TECHNICAL DEVELOPMENT REPORT NO. 318

SIMULATION TESTS OF THE NORTHROP SKY SCREEN AS AN AIR TRAFFIC CONTROL DISPLAY

FOR LIMITED DISTRIBUTION

by

Clair M. Anderson
Thomas E. Armour
Addison B. Johnson
Donald S. Schlots

Navigation Aids Evaluation Division

July 1957

Prepared for
The Air Navigation Development Board
Under
Project No. 6.7

by

CIVIL AERONAUTICS ADMINISTRATION

TECHNICAL DEVELOPMENT CENTER
INDIANAPOLIS 21, INDIANA

SIMULATION TESTS OF THE
NORTHROP SKY SCREEN AS AN AIR TRAFFIC CONTROL DISPLAY

SUMMARY

This report describes the testing of the Northrop Sky Screen to determine its applicability to the present air route traffic control system. The tests were conducted using the dynamic air traffic simulator at the CAA Technical Development Center, Indianapolis, Indiana.

The Northrop Sky Screen is a pictorial display originally developed for air defense use. It combines a radar plan-position indicator, a mirrored plotting surface, and a projection unit to provide a large, bright, filtered display of manually-tracked and identified radar targets.

The tests indicated that the display could not always show the actual spacing between aircraft targets. This was due to the large size of the target markers in relation to the scale of the display, and also to the fact that the markers were moved intermittently in relatively large jumps. When target markers were close together, it was not safe to employ radar separation based on the information displayed on the Sky Screen. A large amount of coordination was required because the trackers were located in a position remote from the rest of the control crew.

Tests showed that a single tracker could track efficiently about 15 targets, under ideal conditions. It was impossible for trackers to maintain positive identity on Instrument Flight Rules flights when large numbers of non-Instrument Flight Rules aircraft were also flying the airways.

For these reasons, it was concluded that the Northrop Sky Screen is not suitable for integration into the present air traffic control system.

INTRODUCTION

Northrop Anaheim, a division of Northrop Aircraft, Inc., manufactures the Sky Screen from prototypes developed by the United States Air Force Rome Air Development Center. Sky Screen was developed as a high-speed filtering and plotting system for tracking aircraft and missiles, and has applications in Air Defense Command (ADC) missions.

In December 1956, Northrop Anaheim provided the Technical Development Center with a Sky Screen display on a loan basis for test and evaluation under Air Navigation Development Board (ANDB) Project No. 6.7. The objective of this test program was to determine the desirability of integrating the Sky Screen into the present air traffic control system. Tests were begun on January 18, 1957.

This report describes tests of various methods of integrating the Sky Screen with the flight progress boards of the type presently used in the air route traffic control centers in this country.

EQUIPMENT

The heart of the Sky Screen display is the plotting-projector unit which is shown in Fig. 1. Figure 2 shows the optical system of this unit. Normally a plan-position indicator (PPI) scope is located at the top of the projection unit, and the image is reflected from a beam-splitter plate to the operator, while the marker chip is seen through the beam-splitter plate. The marker chip can be positioned manually so as to appear superimposed on the radar blip. Light reflected from the colored surface of the marker chip is projected through a variable magnification and focusing lens system onto a translucent screen. The screen is viewed from the side opposite the projection unit as shown in Fig. 3. A standard slide projector is used to project a map of the area on the translucent screen.

As shown in Fig. 4, the marker chip has an arrow pattern and a number on each of four sides, each side reflecting a different color. The numbers are engraved and filled with a fluorescent pigment having the same color as the reflecting mirror on the opposite side. Thus, the color that fluoresces on the top of the chip indicates the color being projected onto the screen.

For the simulation tests, the Sky Screen display was supplemented by two flight progress boards.

TEST PROCEDURES

Traffic Samples.

Three traffic samples of various densities and lengths were used for the simulation tests. These samples were made up of flights operating in the Indianapolis and Terre Haute sectors of the Indianapolis Air Route Traffic Control Center.

Sample I had a density of 30 aircraft per hour and was 2 hours in length. Sample II had a density of 40 aircraft per hour and was 3 hours in length. Sample III had a density of 40 aircraft per hour and was 2 hours in length. In Sample III aircraft were confined deliberately to six altitude levels only, in order to provide many more situations requiring the use of radar separation.

Use of Color.

The target marker chips were colored red, white, yellow, or green. In the majority of the tests, red was used whenever the trackers lost positive identity on a known Instrument Flight Rules (IFR) target which previously had been identified, white was used to indicate a flight landing within the sector, yellow was used to indicate a departing or climbing flight, and green was used to indicate an en route flight. In some of the later tests, yellow was used to indicate aircraft in potentially conflicting situations.

SIMULATION TESTS

System A.

The physical layout of System A is shown in Fig. 5. System A was designed to use the flight progress boards as the primary display and to use the Sky Screen to resolve such problems as were delegated by the sector controllers to a radar controller at the viewing screen. Problems such as departing flights climbing to assigned altitudes, arriving flights descending to assigned altitudes, and flights on crossing courses at the same altitude were handled in this manner.

The trackers obtained identity of targets by monitoring the air/ground (A/G) frequencies, and an assistant at the tracking position used an interphone to pass the chip number and the aircraft identity number (radio call sign) to the assistant controller at the viewing screen. This system utilized two trackers, two interphone men, and one controller at the viewing screen in addition to the regular complement needed to operate the flight progress boards. This system required three sets of radio frequencies, one set for each flight progress board and one set for the radar controller at the screen.

It was found that the trackers were unable to do an adequate job of obtaining target identity by monitoring the A/G radio channels, and approximately five per cent of the flights were never identified by the trackers. This was, in part, because the aircraft was too far past the radio fix over which it reported to be considered as positively identified. Also, the trackers missed the aircraft's identity many times because they had no advance information of the flight and were preoccupied with their tracking and chip moving duties. During some portions of this test, some aircraft had nearly passed through the entire sector before the trackers realized that they had missed a radio call entirely and had no track for the flight on the screen.

The controller at the viewing screen was furnished with a separate set of A/G frequencies. It has found that he could control a maximum of three or four problems at one time, depending upon the types of problems and the locations of the flights, and assuming that the trackers were able to track the flights involved, adequately. One of the limiting factors affecting the number of problems the controller at the viewing screen was able to control was the length coordination necessary between himself and the sector controller. This coordination required the sector controller to "draw" a verbal picture of the control problem to the screen controller. Because the screen controller was simultaneously working A/G radio, this requirement limited the entire operation.

In many cases it was found that the trackers needed route information to maintain or re-establish identification when tracks crossed. When the target markers were close together, controllers needed to check the actual positions of specific targets before radar separation could be employed between such aircraft. For this reason it was soon determined that a monitoring scope should be added to the system.

System B.

The physical layout of System B is shown in Fig. 6. This system was an attempt to provide the trackers with a more positive means of identifying the radar targets. The trackers were equipped with direct A/G radio frequencies which were utilized by aircraft in reporting at entry fixes. After the trackers had marked the target with a marker chip, the flight changed to the radio frequency of the sector assistant and repeated the position report.

Control instructions were initiated by the sector controller, and were issued by the sector assistant who used a monitor scope for fine-grain control. An assistant at the tracker's position used interphone to advise the sector controllers of the target numbers assigned to the various flights. The target number of the chip marker was prominently displayed on the flight progress strip in red pencil.

This system used two trackers and one assistant in addition to the regular complement required to operate the flight progress boards. Four sets of radio frequencies were required, one set for each of the flight progress boards and one set for each tracker. Re-identity of any targets lost by trackers was a difficult coordination problem. A tracker was required to have his assistant call the sector controller, who in most cases had to ask the sector assistant to vector the aircraft in question for identity. This information was then passed back via the same communication route to the tracker.

System C.

The physical layout of System C is shown in Fig. 7. This system was an attempt to reduce the number of personnel required. The two trackers at the tracking scope were the only personnel needed in this system over the normal controller complement required to operate the flight progress boards.

The pilots made their initial progress report directly to the trackers, who assigned each flight the code number of the chip being used to mark that flight's radar blip. The pilot was then required to change to the sector assistant and to repeat the code number and the position report.

The lack of communications between the trackers and the controllers made the job of re-identification an impossibility, a fact which led to the abandonment of this system. This system required one set of radio frequencies for each of the flight progress boards and one set for each tracker.

System D.

The physical layout of System D is shown in Fig. 8. This system was an attempt to combine the best features of the previous systems and to correct the faults that became apparent during earlier tests. This system required two trackers at the tracking scope and one screen controller, in addition to the normal complement required to operate the flight progress boards.

The pilots made their initial progress report to the screen controller. By use of a radar monitor scope and interphone line to the trackers, this controller established target identity and instructed the trackers to mark the target with a chip marker. A sector coordinator wrote the target code numbers on the flight progress strips. The sector controllers were responsible for the over-all control of the traffic. Routine position reports were handled by the sector assistant who also issued control instructions as required by the sector controller.

Re-identification of targets which merged or became questionable was still time-consuming but possible, as trackers were assisted by the screen controller using the monitor scope and the flight progress data. The tracking job was simplified further by eliminating the A/G communications workload.

System E.

The physical layout of System E is shown in Fig. 9. This system combined most of the area into one Air Route Traffic Control (ARTC) sector, producing a heavier traffic load. This required a three-man control team at the viewing screen and two trackers at the radar scope.

To simplify the strip display and place more emphasis on the pictorial display for control purposes, a multi-fix posting system was used

This consisted of a modified ARTC center strip-posting using only one strip per aircraft. Several boxes on the strip were designated as geographical points within the sector where it was considered desirable to post estimated times. Figure 10 indicates this type of posting. The strips were sequenced by altitude to provide the strip controller with advance information on possible traffic conflictions at the same altitude over the same geographical point or radio fix.

A radio controller at the screen controlled the traffic from information available on the multi-fix posting and on the screen. Another controller kept the multi-fix postings current, alerted the radio controller of potential conflictions, and received and transferred data to other sectors and centers. One assistant controller used an interphone to maintain close coordination with the trackers at the plotting surface. He was responsible for placing the target track number on the multi-fix strips. When crossing-course conflictions were noted, the screen controller was alerted and the radar information on the screen was then used to work out the problems with radar separation wherever possible. Since this type of posting does not provide a controller with information suitably displayed to solve climbing and descending problems, the radar information, as shown on the Sky Screen, was used to separate all climbing and descending aircraft from other traffic.

Only one set of A/C frequencies was used in this system. Tests indicated that a larger flight progress strip than the type now in use would have been desirable when more than four fixes were posted on the same strip.

CONCLUSIONS

The following conclusions are based on the data obtained and observations made during the simulation tests described in this report.

1. The Sky Screen presents a large, bright, filtered display which provides the controller with a picture of the general air traffic situation. However, inherent limitations of the system make it unsuitable for use in providing minimum radar separation between aircraft. These include; (a) the relatively large geographic area covered by each target marker, and (b) the fact that the final display does not show exact aircraft position because the target markers are moved in steps by the trackers.

2. Target markers comprised only two digits and an arrow. It was not possible to reverse the heading of the arrow in relation to the digits; therefore, about half the markers had to be read in the inverted position. Target numbers could not duplicate aircraft identifications due to the small number of symbols available. The controller workload involved in associating

a specific target number with its identification, and vice versa, caused considerable difficulty in handling traffic problems. This lowered the effectiveness of the display as a control tool.

3. Fifteen targets was the maximum number which a single tracker could keep identified in the systems tested. The presence of unreported aircraft in the system complicated the identification function tremendously. Without access to flight plan data, the trackers were unable to correct accidental mixups of the target marking chips. The tracking position was physically tiring because of posture and vision requirements. Positioning of the marker chips was an exacting task due to the small scale of the display surface and the need for precise movement of a desired chip without nudging any other chip out of position. The remote location of the trackers in relation to the rest of the control crew created coordination difficulties.

4. The most effective tracking technique was to reposition the chip so that the rear of the chip was aligned with the radar target. This minimized the number of chip movements necessary to keep it superimposed on the radar target.

A two-man tracking team functioned best when one man did most of the chip moving, and the other man communicated with the controllers and aided the tracker when necessary.

The transfer of flight plan route information to the trackers assisted them in maintaining target identity when the targets merged and subsequently diverged. However, the transfer of this information to the trackers greatly increased the communications workload.

5. Altitude coding by color was not effective because only a few colors were available.

6. Changing the scale of the radar display from 12 miles per inch to 17 miles per inch did not increase the efficiency of the system. When the larger scale was used, the radar targets moved faster, and were more difficult to track. When the smaller scale was used, the target chip markers occupied a larger area and increased positioning inaccuracies.

7. These tests showed that although ATC and ADC both utilize the same general type data, that is, flight plan and aircraft position data, the essential differences of their functions make the display requirements of each quite different.

RECOMMENDATIONS

As a result of the limitations which became apparent during the tests, it is recommended that no attempt be made to integrate the Sky Screen into the present ATC system.

ACKNOWLEDGEMENT

The assistance of Northrop Anaheim, a division of Northrop Aircraft, Inc., in loaning the equipment and supplying the trained technicians to set up, adjust, and later to dismantle this equipment is greatly appreciated.

The authors also wish to acknowledge the valuable assistance furnished by Messrs. Victor A. Crawford, Robert D. Colling, Claybourne Waldrop, and Durward M. Phillips of the Indianapolis ARTC Center, and by Roger S. Miller of the Franklin Institute Laboratories.

Fig 1 Sky Screen Projection Unit with Trackers in Position

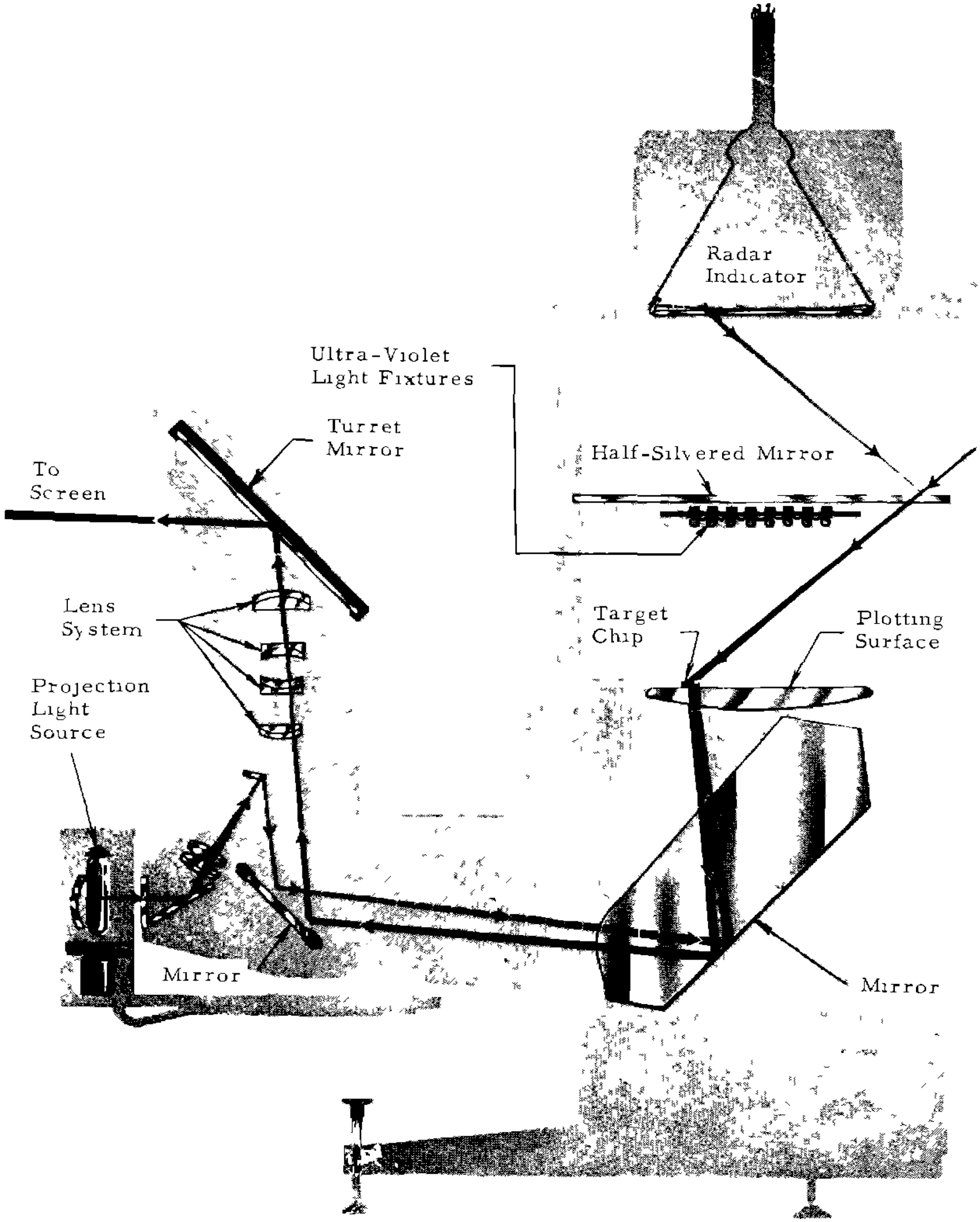

Fig 2 Optical System of Sky Screen

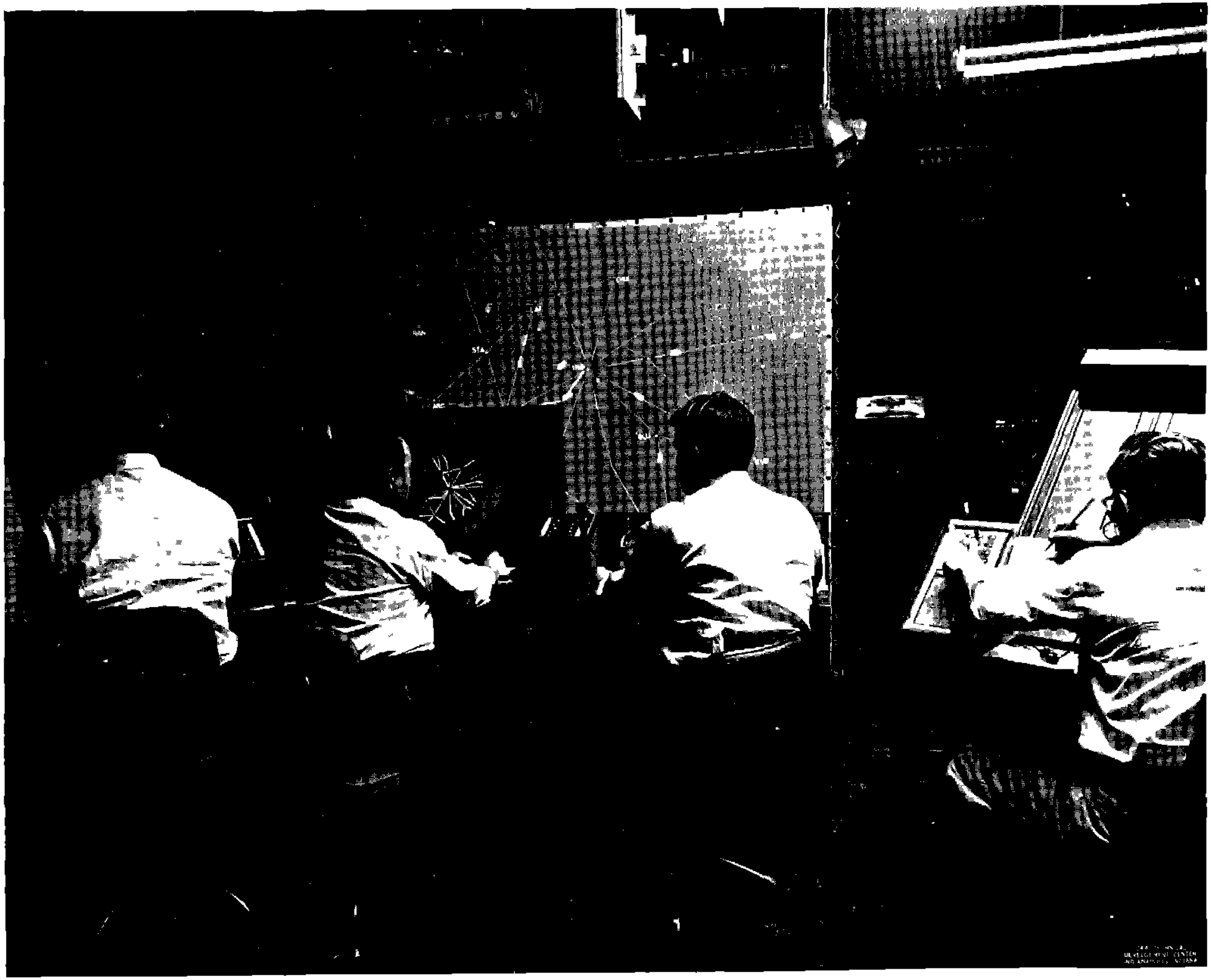

Fig 3 View of Display Equipment

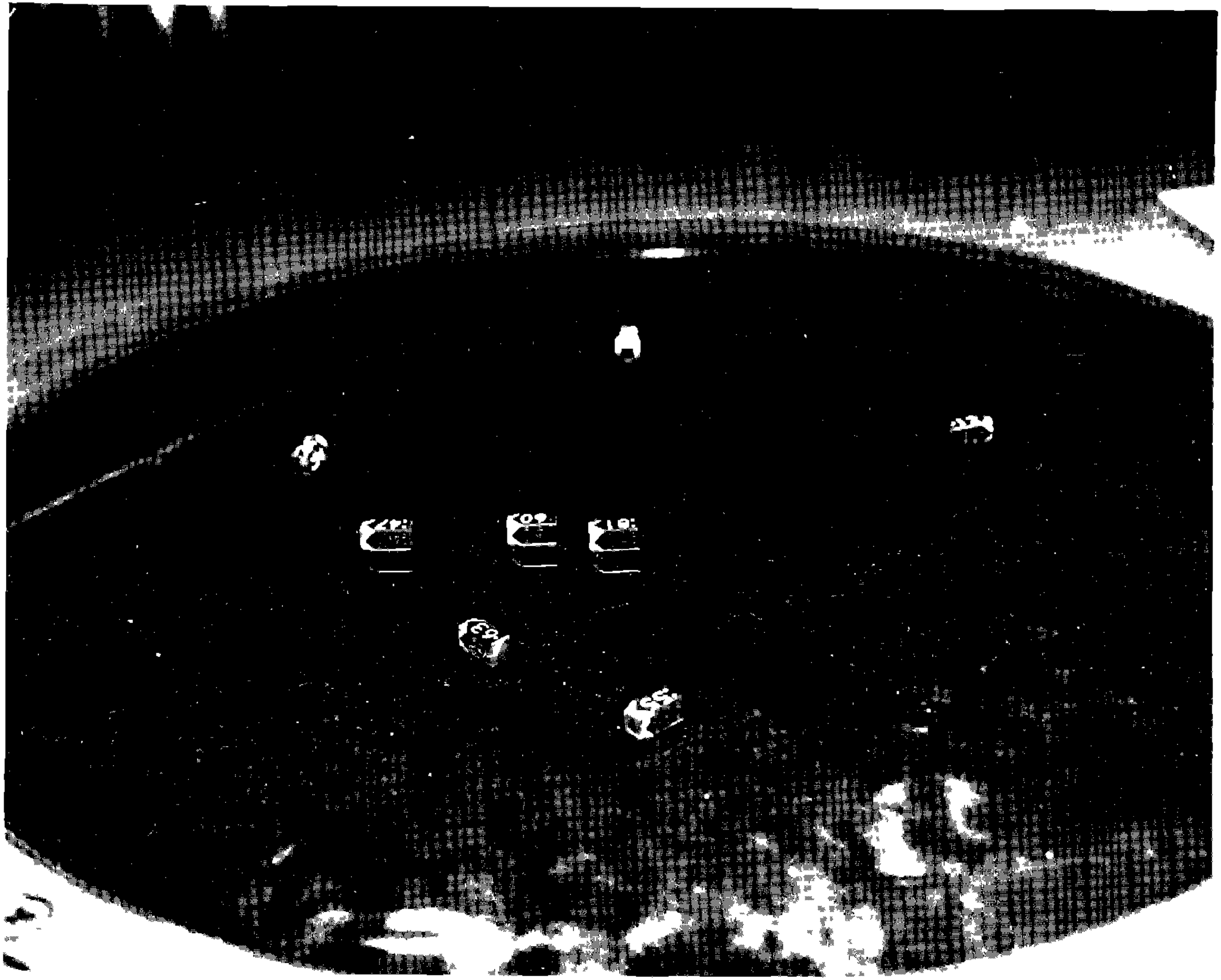

Fig. 4 Target Marking Clips on Tracking Plate

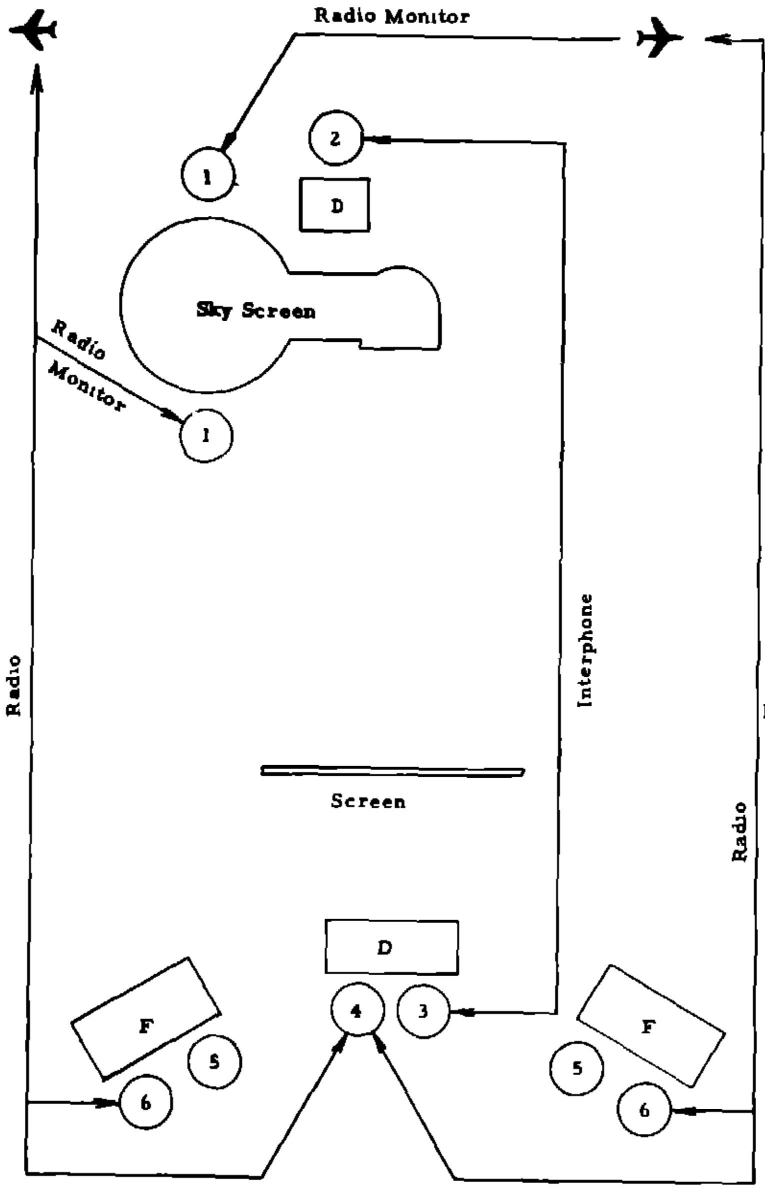

Fig 5 Layout of System A

Legend

1 - Tracker

2 - Tracker Assistant

3 - Screen Assistant

4 - Screen Controller

5 - Sector Controller

6 - Sector Assistant

D - Desk

F - *Flight Progress Board*

M - Monitor Scope

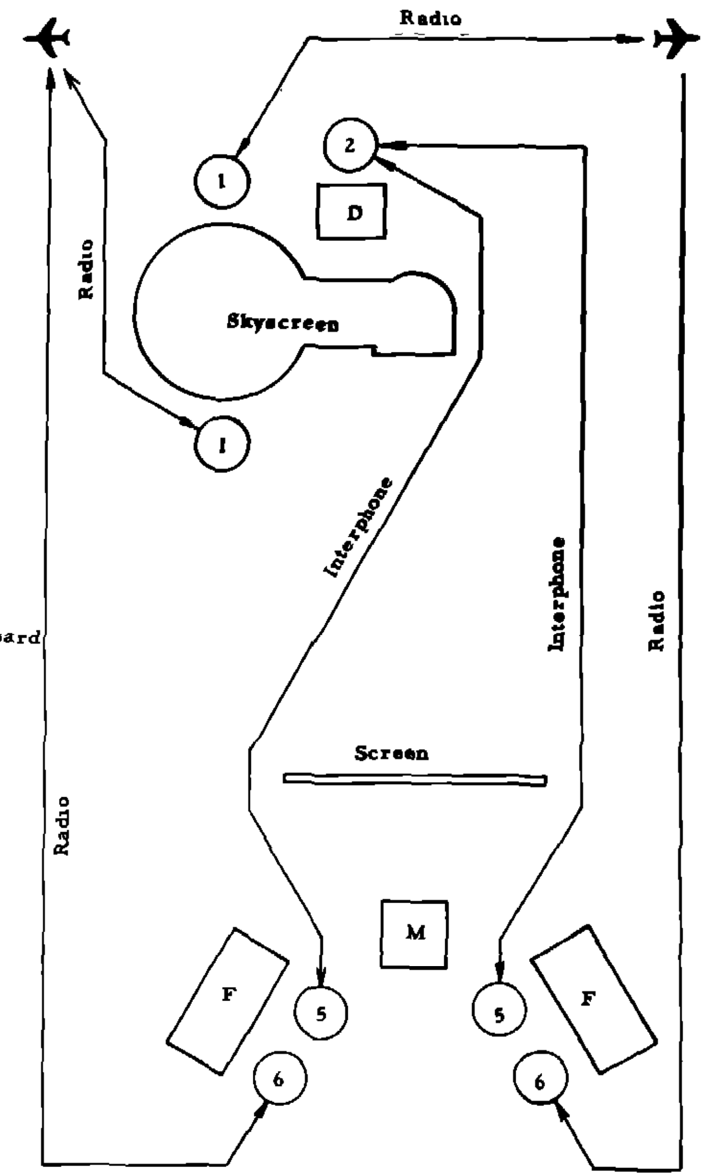

Fig 6 Layout of System B

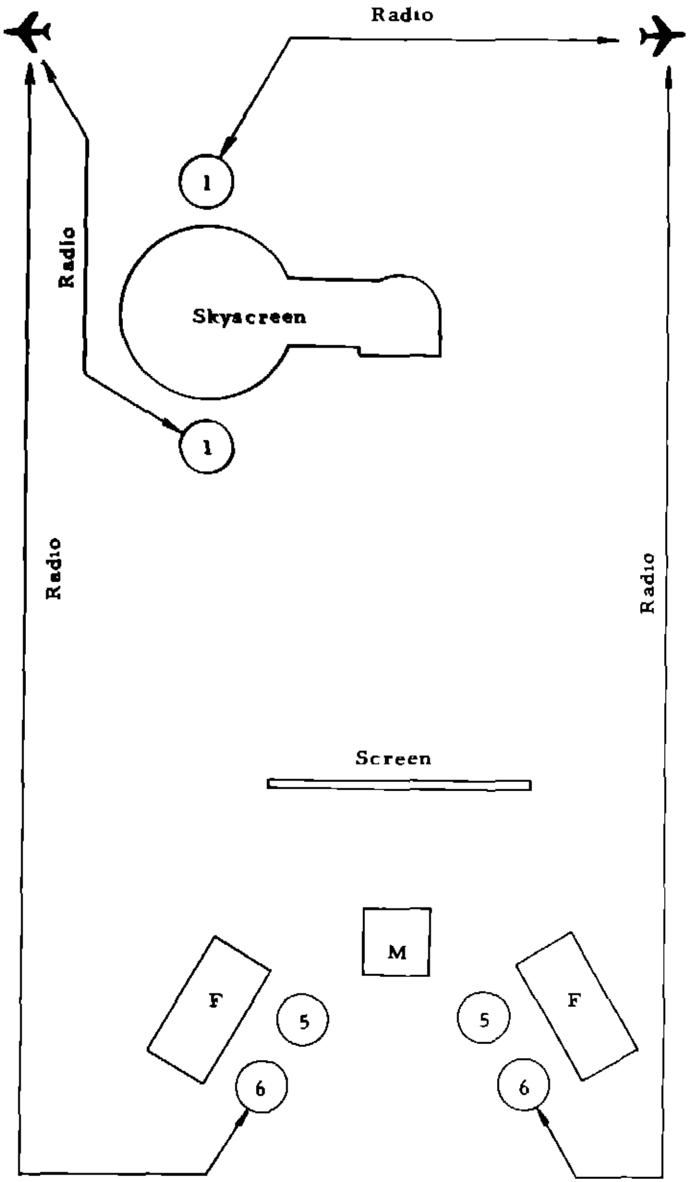

Fig 7 Layout of System C

Legend

1 - Tracker

2 - Tracker Assistant

3 - Screen Assistant

4 - Screen Controller

5 - Sector Controller

6 - Sector Assistant

7 - Coordinator

D - Desk

F - Flight Progress Board

M - Monitor Scope

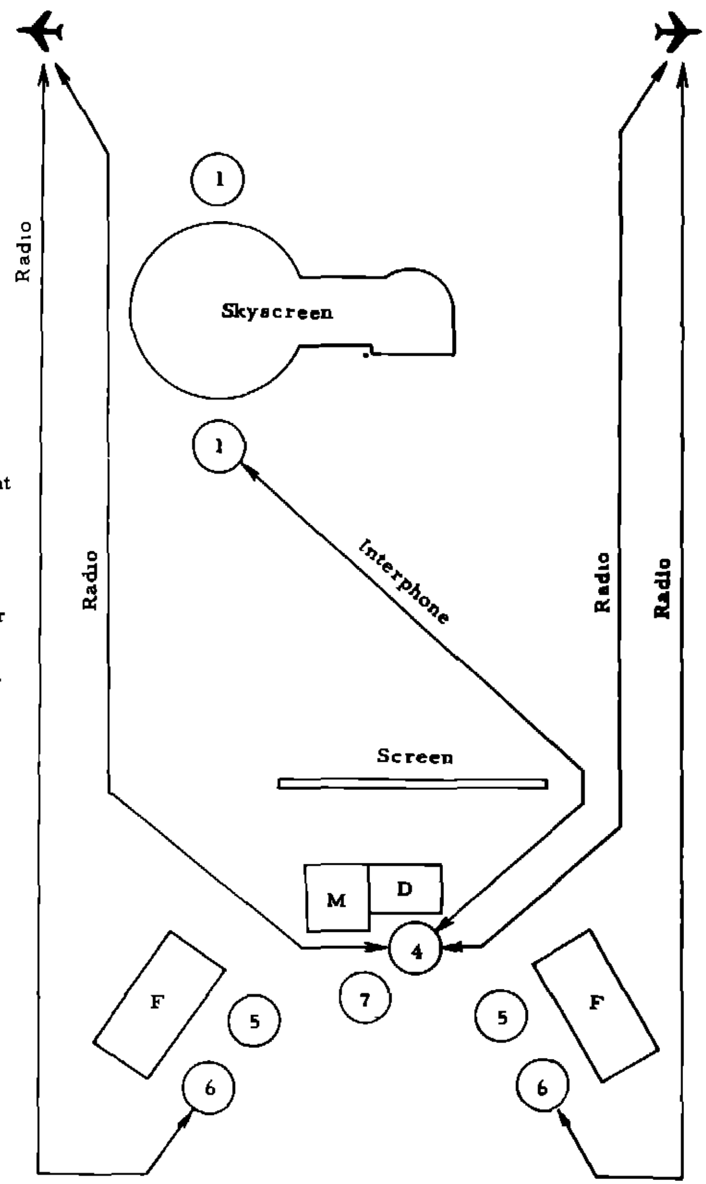

Fig 8 Layout of System D

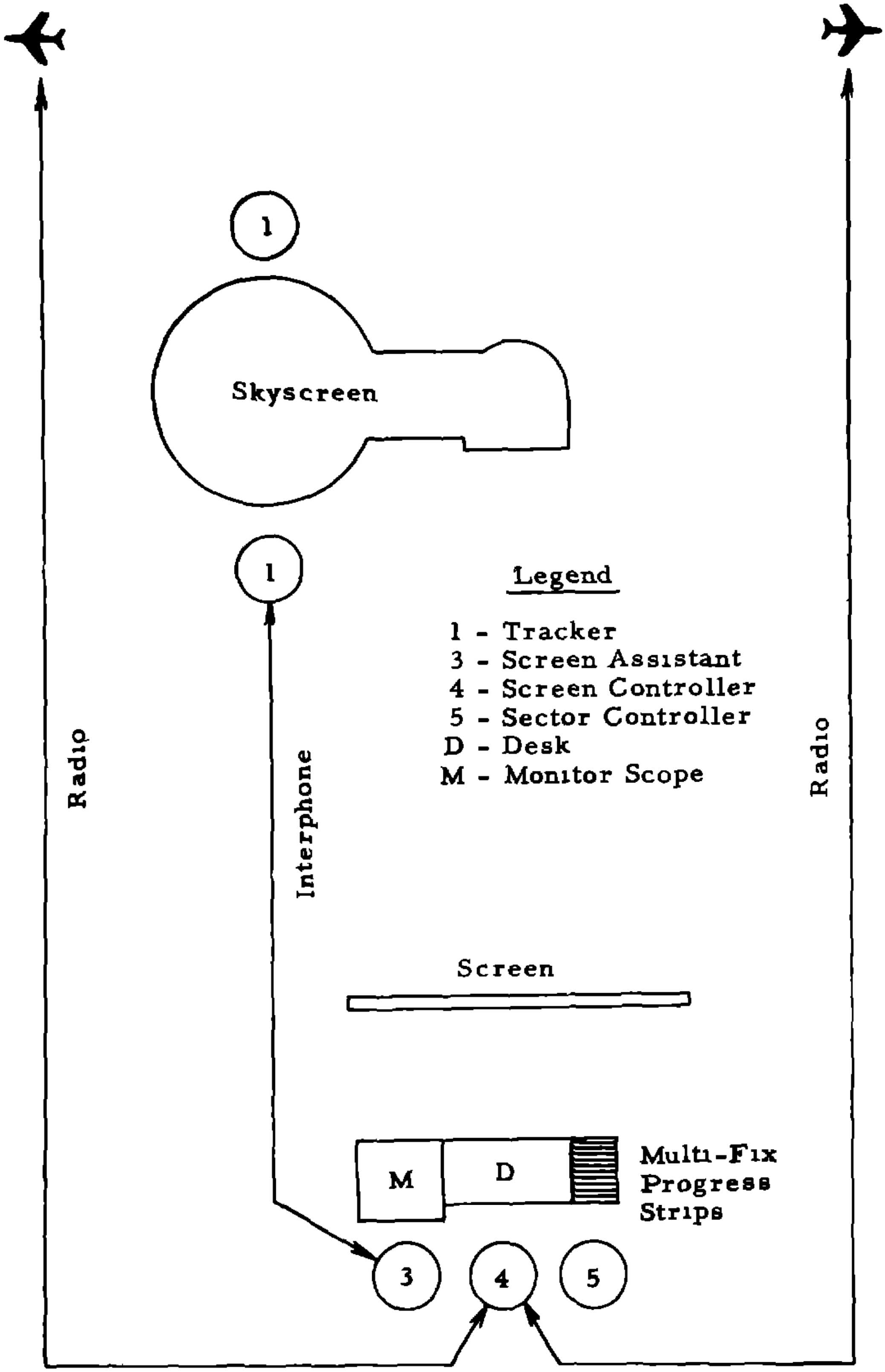

Fig. 9 Layout of System E

IDENTITY AND TYPE	ROUTE	ALTITUDE	FIX IDENTIFIERS					TARGET MARKER NUMBER
			SCJ	IND	MAX	HUF	KOK	
T 10 9	STL V12 PIT	150		1028	1035	1017		42
A5 6	CHI V11 MIA	150	1002	1014			1026	18
U329 C	LOU V171 CHI	150	0940			0951		25

FIG 10 MULTI-FIX STRIP POSTINGS