conclusions re noise models and simulation tools 16
4 Related projects and international working groups evolved in emissions reduction studies 17
4.1 X-NOISE thematic network 17
4.1.1 Resound 17
4.1.2 Ranntac 18
4.1.3 Rain 19
4.1.4 Ducat 19
4.1.5 TurboNoiseCFD 20
4.1.6 JEAN 20
4.1.7 Silencer 21
4.2 AERONET II thematic network 21
4.2.1 AEROCERT 21
4.2.2 AERO2K 22
4.2.3 AEROJET II 22
4.2.4 PARTEMIS 22
4.3 Other noise and emissions projects 23
4.3.1 AWIATOR 23
4.3.2 QAT-Quiet aircraft technology Program 23
4.3.3 Russian ISTC project 24
4.3.4 GARTEUR- Group for Aeronautical and Technology in Europe 25
4.3.5 SAGE 25
4.4 ACARE 25
4.5 CAEP working groups 26
4.5.1 WG1: Noise 26
4.5.2 WG2: Airports and Operations 26
4.5.3 WG3: Emissions-Technical issues 27
4.5.4 WG4: Emissions-Operational issues 28
4.5.5 WG5: Market-Based Options for Emissions reduction 28
4.5.6 Forecasting and Economic analysis Support Group (FESG) 28
4.6 Terminal Airspace RNAV Applications Task Force 28
4.7 Other projects related to SOURDINE II 29
4.7.1 ENHANCE 29
4.7.2 APPROVE 29
4.7.3 TORCH 30
4.7.4 LEONARDO 30
4.7.5 GATE-TO-GATE 2005 30
4.7.6 AFAS/MAFAS 31
4.7.7 AVENUE 31
5 Successfully implemented practices and procedures 32
5.1 Known short-term NAPS 32
5.1.1 Intercept ILS Glideslope from above 32
5.1.2 Higher ILS Glideslope angle. 33
5.1.3 ICAO-A & B Procedure 33

5.1.4 Power Management 36
5.2 Known Medium-term NAPS 36
5.2.1 RNAV SID/STAR 37
5.3 Successfully practices and procedures 39
5.3.1 Amsterdam Schiphol airport (CDA) 39
5.3.2 London city airport (Increased glide slope) 40
5.3.3 London Heathrow airport (CDA) 40
5.3.4 Frankfurt airport (dual threshold) 42
5.3.5 Vienna airport (reduced flap, delayed gear) 43
5.3.6 PRW/ LDA MAP approach 44
5.3.7 Milan Malpensa airport 45
6 ATM/CNS technology 46
6.1 Overview of future on-board systems 46
6.1.1 Communication 46
6.1.2 Navigation 47
6.1.3 Surveillance: 47
6.2 Overview of advanced ATC technologies 48
6.2.1 A-SMGCS 49
6.2.2 DMAN 50
6.2.3 AMAN 50
7 Traffic predictions 51
7.1 Current data on air traffic trends 51
7.2 Air-traffic trend forecast 52
7.2.1 Air-traffic forecast to 2009 52
7.2.2 Air traffic forecast to 2015 55
Appendix A: Aircraft Noise Certification 56
A.1 Aircraft Certification 56
A.2 Chapter 3 Re-certified aircraft 60
A.3 Chapter 4 aircraft 61
Appendix B: Overview of environmental airport problems 64
B.1 Noise 64
B.1.1 Airport noise assessment 64
Appendix C: New European laws about Noise abatement 67
Appendix D: The Netherlands 70
D.1 Noise calculation 70
D.2 Noise regulations 71
Appendix E: France 75
Appendix F: Italy 76
Appendix G: Spain 79
Appendix H: Emissions 82
H.1 Airport emission regulations 82
H.1.1 Regulations and practices concerning aircraft emissions in European countries 82
H.2.1 Regulations and practices concerning aircraft emissions in other ICAO countries 83
H.3 Airport emission assessment 85
H.3.1 Emission measurement indicators 85
H.3.2 Emission calculation methods 88
H.3.3 Aircraft emission certification 89
H.3.4 Results of studies on emission effects 90

List of figures

Figure 1: SOURDINE method and findings 13
Figure 2: Increased Altitude Approach 32
Figure 3: Increased Glide slope angle 33
Figure 4: ICAO Procedure A 34
Figure 5: ICAO Procedure B 36
Figure 6: Conventional vs. RNAV STAR 37
Figure 7: Traffic concentration and dispersion compared for both systems. 37
Figure 8: Way point flight vs Navaid Flyover. 38
Figure 9: Vertical flight profile current CDA 39
Figure 10: Detail of CDA in Schiphol 40
Figure 11: Flight path angle for CDA 41
Figure 12: Vertical speed for CDA. 41
Figure 13: Dual Threshold Procedure in Frankfurt 42
Figure 14: Acceptable fleet mix for the HALS/DTOP procedure 42
Figure 15: NAPs reduce flap setting 43
Figure 16: PRM (SOIA) 45
Figure 17: French Air traffic forecast up to 2009 53
Figure 18: Italian air traffic forecast up to 2009 53
Figure 19: Dutch air traffic forecast up to 2009. 54
Figure 20: Spanish air traffic forecast up to 2009 54
Figure 21: Air traffic forecasts to 2015 for CFMU area 55
Figure 22: Chapter 3 Noise Measurement Points 58
Figure 23: Noise footprint for Chapter 2 and Chapter 3 aircraft 60

List of tables

Table 1: Aircraft movements by greater European airports recorded in 2001 51
Table 2: Aircraft Certification 56
Table 3: Costs in US dollars to remove persons from 65 DNL noise contours 62
Table 4: Statutory noise limits in the Netherlands 72
Table 5: Correction Factors for classifying Italian airports 77
Table 6: Air Quality Limits Values and Guidelines for NO2 (µg/m3) 86
Table 7: Air Quality Limits Values and Guidelines for SO2 (µg/m3) 86
Table 8: WHO Human Health Guidelines for CO and Toluene (mg/m^3) <Longhurst 92> 86
Table 9: Standards for NO_2 applicable at Nice airport 87
Table 10: French Air-Quality Index Thresholds 87
Table 11: Ambient Air-Quality standards for SO2 (µg/m3) 87
Table 12: Ambient Air-Quality standards for Particulate Matter (Total suspended µg/m3) 88
Table 13: WHO Air-Quality Guidelines for Europe for SO2 (µg/m3) 88
Table 14: Austrian Air-Emission standards (µg/m3) 88
Table 15: Danish standards for NO2 (µg/m3) 88

2 Introduction

2.1 Purpose

The SOURDINE II project falls in line with the international idea of a “balanced approach” to noise abatement, which purports to follow different ways of reducing noise impact, not only noise reduction at source. The approach followed by the SOURDINE II project is to identify innovative procedures to reduce the impact of noise around airports and develop a plan for their implementation.

This document represents a starting inventory of the level of international interest in airport noise and emissions pollution. It provides results from other relevant projects, starting with its predecessor Sourdine I, and international working groups engaged in noise and emission reduction studies as well as successfully implemented practices and procedures.

This deliverable also provides information about current noise legislation, such as European Directives concerning noise and emissions, as well as Dutch, French, Italian and Spanish national regulations.

2.2 Document Structure

This document consists of the following chapters:

- The first chapter is about general and supporting information.
- The second chapter shows the results from the Sourdine I project.
- The third chapter provides an overview of related projects and working groups.
- The fourth chapter deals with the “core” of the project: noise abatement procedures. It includes a description of all the procedures currently in use to reduce noise levels around European airports.
- The fifth chapter supplies a brief description of future technology that will allow for the implementation of the proposed procedures.
- The Sixth and last chapter provides information on air traffic forecast for European countries.
- Presented In the appendices are:

  an overview of the latest international certification criteria,

  an overview of European and local noise legislation and

  an overview of emissions assessment and legislation.

2.3 Acronyms

ACI	Airport Council International
AEM	Alternative Emissions Methodology
AENA	Aeropuertos Españoles y Navegacion Aerea
ANEF	Australian Nose Exposure Forecast
APU	Auxiliary Power Unit
ATC	Air Traffic Control

ATM	Air Traffic Management
ATS	Air Traffic Services
BKL	‘Besluit geluidhinder kleine luchtvaart’; noise exposure general aviation
CAEP	Committee on Environmental Aviation Protection
CDG	Charles De Gaulle
CFMU	Central Flight Management Unit
CNS	Communication, Navigation and Surveillance
CO	Carbon monoxide
CRCO	Central Routes Charges Office
DER	Departure end of the runway
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme
EATMS	European Air Traffic Management System
ECAC	European Civil Aviation Conference
EEC	European Economic Commission
EPNL	Effective Perceived Noise Level
FAA	Federal Aviation Administration
FANOMOS	Flight track and Aircraft NOise MOnitoring System
FAR	Federal Aviation Regulation
FESG	Forecasting and Economic Support Group
FIR	Flight information Region
FMS	Flight Management System
GCAM	General Campaign Analysis Model
GNSS	Global Navigation Satellite System
GSE	Ground Support Equipment
HC	Hydrocarbons
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
ICCAIA	International Co-ordinating Council of Aerospace Industries
IFALPA	International Federation of Air Line Pilot Associations
ILS	Instrument Landing System
INECO	Ingeniería y Economía del Transporte
IOAG	Interagency Operation Advisory Group
IPCC	Intergovernemental Panel on Climate Change
IRS	Inertial Refernce System
JAA	European Joint Airworthiness Authority
Ke	Kosten-Eenheid (‘Kosten’- unit)
LA eq	Equivalent continuous sound A-weighted Level
LDA	Landing distance available
L_{Af}	A-weighted level of sound pressure with time constant “fast”
L_{Afma}	Maximum A-weighted level of sound pressure with time constant “fast”
L_{va}	Evaluation level of airport noise
L_{van}	Evaluation level of airport noise in the night time(Italian metric)
L_{DN}	Day evening night equivalent sound level
LTG	Long Term technology Goals
MAGENTA	Model for Assessing Global Exposure to the Noise Transport Aircraft
MLS	Microwave Landing System
MLW	Maximum Landing Weight
MTOW	Maximum Take Off Weight
NADP	Noise Abatement Departure Procedure
MTOW	Maximum Take Off Weight
NBAA	National Business Aviation Association

NLR	National Aerospace Laboratory
OJ	Official Journal of the European Communities
PM	Particulates
PNL	Perceived Noise Level
RLD	Rijksluchtvaartdienst, Ministry of Transport, Public Works and Water Management's Directorate-General of Civil Aviation
RNAV	aRea NAVigation – Random NAVigation
RTD	Research and Technological Development
RWY	Runway
SAE	Society of Automotive Engineers
SEL	Sound Exposure Level
SICTA	Sistemi Innovativi per il Controllo del Traffico Aereo
SID	Standard Instrumental Departure
SO_2	Sulphur dioxide
SOURDINE	Study of Optimisation procedURes for Decreasing the Impact of NoisE around airports
STAR	Standard insTrument ARrival
TARA	Terminal Airspace RNAV Applications Task Force
THR	Threshold
TMA	Terminal Manoeuvring Area
TOW	Take Off Weight
VOCs	Volatile organic compounds
V_{ZF}	Zero Flap minimum safe manoeuvring Speed
WANIM	World Airport Noise Impact Model
WHO	Worldwide Health Organisation

2.4 Reference documents

[AAAE]	American Association of Airports Executive, "Comments to ANAP 2000" by FAA, October 23, 2000
[ANAP]	Federal Aviation Authority, "Aviation Noise Abatement Policy 2000", Federal Register/Vol. 65 No. 136, Friday, July 14, 2000 Notices
[AEMR]	Annual Environmental Management Report 2000 for Madrid/Barajas airport
[ATF_EEC]	C. Vanderberghe, B. Nicolas, C. Cornette, Air Traffic Statistics and Forecasts. Number of flight by Region 1974-2005/2015(total Airspace), June 1999
[AO_V1]	DOC 8168-OPS/611 Volume I, Aircraft Operations
[ATT]	G.F. Austin, Air Traffic Technology magazine, "Move closer", Jan 2002
[CAEP6]	DOC 9777, CAEP/5:Report of CAEP fifth meeting held in Montreal 8-17January 2001
[CAEP_2000]	ICAO CAEP Noise Workshop and steering group "ACI Delegation report", May 2000
[CAEP_2001]	ICAO CAEP Summary of steering group meetings from 04/12/01 to 07/12/01
[D1]	Sourdine I D1 Environment Requirements and Operational Constraints
[D3.1]	Sourdine II D3 Definition of New Noise Abatement Procedures
[D3V83]	Sourdine I D3 Establishment of noise abatement solutions
[D5v1.6]	Sourdine I D5 Final Report
[EC_85]	Directive 2002/30/CE "Rules and procedures for the introduction of

	operational constraints to abate noise in Community airports “
[EC_120]	Council regulation (EC) No 925/1999 of 29 April 1999 on the registration and operation within the community of certain types of civil subsonic jet aircraft[..] modified and re-certificated [..]
[EC_189]	OJ L189/13 of 18/07/2002: Directive of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise
[EPA]	Evaluation of Air Pollutant Emissions from Subsonic Commercial Jet Aircraft, April 1999
[FAA]	Federal Aviation Authority, Aviation Noise Abatement Policy, January 1, 1977
[FFRA]	DFS Deutsche Flugsicherung GmbH Corporate Communications, “Future of FRA, July, 2000
[HAE]	Barry Truax, Handbook for acoustics ecology, 2th edition 1999
[HC]	“Aircraft noise in the vicinity of an airports” by Health Canada website
[ICAO_N.4]	ICAO Journal, N.4 2001, Volume 56
[MAS]	Evans and all, Munich airport study, 1999
[MFF_D311]	Mediterranean Free Flight Programme, Working Area 3, Deliverable D311
[MFK]	M.F. Koeslag: ”Advanced Continuous Descent Approaches – An algorithm design for the Flight Management System-”. Master degree thesis, Delft University of technology, Delft March 1999
[MIT]	J.P. Clarke & R.J. Hansman, “Systems analysis of NAPs enabled by advanced guidance technology”, USA
[Package I]	CARE/ASAS/EUROCONTROL/02-040 – ‘Description of a first package of GS/AS applications’ – Version 2.2, September 30, 2002.
[PPt]	WP3-1 naps.ppt: Sourdine I presentation over NAPs
[SII_DOW]	SOURDINE II “Description of work”, October 18, 2001
[SUR_WP3]	SURVEYOR – Review of the State of the technology in Airport CNS, ATM DPS and avionics Systems – WP3, August 08, 1999

3 Sourdine I results and recommendations

To achieve the contradictory objectives of increasing capacity and reducing environmental impact, new operational procedures and supporting technologies need to be introduced.

The SOURDINE project was conceived as the first stage of a long-term program for the reduction of noise around airports. The final outcome of this program was the definition and assessment of new approach and take-off procedures for some European airports supported by the adequate federation of simulation tools. The issue of automation tools required to assist the end-users (pilots and controllers) in the utilization of the new procedures was also investigated.

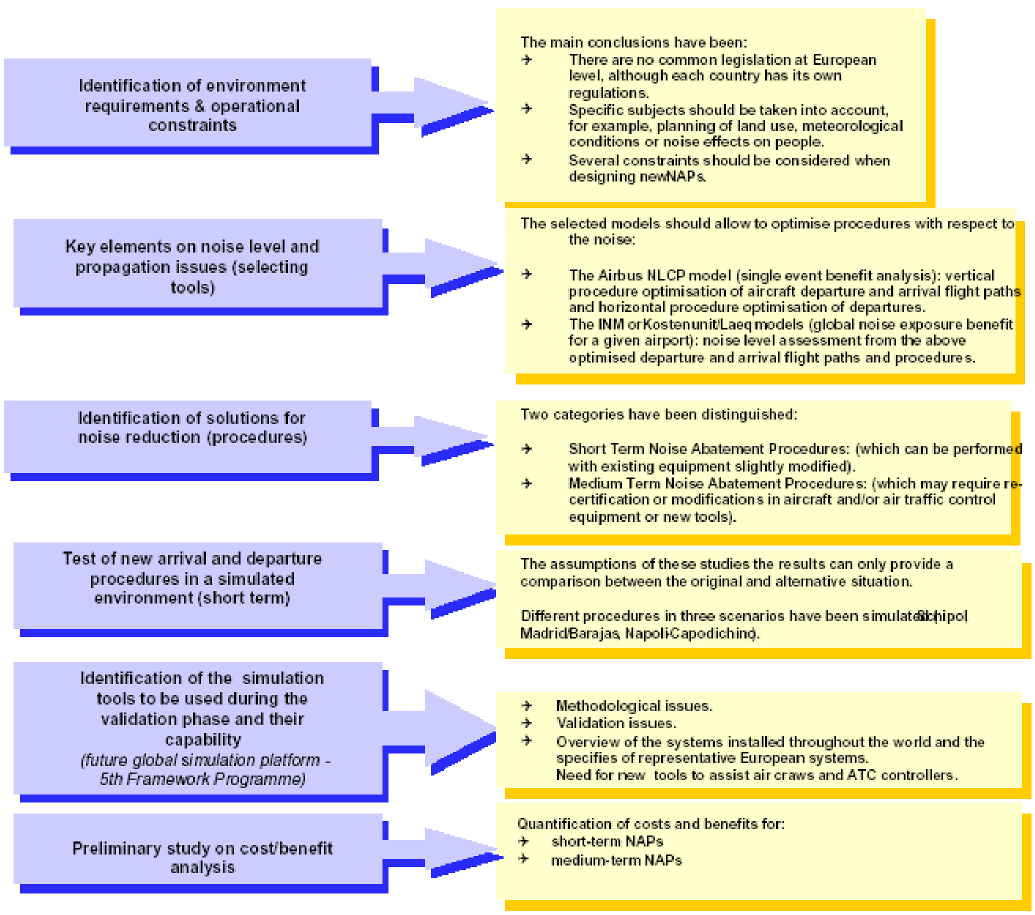


Figure 1: SOURDINE method and findings

3.1 Achieved objectives

SOURDINE I achieved the following objectives:

- to make an inventory of the regulations and practices concerning aircraft noise and to study the operational, safety, capacity and economical constraints that might influence the definition of new procedures,
- to select a set of noise models (amongst the current tools) that allow the optimisation and evaluation of noise abatement procedures and to define the framework for the parametric studies to be performed,
- to propose alternatives to reduce noise levels around airports:
  - a method for updating existing approach and take-off procedures for short-term improvement (based on present-day avionics and ground systems and applicable to most existing aircraft) was elaborated,
  - innovative procedures for medium-term noise reduction, taking advantage of new airborne and ground technologies (GNSS, RNAV, MLS, Enhanced FMS…), were investigated,
- to define new procedures for three selected airports (Schiphol, Madrid and Napoli), considering the feasibility of such procedures,
- to provide qualitative effects in noise reduction to demonstrate to the community and investors that it is worth investigating in this domain,
- to identify simulation tools and their capability of being integrated in a global simulation platform, with the objective of carrying out an operational validation of the new procedures within the 5th Framework Programme,
- to define noise measurement systems and automation tools for assisting operators (pilots, controllers, airport personnel) in their decision making processes,
- to involve end-users (i.e. pilots, controllers, handling agents…) in the preliminary validation of the concepts,
- to perform a preliminary cost-benefit analysis.

Figure 1 shows the methodology and the findings for each step.

However, for several reasons, consideration of the results of the Sourdine I project must be limited to a first level investigation of the selected noise abatement procedures.

3.2 Conclusions re noise abatement procedures

The noise abatement procedures evaluated in Sourdine for the short-term were:

- increased final approach altitude,
- (slightly) increased glide slope angles,
- delayed flaps and/or gear approaches,
- reduced final landing flap settings,
- continuous descent approach.

Investigations on selected short-term procedures have shown significant benefits in terms of noise and capacity. The procedures, and in particular the increased ILS interception altitude and continuous descent approaches, are worthy of being validated in a real environment to confirm and refine the fast time and real time simulation measurements with “in-situ” measures. Experience acquired from Sourdine could be used to build up a full-scale optimisation programme, having the onsite implementation of the validated procedures as its final objective. This objective would require the participation of airports, civil aviation authorities and airlines willing to involve real aircraft in the experiment.

In the medium-term, the following noise abatement measures were evaluated:

- advanced operation of continuous descent approach,
- application of increased glide slope angles,
- approach and departure routes using precision navigation,
- gradual increase of cutback thrust during climb out.

Medium-term solutions could bring potential benefits thanks also to the capacity of flying routes of adhering to more rigorous requirements. In fact, the development of RNAV routes, supported by enhanced navigation systems, should provide new means to adapt current SIDs and STARs to local geography, while still maintaining high navigation capability performance.

The objective of a follow-up programme would be to perform preliminary simulations on these medium-term procedures, in a manner similar to the one followed by the short-term procedures in Sourdine. For these procedures, before starting the on-site operational testing, the potential benefits should be assessed, through modelling and simulation, in relation to:

- safety,
- technical / operational / certification constraints,
- efficiency/capacity,
- crew/controller workload,
- economics,
- airport layout,
- fleet mix typically operating to/from that airport

These objectives would require the adaptation and/or development of new tools (see below) and therefore the participation of the industry (software and aircraft manufacturer), research laboratories, airports, civil aviation authorities and airlines. Taking into account the process outlined above, the result of the noise programme (for short and medium-term) should be a set of validated recommendations to be considered while designing flight procedures for post-2000 air traffic scenarios. Such recommendations would facilitate compliance with operational and certification requirements, thus achieving the best possible solution, while weighing up both the technical feasibility of the procedure and the noise and efficiency/capacity benefits.

3.3 Conclusions re noise models and simulation tools

Sourdine has shown several limitations in the existing tools for developing new noise abatement procedures while taking into account all the parameters and constraints i.e. noise benefits, flight safety, efficiency and capacity and last but not least, the economical aspects.

Several problems were identified:

- the NPD curve figures hide significant effects, such as the aircraft configuration in terms of flap setting and undercarriage deployment as well as an assumed aircraft speed and altitude;
- aircraft manufacturers are normally very reluctant to provide specific details;
- flight path information is not reliable (due to lateral dispersion) and thus actual radar tracking values should be used;
- local temperature and humidity effects are not taken into account;
- the performance data usually corresponds to straight-out or straight-in flight tracks without the inclusion of turns.

Further information on final results achieved by Sourdine I project see:

http://europa.eu.int/comm/transport/extra/final_reports/air/SOURDINE.pdf

4 Related projects and international working groups evolved in emissions reduction studies

This chapter provides an overview of the related projects and international working groups involved in noise and emissions reduction studies. The relationship with Sourdine II will be provided for each project and working group.

4.1 X-NOISE thematic network

Research on environmental noise pollution funded according to the Growth Programme's New perspectives for aeronautics key action revolves around X-Noise, a thematic network on external noise produced by aircrafts. Many organizations participate in the noise network, such as SNECMA, NLR, Aerospatialle, Rolls Royce, British Aerospace, Trinity College and so on.
X-NOISE is complemented by several related projects, some of which have just finished, while others are still trying to achieve their proposed goals. The following is a list of Projects belonging to the X-Noise Cluster:

- RESOUND - Reduction of Engine Source noise through Understanding and Novel Design
- RANNTAC - Reduction of Aircraft Noise by Nacelle Treatment and Active Control
- RAIN - Reduction of Airframe and Installation Noise
- DUCAT - An investigation of duct acoustics and radiation
- SOURDINE - A study of optimisation procedures for decreasing the impact of noise around airports
- TurbonoiseCFD – Turbo-machinery noise source CFD models for low-noise aircraft engine designs
- JEAN - Jet exhaust aerodynamics and noise
- SILENCER – Significantly lower Community exposure to aircraft noise

4.1.1 Resound

(01/01/1998 – 31/12/2000)
The objective of RESOUND, coordinated by Vibro-Acoustic, was to acquire the technology necessary to support the design of derivative and new aero-engines with noise levels 4 dB quieter than those of aircraft currently entering service. The ultimate goal is creating the foundation for the achievement of a mid-term (8 years) objective for reducing aircraft noise levels by at least 6 dB and to allow European industry to compete on an equal footing with the US.

RESOUND addresses the challenge of reducing noise at source, in particular turbo-machinery noise, through:
- engine component aero-acoustic design, and
- novel noise controlling devices which can be integrated within the engine structure.

Innovative technologies to be evaluated, with the aid of theoretical techniques and experiments at model and full scale, include:

- fan noise reduction through reduced tip speed,
- pressure ratio optimisation noise reduction with fan and stator axial sweep and circumferential lean fan noise reduction with variable by-pass nozzle
- passive fan tip treatment combustion noise reduction through improved and validated generation and propagation model assessment of potential noise hazards of low N_{OX} combustors
- LP turbine noise reduction through exit guide vane design
- Turbo-machinery noise reduction through active stator design
- Turbo_machinery noise reduction by means of auxiliary aero-acoustic control devices.

Based on the technology acquired, RESOUND will deliver, like Sourdine II, a full assessment of the community noise benefits of controlling engine noise at source, through design and with novel active/passive devices. The reduction of aircraft noise through improved nacelle technology and airframe design was addressed by complementary proposals (RANNTAC and RAIN respectively) and was supported by the DUCAT project, all of which have been co-ordinated through the X-NOISE thematic network that was formed as a result of the Environmentally Friendly Aircraft study (TEFA).

4.1.2 Ranntac

(01/01/1998 – 31/12/2000)

The RANNTAC programme, the RESOUND programme on engine noise source reduction technology and the RAIN programme on the reduction of airframe and installation noise are the three principal and complementary pieces of the proposed R & D effort co-ordinated at European level by the X-NOISE thematic network on external noise.

The objective of RANNTAC was to acquire the technology necessary to support the development and manufacturing of turbofan engine nacelles featuring noise reduction devices and designs enabling the achievement of up to 4 dB attenuation on engine internal noise sources in addition to that achieved by currently produced acoustic liners.

The practical results of the proposed research are to secure the design capabilities of developing, in future transport aircraft nacelles, a large range of novel sound absorbing liners, air intake shapes allowing the control of the fan noise radiation and in duct active noise control systems. The work programme provided theoretical and experimental acoustic evaluation of all proposed systems and concepts in the context of the real nacelle duct environment and an assessment of the expected benefits on future aircraft noise together with the likelihood of industrial application and the foreseen impact on aircraft economics.

The programme's structure features three tasks:

- Specifications, Assessments, Exploitation and Management;
- Development of novel nacelle treatment concepts;
- Development of Active Noise Control technology in nacelles.

4.1.3 Rain

(01/01/1998 – 31/12/2000)

The airframe can strongly influence the noise radiation from aircraft. This is true not only for the airframe through diffraction, refraction and reflection which modifies the noise radiated by the engines but also acts as a strong source of additional noise radiation either directly from its components (for example the undercarriage and wing with high lift devices deployed) or indirectly by modifying or coupling with certain engine flow features. To date, such sources of noise, whilst important, have had limited impact on the overall optimisation of the aircraft. However, the trend towards very high by-pass ratio engines with their differing source breakdown, coupled with the trend towards larger sized aircraft, leaves us with the prospect of new aircraft designs in the future being prevented from realising their full operational efficiency and therefore their competitiveness, by such acoustic effects. Thus there is a clear industrial need to develop an improved design capability, which would enable the effects of the airframe on the overall aircraft noise radiation to be addressed in the early design stages. Such a capability is essential if airframe noise and installation effects are to feature in the aircraft optimisation process.

On approach, the noise radiated from the airframe itself is comparable to that of the engines' and can limit the potential benefit of future engine noise reductions. The noise contribution from each of the components of the airframe needs to be accurately predicted. As the nature and magnitude of airframe installation effects the noise radiation from the various engine sources in differing ways, the need is to accurately predict the installation effects for the main or dominant components - jet, fan turbine and combustion. The current proposal aims to make a major contribution towards establishing such a competitive design capability by way of advanced analysis tools development and the improvement in model scale experimental noise databases. Full-scale flight test data have been used to establish scale effects and for confirmation of the overall prediction capability. In parallel with the development of analysis tools, practical approaches to noise reduction have been identified and evaluated to provide a basis for the belief that such analysis tools are capable of being implemented within design optimisation studies.

The project is expected to achieve reductions in noise of the order of 5 to 10 dB at component level. The full impact will be realised when the new airframe related technology developed here is integrated with that of the engine's, on an overall aircraft noise level basis. This is expected to result in a net improvement of less than 5 EPNL, depending on the engine noise contribution.

The proposed work is very important as airframe and installation noise is already affecting existing aircraft, and need to be fully controlled at the design development stage of a new generation of aircraft (airframe noise may be a limiting factor in the development of future large European aircraft) if community noise requirements are to be fully satisfied.

4.1.4 Ducat

(*01/01/1998 – 31/12/2000)*

Since fan noise is one of major contributors to the exterior noise of Very High By-pass Ratio (VHBR) and Ultra High By-pass Ratio (UHBR) turbofans, the aerospace industry is planning to introduce new nacelle noise reduction technologies, such as adaptive and active liners (actuators). Optimisation of these in terms of noise reduction requires a thorough understanding and accurate description of sound propagation in ducts. Therefore, the main goal of DUCAT is to develop, extend and validate computational methods for the propagation and radiation of fan noise, including the effects of acoustic liners.

A number of relevant aspects of this topic are not covered by the computation models existing today. Duct acoustics design tools have to be reliable, accurate, fast and versatile. According to aerospace industrial needs, these models should ideally be able to handle:- realistic nacelle geometries and non-uniform flow (in intake and by-pass duct), non-uniform acoustic liners and duct wall mounted actuators, radiation into the far field, realistic frequencies and Sound Pressure Levels. In the short term, it was not expected that all the aspects could be addressed with a single model. Therefore in DUCAT a small number of numerical models (Finite Element (FEM), Boundary Element (BEM), coupled FEM/BEM, a non-linear propagation model and a ray-acoustics model) have been developed covering the whole frequency range of interest for fan noise (kRmax = 100).

The final result of DUCAT is an assessment of the applicability of the various computational models for duct acoustics problems and liner optimisation. With the improved and validated models, the engine and aircraft industries have the possibility of developing adequate design tools for both passive and active liner optimisation. Furthermore, some spin-offs to other industries are foreseen, since fluid machines such as pumps, fans and internal combustion engines are major noise sources in modern society. The work in this project will clearly make progress beyond the state-of-the-art by developing and extending computational models for duct acoustics and validating those by way of a small number of precise experiments.

4.1.5 TurboNoiseCFD

(01/03/2001 – 28/02/ 2003)

The European aircraft engine manufacturing industry is facing increasing pressure to reduce engine noise levels. Community expectations of improved quality of life through reduced noise levels and the current growth in air traffic are major socio-economic problems. A proposed long-term solution is to create a new method for designing low noise turbo-machinery components through the exploitation of existing Computational Fluid Dynamics (CFD) software. This project would enable CFD software to be used for the prediction of noise, if the technical challenges such as dispersion and excessive memory and computational times can be overcome. If successful, the results of this project could be commercially exploited in the same way as the CFD codes are for turbo-machinery aerodynamics. The aim of this project is to contribute to the achievement of the Work Programme RTD objective of a 10 dB reduction in 10 years in aircraft externally perceived noise.

4.1.6 JEAN

(01/02/2001-31/01/2004)

the goal of JEAN is to realise noise forecasts by jet flows including the effects of mixing enhancement and co-axial configurations. CFD techniques will be applied and validated to predict the turbulence characteristics of jets. These will be coupled with noise source generation and propagation models to estimate near and far field noise. The results will be critically evaluated while being compared with data obtained from a series of carefully designed experiments. The validated noise prediction procedures will be applied to mixing enhancement and to co-axial jets and the results compared with existing high quality data for these configurations. The work will recommend the use of a particular suite of techniques, which will have to be validated for specific applications. These will then provide the basis for the development valuation tools for new concepts in low noise design for jet engines.

4.1.7 Silencer

(01/04/2001 – 01/04/2005)

The largest ever European aircraft noise research project, known as SILENCE(R), was launched on 1 April 2001. A consortium of 51 companies is collaborating to validate noise reduction technologies that will allow quieter aircraft operations by up to 6 decibels as from 2008.

No other effects of air transport operations are felt as directly as aircraft noise. Aircraft landings and take-offs generate repeated high peaks of noise that occur quickly and then fade away. While the number of people annoyed by aircraft noise is determined by a variety of factors, including the number of aircraft movements and population patterns around airports, a key area of improvement remains reduction of noise at source and, therefore, the development of quieter aircraft.

SILENCE(R) brings together a wide-ranging consortium to address the issue of aircraft noise, a major cause of concern around European airports. Firstly, the partners will carry out a large-scale validation programme, focusing on noise reduction technologies whose development was initiated by EU and National projects in 1998. An assessment of the applicability of these technologies within the European aeronautics industry will be done, including their effects on cost, weight and performance. Finally, associated achievable noise reduction will be evaluated.

Novel concepts to be validated are to include low-noise fans, LP turbines, scarfed intakes, novel intake liners, bypass and hot-stream liners, nozzle jet noise suppressors, active control techniques and airframe noise reduction technologies.

For more information about X- Noise thematic network see following web site:

http://www.nlr.nl/public/hosted-sites/x-noise/home.html

4.2 AERONET II thematic network

This Thematic Network (2001-2003) of the European Commission Aircraft Emissions and Reduction Technologies includes all the emissions-oriented projects. It is has been founded to facilitate the exchange of information and experiences, to facilitate cooperation on the basis of eprsonal knowledge and trust, and to offer better clarity for citizens.
The main working areas of this thematic are

- Aircraft and Engine Technology Aspects of Emissions Reduction
- Fleet Emissions and Operational Technology Aspects of Emissions Reduction
- Economic- Environmental Balance in the Air Transport System
- Policy Matters

4.2.1 AEROCERT

(01/07/1997 – 30/06/2000)

Aircraft Environmental Impacts and Certification Criteria

AEROCERT's goal was to provide options for improvements to the certification standards and to the recommendations about the environmental impact evaluation. Actually, the main issues were to identify necessary revisions and/or extensions of the emissions certification procedures, to identify the necessary data to evaluate the emissions impact and to quantify it, to propose suited emissions indices, to study the influence of the operational procedures on the aircraft emissions certification and the feasibility of new emissions abatement procedures in economical, effectiveness terms.

Other issues were to see the deterioration effects on noise and emissions values caused by the aircraft and its engines and to deliver recommendations on operational and maintenance procedures to be as close as possible to the certification levels.

4.2.2 AERO2K

(01/01/2001 – 31/12/2003)
Global aircraft emissions data project for climate impacts evaluation

The objective of this project is to update the old emissions database. In fact, the impact of aviation emissions can only be determined from emissions databases. Currently available global emissions databases are about 10 years out of date and cannot meet the current needs of policy makers and scientists. This project (AERO2K) will deliver data required for European and international policy development and future assessments of the impact of aircraft on the climate.

AERO2K will establish a new global 4D inventory of fuel usage and emissions of pollutants (NOx, CO, HCs, CO2, particles) relevant to the impact of aircraft on the upper atmosphere. These parameters will be derived from all commercial and military movements with a spatial resolution of one degree lat/long by 0.5 km in height, by month and include high time resolution (hours) for representative days.

Considering the latest forecasting techniques used by industry, government and air traffic management will also provide a 25-year forecast. A top team of experts from science, technology, industry and policy makers has been assembled for AERO2K.

4.2.3 AEROJET II

(01/03/1998 – 28/02/2001)
Prototyping a Non-Intrusive Exhaust Gas Measurement System for Gas Turbines

The objective of AEROJET II is to prototype the most appropriate instruments/techniques identified in AEROJET for different European end-users. AEROJET II is an industrial research activity, which will provide a non-intrusive analysis capability with accuracy comparable to or better than that currently used.

The project includes the development of a prototype system for this industrial research and the testing of the system by measurements of different turbines on different rigs accounts. These activities include developments of both hardware and software. In the second part of the project extensive testing of the prototypes on test rigs with different running gas turbines are planned.

4.2.4 PARTEMIS

(01/04/2000 – 30/03/2003)
Measurement and predictions of the emission of aerosols and gaseous precursors from gas turbine engines.

The proposal is concerned with both aerosol particles directly emitted by aircraft engines and the new particulate materials formed within the aircraft wake. It arises from the growing concern that such materials might affect the climate through their influence on upper atmospheric chemistry and cloud coverage. The effect of engine conditions on the formation of these materials is not understood. The project aims to rectify this important gap in the present knowledge database so that engine designers will be able to predict more accurately the total emissions performance of new or improved versions of existing engines and thereby control them. The programme involves the application of special equipment, measuring techniques to generate the new database. It also involves the development of mathematical models of the physical and chemical processes so that effective prediction methods can be developed.

For further information on above mentioned projects click on: http://www.aero-net.org/about/rellinks.htm

4.3 Other noise and emissions projects

4.3.1 AWIATOR

(01/07/2002 – 30/06/2006)

This is the most recent project in the emissions and noise abatement area. In fact it started on 1 July 2002 and will last four years. The goal of this project is to develop a new European Technology platform project to reduce fuel burn and noise in future commercial airliners. The partners involved are numerous: Airbus engineering teams in France, Germany and the UK and more than twenty partners from industry in Europe and Israel, as well as from European aeronautics research .

Three key areas will be addressed by the AWIATOR project:

-Far field flow of aircraft, above all addressing the wake vortex and noise phenomena

-Near field flow around aircraft, looking at advanced wing design aspects

-The control of flow around the wing loads of aircraft by use of novel control surface elements and turbulence sensors

The target is a 5 to 7% reduction in drag, especially at take-off and landing, and 2% in terms of trip fuel reduction for long range flights. Benefits are expected in terms of noise reduction of two decibels (EPNdB). New rules for the future design of commercial aircraft and for updating the existing ones will also be delivered.

For more information on the AWIATOR project see following web site:

http://europa.eu.int/comm/research/press/2002/pr0107en.html

4.3.2 QAT-Quiet aircraft technology Program

This is a project funded by NASA, with the goal of developing revolutionary Aeropropulsion Concepts for reducing aircraft noise.

Assuming 1997 is the baseline year, QAT's target is to reduce noise levels by a half (10 dB) by 2007 and by three-quarters within 25 years. There are three critical areas investigated by the QAT project:

-Airframe systems: researchers have to examine and redesign the protruding parts of an aircraft to make the airflow around them quieter and less turbulent.

-Engine systems: subjects of investigation have been angles of fan blades and stator blades behind the fan jet engines, engine inlets and particular noise-absorbing treatments in the inlet. Engine nozzles have also been redesigned to have a scalloped configuration, which has been shown to dramatically reduce jet noise.

-Aircraft operations: this subject is very close to SII's goal. Actually QAT researchers are exploring different flying routes round airports to minimize noise impact on surroundings. As with SII, QAT will define both "low noise" flight paths and tools for pilots and controllers, to help fly more safely and to reduce to a minimum the impact on capacity respectively.

The QAT project, which assesses the new implementation process is not particularly fast. It takes almost 20 years for half of the worldwide commercial aircraft to incorporate new technology, and almost 40 years for 100% implementation. By 2010 the majority of existing U.S. airlines will be approaching its end and nearing replacement. This could facilitate the coming into force of newer and quieter aircraft.

4.3.3 Russian ISTC project

Complex Investigations into the possibility of Reduction of Aviation Influence on Environment and its Utilisation for Ecological Monitoring.

This project is being developed under the cooperation of Gromow LII (Russian Flight Research Institute), DLR and NLR.

The objectives of project are varied and are the:-

-investigation of atmospheric contamination by aircraft engine emissions during cruising;

-development of methods for reducing civil aviation airplanes' impact on the environment (community noise and contamination of atmosphere);

-development of proposals for the creation of aviation complexes for airborne monitoring, achieving the methodology for complex monitoring of the Earth, its waters and atmosphere;

-development and realization of complex methodology of theoretical and experimental (including flight) research.

In particular, recommendations for the achievement of non-standard take-off and landing procedures will be developed and verified by flight tests. These procedures will permit noise reduction for the community of 3-5 dB, with the support of improved communications, navigation, surveillance and air traffic management tools to guarantee the necessary safety requirements. A methodology to refine new NAPs will be also developed.

This project also aims to develop operational methods for studying aero-engines emission effects on atmospheric pollution during cruising, using the results of flight experiments and modelling. It also aims to develop recommendations for the creation of aviation integrated systems for aircraft, airborne equipment, and ground-based systems and software for solving the problem of obtaining ecological data.

For further information see http://www.tech-db.ru/istc/db/projects.nsf/htm/index.htm, project number 0627.

4.3.4 GARTEUR- Group for Aeronautical and Technology in Europe

GARTEUR is an international agreement between European States with important aerospace industries. This agreement is based on the principle of “no exchange of funds” and it aims to coordinate national projects in areas of mutual interest as well as possible. Since 1997, five development macro-lines have been selected which have gone on to initiate different projects and action, known as GIPI.

Two GIPI which are very similar to Sourdine II have been identified. One is the Community noise reduction project, a research topic, and the other is environmental effects on aircraft.

4.3.5 SAGE

The System for assessing Aviation Global Emissions (SAGE) -is a project developed by U.S.– and it is a natural answer to the rapid growth in the aviation sector and its associated emissions.

Among the thousands of questions such a model could help to resolve is the fundamental philosophical difference between the European and US approach to this problem. In general, Europeans want to increase technological stringency, while the US wants first to effect as much efficiency as possible with changes in operations, before increasing technical stringency. By providing a tool to predict what the emissions would be under various scenarios, the SAGE model will provide valuable information for that debate.

4.4 ACARE

ACARE is an Advisory Council for Aeronautics Research in Europe composed of 25-30 members, including Member States, the Commission and stakeholders. Its goal is to develop and implement a strategic approach to European aeronautics research.

ACARE’s most important mission is to establish and carry forward the SRA (Strategic Research Agenda), which serves as a guide in the planning of research projects, above all national and European projects.

The role of SRA aims to materialize the 2020 Vision and the identified goals step by step, with particular regard to public interest, including noise reduction, emissions reduction, travel delays and safer air transport.

Working team 2 is currently working on the definition of the future Strategic Research Agenda (SRA) for “Cleaner and Quieter Air Transport”.

For more click on http://www.europa.eu.int/comm/research/growth/gcc/projects/in-action-acare.html.

4.5 CAEP working groups

Under the ICAO guide, the Committee on Aviation Environmental Protection (CAEP) is engaged in research for the reduction of noise and emissions produced by commercial air traffic. The Committee studies essentially technical feasibility, economic reasons and environmental benefits of noise abatement initiatives.

CAEP researchers adopted a new approach to managing aircraft noise at worldwide airports: the Balanced approach. This new approach claims that it is necessary to combine the following noise abatement measures to guarantee better results on aircraft noise reduction, with reasonable costs and keeping high safety levels:

-reduction of noise at source

-land-use planning of noise at source

-noise abatement operational procedures

-operational restrictions on aircraft

This balanced approach has to take into account the characteristics of individual airports and to plan the best mitigation of noise abatement measures with local resources and constraints.

Under the CAEP working group there are different subgroups, each one engaged in a specific research field [CAEP5].

For further information see web site http:// www.icao.int/icao/en/env/caep.htm.

4.5.1 WG1: Noise

The main aim of Working Group 1 is to keep the ICAO noise certification Standards up to date and effective whilst ensuring that certification procedures are simple and inexpensive In practice.

WG1 was involved in the design of new, more stringent noise limits than those described in Chapter 3 of Annex 16, Volume I. This working group studied the effects of a gradual phase-out of the noisier Chapter 3 aircraft, after the phase-out of Chapter 2 aircraft, in cooperation with MAGENTA and FESG working groups.

The results achieved from the three working groups are an increase in stringency of 10EPNdB to the current Chapter 3 cumulative levels, only to be applied to new aircraft certification.

Relating to the phase-out of current Chapter 3 aircraft, an economic-benefit analysis has verified that the costs for all involved parts would be too high to offset the real noise abatement benefit.

More details about the new proposed Chapter 4 are explained in Appendix A, relating to aircraft certification.

WG1 also investigates the situation of noise abatement programmes concerning technology improvement but, at the same time, taking into account other requirements to achieve the best airframe/technology match.

4.5.2 WG2: Airports and Operations

The objectives of this Working Group are varied:

1) To provide guidance to airport authorities and planners on environmental issues related to airport expansion, construction and operation;

2) To provide guidance and improved means of predicting and quantifying aircraft noise exposure around airport;

3) **To define operational procedures and strategies to reduce noise exposure around airports**;
4) To develop guidance material to encourage optimally compatible land-use around airports;
5) To develop and validate the Global Aircraft Noise impact assessment Model for the assessment of optimal noise control strategies.

Within WG2, a mathematical model, called **MAGENTA** (Model for Assessing Global Exposure to the Noise of Transport Aircraft) has been developed with the goal of assessing the number of people exposed to the nuisance of aircraft noise around the world's jet airports (1700 airports were considered) under any specified noise certification and transition scenario. Output, total noise-exposed population numbers together with regional breakdowns were supplied to FESG to perform cost-benefit analysis for different goals.

Relating to point three above, with critical support from the manufacturers, airlines and airports conducted a detailed survey/study of noise abatement departure procedures in use today and tried to develop new procedures. In fact during the last CAEP meeting in Montreal, WG2 presented two new procedures, named NADP1 and NADP2 to replace the existing ICAO-A and ICAO-B procedures, described in PANS/OPS document 8168.

They were approved by CAEP/5 and were proposed for review and safety aspects by the Air Navigation Commission. ICAO was in charge of updating Doc 8168, once approved.

The first NADP1 is a close-in procedure with the goal of emphasising the direct surroundings of the aerodrome, where people suffer from aircraft noise from brake-release up to a height of 5000 ft. The second NADP2 procedure emphasises the area further away from the aerodrome. The proposed change allows the operator the flexibility to optimise, for safety and maximum noise reduction, the procedures for each aircraft type. Safety is enhanced because pilots would only have two standardised noise abatement departure profiles for each particular aircraft.

Relating to approach procedures, aircraft landing procedures were not defined. Most approach procedures are under trial at very few airports.

WG2 was in charge of supplies guidance, exchange of information on best practices by comparing different national systems, and the possibility of "learning from mistakes" relating to land use planning. For land use planning, WG2 works in two ways: prevention and mitigating action (noise insulation programs, noise barriers and noise protection for engine test-area).

WG2 has to establish responsibility for planning decisions by airports and has to take into account national frameworks to supply guidance for Contracting states, also looking at the provision of new airport capacity.

4.5.3 WG3: Emissions-Technical issues

The objectives of this WG are:

1) To foster development of a scientific nature for the assessment of atmospheric effects caused by exhaust emissions;

2) To carry out an assessment of technological advances and develop necessary recommendations for their incorporation into Annex 16, Volume II.

Two subgroups can be identified within WG3:

-AEM task group, which in particular studies a new methodology for NO_x emissions calculation during cruising and climbing phases of the flight;

-LTG task group investigates the effects of technological improvements on emissions reduction.

4.5.4 WG4: Emissions-Operational issues

The main objectives of this WG are:

1) To quantify and ensure that relevant environmental impacts of aviation emissions are taken into account in the global and regional planning of CNS/ATM and are incorporated into airport planning;
2) To ensure the development, dissemination and use of best operating practices to achieve near-term reductions in aircraft emissions, including aircraft ground level and in-flight operations, ground service equipment (GSE) and APUs with potential action to facilitate broader adoption;
3) To study ATC procedures with a view to reducing emissions impact;
4) To analyse NAPs produced by WG2 taking into account emissions impact.

4.5.5 WG5: Market-Based Options for Emissions reduction

The goal of this WG is to develop and assess the development of the potential role and the implementation aspects of a range of market-based measures to limit or reduce greenhouse gas emissions from aircraft, including voluntary agreements, emissions charges, fuel taxes carbon offset and emissions trading regimes.

4.5.6 Forecasting and Economic analysis Support Group (FESG)

The objectives of this WG are:

1) To maintain databases and assess their suitability for the work of CAEP;
2) To provide comprehensive updated traffic forecasts
3) To provide comprehensive economic analysis for all options considered by CAEP relating to noise and emissions, including market-based options.

4.6 Terminal Airspace RNAV Applications Task Force

At the end of 1996, Eurocontrol started the Terminal Airspace RNAV Applications Task Force (TARA), being a sub-working group of the Air Navigation Team.

Its first objective is to define the requirements for the cost effective application of RNAV in terminal airspace taking account the need to derive short term benefits and the need to define a logical path towards the longer term application of RNAV in Terminal Airspace.

Its current tasks are:

- Define and evaluate targets for RNAV applications in Terminal Airspace.

- Mixed mode operations based upon 2D templates for RNAV arrival/approaches including the use of tactical waypoints. (Available now)
- Mixed mode operations using automated ATC tools (such as arrival managers) and RNAV arrival procedures to achieve continuous descent arrival/approaches and support available runway capacity. (Projected for post 2003)
- RNP-based approaches to benefit from associated reduced minima. (Projected for post 2002)
- Define and, where possible, quantify the benefits which may be derived from such applications.

For further information click on http://www2.ecacnav.com/tara.htm.

4.7 Other projects related to SOURDINE II

4.7.1 ENHANCE

Previously, the Sourdine I project showed several limitations to the existing tools to develop new noise abatement procedures taking into account all parameters and constraints i.e. noise benefits, flight safety, efficiency and capacity and last but not least, economical aspects.

To assess the potential noise benefits of one specific procedure it is necessary to develop a common and validated noise-modelling tool and to use harmonized noise indicators. The current noise models implement different algorithms and the noise information for each type of aircraft is usually provided by means of Noise Power Distance (NPD) databases, noise performance as a function of engine power and the shortest distance to the aircraft flight track.

Moreover, the existence of sophisticated noise monitoring systems in some European airports (e.g. Madrid-Barajas, Schiphol, etc…) encourages a full scale modelling trial at a number of selected European airports in order to obtain high quality data to be submitted to the selected noise model.

The definition of a validated noise modelling tool, together with a valuable database relating to the European fleet mixes and operating conditions, are the main objectives of the Eurocontrol Enhance project. The co-operation already in place between the Sourdine consortium and the Enhance team should ensure a reciprocal interchange of technical information with the scope of avoiding needless duplication as well as taking advantage of a wider community of experienced people. Once a reliable model is available, the impact of implementing a new noise abatement procedure should be assessed while taking into account the fact that simulated results are closely related to real environment data.

Clicking on http://www.eurocontrol.fr/ba_env/Business/projects/enhance.shtml you can see information.

4.7.2 APPROVE

This project, submitted in response to the Fifth Framework Programme Call, task 2.3.1/18, “Advanced Airport Approach Procedures Implementation”, aims to elaborate new approach procedures to increase airspace capacity. These procedures will be developed following the criteria contained in the Procedures for Air Navigation Services-Aircraft Operation (PANS-OPS) and will include the criteria for the approach based on area navigation (RNAV), GNSS and required navigation performance (RNP). The validity of the procedures will be assessed on three different aerodromes at first using fast and real-time simulation, followed by flight tests.

This project has strong links with the SOURDINE II project, since this project not only pursues an improvement in terms of capacity, but also considers the effects on the environment in terms of noise and fuel consumption for the new operational procedures. The project consortium also involves partners involved in the SOURDINE projects.
For further information see the web site of project: http://www.approve.isdefe.es.

4.7.3 TORCH

The Technical, Economical and Operational Assessment of an ATM Concept Achievable by the year 2005 (TORCH; incl. ISDEFE, AENA and DFS)) project is sponsored by DGVII of the European Commission, within its Fourth Framework Programme. TORCH defines, assesses and analyses using FTS techniques and will deliver a viable, consolidated operational concept for the year 2005 onwards ("onwards" can be translated as 2005-2010), which is both coherent with and complementary to the ATM 2000+ Strategy.
For more information click on the web site of TORCH project:
http://www.isdefe.es/torch/torch.htm

4.7.4 LEONARDO

“Linking Existing On Ground, Arrival and Departure Operation”, this project was conceived in response to the 5th Framework Programme Call of the European Commission. The main objective of LEONARDO is to define the method and demonstrate the feasibility of integrating airport traffic planning and management tools. This objective will be achieved by performing an initial operational integration of existing tools for arrival and departure planning management, together with those derived from the planning and routing function of the ground movement concept at Barajas and Charles de Gaulle airports. The study will be complemented with a test bench evaluation. In this context, a full-scale integration of the management and planning system at airports will be experimentally implemented under real operational conditions. The results of the operational assessment of the co-ordination between arrival, ground movement, and departure will provide a quantifiable measure of the benefits in terms of the safety, capacity and efficiency of the system.
For further information see following web site:
http://leonardo.aena.es/leonardo/htdocs/htm/index.htm

4.7.5 GATE-TO-GATE 2005

This project is a DG TREN large-scale integrated, fifth framework programme. Air transport has to be regarded as a whole system including ATM, CNS, aircraft and airport. To face the predicted traffic growth and gain capacity, a system view is needed with real-time optimisation along all flight phases. To gain benefits from previous FP-RTD projects, the development of the forthcoming European CNS/ATM system has to be executed in a non-fragmented and structured way.

Therefore, it is essential to ensure close co-ordination between air and ground systems. The GTG 2005 programme will take care of ground-related segments (including network, CFMU, ATC, TMA, AOC and airport segments).

The objectives of GTG 2005, are threefold:

- To provide a gate-to-gate technical framework by continuing the development of AVENUE ground segment, based on the TORCH concept, supplying sub-system interoperability between en-route, TMA, airport segments;
- To carry out evaluation testing to validate a coherent Gate-to-Gate ATM/CNS system for the medium term 2005 (using AFAS airborne, network INFRANET, TMA and Airport segments);
- To provide guidelines for ATM strategy 2000+ implementation.

For further information on the project click on:
http://www.theatre.isdefe.es/home.sys.html?documents

4.7.6 AFAS/MAFAS

"*(More Autonomous) Aircraft in the Future ATM System*". These projects look at implementing a new ATM system and the corresponding aircraft systems. The AFAS project assumes an air traffic system and an air traffic management scenario with improved characteristics with respect to the current situation, and does not call for research or investigation of that aspect. On the other hand, the MAFAS project more specifically addresses the avionics requirements for this future ATM scenario including free flight scenarios.
For further information click on:
http://europa.eu.int/comm/research/growth/gcc/projects/in-action-afas.html

4.7.7 AVENUE

The AVENUE project is a DGVII project of the fourth framework programme. The objectives of this project are the following:

- To provide a validation platform capable of supporting the large-scale demonstration and validation initiatives of the European Commission, EUROCONTROL and all others concerned with validation of the EATMS. The platform shall also be capable of integrating any potentially representative candidate product: it shall be an open, flexible and modular environment which enables evolution, integration, interoperability and growth
- To provide a look at the validation platform based on a selection of CNS/ATM components representative of state of the art developments in Europe and of the EATMS concept and to develop a technical exercise. This activity aims to verify the suitability of the platform as an overall tool for conducting validation exercises within the Fifth Framework Programme.

For more information see the web site of AVENUE project:
http://www.tls.cena.fr/projets/AVENUE/

5 Successfully implemented practices and procedures

This chapter supplies a short overview on the current Noise Abatement Procedures (NAPs) applied successfully by worldwide airports. Some of procedures are recommended by ICAO and are included in the PANS – OPS Doc. 8168 (ICAO A and ICAO B). Other NAPs are widely recognised efficient in the noise decrease research. Last part of Chapter shows some procedures and practices currently adopted successfully by European airport.

More information about know successful procedures can be found in the Deliverable D3-1, Chapter 5[D3.1].

5.1 Known short-term NAPS

<u>On approach and arrival:</u>

1) Increase in ILS interception altitude
    a) Intercept ILS from above (i.e. Schiphol Airport from 2000ft to 3000)
    b) Higher Glideslope Angle (3'-3.5'-4', i.e. Naples Airport)
2) Reduced flap settings and delayed establishment of landing configuration (see Vienna airport, par. 5.3.4).

<u>Take-off procedure:</u>

a) ICAO-A Standard sound relief further from airport; ICAO-B sound relief closer to airport.
b) Massachusetts Institute of Technology & National Board Aircraft Authority Maximum thrust at takeoff in order to reach the maximum practical rate of climb and build rapidly vertical distance.

5.1.1 Intercept ILS Glideslope at higher altitude

The aim of this procedure is to create as much vertical distance as possible between the A/C and the ground before meeting the ILS for landing, as shown in Figure 2. More details about benefits in terms of noise abatement due to the use of this concept can be found in the results of Sourdine I[D5v1.6].

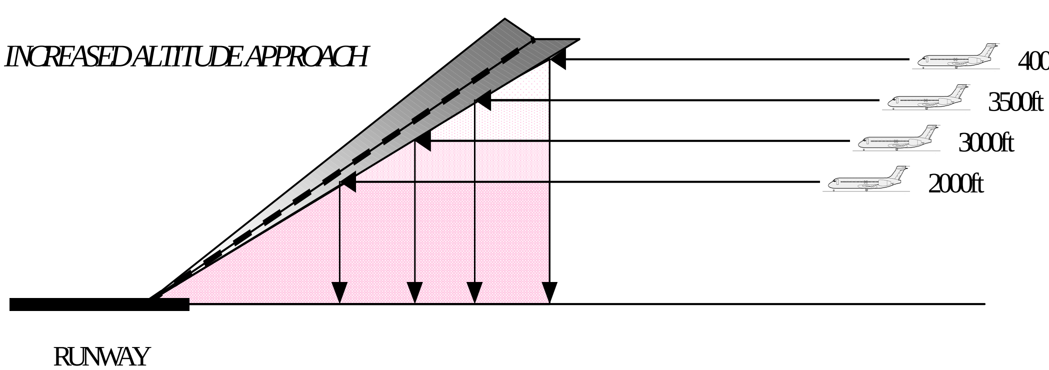


Figure 2: Increased Altitude Approach

The considered procedure decreases the area subjected to high intensity noise, given along the flight path, by keeping a higher vertical distance from the ground and delivering the highest amount nearer to the airport.

5.1.2 Higher ILS Glideslope angle.

The procedure results in a translation of the high noise area towards the airport, as shown below in Fig. 3.

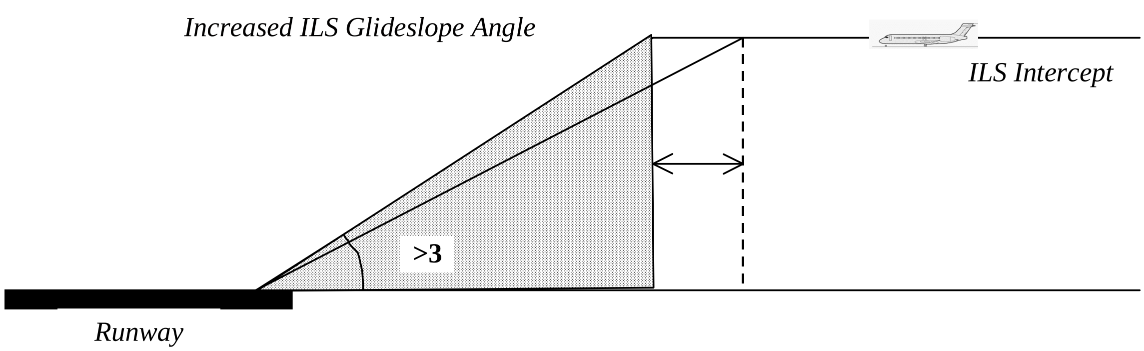


Figure 3: Increased Glide slope angle

The application of an increased glide path angle for a given aircraft type at a constant airspeed in the given (landing) configuration implies a reduction of the required engine thrust to maintain that constant speed. In addition, the aircraft will fly over the ground at a higher altitude thus increasing the distance (altitude).

Since a reduction of the engine thrust also implies a reduced engine noise output (at the source), such a measure could possibly result in a smaller noise footprint below the aircraft.

Down-effects

Effects on capacity: slight negative effect (speed control).

ATC aspects: missed approach number could be higher.

Airworthiness: today, the glide path angle for CAT III is generally 3º. A long campaign of flight test will be required before ICAO approval.

Safety aspects: pilots could perceive this procedure as unsafe.

Feasibility is constrained by manoeuvrability and operability restrictions of some aircraft. Some modification will be required in the software of the auto-pilot to perform auto-landing with higher glide-slope angles (3.5º or even higher).

Implementation: it is not suitable to have different glide-slopes at one airport or at different airports without including the limitations which will come from present fleet and the necessity of increased runway lengths[D3v83].

5.1.3 ICAO-A & B Procedure

These procedures have been developed to reduce the noise impact on the ground around the airports, they shall not be implemented if it’s not verified their necessity[AO_V1]. The two procedures are of two types, one close-in (ICAO-B) and on other distant (ICAO-A), to protect the population in the immediate vicinity of the airport and far form the airport[AO_V1].

The aircraft configuration is given for each phase.

ICAO-A procedure

From take-off roll until reaching 1500 feet (450 m)

Thrust: Take-off
Flaps: Normal take-off setting.
Airspeed: V2 + 10 to 20 knots.

At 1500 feet (450 m)

Thrust: Reduce to climb thrust
Flaps: Take-off setting
Airspeed: V2 + 10 to 20 knots.

Aircraft climbing from 1500 feet (450 m) to 3000 feet (900 m)

Thrust: Climb thrust.
Flaps: Take-off setting.
Airspeed: V2 + 10 to 20 knots.

At 3000 feet (900 m)

Thrust: Climb thrust.
Flaps: Start flap retraction
Airspeed: Accelerating to en-route climb airspeed

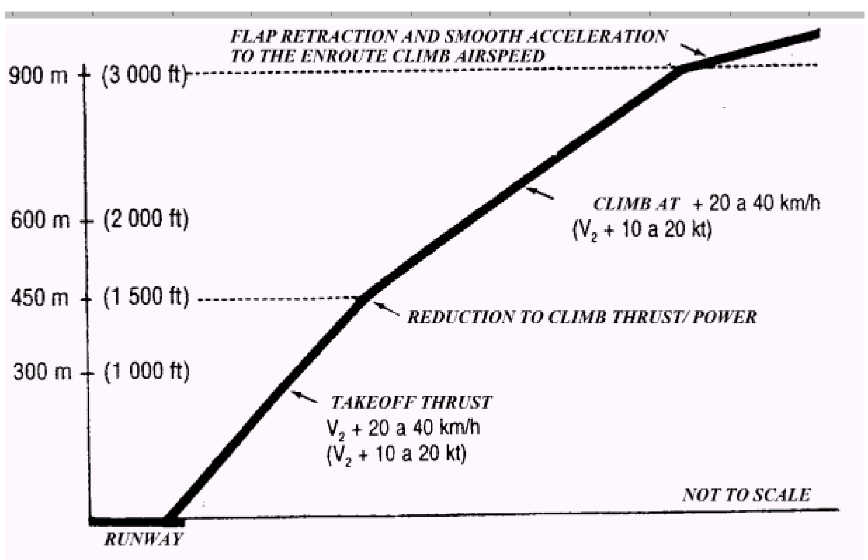


Figure 4: ICAO Procedure A

ICAO B procedure

The aircraft configuration is given for each phase.

From take-off roll until reaching 1000 feet (300 m).

Thrust: Take-off
Flaps: Normal take-off setting.
Airspeed: V2 + 10 to 20 knots.

At 1000 feet (300 m)

Thrust: Take-off
Flaps: Retracting
Airspeed: Accelerating to minimum safe manoeuvring speed without flaps (Vzf)

After flap retraction

Thrust: Climb thrust
Flaps: Retracted
Airspeed: Vzf

Aircraft climbing from 1000 feet (300 m) to 3000 feet (900 m)

Thrust: Climb thrust
Flaps: Retracted
Airspeed: Vzf + 10 knots (20 km/h)

At 3000 feet (900 m)

Thrust: Climb thrust.
Flaps: Retracted
Airspeed: Accelerating to en-route climb speed.

When it is necessary to implement a new procedure, the new one will have to satisfy some limitations:

minimum initial climb airspeed will never be below V2 + 10 knots (20 km/h).

to maintain minimum initial climb speed will not be mandatory if it causes to exceed the maximum acceptable fuselage angle;

thrust reduction will not be instructed unless:

- the aircraft has reached a minimum altitude of 1000 feet (300 m) above airport's level;
- the thrust setting is enough for the aircraft to maintain a climb slope not lower than 4%, at the speeds specified above, with its maximum certified take-off weight;
- take-off flight path with all engines, and n-1 engines, allows obstacle clearance along the flight path.

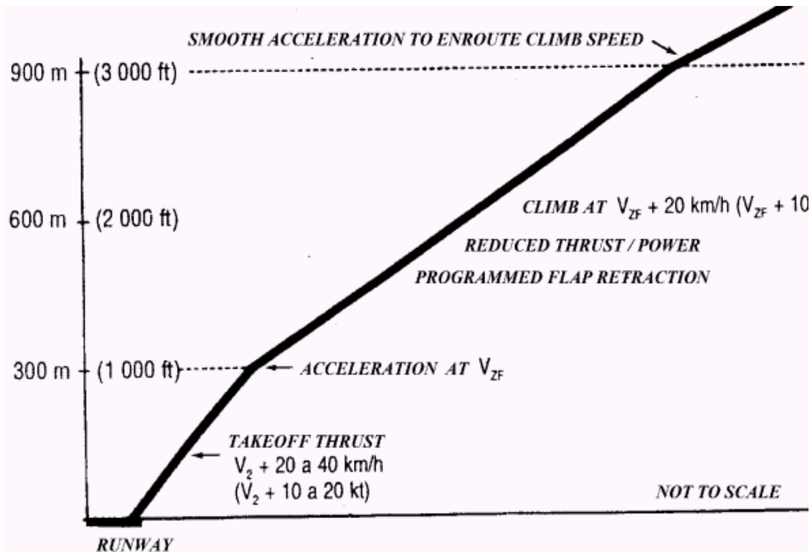


Figure 5: ICAO Procedure B

General observations

Results depend on area to be protected Optimum noise reduction achieved by climbing as high as possible before T/O thrust reduction Moment of T/O thrust reduction is balanced by engine maintenance costs for high thrust settings [Sourdine I].

5.1.4 Power Management

Power Management strategies can minimise noise exposure to the most sensitive areas.
Studies conducted by the Massachusetts Institute of Technology indicated in its results, for noise abatement procedures, that at a fixed thrust rate, any change which will increase the *climb gradient on takeoff will decrease the area exposed to a/c noise*. This may be achieved by as lower climb speed or retracting the flaps at a lower altitude.
The analysis also concluded in that turns do not change the area exposed to noise but may re-direct the noise away from sensitive areas, while power cutback increases the area exposed to moderate intensity noise while providing only a slight decrease in the area exposed to high intensity noise [MIT].

5.2 Known Medium-term NAPS

In the medium-term noise abatement procedures, the following flight procedures have been considered:

Advanced approach and departure procedures using new FMS functions:

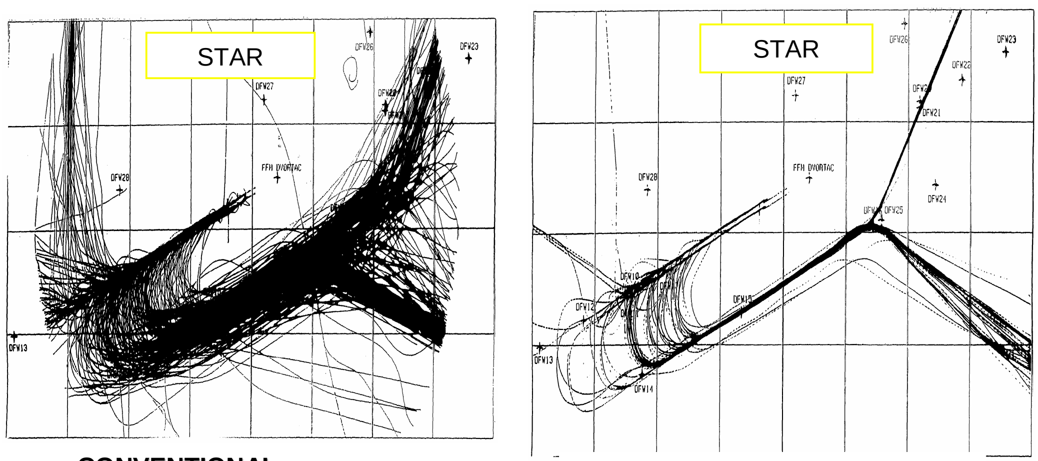
- Dual landing threshold (see Frankfurt airport par. 5.3.3)
- P-RNAV (GPS/FMS-GNSS) based SID/STAR routing (area avoidance and concentration of traffic);
- Continuous Descent Approach (see Amsterdam and London Heathrow airports par 5.3.1 and 5.3.2)

– Increased glide slope angle (see London city airport par.5.3.2).

– Application of new planning or monitoring tools for ATC.

5.2.1 RNAV SID/STAR

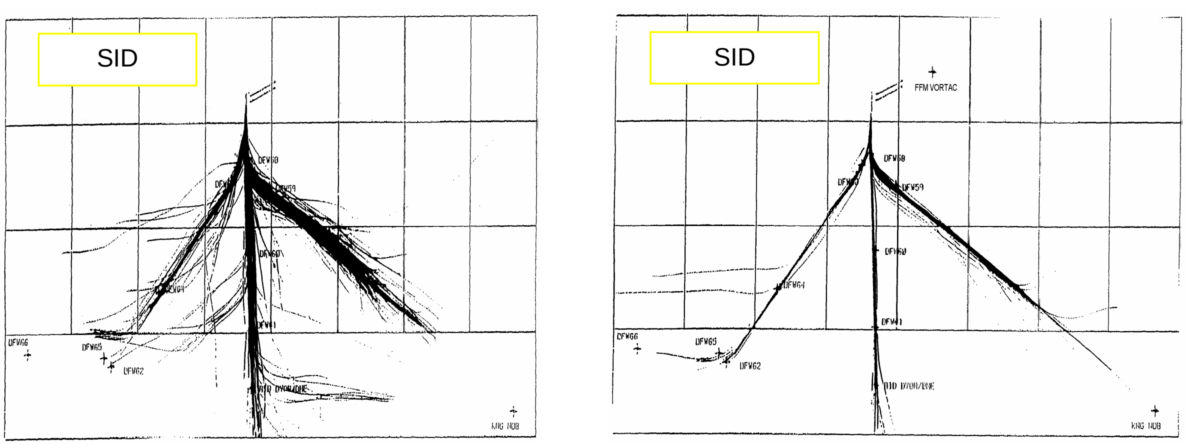
Is based upon the Area Navigation concept which in the terminal area is called P-RNAV (P stands for precise). The procedure relies upon the use of new FMS functions which depending on the combination of Navaids available can secure an RNP1 flight.
Below in the 4 graphs we may find in detail the advantages of such an equipment on the traffic dispersion around the airport surroundings.
Figures[PPt].
Among this, the implantation and use of the RNAV concept offers the flexibility of choosing WAYPOINTS which would relief densely populated areas from traffic noise.



CONVENTIONAL

RNAV

Figure 6: Conventional vs. RNAV STAR



CONVENTIONAL

RNAV

Figure 7: Traffic concentration and dispersion compared for both systems.

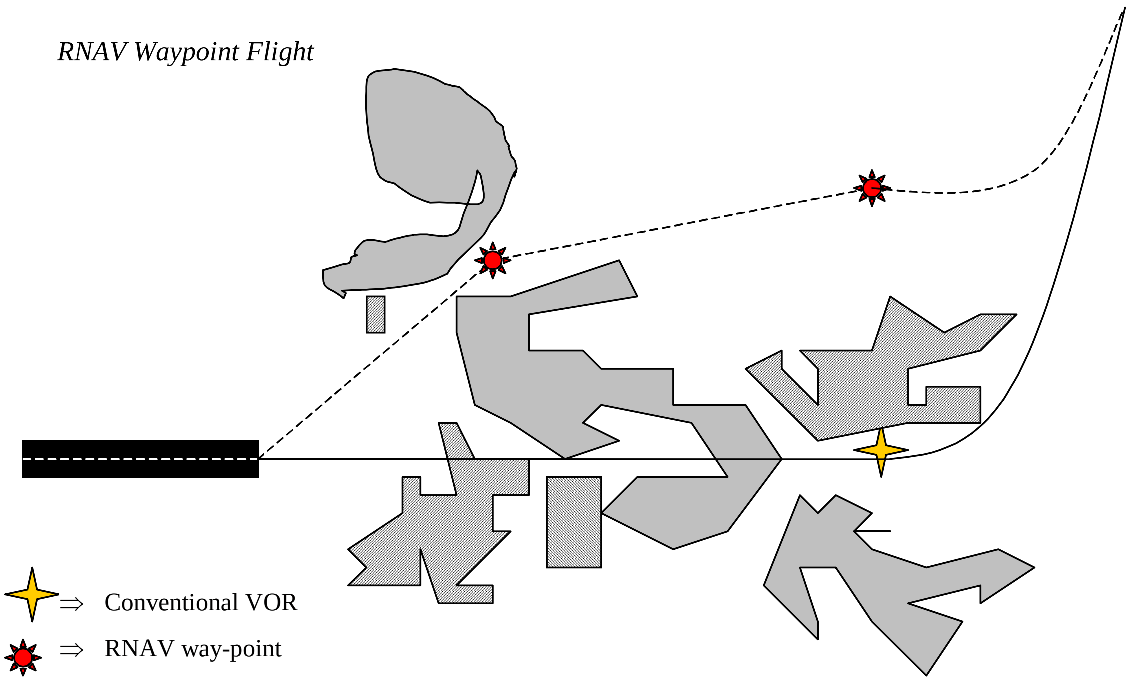


Figure 8: Way point flight vs Navaid Flyover.

The implementation of the RNAV concept requires the establishment of new operational procedures supported by the general acceptance of controllers and pilots. Greater controller education on the employment of RNAV procedures is required in order to accept the concept of separation accomplished by RNAV routes rather than controller intervention techniques.

Using RNAV routings, a reduction of the controller's workload can be expected as it is no longer necessary to transfer ATC instructions for traffic guidance.

Another possible consequence will be the redistribution of the workload between two controller positions (biggest importance of the tactical position).

In any case, any potential of a beneficial effect on workload, when introducing a new system, is counteracted by the costs of the novelty. Cost/benefit calculations must be done.

With the proposed RNAV concept, traffic can be handled safely. However, during the transition period, it might be difficult to achieve and maintain a good separation between RNAV and non-RNAV equipped aircraft.

Synthetically through the RNAV procedures it could have potential noise benefits originate from the use of flexible flight tracks and, close to the airport, a more accurate track keeping.
The effects on capacity are:
-for departures: enable to perform earlier turn on track;
-for arrivals: no benefits without advanced tools.

5.3 Successfully practices and procedures

5.3.1 Amsterdam Schiphol airport (CDA)

Currently CDA procedures are being tested at Schiphol during night-time hours on runway 06 (see figure 3) and at night time in Hong Kong. The reason these CDA-trials are only performed at night is explained in this paragraph.

During the CDA, the aircraft performs a thrust-idle flight until a point before ILS-localiser interception. The distance from this point to ILS-localiser is used as a buffer in case it is necessary to reduce the speed further to landing speed. During this segment of the approach, the descent rate is set at 500 ft/min.

Figure 2 gives a possible vertical flight path of the CDA. In modern civil aircraft, equipped with advanced Flight Management Systems, the FMS calculates the starting point of the CDA, assuming constant airspeed throughout the manoeuvre. The flight path angle is used as free, resulting variable. If, when flying the manoeuvre, speed deviations of more than 10 kts occur, the auto-throttle is engaged or the message ‘Ad Drag’ is displayed.

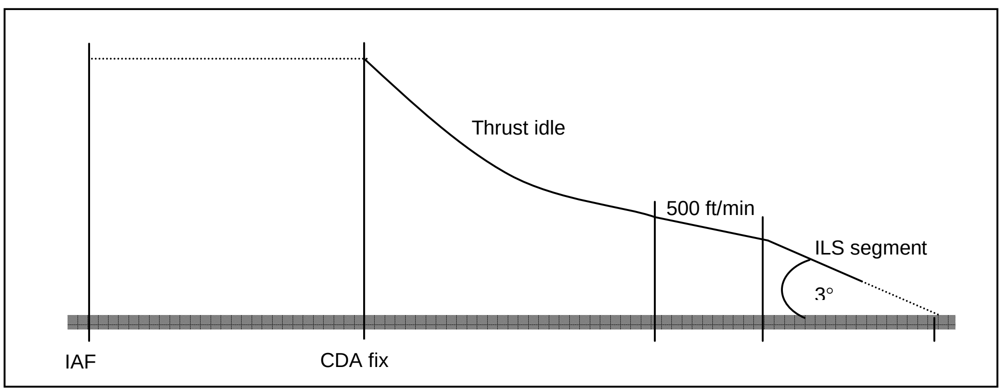


Figure 9: Vertical flight profile current CDA

During a CDA, the thrust is fixed, giving constant speed and atmospheric conditions, which results in a relationship between the position in the vertical plane and the altitude. This means that any instruction from the ATC to deviate from the intended flight trajectory (ground track, speed, altitude) could lead to a situation where thrust has to be added or speed brakes have to be applied, resulting in higher noise production. Therefore, ATC interference has to be limited or avoided, otherwise a conflict arises.

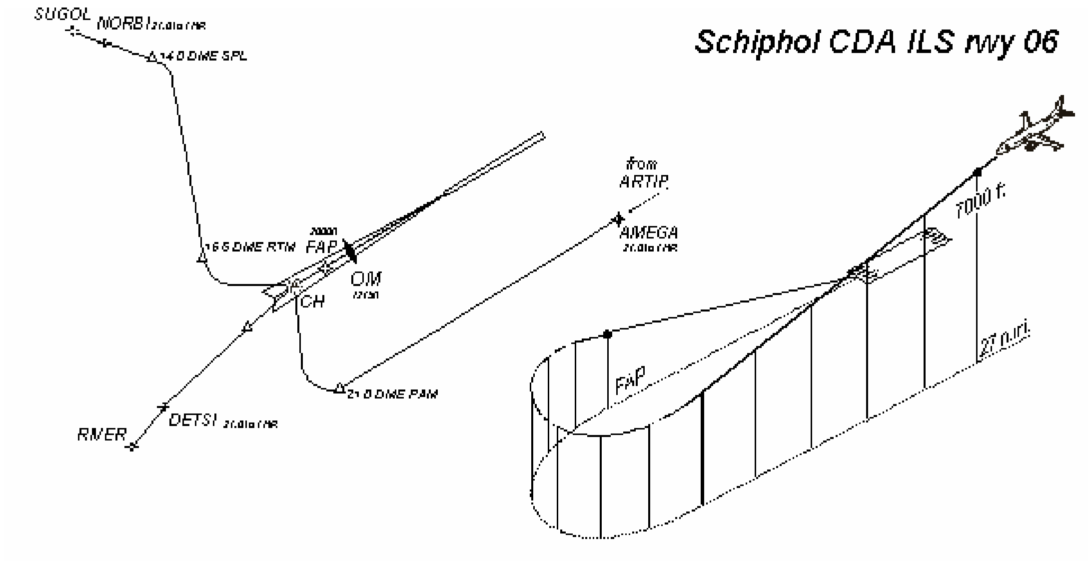


Figure 10: Detail of CDA in Schiphol

Negative side: The procedure, although promising, has a downside effect on the capacity of the runways and hence on the airports performance. It guarantees low levels of noise but the time distance imposed by the ATC on this procedure between two aircraft is twice the normal amount, causing it to be used mainly outside peak hours.

5.3.2 London city airport (Increased glide slope)

All aircraft using the London city airport must be of an approved type. To qualify for approval an aircraft must fit into one of the above noise categories and be capable of making an approach at 5.5 degrees or steeper (this compares with 3 degrees at most other airports). This approach procedures was not planned to abate the noise, but it was born to satisfy local airports needs. This is not a NAP clearly, but it is useful to consider it to see that steep approach procedures can be flyable, even if from a restricted number of aircraft. In fact limited it is the number of aircraft able to operate by London city airport: ATR42, Bae 146/Avro RJ family, Bae4100Jetstream, DHC-6 Twin Otter, DHC Dash7, Dornier Fairchild Do328, Fokker50, Fokker70, Saab 340, Saab 2000. Maximum Take off and Landing Weights of aircraft are not always available at London City Airport. (Note: The Maximum Take off and Landing Weights of aircraft are not always available at London City Airport).
For further information on London city airport click on
http://www.boeing.com/commercial/noise/london_city.html

5.3.3 London Heathrow airport (CDA)

A voluntary Code of practice has been produced for Heathrow, Gatwick and Stansted airports by a group of representing airlines, air traffic controllers, airports and the Department of Transport, local government and the Regions. This code is a technical document for interested people to reduce the noise of arriving aircraft by the use of CDA. It does not give fixed values for every user, but defines the descent angle to set and the descent rate per assigned start altitude and distance to run touchdown. The following graphs show how to set the parameters to realize a CDA depending on one's own particular starting conditions. This code gives all technological and operating requirements to do CDA. All recommendations are to be read as "subject to the requirements of safety".

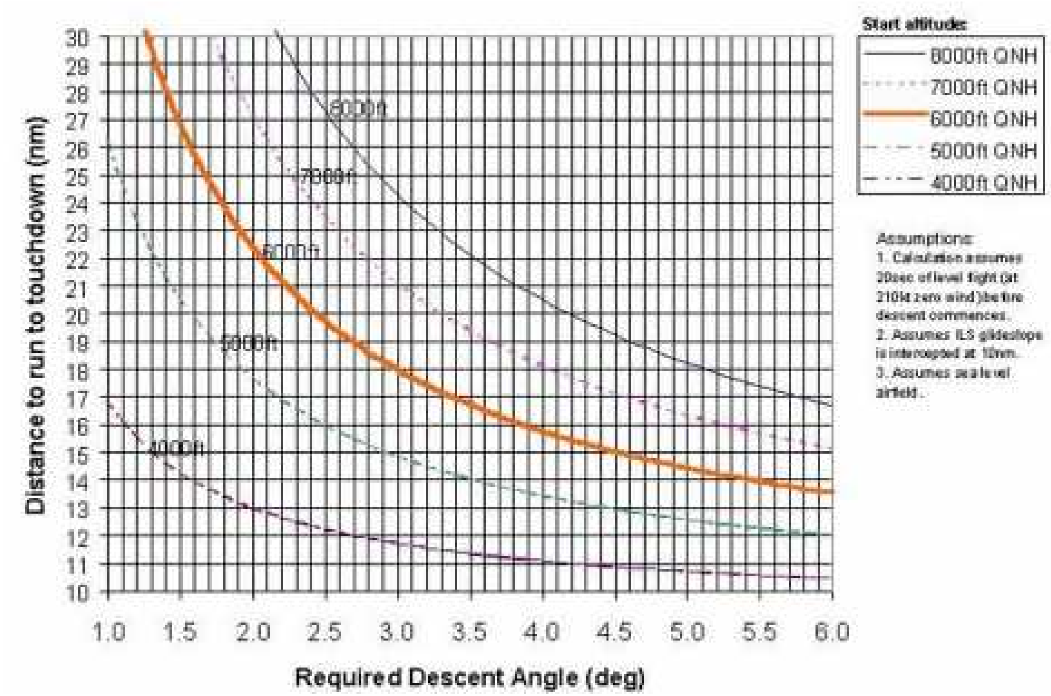


Figure 11: Flight path angle for CDA

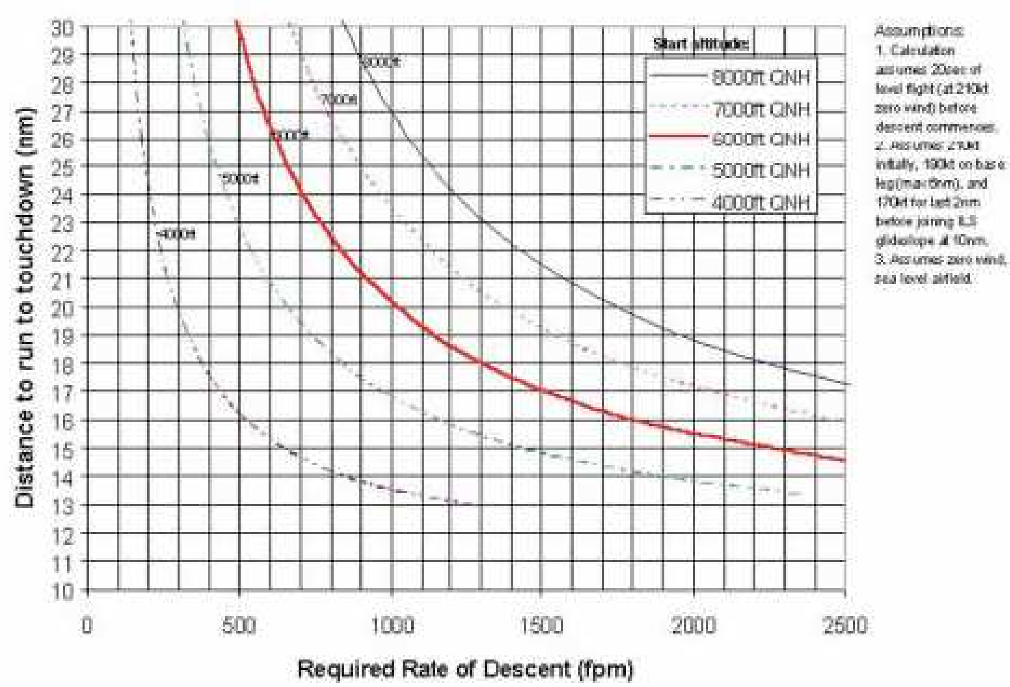


Figure 12: Vertical speed for CDA

5.3.4 *Frankfurt airport (dual threshold)*

Dual landing threshold allows the overall noise contour to be shifted towards the airport by enabling light and medium aircraft to perform approaches to a displaced threshold, thus reducing final approach spacing and runway occupancy time, thus increasing arrival capacity.

Dual landing threshold requires a dedicated implementation study for suitable runways. Evaluation is at its trial phase at Frankfurt airport (HALS-DTOP) [FFRA].

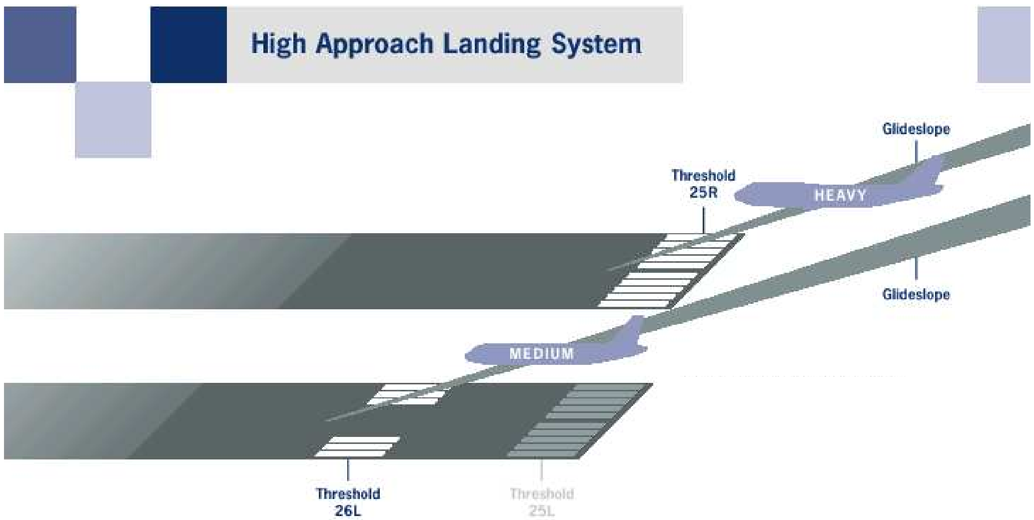


Figure 13: Dual Threshold Procedure in Frankfurt

The procedure is under final testing in Frankfurt Airport and its primary objective is to increase the capacity of the runway. The following image shows the necessary fleet mix for dual landing [FFRA]:

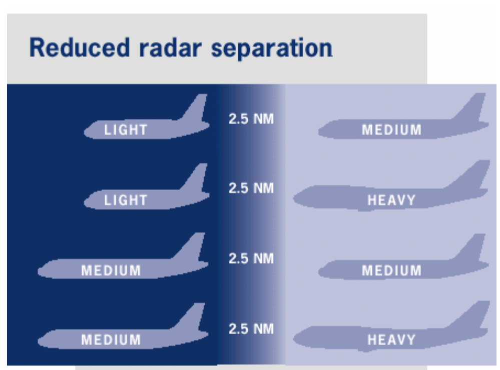


Figure 14: Acceptable fleet mix for the HALS/DTOP procedure

5.3.5 *Vienna airport (reduced flap, delayed gear)*

This procedure relies on the so called Low Drag – Low Power Approach. It is currently widely used and consists of conducting a flight in "clean configuration" for as long as possible and the extension of the landing gear is withheld until as late as is safely possible..

The extension of the landing gear is one of the biggest sources of drag and noise and drag has to be compensated by increasing engine throttle. All this takes place below 1500ft. The procedure aims to make sure that the highest amount of disturbance takes place closer to the airport and the aircraft gets there with enough velocity to manoeuvre. The reduction in flap settings results in two main noise abatement benefits:

- reduced aerodynamic drag hence less aerodynamic noise;
- reduced thrust setting hence less engine noise and fuel saving;
- slight increase in approach speed hence noise source passes more quickly.

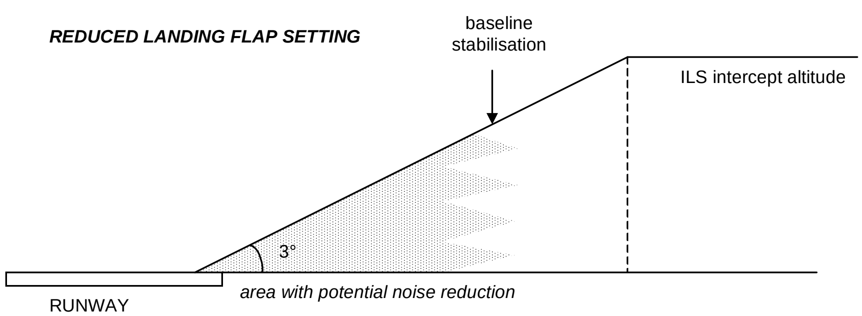


Figure 15: NAPs reduce flap setting

The advantage is a reduction in noise along the entire approach path. Moreover, it is a procedure which can provide noise benefits at all airports, rather than just a limited number. Because it is a stabilized approach procedure, it reduces cockpit workload in that no transition is required between a 3' and 6' flap setting as well as eliminating the inherent potential wake vortex problem, a serious safety problem for following aircraft.

This procedure has some disadvantages re capacity and ATC aspects. In fact, reduced flap settings during final approach leads to a higher final approach speed, which may result in a reduction of airport capacity by increasing runway occupancy time. This measure may increase the overshoot rate. The aircraft may not vacate the runway via the preferred exit. The higher speed of aircraft performing a lower flap setting approach could apparently generate two negative aspects, one pilot related and one controller related. In fact, pilots will have less time for performing necessary corrections to follow the glide path with the right altitude. On the other hand, controllers will have to pay more attention to the final approach due to the differences in approach speeds. So, both controllers and pilots would have a greater workload, but the extra effort can be considered negligible if they are supported by the technological means currently in use at most European airports and onboard all modern aircraft.

From the passengers point of view, it is also to be considered that higher approach speeds, which cause a higher rate of descent, could reduce onboard comfort levels.

5.3.6 PRW/ LDA MAP approach

The Precision Runway Monitor (PRM) is an FAA certified system, which can dramatically reduce delays at major airports, using existing runway sets. The unique radar system also allows new runways to be constructed closer to existing ones, thereby reducing the environmental and cost effects of planned airport expansion [ATT].

PRM is a standalone, electronically scanned, mono-pulse secondary surveillance radar. It has a one-second update rate, coupled with high resolution 20x20in colour digital displays and predictive alert and alarm algorithms, providing increased situational awareness.

Application:

Mainly used by ATC to maintain simultaneous independent parallel approaches to closely spaced runways during degraded weather conditions. Other uses include arrival and departure control as well as high-risk and noise sensitive area avoidance.

The PRM application was designed for parallel runways spaced below the FAA minimum of 4,300ft for simultaneous parallel IFR approaches.

Latest procedures are extending the applicability of PRM to runways spaced as closely as 700ft. An example is given by the simultaneous offset instrument approach developed for San Francisco's parallel runways (750ft separation).

1. PRM approach to the missed approach point (MAP) at 3000ft approach course separation.
2. Visual final segment from the MAP to the runway threshold.
3. Straight in ILS on 28L, on 28R 2.5' offset localiser type directional aid (LDA). After passing the MAP, the a/c transitions to intercept the extended runway centreline of runway 28R.

The procedure is designed for a minimum ceiling of 1600ft and 4 miles visibility.

<u>Results:</u>

The capacity of the runways is increased as the distance is reduced to within the current wake-turbulence separation criteria. It includes sensible area noise avoidance, see Fig. 16 and translates the final approach nearer to the airport. If the Along Track Separation procedure is used, any alteration to the flight path is required.

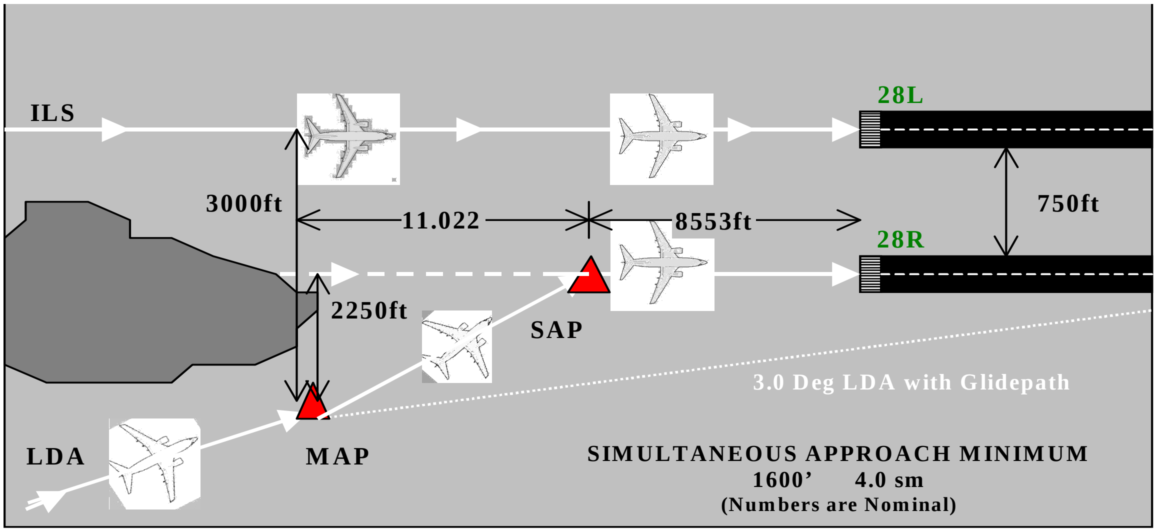


Figure 16: PRM (SOIA)

5.3.7 Milan Malpensa airport

Runways 35L and 35R are used alternately for departures to share noise nuisance between two densely populated areas along two sides of the airport, as described in the following scheme:

First day:

-From 06.30 to 10.30 local time, RWY 35L;

-from 10.30 to 18.30 local time, RWR 35R;

-from 18.30 to 23.30 local time, RWR 35 R.

Second day:

-from 06.30 to 10.30 local time, RWR 35R;

-from 10.30 to 18.30 local time, RWR 35L;

-from 18.30 to 23.30 local time, RWR 35R.

Third day: as the first day

Fourth day: as the second, and so on.

A tolerance of +/- 15 minutes is allowed to the established time for RWY change.

This alternate use of runways may not be applied :

-if required by safety reasons (operational or meteorological conditions);

-from 09.30 to 11.30 local time and from 20.30 to 22.30 local time.

These two periods may be shifted if so required by the peak-traffic forecast. At the beginning and at the end of this period a period tolerance of +/- 15 minutes is allowed.

For traffic necessity a third one hour period of flexibility, up to a maximum of 100 days per year, may be used.

6 ATM/CNS technology

The implementation of technology on the ground and on board the aircraft is one of the more important aspects that will be considered in this project. In fact, until now, many NAPs have been developed, but they need current technology to be used. An objective of SII project is to plan very innovative procedures that need "ad hoc" technology to be implemented.

The implementation of CNS/ATM technology could also provide good results in the emissions research field. In fact, a recent IATA study on "Operational measures to Improve Aircraft Fuel Efficiency and Reduce Emissions", which focuses on the advantages of faster CNS/ATM implementation, demonstrates that if the implementation is achieved more quickly than in the planned time, this could lead to a 9 percent improvement in system fuel efficiency worldwide by 2010.

As a consequence the emissions of nitrous oxides (NOx) will be reduced by 8 percent, and carbon monoxide (CO) and unburned hydrocarbons (HC) will be reduced by 15 to 16 percent [ICAO_N.4].

6.1 Overview of future on-board systems

6.1.1 Communication

The future control paradigm could well be based on the use of datalink, with only emergency communications by voice, thus allowing an increase in datalink capability. The deployment of communications technologies does not provide benefits, but it enables benefits to be accrued by improved procedures that make use of the communications services.

Data link Communications Services – They will support a wide range of services and will also enable remote access to information, for example air-to-ground, air-to-air and ground-to-ground. Supporting the data link services will be a number of different applications:

- **CPDLC** – Controller/ Pilot Data link Communications
- **D-FIS** – Digital Flight information system
- **ADS** – Automatic Dependent Surveillance

Voice Communications – These are necessary as a complementary means of communication, in particular in emergency and other unusual situations for which datalink messages are not appropriate. In general, voice communications systems are not able to maximise the use of bandwidth. Currently voice communication service is primarily achieved by VHF radio between pilots and controllers by use of pre-determined channels, that are continually monitored in the air and on the ground because of consequent congestion problems.

FANS B:

The FANS B package on Airbus SA aims at:

- Covering continental datalink applications using the ATN network. This should give rise to improved reliability compared to first step FANS A (using ACARS network), which is used exclusively on transoceanic routes on Airbus aircraft fitted with 2nd generation FMS.

- Allowing the exchange of datalink messages adapted to continental areas (request to change ATC frequency etc…)

The content of FANS B messages has not been determined on LR yet.

Schedule:

FANS B prerequisites are:

- The availability of the ATN, which is planned around 2007-2008.
- An upgrading of ATIMS (Air Traffic and Information Management System) on board Airbus aircraft. This upgrade will require about 3 and a half years and has not started yet.
- The availability of control centres capable of FANS B CPDLC messages

No schedule exists for FANS B on Airbus SA or on LR

6.1.2 Navigation

The term **FMS** can be used to encompass a range of cockpit devices from systems based on a GPS sensor with simple navigation and routing functions, to computing devices which are used to ensure the optimum flight path of commercial aircraft. The basic elements of an FMS are comprised of;

- Flight Management Computer (FMC);
- Control and Display Unit (CDU);
- Sensors (Position, Altitude, Fuel etc.)

The FMS greatly reduces overall pilot workload, freeing the crew to manage high-level cockpit tasks effectively during all phases of flight. The prime function of the FMS is to make the most efficient solutions to the pilot's flight plan requests available to him - be they strategic or tactical - and to enable them in the most efficient manner.

The FMS automatically selects those navigation aids which offer the most accurate position fix. It can be considered the core of the aircraft avionics system and connects with the majority of on board communications media, on board sensors and navigation/guidance equipment.

6.1.3 Surveillance:

The aim of the future surveillance function is to provide, via networks, high quality, continuous and integrated surveillance data for all phases of flight, available to all users who require it.

Currently, surveillance services are only provided by ground based radar systems. There is no surveillance in oceanic or low density continental airspace and procedural control is required in these areas.

Key surveillance applications in the future are likely to be:

Mode S Transponder (with enhanced capability):

In answer to EUROCONTROL requirements in terms of surveillance, Mode S transponders will allow for the transmission of an increased set of parameters to the ground and to other aircraft equipped with a mode S transponder.

These additional parameters include Roll Angle, True Track, Heading, Mach number, True Air Speed, Indicated Air Speed and Selected Altitude.

This mode S will also have the extended squitter capability.

This capability will be used for:

- transmission of requests for flight plan change by the crew
- potential transmission of ADS-B (not yet confirmed today)

Schedule: Mode S transponder with enhanced capability will be available from 2005

ADS-B: Automatic Dependent Surveillance Broadcast

ADS-B is a function on an aircraft or a surface vehicle that periodically broadcasts its state vector (position coordinates, speed values) and other information. ADS-B is automatic as it does not need external stimulus to elicit transmission; it is dependent because it relies on on-board navigation sources and on-board broadcast transmission systems to provide surveillance to other users. Any user may choose to receive and process ADS-B surveillance information. ADS-B use could bring potential benefits for traffic management (better accuracy on the A/C position and better estimation of predicted trajectories of A/C fitted with ADS-B).

Other applications of ADS-B are envisaged:

- use of ADS-B information from other aircraft to follow flight path of a leading aircraft
- use of ADS-B information for airport navigation (for all vehicles equipped with ADS-B)

A more detailed description of the different possible applications is set out in the "Package I" [Package I]. The main objective of this document is to describe a first package (Package I) of operational applications suitable for an early implementation (i.e. 5-10 years). ADS-B is recognised as a key enabler for Ground Surveillance /Airborne Surveillance (GS/AS) applications.
GS/AS applications have the objective to improve the ATM system. The selected operational applications are suitable for core European high-density traffic areas without excluding other areas, in line with the EUROCONTROL ATM2000+ strategy and the expected Operational Improvements.
This document was developed in the context of the CARE/ASAS project and co-ordinated between the European ADS-B related programmes and projects through the Joint Co-ordination Board (JCB). JCB was created to co-ordinate research, development and validation work performed by these European ADSB programmes and projects, and to expedite implementation.
For further information see http://www.eurocontrol.int/care/asas/index.html.

6.2 Overview of advanced ATC technologies

All across Europe, at national and local levels, there are numerous systems, such as those for airport stand allocation, airline/airport ramp management and ATC ground movement control, and arrival and departure scheduling or sequencing systems, which can be classified as “Airport Traffic Management Systems” (APTMS). In addition to these current systems there are also several specific automation tools currently under development, which are intended to support the arrival and departure scheduling functions, and the Surface Movement Guidance and Control System (SMGCS). Nevertheless, these tools support operations separately from the airport planning system, such that operations are processed by different people and different tools. The continuous growth in air transport demand can only be supported and sustained by full co-ordination between en-route ATM systems and airport planning operations.

Consequently, operations involving arrival, departure and ground movements need to be developed and integrated in a system that manages the traffic flow more efficiently around and within the airport.

Between the current developing ATC tools there are: AMAN, DMAN and SMAN, for arrival, departure and surface management respectively.

The current aim is to integrate these three systems and procedures so as to maximise the performance of the entire airport system. The current situation prevents optimal use of the available capacity, both at airports and in terminal area airspace, as well as more efficient air traffic management and control.

Accordingly, there is a need for the assessment of the potential benefits within a co-ordinated planning function to facilitate the implementation. This has been done initially in the Departure and Arrival Integrated Management System for Cooperative Improvement of Air Traffic Flow project and it is being continued by LEONARDO.

The following are some short descriptions of the above mentioned ATC tools.

6.2.1 A-SMGCS

All airports have some form of Surface Movement Guidance and Control System (SMGCS). They provide guidance to an aircraft from a landing runway to the parking position on the apron and back again to the take off runway. The present SMGCS system relies heavily on the "see and be seen" principle to maintain separation between aircraft and/or vehicles on the movement area. Problems have occurred with the increase in traffic, difficulties in navigating or taxiways on more complex airport layouts and in lower visibility operation. An advanced system is required to resolve these problems and maintain operating capacity in all weather conditions. The term Advanced Surface Movement, Guidance and Control System (A-SMGCS) has been defined to cover these future systems. The A-SMGCS is a system providing routing, guidance, surveillance and control to aircraft and associated vehicles in order to maintain movement rate under all local weather conditions within the Airports Visibility Operational Level (AVOL) whilst maintaining the required level of safety. In addition, planning is considered as an additional supporting function.

A-SMGCS must also be able to ensure separation between all moving aircraft and vehicles in conditions when their speeds prevent such separation being maintained visually.

The major drive of A-SMGCS is to improve operating efficiency at airports, whilst maintaining target levels of safety. This increased efficiency is obtained through improved operations during low visibility, increased safety and improved taxiway operations.

6.2.2 DMAN

DMAN is a computer-based tool for assisting air traffic controllers at airports with the management of departing flights. It is currently at the stage where an operational concept and statement of requirements have been developed by EUROCONTROL and its contractors. The function of DMAN is to plan take-off times and consequent start-up times, and to make these available to ATC, aircraft operational companies and airport authorities.

The primary objective of DMAN is to maximize runway throughput. The possibility of doing this arises from the fact that, given a set of departing flights, some orders of departure will require less runway time than others. This in turn is because the minimum time interval between two successive departures depends on specific details of the flights in question, including the wake turbulence categories of the two aircraft and whether or not they will follow the same route through the TMA.

6.2.3 AMAN

AMAN is one of the ATM Added Functions envisaged for the EATCHIP Phase III System Generation of the ATM system.

AMAN will generate advisories (AMAN) for the controller in order to meet the planned arrival sequence. AMAN functionality is foreseen at three performance levels as follows:

1) ***Basic AMAN*** provides controllers with an optimised sequence and strategic (time to lose) advisories within an operational area confined normally to the last FIR.
2) ***Advanced AMAN*** provides controllers with an optimised sequence and strategic (time to lose/gain) advisories and holding advisories within an operational horizon covering the flight at least from the Top-of-Descent point to the landing. The controller advisories are provided in all ATC sectors within this area regardless of the FIR structure. In addition, common path protection is provided within a vicinity of the destination airport through tactical controller advisories (speed and/or heading) which assist the controllers in maintaining the required spacing between aircraft.
3) ***Very Advanced AMAN*** provides, in addition, tactical advisories (e.g. speed and/or heading) to the controllers in all the sectors within the AMAN operational horizon.

AMAN will automatically adapt the established inbound traffic sequence to the actual traffic evolution as well as to controller decisions deemed necessary in exceptional cases. As a general result, AMAN will advise the controller to adjust the approaching flights in such a manner which ensures an efficient and smooth flow of traffic while maintaining - or even increasing - traffic safety.

7 Traffic predictions

Air traffic forecasting plays a fundamental role in the noise abatement research field, above all when the goal is a long term one. In fact, to plan the correct measures for balancing environmental issues with sustainable growth of air traffic demand, such an estimation is mandatory.

7.1 Current data on air traffic trends

The following table contains recorded aircraft movements by major European airports relating 2001.

	Airport, Country	1999	2000 (thousands)	2001	change 01/00 %
1	Paris Charles de Gaulle, F	475.8	517.7	523.4	+1.1
2	London Heathrow, UK	458.1	466.8	463.6	-0.7
3	Frankfurt Rhein/Main, D	438.9	458.7	456.5	-0.5
4	Amsterdam Schiphol, NL	410.0	432.5	432.1	-0.1
5	Madrid Barajas, E	306.7	358.5	375.6	+4.8
6	Munich, D	299.0	319.0	337.7	+5.8
7	Bruxelles, B	312.9	326.1	305.5	-6.3
8	Copenhagen, DK	298.6	303.7	288.7	-4.9
9	Rome Fiumicino, I	260.5	283.4	283.7	+0.1
10	Stockholm Arlanda, S	276.1	279.4	276.4	-1.1
11	Barcelona, E	233.6	256.9	273.1	+6.3
12	London Gatwick, UK	255.5	260.9	252.5	-3.2
13	Milan Malpensa, I	216.1	249.7	237.0	-5.1
14	Paris Orly, F	245.8	243.6	219.5	-9.9
15	Vienna Schwechat, A	191.8	207.0	204.6	-1.1
16	Nice, F	210.7	217.4	204.2	-6.0
17	Manchester, UK	185.0	197.7	197.2	-0.2
18	Dusseldorf, D	194.0	194.0	193.5	-0.3
19	Dublin, IRL	170.3	180.2	185.7	+3.0
20	Palma De Mallorca, E	166.9	177.0	169.6	-4.2
21	London Stansted, UK	155.1	165.8	169.6	+2.3
22	Helsinki Vantaa, FIN	163.1	165.7	166.1	+0.3
23	Hamburg, D	156.5	164.9	158.6	-3.9
24	Stuttgart, D	150.7	155.5	151.7	-2.4
25	Cologne / Bonn, D	151.3	155.7	150.2	-3.5
	Berlin Tegel, D	124.8	134.3	131.6	-2.0
	Lisbon, P	110.9	112.1	113.8	+1.5
	Luxembourg, L	84.8	85.5	86.2	+0.8
	Total of top 25 above	6 383.0	6 737.7	6 676.3	-0.9

Table 1: Aircraft movements by greater European airports recorded in 2001

For further information on statistic data re air transport, recorded in 2001 and published by Airports Council International, click on:
http://europa.eu.int/comm/energy_transport/etif/lists/mode_air.html#top

7.2 Air-traffic trend forecast

7.2.1 Air-traffic forecast to 2009

EUROCONTROL published a study on the air traffic forecasts for the year 2009. Some of the results are summarised in the follow graphic, where air traffic forecasts for IFR flights to 2009 [ATF_EEC], for three different scenarios are shown:

- baseline scenario
- low growth scenario
- high growth scenario

where low and high scenario represent the worst and best case scenario relating to the baseline situation, that is the average evaluation of air traffic growth

The following graphs show the forecast plan for the three abovementioned scenarios. All graphs are derived from the Eurocontrol document: STATFOR Medium_Term Forecast of Annual Number of IFR Flights (2002-2009), Volume 2, 14 March 2002.

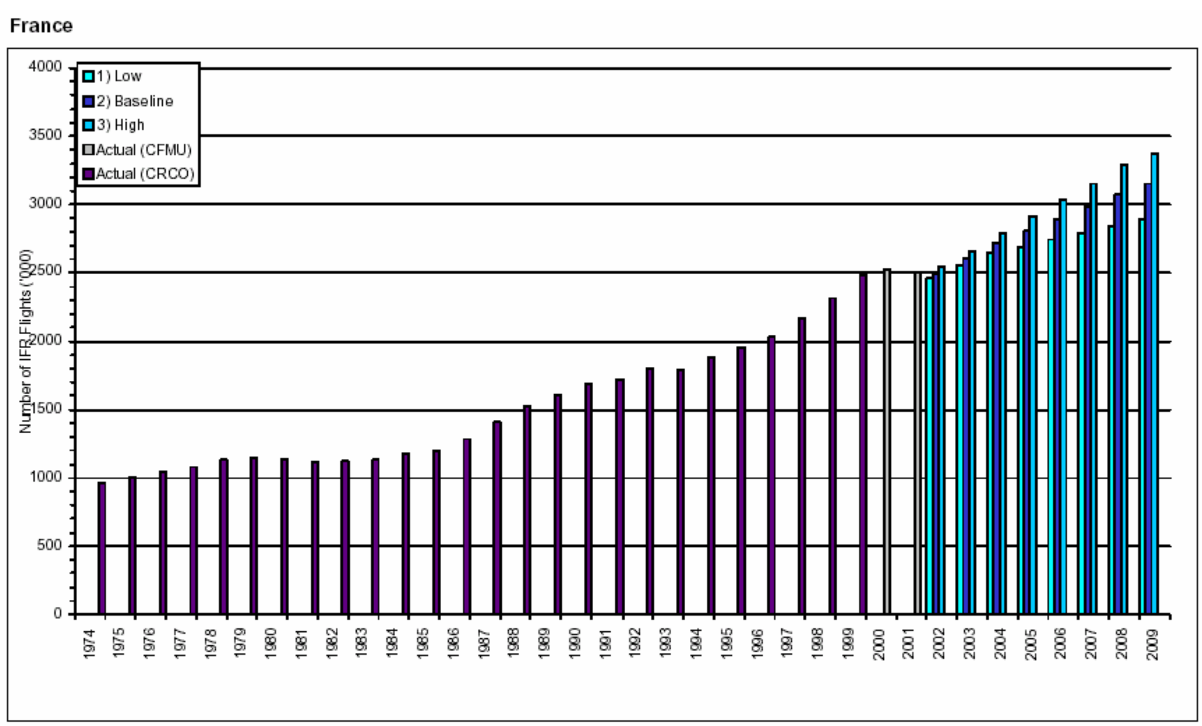


Figure 17: French Air traffic forecast up to 2009

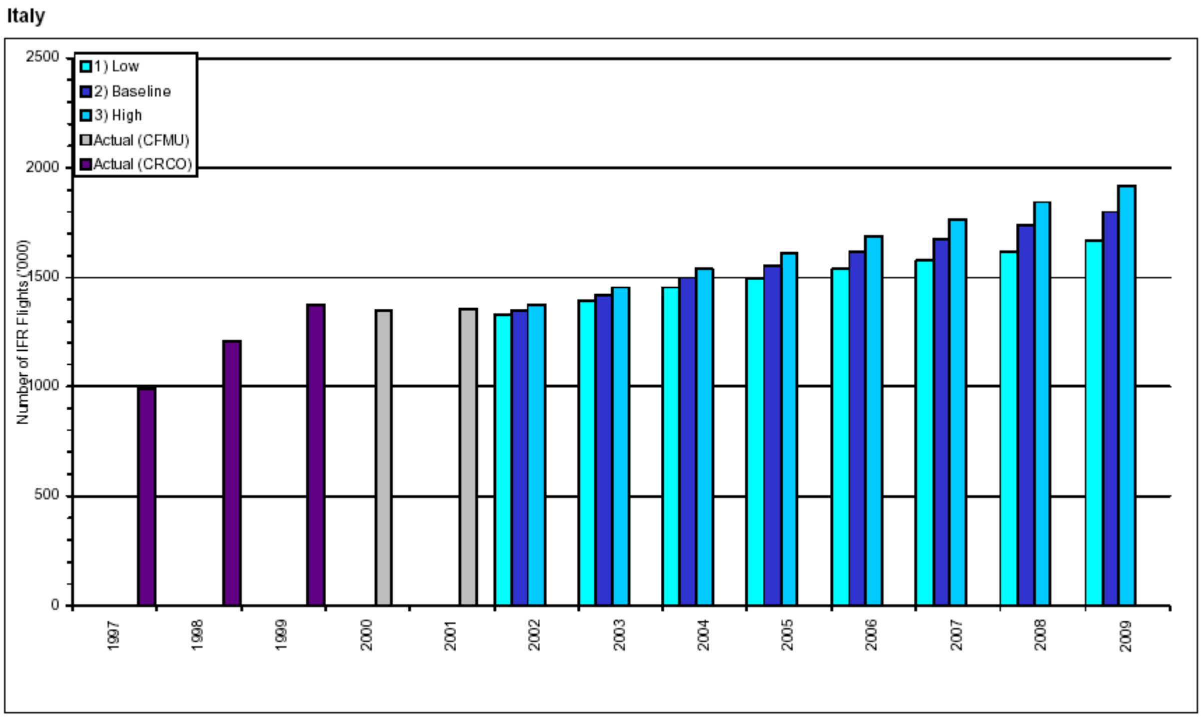


Figure 18: Italian air traffic forecast up to 2009

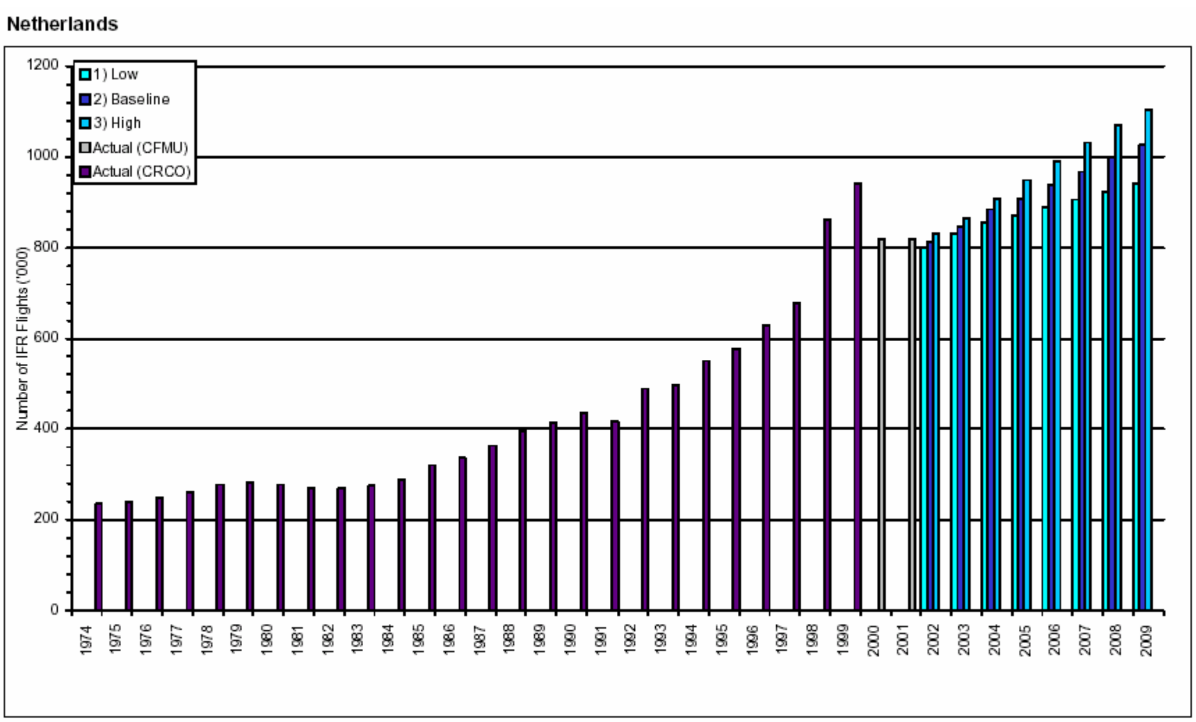


Figure 19: Dutch air traffic forecast up to 2009

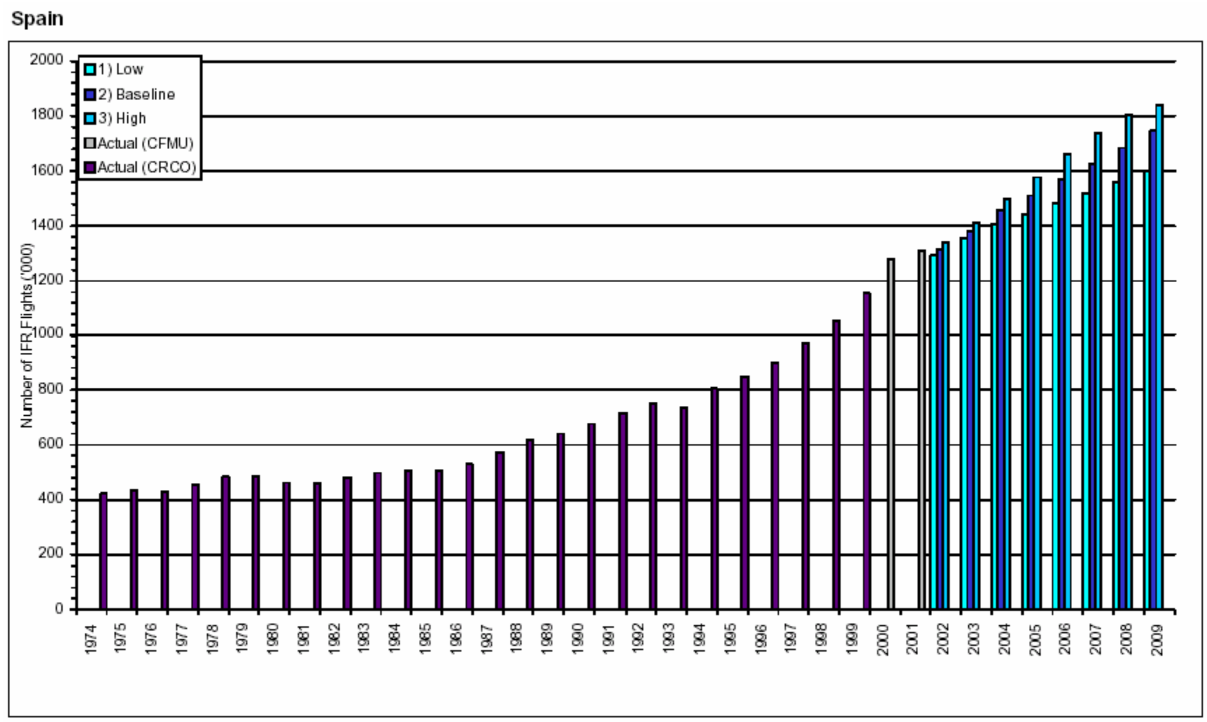


Figure 20: Spanish air traffic forecast up to 2009

7.2.2 Air traffic forecast to 2015

The more recent long term air traffic forecasts (2015) published by Eurocontrol are dated 1 July 2001, before the tragic events of 11 September 2001.
At this moment there are not newer forecasted data, maybe update data about future air traffic could be available before starting FTS.
These data represent the number of annual IFR flights (in 000's) on the CFMU area and they are calculated for the three different scenarios: low, baseline and high scenario as specified in the previous paragraph.

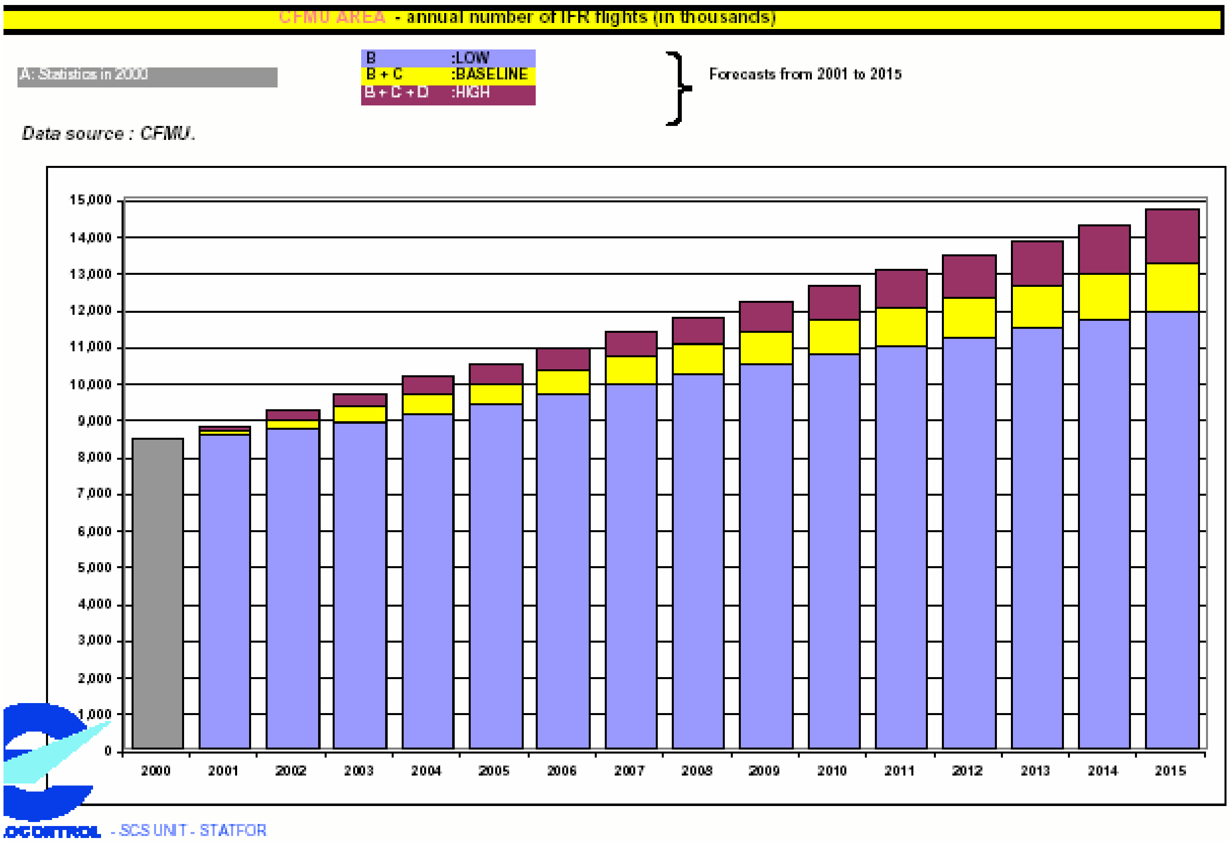


Figure 21: Air traffic forecasts to 2015 for CFMU area

Appendix A: Aircraft Noise Certification

Operational aircraft, in international air navigation, are grouped in noise Chapters, according to the rules established by the ICAO, contained in the Environmental Protection Annex document (ANNEX 16).

This document was issued by the Council on 2 April 1971. The first part contains definitions, the second Standards, Recommended Practices and guidelines for noise certification. Part III, IV and V of ANNEX 16 contain Recommended Practices and guidelines to facilitate the achievement of the use of a common metric for assessing noise, to achieve land use planning and to develop noise abatement operational procedures.

The aircraft are distinguished in the following groups:

CHAPTER 2	CHAPTER 3	CHAPTER 4
Subsonic jet aeroplanes- Application for certificate of Airworthiness for the prototype accepted before 6 October 1977	**Subsonic jet aeroplanes-** Application for Certificate of Airworthiness for the Prototype accepted on or after 6 October 6 October 1977 and before 1January 2006	**Subsonic jet aeroplanes-** Application for Certificate of Airworthiness for the Prototype accepted on or 1January 2006.
	Propeller-driven aeroplanes over 5700 kg- Application for Certificate Airworthiness for the Prototype accepted on or after 1 January 1985 and before 17 November 1988	**Propeller-driven aeroplanes over 8168 kg-** Application for Certificate Airworthiness for the Prototype accepted on or after 1January 2006
	Propeller-driven aeroplanes over 8168 kg- Application for Certificate Airworthiness for the Prototype accepted on or after 17 November 1988 and before 1January 2006	

Table 2: Aircraft Certification

A.1 Aircraft Certification

Chapter 2 aircraft

Noise measurement points

Annex 16 fixes three points where noise values have to be measured:

-Lateral noise measurement point: this point has to be chosen along a parallel line 650 m from the runway centre line and in particular where the measured noise is at a maximum during take-off.

-Flyover noise measurement point: the point is located 6,5 km from the beginning of the take-off run, and along the extension of the runway centre line.

-Approach noise measurement point: this point is located 2000 m from the threshold.

Maximum noise values

The noise limits for the airplanes are established according to the noise measurement points and to the aircraft MTWO:

A) Subsonic jet aircraft - Airworthiness certificate application for the prototype accepted before 06/10/77

M=MTOW in thousand of kg	0	34	272
Lateral noise level (EPNdB)	102	91,83+6,64 log M	108
Approach noise level (EPNdB)	102	91,83+6,64 log M	108
Overfly noise level (EPNdB)	93	67,56+16,61 log M	108

This limits are not valid for aircraft that:
-require a runway length of 610 m or less
-have by-pass ratio of 2 or more and received the certificate of airworthiness before 1st March 1972
-received a certificate of airworthiness before 1st January 1976

B) Derived versions of aircraft specified in A, which have an accepted application to certify a modification of the design dating 26/11/81 or later.

M=MTOW in thousands of kg 0 34 35 48,3 66,72 133,45 280 325 400					
Lateral noise level (EPNdB) all aircraft		97	83,87+8,51 log M		106
Approach noise level (EPNdB) all aircraft		101	89,03+7,75 log M		108
Overfly noise levels (EPNdB)	1 or 2 engines	93	70,62+13,29 log M		104
	3 engines	93	67,56+16,61 log M	73,62+13,29 log M	107
	4 or more engines	93	67,56+16,61 log M	74,62+13,29 log M	108

CHAPTER 2 aircraft phase-out

During the 28th ad hoc session of ICAO the gradual retirement of every Chapter 2 aircraft in the States subject to noise limits (European Community, USA, New Zealand and Japan) as from 01/04/95 to 01/04/2002 was established.

The European Community adopted this ICAO decision (identified as “A 28-3”), setting down the same time period to complete the gradual phase-out of Chapter 2 aircraft by way of Directive 9214 on 12 May 1992. This directive has to be adopted by every EC members State. Exceptions are allowed for emerging States, for historical aircraft, for States that are in particular, short-lived economic difficulty.

CHAPTER 3 aircraft

This aircraft group includes the following three types of airplanes:

- *Subsonic jet aeroplanes*- Application for Certificate of Airworthiness for the Prototype accepted on or after 6 October 6 October 1977 and before 1January 2006;

- *Propeller-driven aeroplanes over 5700 kg* - Application for Certificate Airworthiness for the Prototype accepted on or after 1 January 1985 and before 17 November 1988;

- *Propeller-driven aeroplanes over 8168 kg* **-** Application for Certificate Airworthiness for the Prototype accepted on or after 17 November 1988 and before 1January 2006.

Noise measurement point

Annex 16 fixes points where it is necessary to measure noise values to include an aircraft in the Chapter 3 group:

-Lateral full power reference noise measurement point:

-for jet-powered aeroplanes: this point must be chosen along a parallel line 450 m from the runway centre line and in particular where the measured noise is maximum during take-off.

-for propeller-driven aeroplanes: this point must be chosen along a parallel line 650 m from the runway centre line vertically below the climb-out flight path at full take-off power.

-Flyover reference noise measurement point: the point is located 6,5 km from the beginning of the take-off run, and along the extension of the runway centre line.

-Approach reference noise measurement point: this point is located on a point located 2000 m from the touchdown point.

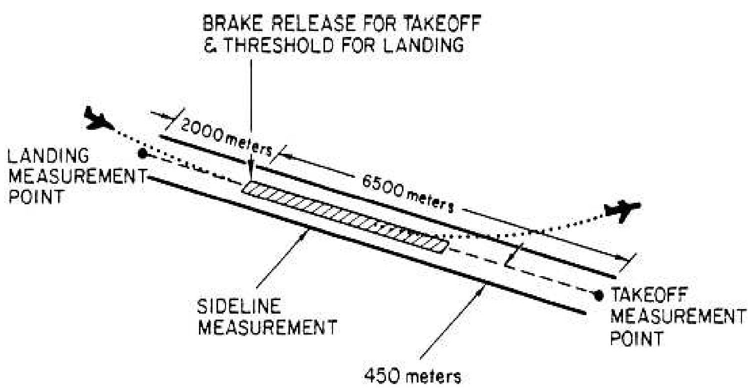


Figure 22: Chapter 3 Noise Measurement Points

Maximum noise values

The noise limits for the airplanes are established according to the noise measurement points and to the aircraft MTWO:

A) Chapter 3 aircraft

<table>
<tr><td colspan="2">M=MTOW in thousands of kg</td><td>0</td><td>20,2</td><td>28,6</td><td>35</td><td>48,1</td><td>280</td><td>385</td><td>400</td></tr>
<tr><td colspan="2">Lateral full power noise level (EPNdB) all aircraft</td><td colspan="3">94</td><td colspan="4">80,87+8,51 log M</td><td>103</td></tr>
<tr><td colspan="2">Approach noise level (EPNdB) all aircraft</td><td colspan="3">98</td><td colspan="2">86,03+7,75 log M</td><td colspan="3">105</td></tr>
<tr><td rowspan="3">Overfly noise levels (EPNdB)</td><td>1 or 2 engines</td><td colspan="4">89</td><td colspan="2">66,65+13,29 log M</td><td colspan="2">101</td></tr>
<tr><td>3 engines</td><td colspan="2">89</td><td colspan="4">69,65+13,29 log M</td><td colspan="2">104</td></tr>
<tr><td>4 or more engines</td><td>89</td><td colspan="5">71,65+13,29 log M</td><td colspan="2">106</td></tr>
</table>

B) Propeller aircraft over 5700 kg - Airworthiness certificate application for the prototype accepted before the 1/1/85.

<table>
<tr><td>M=MTOW in thousand of kg</td><td>5,7</td><td>34,0</td><td>358,9</td><td>384,7</td></tr>
<tr><td>Lateral noise level (EPNdB)</td><td>96</td><td colspan="2">85,83+6,64 log M</td><td>103</td></tr>
<tr><td>Approach noise level (EPNdB)</td><td>98</td><td colspan="2">87,83+6,64 log M</td><td>105</td></tr>
<tr><td>Overfly noise level (EPNdB)</td><td>89</td><td>63,56+16,61 log M</td><td colspan="2">106</td></tr>
</table>

C) Propeller aircraft of 8618 kg or less - Airworthiness certificate application for the prototype accepted before 17/11/88

<table>
<tr><td>M=MTOW in thousand of kg</td><td>0</td><td>0,6</td><td>1,5</td><td>8,618</td></tr>
<tr><td>Noise level (EPNdB)</td><td>68</td><td>60+13,33 log M</td><td colspan="2">80</td></tr>
</table>

D) Propeller aircraft of 8618 kg or less - Airworthiness certificate application for the prototype or derived version accepted on or after 17/11/88.

<table>
<tr><td>M=MTOW in thousands of kg</td><td>0</td><td>0,6</td><td>1,4</td><td>8,618</td></tr>
<tr><td>Noise level (EPNdB)</td><td>76</td><td>83,23+32,67 log M</td><td colspan="2">88</td></tr>
</table>

These figures do not provide a useful understanding of the true size of the difference between Chapter 2 and Chapter 3 aircraft. The following picture gives an idea of the significant results reached in noise abatement research in the technology field. In fact, the difference between the footprints generated by a Chapter 2 aircraft and a Chapter 3 aircraft on the ground is considerable.

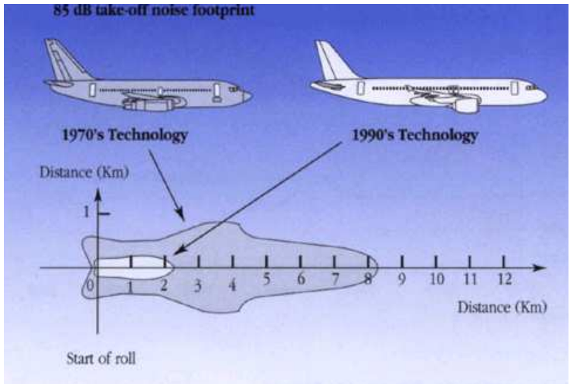


Figure 23: Noise footprint for Chapter 2 and Chapter 3 aircraft[1]

Supersonic aircraft Certification

There are two categories of supersonic aircraft:

-airworthiness certificate application for the prototype accepted before the 01/01/75: maximum noise levels will not exceed the measured levels of the first aircraft of this type certified;

-airworthiness certificate application for the prototype accepted on 01/01/75 or later: Standards and Recommended Practices are not yet developed but the noise levels of Chapter 3 of this Part applicable to subsonic jet aeroplanes may be used as guidelines for aeroplanes for which the application for a certificate of airworthiness for the prototype was accepted or another equivalent prescribed procedure was carried out by certificating authority on or after 1 January 1975.

A.2 Chapter 3 Re-certified aircraft

This aircraft category includes aircraft equipped with hush-kit engines or not (fitted with an aircraft silencing apparatus known as a hush-kit) and aircraft with limited operational performance (for example limiting the landing flaps' set or the maximum take-off weight to satisfy Chapter 3 requirements). On 29 April 1999 the European community issued a Regulation establishing that re-certificated aircraft could not operate inside the European territory as from 1 April 2002 if they have not been registered in some EU register before the coming into force of this decree, 1 May 2000. Since 1 May 2000 re-certificated aircraft could not be registered in any national register[EC_120].

This Regulation has been a point of discussion between Europe and the U.S. because the U.S. do not have this restriction for re-certified aircraft. Due to the proposed European regulation, some American aircraft could not operate in the EU territory, with serious consequences for American airlines which had invested in re-certification providing compliancy with ICAO noise restrictions.

At the Chicago Convention on Civil Aviation, 14 March 2000, the United States challenged this European legislation. In Autumn 2001 the EU made the decision to withdraw the Hush-kit Regulation that would have banned older hush-kit aircraft starting from 1 April 2002. The

[1] Airbus source

EU is in the process of developing new regulations based on the recent ICAO recommendation whereby operational restrictions will be considered from airport to airport[2].

This is a new concept proposed by ICAO. In fact, following the dispute between the U.S. and Europe, ICAO stipulated that it is not possible to create recommendations for all airports, but it is necessary to follow a local approach because each airport has its own constraints and different air traffic needs.

A.3 Chapter 4 aircraft

Each noise Chapter contains different aircraft from a noise point of view. In fact, within the same Chapter there are airplanes which are noisier than others. For this reason, following the Chapter 2 phase-out it was considered necessary to design a new category for aircraft certification, namely Chapter 4.
This new Chapter had to satisfy two different issues:
-one, in the short term, it was to recommend lower noise values to aircraft manufacturers for next aircraft generation.
-the other was to design, after the planning and the manufacturing of airplanes which make less noise, a second aircraft phase-out of those that do not satisfy the new Chapter 4 limits.

Achieving an agreement on this point was very difficult because it was necessary to mitigate and to satisfy the different requests from each party involved in the Chapter 4 setting.

The key factor that guided the discussion was the cost-benefit analysis. In fact manufacturers and U.S. airlines required little more noise reduction than designers have already achieved. On the other hand, noise activists and airport community claimed more stringent limits, to protect the interests of people living round the airports.

They claimed that more strict limits could cause damage overall to airlines that use short-haul airplanes and that invested their capital for hush-kitted or re-engineered aircraft in order to comply with Chapter 3 recommendations in past years.

In June 1999, the ICAO council established a mandate for CAEP to explore possible technical options for the implementation of operational restrictions on Chapter 3.
CAEP steering group proposed three different threshold values under current Chapter 3 values:

-8dB, -11dB and –14dB. The CAEP steering group has analysed 26 hypothetical scenarios and in one year it has reached the final scenario.

The best fixed solution for the new threshold is" –10dB" over current Chapter 3 levels. This new certification level will be adopted from 1 January 2006 onwards. This CAEP proposal is only valid for new airplanes and it does not carry a phase-out of airplanes that do not satisfy the new noise limits (see next page). In fact, following a cost-benefit analysis, the CAEP steering group has established, by cost/benefit analysis, that results were not sufficient to recommend a global Chapter 3 phase-out.

FESG working group, inside the CAEP, achieved a preliminary estimation of the necessary costs to achieve a Chapter 3 phase-out which does not include consideration of re-certification to verify the feasibility of a possible phase-out.

[2] http://www.boeing.com/assocproducts/noise/ecac.html

The results are that the costs per person removed from 65 DNL contour are approximately $2500 for the Stage 2 phase-out in the U.S. The phase-out options under consideration for possible transition scenarios represent 50 or 300 times the cost for removing a person from the noise contours as compared with the Stage 2 phase-out[3].

Stage 3	Replacement-Only	# Individuals	US Dollars per Person Removed	
Scenario	Costs($Million)	Benefited	Non-Discounted	
			In 1990 $	In 1999 $
3	1,253.00	900,000	$1,392.22	$2,559.54
4B	273.00	900,000	$303.33	$557.66

US & Canada Data for Stage IV			Cost in $Billions, People Removed in Units		
	Cost($Billion)	Discounted People Removed	Non-Discounted	**$/Person**	**Multiple of Stage II Phase-In**
2.1	0.0	571	1,252	**$0**	**0**
2.2	0.6	1047	2,295	**$261,438**	**102**
2.3	3.7	10977	27,975	**$132,261**	**52**
3.1	23.4	36212	82,404	**$283,967**	**111**
3.2	39.3	47745	101,952	**$385,476**	**151**
3.3	11.6	24743	82,404	**$140,770**	**55**
3.4	19.1	30694	101,952	**$187,343**	**73**
3.5	31.4	39782	121,400	**$258,649**	**101**
4.1	36.5	50601	82,404	**$442,940**	**173**
4.2	59.4	63191	101,952	**$582,627**	**228**
4.3	61.0	56015	121,400	**$502,471**	**196**
5.1	25.1	42994	82,404	**$304,597**	**119**
5.2	32.9	49690	101,952	**$322,701**	**126**
5.3	45.5	56355	121,400	**$374,794**	**146**
6.1	53.5	83278	82,404	**$649,240**	**254**
6.2	77.4	95868	101,952	**$759,181**	**297**

Table 3: Costs in US dollars to remove persons from 65 DNL noise contours

CAEP recommendations were forwarded to the ICAO Council who refined and improved them including them as an Amendment to Annex 16, introducing a new Certification category, Chapter 4, that replaced the previous Chapter 4, containing Supersonic aircraft. The selected noise measurement points are the same selected in Chapter 3 and each of following conditions shall be apply:

$EPNL_L$[$LIMIT_{L;}$; $EPNL_A$[$LIMIT_A$ and $EPNL_F$[$LIMIT_{F;}$;

[($LIMIT_L$-$EPNL_L$)+ ($LIMIT_A$-$EPNL_A$)]+ ($LIMIT_F$-$EPNL_F$) /10

[($LIMIT_L$-$EPNL_L$) + ($LIMIT_A$-$EPNL_A$)] /2; [($LIMIT_L$-$EPNL_L$)+($LIMIT_F$-$EPNL_F$)] /2; and [($LIMIT_A$-$EPNL_A$)+ ($LIMIT_F$-$EPNL_F$)] /2

where:

[3] Preliminary results from economic analysis made by FESG and shown during the CAEP/5 meeting in Montreal(January 08-17, 2001)

$EPNL_L$, $EPNL_A$, $EPNL_F$ are respectively the noise levels at the lateral, approach and flyover reference noise measurement points when determined, to one decimal place, in according to the evaluation method;

$LIMIT_L$, $LIMIT_A$, $LIMIT_F$ are respectively the maximum permitted noise levels at lateral, approach and flyover reference noise measurement points determined, to one decimal place, like prescribed for Chapter 3 aircraft.

Appendix B: Overview of environmental airport problems

In recent years, the interest in the quality of life of private citizens has increased and so environmental issues have come to the fore. To understand the environmental problems relating to airports one should first describe the airport's role.

The airport's role is unique. In fact, aircraft are becoming more and more used as a means of transport and so air traffic has increased and is increasing year in, year out.

Furthermore, airports significantly influence the surrounding area. In fact it is a big employment centre (as business, catering, oil industry, etc.) and at the same time attracts, in its surrounding area, many people that can exploit the airport's local vicinity (manufacturing industry, electronics industry, hotels, etc.).

For this reason, the number of people round airports is increasing instead of decreasing, and at the same time air traffic is increasing too.

So, as a direct consequence, the number of citizens liable to high noise values is increasing and simultaneously the number of constraints to the airport's geographic and capacity development is increasing too.

An other direct consequence of the increase in air traffic is the increase of emissions in the atmosphere, but this effect is not as palpable as the noise problem, and so, for this reason, noise abatement is the primary issue.

B.1 Noise

Airport noise is becoming a big problem for all airports, whether big or small, which must satisfy consumers' demand, the needs of the people in the airport's neighbourhood and airline business.

In recent times the citizens living around airports have been increasing their protests and so it is becoming more difficult to design development plans without considering the effects on the people around the airport for airport management.

B.1.1 Airport noise assessment

Noise measurement is generally an arduous task. In fact, this type of measuring is much different to other quantitative assessments, which are possible to carry out in an objective manner. Noise disturbance depends on many factors, some of whom can be evaluated in an objective manner, like source power, sound wave frequencies, weather conditions, source-observer distance and the effects of natural and artificial hurdles noise-source, while others can be evaluated in a subjective manner, like the state of mind of the receiver. But the most difficult task is to evaluate the final measured noise arising from the influence of and interaction between all of these factors.
Sound (or noise) measure represents physical, atmospheric, pressure variations with regard to an assigned value. In fact sound waves, when spreading, oscillate the particles on their balance position and this gives rise to local pressure level changes.

This change in local pressure is then perceived by the human ear, which alters the pressure variation in sound or noise, depending on the source power, propagation frequencies, distance between source and receiver, meteorological conditions and on the personal conditions and state of mind of the receiver.

Evaluating airport noise is even more difficult than evaluating other sources, because in an airport there is more than one aircraft noise source, such as those on the move, that in turn have many varying noise sources on board.

In fact during the various phases of a flight, the noise source changes, new noise sources start and stop (gear up or down, flap up or down) and the source-receiver distance changes point by point and also the means (weather conditions) of propagation.

It is clear that, to choose a measurement unit, creating a model is an arduous task.

B.1.1.1 Noise measurement indicators

Many critical aspects characterize airport noise assessment. Therefore it is necessary to focus on the available measurement units that can carry out realistic noise evaluation as much as possible.

Currently there are a lot of adopted metrics which measure not only the noise values relating to a single event, but also calculate daily average values (24 hours) or average values for selected time lapses (16 hours, 8 hours, etc). The metrics for the single event can be used for aircraft certification or to evaluate if a specific aircraft, following a certain procedure, gives better results in terms of noise values. The question arises as to how it is possible to evaluate in a realistic way noise nuisance to citizens living in the airports neighbourhood, citizens that have to suffer all day the numerous aircraft operations, rather than just a single event?

Generally, to evaluate the global nuisance to citizens, cumulative metrics are used, which add the measurements of all the recorded events during a fixed time period, weighting in a different way daily and the nightly operations, to give an average value for noise nuisance. In fact night flights are more of a nuisance than day flights and for this reason, in a cumulative value, their importance has to be greater.

The more commonly used metrics are SEL and LAeq, for single event and for cumulative measurements respectively.

$$SEL = 10\log\left[\frac{1}{T_0}\int_{t_1}^{t_2} 10^{L_{AF}(t)/10} dt\right]$$

Where:

T_0=1 s

t1-t2 is the time when the noise level L_{AF} is between L_{AFmax}-10 dB and the maximum value L_{AFmax}

Leq is defined as the continuous sonorous level of a mean noise, measured in dB, that contains the same energy of the real variable noise for a defined period of time. Leq is usually defined over relatively long periods of time, for example 1, 8, 12, 16, 24 hours.

$$L_{eq}(T) = 10\log\left[\frac{1}{T}\frac{p(t)^2}{{p_0}^2}dt\right]dB(A)$$

If the sound level is weighted with the constant A, that filters out the low and high frequency components to better represent the behaviour of the human ear, the formula becomes:

$$L_{Aeq}(T) = 10\log\left[\frac{1}{T}\int_0^T 10^{\frac{L_A}{10}}dt\right]dB(A)$$

This index has the inconvenience that it underestimates occasional sonorous events and softens the short duration events energy during the calculation process.

B.1.1.2 General expression for measuring airport noise

Past studies have elicited one general formula that can sum up all the international formulas that take a specific form in each State.

In fact in 1993, an investigation was carried out under a contract awarded by Directorate General VII, Transport, of the European Commission: 'A study on measures to protect the environment in and around airports against aircraft noise', which led to the following conclusion:
Based on a comparison of different noise exposure indices it can be concluded that the general form of the most used noise exposure index is given by:

$$index = 10\log 1/T(\sum g(i) * 10^{L(i)/10})$$

Where:

T= reference period

i= index denoting the i'th aircraft movement

Σ = number of aircraft movements during the reference period

g(i) = weighting factor for the i'th aircraft movement; this factor is dependent on the time of observation

L(i) = single event noise descriptor of the i'th aircraft movement

For a common aircraft noise exposure index, the methodology described in an ECAC recommendation (ECAC doc. No 29-February, 1986, Amendment no. 1-February 1987is suggested.

Appendix C: New European laws about Noise abatement

On 25th of June 2002 the European Parliament issued a Directive to assess and to manage environmental problems.

The aim of this Directive is to define a common approach intended to avoid, prevent or reduce the harmful effects, including annoyance, due to exposure to environmental noise, by different actions.

These actions are:

-determination of exposure to environmental noise, through noise mapping, by common methods to the Member States

-ensuring that information on environmental noise and its effects is made available to the public

-adoption of action plans by the Member States, based upon noise-mapping results, with a view to preventing and reducing environmental noise where it is necessary, particularly where exposure levels can induce harmful effects on human health, and to preserving environmental noise quality where it is good[EC_189].

The selected common noise indicators are L_{den} to assess annoyance and L_{night} to assess sleep disturbance. It is also useful to allow Member States to use supplementary indicators in order to monitor or control special noise situations.

The day-evening-night level $\mathbf{L_{den}}$ is defined by the following formula:

$$L_{den} = 10 \lg \frac{1}{24}\left(12*10^{\frac{L_{day}}{10}} + 4*10^{\frac{L_{evening}+5}{10}} + 8*10^{\frac{L_{night}+10}{10}} \right)$$

L_{day}: is the A-weighted long-term average sound level, as defined by ISO 1996-2(1987), determined over all the day periods in a year,

$L_{evening}$: is the A-weighted long-term average sound level, as defined by ISO 1996-2(1987), determined over all the evening periods in a year,

L_{night}: is the A-weighted long term average sound level, as defined by ISO 1996-2(1987), determined over all the night periods in a year;

The day length is 12 hours, the evening length is 4 hours and the night length is 8 hours, but the length of the evening period can be reduced and then the night length can increase. These three selected periods can be chosen during 24 hours; the default values are 07.00 to 19.00, 19.00 to 23.00 and 23.00 to 07.00 local time.

It is also possible to use other metrics in particular situations, in the case of short noise nuisance periods, in the case of noise with low frequency, tonal and impulsive components and in the case of request of extra protection during weekend, day, evening or selected periods.

Each Member State has to draw up a “strategic noise map” no later than 30 June 2007 for major airports within their territories to show what has been done in the preceding calendar year. No later than 30 June 2005, and thereafter every five years, Member States shall inform the Commission about the results received from major airports.

“Major airport” is a civil airport which has more than 50000 movements per year. Noise mapping means the presentation of data on an existing or predicted noise situation in terms of a noise indicator, indicating breaches of any relevant limit value in force, or the number of people affected in a certain area, or the number of dwellings exposed to certain noise values in a certain area measured by a selected indicator.

A “strategic noise map” is also defined. It is a map designed for the global assessment of noise exposure in a given area due to different noise sources.

Member States shall adopt the measures necessary to ensure that no later than 30 June 2012, and thereafter every five years, strategic noise maps showing the situation in the preceding calendar year will have been made.

Similar noise restrictions are established for agglomerations, roads and railways.

Member States shall ensure that no later than 18 July 2008 the competent authorities have to drawn up action plans to manage, within their territories, noise issues and effects including noise reduction for major airports, when necessary.

Member States shall ensure that, no later than 18 July 2013, the competent authorities have drawn up action plans notably to address priorities which may be identified by the exceeding of any relevant limit value or by other criteria chosen by Member States for agglomerations and for major road as well as major railways within their territories.

This directive also establishes that Member States have to contact the private citizens on the proposed action plans so they can participate in the drawing up and revision of these plans and they have to inform the public of all the decisions taken.

Until the use of common assessment methods for the determination of L_{den} and L_{night} is made obligatory, Member States can use national noise indicators and metrics using data no more than three years old. Member States have to convert national metrics into the metrics defined in this directive. The Member States have to communicate the relevant noise limit values to the Commission no later than 18 July 2005.

For the full test of Directive click on:
http://europa.eu.int/eur-lex/pri/en/oj/dat/2002/l_189/l_18920020718en00120025.pdf

Recently, on the 26th of March 2002, a Directive that establishes rules and procedures for the introduction of operational restraints in order to reduce noise around European airports, was passed by the European Parliament. The objectives of this directive are:

-to establish European rules to facilitate the adoption of common operational restraints to reduce the number of people exposed to high noise levels produced by aircraft.

-to provide a framework which safeguards internal market requirements;

-to promote the increase of airport capacity but being environment friendly;

-to facilitate the noise reduction for the single airport.

-to plan different scenarios, to achieve the maximum environmental benefit with a cost as little as possible.

This directive also defines" Marginally compliant aircraft", which are civil subsonic jet airplanes, that meet the certification limits laid down in Volume 1,Part II, Chapter 3 of Annex 16 to the Convention on International Civil Aviation by a cumulative margin of not more than 5EPNdB (Effective Perceived Noise in decibels), whereby the cumulative margin is expressed in EPNdB and it is obtained by adding the individual margins (i.e. the differences between the certificated noise level and the maximum permitted noise level) measured at each of the three reference noise measurement points as defined in Volume 1,Part II, Chapter 3 of Annex 16 to the Convention on International Civil Aviation;

This Directive also defines the operational constraints to reduce noise nuisance, among these, operations for aircraft with noise emissions values very close to those fixed by certification are forbidden.

It also dictates the necessity to follow the approach suggested by the CAEP during the 33th ICAO assembly, the "balanced approach", that suggests the reduction of noise impact through four different ways (see 4.5 paragraph).

If the assessment of every available measure, including operational restrictions of a partial nature, demonstrates that the achievement of the objectives of this Directive requires the introduction of restrictions aimed at the withdrawal of marginally compliant aircraft, the following rules shall apply to these procedures at the airport under consideration:

a) six months after the completion of the assessment and decision on the introduction of an operational restriction, no services over and above those operated in the corresponding period of the previous year shall be allowed with marginally compliant aircraft at that airport;

b) not less than six months thereafter, each operator may be required to reduce the number of movements of his marginally compliant aircraft serving that airport at an annual rate of not more than 20 %of the initial total number of these movements.

Subject to the rules on assessment of Article 5, city airports ("metropolitan airports", that have runways with lengths of less than 2000m and are located in the centre of a densely populated area) may introduce measures that are more stringent, in terms of the definition of marginally compliant aircraft provided that these measures do not affect civil subsonic jet airplanes that comply, through either original certification or re-certification, with the noise standards in Volume 1,Part II, Chapter 4 of Annex 16 to the Convention on International Civil Aviation.

These restrictions are not valid for operational restrictions that were already established on the date of entry into force of this Directive, and for aircraft registered in developing countries there are foreseen exemptions.

Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by 28 September 2003 at the latest[EC_85].

For the full text of Regulation see:
http://europa.eu.int/eur-lex/pri/en/oj/dat/2002/l_085/l_08520020328en00400046.pdf

For general information on the European Noise Policy click on:
http://europa.eu.int/comm/environment/noise/home.htm

Appendix D: The Netherlands

D.1 Noise calculation

For aircraft noise, there are 3 specific metrics (National Aviation Act, article 25):

Ke (>6000 kg);

L_{aeq} (>6000 kg);

BKL (<6000 kg).

In the Directive of Schiphol airport, two noise zones are considered: the LAeq dB(A)-zone and the Ke-zone. Within both of these zones, a predetermined maximum number of houses with noise nuisance is defined.

Ke

The 'Kosten method'. This metric is in use for the calculation of the noise load for the 24-hour period, for large aircraft (heavier than 6000 kg), small aircraft following instrument procedures and helicopters. Variables that influence the amount of noise are: time of day, aircraft type, height profile of the aircraft, etc. It protects the people in the surroundings of the aerodrome for the whole day.

Formula:

$$B = 20 *^{10} \log(\sum_i nsf_i * 10^{LA_{max_i}/15}) - 157 \text{ [Ke]}$$

In which:

B: is the number of 'Kosten'- units;

i: indicates the aircraft movement;

nsfi: is the night penalty, belonging to movement i;

LAmax,i: is the maximum of noise production of movement i.

The night penalty depends on the time of day the movement took place, and differs from 1 (08:00 - 18:00 h) up till 10 (23:00 - 06:00 h), meaning that an aircraft departing or landing during night hours counts10 times as heavy as a departure or landing during daytime.

L_{Aeq}

This metric is in use for calculation of the noise load during night hours (23.00 – 06:00 h), for large aircraft, small aircraft following the procedures for large aircraft and helicopters.
At Schiphol airport, where regular night operations take place, a special night noise index is applied of LAeq 26 dB(A)-indoors. Sleeping rooms inside this 26 dB(A)-contour are to be insulated to this limit value. The reason for this additional metric was the concern for the

health of people living around the airport due to possible sleep disturbance because of aircraft noise.
Formula:

$$LAeq = 10 *^{10} \log(\sum_{p=1}^{N} 10^{LAX_p / 10}) - 44 \quad [dB(A)]$$

The LAeq formula, in which:

N: is the total number of aircraft passages in one year caused by arriving and departing aircraft during night hours (23.00 - 06:00 hr) divided by 365;

p: index for aircraft passage;

LAXP: the time integrated A-weighed noise level in a specific point (with co-ordinates) in a bedroom is caused by passage p;

To calculate the noise level in a bedroom, a damping factor is applied of 22 dB(A) for arrivals and of 20.5 dB(A) for departures.

BKL

Noise metric for small aircraft up to 6000 kg MTOW is the BKL, which is based on the Lden (day-evening-night equivalent sound level). The difference with the Lden is that aircraft movements during weekends and holidays in the six busiest months of the year get an extra weighting. Noise zones have been established with a legal limit value of BKL = 47 dB. New noise sensitive developments are not allowed. Existing noise sensitive buildings may remain without noise insulation.

All noise calculations are based upon theoretical noise values, meaning that no noise monitoring terminals in the field are being used. Noise zones (limits) in BKL have been established for all airfields whose traffic consists mostly of aircraft up to 6000 kg MTOW. Each year, a noise load calculation is made to check whether the limits of the noise zone are met. A detailed description of the way these noise zones are defined, is available (in Dutch, part in English).

D.2 Noise regulations

It is compulsory for aerodromes to prepare an Environmental Impact Statement in the case of:

-the creation of a totally new airport, or,

-changes in dimensions of runways with a length exceeding 1000m, or;

-a change in the use of an airport, which results in an enlargement of an existing noise zone.

The Minister Transport, Public Works and Water Management is responsible for noise nuisance caused by aircraft is

The Minister of the Environment is responsible for noise nuisance of all other sources.

Legal framework for non-aeronautical areas

In the Netherlands the Noise Nuisance Act is in force, in which all noise limitations are laid down except those for aircraft. These limitations are based on the LAeq but they are not completely similar. The Dutch and European legislation are more or less similar. However, there are (small) differences between national legislation and European legislation, knowing that European legislation takes priority over national legislation.

Review of statutory noise Limits in the Netherlands

Noise Nuisance Act						
Limits in Lcorrected, 24 hrs dB (A) (+..): temporary correction anticipating less noisy equipment (-..): penalty to be subtracted (--): not specified in the regulations						
	Preferred level	**Maximum allowable if conditions are met**				
Source		New Residential area	New source	Both new	Both Existing	Inside
Road traffic (local)	50 (+5) dB(A)	65 (+5) dB(A)	65 (+5) dB(A)	60 (+5) dB(A)	70 (+5) dB(A)	35 dB(A)
Road traffic (Motorways)	50 (+3) dB(A)	55 (+3) dB(A)	60 (+3) dB(A)	55 (+3) dB(A)	70 (+3) dB(A)	35 dB(A)
industrial areas	50 dB(A)	55 dB(A)	55 dB(A)	55 dB(A)	65 dB(A)	35 dB(A)
impulse noise	50 dB(A) (-5)	50 dB(A) (-5)	50 dB(A) (-5)	55 dB(A) (-5)	65 dB(A) (-5)	35 dB(A)
railway noise	57 (+3) dB(A)	70(+3) dB(A)	70(+3) dB(A)	70(+3) dB(A)	existing level	35/37 dB(A)
Environmental Protection Act						
Small enterprises	50 dB(A)	--	--	--	--	--
Aviation Act						
Aircraft over 6000 kg ('Kosten-unit')	35 Ke	45 Ke	45 Ke	45 Ke	65 Ke	35 à 40 dB(A)
Small aircraft (below 6000 kg) BKL-unit	47 + 3 BKL	--	--	--	--	--

Table 4: Statutory noise limits in the Netherlands

Definition of $L_{corrected}$, 24hrs

Values are calculated for separate day (7.00-19.00), evening (19.00-23.00) and night (23.00-7.00) levels. 5 dB(A) has been added to the evening level and 10 dB(A)to the night level. So $L_{corrected}$ is the maximum of:

L_{day};

$L_{evening}$ + 5 dB(A);

L_{night} + 10 dB(A).

This looks like, but is NOT the same, as the standard L_{dn} procedure with a penalty of 10 dB(A) during night hours.

Legal framework for aeronautical areas

Due to the National Aviation Act each aerodrome is obliged to have a so-called Directive, in which at least one noise nuisance zone has been considered. Local authorities are obliged to incorporate airport noise zones and land-use measures in local development plans.

The noise zones to be considered in the Directive depend on the operations which take place on the aerodrome as well as its type of traffic. There are three metrics for noise zone calculations.

The legally established noise zones around airports are enforced by preventive and repressive measures.

Preventive measures are the Airport Usage Plan, together with the continuous monitoring of noise development throughout the year. The Airport Usage Plan has to be submitted to the Minister of Transport each year (National Aviation Act, article 30b). If the plan shows that the expected operations for the following year will stay within the legal noise zone the plan is accordingly approved, otherwise measures have to be taken to keep it within the noise zones. By continuously monitoring and reporting real development (possible) infringements of the legal noise zones can be detected at an early date. The monitoring system at Schiphol airport is called FANOMOS (flight track and aircraft noise monitoring system). During a given period of a year, it registers the actual flight data (flight plan and radar plots, which lead to actual flight paths). This data is input for 'actual' noise production during the year. When there are differences between the forecast and actual registrations, the airport authorities have to adjust the data which is the input for the noise contour for the remaining period of the year, in a way the air traffic within the legal noise zone again. The legislator (RLD) is responsible for the FANOMOS; it is the task of the RLD to monitor whether or not the forecast deviates from the actual development of the traffic (National Aviation Act, article 25h).

If a noise zone is exceeded, the Minister for Transport, Public Works and Water Management is also responsible for taking measures to prevent further growth of this excess.

Repressive measures exist for the enforcement of the standard routings with tolerance areas to match. Airline captains will be prosecuted in case of unauthorised deviation from flight tracks[D1].

Immissions in the Netherlands

The legal limit values for land use measures are:

within the 35 Ke-contour new noise sensitive developments are not allowed;

within the 40 Ke-contour existing noise sensitive buildings are to be noise-insulated;

within the 65 Ke-contour all noise sensitive buildings are to be demolished.

Relationship between number of movements and noise levels within Ke-zone:

twice the traffic results in a growth of 6 Ke (and the opposite: a reduction of the traffic with 50% results in a reduction of 6 Ke);

a reduction of aircraft noise of 4,5 dB(A) results in a reduction of 6 Ke (and the possibility of accommodating twice as much traffic).

Recently the Dutch Government created two regulations where taxation is used to promote initiatives for environmental protection. The first regulation is general and concerns public energy saving. The second regulation encourages people to invest money in environmental protection. Under article 3.31, paragraph 1, of the 2001 law re income taxes, taxpayers can apply an optional tax re depreciation for company instruments caused by the environment. This regulation is valid for water, air and earth pollution and for limitations of noise nuisance limitations to select the best techniques for noise pollution reduction. Under article 3.42a of the 2001 income tax law, if tax payers so require, a fixed percentage of investment is deducted from their taxable income. So taxable income is reduced and business people have to pay less taxes[AEMR].

Appendix E: France

In France the L_{Aeq} metric is applied.

Since July 1, 1999, French law provides airport authorities with a means to finance installation of automatic surveillance systems for sound nuisance. The DNA (Directorat Navigation Aérienne) and SBA (Service Bases Aériennes) made STNA (Service Technique de la Navigation Aérienne) responsible for providing technical assistance during the implementation of noise monitoring systems at airports. The noise exposure plans are defined for the main French airports and consist of four zones- A, B, C and D. The automatic surveillance systems allow airport authorities to continuously evaluate if noise limitations in these zones are being respected and to inform people living in the vicinity of the airport.

Appendix F: Italy

Italian legislation requires the use of metric L_{VA}, which stands for “Evaluation level of airport noise”. This metric is very close to the DNL metric, in fact it weights day, evening and night aircraft operations with the same factors used by L_{VA}. The difference is that DNL is calculated on a yearly basis for an average day and L_{VA} on a 3 weeks basis, chosen in three selected periods. The L_{VA} index is defined by the following formula:

$$L_{VA} = 10 \cdot \log\left[\frac{1}{N}\sum_{j=1}^{N} 10^{L_{VAj}/10}\right] \quad dB(A)$$

Where:

N is the number of days of the observation period and L_{VAj} is the daily value of the airport noise level.

The daily airport noise level is calculated considering all aircraft operations (flyover and on the ground) occurring during the day. It is determined by the following formula:

$$L_{VAj} = 10 \cdot \log\left[\frac{17}{24}10^{L_{VAd}/10} + \frac{7}{24}10^{L_{VAn}/10}\right] \quad dB(A)$$

Where:

L_{VAd} and L_{VAn} represent airport noise levels measured during daytime (defined from 06.00 to 23.00) and night-time (defined from 23.00 to 06.00), and they are calculated as follows:

$$L_{VAd} = 10\log\left[\frac{1}{T_d}\sum_{i=i}^{N_d} 10^{SEL_i/10}\right] dB(A)$$

$$L_{VAn} = 10\log\left[\frac{1}{T_n}\sum_{i=i}^{N_n} 10^{SEL_i/10}\right] dB(A)$$

Where:

Td=61200 s.

Tn=25200 s.

Nd is the total number of day flights.

Nn is the total number of night flights.

SELi is the level of the analysed sound event

Twenty-one (21) days are used for the assessment of the L_{VA} index, corresponding to the abovementioned three weeks. From the following three periods, the busiest week, in terms of overall movements, must be chosen:

1st October – 31st January;
1st February – 31st May;

1st June – 30th September.

Since the end of the Sourdine I project, different regulations have been promulgated about airport noise decrease.

On 20 May 1999, the Italian Ministry for the Environment, in agreement with the Ministry of Transport, issued a decree "Norms for monitoring systems", to supervise noise pollution around airports and to classify airports on the basis of the measured noise levels.

This decree establishes that noise monitoring systems must be located within the airport territory (where the measured noise is greater than 60 dB(A) using the L_{VA} metric) and they must be linked with the meteorological monitoring systems, so that it is possible to unite relative meteorological conditions to each flight operation (as set out in the decree dated 31/10/97).

These systems must also be able to link the evaluated noise with the radar track and with the flight data of the aircraft generating the noise.

It specifies that the monitoring station's location is correct if the difference between the L_{Afmax} value and the rest of the noise L_{Aeq} is greater than 20 dB, during a lapse time of ten minutes when at maximum noise levels.

Thus, noise monitoring stations shall supply the following data:

-station position

-measurement date and time

-event's SEL

-event's LAfmax

and they must also be able to calculate the underlying noise, to supply the L_{VA} values and to plot the noise contours.

Airports are classified according to the following parameters:

-the stretch of the airport territory

-the stretch of the three zones "A", "B" and "C" (decree 31/10/97)

-the stretch of three residential areas "Ar", "Br" and "Cr", that belong respectively to the "A", "B" and "C" zones

-population density, greater number of people per hectare

The three parameters, "Ar", "Br" and "Cr", must be correct according to population density, and so they become Arc, Brc and Crc:

Residential area	Population density	Correction factor
Low	10-150	K=1.1
Medium	150-250	K=1.2
High	>250	K=1.3

Table 5: Correction Factors for classifying Italian airports

In this way it is possible to calculate three correction factors and thus the noise indexes in the residential zones:

Ia=Arc*A

Ib=Brc*B

Ic=Crc*C

These three indices distinguish airport areas from an acoustic point view.

The decree, dated *3 December 1999*, called "*Noise abatement procedures and airport defended zones*", synthesizes all the regulations to follow for the reduction of noise impact, such as design procedures, use of reverse thrust, use of sound absorption walls and rules for engine tests.

The decree, dated *17 December 1999*, titled "*Modification to Decree on Night flights prohibition dated 11 December 1997*", extends night flight prohibitions to all Italian airports from 11.00 p.m. to. 6.00 a.m. Before this came into force, this ban was valid for every Italian airport except for Roma Fiumicino and Milano Malpensa.
But this decree sets out that each airport must guarantee possible State, emergency and sanitary flights when necessary at night.

Contemporarily it is possible to authorize night flights in some airports if the measured noise in zone-A of the airport territory does not exceed the 60dB(A) value using the L_{van} metric, but this authorisation is only available to Chapter 3 aircraft.

One of the more recent Regulations about noise containment, dated *29 November 2000* and called "*Norms to establish intervention plans to contain and abate noise created by private companies, public transport service companies or relative infrastructures*", gives general information for the reduction of noise impact for every means of transport.

In particular, re airport noise pollution, this decree establishes that the managing authorities have 18 months to locate the three noise zones "A", "B" and "C" from 7 December 2000.
After this step trades people have 18 months to realize noise abatement and containment plans. The planned targets must be achieved within five years.
In this decree, the actions' sequence to be followed to reduce noise is also described:
-intervention on noise sources
-intervention along the noise propagation route (sound absorption walls, etc.);
-intervention on the receiver (buildings insulation walls, etc.)
It also adduces the possibility of using mathematical models, but they have to allow for the:
-description of the characteristics of noise propagation;
-collection and updating of the sound's power sources;
-collection of the acoustic characteristics of building materials.

Appendix G: Spain

Noise Metric

Government Directive 2002/49, relating to evaluation and management of noise, prescribes the use ofLAEq day, LAEq night and LAEq(den) to assess airport noise.

Responsible body and regulations

In Spain, the Spanish state, via AENA (Aeropuertos Españoles y Navegación Aérea) , which is part of the Ministry of Transport and Infrastructure and is responsible for the administration of the responsible body, is responsible for the Airport sector. Its areas of influence are airports, airspace control, transit and air transport, apart from aircraft registry.

The regulations which specifically concern the avoidance of noise coming from aircraft can be divided into three groups:

-Technical regulations concerning aircraft manufacturers. Basically to avoid noise emission by checking the noise sources at aircraft and engine construction. These guarantee consistency with ICAO requirements.

-Technical regulations concerning Aircraft use. These regulations are intended to minimise noise disturbance to the airport neighbourhood as much as possible.

In order to work efficiently, an exhaustive noise study (sound countour) has to be conducted measuring real noise values on the airport surroundings. The relevant input data for determining airport noise footprints is that relating to take-off and landing operations, air and ground operations and engine trials.

It has been demonstrated that one of the most effective method to solve the noise abatement problem, among others, is the establishment of departure and landing routes. Effectively changing the routes so that aircraft will certainly not overfly sensible areas at a low altitude. Other regulations include restrictions imposed on night hours and the moderate use of reversed thrust and APU turbines. AENA is responsible for this.

-Regulations which tend to protect buildings close to the airports in case of urban expansion in the airport vicinity. DGAC and AENA are responsible for these regulations.

Otherwise, “taxes” are applied to those airlines whose aircraft do not respect the noise abatement routes or procedures without a justifiable reason. In this case AENA will report the aircraft not fulfilling the requirement, but the Ministry of Transport and Infrastructure is responsible for charging.

Laws and Regulations

The following is a synthesis of the more important laws that have come into force in Spain in recent years to mitigate noise effects due to transport vehicles.

-Directive 2002/49, (dated 25th of June 2002)”Evaluación y gestión del ruido ambiental” (DOCE L189/12, 18/07/02). This directive relates to the evaluation and management of noise.

-R.D. 1256/1990 (BOE 250, 18/10/1990) "Limitación de emisiones sonoras de los aviones de reacción subsónicos civiles; que traspone la Directiva 86/629 (DOCE L363, 13/12/1989)". This Decree is about limitation of civil subsonic jet airplanes noise.

-R.D. 1422/1992 (BOE 302, 17/12/1992), "Limitación del uso de aviones de reacción subsónicos civiles". This decree is about the limitation to the use of civil subsonic jet airplanes, replacing the former directives: Directive 92/14 (DOCE L 76, 23/03/1992) and Directive 98/20 (DOCE L 107/4, 07/04/1998).

New legislation for civil subsonic jet airplanes with MTOW over 34000 Kg or exceeding 19 seats has been introduced. They can be used in Spain, only with an acoustic certification equivalent as a minimum to that specified in ICAO Annex 16, Vol. I, Part Two, Chapter 3.

An important general regulation in the matter of atmospheric contamination is Law 38/1972, dated 22 December 1972 "Protección del Ambiente Atmosférico" which exclusively regulates the problems generated by emissions and the introduction of different polluting gases into the atmosphere.

It is also necessary to mention Decree 833/1975, of 6 February, that develops the previous Law, and other later regulations that modify it partially to protect the quality of the air from certain substances.

The problem of acoustic contamination (noise, vibrations, etc.) are considered disturbing activities and, in their case, unhealthy by Decree 2414/1961, of 30 of November, for which a Regulation or: Reglamento de Actividades Molestas, Insalubres, Nocivas y Peligrosas-RAMINP (B.O.E. núm. 292, de 7.12.1961 ; corrección de erratas en B.O.E. núm. 57, de 7.3.1962), was approved.

The General directorate for Quality and Environmental Evaluation of the Ministry of the Environment, is preparing a Law on acoustic contamination(it is in final draft form), that will regulate in a general character a matter that already counts on diverse dispositions in some Independent Communities.

On the other hand, all activities related to any project must be put under the Environmental Impact Evaluation (Evaluación de Impacto Ambiental (E.I.A.)). In agreement with legislation approved to the effect, any project which has as its object or need the application of specific corrective measures may be of State or Independent character. These corrections or measures have to be gathered and included within the corresponding Declaration of Environmental Impact (D.I.A.) formulated by the corresponding Administration.

Some corrective measures included in a Declaration of Environmental Impact relative to a project, whose evaluation and formulation is responsibility of the General directorate for Quality and Environmental Evaluation(part of the Ministry of Environment the requirements for the extension of Madrid-Barajas airport can be mentioned) are contained in the Declaration of Environmental Impact for the accomplishment of extension works to the airport, which was formulated on the 10th of April 1996 (B.O.E. of 12-4-1996).

In fulfilment of what was established in its day in the abovementioned Declaration, the above mentioned General directorate approved the Sound Plan insulation for the extension of Madrid-Barajas airport (Resolution of the 4 of November of 1998, published in the B.O.E. of (5-11-1998). As a result, the Inter-ministerial Noise Monitoring Commission integrated by representatives of the Ministry of the Environment, the Ministry of Infrastructure and the Economy and the affected City councils, approved the "sound area" of the airport on the 28th of June 1999. Since then, the City councils have had to census those houses which are affected by this specific noise level and which will be looked at for sound insulation.

Appendix H: Emissions

H.1 Airport emission regulations

Regulations concerning emissions from aircraft are generally contained in national regulations concerning emissions in general. These, in turn, are usually based on ICAO regulations, European Commission (EC) directives and recommendations of the World Health Organization (WHO). The principal ones are described briefly in the following sections.

H.1.1 Regulations and practices concerning aircraft emissions in European countries

Section 3 of the EC document "Handbook on the Implementation of EC Environmental Legislation" concerns Air Quality[4]. Relevant parts of this are given here.

H.1.1.1 EC Principles for Air Quality Management

For ambient air quality standards (limit values and guide values):

Effects-based approach. Ambient air quality standards (limit values and guide values) for pollutants are set according to their scientifically observed or estimated effects on human health and/or on the environment and are not based on the technological or economic feasibility of achieving them.

Universality. The same standards apply in general throughout the EU. There are however provisions for special zones (e.g. for nature protection).

Practicality. The difficulty of achieving compliance with standards within a short time leads to the recently-introduced concept of Margins of Tolerance or (in earlier legislation) timescales for compliance.

H.1.1.2 Legislation Considered in the Air Sector

The following gives the principal EC directives and other legislation in force at the time of writing.

Ambient air quality assessment and management:

The ozone in ambient air Directive 2002/3/EC

Monoxide in ambient air 2000/69/EC

The Air Quality Framework Directive, 96/62/EC.

Ambient air quality standards (limit values and guidelines):

The Directive on Sulphur Dioxide, Nitrogen Dioxide and Oxides of Nitrogen, Particulate Matter and Lead in Ambient Air, 99/30/EC.

[4] http://europa.eu.int/comm/environment/enlarg/handbook/air.pdf

Product control and material handling:

The Directive on the Sulphur Content of Liquid Fuels, 93/12/EEC, as amended by 99/32/EC.

Monitoring and information exchange:

The Tropospheric Ozone Pollution Directive, 92/72/EEC;

The Council Decision on Monitoring of CO_2 and other Greenhouse Gases, 93/389/EEC;

National governments are ultimately responsible for achieving and maintaining compliance with EC policies and legislation on air quality issues. They have a duty and an obligation to secure compliance in a manner and within a programme either stipulated in the relevant EC instrument, or agreed with the responsible EC institution. Typically the primary responsibility for achieving and maintaining compliance is delegated to a single national institution e.g. a Ministry, Department or government Agency with responsibility for the environment.

The role of regional and local government in the context of air quality management is important for two reasons. Most countries have a tiered administrative structure in which certain powers are devolved to the regional (county, département, Länder) or local level of government (local planning authority or municipality). This decentralization is stronger in federal countries, but exists elsewhere, and usually includes at least some air quality management functions, for example those relating to road traffic and domestic heating boilers. Consequently, the implementation of central government functions is not in itself sufficient to implement EC requirements on air quality. Certainly, some air quality issues are most easily and efficiently detected and resolved at local level.

EC legislation does not stipulate the division of powers and responsibilities between national, regional and local administration. However, it is logical for some functions (for example, setting technical standards) to be undertaken at national level and others (for example, inspection of small air pollution sources) to be undertaken at local level. A range of tasks between these two extremes may be undertaken either nationally or locally, depending on the country concerned.

To ensure a uniform approach, national technical standards are adopted. These have to comply with the requirements of EC directives regulating emissions. Standards need to take account of best practice in the country and elsewhere, and of economic constraints on the operators of emission sources. In some cases, national authorities have discretion to determine the technical standards that are to be applied, provided that the standards adopted are at least as stringent as those contained in the directives and that the intended result is achieved. In other cases (though not generally for Aviation emissions) the directives specify exact standards and there is no discretion for more stringent standards to be adopted, since variations between Member States would interfere with the functioning of the Single Market.

H.2.1 Regulations and practices concerning aircraft emissions in other ICAO countries

ICAO CO and first-stage NO_x standards have been in effect since 1986. The US Environmental Protection Agency (EPA) has promulgated an aircraft emission rule[5] which brings United States emission standards into alignment with these internationally adopted

[5] Fact Sheet: "Adopted Aircraft Engine Emission Standards" (EPA420-F-97-010, April 1997)

standards. In addition, the EPA has amended the test procedures for gaseous exhaust emissions and smoke exhaust emissions to correspond to recent ICAO amendments. The EPA has also adopted ICAO's requirement that these standards also apply to applications that otherwise would have been fulfilled by turbojet and turbofan engines (e.g. propfan, unducted fan, and advanced ducted fan). United States certification test fuel specifications have also been amended to make them consistent with ICAO's test fuel specifications. The adopted emission standards and test procedures apply to commercial aircraft engines with rated thrust greater than 26.7 kilonewtons (kN) that are either newly certified or newly manufactured after the effective date of these regulations. The adopted emission standards are described below.

CO Standard

The CO standard applies to newly manufactured aircraft gas turbine engines (turbofan and turbojet engines).

CO = 118 grams/kilonewton (g/kN)(rated output)

NOx Standards

The NOx standards apply to newly certified and newly manufactured aircraft gas turbine engines (turbofan and turbojet engines).

For engines of a type or model of which the date of manufacture of the first individual production model was on or before December 31, 1995 and for which the date of manufacture of the individual engine was on or before December 31, 1999:

NOx = (40 + 2(rated pressure ratio))g/kN(rated output);

For engines of a type or model of which the date of manufacture of the first individual production model was after December 31, 1995 or for which the date of manufacture of the individual engine was after December 31, 1999:

NOx = (32 + 1.6(rated pressure ratio))g/kN(rated output).

The first NO_x emission standard presented above matches the ICAO standard that became effective in 1986. The second NO_x emission standard above matches the ICAO 1993 amendments which will result in a 20 percent reduction and became effective in the year 1996 for newly certified engines and in the year 2000 for newly manufactured engines. There is a four year period between when newly certified engines must meet the standards and when all newly manufactured engines must meet the standards to provide lead time for the production of 100 percent compliant products.

H.3 Airport emission assessment

H.3.1 Emission measurement indicators

Different regulations and guidelines, and different countries, specify very different indicators for air pollution.

The Air Quality Framework Directive, 96/62/EC, focuses on the maintenance and improvement of air quality with respect to the following thirteen pollutants, of which the first six are to be studied at an initial stage:

sulphur dioxide;
nitrogen dioxide;
fine particulate matter such as soot;
suspended particulate matter;
lead;
ozone;
benzene;
carbon monoxide;
poly-aromatic hydrocarbons;
cadmium;
arsenic;
nickel; and
mercury.

The directive does not itself specify any air quality thresholds. These are set out in "daughter" directives, the first of which is now in force - Directive 99/30/EC relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air. The thresholds take the form of a number of different values whose purposes are defined in the directive:

a "limit value";
a "target value";
an "alert threshold"; and
a "margin of tolerance".

The directive allows Member States to set more stringent limit values than those adopted by the Commission, and the competent authority needs to decide whether this should be done. If the Member State proposes to set limit values or alert thresholds for pollutants not covered in the directive, the competent authority must inform the Commission first, so that consideration can be given to the need to act at a Community level.

The following tables give EC and WHO Air Quality Standards and Guidelines for some more notable pollutants:

	98 percentile	50 percentile	24-hour average	1-hour average
EC Directive Guide Value	135	50		
EC Directive Limit Value	200			
WHO Guideline			150	400

Table 6: Air Quality Limits Values and Guidelines for NO2 (µg/m3)

	98 percentile	Annual average	24-hour average	1-hour average	10-minute average
EC Directive Guide Value		40-60			
EC Directive Limit Value	250 (≥150)[6] 350 (≤150)	80 (≥40) 120 (≤40)	100-150		
WHO Guideline				350	500

Table 7: Air Quality Limits Values and Guidelines for SO2 (µg/m3)

	24-hour exposure	8-hour exposure	1-hour exposure	15-minute exposure
CO		10	30	100
Toluene	7.5			

Table 8: WHO Human Health Guidelines for CO and Toluene (mg/m^3) <Longhurst 92>

Some examples of standards used in some member sates are given below:

µg/m^3	Duration	Type	Origin	Tolerance
400	1 hour	Alert threshold	EC directive 99	/
200	1 hour	Recommendation	WHO for Europe 96	/
200	1 hour	Limit value	EC directive 99	18 hours per year Applicable on 1st Jan 2010
135	1 hour	Guide value	PRQA PACA[7]	17 days per year
40	1 hour	Guide value	PRQA PACA	50% of the year (4 380 hours)
40	1 year	Limit value	EC directive 99	Applicable on 1st Jan 2010
40	1 year	Recommendation	WHO for Europe 96	/
30	1 year	Limit value for Vegetation	EC directive 99	/
30	1 year	Recommendation for vegetation	WHO for Europe 96	/

[6] 250µg/m^3 if smoke ≥ 150 µg/m^3
[7] Provence-Alpes-Côtes d'Azur Regional Air-Quality Plan

Table 9: Standards for NO_2 applicable at Nice airport

Values of measurements of various pollutants are categorised according to threshold indices. France has ten categories:

Index	SO_2 - Average of hourly max µg/m^3	O_3 - Average of hourly max µg/m^3	NO_2 - Average of hourly max µg/m^3	PM - Average of daily average µg/m^3
10 (Very bad)	≥ 600	≥ 360	≥ 400	≥ 125
9 (Bad)	400 → 599	250 → 359	275 → 399	100 → 124
8 (Bad)	300 → 399	180 → 249	200 → 274	80 → 99
7 (Poor)	250 → 299	150 → 179	165 → 199	65 → 79
6 (Poor)	200 → 249	130 → 149	135 → 164	50 → 64
5 (Average)	160 → 199	105 → 129	110 → 134	40 → 49
4 (Good)	120 → 159	80 → 104	85 → 109	30 → 39
3 (Good)	80 → 119	55 → 79	55 → 84	20 → 29
2 (Very good)	40 → 79	30 → 54	30 → 54	10 → 19
1 (Very good)	0 → 39	0 → 29	0 → 29	0 → 9

Table 10: French Air-Quality Index Thresholds

On the other hand, the United Kingdom has just four index categories: Very good, Good, Poor and Very poor.

The SILAQ (Sofia Initiative on Local Air Quality) countries (Bulgaria, the Czech Republic, Hungary, Poland, Romania, Slovakia and Slovenia) have defined standards for ambient air quality, in many cases much more stringent that those in force in the EU.

	Bulgaria	Czech Republic and Slovakia	Poland	Romania	EU	USA
Short term	500	500	600	750		
Medium term	150	150	200	250	250	365
Long term	50	60	32	60	80	806

Table 11: Ambient Air-Quality standards for SO2 (µg/m3)

	Bulgaria	Czech Republic and Slovakia	Romania	Slovenia
Short term	500	500	500	300
Medium term	250	150	150	175
Long term	150	50	75	70

Table 12: Ambient Air-Quality standards for Particulate Matter (Total suspended µg/m3)

Other countries, and the World Health Organisation, propose different measures:

10 minutes	500
24 hours	125
1 year	50

Table 13: WHO Air-Quality Guidelines for Europe for SO2 (µg/m3)

	½-hour mean	8-hour mean	Daily mean
SO_2	0.20		0.12
CO		10	
NO_2	0.20		
TSP			0.15

Table 14: Austrian Air-Emission standards (µg/m3)

	Hourly	Daily
Limit value		200
Guide value	50	135

Table 15: Danish standards for NO2 (µg/m3)

Emission indices (i.e., emission factors) and average fuel consumption rates for aircraft engines are listed by operating mode in the US EPA's *Procedures for Emission Inventory Preparation*, Volume IV, Chapter 5 and in the ICAO *Engine Exhaust Emissions Databank* (Reference 27). Generally, emission factors are listed in mg of pollutant per gram of fuel consumed and fuel flow is listed in pounds per minute. Only the EPA's *Procedures* document provides particulate emission factors, and data are available for only a few engines. A recent investigation of particulate emissions by the EPA indicates that the particulate emission factors can be used to calculate reasonable estimates of PM-10 (particulate matter with a diameter of less than 10µm) missions from these engines. Neither source provides SO_x emission factors. An SO_x emission factor of 0.54 mg/g can be used for most air carrier aircraft, which is based on a national average sulphur content of aviation fuels.

H.3.2 Emission calculation methods[8]

The US EPA has set forth procedures for calculating exhaust emission inventories of commercial aircraft standard LTO cycle operations. Exhaust emissions are calculated for one complete LTO cycle of each aircraft type by knowing the emission factors for the

[8] Adapted from "Air Quality Procedures For Civilian Airports & Air Force Bases" FAA-AEE-97-03 AL/EQ-TR-1996-0017

aircraft's specific engines at each power setting or mode of operation, as well as the time spent in each mode. Then the activity of aircraft for the inventory period can be applied to calculate their total emissions. This emissions calculation procedure is presented in the EPA's *Procedure for Emission Inventory Preparation*, Volume IV, Chapter 5. Currently, no information is available on calculating evaporative-related emissions (e.g., refueling emissions) from commercial aircraft. Evaporative related emissions are small due to the low vapour pressure of the fuel and quick-connect refuelling nozzles.

This EPA procedure addresses emissions for five operating modes of a standard LTO cycle: approach, taxi/idle-in, taxi/idle-out, takeoff, and climb out. A sixth operating mode, reverse thrust, often is included in a standard LTO cycle but is not included in the EPA's procedure. After aircraft land, engine thrust reversal typically is used to slow the aircraft to taxi speed (otherwise the aircraft is slowed using only the wheel brakes). Reverse thrust is now considered by the EPA as an official mode and should be included in calculation procedures as a sixth operating mode when applicable. Since reverse thrust engine operating conditions are similar to takeoff, time spent in reverse thrust should be combined with takeoff mode emission indices and fuel flow as a means of accounting for reverse thrust mode emissions. Aircraft reverse thrust typically is applied for 15-20 seconds on landing.

The emissions calculation methodology presented in the EPA's *Procedure for Emission Inventory Preparation* estimates emissions for HC, CO, NOx, SO2, and PM-10. The NOx emission factors provided in the EPA's procedures should be used to calculate a NOx emissions inventory that is used to compare against NO2 emission standards. (When both nitric acid (NO) and NO2 are emitted, they are referred to collectively as total oxides of nitrogen, or NOx.)

H.3.3 Aircraft emission certification[9]

Aircraft are required to meet the engine certification standards adopted by the Council of ICAO. These are contained in Annex 16 — Environmental Protection, Volume II — Aircraft Engine Emissions to the Convention on International Civil Aviation. These were originally designed to respond to concerns regarding air quality in the vicinity of airports. As a consequence, they establish limits for emissions of oxides of nitrogen (NOx), carbon monoxide, unburned hydrocarbons, for a reference landing and take-off (LTO) cycle below 915 meters of altitude (3 000 ft). There are also provisions regarding smoke and vented fuel.

While these standards are based on an aircraft's LTO cycle, they also help to limit emissions at altitude. Of particular relevance is the standard for NO_x, a precursor for ozone, which at altitude is a greenhouse gas. The standard for NO_x was first adopted in 1981, then made more stringent in 1993, when ICAO reduced the permitted levels by 20 per cent for newly certificated engines, with a production cut-off on 31 December 1999. In 1999, the Council further tightened the standard by about 16 per cent on average for engines newly certificated from 31 December 2003.

The ICAO Engine Exhaust Emissions Data Bank (Doc 9646), issued in 1995, contains a comprehensive database of aircraft jet engine emissions certification data. Subsequent updates of the data bank are available through the ICAO web site.

ICAO is currently considering alternative parameters on which to base future high altitude emissions controls, taking into account trends in emissions reduction technology, as well as the performance of the whole aircraft and its productivity. Particular attention is being given

[9] ICAO: http://www.icao.int/icao/en/env/aee.htm

to NO_x. In the case of CO_2, it has been decided not to develop an ICAO standard, since CO_2 production is directly related to fuel consumption and there is already intense economic pressure to keep fuel consumption to a minimum and, in addition, there would be significant difficulties in designing a certification condition.

H.3.4 Results of studies on emission effects[10]

The most comprehensive assessment so far concerning aviation's contribution to global atmospheric problems 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. This told us *inter alia*:

that aircraft emit gases and particles which alter the atmospheric concentration of greenhouse gases, trigger the formation of condensation trails and may increase cirrus cloudiness, all of which contribute to climate change; and

that aircraft are estimated to contribute about 3.5 per cent of the total radiative forcing (a measure of change in climate) by all human activities and that this percentage, which excludes the effects of possible changes in cirrus clouds, was projected to grow.

The Report recognised that the effects of some types of aircraft emission are well understood, revealed that the effects of others are not, and identified a number of key areas of scientific uncertainty that limit the ability to project aviation impacts on climate and ozone.

Health effects from exposure to air pollution include: irritation and annoyance, loss of organ functions (e.g. reduced lung capacity), morbidity and mortality. Some effects can be acute and reversible, while others develop gradually into irreversible chronic conditions. The respiratory system and the eyes are the main organs affected by air pollution.

There is conclusive evidence, based on epidemiological research studies and analysis of medical insurance records in countries with heavily polluted areas, of a link between different acute and chronic health effects and the incidence of significant particulate matter and SO_x pollution. In polluted areas the prevalence of persistent coughing and respiratory tract infections is 2-3 times higher than in areas here pollution is less extensive. A similar relationship is also shown for areas where mortality results from lung cancer. In Hungary, for instance, acute respiratory diseases are known to be the cause of between 23 and 25 percent of all sick-leave cases. Among the acute respiratory diseases, catarrh in the lower respiratory tract (e.g. bronchitis, pneumonia) warrants particular attention.

SO_x, primarily resulting from the combustion of sulphur-containing fuels as well as from production processes in the chemical industry, is the precursor of sulphate particulates which can irritate eyes and the respiratory tract, reduce lung function, aggravate emphysema, asthma, and chronic bronchitis and may result in mortality. Particulates originate from a variety of mobile and stationary sources, and vary in terms of physical composition, chemical content, and size. Particulate matter can lead to pulmonary irritation and respiratory diseases. The effects of particulate matter vary considerably depending on its composition, and can be potentially carcinogenic and mutagenic. The most harmful elements to human health tend to be small particulates, owing to their ability to reach the lower regions of the respiratory tract, which can contribute to negative effects on the

[10] Adapted from ICAO: http://www.icao.int/icao/en/env/aee.htm and the executive summary of "SOFIA INITIATIVE ON LOCAL AIR QUALITY: Reduction of SO2 and Particulate Emissions - Synthesis Report" REC-CEE. ARH.CONF/BD.25

respiratory system, aggravation of existing respiratory and cardiovascular diseases, anomalies in the body's defence systems to foreign substances, damage to lung tissue, carcinogenesis and premature death.

It should be noted that SO_x and particulates have a compounded negative effect on health, as particulates carry SO_x to the lower part of the respiratory system which would not otherwise be reached. High levels of SO_x and particulates can increase the occurrence of asthma, in particular among children. A similar tendency is observed with regard to lung cancer. As a result, there has been a tendency in recent years to focus regulatory measures on controlling small particles, with a diameter of less than 10 micrometers.

Finally, it should be mentioned that significant negative economic consequences arise from SO_x and particulate pollution, including deforestation, acidification of water bodies and soils, and deterioration of concrete structures and historic sites.

The common air pollutants from aircraft and their effects are given below:[11]

Ozone (ground-level ozone is the principal component of smog)

Source - chemical reaction of pollutants; VOCs and NO_x

Health Effects - breathing problems, reduced lung function, asthma, irritates eyes, stuffy nose, reduced resistance to colds and other infections, may speed up aging of lung tissue

Environmental Effects - ozone can damage plants and trees; smog can cause reduced visibility

Property Damage - Damages rubber, fabrics, etc.

VOCs (volatile organic compounds)

VOCs include chemicals such as benzene, toluene, methylene chloride and methyl chloroform

Health Effects - In addition to ozone (smog) effects, many VOCs can cause serious health problems such as cancer and other effects

Nitrogen Dioxide (NO_2)

Health Effects - lung damage, illnesses of breathing passages and lungs (respiratory system)

Environmental Effects - nitrogen dioxide is an ingredient of acid rain (acid aerosols), which can damage trees and lakes. Acid aerosols can reduce visibility.

Property Damage - acid aerosols can eat away stone used on buildings, statues, monuments, etc.

Carbon Monoxide (CO)

Health Effects - reduces ability of blood to bring oxygen to body cells and tissues; cells and tissues need oxygen to work. Carbon monoxide may be particularly hazardous to people who have heart or circulatory (blood vessel) problems and people who have damaged lungs or breathing passages

Particulate Matter (PM-10); (dust, smoke, soot)

[11] From “The Plain English Guide To The Clean Air Act” US EPA,

Health Effects - nose and throat irritation, lung damage, bronchitis, early death

Environmental Effects - particulates are the main source of haze that reduces visibility

Property Damage - ash, soot, smoke and dusts can dirty and discolour structures and other property, including clothes and furniture

Sulphur Dioxide (SO_2)

Health Effects - breathing problems, may cause permanent damage to lungs

Environmental Effects - SO_2 is an ingredient in acid rain (acid aerosols), which can damage trees and lakes. Acid aerosols can also reduce visibility.

Property Damage - acidic aerosols can eat away stone used in buildings, statues, monuments, etc.