Air Traffic Control Evaluation Unit

Report No 421

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AUTOMATIC PREVENTION OF LABEL OVERLAP

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INTRODUCTION

1 The project comprised a number of simulation exercises designed to evaluate methods of either preventing or resolving the problems likely to be caused by label overlap on Labelled Plan Displays (LPD). The automatic prevention of label overlap was investigated in ATCEU Project EU 146, (ATCEU Report No 351). These earlier trials determined that one of the methods used, automatically alternating overlapping labels, was not suitable. The report concluded that the other methods used, machine re-positioning and reversion to a tabular display, were effective whether used separately or together, but that they should be brought into operation manually and not automatically. The exercises in EU 146 compared the amount of data which controllers could extract from the LPD when the different methods of preventing overlap were used. The controllers were not exercising any control function, nor was there any other source of flight data such as a flight progress board. The project which is the subject of this report was a follow-up of the earlier trial, using manually controlled methods as had been recommended, and conducted in an active control environment. The simulation also presented an opportunity to demonstrate a new input device, the Touch Sensitive Digitiser (TSD). This was in no way an evaluation of the device, but some observations on its use in the ATC role are included after the discussion section. The project was sponsored by the Director of Control (Plans) NATS, and carried out at the ATCEU Bournemouth (Hurn) Airport in two stages, a pilot study between 11 and 29 June and the main simulation between 13 August and 14 September 1973.

OBJECTIVES

2 The objectives of the simulation was to investigate further the problem of label overlap and to evaluate, singly and in combination, the following techniques for preventing or overcoming label overlap on a 16-in LPD:

a. Vectoring aircraft for ATC purposes or to prevent label overlap

b. Suppressing either, or both, lines of label data within a defined aircraft track category. (The TOP, BOTTOM, BOTH, line selection).

c. Suppressing both lines of label data on a selected aircraft. (The SUP LABEL function).

d. Transferring all label data within a defined aircraft track category to a tabular display on the LPD. (The ALL TAB function).

e. Transferring the label data on a selected aircraft to a tabular display on the LPD. (The TAB LABEL Function).

f. Re-positioning a selected aircraft label by extending the leader line in one or more fixed increments. (The MOVE LABEL function (1)).

g. Re-positioning a selected aircraft label at any selected position on the LPD. (The MOVE LABEL function (2)).

h. Re-positioning a selected aircraft label by rotating the leader line through one or more fixed increments. (The ROT LABEL function).

3. The exercises were to be carried out in a simulated operational control environment with an alternative source of flight data provided by a flight data display. The equipment used was intended to simulate a post Mediator 1 environment in the 1980's and consisted of:

a. Labelled plan display. A processed display of the controller's own tracks and tracks of interest on a 16 in monochrome display with controller input to the display processor by static controls, functional keyboard and rolling ball.

b. Flight data display. A dynamic display in three colours on a 14 in Electronic Data Display (EDD), with controller input to the Flight Data Processing System (FDPS) by an 8½ in touchwire display (TWD). (In the event the 14 in EDD had to be obtained by masking 1 16 in circular display).

c. Touchwire Display. Provided controller access to the FDPS in order to update the system or to extract flight data from it.

CONCLUSIONS

4 Label overlap does present a problem on LPD. It may not be as great a problem as might have been expected, partly because of the high quality of the display. Nevertheless, the problem does exist and may well have an adverse effect on the overall efficiency of the ATC system.

5 The problems caused by label overlap on the LPD are not resolved by having flight data separately displayed on an EDD. Some facilities to resolve overlap on the LPD are needed.

6. The facilities which should be provided on the LPD are:

Label Data Line Selection. Where a system of track categorisation is used, and where more than one line of data is displayed, the facility to select which lines of data should be displayed. This facility to operate within a given track category.

Extension of the Leader Line. The facility to move an individual aircraft label by an extension of the leader in one, two or three fixed increments.

Rotation of the Leader Line. The facility to move an individual aircraft label by rotating the leader line. The amount of rotation to be selectable.

Selective Repositioning of the Label. The facility to reposition an individual aircraft label to any selected point on the display.

7 Where the rolling ball and functional keyboard form the input system, the two devices should be combined in such a way that the functional keys can be identified by touch and the input sequence can be completed without diverting the controllers visual attention from the LPD.

8 In principle, when presenting data to a controller, the aim should be to present the data on an integrated display where labelled plan data and tabulated flight data can be displayed on the one display.

SIMULATION PLAN

General

9 This was the first simulation carried out at the ATCEU using the Cossor 1000 display in association with the Computer Technology Modular 1 computer functioning as a display processor. As only one display could be made available in time for the project it was planned to investigate the problems likely to be caused by the label overlap in a combined CAS/GAT sector. The simulation sector was based on the existing Clacton sector, the one active control position being called Clacton South. The playing area in which the traffic was generated was a square, 256 x 256 nm, centred on 5200N 0100E. Within this area, the displayed exercise area was a circle, radius 64 nm. Initially this was centred on 5200N 0130E, but controllers had the facility to shift the centre of the display as required. The exercise area and routes are shown in figure 1.

Area of Responsibility

10 The exercise sector airspace was assumed to be that part of London Airways east of a line bearing 035°(M) from Heathrow and north of a line joining positions 5127N 0047E (10 nm NE of Detling) and 5123N 0200E (London/Brussels FIR boundary), but including control of traffic on airway B29 and R1S east of the FIR boundary. The triangular section of airspace between airways B29, R1 and the FIR boundary was considered to be part of airway R1, it being assumed that Danger Area D144 was not active.

Sector Routes

11 The standard routes used in the exercise sector were:

a. R1N/UR1N. Eastbounds. Brookmans Park - Clacton - Redfir North.

b. R1S/UR1S. Westbounds. Redfir South - Longsand - Tripod - Ongar

c. B29/UB29. Westbounds. 0230E - Blue Sea - Longsand

d. Gatwick Inbounds. Southend - Detling

e. Gatwick Outbounds. Sevenoaks - Pilgrim - Southend - Clacton

f. UA37. Bluebell - Gabbard

g. Military. Braintree - Southend - Dover

Sector Organisations. The exercise sector operated in two parts:

a. Clacton South. The active simulation position.

b. Clacton North. A peripheral position.

Sector Responsibilities

12 The routes within the exercise sector were allocated as follows:

a. Clacton South.

1 Westbound R1S/UR1S between RFS and ONG.

2 Westbound B29/UB29 between 0230E and LSD.

3 Westbound UA37 between GAB and TRI.

4 Eastbound Gatwick departures between PIL and CLN.

5 Eastbound Joiners between BRA and SND.

Sector Procedures

a. Heathrow Inbounds. Aircraft inbound to Heathrow were to be descended to be at FL 130 at ONG, radar separated and speed controlled. All pilots were briefed to reduce speed to 240 kt or below by 3 mins before ONG.

b. <u>Gatwick Inbounds/Outbounds</u>. Aircraft outbound from Gatwick were routed SEV - PIL - SND - CLN. The agreed level at SND was FL 90 and departing aircraft passed SEV at 3000 ft, climbing to FL 90. Aircraft inbound to Gatwick were routed TRI - SND - DET. The agreed level at SND was FL 100 and aircraft were to be descended to cross SND at this level. All pilots were briefed to reduce speed to 240 kt or below by DET.

c. <u>Joiners</u>. Military aircraft joining at BRA were routed BRA - SND - DVR. The pre-planned joining level was displayed as a cleared level on the flight data display, but the CLN South sector controller was not required to provide separation between joining aircraft and eastbound traffic on R1N. He was, however, required to provide separation between joining aircraft and his own traffic on R1S, and should it be necessary, to hold the joining aircraft to do so at Wethersfield which was established as a holding point.

d. <u>Overflights</u>. For the purpose of the simulation all westbound overflights were transferred to the DVR sector.

13 As the control facilities available for this simulation were limited they could only be fully provided at one exercise control position, Clacton South, and the degree of control which could be exercised in sectors which are peripheral to the Clacton sector was very restricted. It was assumed, however, that a silent handover system was in operation and that transfer of control was effected through the TWD. The other agency position simulated CLN north, MAS, TMA and DVR, but was able to provide only pre-planned data on assigned levels for aircraft joining at BRA and routed to DVR, and assigned and initial cleared levels east of CLN for Gatwick outbounds. The eastbound traffic on R1N was planned to appear as controlled traffic but was not in fact under control. The other agency controller had a LPD but did not have control of the display, it displayed only what the CLN South sector controller had selected. Nor did the other agency controller have a flight data display of the eastbound traffic. He was, however, required to take control of those aircraft which were to join CAS at BRA, from the time they entered the display area until they changed to the airways frequency; and of the Gatwick outbound aircraft after they joined R1N at CLN. In the latter case he was to continue the aircraft climb to the assigned level, maintaining radar separation from other eastbound traffic.

<u>Traffic Samples</u>

14 Six traffic samples of varying density were prepared for the exercises. Those of 100% loading of which there were four, contained approximately 35 aircraft per hour entering the active sector. The remaining two samples were loaded at 75% and 50% of this figure.

OPERATIONS ROOM

15 The following sections (paras 16 to 27) describe in detail the control facilities which were provided in the operations room. The specification for the LPD system was prepared in 1969, and was broadly based on the principles documented in the relevant Linesman/Mediator project authority memoranda and systems characteristics. These reflected the thinking prevailing at that time on post Mediator 1 developments. They called for composite radar data and flight data processing systems with an associated display processor and LPDS. It should be noted that the sections which follow describe the system as it was defined for use in this project. The system is flexible and the facilities used were not exhaustive. A more detailed description of the overall system capability is contained in the ATCEU Memorandum on A Synthetic Advanced Air Traffic Control System at ATCEU, Hurn (TEU/G1/01 dated November 1972). The format of the dynamic flight data display was developed from trials carried out during ATCEU Project EU 145, a Further Evaluation of A dynamic Format for Electronic Data Displays for use by GAT Controllers, Mediator, Post Stage 1 (ATCEU Report No 384) and ATCEU Project EU 179, Evaluation of Colour Displays (ATCEU Report No 396). Figure 2 illustrates the active control position.

LABELLED PLAN DISPLAY

Aircraft Track Categories

16 The LPD was a Cossor 1000 16-in bright monochrome display mounted in a near vertical position. Aircraft displayed on the LPD were divided into two categories, "Own Tracks" and "Tracks of Interest". It was assumed that the overall ATC system would be based on a number of primary and secondary radar heads from which the radar data would be obtained. This data would then be processed, associated with flight plan data, and each aircraft automatically placed in one or more of a number of track categories according to its flight planned intention and the control positions at which it was to be displayed. Aircraft in a particular category, or categories, would then be automatically displayed, or would be available for display, at the appropriate sectors. For the purposes of the simulation all aircraft were categorised as either own tracks or tracks of interest as follows:

a. Own Tracks Own tracks were those tracks under control in the CLN South sector between:

1 RFS, 0230E or GAB, and the point at which transfer to the next sector was made. This applied to aircraft inbound to Heathrow and Gatwick, and to overlights.

2 PIL and the point at which transfer to CLN North was made, for Gatwick outbounds.

3 Wethersfield and the point at which transfer to DVR was made, for aircraft joining at BRA and routed to DVR.

b Tracks of Interest Tracks of interest were those tracks:

1 Assumed to be under control in the CLN North sector.

2 On an adjacent sector enroute to or from the CLN South sector.

3 Which were going to join CAS in the CLN sector.

17 Figure 3 illustrates the distinction between the two categories of tracks in the exercise sector. One constraint imposed upon the simulation was associated with this system of track categorisation and symbology. Since the exercise was restricted to one display and the adjacent sectors could not be fully simulated, the change of track category and symbols could not be linked with any transfer function initiated by an adjacent sector controller. The change for aircraft entering the sector was therefore based on geographic rules. That is to say aircraft which were to enter the CLN South sector appeared firstly as a track of interest, the change to own track being made automatically when the aircraft arrived in the vicinity of a sector entry point. For aircraft leaving the active sector, however, the change was associated with controller input of the transfer sequence on the TWD.

LPD Symbols

18 The following symbols were used on the LPD:

Own Tracks □

Tracks of Interest ▽

Track Direction and Speed 

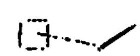
Vector Length indicates speed

0-200 kt 3mm

201-400 kt 6mm

401-600 kt 9mm

Over 600 kt 12mm

Aircraft Turning 

When the computer detected that an aircraft was turning, an additional vector, cranked at 45 deg, was displayed.

B - Up to 4000fpm

C - Up to 6000fpm

D - Over 6000fpm

A leader line at 90 deg to the aircraft track joined the label to the track symbol. This line was 16mm long but could be extended by the controller as one of his overlap resolution techniques.

LPD Controls - Static Functions, Fig 4,5 and 6

20 The layout of the LPD console is shown in fig 4. The controls were divided into static and dynamic functions, and details of these are shown in fig 5 and 6. The static functions were exercised by a simple switch selection and were:

Reset Fig 5 Reset all static functions to a fixed state.

Rolling Ball Fig 5 Switched on the rolling ball and the * marker was then displayed in the centre of the display. Re-operation of this switch repositioned the marker to the centre of the display at any time.

North Marker Fig 5 Inoperative

Met Information Fig 5 Inoperative

Range Selection Fig 5 The diameter of the displayed range was selectable as 64, 128, 192, 256, 384 or 512 nautical miles. The 128 nm range was used throughout the simulation.

Label Format Fig 5 This control gave selection of either Label A or Label B.

Own Aircraft Labels Fig 5 Three buttons to select either:

1 Top Line

2 Bottom Line

3 Both lines

Other Aircraft Labels Fig 5 Three buttons to select either:

1 Top Line

2 Bottom Line

3 Both lines

Operation of this control brought up the labels on the tracks of interest. It was not the same as the quick look facility.

Label Position Fig 6 The aircraft labels were normally positioned 90 deg to left or right of the aircraft track. The aircraft label was connected to the aircraft symbol by a leader line 16mm long. The position was selectable LEFT or RIGHT. Since a parallel track system was operating in the exercise sector, with westbound aircraft on the southerly track, the normal label position was LEFT.

All Labels Tabulated Fig 6 This function placed the labels of all aircraft in the own tracks category in a tabulated area on the LPD. An alpha-numeric pair was then displayed alongside the track symbol to identify the data in the tabulation area. The alpha character identified the row, the numeric the column. When the labels were transferred to the tabular mode, the character size was automatically enlarged one size, unless the size selected was already the largest size.

Quick Look Fig 6 This control over-rode the automatic aircraft category selection. When it was operated all aircraft in the display area were displayed. It was not significant in this simulation.

Character size Fig 6 Choice of three character sizes was provided:

Small (SM) 2½mm, Medium (MED) 3mm and Large (LRGE) 3½mm

LPD Controls - Dynamic Functions Fig 6

21 In addition to the static functions which were exercised through the controls listed in para 20, there were a number of dynamic functions which necessitated identifying an aircraft or a position, or perhaps both, and composing and executing an input message via a small functional keyboard. Not all the functions available were applicable to this simulation; those which were are listed in the following sub-paras. A variety of input devices was available to identify an aircraft or a position to the display processor, the console being fitted with a rolling ball, light pen and alpha-numeric keyboard. One device had to be selected for the simulation since time would not permit an evaluation of input devices, nor was this an objective of the project. In the event, the rolling ball was selected. The basis for this selection is discussed in para 29. The procedures for which the controller used the rolling ball and functional keyboard were:

a Display/Suppress Individual Label To suppress the label of an individual aircraft:

1 Operate the SUPP LABEL function key.

2 Identify the aircraft, and input.

3 Operate the EXE key.

To recall the label the same procedure was adopted but:

3 Operate the CAN key.

b Move Label (1) To move a label a pre-determined amount by extending the leader line:

1 Operate the MOVE LABEL function key.

2 Identify the aircraft, and input.

3 Operate the EXE key.

To return the label to its original position the same procedure but:

3 Operate the CAN key.

The effect of this function was cumulative, further inputs further extended the leader line, up to a maximum of 3 increments of 12mm, making the total length of the leader line 52mm. An attempt to input a fourth increment had the same effect as a CAN input, returning the label to its original position.

c Move Label (2) To move an individual label to any selected point on the display:

1 Operate the MOVE LABEL function key.

2 Identify the aircraft, and input.

3 Identify the new position, and input.

4 Operate the EXE key.

To return the label to its original position the same procedure was adopted but:

3 Operate the CAN key.

d Move Label to Tabular Display To move an individual label to the tabular area:

1 Operate the TAB function key.

2 Identify the aircraft, and input.

3 Operate the EXE key.

To return the label to its original position, the same procedure but:

3 Operate the CAN key.

e Position Tabular Area To determine the location, shape and size of the tabulation area on the LPD:

1 Operate the SET TAB function key.

2 Identify the top lefthand corner position of the required area, and input.

3 Identify the bottom righthand corner position of the required area, and input.

4 Operate the EXE key.

f Rotate Label To re-position a label by rotating the leader line clockwise:

1 Operate the ROT function key.

2 Identify the aircraft, and input.

3 Operate the EXE key.

To return the label to its original position the same procedure but:

4 Operate the CAN key.

As with extending the leader line, the rotate function could be cumulative. The increment of rotation was, however, a pre-exercise parameter. For this simulation, where fixed route traffic predominated, it was decided to make the increment of rotation 180 deg. Thus, the rotate function became an individual LEFT/RIGHT function.

g Shift Display To change the geographic area displayed on the LPD by specifying the geographic position required at the centre of the display:

1 Operate the SHIFT function key.

2 Specify the position to be the centre of the display, and input.

3 Operate the EXE key.

With all the dynamic functions a scribble line was built up at a pre-determined place on the LPD as the message was composed. To show that a position had been recorded a small flashing dot was displayed as part of the input message.

FLIGHT DATA DISPLAY

22 Flight data was presented in colour on an EDD. The Marconi S3016 16 inch colour display was used for this purpose, asked to represent a 14 inch rectangular EDD, a fact which imposed some constraint on its location in the console. The dynamic format in which the data was displayed (see figure 7) gave a scaled presentatic of the longitudinal and vertical distribution of aircraft in the active part of the sector, ie CLN south. The information on each aircraft was displayed, as near as was possible, in the same relative position across the EDD as it was along its track on the LPD. The aircraft data lines were sequenced in ascending order of cleared flight level, each level being separated by a row of dots.

Where two or more aircraft occupied the same cleared flight level they were sequenced vertically in order of sector exit times. Should westbound and eastbound tracks have been cleared at the same flight level, the westbound data was displayed below the eastbound. The colour convention used was that eastbound traffic data was shown in red and westbound in green, while permanent background data such as reporting points was shown in yellow. The data on each aircraft was confined to one line on the EDD and was divided into two sections, static and dynamic.

<u>The Static Section</u>

23 The static data was displayed on the righthand side of the display. It contained:

a An attitude arrow. The direction of flight and the attitude of the aircraft were indicated as follows:

Eastbound in level flight	→
Westbound in level flight	←
Eastbound climbing	↗
Westbound climbing	↖
Eastbound descending	↘
Westbound descending	↙

b The cleared flight level

c The assigned flight level. This was only displayed if it differed from the cleared level. It was then separated from the cleared level by an asterisk.

d Aircraft type. This was normally displayed, but if a speed control function had been entered by the touchwires, and the speed was outside the normal range of cruising TAS of the aircraft type, then the speed took the place of the aircraft type in the static information.

e Destination.

<u>The Dynamic Section</u>

24 The dynamic section was displayed to scale, representing the routes covered by this part of the sector. Estimates were displayed above the reporting points, which were written along the base line of the display. The computer automatically updated the display every 30 secs and the dynamic tag progressed across the display as the aircraft symbol moved across the LPD. The dynamic tag contained:

a The attitude arrow. This now also indicated the position of the aircraft.

b Callsign. Up to seven alpha-numeric characters.

c Either:

1 The SSR code, or

2 The sector to which the aircraft had next to be transferred.

Before the aircraft was associated the SSR code was displayed. Once associated, however, it was the next sector designator which was displayed.

d An over-written estimate. As the tag moved across the display and obliterated an estimate, the estimate appeared at the end of the tag with a space separating it from the next sector designator. This estimate remained for $1\frac{1}{2}$ min and was then automatically erased.

Progress

25 The static and dynamic sections of the aircraft movement data, together with the estimates, appeared four minutes before the aircraft was due to enter the sector. The dynamic tag was positioned next to the estimate at the first reporting point, where it remained stationary until that estimate was reached. The dynamic tag was automatically made to flash at first showing, indicating a new flight plan. The flashing was stopped by TWD operation. The dynamic tag then progressed across the display being automatically updated every 30 secs, until the aircraft was transferred, whereupon the system automatically removed all but the dynamic tag from the display. This dynamic tag continued to progress for a further two minutes and was then automatically cancelled. If the transfer touch was not made, the dynamic tag continued to the edge of the display and the whole data line was made to flash. This continued until the transfer touch was made and the whole data line was then erased.

TOUCHWIRE DISPLAY

26 Controller input to the FDPS was by the TWD. Functions which were exercised by means of the touchwires were to:

a Acknowledge new data, stop the flashing of the dynamic tag, and sequence the callsigns.

b Call down additional flight plan data.

c Update an estimate at a reporting point, although this was automatic once an aircraft was associated.

d Record a change in the rate of climb or descent.

e Input a new cleared level.

f Input a new assigned level.

g Input a new cleared and assigned level where these were the same.

h Input a new cleared and assigned level of FL 130. This was the standard level for traffic inbound to Heathrow.

j Record that a cleared level had been attained. This changed the attitude arrow on the EDD, but this was done automatically once an aircraft was associated and Mode C height information was available.

k Record a change of SSR code.

l Record a change of aircraft speed.

m Transfer to the next sector.

n Cancel the display.

Aircraft callsigns appeared on the TWD 4 mins before the aircraft were due to enter the sector.

Sequence of Events

27 In brief summary, the sequence of events was:

a An aircraft without SSR first appeared on the LPD as a primary target symbol carrying a computer reference number.

b On coding SSR the aircraft was categorised a track of interest, the track symbol changed, and SSR derived information was displayed in label form.

c All active flight plans were sent from the FDPS to the RDPS for association. When the RDPS found a flight plan which agreed with the primary and secondary radar data, association was considered to have taken place. The tolerances for the association window were established as 10 across track and 20 nm along track as a pre-exercise parameter.

d After association the aircraft label contained both SSR derived and Flight Plan derived information.

e After association, updating the FDPS by the TWD automatically updated the FDPS derived data in the aircraft label, eg cleared level.

f After association, RDPS derived information automatically updated data on the EDD, eg attaining level and positional information.

g After association, categorisation to own track was automatic and re-categorisation to track of interest was linked to transfer of control on the TWD.

CONDUCT OF THE SIMULATION

General

28 Two important factors influenced the design and conduct of the simulation. Firstly, it was the first exercise to be carried out at the ATCEU using three computers, Hermes, Euclid and Modular One, linked together to form a composite RDPS, FDPS and Display Processing system. Secondly, only one independent display unit would be available for the exercises. Three main considerations stemmed from factor one.

- a Time would be needed to test the composite system on-line and bring it up to a level of performance acceptable for simulation purposes.
- b The system included a number of input devices from which an arbitrary choice would have to be made, since time would not permit a systematic evaluation of each of these devices.
- c The overall system would be new to the participating controllers to whom it would probably be totally unfamiliar. The amount of training required before valid judgements could be made about its use was, therefore, in question.

The main consideration arising from factor two was that only one subject controller could carry out an exercise at a time. With these considerations in mind, three weeks were allocated for a pilot study and five weeks for the main simulation. The period selected for the main simulation was further divided by allocating four weeks for measured exercises and one week, the middle week, to visitors. Although more would have been desirable, eight subject controllers were selected, each of whom was expected to complete nine hours training and six hours of measured exercises. To complete this total exercise program of 120 hours exercises in four weeks necessitated planning a daily programme running from 0900 hrs to 2200 hrs.

The Pilot Study

29 The pilot study fell into two distinct phases. To bring the system up to a functional level at which simulated ATC could be exercised took two weeks. During the third week the samples were tested and a number of subjective judgements made on the traffic loading, the amount of label overlap occurring, the exercise design, training and measured exercises, and the input devices. It was concluded that the high intensity samples with 35 aircraft per hour entering the active sector provided sufficient label overlap to examine the resolution techniques, that nine hours training would be required before controllers could reasonably be asked to carry out measured exercises, and finally, that the rolling ball should be used as the input device. These judgements were made in the light of experience gained by employing an ATCEU staff controller to go through the sequence of exercises planned for the subject controllers. Additionally, other periods were used for familiarisation with techniques and input devices.

The selection of the rolling ball as the input device was made on the grounds that for these exercises, in this particular task, and in comparison with the other devices as they operated at this console, the rolling ball provided the easiest, quickest, most precise and most positive tool to give to subject controllers who would be using such a device for the first time. Three further pre-exercise parameters were determined at this stage:

a The rolling ball window was reduced to six display units (approx 2.4 nm) square making its use in congested traffic situations very precise.

b The increment of extension of the leader line had been set at 8mm. This was found to be inadequate in the prevailing traffic configuration and was increased to 12 mm.

c The increment of rotation of the leader line had been set at 45 deg. This was found to be inadequate in the prevailing traffic situations and was increased to 180 deg.

These latter points are further discussed in paras 63, 64 and 65.

The Organisations

30 Four organisations were planned for the simulation.
Organisation 1 was meant to represent facilities much as they are at present, with no special facilities to deal with an overlap situation. It was intended to provide a basis for comparison. Organisations 2 and 3 were logical groupings of facilities, intended mainly for training and to ensure that controllers obtained experience in two basic modes of operation, tabular and repositioning. They were not meant to represent alternative proposed systems. Organisation 4 gave controllers complete freedom of action and it was this Organisation which was intended for use in measured exercises in comparison with Organisation 1. In summary, the organisations were:

a <u>Organisation 1</u> No method of repositioning the labels, but the facility to delete either, or both, lines of label data, and the freedom to vector aircraft for ATC purposes or as required to prevent label overlap.

b <u>Organisation 2</u> The freedom to vector aircraft and delete data as in organisation 1, but with the additional facilities to send own aircraft labels, collectively or individually, to a tabular display on the LPD.

c <u>Organisation 3</u> The freedom to vector aircraft and delete data as in organisation 1, but with the additional facilities to reposition individual labels by extending and/or rotating the leader line, selective repositioning, and to suppress individual labels.

d Organisation 4 A combination of organisations 1,2 and 3, ie freedom to use any of the methods which were available.

Exercise Programme

31 The exercise programme was in three phases. Phase one was a period of familiarisation lasting three hours. One hour was devoted to demonstrating the facilities and techniques and two hours spent on exercises in which each facility or technique was systematically employed. During this phase a busy sample was used, but the controller was not required to control the traffic. The aim was for him to become familiar with the working of the LPD, EDD and TWD, and use of the keyboard and rolling ball. Phase two was a period of training of six hours during which full control was exercised in organisations 1,2 and 3. These ensured that limited groups of facilities were available to the controller in each exercise and the traffic loading, initially light, was progressively increased. Phase three was a period of measured exercises using busy samples in organisations 1 and 4; ie the controller had either very limited facilities, or, in comparison, freedom to select whichever facility or group of facilities he had found most effective in the earlier exercises. The complete exercise programme was as follows:

	Period	Subject 1	2	3	4	5	6	7	8
Phase 1	1				Demonstration				
	2				Familiarisation				
	3				Familiarisation				
Phase 2	4	A1	A1	A1	A1	A1	A1	A1	A1
	5	A2	A3	A2	A3	A2	A3	A2	A3
	6	B3	B2	B3	B2	B3	B2	B3	B2
	7	B1	B1	B1	B1	B1	B1	B1	B1
	8	C3	C2	C2	C3	C3	C2	C2	C3
	9	C2	C3	C3	C2	C2	C3	C3	C2
Phase 3	10	D1	E4	F1	D4	E1	F4	D1	E4
	11	E4	F1	D4	F1	D4	E1	F4	D1
	12	F1	D4	E1	E4	F1	D4	E1	F4
	13	D4	E1	F4	D1	E4	F1	D4	E1
	14	E1	F4	D1	F4	D1	E4	F1	D4
	15	F4	D1	E4	E1	F4	D1	E4	F1

Data Recording

32 Time occupancy of RT and telephone channels was recorded in 6 second periods. Aircraft position data was recorded every 10 seconds. All inputs from the aircraft control positions to the Hermes computer were recorded, as were the time and content of all controller inputs via the touchwires and keyboard. These recordings were made for subsequent analysis to determine aircraft separations, changes of the positions of labels relative to the aircraft, and when and where and for how long label overlap occurred.

SUBJECTIVE RESULTS

Questionnaire

33 Each of the eight subjects participating in the simulation filled in a questionnaire at the end of his complete series of exercises. There were forty-five questions altogether and apart from questions on personal details these were divided into a number of substantive areas: viz 'overlap as a problem', 'overcoming overlap', 'appearance of the displays' and 'conduct of the simulation'. Subjects took between about one and two hours to answer all the questions. Not all of the questions yielded responses that were amenable to statistical test, but tests were conducted when appropriate and the results are reported in this section. Non-parametric methods were used and the details of the tests may be found in Siegal (1956). All subjects were male, aged between 29 and 51. All were right-handed. All had at least seven years experience in ATC.

34 Label Overlap as a Problem The controllers were asked how far label overlap posed a problem:

a In their everyday work.

b In the simulation, when no special facilities to prevent or overcome the overlap were provided.

c In the simulation, when special facilities were provided.

Four response categories were available for each part of this question, ranging from 'not at all' through 'slightly' and 'seriously' to 'to an impossible degree'. A Friedman analysis of variance by ranks showed no significant difference in the subjects' answers among the three conditions identified. The 'slightly' category was most frequently used and no one used the category 'to an impossible degree'. The controllers were also asked how frequently label overlap occurred, again under the three conditions identified in sub-paras a, b and c. The four categories for the answer to this question ranged from 'never' through 'occasionally' and 'often' to 'continually'. Again, there were nosignificant differences in the three situations identified in the question. The category 'occasionally' was most frequently used, followed by 'often'. No one said 'never' and only one said 'continually'. The main difficulties reported with label overlap, both in everyday work and in the simulation, were caused by delays in aircraft identification, or a subsequent loss of identification, or loss of height information. One controller, enlarging on this aspect, said that these difficulties caused delays in the movement of aircraft; another said that at times they made it necessary to place restrictions on climbing and descending aircraft.

Overcoming Overlap Problems

35 <u>By Use of the EDD</u> Controllers were asked if they had attempted to overcome label overlap problems by reference to the alternative source of information provided by the flight data display on the EDD. This question applied separately to both types of exercises, those with label overlap facilities and those without. Again, answer categories ranging from 'never' to 'continually' were available. The Wilcoxon matched pairs test showed no significant difference in the categories marked under these two different conditions. The most common response was that reference had been made 'occasionally'. In both cases the question went on the ask if the procedure had been satisfactory. In the case of those exercises where no special facilities had been available, four controllers replied that it had and three that it had not; the remaining subject had already indicated that he never referred to the EDD to resolve overlap problems. There were a number of observations about the EDD, some concerning its location, others about the layout and content. These are dealt with in paras 70-74. Two controllers commented, however, that in a label overlap situation, reference to the EDD could not provide flight level information when aircraft were climbing and descending.

36 <u>General Use of LPD Label Functions</u> Controllers were asked how often they attempted to use the facilities to resolve overlap, again using answer categories ranging from 'never' to 'continually'. Two said that they used the facilities 'occasionally', five that they used them 'often'; the remaining subject preferred to use a vectoring technique. The question went on to ask controllers who had used the facilities how effective they considered them to have been, again using a similar range of response categories. Five said they were 'often' effective, two that they were 'always' so. A further question asked whether controllers used the facilities to prevent overlap occurring, to overcome it after it had occurred, or whether they ignored it. Four controllers said that they used them to prevent overlap, two that they used them to overcome it, and one that he ignored it. The latter was the subject who preferred to use vectoring. The remaining controller tried to prevent overlap occurring, but reverted to using the facilities to overcome overlap in heavy traffic conditions.

37 <u>Effectiveness of Individual Methods</u> A series of questions dealt with each of the methods of preventing or overcoming overlap in turn. The first part of each question asked if the method had been effective, while the second part asked how frequently it had been used. For the first parts of these questions a Cochran Q test was conducted to see if there were differences between the numbers of subjects indicating that each particular method was or was not effective. The differences obtained were not significant and most controllers indicated that each method was effective. There were, however, a number of

qualifying comments. One controller regarded vectoring as being non-effective as he did not consider it an operationally acceptable procedure; another, on the other hand, rated it very highly. Deleting one line of label data was not highly regarded by three of the controllers; one thought it not worthwhile, another that it was unsatisfactory to have mode C height information without identification, and another that it was only satisfactory where partial overlap occurred. Two controllers said that suppressing an individual aircraft label could lead one to forget about the aircraft, though one added that with practice he might find the suppression technique useful on occasions. The tabulation of all labels was thought by one controller to destroy the value of having labels, while another commented that overlap between the alpha-numeric pairs still occurred and that this compounded the problem. All subjects said that the tabulation of individual labels was satisfactory but some commented on the layout of the tabular section and one that the effectiveness of this method varied with the type of flight. One controller commented on extending the leader line, saying that this method was not always effective on its own. On the selective re-positioning of labels, one subject said that he never seemed to have the time to do this when it might have been useful, but added that he might have used the technique to better advantage with more practice. All controllers thought that rotation of the leader line was effective, but one favoured a smaller increment of rotation. The answers to the second part of these questions, how frequently each method was used, were compared using Friedmans analysis of variance by ranks. The value obtained here was significant ($p < .05$).* This was a test of overall significance rather than one capable of distinguishing between different pairs of methods. It was noted, however, that deletion of individual labels appeared to be least frequently used, while the rotation of labels by fixed increments appeared to be most frequently used.

*Note:- The probability value (p) quoted indicates the degree of statistical significance of the results; $p < .01$ represents greater statistical significance than $p < .05$.

38 <u>Ranking of Individual Methods</u> Two questions asked the controllers to rank the methods in order of preference, firstly in terms of how effective they were in preventing overlap, and secondly, in terms of how effective they were in overcoming overlap where this had already occurred. Reasons for the ranking were asked for. Two subjects repeated their answer to the first question in their second, making no distinction between the two cases. Others gave different orders of ranking in each case. In each case the answers were compared using the Friedman analysis of variance. In the first case, that of preventing overlap, no significant differences were found. Several subjects who favoured the rotation of labels said that this was an easy method of re-positioning them. Similar comments were made on extending the leader line. Several ranked vectoring fairly highly, saying that this would be used for ATC purposes anyway. Many also indicated that different methods might suit different traffic situations.

In the second case, that of overcoming overlap, a significant difference was found ($p < .01$). Rotating the label was the most highly ranked technique, tabulating all labels was the least highly ranked. Simplicity and speed of operation were again mentioned in favour of rotating and extending the leader lines. Different views were expressed about vectoring. One controller thought vectoring was the simplest method of overcoming overlap, another thought that it was unsatisfactory.

39 <u>Additional or Re-organised Facilities</u> All controllers were asked for suggestions about re-organising or re-combining the facilities, or for making additions to them. The generally expressed view was that the facilities were adequate in the simulation and would be so in operational practice. One subject considered the facilities to rotate and to re-position labels by extending the leader line or selective re-positioning to be adequate for all cases. Another subject gave a similar view, but added the individual label tabulation facility. Others also suggested that the number of facilities should be reduced, in order to simplify the keyboard and possibly eliminate some of the steps. It was also suggested that aircraft labels should be displayed closer to the aircraft track mark but without a leader line, the latter being displayed only when the label is re-positioned away from the track mark. Another suggestion was that the rotate function should provide a continuous rotation of the label as long as a button was pressed.

40 <u>Application to Other Situations</u> A further question asked the controllers if they considered that their answers to the questions about the effectiveness and the relative merits of the various methods of preventing or overcoming label overlap would apply to situations other than those simulated in the trial. Six considered that they would, two that they would not. Of the latter, one, who had favoured the use of rotation by fixed increments, thought situations might be changed in a sector with a large change of direction in an airway, as labels might be below the airway running east to west but in the airway on traffic running north to south. This point was repeated by the other controller, who had ranked selective repositioning of labels first and rotation by fixed increments second. He also said that he would have liked to have seen aircraft in holding configurations and was not sure about the application to traffic in a TMA.

41 <u>The Organisations</u> Although, as explained in para 30, the organisations used in simulation were not intended to present alternative systems for comparison, controllers were asked to compare each of the organisations with organisation 1, saying for each whether they considered it worse than, about the same as, or better than organisation 1. A Friedman analysis of the variance by ranks was conducted to compare the three organisations 2, 3 and 4, but no significant differences were found. Most commonly, the other organisations were ranked as better than organisation 1.

42 ATC Performance Finally in this section the controllers were asked if they felt that using the facilities to overcome label overlap had detracted from their ATC performance, and also if they were aware of any potentially hazardous situation having arisen from either label overlap or action taken to resolve it. In the first case, five controllers felt that it had detracted from their performance, although one of these thought that this was only an initial reaction, and three thought that it had not. Much of the comment referred to the time taken to operate the facilities, in general and in particular, saying that this took up time that could have been used elsewhere. Operating the facilities was also reported to be a distraction from the rest of the task. One controller mentioned that his performance had been particularly affected when using the all tabular mode. Another observation was that moving a label to separate the labels could give the impression that separation between the aircraft had been achieved. This view was expressed by the controller who had always preferred to use a vectoring technique. In the second case, that of potentially hazardous situations, two were quoted in answer to each part of the question. The incidents quoted during label overlap were, however, mainly due to other causes. In one case the controller concerned felt this to be his failure to cross refer to the EDD, whilst in the other the controller was distracted by the presence of visitors. Of the answers to the question about situations arising from action taken to resolve overlap, one was a general observation that suppressing aircraft labels had tended to make the controllers overlook the aircraft. The other was a report that two aircraft at the same level had come close to each other while the controller was separating the labels, this he thought had partly been due to some lack of realism in the behaviour of the aircraft.

Appearance of the Displays

43 Although some of the displays and their associated controls, contents and format were not strictly subjects of the evaluation, controllers were asked about them and invited to comment on all elements of the overall system.

44 The LPD The quality of the display drew appreciative comment. There was general satisfaction with the size of the LPD alpha-numerics and symbols. It was noted that most controllers preferred the small character size. Some criticism of the symbols came from three controllers. The need for different symbols to distinguish different track categories was questioned, as was the need for the leader line, and the turning symbol, the cranked vector. One thought the leader lines and track lines could be confused, particularly in crossing traffic. The label format was considered satisfactory, but the content was not. The main point brought up here was the need to put the destination in label A, possibly at the expense of the cleared level, which four controllers thought it unnecessary to include. Finally, one controller mentioned the need for some indication that an aircraft had been put on a radar vector. The rolling ball and keyboard are dealt with in para 72 and 73.

45 <u>The EDD</u> All controllers expressed satisfaction with the character and symbol sizes on the EDD. Five made isolated comments or suggestions on the layout and content. One suggestion was that for ease of reference the sector designators should be displayed at the top as well as at the bottom of the display. Another asked for the destination to be coupled with the callsign, another called for the route to be displayed instead of the next sector designator, while another suggested that the callsign be displayed in the static section. One commented on the colour coding, saying that he would have preferred the eastbound traffic to have been displayed in yellow and thought that there was no need for the lines of yellow dots between the flight levels. The need for a symbol to indicate when co-ordination had been effected was also mentioned by one controller. Another criticism was that traffic should appear earlier on the EDD.

46 <u>The TWD</u> There was considerable favourable comment on the TWD. One controller described it as an excellent data system and others made similar comments. More standard inputs were suggested, eg a 'Transfer TMA N' touch and a 'Cleared/Assigned FL 90' touch. One controller found the callsign character sizes too small and would have preferred the wires and callsigns to have been in a vertical sequence. Another questioned the need to display the build-up of an input message in the scribble line in the TWD. This subject made similar comment on the functional Keyboard and LPD.

<u>Controls and Layout</u>

47 <u>The Rolling Ball</u> All controllers found the rolling ball satisfactory, one described it as perfect. One said he would have preferred to have had it under his left hand, while another thought that the window should have been larger.

48 <u>The Functional Keyboard</u> Seven controllers found the use of the functional keyboard satisfactory and six said the same of the combined use of the rolling ball and keyboard. The comment accompanying the negative answers referred to the positioning of the two facilities, suggesting that they should be so positioned that the keyboard and rolling ball could be operated without moving the hand from the rolling ball. Eliminating the execute function and the addition of a control for continuous label rotation was again mentioned. The close proximity of the cancel and execute keys was critised and one subject questioned the need to display the build-up of an input message on the LPD. This subject had made similar comment on the TWD.

49 <u>Any other Comment</u> Controllers were invited to conclude with any comment not already covered in the questionnaire. Four responded, and where relevant their comment has been included in the appropriate section. Apart from these, one controller thought that a controller should not operate a sector with this equipment entirely by himself but should have an assistant or a second controller.

NUMERICAL RESULTS

Static Display Functions

50 . In order to assess the use made by the controllers of the various static display functions, measures were taken of the time spent in each display state - as well as the number of inputs to each keyboard display function. These two quantities are summarised in respect of all subjects and samples, although separately for each organisation, in Table 1.

FUNCTION		Number of Input		Percentage of time spent in each display state	
		Org 1	Org 4	Org 1	Org 4
Label Position	Left Right	0 0	0 0	100 0	100 0
Label Format	Label A Label B	37 37	21 21	99.1 0.9	99.7 0.3
Character Size	Small Medium Large	6 1 1	4 0 0	97.8 0 2.2	94.8 0 5.2
Own Traffic Labels	Both Lines Top Line only Bottom line only	50 88 66	21 21 15	84.2 14.6 1.1	88.9 10.9 0.1
Other Traffic Labels	Both lines Top line only Bottom line only	21 18 19	5 12 10	71.1 20.8 8.1	78.0 19.8 1.6
All Tab	On Off	N/A	5 5	N/A	1.1 98.9

N/A - Not applicable

TABLE 1 - Static Display Functions - Inputs during the measurement period and percentage of time spent in each display state.

It will be seen from the table that the preferred format was as follows:

i. Label Position - Left of A/C relative to direction of flight.

ii. Label format - Label 'A' (Para 19a).

iii. Character size - Small.

iv. Own Traffic Labels - Both Lines.

v. Other Traffic Labels - Both Lines.

vi. All Labels Tabulated (Org 4 only) - Virtually ignored.

The only functions that were used to any extent in the course of an exercise, as opposed to being preset, were the label format, and that selecting the number of lines being displayed on 'own' and 'other' traffic labels. In Org 4, (when the dynamic keyboard functions were available), there was a 60 per cent reduction in the use made of the static functions while an exercise was in progress. It is interesting to note that two of the participants accounted for two-thirds of all the inputs and nearly all of these concerned the number of lines displayed on own and other traffic.

Dynamic Display Functions

51 The dynamic display functions are by their definition only applicable to individual aircraft in Org 4, and therefore their usefulness can only be judged directly by the number of occasions that they were used, and indirectly by the amount of label overlap that existed in Org 4 as compared with Org 1. The total number of occasions that each function was used was as follows:-

Function	Number of times used
Rotate label	82
Move Label - fixed amount	46
Move label - new position	16
Tabulate label -	70
Suppress label -	3

The 'rotate', 'move and 'tabulate' functions were used most frequently. However little inference can be drawn from this since there were large differences between individuals in the number and type of inputs made. For example, one controller made 2 inputs and another 69 - further, in respect of the tabulate label function, 50 of the 70 were made by one individual. No clear pattern therefore emerges apart from the fact that the 'suppress' label function was virtually ignored. It would seem reasonable to conclude that to allow for the normal variation in individual techniques when using display systems, several different methods of operation should be provided - and that the system here simulated proved sufficiently flexible to accommodate individual preferences.

Label Overlap

52 The number of occasions on which label overlap existed between aircraft when both were on the subject's frequency were 939 in Org 1 and 765 in Org 4. Thus the introduction of the dynamic control functions reduced the frequency of label overlap by about 20 percent. In addition to the number of overlaps, the time for which each overlap persisted and the maximum proportion of the label which was observed during this period, (the label overlap ratio) were calculated. No significant difference existed between ORG 1 and ORG 4 in respect of either the label overlap ratio or the duration of label overlap, accordingly they are shown as a combined distribution for both organisations in fig 9. These distributions show that for over 40 percent of the label overlaps less than one tenth of the label was obscured and that over 50 per cent of the overlaps lasted for less than 20 seconds.

Conflicts

53 Loss of standard separation occurred on 89 occasions during the study. These were distributed between subjects and organisations in such a manner that no conclusions can be drawn. An interesting breakdown was possible, however, regarding the correlation between conflicts and label overlap and is given in Table 2. These figures show that on over 70 percent of the occasions when a confliction was recorded there was no label overlap between the respective aircraft.

	Number
Conflicts where neither label was in overlap	65
Conflicts between pairs of aircraft where their labels were just touching	6
Conflicts between pairs of aircraft where their labels were partly obscuring each other	9
Conflicts between pairs of aircraft where their labels were almost totally obscuring each other	4
Conflicts between pairs of aircraft whose labels were not overlapping but were partly obscured by another aircraft	5
Total	89

TABLE 2 Distribution of conflicts

Conclusions

54 a. The introduction of the dynamic control functions reduced the frequency of label overlap by 20 percent. Use of these extra facilities, however, had no effect upon the number of conflictions recorded or the distribution of label overlaps.

b With the exception of the suppress label function which was universally unpopular, the selection of dynamic functions recorded during the exercises did not produce any order of merit. However, it may be concluded that more than one method of resolving label overlap problems should be provided in order to accommodate the normal variations in patterns of route structure and sectorisation, in addition to those of human behaviour and preference.

c It appears likely that there is no correlation between the number of conflictions that occurred during the exercises and the incidence or degree of label overlap.

DISCUSSION

55 Label Overlap as a Problem From the subjective results it appears that label overlap did present problems during the simulation and does so in every day ATC operations, but that in both cases the problem may not be as great as has perhaps been anticipated. At the same time, however, it must be remembered that the simulation exercises were conducted in a CAS/GAT enroute sector environment in which the traffic flow was channelled and in which aircraft manoeuvres were to some extent predictable. Another factor which perhaps reduced the problem in simulation was the very high quality of the Cossor 1000 display used for the LPD. Any degradation of the LPD in operational use might also affect the degree to which the overlap becomes a problem. What is perhaps most significant, however, is that it is thought that the problems caused by overlap do not just affect the controller alone, in the sense that his task is made somewhat more difficult, but that they do have an impact on the overall efficiency of ATC operations.

Overcoming Overlap Problems

56 By use of the EDD It has been thought that controllers might find the alternative source of data provided by the flight data display on the EDD a means of overcoming difficulties caused by label overlap on the LPD. No clear view about this emerges from the subjective results except that most controllers felt that they had occasionally made use of the EDD for this purpose, whether or not the other LPD facilities had been available or not, but they were equally divided as to whether or not this procedure had been satisfactory when in addition there had been no other LPD facilities. In principle, a solution which diverts a controller's attention from the LPD to another display is not to be recommended. Vital information which was not available on the EDD was current flight level information derived from Mode C height readout. Since the

EDD is updated every thirty seconds, and it would detract from the readability of the display to update it more frequently, current Mode C height cannot be displayed. The EDD is further discussed in para 70 but it is thought that it is not a solution to the label overlap problem and that it is not true to say that since an alternative source of certain data is available, overlap on the LPD can be ignored.

57 General use of the LPD Facilities One controller preferred to employ vectoring techniques to resolve overlap problems, whilst the majority of the remainder made frequent use of the various resolution facilities in those organisations which permitted them to do so. In general terms the participants considered that the organisations which had afforded the resolution functions were superior to those which had not. This, they felt had been because their efforts at label overlap resolution had been successful which in turn had contributed to easier solution of the ATC problems. One may thus conclude that the LPD facilities were used when the option to do so was there, that they were effective, and that a system with some facilities was better than one without. It would seem likely that controllers would prefer to prevent the overlap occurring, keeping the data with which they are interested clearly displayed, rather than overcoming overlap which has already occurred. This is not always possible, however, due to pressure of work. Figure 8 shows a view of the LPD when some of the label functions have been exercised. Reading from right to left along B29 and R1S it can be seen that the first aircraft, BE721, is still a track of interest, not having entered the sector. Only the top data line has been selected for tracks of interest. With the next aircraft, OS 453, the leader line has been rotated through 180 deg, whilst with the next, OOSCA, it has been extended. JL447 is displayed normally, but with the low flying GBBAW the label data has been transferred to a tabular display and the alpha-numeric pair A1 remains with the track mark. BE771 and SK505 are displayed normally. There are five aircraft in the vicinity of Ongar. BE511 and EC744 are rotated, PA103 is extended, N264FE is normal and AI 109 has been selectively repositioned.

Effectiveness of Individual Method

58 Vectoring The controllers considered that they had only rarely used vectoring techniques to resolve label overlap problems, preferring to reserve the procedure for the higher priority task of aircraft separation or as one controller put it 'to prevent aircraft overlap'!. Most felt that on principle the fewer aircraft on radar vectors the better, and in any case with the advent of more accurate navigation aids coupled with automatic conflict detection and resolution, permitting reduced separation standards, controllers would have less freedom to vector aircraft anyway. On balance then the general view that vectoring alone is not a suitable solution seems reasonable.

59 Deleting One Line of Label Data Deleting one line of label data is not very effective in resolving overlap, and even where it does do so, it is only at the expense of losing a great deal of data, since the operatinn of this facility affects all aircraft in a particular track category. This is a disadvantage

when applied to own traffic. On the other hand, however, it can be used with some effect to cut down the amount of unwanted or unessential data on the display if used in the 'other aircraft' mode. For example, in this particular case the active sector controller might be interested in the levels of eastbound traffic but not necessarily the identification. Fig 8 shows this facility in use although in this case it is the top line which has been selected. This facility should be retained.

60 <u>Suppress Label Function</u> This facility suppressing an individual aircraft label was not popular. It can be effective in preventing or overcoming label overlap but again, only at the expense of losing the aircraft identification and other data. These can only be recovered by a further input sequence using the rolling ball and keyboard. There seems little merit to this facility when, by using the similar TAB LABEL input sequence, the data can be put in a tabular mode and the aircraft identity maintained. This facility need not be retained.

61 <u>The ALL TAB Function</u> Transferring the label data of all own aircraft to a tabular mode was not popular. Obviously it is most effective in preventing or overcoming label overlap, because it removes all the labels in that particular category. But this does not necessarily help the controller in the performance of his ATC task, in fact it almost certainly does not. He may still have an overlap problem with the overlap of the alpha-numeric pairs, and has the problem of cross referring from one type of display to another. This finding seems to run counter to the results of EU146 when reversion to a tabular display was found to be the most effective organisation but this was when used in an automatic mode in comparison with a different set of automatic alternatives. Furthermore, the controllers were not exercising control of the traffic. It must be admitted, however, that in the current simulation there was no attempt to optimise the layout of the tabular display. Controllers were able to set the tabulated area so that the aircraft were displayed in one, two or three columns, whichever they preferred; the computer then automatically displayed the data in the space which the controller had delineated. The computer did not, however, sequence the aircraft data in any meaningful ATC manner. There is little merit in the tabular mode in its present form. There may, however, be merit in a tabular mode automatically associated with some other function or category of aircraft and this is further discussed in the next paragraph.

62 <u>The TAB LABEL Function</u> The facility to tabulate individual labels is useful. In the enroute sector its application is limited and best suited to particular relatively infrequent classes of traffic such as low slow aircraft at levels below the standard inbound flight levels, or high fast overflights. Used in this way it can be used to prevent overlap without the problem of cross referring to another display becoming disproportionate. Its use may, however, result in some late transfers as there may be a tendency for a controller to overlook transferring an aircraft without a label. It is thought that this mode is best suited to a holding configuration, when transfer of the data to a tabular display could be associated with a TWD input function and the data sorted by the computer into a logical ATC format and sequence. This facility should be retained.

63 <u>The MOVE LABEL Function (1)</u> The facility to reposition a label by one or more extensions of the leader line is very useful. For example, it can be used to prevent overlap by a single or perhaps double extension in the case of a slow aircraft as it enters the sector. It is most effective, of course, along a single route. Where tracks converge it is not always useful, only being effective on one of the tracks. On the other hand, it can be used in conjunction with the rotate label function. The increments of extension can be suited to the traffic configuration. On the display of a sector with a predominantly east/west flow, the increment need not be as great as that on a display with a mainly north/south flow. This is because the alignment of the label is always the same, with the longer side running east/west and the shorter side north/south. There is a case for shortening the leader line in order to make the combined track mark, velocity vector and label data a more compact entity, and perhaps, for simultaneously dispensing with the leader line except when the label has been repositioned. To prevent confusion between leader lines and velocity vectors the leader line can be displayed at a lower brilliance level than the track mark, velocity vector and label data. Video map data could also be displayed at a lower brilliance level. This would also help to resolve overlap between labels and static data.

64 <u>The MOVE LABEL Function (2)</u> In principle, this function which allows a controller to re-position a label anywhere on the display that he wishes, is an extremely flexible facility. In practice, however, it appeared that controllers did not find any great call for this degree of flexibility. Moreover, performing this function required an additional step in the input message, that of specifying the new position with the rolling ball and inputting that position. Any additional step of this nature diminishes the value of a function as far as the controller is concerned. In general, therefore, controllers did not employ this facility to any great extent. What was noted, however, was that where it was consistently used, the controller concerned did not always position the label further away from the track mark, but frequently used the facility to shorten the leader line and tuck the label in closer to the track mark. It is thought that the time spent on this simulation did not allow controllers to fully appreciate and explore the possibilities of this very flexible function, that they took more quickly to the rotate and extend functions where results were predictable and the execution a little simpler, but that with practice over a longer period some would undoubtedly develop techniques using this facility.

65 <u>The ROTATE LABEL Function</u> This facility was the most frequently used. As with the leader line extension the technique is most effective on a single route. Where tracks converge it is not always effective, but again, can be used in conjunction with the extend function. The increment of rotation was a pre-exercise parameter. The increment of 180 deg was selected after the pilot study had shown that in this particular traffic configuration the most common requirement was to rotate the label though 180 deg to position it on the opposite side of track. The increments can be varied, however, and each display have an increment of rotation best suited to the traffic

configuration in that sector. Possible combination and modification to the rotate and extend functions are further discussed in para 73.

66 <u>Additional or Re-organised Facilities</u> In essence, the need is to reduce the number of facilities, eliminating those of little value, and to simplify the operation of the remainder. The facilities which can be dispensed with are label suppression and tabulation of all labels, in its present form. Facilities which should be retained are the data line selection, rotation and extension of the leader line, tabulation of individual labels and selective repositioning of an individual label. Additionally, tabular mode associated with a TWD input should be considered . See paragraph 62. It was often found that the simple rotation or extension of a leader line was not enough on its own and that frequently these functions need to be used in combination. Simple operation of the rolling ball and keyboard was called for, requiring fewer steps in the input sequence, and so arranged that the controller could operate the rolling ball and keyboard without taking his attention from the LPD. The way the reduced facilities should be re-designed in terms of the rolling ball and keyboard are discussed in para 72.

67 <u>Application to Other Situations</u> The general opinion was that the facilities provided would be suitable for application to other situations. It is thought that the reservations made regarding the increments of rotation, the holding configuration, and traffic in the TMA would be largely catered for if the facilities are re-designed along the lines advocated in para 73.

68 <u>ATC Performance</u> About half of the participating controllers felt that using the label overlap facilities detracted from the performance of their other ATC tasks. To what extent lack of familiarity with the overall system, and ergonomic factors, influenced this opinion is difficult to judge. All the displays were new and unfamiliar. The layout of the console was not ideal. In the case of the coloured EDD, a constraint was imposed by the size of the Marconi S3016 colour display which was masked in order to simulate a 14" EDD in colour. Due to its size this display could not be located other than in the top right position as seen in fig 2. This position was far from ideal and undoubtedly contributed to the difficulties of cross referring from one display to another. Again, it had been thought that a more suitable position for the TWD might be below the LPD, but this position was not available on the console as provision had also been made for an alpha-numeric keyboard. These ergonomic considerations, plus the limited practice during such a short period of operation may have contributed to this general comment where it was expressed. Not all controllers did express this view, of course, and among those who did, one said he felt it was an initial impression, and another qualified his view by remarking that the label overlap function which had detracted from his overall performance had been the all tabular display. Time taken to operate the facilities was another factor mentioned under this heading and, as noted in para 66 speed and simplicity are essential in the operation of these processed display functions. The observation that separating labels may give the impression that aircraft have been separated must be noted,

particularly since one controller reported an incident which may possibly have been partly attributable to such a tendency.

Appearance of the Displays

69 The LPD Some of the points raised were outside the scope of the simulation. For example, the need for separate symbols for different aircraft track categories was questioned, but the scale of the simulation was such that no judgement can be made on a point such as this. As noted in para 63 there does seen a case for shortening the leader line and since this is an adjustment which can be easily made and varied it is suggested that something of the order of 4 mm be tried. This point has already been mentioned in para 63 together with variation of the display brilliance levels. Two other valid comments were made in this section. Firstly, the need to include the destination in the label format which is most commonly displayed, in this case Label A. There does seem to be some opinion that this could be done at the expense of dispensing with the cleared level without detracting from the overall efficiency. Secondly, there is a need to indicate when an aircraft has been placed on a radar vector. This could be done by an input to the FDPS by the TWD and the fact recorded on either the EDD or LPD, or perhaps both. Treating the LPD as the main data display, it is suggested that this information be displayed on the LPD by the addition of a symbol V to the aircraft track label, or a change of the track vector symbol from a solid line to track history dots or vice versa.

70 The EDD There was little choice for the position of the EDD and that in which it was placed was not thought to be ideal. Comment on the positioning of the displays is dealt with in para 74. Another adverse factor was the difference in the type of display between the EDD and LPD. The LPD was a bright display, easily viewed in relatively high ambient light levels. The EDD could also be viewed under similar conditions but for technial reasons the display was not as crisp and well defined as the LPD. Nevertheless, there was no adverse comment on the symbols and character sizes. Most of the critical comment concerned the concept, content and layout of the dynamic display. EDD formats for GAT controllers were the subject of an earlier evaluation, ATCEU Project EU145, and the dynamic format was recommended as a result of these trials. Further comment, arising from this current simulation, where the EDD is of peripheral interest, must therefore be treated with some reserve. An exception to this is perhaps the point, discernible from the LPD comment as well, that aircraft identity and destination do need to be more intimately linked. Although this information was displayed on both the EDD and the LPD, and for that matter was available on the TWD, there was still a tendency for controllers to overlook the fact. It is suggested that the callsign be displayed in the static section in addition to the dynamic section, once association has taken place. This supports the suggestion made more recently in ATCEU Report No 396 on the Evaluation of Colour Displays. Before association has taken place the SSR code may be displayed in its place in the static section. It is further suggested that the destination be displayed in its place in the static section. It is further suggested that the destination be displayed in the dynamic section against the callsign, in place of the next sector designator. A further suggestion is that the route designators which form part of the

background data on the display be shown at the top as well as at the bottom of the display. Another, that a symbol be introduced to indicate when coordination had been effected. The use of colour drew no response apart from that one controller who stated that he would have preferred the eastbound traffic to have been displayed in yellow, and would have dispensed with the yellow dots separating the different flight levels. No explanation accompanied these comments however, and since this was an exercise in which the traffic under control was mainly uni-directional and other visual codes evidenced the traffic direction, it is questionable whether the use of the coloured EDD had much bearing on the results of this particular simulation. Another point, on which no comment was made in this section although it had been mentioned earlier in connection with the EDD, was the introduction of Mode C height information on the EDD once association has taken place.

71 Touchwire Display The TWD was liked by all controllers. Their suggestion that more standard inputs particular to the sector concerned be incorporated would present no difficulty, It has always been noted, of course, that controllers do take some time to find the required callsign on the TWD reset picture during peak periods, when even an additional page of callsigns may be required. It is unfortunately axiomatic that scanning time increases proportionately to the number of aircraft, and hence the workload increases. However, there are means of alleviating the situation. One suggestion made in the earlier evaluation of colour displays was the use of colour coding similar to that used on the EDD. In a mainly uni-directional traffic flow this would not be very effective. Another suggestion is that callsigns be automatically sequenced in logical groups, eg major users, state airlines or independents, etc. In any event, the scanning time would seem to be a small penalty to pay for the ease and rapidity with which the subsequent input messages are compiled. Indeed, if controllers had had to memorise the format and content of a number of input messages, as with a conventional keyboard, it is doubtful whether a simulation of this nature could have been mounted in the time available.

Control Layout

72 All controllers found the rolling ball satisfactory, but there was a minority view that the rolling ball window was too large. This, however, is an easily varied parameter. The case for the small window is that it improves the precision of the device, reduces the risk of picking up more than one aircraft in the window and of the wrong aircraft identity being input to the computer. It is thought that a small window should be used and that it does not introduce too much difficulty as long as the controllers' actions are related to the correct input sequence. Alternatively, the computer can be programmed to recognise either input message format, so that the rolling ball input could be made first and the function second. It is still true of course, that the display may update a fraction of a second before the controller inputs the rolling ball position and thereby misses the aircraft, but on balance it is thought that the advantage of the small window in dense traffic conditions outweighs this disadvantage.

73 Although there was little specific criticism of the rolling ball and functional keyboard, a general theme throughout the subjective comment was the call for speed and simplicity of operation. If it is accepted that the label functions, apart from the selections associated with the categories of track and lines of data, be limited to extending and rotating leader lines, selective repositioning and individual tabulation, then the layouts illustrated in figure 9 are offered for consideration. The increment of rotation is 45 degs. The rotation is selective, not cumulative, the total angle of rotation being selected by touch on the keyboard. The other functional keys, rolling ball position input key, cancel and execute keys are positioned in identifiable positions in relation to the rolling ball.

Console Layout

74 Most controllers criticsed the console layout. As noted in para 68 constraints had been imposed by the size of the units used. Nevertheless, even allowing for this, the points they made remain valid. In principle, it is the time taken in cross referring from one display to another which is criticised. The theme emerging is that displays should be as close to each other as possible and one layout suggested was that TWD, LPD and EDD should be positioned one above the other. Although this layout would not be satisfactory ergonomically, some improved layout with the existing facilities could be devised. A further development along this line is that LPD and EDD should be combined in one display. From the controller point of view there is no longer any reason why his plan display should be circular in shape. One rectangular display could display both labelled plan data and the flight data which has hitherto been displayed on the separate EDD. Alternatively if two displays are needed to provide an element of redundancy, two similar rectangular displays could be used.

TOUCH SENSITIVE DIGITIZER

75 The Touch Sensitive Digitizer (TSD) is an input device which offers an alternative to keyboards, lightpens, rolling balls or touchwires, and provides a direct interface between the controller and the computer. The unit is an X - Y position encoder or digitizer, which senses the position of a controller's finger or of a passive stylus on the face of the CRT, and provides a direct digital input to the computer. The digitizing area is a transparent plate glass screen over the face of the CRT. Its operation is based on pulse echo-ranging techniques using HF elastic surface waves, 72 transducers being located along two adjacent sides of the glass screen, 36 to a side, to provide the X - Y arrays. They are alternatively connected to a transmit and receive circuit. The time lapse between the transmission of the 4 MHz pulse modulated elastic surface wave, and the reception of the relfected pulse from any object on the glass, provides a highly accurate indication of the distance of the object or probe on the glass. The X and Y transducer arrays are activated alternatively to prevent mutual interference.

76 The TSD was not part of the main simulation. Since it was available at the unit however, it was fitted over the CRT at the peripheral console. Areas of the display were programmed to provide the same functions as were available by use of the static controls, functional keyboard and rolling ball at the other LPD. The functions were then exercised by the controller touching the selected aircraft track mark and the selected function and execute touches on the face of the CRT. The trial installation is illustrated in figure 9.

77 No special time could be allocated for an evaluation of the TSD but the third week of the simulation was set aside for visitors to the main project. Two controllers who had completed their measured exercises during the second week stayed over to demonstrate the LPD system to the visitors in the third week. The demonstration programme allowed a certain amount of spare time, and advantage was taken of this opportunity to carry out a limited number of exercises using the TSD. The device was also demonstrated to the visitors.

78 No attempt had been made to optimise the positioning or grouping of the functional touches on the TSD, the aim was rather to demonstrate the principle. Therefore many of the controllers' comments, though valid, were predictable, but one suggestion perhaps worthy of note was that some sterile area should be left between adjacent touches.

79 The sensitivity of the device was not uniform over all the surface area, and in some areas it was difficult to get a response. Again, this deficiency had already been appreciated and will need correcting before any proper evaluation can be continued. First impressions are that the controllers found the TSD quicker and easier to use than the rolling ball, but less positive and subject to more errors, particularly in dense traffic conditions. It is emphasised that these are first impressions based on the limited use of an installation with known deficiencies. One firm comment, however, is that the human finger is a very coarse instrument with which to discriminate between close track marks in dense traffic conditions. The TSD must be sensitive to a much finer stylus if it is to be used with anything approaching the discrimination of the rolling ball.

ACKNOWLEDGEMENTS

80 Grateful thanks are accorded to the Regional Inspector Southern Division for the loan of experienced staff to participate as subjects, to the eight controllers concerned for their co-operation and valuable comments, and to all those who assisted in the preparation and running of the trials.

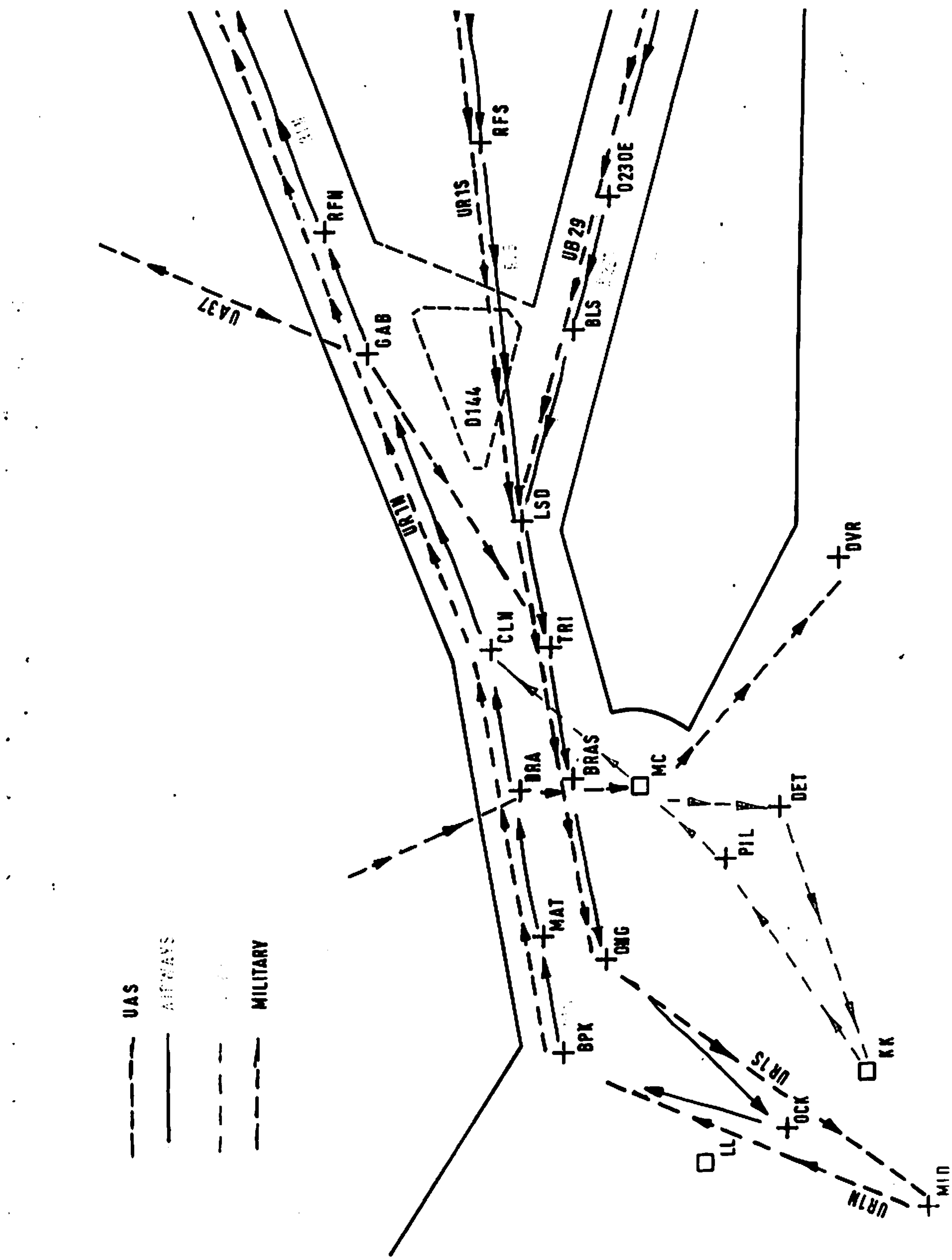


FIG 1 EXERCISE ROUTE STRUCTURE

Fig 2 Trials Console

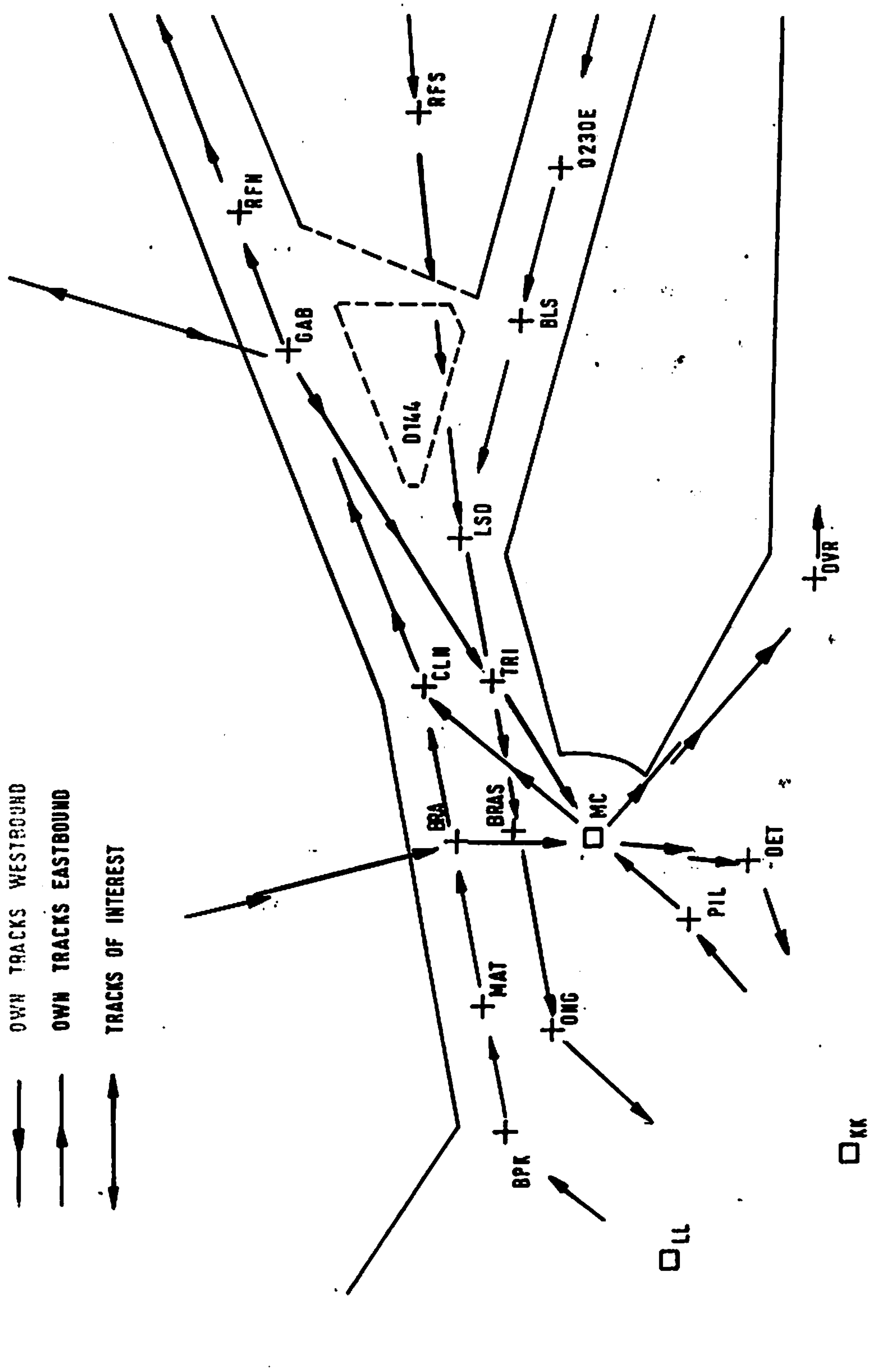


Fig 3 Aircraft Track Categories

CLACTON SOUTH

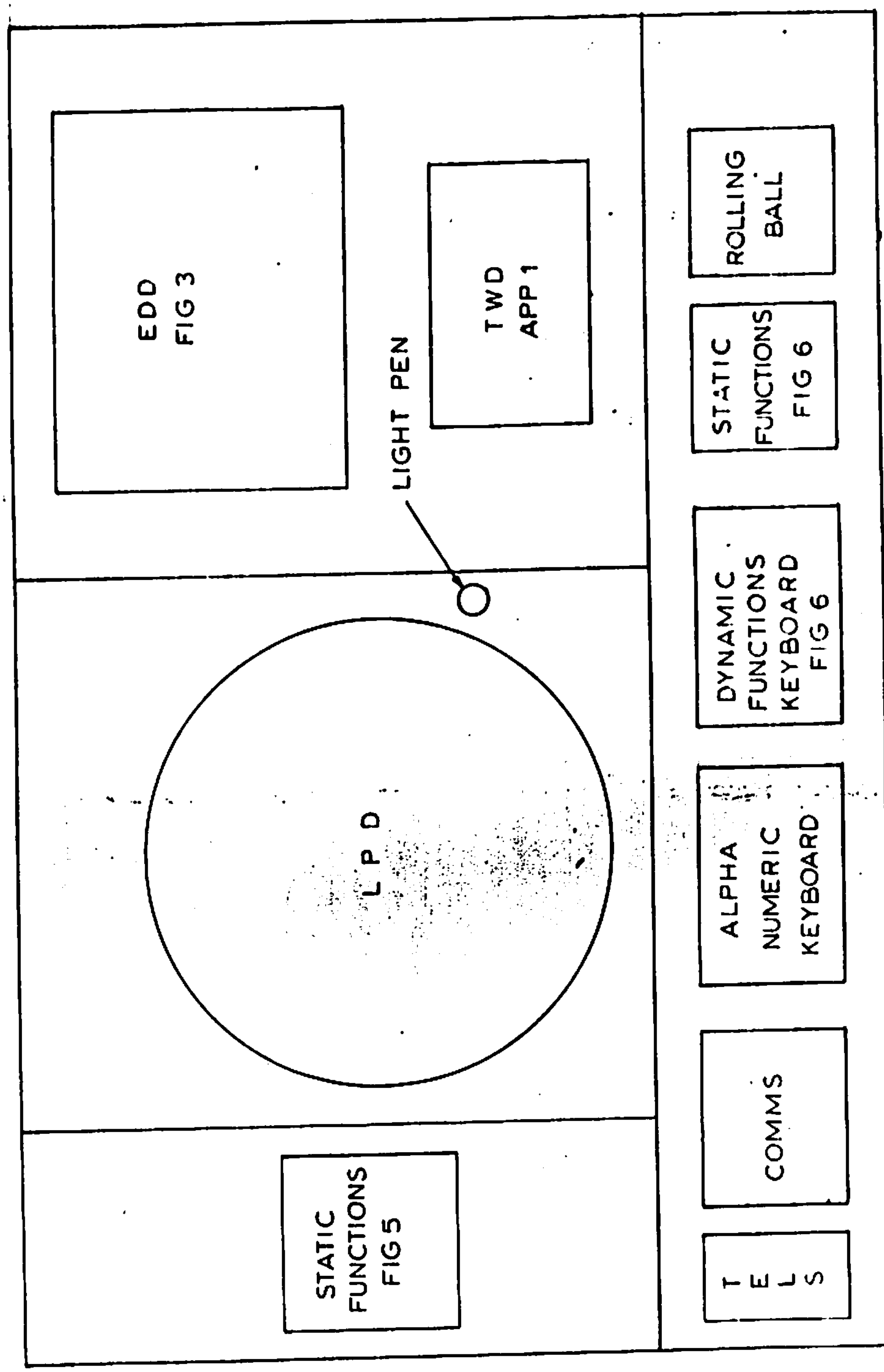


FIG 4 LPD SYSTEM - CONSOLE LAYOUT

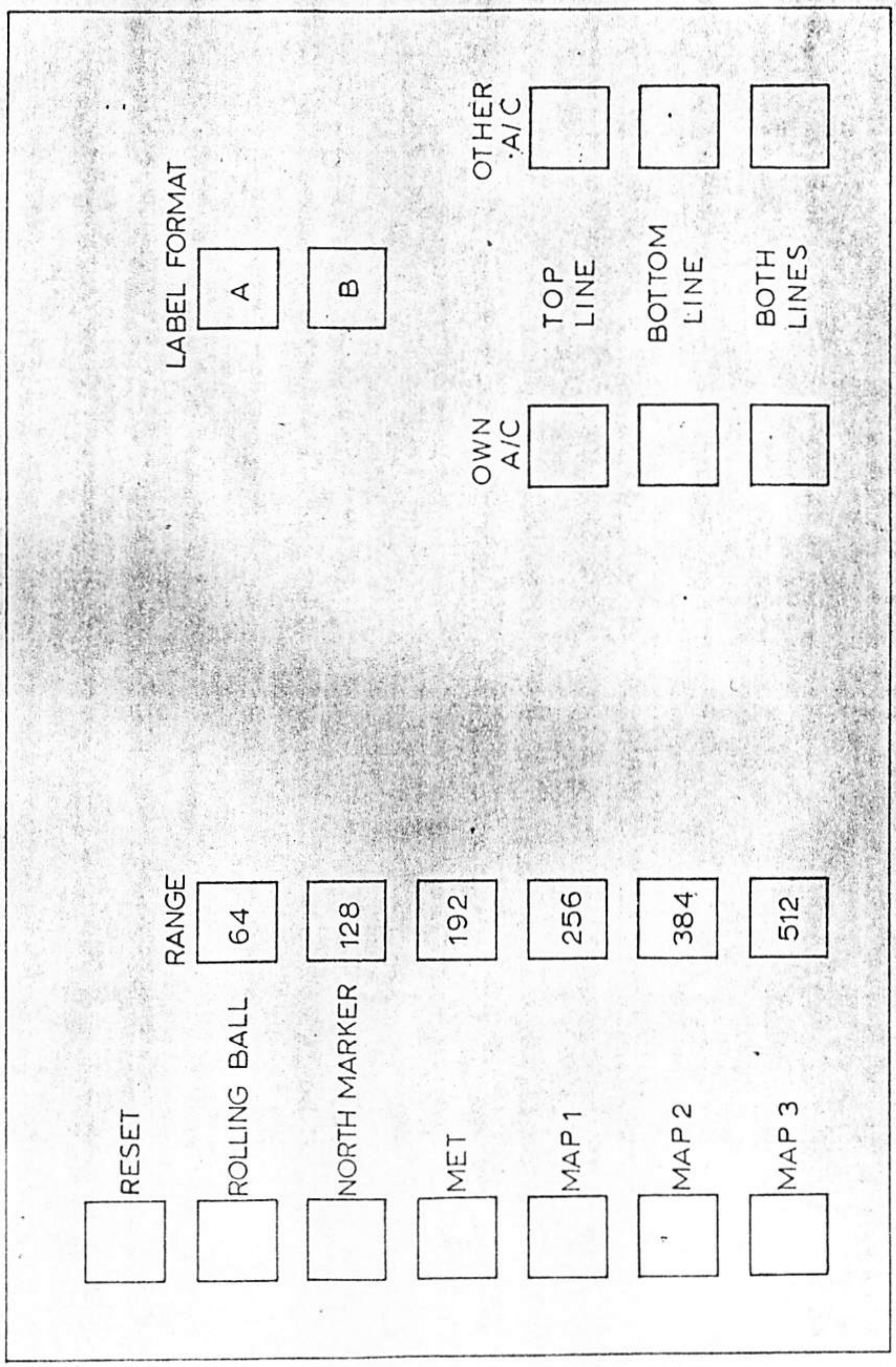


FIG 5 LPD STATIC FUNCTIONS (1)

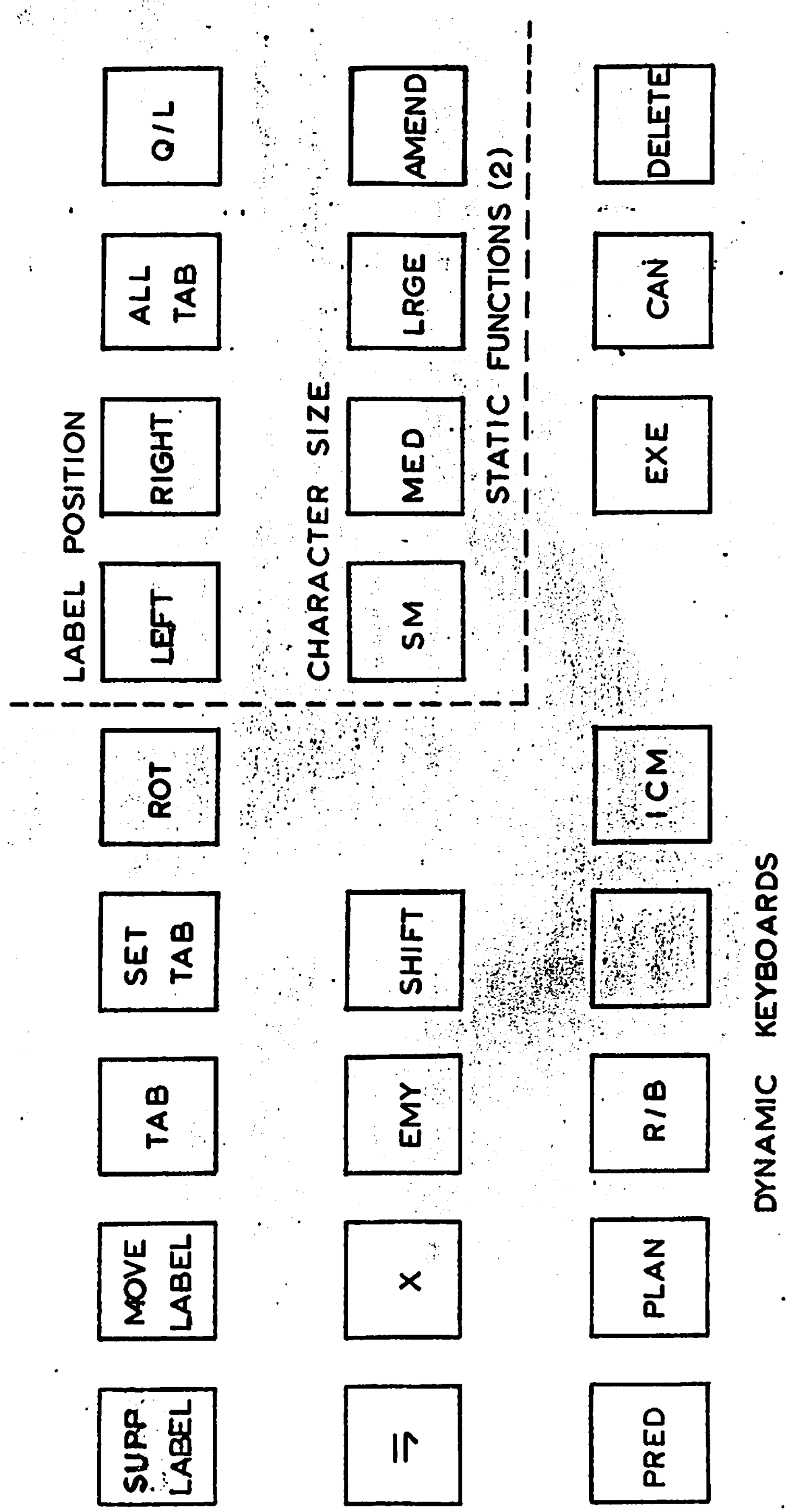


FIG 6 LPD DYNAMIC KEYBOARD & STATIC FUNCTIONS (2)

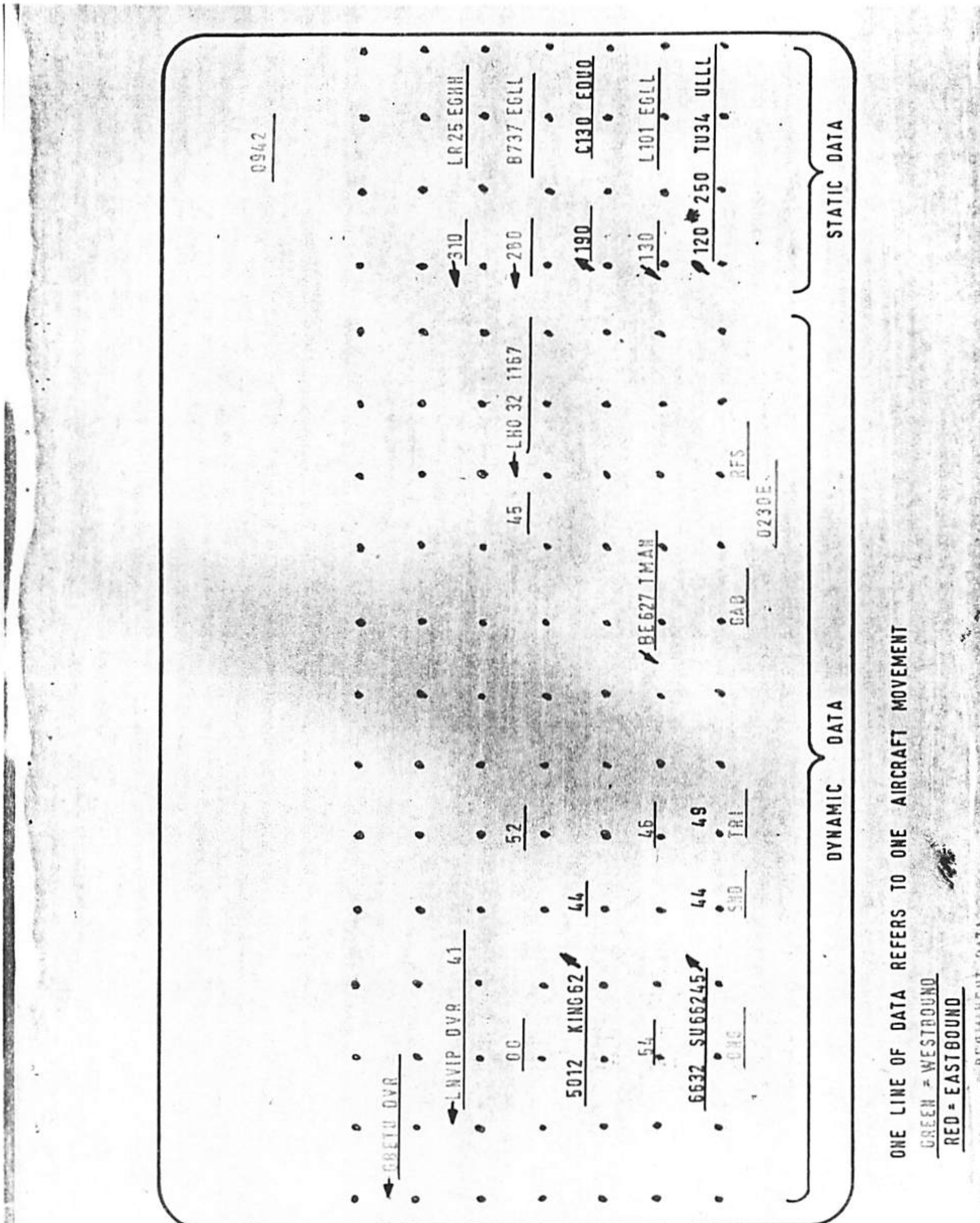


FIG 7 FLIGHT DATA DISPLAY

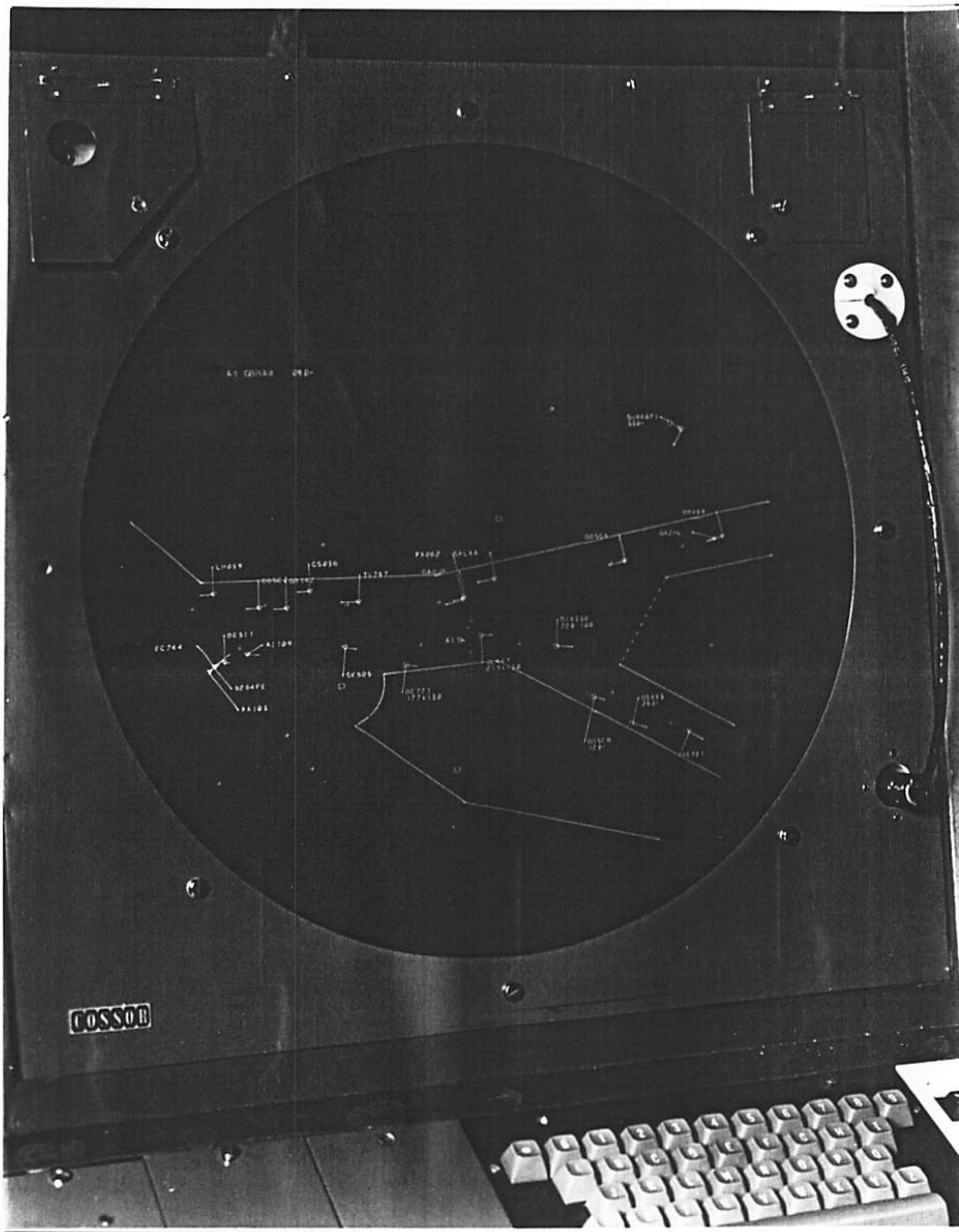


Fig 8 Label Functions

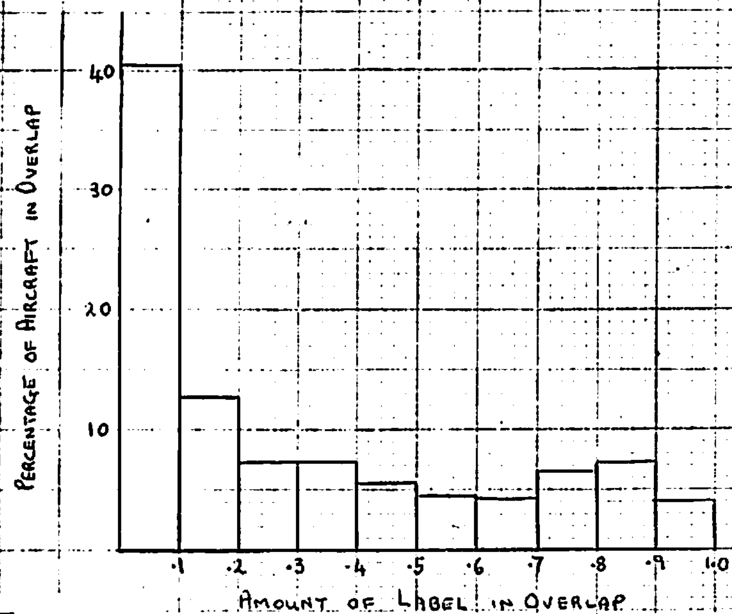


Fig 9a Distribution of Label Overlap Ratios for Orgs 1 & 4 Combined

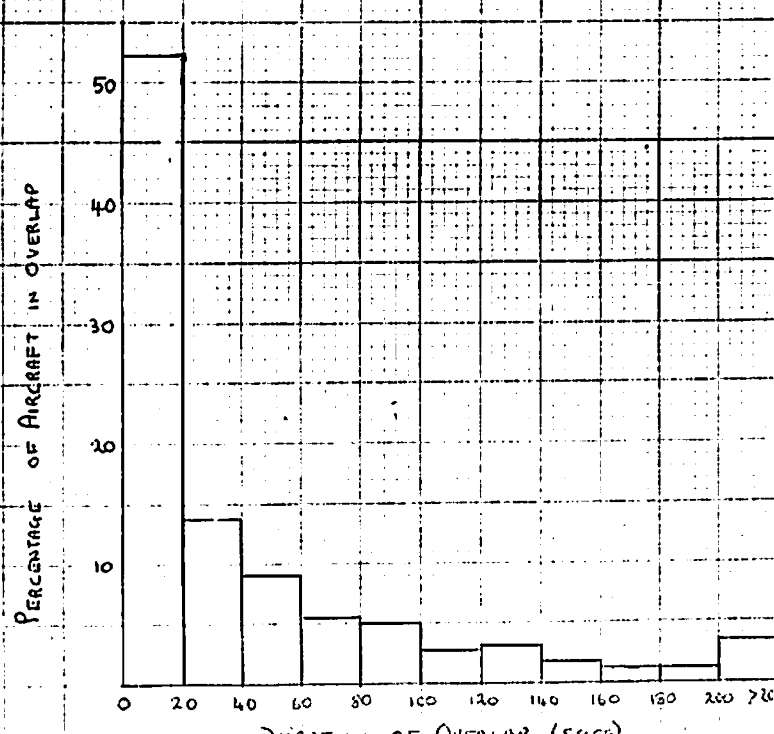


Fig 9b Distribution of Duration of Label Overlap for Orgs 1 & 4 Combined

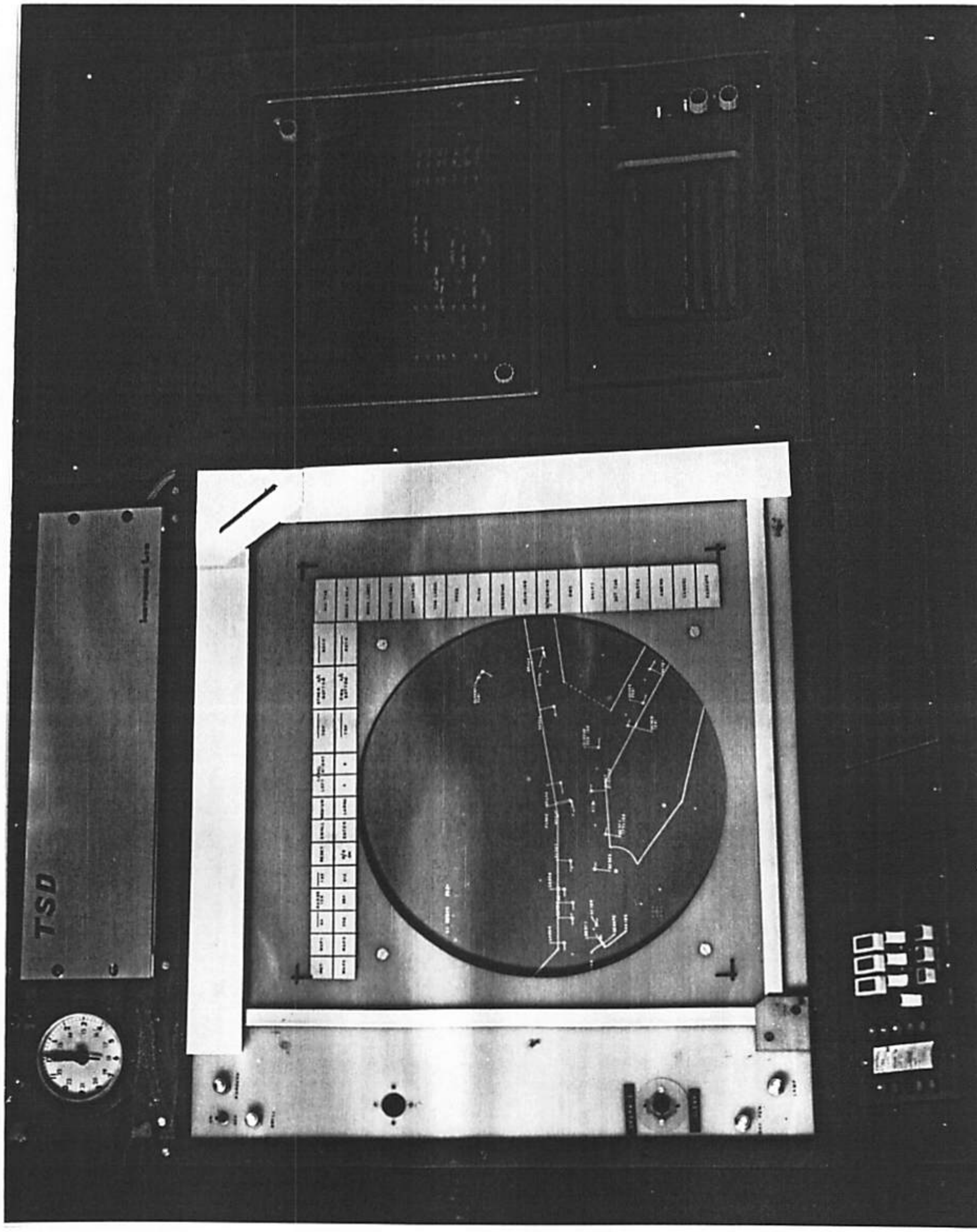


Fig 10 Touch Sensitive Digitizer