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AN OPERATIONAL EVALUATION OF RADAR DISPLAYS UTILIZING SCAN-CONVERSION EQUIPMENT

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by

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SUMMARY

In searching for improved displays of radar information, five configurations were tested at the FAA Technical Development Center and the Indianapolis Air Route Traffic Control Center. Flight following and tracking constituted the bulk of the testing, however, actual control of IFR flights was conducted for approximately four months. The FPS-8 radar information was converted to television by the TI-440 French scan-conversion equipment and then fed to the different displays described by this report. These were.

1. TV monitors using 17-, 21-, and 27-inch (diagonal measurement) rectangular tubes.

2. A 22-inch, round, flat-face tube mounted horizontally in line with Type A-3 flight progress boards.

3. A 22-inch, round, flat-face tube mounted horizontally in an "island" arrangement.

4. A SPANRAD unit in the Air Route Traffic Control Center for local tracking.

5. A SPANRAD unit in the Technical Development Airways Operations Evaluation Center with a TV monitor in the Air Route Traffic Control Center for remote tracking.

At the end of these tests, it was concluded that the 22-inch, flat-face horizontal plotting display was favored over the SPANRAD, the TV monitors (either 17- or 21-inch size) mounted vertically in the flight progress boards. Also, an in-line arrangement of radar displays and flight progress boards is preferred to the island-type installation.

INTRODUCTION

The installation of radar in Air Route Traffic Control (ARTC) Centers introduced a problem of displaying the radar in the high ambient light required in reading and writing flight progress strips. All PPI and VG-1 displays required a drastic reduction of light levels in the control quarters. The problem of displaying radar information has been studied for several years at the Technical Development Center (TDC) at Indianapolis. This report describes the results of one year's testing of five different configurations of radar displays using the Indianapolis medium-range FPS-8 radar and a TI-440 scan-conversion equipment. The output of this equipment is a television picture which can be displayed under relatively high ambient light conditions on any standard TV monitor. The equipment tested included three different size monitors, two different configurations of superimposed panoramic radar displays (SPANRAD), and two arrangements of a 22-inch flat-face TV tube display. The 22-inch flat-face configuration resulted in a display approximately the same size as the VG-1. A transparent implosion shield placed over the flat-face tube to provide a working surface on which plastic flight identification markers could be used, similar to the VG-1 arrangement, also was tested.

The coverage of the FPS-8 radar was approved for air traffic control to a radius of 75 miles from the site. This area encompassed all of the Indianapolis sector and most of the area controlled by the Bunker Hill and Terre Haute sectors of the Indianapolis Air Route Traffic Control Center. See Fig. 1. Traffic in these sectors is divided between terminal (landing and takeoff) and over-flights approximately as follows:

Area (Indianapolis ARTC Center)	Flight Operations Terminal (per cent)	Over (per cent)
Indianapolis Sector	50	50
Bunker Hill Sector	32	68
Terre Haute Sector	7	93

Active radar control of IFR traffic in these three sectors was conducted for four months on the test displays described in this report. Because of the high percentage of over-traffic, control problems included crossing traffic, en route change of altitude, as well as climbing and descending terminal traffic interspersed with over-traffic.

Since the Indianapolis ARTC Center controllers concerned with these tests had been certified for radar control, just prior to these tests, radar controllers from the Chicago ARTC Center, McChord RAPCON, and Denver Tower, who had additional radar experience, participated in the tests at Indianapolis.

This report describes the several display configurations tested, the methods of operation, and reflects the composite opinion of the experienced radar controllers as well as Indianapolis controllers and TDC airways operations specialists who replied to a detailed questionnaire.

EQUIPMENT

The FPS-8 radar at Indianapolis is a single-beam radar operating in the L-band with an approved operational range of approximately 75 miles. The pulse width is 2 microseconds, the beamwidth is 2°, and the antenna rotation was adjusted to 6 rpm.

The scan-conversion equipment used in these tests was manufactured in France and imported for distribution in this country by the Intercontinental

Electronics Corp. This equipment,[1] Model TI-440, transforms radar signals into television signals by the use of a TMA-403X two-gun storage tube. A writing gun impresses the radar information on an internal target in the form of electrostatic charges, and a reading gun on the other end of the tube converts these charges into television video signals. The decay of the written information is controllable and provides an adjustable memory of a few seconds to several minutes. This persistence provides aircraft trail information on the display. The bright television display makes the picture usable under high ambient light conditions. The TI-440 equipment operates on a 625-line TV system. The horizontal resolution is in excess of 600 lines and the vertical resolution is approximately 450 lines.

Four sizes of TV displays were used during these tests, namely, 27-inch, 22-inch, 21-inch, and 17-inch. All but the 22-inch were standard CONRAC TV monitors, enclosed in metal cases. The 22-inch size used a special Rauland flat-face tube mounted so that the face was horizontal. This 22-inch tube required special mounting and the consoles were fabricated at TDC. The CONRAC monitors were mounted at several angles in the flight progress boards. This included the 45° slant of the Type A-3 flight progress bays, a vertical alignment, and a 15° forward tilt. Figure 2 illustrates the information flow from the radar to the various displays.

The superimposed panoramic radar display (SPANRAD) originated at the TDC. This equipment included, in addition to the TI-440 scan-converter, an RCA vidicon camera, Type TK-21B. The camera equipment was augmented by video switches, RCA Type TS-5A, RCA vidicon remote control panel, Type M126218, and RCA mixer-fader controls. A special console was built for the SPANRAD which housed the monitor and supported the TV camera high enough above a plotting table to insure the proper scale factor. A 27-inch TV monitor was used in the SPANRAD. The plotting table on both SPANRAD's was painted a dull black to eliminate reflections and form a contrasting background for alpha-numeric characters used on identification markers.

SPANRAD can be used only with high ambient light on the plotting table. In order to obtain this high-intensity light, several different lighting combinations were tested, among which were: (1) three 2-tube fluorescent fixtures, each equipped with 20-watt tubes, (2) three 150-watt incandescent bulbs placed near the level of the camera, and (3) two 150-watt spotlights directed on the plotting table. In one other application of the 150-watt spotlights, they were directed at the white acoustical tile ceiling of the Center quarters to give a diffused indirect light. In addition, two 40-watt, 4-tube fixtures were placed one on either side and above the plotting table. This produced a total of 320 watts of fluorescent illumination.

[1]William E. Miller and William G. Covell, "Evaluation of the TI-440 Picture Transformer Equipment and Notes on Television-Type Air Traffic Control Displays," Technical Development Report No. 388, March 1959.

Several types of flight identification markers were tried on the SPANRAD. Different colored papers and card stock with various colored inks, chalks, crayons, paints, and lead pencils were tested. High contrast between the background and the marking medium generally produced best results; for example, black on white. However, white inks and crayons, which were easy to write with, did not produce sufficient contrast on any colored paper to be considered usable. The height, width, and spacing of alpha-numeric characters were important factors from a readability standpoint. The RCA vidicon camera equipment used during these tests did not resolve characters under 3/8-inch high satisfactorily. The line-breadth of characters also affected the legibility. Broad nib pens, brushes, or heavy-line crayons were necessary for reproduction but were difficult to use. Commercially manufactured letters of plastic and metal were tried. The smallest size readable was 3/8-inch high with stroke 2 millimeters wide (1/16-inch plus). These letters and numerals were 8 millimeters wide, except the letter M, which was wider, and the letters I and l, which were narrower. Manufactured letters showed better on the SPANRAD display but were not easy to place on a marker. The small size made them very difficult to pick up with the fingers. It did not appear that tweezers would improve the handling, since the body of the letters was rounded and smooth.

Larger plastic characters did not add much to the legibility but did increase the over-all size of the marker to such an extent that too much plotting area was covered by the marker. Figure 3 illustrates the scale and radar display area covered by the several markers tested on the SPANRAD. The flat-face of the 22-inch horizontal display presented 20 inches of radar picture, which was a diameter of about 160 miles of radar coverage. Hence, the scale was about the same as that of the SPANRAD; that is, 1 inch of marker covered 8 miles of radar coverage. This may be compared to the VG-1 which in the New York ARTC Center is scaled 8 statute miles per inch from sectional charts.

The Chicago ARTC Center uses two range scales of 80 and 100 miles on the VG-1 displays. Two sizes of plastic markers are used so that the markers on both scales cover an area approximately 5 by 10 miles. Controllers, in general, feel that a marker should be as small as possible in order to restrict the area blocked or covered on the display to an absolute minimum. Most controllers, therefore, prefer the small, clear plastic marker 1/2-inch by 1 1/4-inch, with grease pencil marking of identification. In general, controllers believe that identification is sufficient information on radar markers. There were some, however, who believe that the altitude information is important, especially on constant altitude traffic.

DISPLAY EVALUATIONS

Vertical TV Monitors.

Monitors depicting the TV picture of the scan-converted radar information were tested in various sizes and in several locations on the

A-3 flight progress boards for 14 weeks of actual control. At the Indianapolis ARTC Center, radio controls are mounted in turrets suspended from the ceiling behind the D positions. In early tests, the TV monitors were mounted high in the bulletin board area, with the radio operator doing the radar control. See Fig. 4. The high location of the monitor was not satisfactory because the operator was forced to look up all of the time, which placed him in an unnatural position and which became very tiresome. Since no markers or memory reminders could be used on the vertical radar display, the amount of radar control was restricted to three or four aircraft, or even less when a vectoring problem was involved. Later, a 21-inch TV monitor was placed in the flight progress board strip holder bay area by removing a five-bay unit. This arrangement, shown in Fig. 5, placed the display much nearer to the controller and at a level which was easy to view from a seated position in front of the flight progress board strip holder bays.

While the 27-, 21-, and 17-inch monitors were tested in the flight progress board locations, controllers generally agreed that the 27-inch display was too large. Some controllers considered the 17-inch display sufficiently large, while others preferred the 21-inch size. Controllers were of the opinion that the use of vertically mounted TV monitors in the flight progress boards at certain sectors, controlling little or no terminal traffic, and where crossing and change of altitude problems occurred, would be helpful. As mentioned above, the radar operator handled the air/ground communications and the flight progress strip controller used service F exclusively. All planning, and a high percentage of the total control of a sector, were accomplished by the flight progress strip controller, with the radar controller assisting by handling air/ground communications and using radar to solve some problems.

Advantages.

The advantages of vertical TV displays in the flight progress boards were:

1. The displays were easily visible to both the radar and ANC controllers.

2. Little or no reflection of light or images occurred.

3. Coordination between the two controllers of the sector was simplified.

4. Definition, resolution, trail, and brightness were very satisfactory.

5. The transition of the eye scanning from TV to flight progress board was easy.

6. No light filter was required over the TV display.

7. The required equipment was less than in a SPANRAD configuration.

8. No special lighting was required.

9. Flight progress strips could be read and marked by the radar controller.

Disadvantages.

The disadvantages were:

1. No memory aids, such as identification markers, could be used.

2. Controller capacity was limited to approximately five aircraft.

22-Inch Horizontal Display.

Two different applications of the 22-inch flat-face TV tube were evaluated. In one application, the 22-inch tube was mounted horizontally in a console that would fit in line with the Type A-3 flight progress boards in a space occupied normally by five flight progress bays. See Fig. 6. This configuration was used for actual control for about 10 weeks. During part of the period, the console was placed at the end of the south bank of the flight progress boards in the ARTC Center adjacent to the Terre Haute sector. During another period, it was located between the Terre Haute and Indianapolis sectors in the south bank. In both instances, the console was in line with the Type A-3 boards so that the radar and the flight strip controllers were teamed, with the radar controller handling the air/ground radio communications and the flight strip controller using service F exclusively. At the location between the Terre Haute and Indianapolis sectors, the 22-inch display could be used by two radar controllers, one who was adjacent to the Terre Haute sector could control the Terre Haute traffic, and the other, who was adjacent to the Indianapolis sector, could control traffic in the Indianapolis sector. This display was 35 1/2 inches above the floor, which is the level of the base of the flight progress board. This arrangement permitted the radar controller to scan the flight progress strip bays and also enabled him to reach the flight progress boards for strip marking, as the occasion required. Operationally, this configuration compares closely to VG-1 operations.

Several different types of markers were used, including paper, sections of nylon and aluminum strip holders, and small 1/2- by 1 1/4-inch clear plastic markers. The latter type was preferred, although the markings had to be restricted to identification only. Most controllers feel that the identification is sufficient for such markers, since altitude or route information can be obtained by scanning the flight progress strips.

Two different PPI tubes were used, the P4 and P7 phosphors. The P4 phosphor was preferred because of increased brightness. Brightness, resolution, definition, and persistence all were considered to be satisfactory by the controllers. The implosion shield, which is a 1/4-inch plastic sheet over the face of the tube, tends to reflect some images or lights which are directly above the tube. During the tests at the Indianapolis ARTC Center, a strip of plywood was laid across the bulletin board to the radio turrets to shade the implosion shield from direct light. This arrangement appeared to be satisfactory and no other reduction in ambient light was necessary. Another approach to the reflection problem would be to install a polarized filter on top of the implosion shield. This method was tried on an earlier model of a 22-inch flat-face console and tested at TDC with moderate success. Although the polarized filter reduced the light output from the cathode-ray tube (CRT), it improved contrast.

Advantages.

Advantages of the flat-face, horizontal TV display were.

1. The display can be used in normal room lighting but some lighting control is required.

2. The display permits the use of identification markers.

3. The brightness and resolution of the display are very good.

4. This display can be operated in line with flight progress boards.

5. No filter is required. A polarized shield would help decrease troublesome reflections.

6. There is no objectionable heat generated in the console.

7. Flight history is available from trail information.

Disadvantages.

Disadvantages of the flat-face, horizontal TV display were:

1. The implosion shield reflects some light and images.

2. Use of a grease pencil on small plastic markers limits information that can be written to identity only.

3. The maximum usable size of the display is 20 inches in diameter.

4. The 22-inch, flat-face tube is a special one not in regular production.

22-Inch Flat-Face Horizontal Island Display.

At the New York ARTC Center, a two-sided flight progress board is arranged between two VG-1 radar displays. Based on this configuration, engineers of the Office of Air Navigation Facilities in Washington designed an arrangement with a 22-inch horizontal TV display at each end of a two-sided flight progress board. See Fig. 7. A prototype unit was constructed at TDC and later was evaluated. This configuration, however, was not used for actual traffic control due to a lack of space and a lack of trained personnel.

The island equipment is included in this report because of the interest shown by traffic control personnel who viewed the demonstrations adn who tracked aircraft on the display. If the island arrangement were to be used in a Center, one or more radar controllers would man each 22-inch display. Air/ground communications equipment would be available to the operators of the radar positions. The flight progress strip controllers would sit, one on either side of the center section, manning a D position. Hence, a pairing of controllers, that is, one radar controller and one flight progress board controller, would be used at any one sector. One island would accommodate two sectors because it has two displays.

The island configuration could be employed at the high-altitude sectors. An island arrangement planned for the Indianapolis Center is to be used for two-sector high-altitude operation. Two possible methods of operation are visualized. One will be to group all of the high-altitude fix postings on one side of the center section, with the radar displays depicting information from both the London and Indianapolis long-range radars, one on each display. Controller arrangement would be to use two flight progress strip controllers and one or more radar controllers at each radar display. The reasoning behind this plan is that extensive coordination is necessary, and the high-speed aircraft make it mandatory that all postings be in close proximity for rapid coordination. A second proposed method of operation is to place a flight progress strip controller on each side of the center section of the island. These controllers each would control one-half of the Indianapolis Center's high-altitude area, with the assistance of a radar controller at the TV displays and the same radar information as in the method described above. Coordination then would be conducted over the board by intercommunication. In both methods, the radar controllers would accomplish most, if not all, of the air/ground communications.

Advantages.

The advantages of the island arrangement were:

1. Three or more radar controllers could operate around each end of the island display.

2. Normal ambient room lighting could be used.

3. The display permitted the use of identification markers.

4. No camera chain equipment was required as with SPANRAD.

5. No excessive heat was generated by the equipment as with the VG-1.

6. The radar controllers could operate from a seated position, provided the seats were approximately 24 inches above the floor.

Disadvantages.

The disadvantages of the island arrangement were:

1. The island arrangement did not lend itself to simplified coordination between other sectors of the Center.

2. The reflection of light from the implosion shield was more severe than with other installation methods.

3. A 20-inch display was the maximum size available.

SPANRAD (Local or Proximity Tracking).

A SPANRAD unit was installed at the Indianapolis ARTC Center in the south bank of the Type A-3 flight progress boards between the Indianapolis and Terre Haute sectors. The plotting board and 21-inch monitor occupied the space of five flight progress bays, or 41 3/4 inches. The camera boom was mounted on the bulletin board so that the coverage of the lens just missed the front side of the board. See Fig. 8. Operators seated in front of the monitor could reach the flight progress board for marking as well as for reading data posted on the flight strips. In this configuration, two controllers were able to sit in front of the SPANRAD and act as radar controllers for two sectors, and since they were located adjacent to the flight progress board controllers, coordination was readily accomplished. Another advantage of SPANRAD was that the radar controller could read data from the flight progress board strips, which permitted him to scan the board and pick out potential traffic conflictions. In all tests using this SPANRAD, the radar operator normally carried on the radio communications for the sector he was covering. The identification markers were prepared normally by the controller for only those aircraft which would be controlled by radar. The SPANRAD at the Center was used for approximately 5 weeks for actual control of IFR flights in the Indianapolis and Terre Haute sectors. In general, the controllers did their own tracking but felt that, with an assistant tracker adjacent to the controller, the number of aircraft which could be controlled would be increased by approximately 50 per cent. Opinion varied as to the number of aircraft a controller could track without assistance. The average was eight.

Advantages.

The advantages of the local-tracking SPANRAD were:

1. It could be operated in high ambient light.

2. Identification markers could be used.

3. Operators could either stand or be comfortably seated.

4. Markers could be of various sizes. Large markings were required for the camera to photograph, or small markers could be used if read directly by the operator.

5. Negative or positive marker polarity was a controller choice.

6. SPANRAD could be used "in line" or as an "island" installation.

7. The scan-converted picture was bright, had excellent contrast, good resolution and adjustable trails.

Disadvantages.

The disadvantages of the local-tracking SPANRAD were:

1. Markers large enough to carry the 3/8-inch plastic letters covered too much area on the 80-mile-radius display. Ink or crayon marking had to be larger than normal writing or printing.

2. The addition of a TV camera, with its associated equipment, decreased the reliability of the display.

3. The implosion shield reflected some light and images.

SPANRAD (Remote Tracking).

The SPANRAD unit discussed in this section was installed in the Airways Operations Evaluation Center (AOEC) quarters, which are adjacent to the Indianapolis ARTC Center operating room. See Fig. 9. In addition, 2 21-inch TV monitor was mounted vertically in the Type A-3 flight progress board line-up between the Indianapolis and Bunker Hill sectors in the ARTC Center. See Fig. 10. This arrangement provided both the controller in the ARTC Center and the tracker in the AOEC with the same pictorial information.

The controller in the ARTC Center was in direct communication with both the aircraft in flight by radio and the tracker in the AOEC by intercommunication line. A switch located on the radio control turret permitted the controller to communicate with the tracker by switching his microphone from the radio to intercommunication only. This switch did not cut off the radio receiver from the controller's headset. A loudspeaker near the tracker's position permitted the tracker to listen to the pilot's transmission while monitoring the controller's transmissions with his headset. A second loudspeaker was installed on one of the Tower-Center interphone lines which gave the tracker information on departures from Indianapolis at the same time the Center received them.

The method of operation varied somewhat, but in general, the controller in the Center gave the tracker only the information (identification, altitude, airway, and where entry onto the radar display could be expected) on the flights which he wanted tracked. This operation worked in the following manner: When the controller had identified the video target as being the desired aircraft, the tracker was advised via intercommunication to place an identification marker on the target. This also could be accomplished by the tracker at times without prompting. The tracker was then responsible for moving the marker along with the moving video. Factors which caused the tracker to lose identification were: (1) congested traffic areas, (2) aircraft passing through the "nugatory cone"* over the radar antenna, or (3) aircraft were lost in precipitation clutter. Whenever aircraft identity was lost, it was necessary for the controller to establish radar contact, at which time the tracker again began the flight-following process. It appeared that a tracker could keep 8 to 15 markers current, depending on the adverse circumstances listed above.

* Nugatory cone: the area above the radar antenna that is not scanned.

More targets could be followed if this were the only activity of the tracker. A procedure was tried, using a second intercommunication channel and two additional operators. In this procedure, flight information on all IFR flights was passed from an operator in the ARTC Center to a second operator in the AOEC. The operator in the AOEC prepared the markers for the tracker, thereby relieving him of this duty. The size and number of markers congested the display and confused the controller.

Advantages.

The advantages of the remote-tracking SPANRAD were:

1. A bright, easy-to-read display was available at both the ARTC and AOEC consoles.

2. Some personnel could be removed from the ARTC to a remote location.

3. There was a division of tracking workload among more personnel (remote tracking only).

4. Identification markers could be used.

5. Darkening of the control quarters was not necessary.

6. Operators could be seated comfortably at the displays.

7. The arrangement could be operated either in line with flight progress boards or in an island arrangement.

8. The scan-conversion equipment gave flight history by trails.

Disadvantages.

The disadvantages of the remote-tracking SPANRAD were:

1. The alpha-numeric characters had to be at least 3/8-inch or larger to be readable on the radar display.

2. Additional light on the plotting board was required in order to produce a bright camera picture.

3. More electronic equipment was needed, thereby increasing the cost and also lowering the reliability.

4. Some light and images were reflected by the implosion shield.

5. Coordination between the controller and his tracker imposed a considerable workload.

CONCLUSIONS

Based on the observations made during the testing period, and on the opinions expressed in a questionnaire, it is concluded that:

1. The scan-converted radar displays are bright enough and have sufficient contrast for use in ARTC Centers, provided that some control of ambient lighting is effected to reduce direct reflections of light fixtures, or brightly illuminated areas such as ceilings, from the face of the CRT and the implosion shield.

The 21- or 17-inch CONRAC TV studio monitors used with flight progress boards should be mounted vertically or at a slight negative angle, to reduce reflections from the ceiling and light fixtures. The center of the TV indicator should be at or slightly below the eye level of a controller seated at the boards.

The 22-inch horizontal TV display will require control of ambient lighting in the vicinity of the indicator to insure usable brightness and contrast. It appears also that polarized filters may be suitable; however, these have not been evaluated completely. Polarizing filters reduce light output from the CRT but improve contrast.

2. The target trail or storage provided by the TI-440 scan-conversion equipment is excellent and very beneficial for control purposes.

3. Resolution of radar targets on the scan-converted display is adequate.

4. In general, the controllers using the displays felt that it is best not to attempt to identify and track all IFR traffic except for departures and arrivals on high-density, one-way routes. For general en route sectors and medium-density terminal operations, they believe it is best to identify only the aircraft with less than ANC nonradar separation and use the radar for separation of these aircraft.

5. All Center radar controllers felt that tracking aircraft was a major workload. They felt that it is desirable to have someone to track targets for them at the same position, but were unwilling to accept remote tracking using the SPANRAD technique. If someone is assisting the controller in tracking, either locally or remotely, they expressed the opinion that this man should be a certified radar controller also.

6. Center radar controllers estimated that one controller could handle about 8 aircraft on the average, doing his own tracking, and 9 to 12 aircraft with someone else tracking for him. These figures are the average of the estimates submitted by the Center radar controllers. Individual estimates ranged from 4 to 24 aircraft in various situations.

In actual tests observed by TDC personnel, it appeared that 8 to 10 aircraft is a workable number when the controller does his own tracking, and 10 to 12 is a workable number when someone else tracks for the controller during average en route control conditions.

7. Control personnel in general preferred the 22-inch, flat-face indicator to the SPANRAD indicator. The principal objection to the SPANRAD

technique was the large size of the marker required to make the identification data on the TV indicator readable. Controllers did not try the technique of small writing on the SPANRAD marker and foregoing the identity data. It was found necessary to position SPANRAD markers to the side of the radar targets to prevent loss of the trail information on the display. The best SPANRAD markers tested made use of 3/8-inch raised bulletin-board-style plastic letters and numbers on a black felt background.

8. The principal advantage of SPANRAD over the 22-inch horizontal plotting display is the possibility of making visual radar handoffs from one sector to another.

9. In-line installation of the radar displays with flight progress boards generally is preferred. In-line operation permits use of the display by two persons, whereas the island installation permits three persons to work on one display.

10. When using radar to solve most typical en route control problems except high-density, one-way departure and arrival routes, controllers favored multiple A/G channels with only selected flights requiring radar separation on the discrete radar control frequency, and a separate Center A/G channel manned by a radio controller for most of the other IFR flights.

However, this arrangement requires a larger number of channels. It is believed that more radar control experience on the part of personnel may alter this opinion.

RECOMMENDATIONS

It is recommended that:

1. The 22-inch, flat-face indicator be used as a standard for ARTC Centers, preferably mounted in line with the flight progress boards.

2. Further in-service tests of SPANRAD installations be made at two other radar Centers in sectors where radar handoffs are required from one sector to another.

APPENDIX I

QUESTIONNAIRE ON RADAR DISPLAY EVALUATION

There are five different scan-converted display configurations which you are asked to compare. In some cases you will be asked to compare these with the VG or with a standard PPI 10- or 12-inch radar indicator. The scan-converted display configurations are:

1. The 21-inch TV monitor mounted vertically in the flight progress boards with no provision for associating identity markers with radar targets.

2. The 22-inch horizontal plotting display mounted in line with the flight progress boards.

3. The 22-inch horizontal plotting display mounted with a flight progress board as a separate "island".

4. The SPANRAD display mounted in line with the flight progress boards with the controller moving the identity markers.

5. The SPANRAD system using a remote tracker with the controller using the 21-inch vertical display in the flight progress boards.

Some of the questions below can be answered by a check mark for YES or NO. Some ask for a relative rating or comparison between displays. Where rating on a scale basis is requested, use 1 to represent the lowest rating and 6 to represent the highest. A rating of 3 would represent minimum acceptable and 4 would represent satisfactory.

A. General Characteristics

1. Brightness

One of the factors affecting use of a radar display by a controller is the brightness available since he must also refer to other written or printed data during control.

Please rate the displays on a scale basis.

Standard PPI such as OA-99	9	1	3	1	2	2
VG (4 only)	13	3	4	3	3	-
21-inch TV in boards vertically	26	6	6	4	5	5
22-inch TV horizontal	27	6	6	6	4	5
SPANRAD	28	5	6	5	6	6

2. Contrast

Another factor affecting the usefulness of displays is the contrast between targets and the background. Please rate the displays on a scale basis.

Standard PPI such as OA-99	25	5 6 3 5 6
VG (4 only)	14	4 3 3 4 -
21-inch TV in boards vertically	26	6 5 6 4 5
22-inch TV horizontal	25	6 5 5 4 5
SPANRAD	24	6 5 4 4 5

3. Persistence or "Target Trail"

A certain amount of "target trail" appears essential in use of radar for ATC purposes. "Trail" makes it easier for the controller to maintain continuous identification of an aircraft, to detect turns when a vector has been assigned for identification or separation; and to obtain an estimate of relative speed of aircraft. Please rate the displays on a scale basis.

Standard PPI such as OA-99	13	1 3 2 3 4
VG (4 only)	19	5 6 4 4
21-inch TV in boards vertically	26	6 6 6 4 4
22-inch TV horizontal	26	6 6 6 4 4
SPANRAD	26	6 6 6 4 4

For Center use with radars of 5 to 6 rpm, how much trail do you feel is desirable on an indicator? Check appropriate answer.

2 antenna scans or less	___
3 to 5 antenna scans	3
5 to 10 antenna scans	2
more than 10 antenna scans	___

Comments:

4. Resolution

Another important characteristic is the ability to resolve targets such as when aircraft are in close proximity to each other or in close proximity to clutter. Please rate the displays on a scale basis.

Standard PPI such as OA-99	25	5 6 6 4 4
VG (4 only)	13	3 3 4 3
21-inch TV in boards vertically	22	4 4 5 4 5
22-inch TV horizontal	21	4 4 5 4 4
SPANRAD	20	4 4 5 3 2

B. Control Techniques

1. Tracking Aircraft

It is common practice today in Centers to use the VG horizontal indicator for the primary radar display. Small plastic markers with the flight identification written on the markers are positioned manually alongside the radar targets to assist the controller in retaining identity of a number of aircraft. In approach and departure control operations in Towers, standard sloping panel PPI indicators have been used effectively without any memory aid markers. Two philosophies for use of radar in Centers have been set forth: one is that only those IFR flights requiring radar separation should be identified and separated by the radar controller; the other is that all IFR flights active within a sector should be tracked continuously. Please indicate by a check mark in the appropriate column, which of these philosophies you believe is the best for most efficient use of radar in the various phases of Center control work indicated.

	Track all IFR flights in sector with markers.	Identify only the aircraft with less than ANC nonradar separation and separate these by use of radar.
Departing Aircraft		
a. Providing radar separation between successive departures during climb to cruising altitude on high-density one-way route (such as westbounds out of New York airports).	4	1
b. Providing radar separation between successive departures, and other over and arrival traffic for medium density traffic with departing aircraft entering two-way airway.	2	3

	Track all IFR flights in sector with markers.	Identify only the aircraft with less than ANC nonradar separation and separate these by use of radar.
En Route Aircraft		
a. Providing radar separation for crossing airway/course problems with aircraft at same altitude or changing altitude levels with less than standard time separation.		5
b. Providing radar separation for same direction traffic in overtake problems.		
With aircraft at same altitude.		5
With altitude change taking place.		5
c. Providing radar separation for opposite direction traffic making altitude change.		5
Arriving Aircraft		
a. Providing radar separation between aircraft descending to approach fix on high-density one-way airway.	4	1
b. Providing radar separation between successive aircraft descending to approach fix and other over or departing aircraft on two-way airway; medium density traffic.	1	4

	Track all IFR flights in sector with markers.	Identify only the aircraft with less than ANC nonradar separation and separate these by use of radar.
c. Spacing successive arriving aircraft by use of delay patterns to provide intervals across a perimeter fix without stacking.	3	1
Comments:		

2. Tracking Workload

a. Do you feel that moving target markers is a major workload on the Center radar controller? YES 5 NO___

b. Do you feel it would be desirable for another man to move these markers for the radar controller so that the controller would not have this workload? YES 4 NO 1

c. Do you think you could provide better radar control service to aircraft if you were not required to move the target markers? YES1/2 4 NO1/2

d. If someone were assigned to track radar targets for you, would you prefer to have the tracker (check one):

Adjacent to you at the position?	5
Within talking distance near the position?	___
Completely removed from the position, but constantly monitoring you on interphone?	___

e. Would you prefer to accept radar handoffs from towers and other facilities (including handoffs from adjacent radar-controlled sectors) in lieu of your tracker doing this job for you? YES 3 NO 2

f. How many aircraft do you estimate one Center radar controller can safely handle at one time in the following situations with the controller moving his own markers, and with someone else or some other equipment moving the markers for him?

Insert number of aircraft under appropriate column.

	SELF	OTHER
Departing Aircraft		
a. Providing radar separation between successive departures during climb to cruising altitude on high-density one-way route.	12 15 12 9 10	14 15 16 20 17
b. Providing radar separation between successive departures, and other over and arrival traffic for medium-density traffic with departing aircraft entering two-way airway.	12 6 8 6 7	12 6 12 10 11
En Route Aircraft		
a. Providing radar separation for crossing airway/course problems with aircraft at same altitude or changing altitude levels with less than standard time separation.	6 6 12 4 4	6 6 8 8 9
b. Providing radar separation for same direction traffic in overtake problems.		
With aircraft at same altitude.	6 10 12 4 5	6 8 10 10 8
With altitude change taking place.	6 10 12 4 4	6 8 10 8 8 8
c. Providing radar separation for opposite direction traffic making altitude change.	6 6 6 4 4	6 6 4 8 7
Arriving Aircraft		
a. Providing radar separation between aircraft descending to approach fix in high-density one-way airway.	12 10 16 10 4	12 8 10 12 20
b. Providing radar separation between successive aircraft descending to approach fix and other over or departing aircraft on two-way airway, medium-density traffic.	6 6 14 6 4	6 7 6 10 10
c. Spacing successive arriving aircraft by use of delay patterns to provide intervals across a perimeter fix without stacking.	6 14 4 4	6 10 8 8

d. Do you feel there is any difference in manual tracking workload between the VG, 22-inch TV horizontal display, and SPANRAD systems, assuming that all targets markers could be the same relative size as far as the radar display is concerned?

YES 1 NO 4

If yes, what are the differences?

e. Do you feel that remote tracking with a SPANRAD-type of installation is safe and reliable if the remote tracker is an experienced radar man (not necessarily a controller, but someone who understands radar and the problems associated with its use)? YES 1 NO 4

Comments.

3. Information on Target Markers

Because of the limited size of the VG indicator, the markers used in Centers today must be small and only limited information can be written on the plastic chip.

a. If the size of the display and the marker could be increased, do you feel it would make a more efficient display if altitude also could be carried on this marker? YES 3 NO 2

b. Would you also like other items of information on the marker if physical size was no limitation? For example:

New assigned altitude as well as actual altitude.	YES 2	NO 3
Route of flight through your sector.	YES	NO 5
Destination.	YES 1	NO 4
Type of aircraft.	YES 2	NO 3
Speed.	YES	NO 5

Comments·

c. Do you think it would be advantageous to have only altitude information on some types of flights such as "over" flights?

YES 3 NO 2

d. Would you prefer to have selective control of information on the target marker, so that you could inspect either identification, altitude, or route? YES 3 NO 2

e. Do you think it is necessary to have an arrow associated with the marker to indicate direction of flight? Why?

YES NO 5

Comments·

4. Radar Handoff

As use of radar becomes more widespread, it appears it will be desirable to accomplish radar handoff from one sector to another in the same Center, from one Center to another, and between towers and Centers as is done today. One advantage of the SPANRAD system is that an identity marker with an aircraft target can be presented at more than one sector on the same or a second TV display. Thus, it should be possible to set up procedures for visual handoffs with little or no verbal coordination.

a. Do you feel this would be satisfactory? YES 5 NO___

b. Do you feel this could be a major advantage of the SPANRAD technique compared to the 22-inch horizontal display? YES 5 NO___

Comments:

5. Display Configuration

The present Center radar control system makes use of both flight progress strips and the horizontal plotting radar display (VG) with markers for the radar sector. Due to the large bulky equipment, the problems in maintenance, and limited space available, the VG indicators with supplemental posting boards have been installed as islands, away from the main flight progress boards. We have been experimenting with the use of TV radar indicators mounted in line with the flight progress boards at Indianapolis with the thought that coordination problems might be reduced if the radar was in line with the boards. However, island installations have certain advantages in other respects such as permitting three people to work around the one display, etc.

Which type of installation do you feel would be best for future Center installations for the various control problems listed below:

	ISLAND	IN LINE
Departing Aircraft		
a. Providing radar separation between successive departures during climb to cruising altitude on high-density one-way route.	3	2
b. Providing radar separation between successive departures, and other over and arrival traffic for medium-density traffic with departing aircraft entering two-way airway.	1	4

	ISLAND	IN LINE
En Route Aircraft		
a. Providing radar separation for crossing airway course problems with aircraft at same altitude or changing altitude levels with less than standard time separation.		5
b. Providing radar separation for same direction traffic in overtake problems		
With aircraft at same altitude.		5
With altitude change taking place.		5
c. Providing radar separation for opposite-direction traffic making altitude change.		5
Arriving Aircraft		
a. Providing radar separation between aircraft descending to approach fix in high-density one-way airway.	2	3
b. Providing radar separation between successive aircraft descending to approach fix and other or departing aircraft on twoway airway, medium-density traffic.		5
c. Spacing successive arriving aircraft by use of delay patterns to provide intervals across a perimeter fix without stacking.		5

6. Division of Control Duties

Several modes of operation are possible when radar is used in a Center. In the in-line operation, one controller on the flight progress boards can handle all interphone work with the tower, other Centers and/or sectors, including taking of position reports and issuing clearances to aircraft that are not on Center A/G radio. The radar controller seated alongside can communicate with the aircraft on direct Center radio and use the radar for separation with both controllers sharing the same strip postings. The two controllers can work as a team with equal responsibility or the "strip"controller or radar controller could be assigned primary responsibility with the other position as secondary.

A second mode of operation would be to use the radar display as the primary display with the controller tracking all IFR flights (or having them tracked) in the sector, and communicating on direct A/G radio with as many of the IFR flights as possible. An experienced assistant in this case would maintain a minimum number of flight progress strips for the sector and handle interphone work with the tower. (Assume FLIDAP operation for initial flight plan strips.)

a. Which of the above do you feel is best for Center use, assuming that each radar control sector is limited to a workable number of aircraft under control of one controller?

FIRST MODE 5 SECOND MODE ___

Comments:

7. A/G Communications

Several techniques are possible for handling aircraft position reports and clearances when a combination of radar and flight progress boards are used with some aircraft being provided radar separation and others having standard nonradar separation.

These include.

A. All IFR flights equipped with the sector discrete frequency in communication with the radar controller.

B. Only selected flights requiring radar separation on the discrete sector frequency with the balance of the flights on company or other ATC channels.

C. Selected flights requiring radar separation on the discrete radar control frequency with most of the other IFR flights on a separate Center frequency manned by a third controller.

Please check the communications arrangement which you feel is most efficient for the various types of control operation listed:

	A	B	C
Departing Aircraft			
a. Providing radar separation between successive departures during climb to cruising altitude on high-density one-way route.	5		
b. Providing radar separation between successive departures, and other over and arrival traffic for medium-density traffic with departing aircraft entering two-way airway.	3		2

	A	B	C
En Route Aircraft			
a. Providing radar separation for crossing airway/ course problems with aircraft at same altitude or changing altitude levels with less than standard time separation.	1	1	3
b. Providing radar separation for same direction traffic in overtake problems.			
With aircraft at same altitude.	1	1	3
With altitude change taking place.		1	3
c. Providing radar separation for opposite direction traffic making altitude change.		1	4
Arriving Aircraft			
a. Providing radar separation between aircraft descending to approach fix in high-density one-way airway.	5		
b. Providing radar separation between successive aircraft descending to approach fix and other over or departing aircraft on two-way airway, medium-density traffic.	2	1	2
c. Spacing successive arriving aircraft by use of delay patterns to provide intervals across a perimeter fix without stacking.	3	1	1

8. Operator Convenience

Please rate each of the display configurations listed, from the standpoint of ease of operation and use by the controller. Use scale 1 through 6.

Standard PPI slope panel	1	3	1	4	3	12
VG	3	4	3	3		13
21-inch TV vertical indicator in boards	4	5	4	5	5	23
22-inch TV horizontal display in boards	6	6	4	4	4	24
22-inch TV horizontal display in islands	5	6	3	4	4	22
SPANRAD in boards	5	4	5	5	4	23
SPANRAD - remote tracking	2	1	5	6	4	18

DATE ____________________
NAME ____________________
FACILITY ____________________
YEARS EXPERIENCE AS CENTER CONTROLLER __________
YEARS EXPERIENCE WITH CENTER RADAR __________
YEARS EXPERIENCE IN OTHER RADAR FACILITY __________

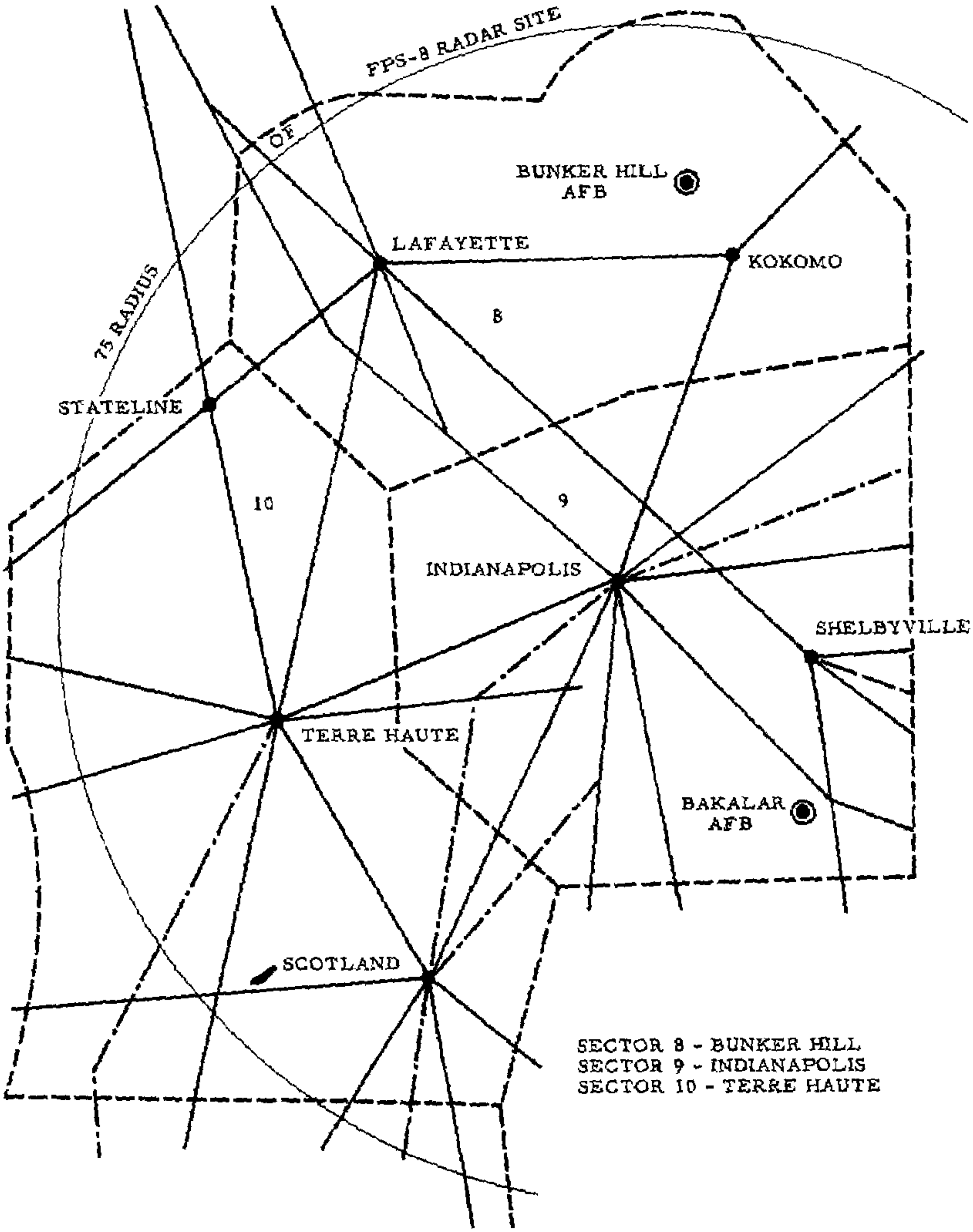


FIG. 1 FPS-8 RADAR COVERAGE OF THE INDIANAPOLIS ARTC CENTER AREA

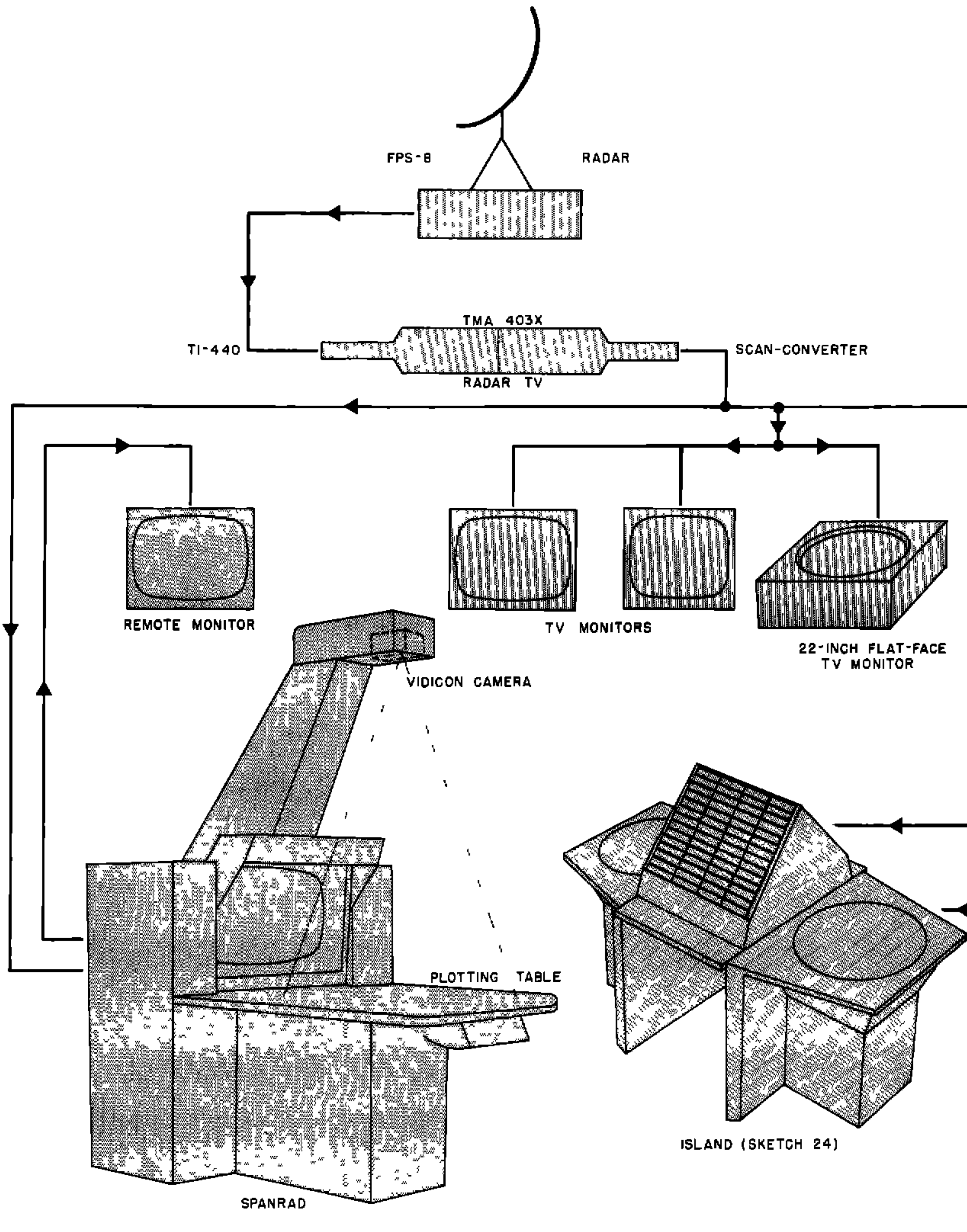
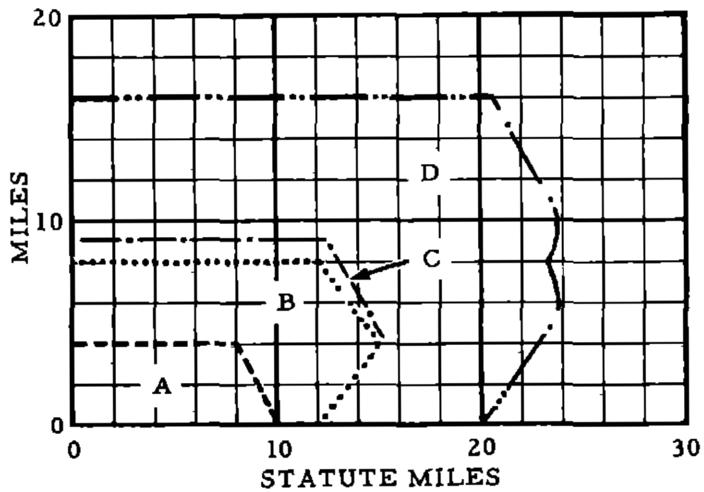


FIG 2 AN ILLUSTRATION OF THE FLOW OF RADAR INFORMATION FROM THE RECEIVER TO THE VARIOUS DISPLAYS TESTED



A = 1/2- X 1 1/4-INCH PLASTIC MARKER USED ON VG-1 AND 22-INCH FLAT-FACE DISPLAYS.

B = 1- X 2-INCH FELT COVERED WOOD-PLASTIC LETTERS TESTED ON SPANRAD.

C = 2- X 1 1/8-INCH SECT. FLT. PROG. STRIP HOLDER MARKED WITH BROAD NIB PENS, ETC.

D = 2- X 3-INCH PANOP MARKER. TABULAR FLIGHT INFORMATION WRITTEN ON PAPER SLIPS FOR INSERTION IN MARKER.

FIG. 3 DIAGRAM ILLUSTRATING RADAR COVERAGE AREA BLOCKED BY VARIOUS IDENTIFICATION MARKERS.

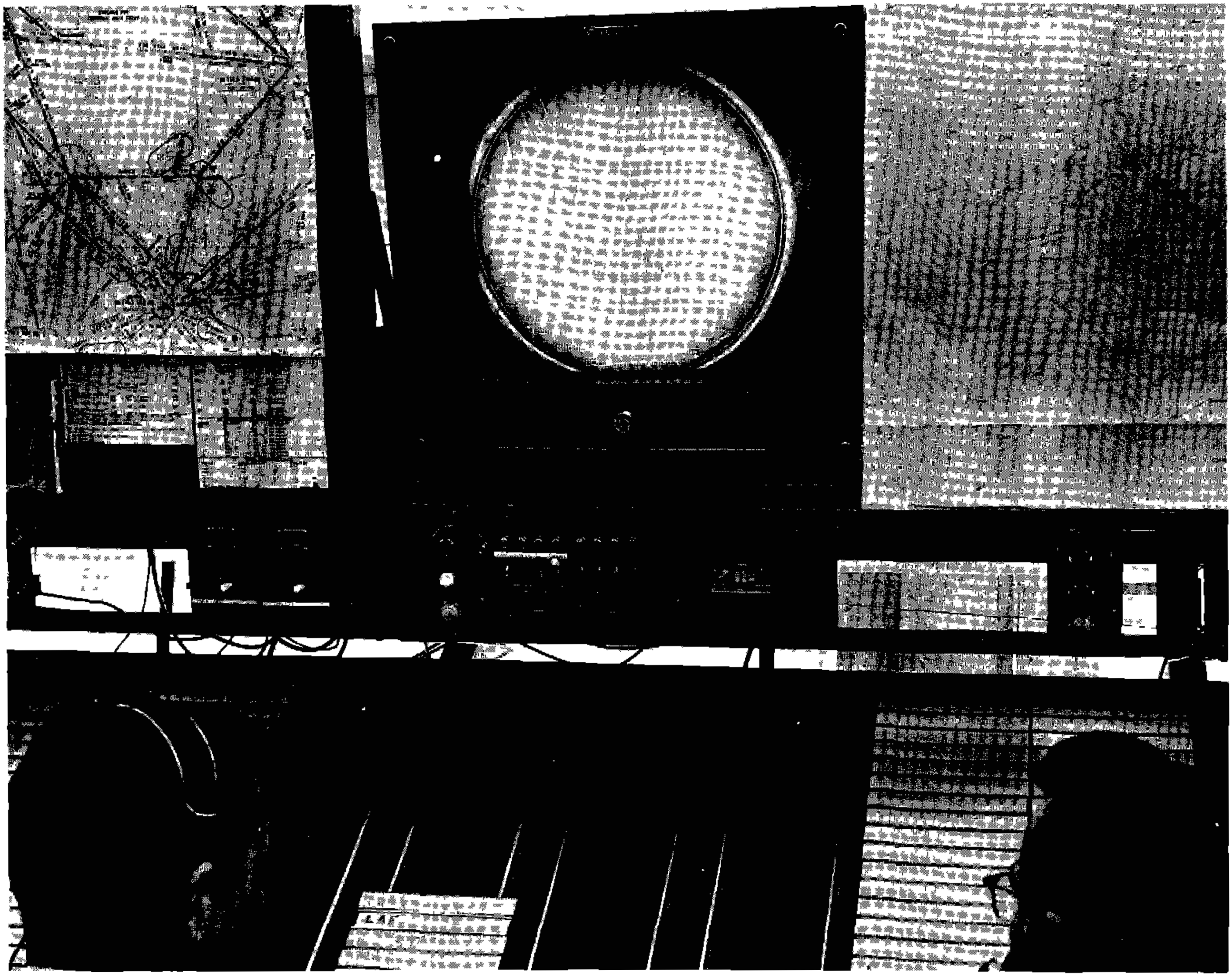


FIG 4 21-INCH VERTICAL MONITOR MOUNTED IN LINE WITH FLIGHT PROGRESS BULLETIN BOARD

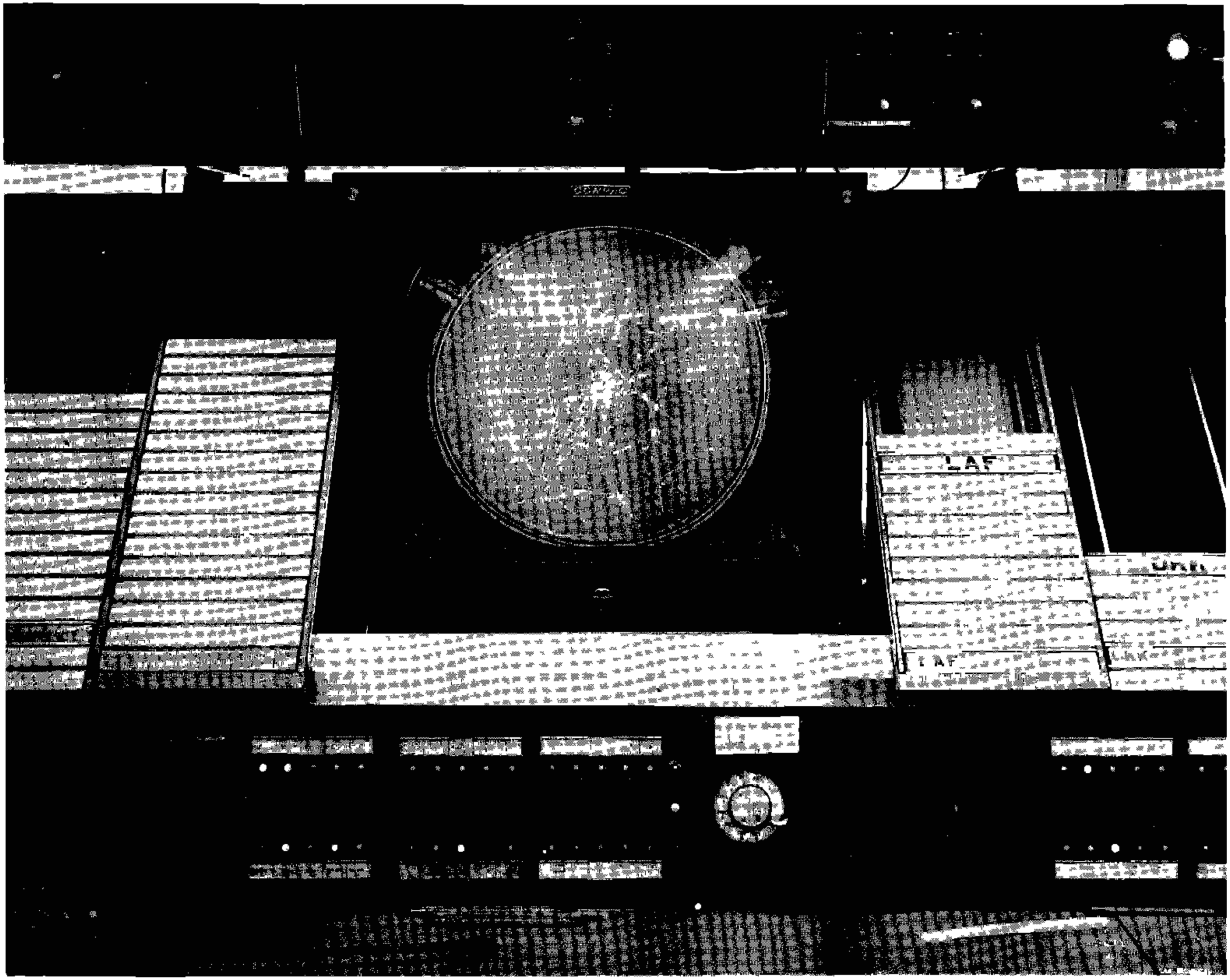


FIG 5 21-INCH TV RADAR INDICATOR MOUNTED VERTICALLY IN FLIGHT PROGRESS BOARDS IN INDIANAPOLIS ARTC CENTER

FIG 6 22-INCH FLAT-FACE HORIZONTAL TV DISPLAY MOUNTED IN LINE WITH FLIGHT PROGRESS BOARDS IN INDIANAPOLIS CENTER

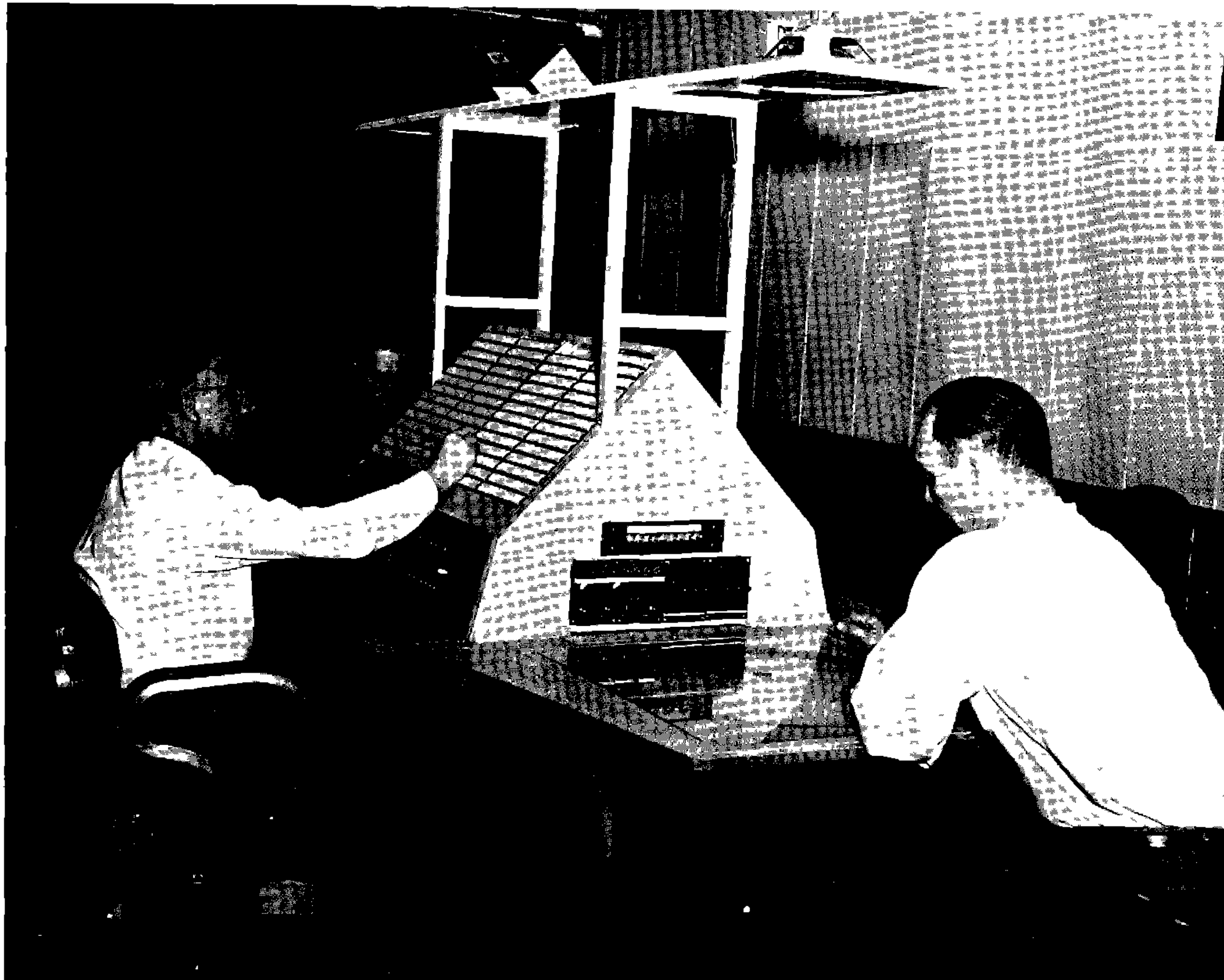


FIG. 7 EXPERIMENT 1 [illegible]

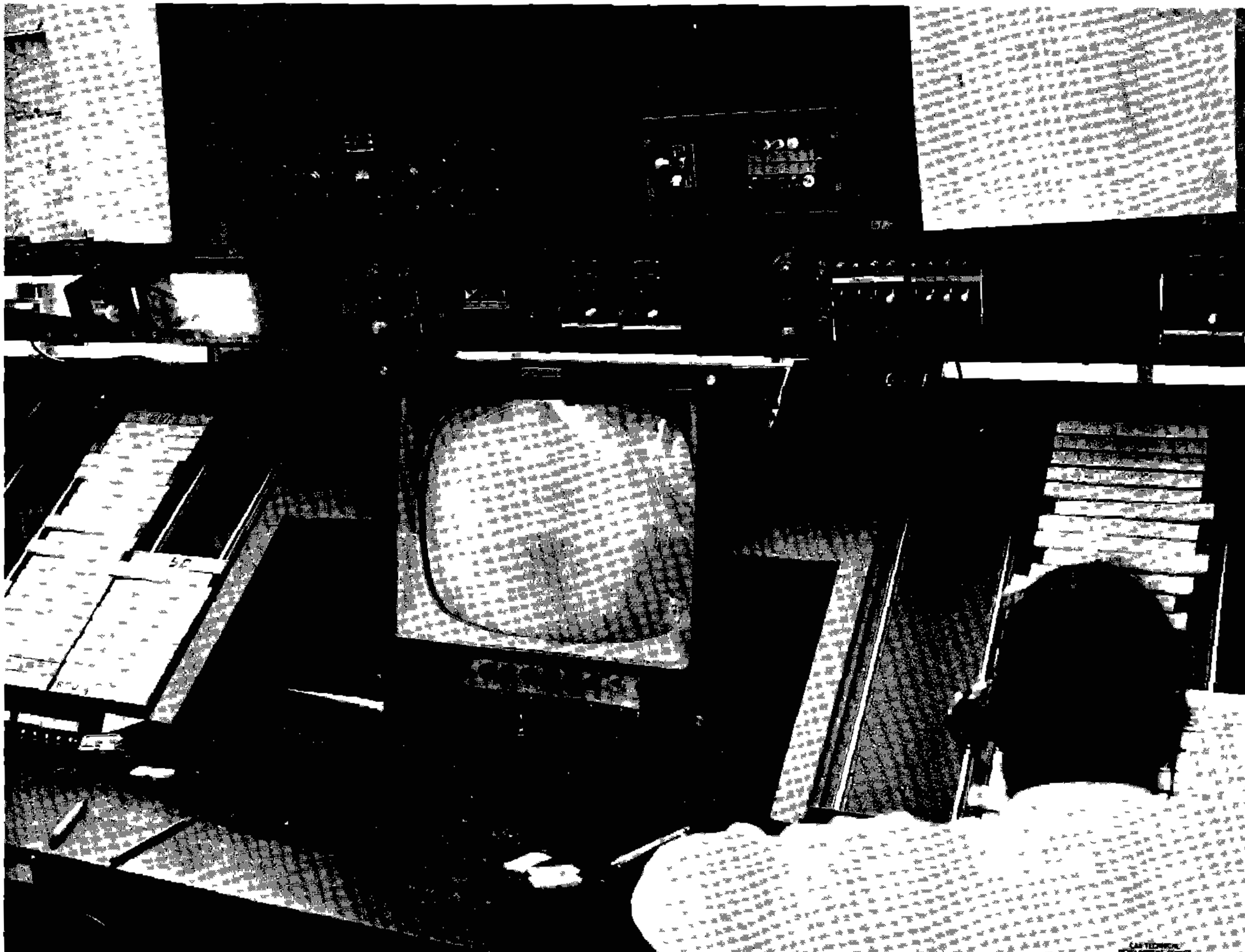


FIG 8 SPANRAD DISPLAY MOUNTED IN FLIGHT PROGRESS BOARDS
IN INDIANAPOLIS ARTC CENTER

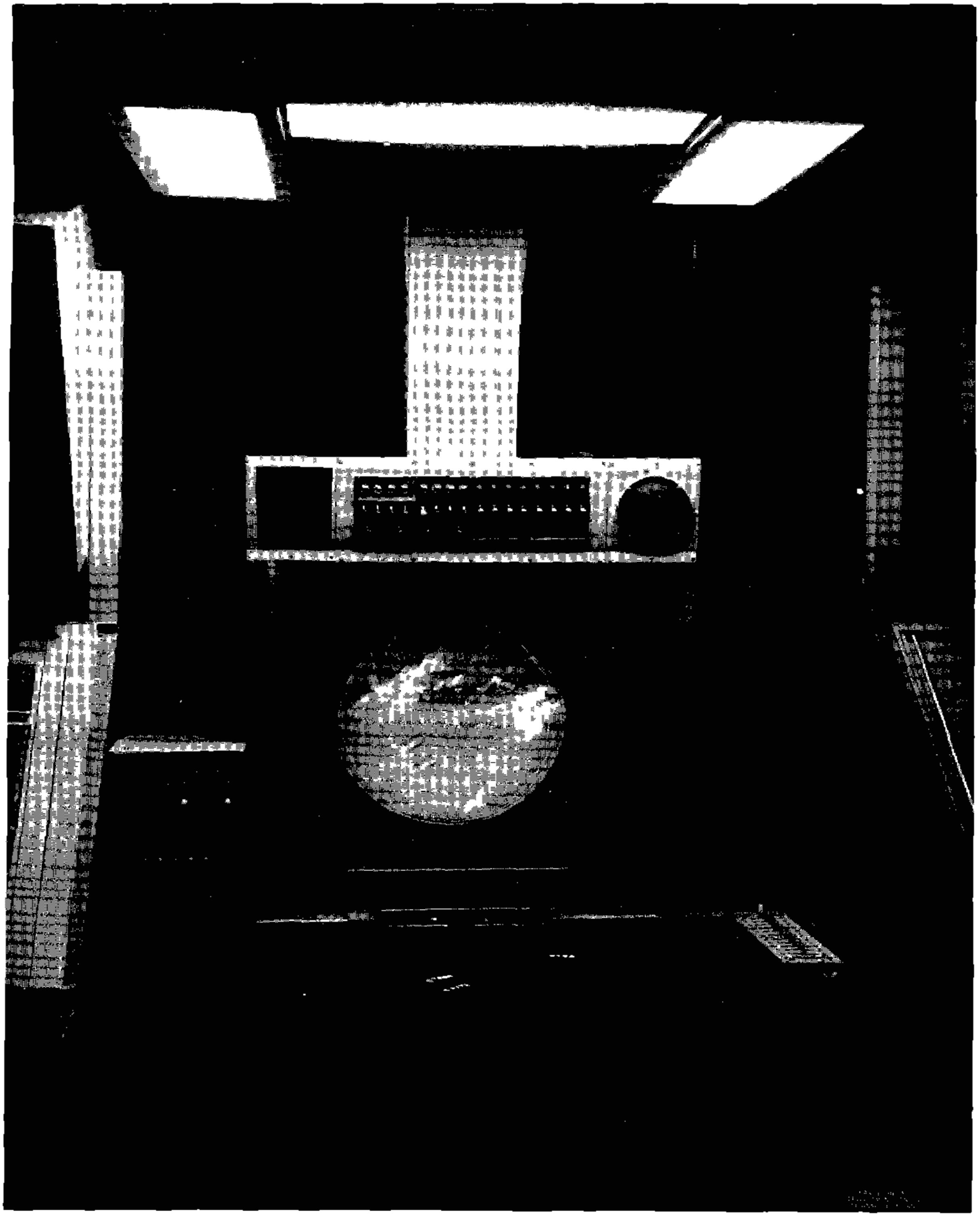


FIG 9 SUPERIMPOSED PANORAMIC RADAR DISPLAY (SPANRAD) LOCATED IN AOEC WITH REMOTE READING DISPLAY IN ARTCC

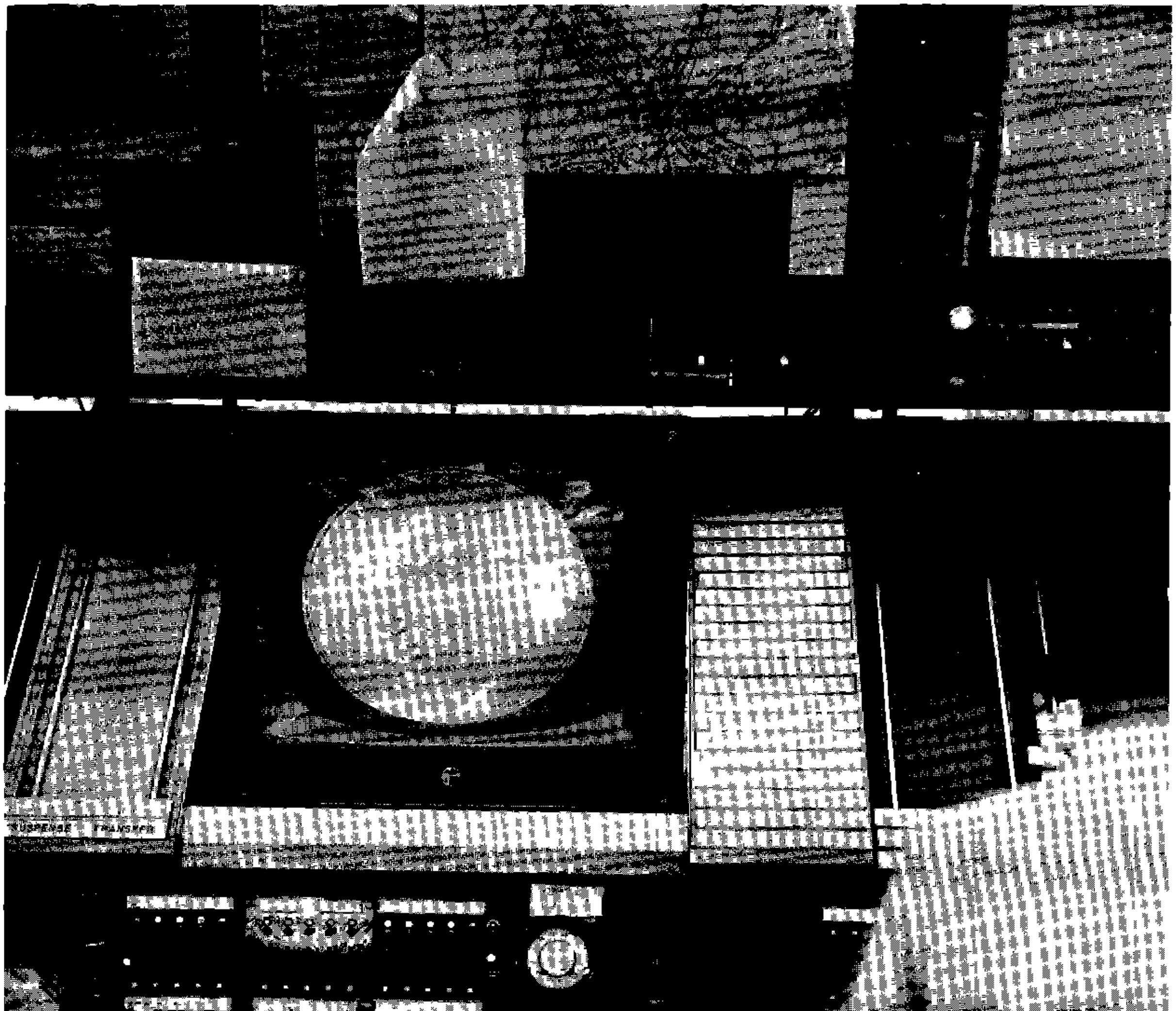


FIG 10 REMOTE DISPLAY IN ARTC FROM SPANRAD IN AOEC