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Development of Noise Abatement Procedures in the Netherlands[1]

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Summary

In this paper attention is paid to the noise problem around airports and to the way in which new noise abatement procedures can contribute to the solution of this problem. In particular the situation around Amsterdam Airport Schiphol (AAS) is considered. Some results from recent NLR studies are presented. Moreover the current own research of NLR on advanced noise abatement procedures is highlighted.
Finally a brief summary is given of the Sourdine project, which is an international project carried out under contract with the European Commission.

Abbreviations

AAS	Amsterdam Airport Schiphol
ACDA	Advanced Continuous Descent Approach
ATC	Air traffic Control
CDA	Continuous Descent Approach
FAST	Future Aircraft Systems Testbed
FMS	Flight Management System
GPS	Global Positioning System
ILS	Instrument Landing System
KLM	Koninklijke Luchtvaart Maatschappij N.V. (*KLM Royal Dutch Airlines*)
LVNL	Luchtverkeersleiding Nederland (*AirTraffic Control the Netherlands*)
MLS	Microwave Landing System
NARSIM	NLR ATC Research Simulator
NAP	Noise Abatement Procedure
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium (*National Aerospace Laboratory NLR)*
PNID	Precision Navigation Instrument Departure
RFS	Research Flight Simulator
RLD	Rijksluchtvaartdienst (*Netherlands Department of Civil Aviation*)
RNAV	Area Navigation
TAAM	Total Airspace and Airport Management System
TMA	Terminal control area
TOMS	Technical Operational Measures Schiphol

Introduction

Aircraft noise near airports is becoming a worldwide problem for airports located in densely populated areas. In The Netherlands this is a major problem for Amsterdam Airport Schiphol. In November 1996 the Dutch Ministry of Transport, Public Works and Water Management has adopted a law on noise regulations that defines noise zones around AAS. On a yearly basis cumulative noise calculations are performed in order to verify if the actual noise production remains within the compulsory noise contour zones. Ultimately this will limit the amount of arrivals and departures at the airport.

To alleviate this problem, NLR is carrying out research into the development of noise abatement flight procedures. Not only the effects on ***noise reduction*** of a particular procedure are established, but also the consequences on ***safety*** and ***airport capacity*** are considered.
Simple procedures, which could be implemented in the short term, as well as procedures, which require modification of airborne and/or ground equipment (medium term procedures), are being studied.
In this area NLR collaborates closely with airport authorities (AAS), the Netherlands Department of Civil Aviation (RLD), Air Traffic Control the Netherlands (LVNL) and airline operators (KLM).
Recently, under contract with the RLD, NLR completed noise evaluation studies for three proposed noise abatement procedures.
Since December 1998, within the scope of European Commission DG VII, an international project on the determination and evaluation of noise abatement flight procedures was initiated. This project, named SOURDINE, is coordinated by ISR / Thomson-CSF.
NLR plays here an important role in the definition and evaluation of new noise abatement procedures.

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[1] Presented at the “New Aviation Technologies International Symposium”, held in Zhukovsky, Moscow Region, Russia, August 17 – 22, 1999.

Expected growth of Schiphol

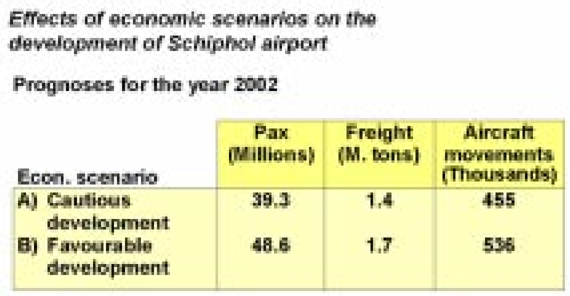
Schiphol is ranked as the 4th European airport, serving in 1997 31.6 million passengers and 1,161,000 tons of cargo. This required 349,500 aircraft movements.

Concerning the expected growth of the Schiphol airport towards the year 2002, two scenarios have been studied [1]. One scenario [A] is based on a cautious development considering a moderate economic growth and a steady (constant) market share of KLM.

The second one [B] originates from a favourable economic development with substantial economic growth and an increasing market share of KLM.

For these two economic scenarios prognoses have been made on the growth of Schiphol airport for the year 2002.

As shown in figure 1, the number of passengers will grow to approx. 39 up to 49 million passengers and the amount of freight will increase to 1.4 up to 1.7 million tons, depending on the scenario concerned. This will require a number of 455,000 to 536,000 aircraft movements per year.



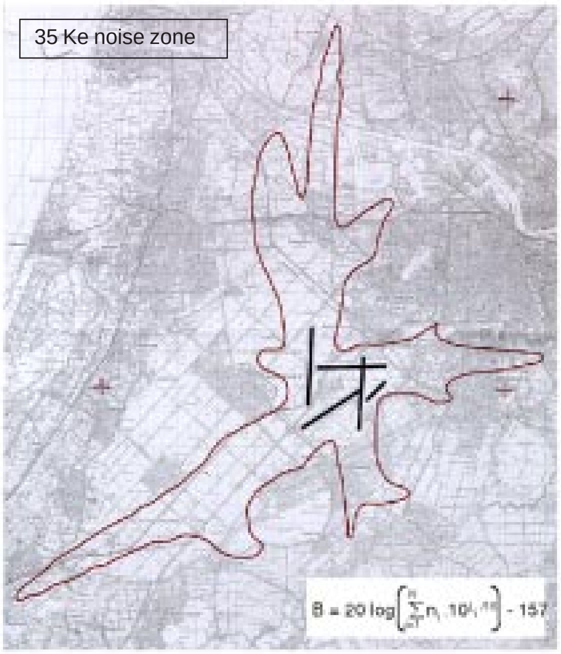
Effects of economic scenarios on the development of Schiphol airport

Prognoses for the year 2002

Econ. scenario	Pax (Millions)	Freight (M. tons)	Aircraft movements (Thousands)
A) Cautious development	39.3	1.4	455
B) Favourable development	48.6	1.7	536

Fig 1. Estimated growth of Schiphol towards 2002

In a previous paper, presented at the Zhukovsky "Aviation 2000 Prospects Symposium" in August 1997 [2], an explanation was given on the noise constraints imposed by the Dutch Government. Noise contours indicate the amount of noise exposure on the surroundings of the airport. The 35 Ke noise zone as applied to Schiphol is shown in figure 2. At the end of each year the actual noise contour will be calculated and compared to the noise zones. It is not allowed for the airport to exceed the noise zone. Before the end of 1997, however, the zone was already slightly exceeded at two locations.



$$B = 20 \log \left[\sum_{i=1}^{N} n_i \, 10^{L_i/15} \right] - 157$$

B = noise exposure index (Ke)
N = total number of aircraft movements in one year
L_i = maximum noise level $L_{A,max}$ in a point P during the passage of aircraft i
n_i = night weight factor

Fig. 2 Noise contour around Schiphol

It will be obvious that, if no measures are taken and considering the expected growth, the noise zones will undoubtedly be exceeded substantially. Hence, if the airport really wants to accommodate this growth, something has to be done in order to comply with the noise constraints imposed by the Government.

Airport growth limiting mechanism

Figure 3 illustrates the mechanism for the growth of the airport. The mechanism can be considered as a closed-loop control system:

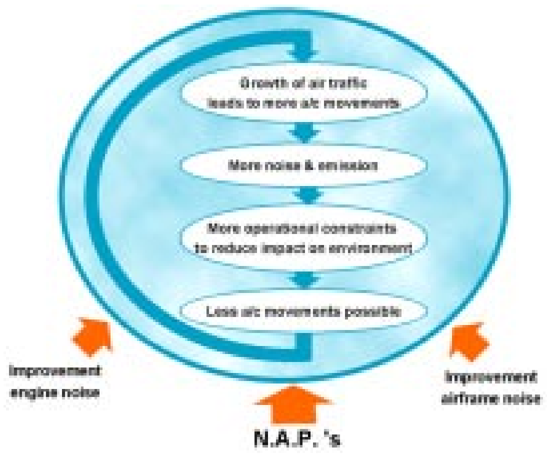


Fig. 3 Airport growth limiting mechanism

If the system of civil air transportation will not change dramatically, for example as a result of the upcoming of a new generation of Very Large Transport Aircraft, the growing demand for aircraft seats will undoubtedly lead to more aircraft movements. In turn, this will lead to more aircraft noise and aircraft emissions. Consequently due to political pressure, more operational constraints will be imposed on the airport to reduce the adverse impact on the environment. Finally this will lead to a decrease of the number of aircraft movements.

This ”control system” settles at a particular equilibrium for the number of aircraft movements. A change in this equilibrium condition can only be achieved by realisation of technological or operational improvements, such as engine/ airframe noise reduction and/or by the introduction of new - more environmental friendly - arrival and departure procedures.

NLR studies focus on the possibilities of the last issue, namely: on developing and implementing new noise abatement procedures, under the condition that the current level of safety is maintained and airport capacity is not significantly reduced.

Constraints on procedure development

It is generally assumed that within the next 20 -25 years the majority of the fleet of civil transport aircraft will still consist of the present generation of modern transport aircraft. Candidate noise abatement procedures are therefore constrained by restrictions imposed by the characteristics of this fleet of contemporary transport aircraft. These constraints concern:

- *Load factor*: manoeuvres shall remain within the present criteria for load factors, because of life span considerations and passenger comfort limitations.
- *Speed regimes* for take-off/departure and approach/arrival procedures will not change significantly.
- The pilots will perform *control of flaps and gear* manually.
- *Manoeuvrability restrictions* with respect to maximum pitch roll and yaw rates as well as to bank angles and vertical speed limitations will not change.

In NLR’s procedure development for noise abatement these constraints are taken into account.

Research on Technical Operational Measures TOMS

Under contract to the Netherlands Department of Civil Aviation (RLD), NLR evaluated last year, within the scope of a project called Technical Operational Measures Schiphol (acronym TOMS), three noise abatement procedures, which seemed to have noise abatement potential.
The TOMS project aims at reducing the aircraft noise around the airport, or more specifically:

- to improve operational flight procedures with respect to noise abatement,
- to optimise runway use.

At the same time two boundary conditions shall be satisfied:

1. **Safety** per individual flight may not be adversely affected by the measures.
2. **Capacity** during peak hours should not reduce significantly as a result of the introduction of new measures.

Up to now three measures have been evaluated:

- *Reduced flaps approach*, whereby the landing is performed with a flap setting that is one step lower than maximum landing flaps.

- *Slightly increased ILS glide slope.*
  The effect of noise was determined for an ILS glidepath that was increased by 0.2º. A steeper glide slope was not possible since it would have lead to autoland re-certification problems for a series of aircraft types.

- *Increased final approach altitude*
  A procedure was evaluated whereby the final approach altitude was increased from 2000ft to 3000ft. This procedure is already in force during the quiet night hours at Schiphol. The intention of the present measure is to apply this procedure over a 24-hr period. A preliminary airport capacity study indicated that no serious problems are to be expected with respect to ATC and airport capacity.

Although only modest noise benefits for these measures were expected, the important advantage is that these measures could be implemented on rather short time scale, if they proved to be sufficiently noise efficient. Other new measures are yet to be defined for evaluation by a Working Group consisting of RLD, KLM, LVNL and NLR.

The effects on noise exposure of the above-mentioned measures have been evaluated for three categories of aircraft, represented by MD-11, B747-400 and B737-400.
In order to obtain reliable data for the noise computations, simulated approaches were carried out on flight simulators of KLM. Both aircraft and engine parameters were recorded. The collected data were used to calculate the so-called noise footprints for 65 and 55 dB(A) respectively. These noise footprints were used as input data for the computation of the effect on the Schiphol noise contour plots. Results of these evaluations have been described in [3] and [4].

The *reduced flaps approach* showed modest - but obvious - reductions in the noise footprints. The procedure was accepted by both pilots and air traffic controllers. Therefore this procedure has already successfully been implemented at Schiphol.

The noise benefits for the *slightly increased ILS glideslope* measure appeared to be very marginal. Moreover, due to flight operational reasons, this procedure cannot be combined with the reduced flaps procedure. On the other hand substantial resistance was foreseen from airline pilot associations and ICAO, because of the reluctance of these organisations to deviate from the standardised 3° approach merely for reasons of noise abatement.

In figure 4 the simulator test results are shown for the *increased final approach altitude* procedure. Figures 4a –4d show a comparison between the 2000ft and 3000ft approach procedures, as carried out on a B737-400 simulator of KLM.

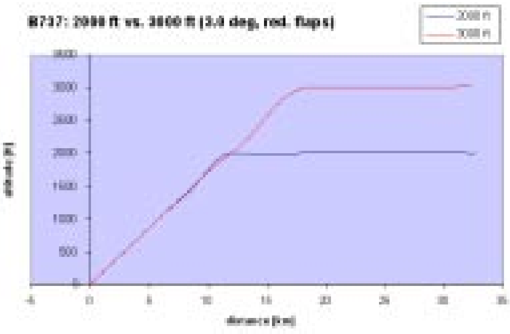


Fig. 4a Altitude versus distance to threshold for the 2000ft and 3000ft approach

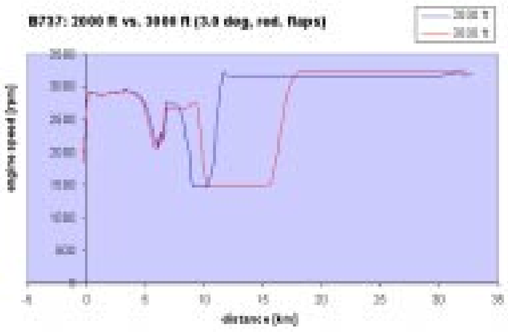


Fig. 4b Thrust (engine rpm) versus distance to threshold for the 2000ft and 3000ft approach

Figure 4a shows the two altitude profiles. In figure 4b a comparison is made for the thrust curves. As can be observed, the main engine benefits are obtained during the descent segment between 3000 and 2000ft.
Figures 4c & d show a comparison of the noise footprints for these two cases. The red curves represent the 3000ft approach, whereas the 2000ft contours are indicated by the blue curves.

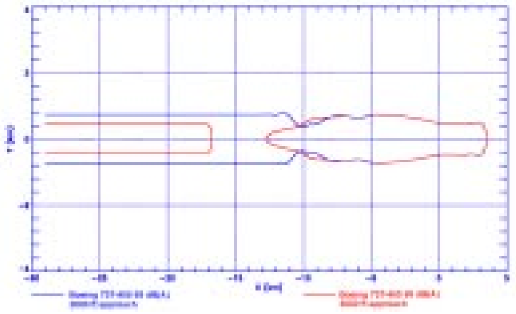


Fig. 4c Noise footprint Boeing 737-400, 65 dB(A), 2000 ft versus 3000 ft

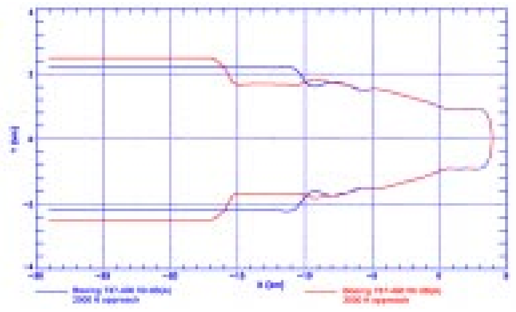


Fig. 4d Noise footprint Boeing 737-400, 50 dB(A), 2000 ft versus 3000 ft

The plots in figure 4c show the 65 dB(A) footprints; in figure 4d the plots for the 50 dB(A) contours are shown.
It appears that the benefits are substantial for the high noise level (65 dB(A)). However, for the lower noise level (50 dB(A)), there is only a modest benefit along the range between 16 and 10 km.
However, along the horizontal flight segment, in the 50dB(A) case, the noise contour for the 3000ft approach is even wider than for the 2000ft contour.
Apparently this is due to the effect of lateral noise attenuation[2] .
It is obvious that these short term measures only provide a limited relief of the noise problem and that these measures cannot provide a long term solution for the sustained growth of the airport.

NLR own research program on advanced noise abatement procedures.

Within the scope of NLR's own research programme, an investigation is carried out into a number of more complex procedures. These could contribute to a substantial improvement of the noise exposure around airports.
At this moment there are two candidate advanced procedures under study:

- *Advanced Continuous Descent Approach (ACDA).*
  This project focuses on improving the current Continuous Descent Approach (CDA) procedure, which has already been implemented on runway 06 at Schiphol. This research topic will be explained in more detail in the next sections.
- *Precision Navigation Instrument Departure (PNID).*
  This concerns a Standard Instrument Departure (SID) flown as an RNAV procedure along a predefined 2-D horizontal route. This route is composed of straight and circular segments. The use of satellite navigation systems (and/or MLS) for closed-loop guidance along this path guarantees maximum flexibility as far as route definition is concerned. Therefore, the departure route geometry can be adapted to the local situation in a way that populated areas are avoided as much as possible and existing noise abatement departure routes become more effective because of the very accurate way the prescribed routes can be followed.

The introduction of these procedures will take more time, due to the fact that implementation of these more complex procedures requires modifications in the on-board aircraft equipment as well as additional tools for the air traffic controllers.
Detailed investigations, on both aircraft and ground (ATC) issues, are required to establish the feasibility of the implementation of such procedures.
This includes the use of flight simulators and ATC simulators, as well as the use of other research tools for establishing the effects of new procedures on the capacity of the airport and the airspace around the airport.
NLR operates three dedicated facilities to carry out such evaluations:

- Research Flight Simulator (RFS) (Fig. 5)
- NLR ATC Research Simulator (NARSIM) (Fig. 6)
- Total Airspace and Airport Management System (TAAM) (Fig.7). This is a workstation-based tool. It allows analysis studies on airport capacity and airspace.

Fig. 5 RFS cockpit interior

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[2] *The lateral attenuation is a function of both slant range and elevation angle between the aircraft and the observer. It reduces with reducing slant range and increasing elevation angle. In case of the 65 dB(A) contours differences in slant range and elevation angle are negligible. In case of the wider 50 dB(A) contours the elevation angle for the 3000 ft approach is significantly greater than for the 2000ft approach. Hence the reduction in lateral attenuation for the 3000ft approach cancels the primary benefit of the higher altitude.*

Fig. 6 NLR ATC Research Simulator NARSIM

Fig. 7 TAAM example of airport study

Moreover for in-flight demonstrations NLR's Cessna Citation II twin-jet aircraft (Fig. 8) is available. This laboratory aircraft has been converted into a Future Aircraft Systems Testbed (FAST).

Fig. 8 Cessna Citation II research aircraft

Continuous Descent Approaches (CDA) at Schiphol

The Continuous Descent Approach procedure

At Schiphol a new approach procedure has been introduced on runway 06. This very noise efficient noise abatement procedure (see figure 9) is called Continuous Descent Approach (CDA). It has been proven that this procedure indeed reduces the noise exposure on the ground significantly.

Due to uncertainties in approach time prediction, however, the separation between approaching aircraft was increased substantially. The landing interval had to be increased from 1.8 to 4 minutes. This measure reduces the airport capacity dramatically. It prevents the procedure from being applied outside the quiet night-time period. As a consequence, the present CDA procedure can only be carried out during the quiet night hours when the traffic densities are very low. This reduces the potential benefits of the CDA procedure considerably.

Figure 9 shows the CDA noise abatement approach procedure as it has been implemented on runway 06 at Schiphol.

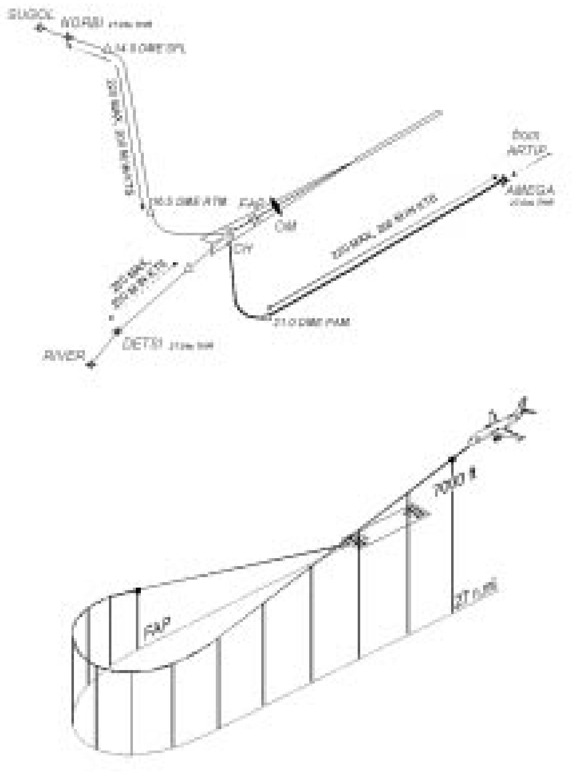

Fig. 9 Continuous Descent Approach

Aircraft arrive from three Initial Approach Fixes (AMEGA, DETSI and NORBI) at Flight Level 70 for approaches to runway 06.

When cleared for the CDA the pilot starts his descent from FL 70 in such a way, that the ILS intercept point at 2500 ft is reached with idle or near idle power setting. The procedure requests the pilot to make the descent path with engines set at idle or nearly idle thrust. The procedure is allowed for RNAV as well as for non-RNAV equipped aircraft.

One has to realise that although the distances from the CDA starting waypoints to runway 06 are all 27 nm, yet the elapsed time to fly each of these approaches can differ appreciably due to effects of wind.

In-flight recorded conventional approach procedure

Current ILS approach procedures include several horizontal segments, which require high thrust settings, thus producing a considerable amount of community noise and pollution. During daytime operations the air traffic controller manoeuvres the aircraft from the arrival route, via a step down procedure, to an altitude of 2000ft (during night hours 3000 ft) on a downwind leg.

Figure 10 shows results of an actually flown conventional step-down ILS approach on runway 06 by a Boeing747-400.

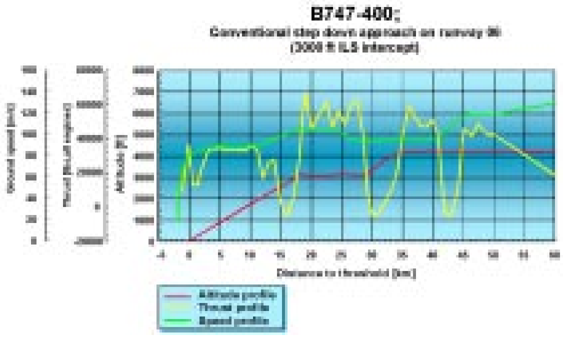

Fig. 10 Boeing 747-400 conventional ILS approach

The red curve depicts the altitude profile, which clearly shows two long horizontal segments. The green line shows the speed curve. Although the intention is to have a continuously reducing speed, one can observe an obvious speed increase on the last horizontal segment.

The yellow curve shows the huge thrust variations during the approach. Note that many thrust variations appear between 60 km and 15 km before the threshold.

In-flight recorded CDA procedure

Figure 11 shows the results of an actually flown CDA (Amega) approach by a Boeing747-400.

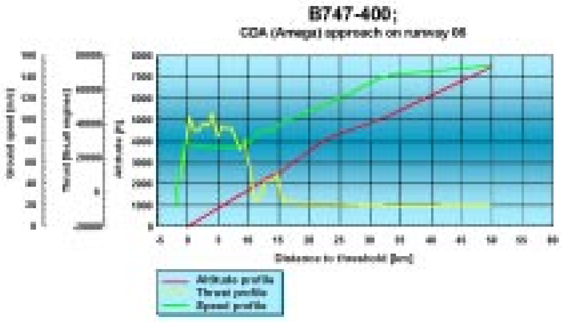

Fig. 11 Boeing 747-400 CDA (Amega) approach

As one can see from the altitude profile (red curve) the discontinuities in the flight path are absent. As the thrust curve (yellow) shows, the engines are running at flight idle rpm (each engine producing 200 lb drag).

The speed (green curve) bleeds-off continuously from 270 kts at FL 70 down to 160 kts at a distance of 10 km before the threshold. The throttles are in the flight idle position until the aircraft arrives at a distance of some 15 km (8 nm) before the threshold. Since at this point the aircraft is reaching its final approach speed, the throttles are moved forward.

Comparison of noise footprints: conventional approach versus CDA.

In figure 12 a comparison is made between the noise footprints for the two approaches discussed before.

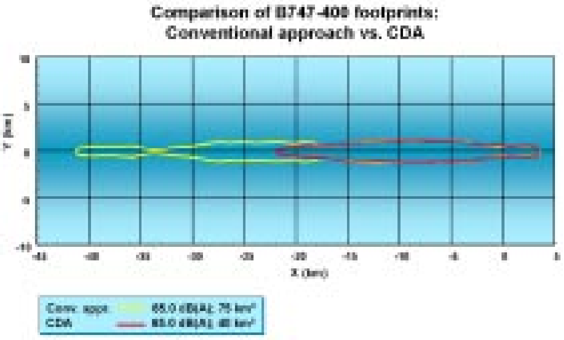

Fig. 12 Comparison of noise footprints

The noise contours show the 65 dB(A) contours. The noise benefit is very obvious. The area enclosed by the CDA footprint is approximately half the one for the conventional step-down approach. [Compare 40 km² with 75 km²]. The 50% noise reduction was also proven in simulator trials carried out in 1996 with the RFS [1].

Advanced Continuous Descent Approach procedure

Because of the difficulties in predictability of approach path and time for the present CDA, NLR started a research project on a new concept named: "*Advanced* Continuous Descent Approach", indicated by the acronym ACDA (figure 13).

Fig. 13 Advanced Continuous Descent Approach (ACDA)

Research is being carried out, on both the cockpit and the air traffic control aspects, into improving the accuracy and predictability of the CDA flight procedure in order to restore the separation distances to a level that applies to the conventional approach procedure.
The ultimate goal is to end up with an Advanced Continuous Descent Approach (ACDA) procedure that can be used even during peak hours.

ACDA allows the aircraft, after passing the Initial Approach Fix, to start a continuous descent to the runway threshold along a curved, earth referenced, approach path with both lateral and vertical guidance.
NLR's previous research on MLS curved approaches has proven that with this new approach and landing system these procedures are feasible.

In the ACDA procedure the following technologies are integrated:

1. **Curved approach** with continuous lateral and vertical guidance. In principle a constant 3° glide path will be flown.
2. The procedure is carried out as a **decelerated approach,** controlled via an - in the FMS programmed - energy management algorithm.
3. **4-D RNAV:** a prediction of the aircraft track in position and time, is made before the aircraft initiates an ACDA procedure. The prediction is based on the flap/speed schedule and the available information on the wind profile.

The curved approach path, as applied in the ACDA concept, consists of straight and circular segments. A constant 3° glide path angle is maintained along the entire path, including the turns.
It is expected that the three above-mentioned issues, together with the additional planning and monitoring tools for the air traffic controller, will reduce the uncertainties in the time of arrival over the threshold to the accepted level of the current practice. Consequently the capacity of the airport during CDA approaches will be restored to the level for conventional approaches.

Developments for realising the ACDA concept

Assistance tools for the air traffic controller.

As mentioned on page 5, in the development of new procedures two boundary conditions apply. The second one reads that *capacity should not reduce significantly* due to the introduction of new noise abatement measures.
At the NLR ATC department, studies are performed to extend the CDA operations to higher traffic density conditions, in order to obtain or come close to the normal operating capacity.
Within the plan view display of the air traffic controller, a display tool was developed that projects, on the extended centreline of the runway, the positions of all aircraft flying a CDA. An example of this so-called "ghosting" principle is shown in figure 14.
Three aircraft are approaching runway 06 via three different CDA's. Their "ghost" positions are depicted on the extended centreline. The yellow colour of the Air France Boeing 747 (AFR2247), approaching from SUGOL, indicates that there is a separation problem with the British Airways Boeing 737 (BAW5138), arriving from RIVER.

Fig. 14 Picture of the air traffic controller "ghosting" display aid for CDA approach

This problem becomes visible when their ghost-positions are depicted on the centreline of the runway (see positions N and D respectively).
The air traffic controller is now able to determine whether the separation at the fixing point of the three CDA routes will be sufficient.
An evaluation of the described tool has shown that this relatively simple enhancement in the plan view display enables the insight in how a CDA proceeds. Due to this additional information the longitudinal separations between approaching aircraft can be reduced and as a direct result the capacity can be increased.
To implement this tool some real-time simulations with air traffic controllers are necessary to investigate the different configurations (layout of the "ghost" label, effect of winds, acceptable separation margins, etc.).

ACDA mode in the FMS

An algorithm was developed to be able to fly ACDA's [5]. The designed computer algorithm for the FMS ensures that the thrust levers remain in the flight-idle position during the greater part of the approach.
The algorithm has been implemented in the Research Flight Management System (RFMS) of the RFS. This RFMS is a computer simulation of a real FMS with full functionality and complete free-play capability. Hence it can be easily adapted to new subroutines, such as the ACDA. It is used in the RFS (see figure 5).
Although the algorithm has been designed for a generic type of aircraft, it should be remarked that for the ACDA research the aircraft characteristics of a Boeing 747-400 were stored in the RFMS data files.
The ACDA algorithm is based on two requirements:

1. To determine the positions along the flight track where the throttles are set to idle thrust and where the first flap setting has to be selected. This has to be performed in such a way that a certain target speed is reached at a particular distance before the runway threshold.
2. If, due to disturbances, deviations from the predicted flight path appear (e.g. due to unpredicted changes in the wind), the system shall adapt the moment of flap selections in such a way that the target speed at the end of the approach remains unchanged.

Recently, based on a preliminary evaluation, carried out on the RFS, it was concluded that the algorithm worked well.
Since no airline pilots have been involved in this evaluation, further research is needed on the human machine interface aspects.
Also a combined RFS-NARSIM research simulator experiment is foreseen in order to evaluate the opinion of air traffic controllers.

Safety philosophy

The first boundary condition in the development of new procedures reads (see page 5) that the *level of safety per individual flight may not be adversely affected* by the introduction of new noise abatement measures.
How this can be realised will be shown by means of an example that concerns the reduction of the longitudinal separation, between approaching aircraft, from 3 nm to 2.5 nm. Figure 15 explains the philosophy how the required safety level can still be maintained or even improved in this case.

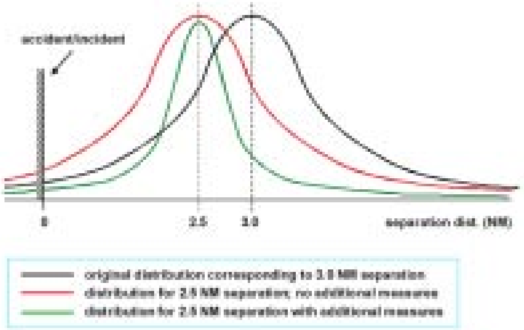

Fig. 15 Safety philosophy

Assume that for the 3 nm separation rule the black incident or accident distribution curve applies. The accepted probability of an incident or accident is proportional to the area under the black curve left of the hatched line.

If one now should decide to reduce the separation from 3 nm to 2.5 nm, without applying any additional measure, the accident/incident distribution curve will shift to the left, resulting in the red curve. The area under the red curve, left of the hatched line, is evidently larger than that under the black one. Hence the safety would have been reduced by the introduction of this rule.

However, if at the same time additional measures are implemented, such as better and more accurate tools for the air traffic controller, the standard deviation of the distribution curve (green curve) will become smaller. Consequently the area under the curve left of the line will become smaller. This could even lead to a safety improvement compared to the 3 nm separation case.

Of course the question remains: how can the effect of an additional tool on the shape of the distribution curve be established?

The SOURDINE project

Apart from national projects, NLR is also participating in a project on noise abatement procedures of the European Commission. This project, called Sourdine, (French word for “mute”), aims at defining new procedures leading to the reduction of noise in the airport vicinity and the requirements for supporting tools.

The Sourdine project is the first stage of a long-term programme in the noise reduction field. The present programme, which started in December 1998, will be completed at the end of 1999. It will be continued in 2000 under the 5th Framework Program meof the European Commission.

This project is the first step towards the definition, validation and use of noise abatement procedures, with emphasis on new arrival and departure procedures.

It has the following objectives:

1. To study and to propose alternatives to reduce noise levels around airports, by:
   - elaborating generic rules for updating the existing approach and take-off procedures for short term improvement, which have to be applicable to most of the existing transport aircraft,
   - investigating new procedures taking benefit from new airborne and ground technologies, such as: MLS, GPS, enhanced FMS, etc.
2. To apply these rules to define new procedures for selected airports (Amsterdam Schiphol, Madrid Barajas and Naples Capodichino), considering the feasibility of such procedures.
3. To identify the simulation tools and their capability of being integrated in a global simulation platform aiming at the operational validation of the new procedures within the scope of the 5th Framework Programme. The noise measurement system and the automation tools for operator assistance will also be defined. End-users will be involved for preliminary validation of the concepts.

In figure 16 the methodology of the Sourdine project is illustrated. More information on this project is given in [6].

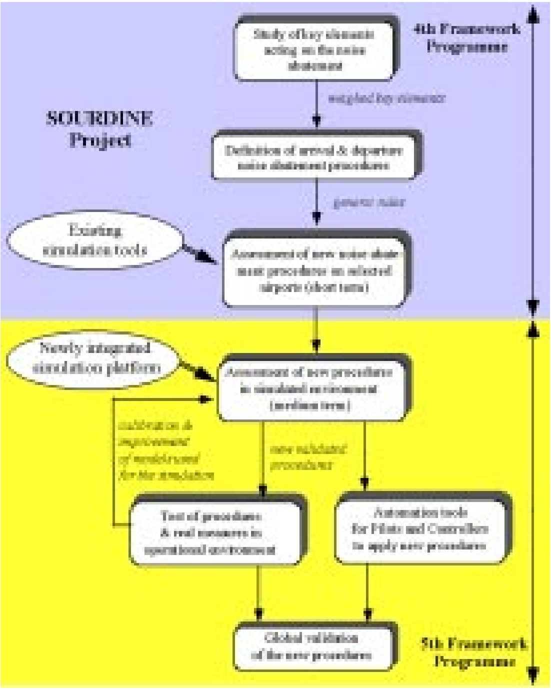

Fig. 16 SOURDINE project methodology

Concluding remarks

Optimal utilisation of the upcoming new systems for approach, navigation and flight management will lead to the introduction of more efficient flight procedures. These will contribute to:

- Improvements in noise abatement
- Airport capacity enhancement
- Reduction of radar vectoring, leading to ATC workload relief
- More efficient and safer operations in the terminal control area (TMA).

Before these flight procedures become available for operational application, however, a lot of research work has to be carried out. This comprises not only flight- and ATC simulation studies but also in-flight demonstrations, to prove the operational feasibility of the concept of a particular procedure under real life conditions.
Since a world-wide implementation of these procedures is pursued, international co-operation is urgently recommended between aircraft, engine and avionics manufacturers, civil aviation authorities and research organisations.

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