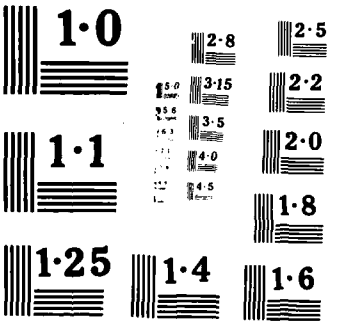
AD-A151 991 CALCULATION AND DISPLAY OF STACK DEPARTURE TIMES FOR AIRCRAFT INBOUND TO..(U) ROYAL SIGNALS AND RADAR ESTABLISHMENT MALVERN (ENGLAND) J O COOK 31 AUG 84 1/1

UNCLASSIFIED RSRE-MEMO-3750 DRIC-BR-94334 F/G 1/5 NL


1·0
2·8
2·5
3·15
2·2
3·5
1·1
4·0
2·0
4·5
1·8
1·25
1·4
1·6

UNLIMITED

RSRE
MEMORANDUM No. 3750

ROYAL SIGNALS & RADAR ESTABLISHMENT

CALCULATION AND DISPLAY OF STACK DEPARTURE TIMES FOR AIRCRAFT INBOUND TO HEATHROW AIRPORT

Author: J O Cook

PROCUREMENT EXECUTIVE,
MINISTRY OF DEFENCE,
RSRE MALVERN,
WORCS.

UNLIMITED

REPRODUCED BY GOVERNMENT [illegible]

ROYAL SIGNALS AND RADAR ESTABLISHMENT

Memorandum 3756

Title: CALCULATION AND DISPLAY OF STACK DEPARTURE TIMES FOR AIRCRAFT INBOUND TO HEATHROW AIRPORT

Author: J O Cox

Date: 31 August 1984

SUMMARY

This Memorandum outlines a method for calculation and display of Stack Departure Times and other Air Traffic Control information. It is considered that this could be implemented in the short-term, with consequential benefit to airlines and Control Staff.

MEMORANDUM NO 3750

CALCULATION AND DISPLAY OF STACK DEPARTURE TIMES FOR AIRCRAFT INBOUND TO HEATHROW AIRPORT

CONTENTS

1 INTRODUCTION

1.1 The problem of calculation of accurate Stack Departure Times has been with us for a long time. However, discussions with aircrew elicit the opinion that one of the most useful pieces of information that Air Traffic Control could give to the pilot would be a realistic estimate of the delay that his flight will incur. Many of the difficulties in providing such an estimate are due to the manual methods that have been used. When aircraft are expected to be delayed for more than 20 minutes, the Air Traffic Control Centre (ATCC) should provide an estimate of the delay for each aircraft, based upon its position in the landing queue, and the landing-rate at the destination airfield. But the delay given has rarely been very accurate because of the problems of deciding upon the landing-order, and the time-lags in updating the landing-rate. If the landing-rate given to the ATCC is optimistic, aircraft are given estimates that understate the delay and may therefore decide to remain in the holding-pattern awaiting their turn to land when their fuel-margins are becoming limited. On the other hand a pessimistic landing-rate means that aircraft are passed an over-long delay and may decide to divert unnecessarily, with the consequent costs to the aircraft operator.

1.2 With the assistance of the computer, electronic data displays (EDD's) and modern data-transfer techniques, these difficulties may be reduced or overcome. A computer program has been written to demonstrate a method of calculation of Stack Departure Times (SDT's) for aircraft inbound from the airways system to land at Heathrow. The program outputs flight-plan, descent and holding information, together with Stack Departure Times, on a 14" Colour EDD.

1.3 The work described here was stimulated by the experimental automated Departure Flow Regulation System designed by AD4, RSRE and demonstrated to NATS at the 1982 CAA Review and subsequently to the Monopolies and Mergers Commission and others.

2 DESIGN OF STACK DEPARTURE TIME PROGRAM

2.1 The area within which aircraft were considered was that covered by the London Flight Information Region (FIR). Inbound aircraft used five separate routes: G1 West from Strumble; R1 South from 50°N;R1 East from the FIR boundary; A1 North from 50°N; and A2 South from Abbeville. These five routes fed the normal four inner stacks for Heathrow: G1W and R1S to Ockham (OCK); A2S to Biggin (BIG); A1N to Boringdon (BNN); and R1E to Lambourne (LAM). In addition to these inner stacks, associated with each route was an outer, high-level stack: Brecon (BCN) for G1W; Coleshill (CSL) for A1N; Ibsley (IBS) for R1S; Channel (CNL) for A2S; and North Sea (NSE) for R1E, (see Diagram 1).

2.2 The program used two variable parameters. These were the Landing-rate at Heathrow, and the maximum time that aircraft should be required to hold at the inner stack - the Planned Delay (Plandel). Both parameters are set at the start, but can be varied on-line.

2.3 The fixed data consisted of the distances along the five inbound routes from the FIR boundary or other aircraft entry point, to the appropriate inner holding stack; and the distances between the outer, high-level stacks and the inner stacks. The distances from the inner stacks to the runway were stored, together with minimum stack levels. Fixed data included also the descent times and distances for a number of representative aircraft types. These latter data were obtained from airline operating instructions for the types.

2.4 It was assumed for the purposes of demonstration that there was a control position that would accept and enter into the computer the Estimated Time of Arrival (ETA) of aircraft at the FIR boundary or other entry-point. This position would be the SDT Allocation Cell, and would have access via the computer to all flight-plan data on aircraft inbound to Heathrow. For this purpose, a small traffic-sample was prepared for use in conjunction with the SDT program. The sample data consisted of aircraft callsign and type, route, cruising-speed and altitude.

3 OPERATION OF STACK DEPARTURE TIMES PROGRAM

3.1 At the start of program operation the time must be set, together with the two variable parameters, i.e the Landing-rate, from which the computer calculates the landing interval; and the Planned Delay at the inner holding stack (Plandel).

3.2 An aircraft callsign from the traffic sample is entered: this causes the aircraft's flight details to be displayed. At this stage, the cruising-level may be altered on-line.

3.3 The program obtains from the fixed data the distance from the entry-point to the inner stack; the descent time and distance for the aircraft type and cruising-level; and the time from the appropriate inner stack to the runway for the route and aircraft type. From these data the program calculates the time at top of descent and the ETA at the runway. (Flight ETA). The program stores the Flight ETA (see Diagram 2).

3.4 The aircraft is inserted in a landing-list: this list is in order of Flight ETA, i.e the time at which aircraft would arrive at the runway in the absence of any constraints due to other traffic. The landing-interval

is then applied to the landing-list to produce a Runway-time for each aircraft. The difference between the Flight ETA and the runway-time for an aircraft is its total delay.

3.4.1 The total delay for an aircraft is divided between low-level and high-level delay. If the total delay is less than Plandel, then the whole delay is taken at the inner stack. For delays less than two minutes, (i.e one complete orbit at Rate 1 turn), it is assumed that such small delays would be absorbed within the Approach Sequencing Area (ASA).

3.4.2 If the total delay is greater than Plandel, then the aircraft would hold at the inner stack for the period of Plandel, but the remainder of the delay must be absorbed in the outer, high-level stack. However, there is a minimum period that an aircraft can absorb at high level, equivalent to one complete orbit. This is at present set arbitrarily at four minutes. If taking the whole of Plandel at the inner stack would result in a high-level holding-time of less than four minutes, then the high-level hold would be set at four minutes and the remainder of the total delay would be taken in the inner stack.

3.5 20 minutes before Flight ETA, an aircraft's position in the landing-order becomes "fixed". After that time, any aircraft entering the system with an earlier Flight ETA is automatically placed after all aircraft in the "fixed" state. This ensures that there is a limit to the alterations in the landing sequence and that there is an element of system stability.

3.5.1 This procedure means that pilots know with a fair degree of accuracy, and well in advance, the time that they can expect to land. They will have 20 minutes notice if there is no delay; or, if the aircraft is required to hold, 20 minutes plus the expected delay. Thus, if an aircraft has 15 minutes total delay, the pilot would know 35 minutes beforehand the time at which his aircraft would land, and his departure-time from the inner stack in order to achieve that landing-time.

3.5.2 Aircraft in the "fixed" state are indicated by a change of colour of their data-line on the FDD.

3.6 Landing-rate and Plandel can both be altered on-line at anytime. The display is updated immediately. Such variations would have no effect on the landing-order, but a change in landing-rate would affect the runway times and thus the total delay.

3.6.1 A change of either parameter would alter the holding-times at high and low levels. However, if an aircraft has left or passed the high-level when a change in parameter is made that would affect the high-level holding-time, that aircraft would not be required to return to the high-level stack. Instead, it must continue to the inner stack and absorb any extra delay there.

3.6.2 With a change of landing-rate, although an aircraft's position in the landing-order remains fixed, its stack departure time will alter and this updated information would have to be passed to the pilot.

3.3 When a change in landing-rate occurs after an aircraft has left the inner stack, it is assumed that it is possible to deal with variations in runway-time by the use of path-stretching or shortening within the approach sequencing area. Aircraft which have not left the inner stack will have their SDT's adjusted accordingly.

4 PROGRAM OUTPUT

4.1 All information was output via a 14" Colour EDD of 25 lines x 80 characters. The colour-coding was fairly arbitrary, but various types of information were presented in different colours. There is no reason why a hard copy should not be made available.

4.2 The use of colour was as follows:

Column Headings	-	Violet
Data being input on-line	-	Green
Variable parameters	-	Yellow
Aircraft Data Lines	-	White
Aircraft in "fixed" state	-	Red

4.3 Information on aircraft was presented in the form of horizontal data-lines, one line per aircraft. The data consisted of:

Callsign
Type
Cruising level
Route
Time at top of descent*
Name of outer stack (HSTK)
ETA/STD for HSTK
Level at which to leave HSTK if aircraft required to hold
Time at top of descent*
Name of inner(low)stack (LSTK)
ETA/STD for LSTK
Level to hold at LSTK
Runway Time

* The two columns for "time at top of descent" are because some high-cruising aircraft will want to commence their descent before reaching HSTK, whilst others with lower cruising levels will be past HSTK before starting to descend. The time for top of descent is the time at which aircraft would require to leave their cruising level in order to reach their holding level in the inner stack by ETA LSTK.

4.4 After its Runway Time has passed, an aircraft's details are deleted from the EDD.

5 SYSTEM LIMITATIONS

5.1 Further development would be necessary to bring the program up to an operational status. At present there is no mechanism included for feeding an aircraft back into the system in event of an overshoot. Similarly, there is no means of removing an aircraft that decides to divert. Most importantly, the program needs to be developed to cater for different weather conditions, particularly where Cat.3 ILS-equipped aircraft can make approaches but less

well-equipped aircraft cannot. Some priority rules must be established. Further to this, there is the corresponding difficulty when weather conditions improve and perhaps priorities have to be rescinded.

5.2 In the current model, all routes are displayed on the same EDD. In an operational system, sector and TMA controllers would need to have displayed only those aircraft with which they were concerned. However, there might be an advantage in being able to display the complete traffic situation.

5.3 The model uses only representative routes and aircraft types: an operational system would therefore be more complex. Also, the model is concerned solely with Heathrow. Further complications would arise if other airports were included, particularly as the same high-level holding areas would have to be shared between several airports.

5.4 The current program works only for the still-air condition: wind velocity is not taken into account.

5.5 The program makes no attempt to optimise the landing sequence: the interactions of narrow - and wide-bodied aircraft are not considered. The landing-interval is merely a simple function of the landing-rate, which itself is only an estimate of what Approach Control hopes to be able to achieve over the next hour or so.

5.6 There is no provision for on-line entry of flight-plan data on aircraft not present in the data-base. However, this would require only small additions to the program.

6 SUGGESTED OPERATIONAL SYSTEM

6.1 The model was conceived originally as a free-standing system, only requiring an input from the 9020D computer for transfer of flight-plan data on aircraft inbound to Heathrow. This would still be possible. The system would require a computer capable of driving several colour displays. Displays would be required (a) on individual en-route sectors dealing with aircraft inbound to Heathrow; (b) on the TMA sectors, and (c) in Heathrow Approach Control. The displays would have associated input keyboards.

6.2 The Approach Control Supervisor at Heathrow would be responsible for the input of the variable parameters-Planned Delay and Landing Rate. He would update the Landing Rate in the light of rates achieved. By leaving this responsibility with Approach Control, Heathrow would feel that they retained some influence over the system. Additionally, Approach Control is able to assess and react to sudden occurrences at the airfield, which might have a bearing on operations.

6,3 The wing positions of the en-route sectors would be responsible for input of entry-point estimates and actual times at the entry point. As the 9020D should have transferred the flight-plan to the Stack Departure Time computer, the wing-man would input the aircraft callsign, display the flight details, and then insert the relevant time. Entering the time would cause the program to output details about high- and low-level holding and time at top of descent. This information would be output to the en-route and TMA sectors and to approach control.

6.4 Instead of a free-standing system, the program could be integrated with EDDIS and its associated displays. However, this would be a more long-term approach.

6.5 There would obviously need to be an assessment made of what equipment should be used, and where the displays and associated input-devices should be located in operational furniture.

ADVANTAGES OF THE SYSTEM

7.1 Many discussions with airline pilots have elicited that the most valuable piece of information that ATC could provide would be an accurate estimate of delay. The Stack Departure Time program would give this at 20 minutes before their original flight ETA.

7.2 The economic savings to operators to operators from not diverting unnecessarily are large.

7.3 Pilots who know the delay that they can expect can operate their aircraft in an optimum way to absorb that delay. This becomes increasingly important as more aircraft are fitted with Flight Management Systems.

7.4 There would be an advantage to the airport ground handling organisation if accurate runway times could be notified well in advance.

7.5 Sector controllers wouldunder normal operational circumstances have adequate warning that an aircraft will be required to hold at an outer stack.

7.6 Sector controllers would have warning of what time an aircraft would wish to commence descent. This, with 7.5, would make planning strategies easier.

7.7 The TMA Controllers would have adequate notice of the order and time that aircraft would vacate the inner stacks. Again, this makes for better planning.

7.8 Heathrow Approach Control would be aware of the order in which aircraft should land, but could possibly vary this slightly to optimise runway utilisation. However, knowledge of what others in the control system expect to happen will encourage better coordination.

7.9 The system would allow rapid reaction to unforeseen circumstances, e.g a runway blocked, causing an instantaneous reduction of aircraft movement rate.

7.10 As Heathrow Approach Control Supervisor would have immediate control over the input of landing-rate, the difficulties in coordination with LATCC over EAT's would be mimimal or non-existent.

7.11 A free-standing system could be implemented in the short-term. The economic benefits to airlines and operational staff would probably justify the cost.

7.12 Adoption of such a system would be an overt demonstration of NATS making a very positive effort to reduce airlines' costs, and as such would be a valuable publicity excercise.

8 DISADVANTAGES OF THE SYSTEM

8.1 Adoption of a free-standing system would involve finding space for extra displays in areas where space is already at a premium.

8.2 The controller has already several areas, apart from his radar display, to which he must devote attention, e.g flight-progress strips, danger area maps, weather information displays. Another display could be a distraction, particularly if it were free-standing.

8.3 The disadvantage in 8.2 above is discounted if the system were integrated with EDDUS and another display would be unnecessary. But the integrated solution would mean a longer delay before this system could be operational.

8.4 There would be additional equipment costs to provide a free-standing system.

8.5 High-level holding-areas could sterilise large areas of airspace. However, with the increasing use of modern aircraft area nav-aids and flight management systems, it is hoped that the size of holding-areas may be reduced.

8.6 If pilots were aware early in their flight that they were going to suffer delays, they might choose to operate their aircraft in a different way from that which the controller expects. This could have implications for the separation of aircraft.

8.7 As mentioned in 5.1 there are difficulties when the runway visual range is changing to or from Cat. III ILS conditions. Unless some fairly rigid rules of priority were established, controllers and pilots could find themselves in confusing situations.

8.8 The system relies to a large extent on the expertise of the Approach Control Supervisor in estimating the landing-rate which is going to be achieved by the airport.

9 CONCLUSIONS

9.1 The system described is not contradictory to the aims of the medium-term BEEKER plan for the London Terminal Control Area, or to the longer-term plans of the Terminal Control Systems Development Group. The concept has been demonstrated to several NATS headquarters staff in DCR, DCAP and DORA, and interest has been generated. The report on the BEEKER plan simulations suggests that the system could be developed for incorporation into TMA procedures. (LTMA Operations Reorganisation Feasibility Study: Jan 1984, p117). As far as TCSDG plans are concerned, the system uses a similar concept in determining the landing-order and estimate of total delay, but the TCSDG plans involve a more complex procedure for the absorbtion of delays by individual aircraft, and the separation of aircraft. However, the system described in this memo is a useful half-way stage in the progress, enabling some investigations to be carried out into display formats, and the use of a similar system is planned as a part of next year's R & D programme of the TCSDG.

9.2 On balance, the advantages of adopting some version of the system described in this memorandum appear to outweigh the disadvantages. The system operates on times, or estimates of times, at entry points: there is no reason why these should not be updated to achieve greater accuracy. Even so, this is essentially an off-line system, and the Flight ETA could be in error by a few minutes. However, this would not detract from the value of the system, the effect of which would still be to give the pilot the best possible information about the delay which his aircraft would suffer. This would still be achieved.

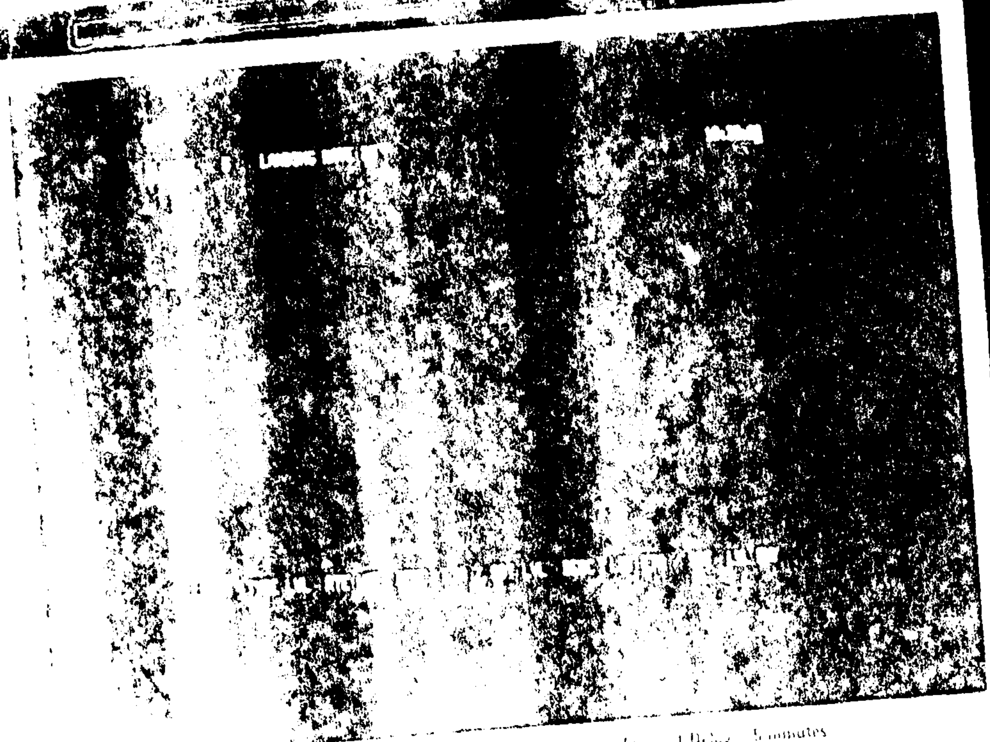


Figure 1 Basic Picture. Var. [illegible] Parameters input: [illegible] Delay [illegible] 5 minutes Landing [illegible] 20 [illegible] per hour

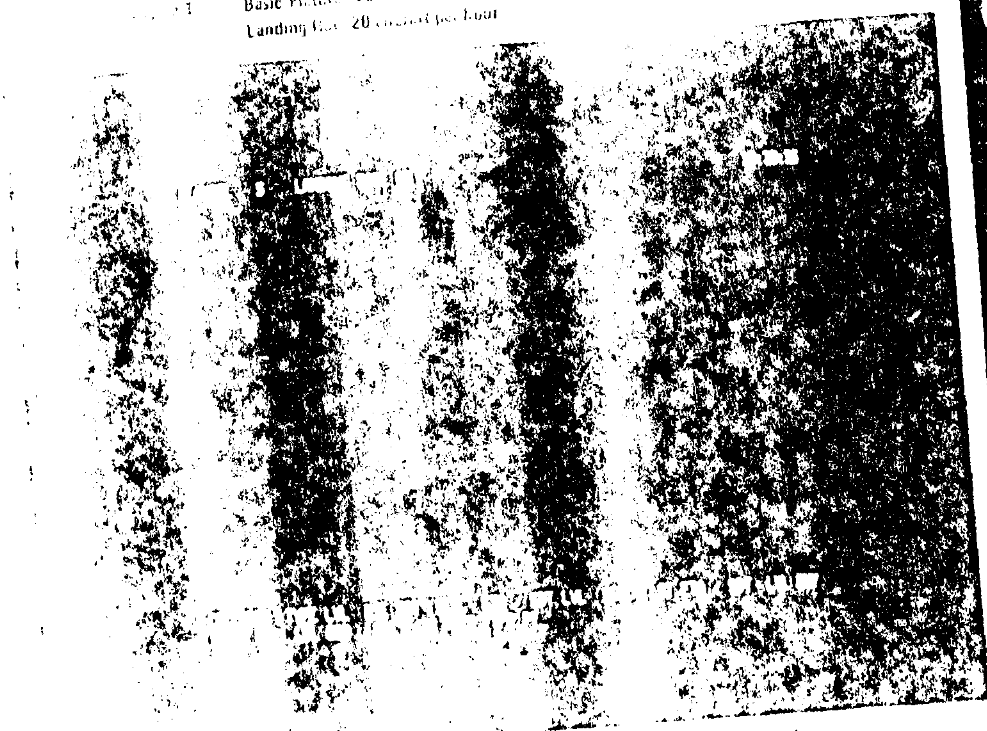
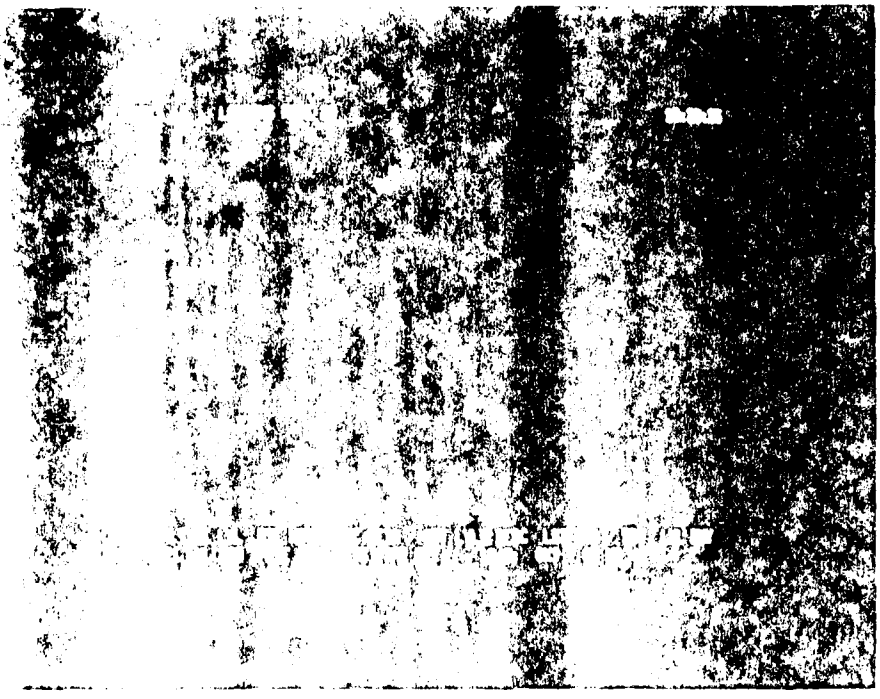
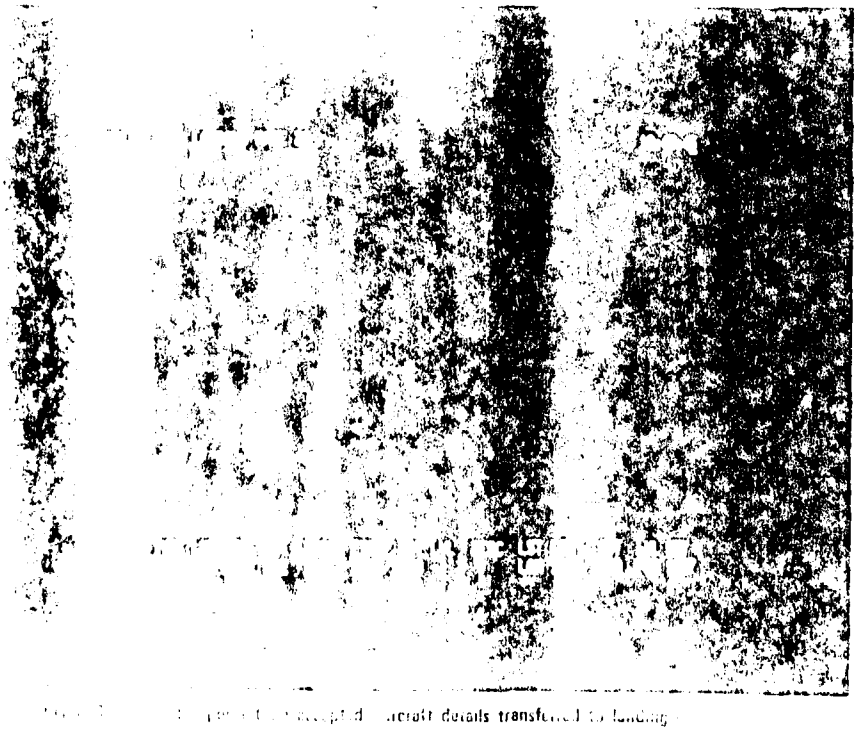


Figure 2 Callsign [illegible] BA 123. Flight Plan [illegible] displayed on scribble [illegible]



[illegible] Point 1043



[illegible] aircraft details transferred to landing

Figure 5 Time 1048, more aircraft in system. Because time is after 1047 (20 minutes before Flight ETA for BA 123), the data line for BA 123 is now in red

Figure 6 CY200 now in system. Note that earlier LTA for CY200 has put back landing time on subsequent aircraft.

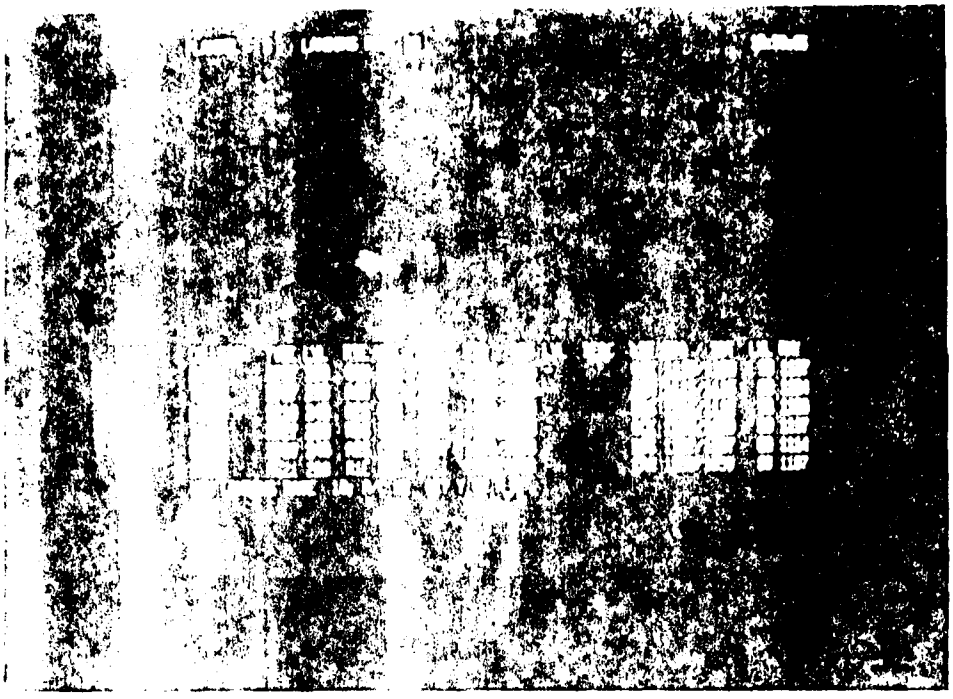


Figure 7 Lower landing rate about to be entered.

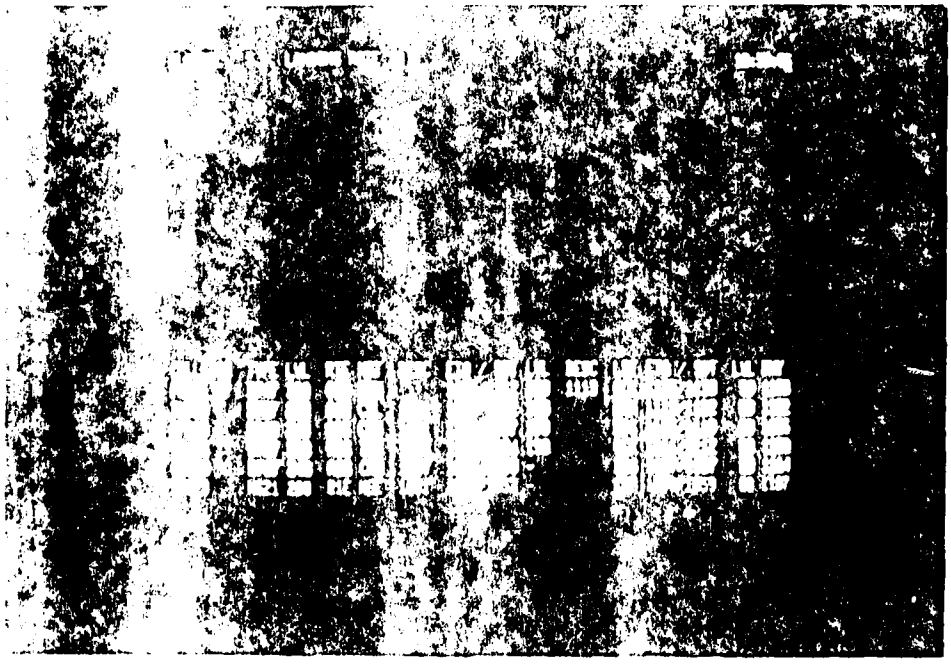
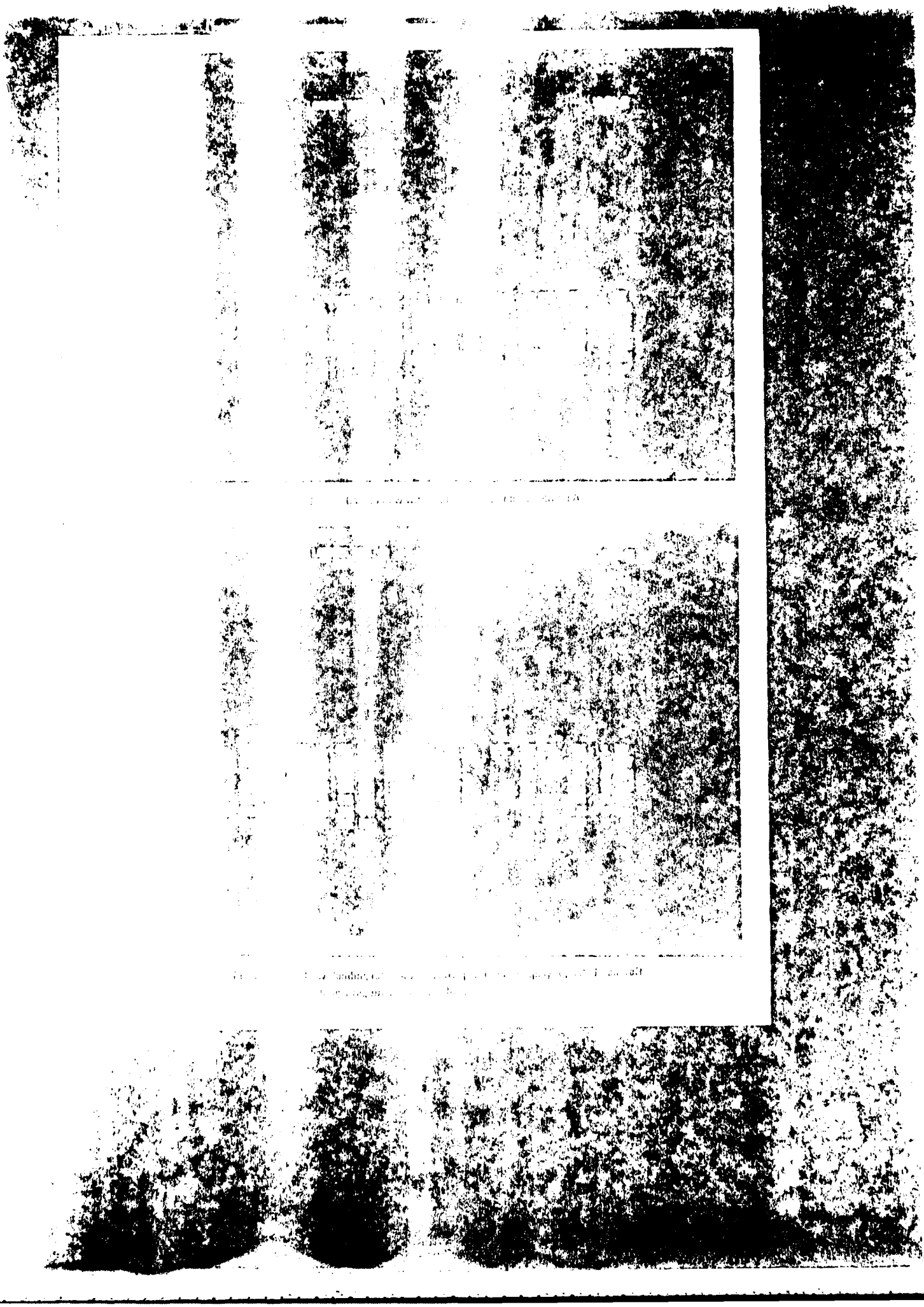


Figure 8 Lower landing rate (10 aircraft per hour less) implemented. Aircraft are now holding in the high level stack



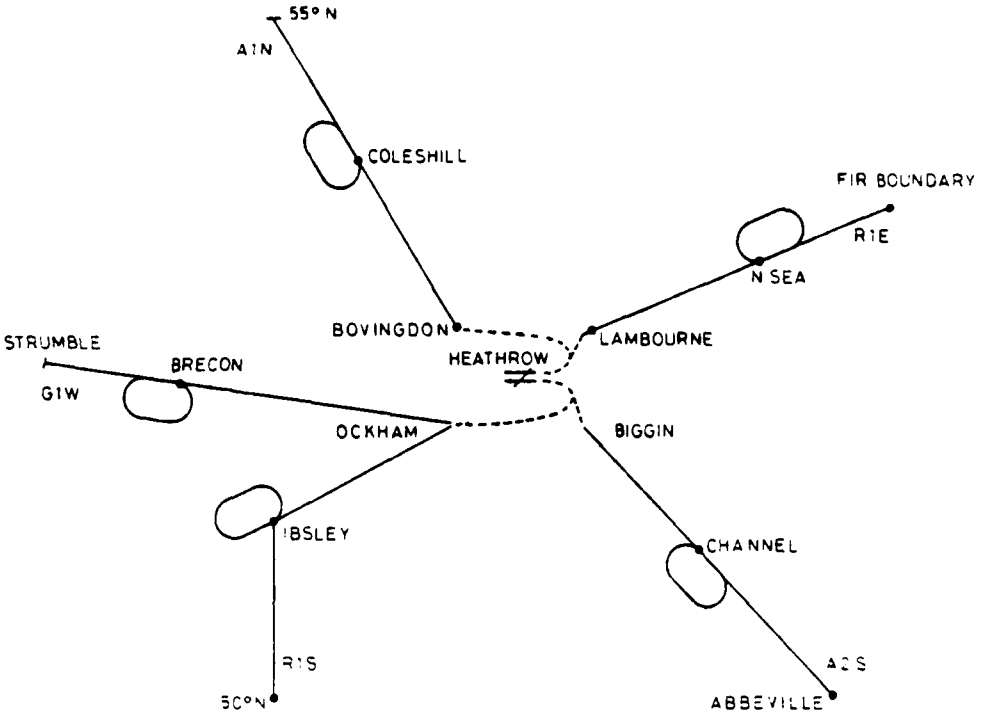
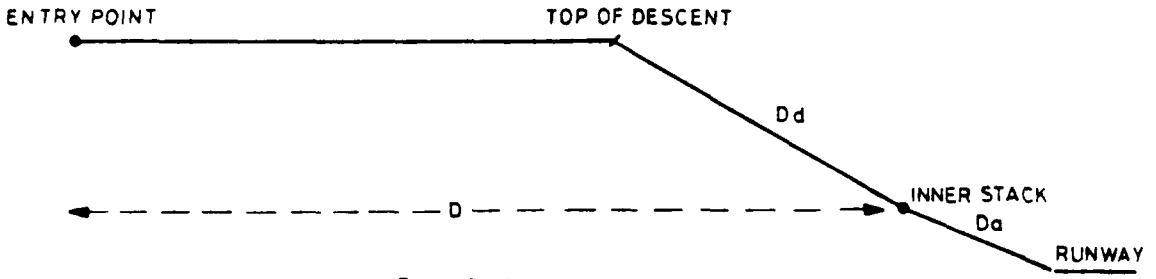


DIAGRAM 1 ROUTE STRUCTURE
Not to Scale



$$\text{FLIGHT ETA} = Td + \frac{Da}{Vf} + \left(\frac{D - Dd}{Vc}\right) + \text{TIME AT ENTRY POINT}$$

WHERE D = DISTANCE FROM ENTRY POINT TO INNER STACK
Dd = DESCENT DISTANCE FROM CRUISING ALTITUDE FOR AIRCRAFT TYPE
Td = DESCENT TIME FROM CRUISING ALTITUDE FOR AIRCRAFT TYPE
Da = FINAL APPROACH TRACK DISTANCE
Vf = FINAL APPROACH SPEED FOR AIRCRAFT TYPE
Vc = CRUISING SPEED

DIAGRAM 2 CALCULATION OF FLIGHT ETA

DOCUMENT CONTROL SHEET

Overall security classification of sheet ..... UNCLASSIFIED .....

(As far as possible this sheet should contain only unclassified information. If it is necessary to enter classified information, the box concerned must be marked to indicate the classification eg (R) (C) or (S))

1. DRIC Reference (if known)	2. Originator's Reference	3. Agency Reference	4. Report Security Classification U/C
5. Originator's Code (if known)	6. Originator (Corporate Author) Name and Location Royal Signals and Radar Establishment, Malvern.		
5a. Sponsoring Agency's Code (if known)	6a. Sponsoring Agency (Contract Authority) Name and Location		

7. Title Calculation and Display of Stack Departure Times for Aircraft inbound to Heathrow Airport

7a. Title in Foreign Language (in the case of translations)

7b. Presented at (for conference papers) Title, place and date of conference

8. Author 1 Surname, initials	9(a) Author 2	9(b) Authors 3,4...	10. Date	pp. ref.
Cook J O			31.8.84	

11. Contract Number	12. Period	13. Project	14. Other Reference

15. Distribution statement

Descriptors (or keywords)
Approach Control
Flow Control
Air Traffic Control
Aircraft Sequencing

continue on separate piece of paper

Abstract The accurate calculation of delays to be absorbed by inbound aircraft is difficult in a manual Air Traffic Control environment. However, when flight plan information is computerized with adequate on-line data - transfer facilities, the problem may be solved. This memorandum suggests a way of automating and displaying to Air Traffic Controllers information about strategies for absorbing aircraft delays. Adoption of the proposed methods would have advantages for pilots, airline operators and Air Traffic Controllers.

ORIGINATOR - SUPPLIED KEY WORDS INCLUDE:

END

FILMED

5-85

DTIC