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The influence of ATC in approach noise abatement

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ABSTRACT

Aircraft noise has become a significant threat to the growth of air transport. To date, the focus of pressure to reduce aircraft noise exposure has been on operators. However, the issue is increasingly regarded as an industry-wide problem with shared responsibility to minimise the negative externalities of air transport.

This research examines ATC instructions and information that can have an effect on noise exposure in communities around airports. Radar data and full radiotelephony transcription were collected for 210 arriving flights. Flight data recorder information was acquired for a selection of the flights. The effect of ATC instructions on flight profiles was then analysed.

ATC has an important part to play in enabling the achievement of approach noise abatement procedures. The continuous descent approach (CDA) is confirmed as the most effective approach noise abatement technique. Although the airspace around Heathrow is capacity constrained and among the busiest in the world, co-ordination between controllers and flight crews enables CDA on 45% of approaches. Despite this relatively high success rate, the study highlights opportunities for further improvement of the CDA achievement rate. Analysis indicates that the track distance from touchdown at which descent from holding level is given has an influence on the achievement of CDA.

Air traffic providers should, where possible, consider maximising the benefits of the Continuous Descent Approach, through future approach tools and ATM concept developments.

1. INTRODUCTION

This paper describes the influence of ATC in approach noise abatement.

1.1 Background

Aircraft noise has become a critical constraining factor around many European airports. There are two main reasons for this:

Significant reductions in source noise were achieved during the 1970s with the application of high by-pass ratio engines. Large improvements of this kind through the application of new technology are no longer possible. Combined with the continued strong growth of air transport, total noise exposure around airports is beginning to increase.

At the same time, adverse public reaction and sensitivity towards aircraft noise have intensified.

Approach noise contributes an increasing proportion towards total noise exposure at many European airports. This is largely because approaches are constrained by the 3° ILS glideslope whereas average departure profiles have steepened due to improvements in aircraft climb performance, and an increase in the proportion of high performance twin-engine operations.

In 1993 the UK government directed the Aircraft Noise and Monitoring Advisory Committee (ANMAC) to conduct a study of approach noise. The final report of the ANMAC technical working group was published in December 1999 [1]. This paper describes the findings of that study from an ATC perspective.

1.2 Data Collection

Data were collected for 210 flights arriving at Heathrow between 0530 and 1100 local time on the morning of 13th August 1998. Radio-telephony (R/T) communications to and from the Intermediate Director North and the Final Director were collected. Ground track, ground speed, height, rate of descent and distance from touchdown were derived from radar data for each flight. Flight profile data and R/T information were synchronised to reconstruct the interaction between controller and flight crew. In addition, high quality FDR data were collected for a number of the studied flights.

Figure 1 is an example of the ATC instructions and information combined with the flight profile of one of the studied flights. Vertical bars indicate the distance from touchdown at which ATC instructions and information were given. Flight parameters shown are airspeed, height above threshold and thrust per engine.

1.3 Approach procedures

Aircraft approaches are strictly controlled through regulations and procedures for safety and traffic management purposes. ICAO Procedures for Aircraft Navigation Services – Operations (PANS-OPS) detail the requirements for approach procedures. In addition the UK Aeronautical Information Publication (AIP) describes requirements including approach noise abatement procedures specific to Heathrow. ATC requirements are described in the Manual of Air Traffic Services (MATS).

At Heathrow, Intermediate Directors are responsible for the initial streaming of aircraft from the Terminal Holding Patterns into a preliminary, fairly coarse, sequence.

Once the Intermediate Director has set up the initial stream of aircraft and issued initial descent clearance, aircraft are transferred to the Final Director. His/her responsibility is to accurately sequence aircraft onto the ILS at the optimum speed and spacing to achieve the maximum runway utilisation.

The appropriate minimum arrival spacing between the successive aircraft is primarily achieved by vectoring instructions, reinforced by the application of rigid speed control.

1.4 Noise abatement operating procedures

Since the 1960s a number of approach noise abatement operating methods have been proposed [2,3]. These include steep glideslopes, two-segment approaches and decelerating approaches. Most of these have been rejected on flight safety grounds. The only methods that have been adopted are the Continuous Descent Approach (CDA) and the Low Power Low Drag Approach (LPLDA). Of the top 30 European airports, just 6 apply CDA approach procedures.

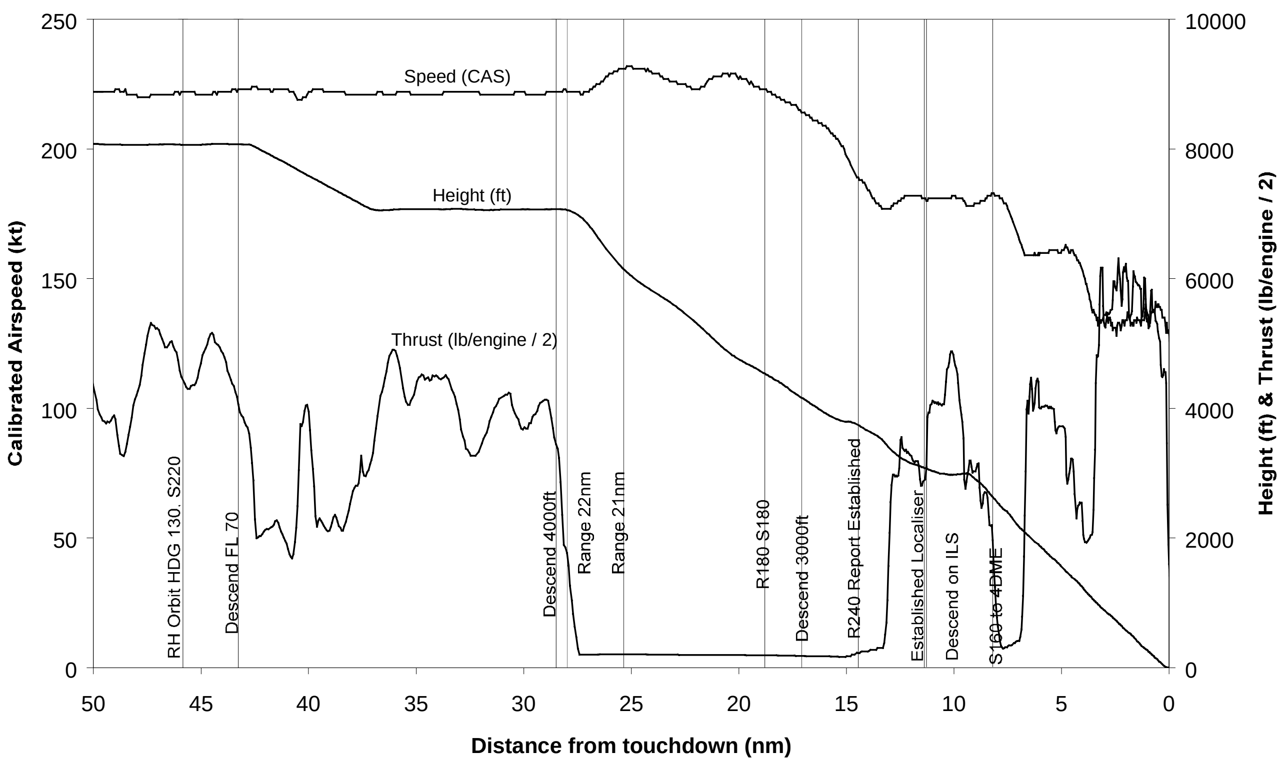

Figure 1 Example of ATC R/T matched against FDR flight profile

CDA requires an aircraft to descend from 6000ft altitude to interception of the ILS glideslope without recourse to level flight[1]. At Heathrow, CDA is achieved through joint participation of controllers and flight crews. Controllers give range estimates from touchdown, from which flight crews select appropriate rates of descent in order to maintain descending flight until joining the glideslope.

NATS is one of the few air traffic providers to use CDA procedures at an operational level and this research supports the continuing efforts to increase CDA achievement concurrently with increases in capacity.

LPLD requires an aircraft to be flown at the highest speeds commensurate with safety requirements, throughout the approach. The objective of LPLD is to keep aircraft configuration as 'clean'[2] as possible throughout the approach, thus minimising engine thrust requirements. The speed regime at Heathrow is already close to best practice for the LPLD noise abatement procedure.

For a Boeing 747-400, CDA reduces noise by up to 5dBA SEL and LPLDA by up to 1dBA SEL compared to a 'normal' approach.

2. SYSTEM CONSTRAINTS

A number of system constraints affect the degree to which approach noise can be reduced. These are summarised in figure 2.

Close to the airport, operators and flight crews have limited scope to improve the application of noise abatement procedures. During the intermediate descent, there is some scope within ATC procedures to enable flight crews to apply noise abatement procedures more effectively, although the constraints and implications are significant. A large number of noise complaints now come from areas at large distances from the airport, where aircraft are not yet established on the ILS.

3. DESCENT CLEARANCE

This study shows that 'early' descent clearance can result in flight crews flying lower than is desirable for noise minimisation. Level flight segments also become more likely, with an associated reduction in the achievement of CDA.

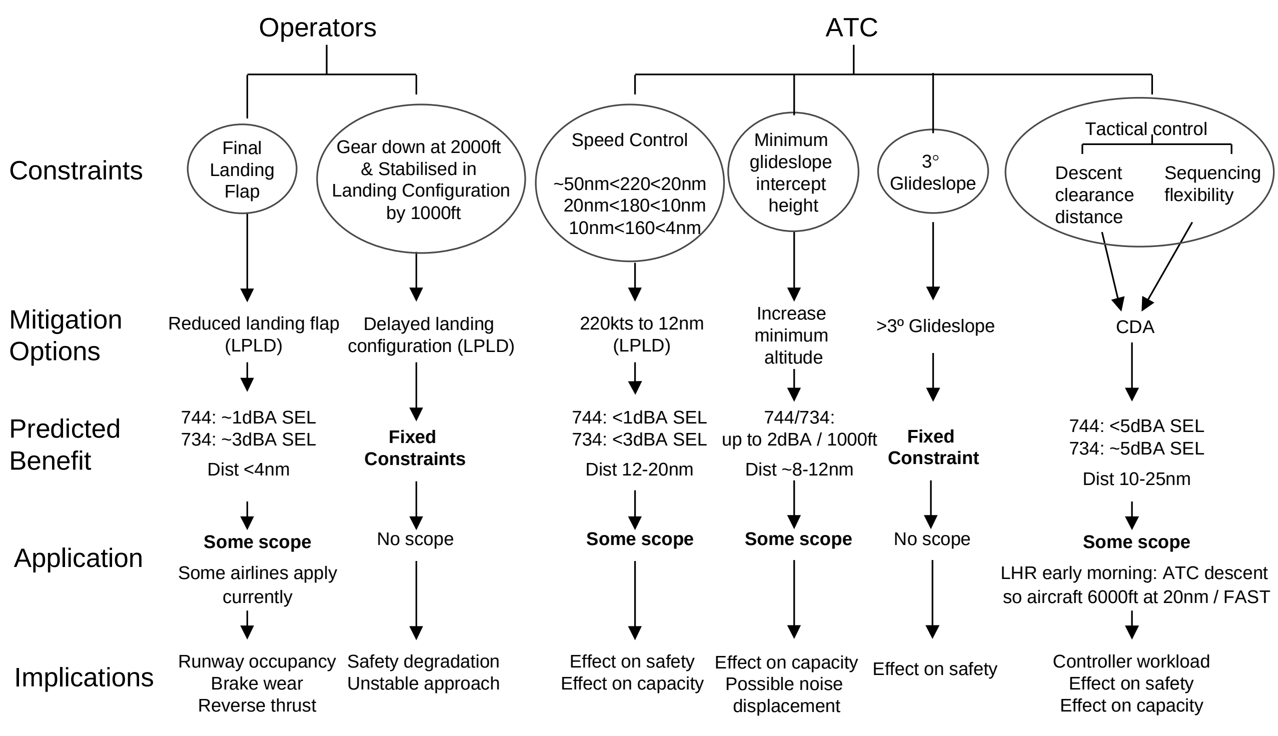

Figure 2 Approach noise mitigation options within operational constraints

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[1] The definition of CDA used in this study includes up to a 2nm level segment of flight.

[2] An aircraft is fully 'clean' when no high lift or high drag devices such as flaps, slats and spoilers are deployed and undercarriage is retracted.

3.1 ATC Descent Procedures

Descent clearance in the initial approach is normally given from minimum stack level (MSL)[3] although clearance may be given from higher levels. Descent clearance is issued with regard to the vertical and lateral boundaries of the airspace available, departing aircraft, obstacle clearance and other traffic flows.

3.2 Descent from MSL analysis

Analysis was conducted to investigate the influence of ATC descent clearance on CDA achievement.

The track distance between descent clearance from FL70 (or when passing FL70) and touchdown was calculated for each flight. Figure 3 illustrates the relationship between the distance from touchdown out of FL70 and CDA achievement. There is clearly a strong relationship, and the results indicate a significant opportunity for flight crews to increase achievement of continuous descents through improved ATC descent clearances.

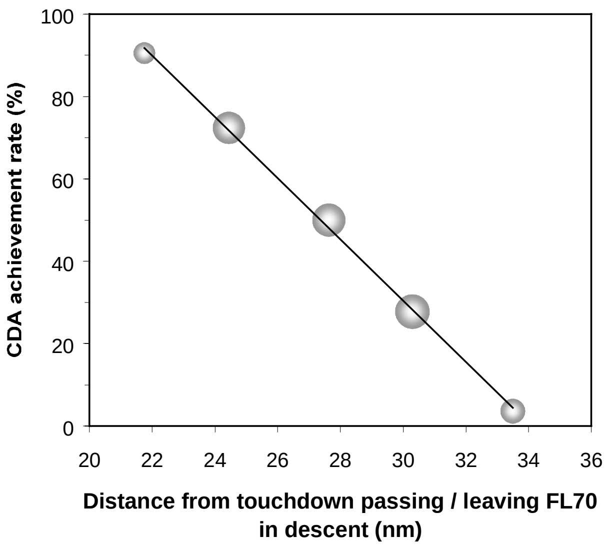

Figure 3 Relationship between CDA achievement rate and distance from touchdown out of FL70 (bubble area indicates group sample sizes)

3.3 Comparison with 1977 descent studies

A previous CAA study of approach noise abatement procedures in 1977 [4] found a relationship between descent clearance and CDA achievement consistent with that found in this study.

This study found that, on average, descent from FL70 was given at 27.8nm from touchdown (standard deviation 3.7nm). The equivalent distance in 1977 was 24.1nm.

4. DISTANCE FROM TOUCHDOWN ESTIMATES

This study has found that underestimates of remaining track distance (range) by ATC results in flight crews descending at higher rates of descent, and flying at lower altitudes than necessary for CDA. These underestimates are considered to be the result of confounding factors such as track stretching, and controllers erring on the side of caution and safety.

4.1 ATC Distance Estimation Procedures

On receipt of descent clearance, flight crews are expected to descend at the rate judged to be best suited to the achievement of continuous descent without recourse to level flight. At Heathrow, controllers pass range estimates to facilitate the CDA procedure. Range estimates are passed as follows:

- When first issuing descent clearance from stack level.
- As soon as possible after first contact with the Final Director.
- At any time if a previous estimate has become invalid.

4.2 Range estimate analysis

Range estimates were given by Intermediate directors to 69% of flights and by Final directors to 61% of flights in the study.

The combined average distance under-estimate of Intermediate and Final directors was 3.2nm. One reason that range estimates are generally under-estimated is likely to be a subconscious decision by controllers to err on the side of caution and safety. Certainly, controllers wish to avoid over-estimating range as this might pressure flight crews into a rushed approach.

During the initial approach, flight crews are required to follow radar vectors to ILS interception enabling ATC to sequence aircraft on final approach with optimum separations. The process requires controllers to continually plan and reassess the traffic situation, accounting for factors such as wind and pilot response time[4]. This minute to minute variability in ATC routings is undoubtedly the main reason for variability in estimations of remaining track distance.

[3] The minimum stack level at Heathrow depends on sea level atmospheric pressure (QNH), in general, if QNH is 1013mb or above then FL70 is the minimum and when QNH is less than 1013mb FL80 is the minimum. The QNH was 1019mb during the study period, therefore FL70 corresponded to a height of 7094ft aal.

[4] See discussion section.

4.3 Rate of Descent

Analysis was conducted to evaluate the influence of ATC range estimates on CDA achievement.

ILS glideslope information allows pilots or autopilots accurately to descend at 3 degrees on final approach to landing. During initial approach however, there is no comparable vertical guidance system[5]. When aircraft are ATC vectored prior to joining the ILS, pilots do not know the optimum descent rate to set in order to achieve continuous descent. However, when ATC pass accurate estimates of remaining track distance, pilots can estimate appropriate rates of descent (RoD) in order to achieve CDA.

The greater the track distance from touchdown, the lower the appropriate RoD. It might be expected that where CDA is required and ATC range estimates are reasonably accurate, measured rates of descent will accord with the RoD required for CDA.

Figure 4 compares measured average RoD from the point of receiving an ATC range estimate for each flight, against the theoretical RoD required to achieve CDA.

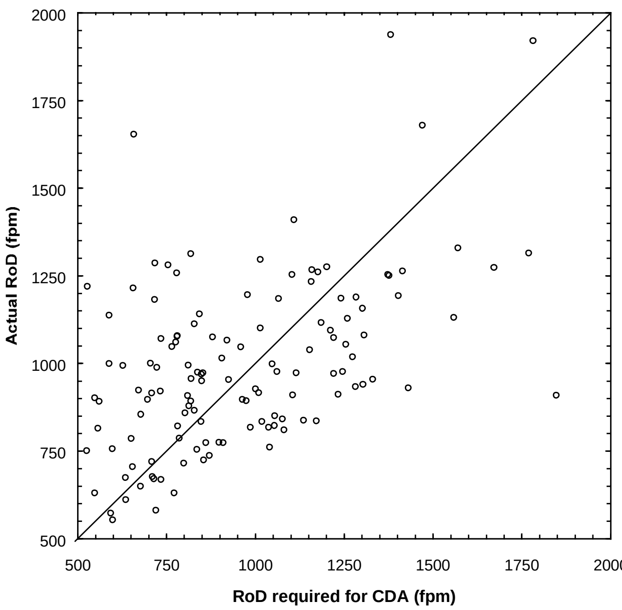

Figure 4 Comparison of actual RoD with required RoD for CDA

5 Distance Measuring Equipment (DME) is installed at the London airports to inform pilots of their distance from the airport, but this is only applicable to the straight distance from the DME location to the aircraft location.

In addition, aircraft navigation systems can be used to plan approach tracks with appropriate altitude markers for vertical guidance. This of course is only accurate if the planned approach track is followed. Since not even ATC know the precise ground track that will be flown, pilots would simply be guessing; hence it is not used for the majority of approaches.

In figure 5 those flights that applied a RoD too high to achieve CDA have been adjusted to account for any ATC range under-estimation. The 'x' data points therefore show the measured average RoD against the RoD expected as a result of the ATC range estimate.

This analysis suggests that ATC range estimates can influence the propensity of flight crews to perform CDA procedures. An opportunity exists to improve CDA achievement through improved ATC range estimations.

Clearly other factors will confound the propensity of flight crews to perform CDA procedures (see discussion section).

5. SPEED CONTROL

Early speed control requires aircraft to fly in higher drag configurations and therefore using higher thrust than necessary in LPLD approaches.

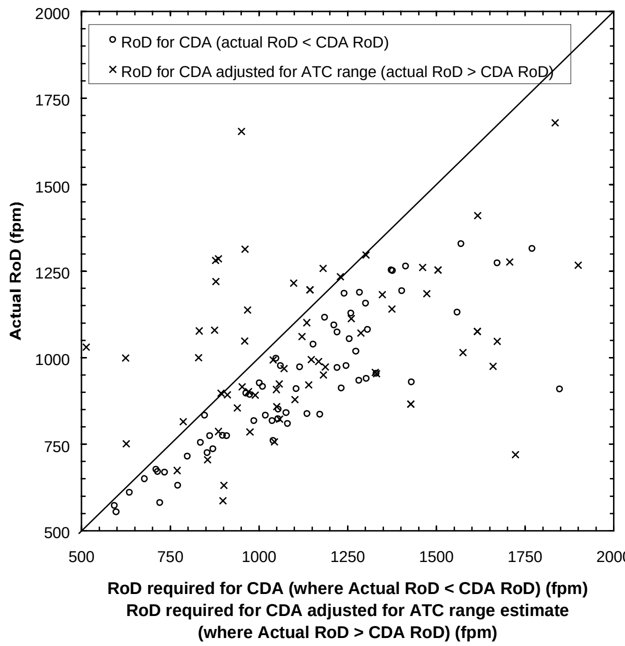

Figure 5 Comparison of actual RoD with required RoD for CDA where actual RoD < CDA RoD, OR with RoD required for CDA adjusted for ATC range estimate

5.1 ATC Speed Control Procedures

Between the arrival hold and base leg (approximately 6nm before turning onto the ILS intercept heading) an airspeed of 210kts[6] is instructed. Thereafter, until established on the ILS localiser, 180kts is instructed. Once established on the localiser, speed 160kts until 4nm DME is instructed.

Strict speed control regimes of this kind are typical at many airports around the world, although the actual speeds used vary between airports. Further research in this area is recommended to review the applicability of these speeds to recent aircraft types and to the maximisation of noise reduction using LPLD procedures.

Although the Heathrow approach speed regime is employed primarily to achieve appropriate aircraft separations and to maximise arrival capacity, it is already close to best practice for the LPLD noise abatement procedure.

5.2 Speed control analysis

Only 2% of flights were issued with “no ATC speed control”, allowing pilots full autonomy in determining the airspeeds flown during the approach.

93% of flights were given speed control of 180kts. On average, speed 180kts was instructed at 20.5nm from touchdown (standard deviation 3.4nm). Once aircraft were established on the ILS, 92% of flights were given speed control of 160kts. On average, speed 160kts was instructed at 10.3nm from touchdown (standard deviation 2.7nm).

5.3 Effect of ATC instructions on aircraft configuration

Given that flight crews are expected to follow ATC speed instructions accurately and that at most busy airports ATC operate a rigid speed control regime, there is clearly a strong link between ATC speed control and aircraft configuration.

When an aircraft slows down prior to landing, flaps must be extended in order to maintain sufficient lift. At progressively lower speeds, greater angles of flap are required. Flap settings are defined in a number of increments such as 1°, 5°, 10°, 20°, 25° & 30°. For each of these increments there is an applicable speed range and associated normal manoeuvring speed for a particular aircraft weight. At progressively higher aircraft weights, the normal manoeuvring speeds increase. If the maximum speed for a particular flap setting is exceeded then structural failure may occur. If speed falls below the minimum speed for a particular flap setting then the chances of a stall and loss of control increase. Hence for safety reasons it is vital that flight crews select flaps at the appropriate speeds during approach to land.

Table 1 shows a typical flap / speed schedule for a Boeing 747-400. When ATC issue a speed control, the appropriate flap setting must be selected in order to fly at that speed. For example, consider the following scenario: A B747-400 is descending from stack level at Heathrow at 220kts with 1° flap selected. ATC issue a speed control of 180kts at 20nm from touchdown. The minimum flap setting is therefore 10°. Before speed can be reduced below 211kts, 5° flap must be in position, and before speed can be reduced below 191kts, 10 flap must be in position[7].

Flap Angle	Normal manoeuvring speed* (kts)
0	231
1	211
5	191
10	171
20	156
25	146
30	141

* Computed airspeed (CAS), based on a typical landing weight

Table 1 Boeing 747-400 flap / speed schedule

6. DISCUSSION

6.1 Confounding factors in the current ATC operating environment

The airspace around Heathrow is capacity constrained and among the busiest in the world. Controllers continually have to make judgements about the progress and relationships of aircraft during the initial approach and update those judgements in the light of what is observed. Ultimately the routeing of a particular aircraft in the approach sequence depends on the progress of the aircraft ahead of it in the sequence, which in turn depends on the progress of the aircraft ahead of it.

Most of the variability from the exact profile and track intended by a controller, and therefore variability in

[6] Pilots may request the use of their minimum clean speed during this phase of flight, commonly 220/230 kt.

[7] When a particular flap angle is selected, there is a delay of several seconds before the flaps actually reach the desired angle (the delay between 5° and 10° flap on the 747-400 is around 5 seconds).

descent clearance distances and range estimates, can be explained by the following list of factors.

Wind changes in direction and speed with altitude. As aircraft descend, the effect of the wind on the ground track (drift) varies. For aircraft which descend at different rates the overall effect of drift will be different.

Pilots do not respond uniformly to ATC instructions. Cockpit workload is high during the approach phase. Sometimes there is a delay before a pilot reacts to an instruction. Occasionally a pilot may request clarification of an ATC instruction causing delayed initiation. Some aircraft systems apply bank angles to initiate turns more quickly than others.

Aircraft may turn at different rates, resulting in different turn radii. The radius of the turn depends on the bank-angle, the speed of the aircraft, its altitude and the effect of wind.

When wind shear exists an aircraft may experience a rapid change to its ground track or speed as it descends through the wind shear level.

All of these variables will affect the initial tactical plan that the controller sets up. Particularly when integrating multiple traffic flows into a single stream (e.g. from two holding patterns into a single downwind leg stream) the initial estimate has to be adjusted following continuous observation. The initial heading given may have to be widened out or tightened up as a result of the actual response of each individual aircraft to the instructions given. Sometimes even the initially planned order of flights has to be changed.

When the controller setting up the initial sequence hands his traffic stream over to the Final Director, further fine-tuning may be needed to achieve the optimum spacing on final approach, lengthening or shortening the paths of each aircraft or adjusting their speed.

In the case of Heathrow approaches, two Intermediate Directors are setting up the two initial traffic streams independently of each other, although each will be aiming to achieve a flow which will be easily integrated into the opposing flow by the Final Director. So in the early stages of the approach, when the initial descent instructions are given, there can be no certainty of the eventual ground track along which the aircraft will be directed. The controller's task involves planning, instructing, observing and adjusting.

6.2 Considering 'early' descent from MSL

'Early' descent from MSL is likely to be related to the confounding factors discussed above. The most significant factor appears to be the technique of path stretching, such that when the path of an aircraft is extended prior to joining the ILS, the descent clearance will appear to have been given early.

Controller shift changes were analysed in order to investigate whether some controllers tended to give descent clearances at longer track distance than others, but no obvious trends were noted. In fact, each controller showed similar variability.

It is argued that the main reason for variation in the descent from MSL distances is that descent is instructed at roughly the same point in space for each flight with what the Intermediate Director believes to be an appropriate range estimate. Once an aircraft has been handed over to the Final Director, path stretching may be applied in order to maintain appropriate safe separations and sequencing. If path stretching does occur, the ILS closing heading will generally be at a greater distance from touchdown than originally envisaged by the Intermediate Director. The 'out of FL70' distance will appear to be longer and the rate of descent too high for the actual distance flown. Consequently the probability of the flight crew achieving continuous descent will be low.

Where range estimates are revised, the probability of flight crews achieving CDA will be higher.

7. CONCLUSIONS

ATC has an important part to play in enabling the achievement of approach noise abatement procedures.

The Continuous Descent Approach (CDA) is confirmed as the most effective approach noise abatement technique. For a Boeing 747-400, CDA reduces noise by up to 5dBA SEL.

The CDA procedure is not only the most effective method to reduce noise exposure, but is preferred by airlines as it also reduces fuel burn, exhaust emissions and improves passenger comfort.

The main finding of this research is that when descent clearance from MSL is given 'early', the likelihood of achieving CDA is decreased. The results indicate a significant opportunity for flight crews to increase achievement of continuous descents through improved ATC descent clearances.

This study suggests that ATC range estimates influence the ability of flight crews to perform CDA procedures. An opportunity exists to improve CDA achievement through improved ATC range estimations.

A number of confounding factors have been identified that currently cause variability in descent clearance distances and associated range estimates. Key factors include path stretching for appropriate safe separation and the effect of wind variation on groundspeed and drift. The Final Approach Spacing Tool (FAST) developed by NATS has the potential to improve the achievement of noise abatement procedures by reducing such sources of variability.

ATC speed control directly affects the achievement of Low Power Low Drag Approaches (LPLD). The speed control regime currently in place at Heathrow is already close to best practice for the LPLD noise abatement procedure.

Since the achievement of approach noise abatement procedures is influenced by ATC operations, ATS providers and ATC R&D organisations should, where possible, consider features to maximise the benefits of Continuous Descent Approach procedures in the development of approach co-ordination tools and procedures.

8. REFERENCES

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