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MAY 52 J H TERRY , G D ROBERTSON

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OCTOBER-NOVEMBER 1951

Project 6.4

AIRBORNE RADIAC EVALUATION

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OPERATION BUSTER

PROJECT 6.4

AIRBORNE RADIAC EVALUATION

by

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9 MAY 1952

DEPARTMENT OF THE NAVY
Bureau of Aeronautics
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DEPARTMENT OF THE AIR FORCE
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ABSTRACT

The Navy and the Air Force have developed airborne radiac equipment to detect the presence of a cloud resulting from an atomic explosion and to indicate its bearing with respect to an observing aircraft. The equipment was intended to detect an atomic cloud at sufficient range for an approaching aircraft to take evasive action. Both the Navy AN/ADR-3 and the Air Force Type D-1 equipment were found to be inadequate for this purpose against the comparatively low yield shots of Operation BUSTER. Recent information indicates that an atomic cloud need not be considered a critical hazard to aircraft on atomic bombing mission. Accordingly, and in view of their limitations, further development of the two types of cloud tracking equipment is not recommended.

CHAPTER 1

HISTORICAL BACKGROUND

1.1 GENERAL

The need for airborne radiac equipment to warn air crewmen of the presence of radioactive contamination and radiation was recognized at least as early as 1946. Data obtained in Operations SANDSTONE and CROSSROADS confirmed the requirements and development contracts for various types of equipment were let in 1948 or soon thereafter. Among these types were the Navy cloud tracker AN/ADR-3 and the Air Force Type D-1.

These equipments were available in sufficient quantity by late 1950 to propose them for test in Operation GREENHOUSE. A Navy P2V-2 and an Air Force B-17 were equipped with all of the airborne radiac equipment then available and were flown to Eniwetok to participate in Operation GREENHOUSE in the spring of 1951.

The two aircraft participated in only three of the shots of Operation GREENHOUSE and it was considered desirable to secure confirmatory evidence of the adequacy of the equipment in the additional shots proposed for Operation BUSTER. Such evidence was particularly desirable in the case of the cloud trackers where the response against the lowest yield shot of Operation GREENHOUSE had been marginal at best.

Accordingly both the P2V-2 and the B-17 radiac aircraft were proposed for participation in Operation BUSTER, particular attention being given to the cloud tracking test program inasmuch as the air burst shots of Operation BUSTER were not likely to result in sufficient ground contamination to warrant test of the airborne ground survey equipment. Automatic recording dosimeters and beta monitors were retained in the aircraft but their test was incidental to the principal objective.

1.2 OBJECTIVE

The objective of this project was to determine the maximum range at which an atomic cloud could be detected and defined directionally, as a function of time after detonation, using cloud trackers AN/ADR-3 (Navy) and Type D-1 (Air Force). Both of these trackers had performed satisfactorily against the comparatively high energy yield detonations of Operation GREENHOUSE but the results against the lowest yield shot had been very doubtful. It was therefore anticipated that the trackers would be ineffective against a cloud resulting from a bomb of nominal energy yield or less. The comparatively low yield detonations of Operation BUSTER offered an opportunity to determine the lower limit of bomb yield against which the cloud trackers would be effective. The determination of the lower limit was important in estimating the usefulness of the trackers in actual warfare.

CHAPTER 2

INSTRUMENTATION

2.1 AN/ADR-3 RADIOACTIVE-CLOUD TRACKER

2.1.1 Purpose

The purpose of this equipment is to detect and track a radioactive cloud produced by the detonation of an atomic bomb at sufficient range and with sufficient definition to permit an approaching aircraft to take evasive action.

2.1.2 Principle of Operation

The AN/ADR-3 airborne radioactive-cloud detector and tracker is a microwave radiometric type of equipment that is based on the reception of microwave radiation from an atomic cloud. It could reasonably be described as a directionally sensitive thermometer responding to radiation in the microwave region although it has no resemblance to a conventional thermometer in appearance.

In designing this cloud tracker, it was assumed that an atomic cloud would be characterized by the large number of ions and electrons present. It was further calculated that such a cloud would therefore be both a good absorber and radiator (approximating a black body) of wave-lengths in the 8.5-centimeter region to which ordinary clouds of water vapor are relatively transparent. Consequently, a suitably designed directional thermometric device scanning the sky for sources of 8.5-centimeter radiation should distinguish an atomic cloud from the background of clear or ordinary cloud-filled sky, by an apparent rise in "temperature" in the direction of the atomic cloud.

The Dicke-type radiometer, a sensitive device for this purpose, involves the modulation of the output of a parabolic dish-type receiving antenna and its transfer to an ordinary superheterodyne receiver. The modulation at about 30 cps is accomplished by the periodic insertion of an attenuating disc in the input wave guide. The modulation is the difference between the microwave energy received by the antenna and the energy being radiated by the attenuating disc. Since the energy radiated by the attenuating disc is proportional to its own temperature, the resulting modulation is a measure of the difference between the temperature of the attenuating disc and the equivalent temperature (black body) of the microwave energy being received by the antenna.

The temperature of the attenuating disc and the response to background (ordinary clouded sky) can be fixed at the time of test by theromstatic control so that the atomic cloud will be observed on the cathode-ray-scope indicator as a trace above zero level at the corresponding azimuthal position.

The presentation is a line from the center of the scope to the periphery that follows the antenna in azimuth, its length being an indication of the relative amount of energy being received in the 8.5-centimeter region.

Controls are provided to scan the sky continuously through 360° at selected angles of elevation, or through a pre-determined sector at selected angles of elevation, or manually alone.

Figure 2.1 is a block diagram of the AN/ADR-3 showing the basic circuits employed. Figures 2.2, 2.3, 2.4, 2.5, 2.6 and 2.7 show the actual components. A detailed discussion of their circuits is not considered necessary for the purposes of this report. Table 2.1 contains pertinent data.

2.2 D-1 RADIOACTIVE-CLOUD TRACKER

2.2.1 Purpose

The purpose of this equipment is the same as that of the AN/ADR-3 but utilizes nuclear gamma, rather than microwave, radiation from the atomic cloud.

2.2.2 Principle of Operation

This equipment uses a scintillation crystal (stilbene phosphor) and two photomultiplier tubes as a detector unit. It contains a high- and a low-sensitivity circuit to indicate the direction of a gamma source. The first, or high-sensitivity circuit, is an early-warning system which produces single-sweep lines on a polar-coordinate oscilloscope screen for each detected gamma ray. The angular position of the sweep trace on the scope is correlated with the position of a slit opening in a rotating shield through which the gamma rays pass to the scintillation crystal.

Cosmic rays penetrating the lead shield will produce randomly oriented traces, but small levels of gamma radiation from a radioactive cloud should be detectable by their preferred orientation on the scope.

Multiple scattering of the gamma rays by the air between the detector and the source would tend to diffuse the radiation and reduce the directionality of the source radiation. This limitation could only be assessed, however, by actual field test although preliminary estimates could be made based on assumptions with regard to initial cloud activity, its decay rate, its rate of dispersion, and absorption by the intervening air mass.

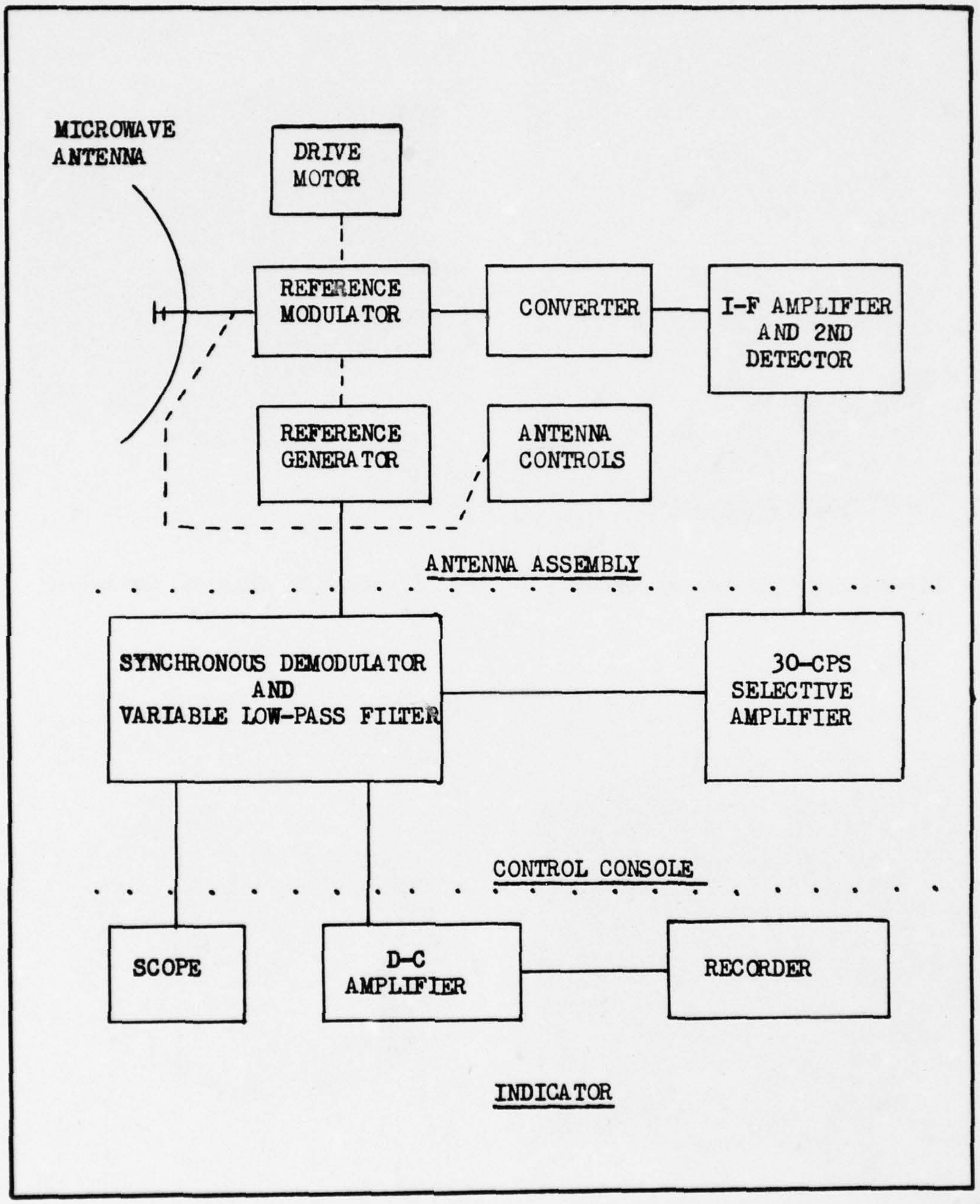

Figure 2.1 Block Diagram of AN/ADR-5 Radioactive-cloud Tracker

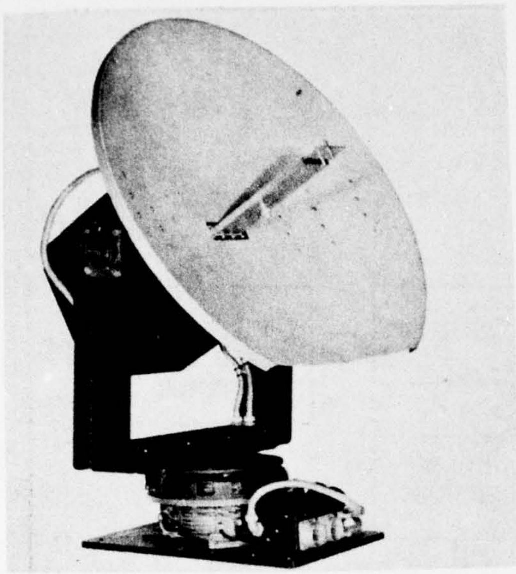

Figure 2.2 Antenna Assembly

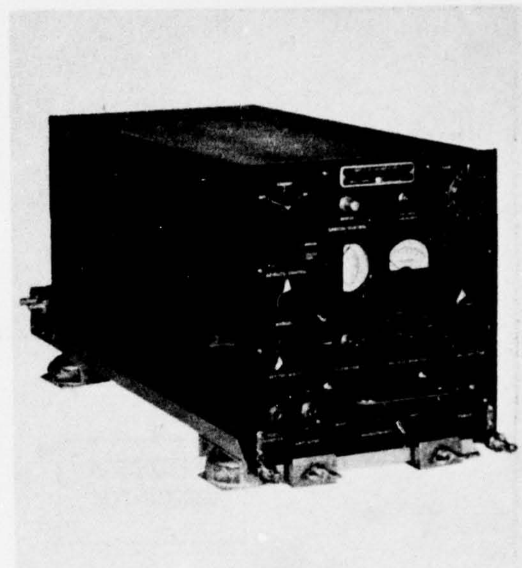

Figure 2.3 Control Console

Figure 2.4 Power Supply

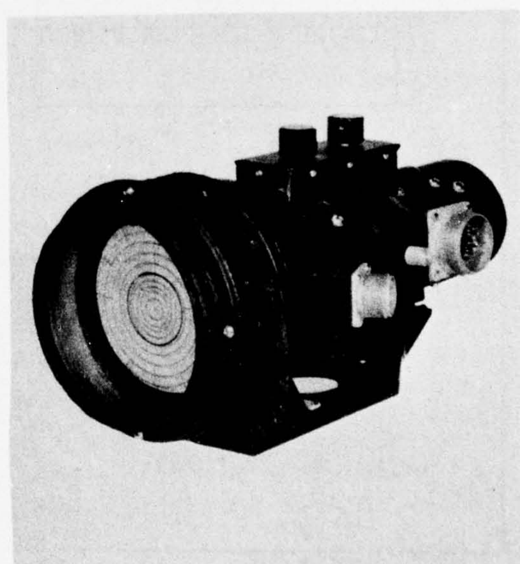

Figure 2.5 Cathode-ray Scope

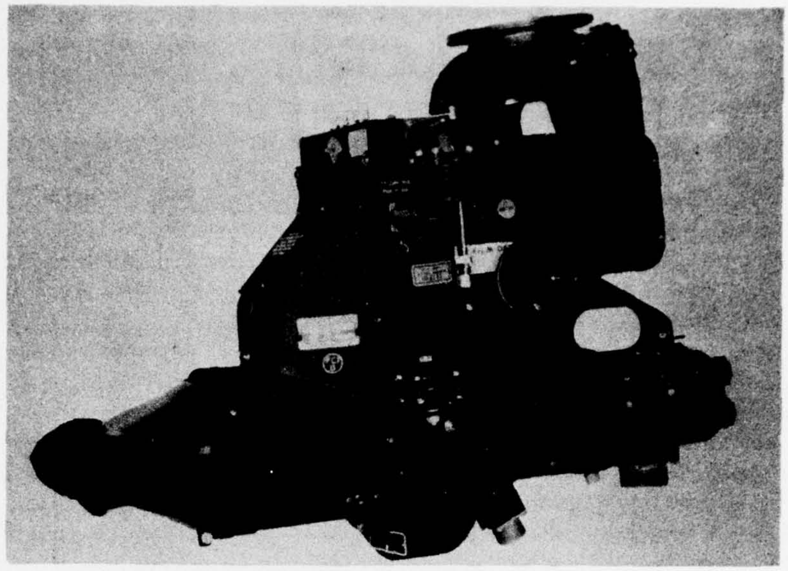

Figure 2.6 Scope Camera Used with Radioactive-cloud Tracker AN/ADR-3

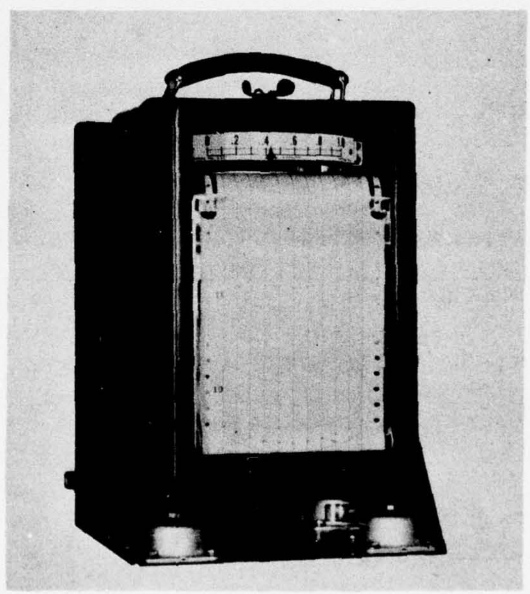

Figure 2.7 D-C Recorder Used with Radioactive-cloud Tracker AN/ADR-3

TABLE 2.1

Data for AN/ADR-3 Radioactive-Cloud Tracker

Physical Data				
Unit	Weight (lb)	Height (in.)	Width (in.)	Depth (in.)
Antenna assembly	55	38	30	30
Control console	20	11 1/8	12 3/8	23 3/8
Power-supply	30	11 1/8	12 3/8	23 3/8
Scope	10	14 1/4	7	7
Scope camera	15	14 1/2	10	24
Recorder	30	14 1/2	8 5/8	9 1/2

Miscellaneous Data	
Operating wavelength (cm)	8.5
Antenna-beam width	Approximately 6°
Type scan	Continuous 360° Sector (automatic) Manual
Antenna tilt	±30°
Type presentation	Azimuth scope Paper-ink recorder
Total power requirement	700 va - 400 cps

As the equipment moves closer to the source of radiation, more radial sweep traces are noted on the oscilloscope screen, the direction of the source still being indicated by their preferred orientation. As the radiation intensity approaches a level of approximately 10 mr/hr, the scope screen becomes filled with traces in the appropriate sector and results in a bright section on the scope.

At the 10 mr/hr level, the bright lines are blanked from the center out and the low sensitivity circuit of the system begins to operate. A darkened lobe replaces the brightly lit sector. The lobe is a polar coordinate plot of the radiation field and its intensity. A logarithmic intensity scale on the scope provides preference lines for comparing the relative intensities in different directions. As the intensity of the radiation increases, the magnitude of the darkened lobe increases, shifting in direction in accordance with the relative position of the source.

Figure 2.8 is a block diagram of the D-1 tracker showing the basic circuits employed. Figures 2.9, 2.10, 2.11 and 2.12 show the actual components. A detailed discussion of their circuits is not considered necessary for the purposes of this report. Table 2.2 presents pertinent data.

2.3 INSTALLATION OF THE CLOUD TRACKERS

Both Navy and Air Force radiac equipment was installed in each of the project aircraft, each aircraft crew assisting in the maintenance of its equipment in the other airplane.

The dish antenna of the AN/ADR-3 was mounted atop the fuselage of each aircraft. Each antenna was housed in a dome transparent to 8.5-centimeter radiation.

The detector unit of the type D-1 equipment was installed in the nose section of each aircraft.

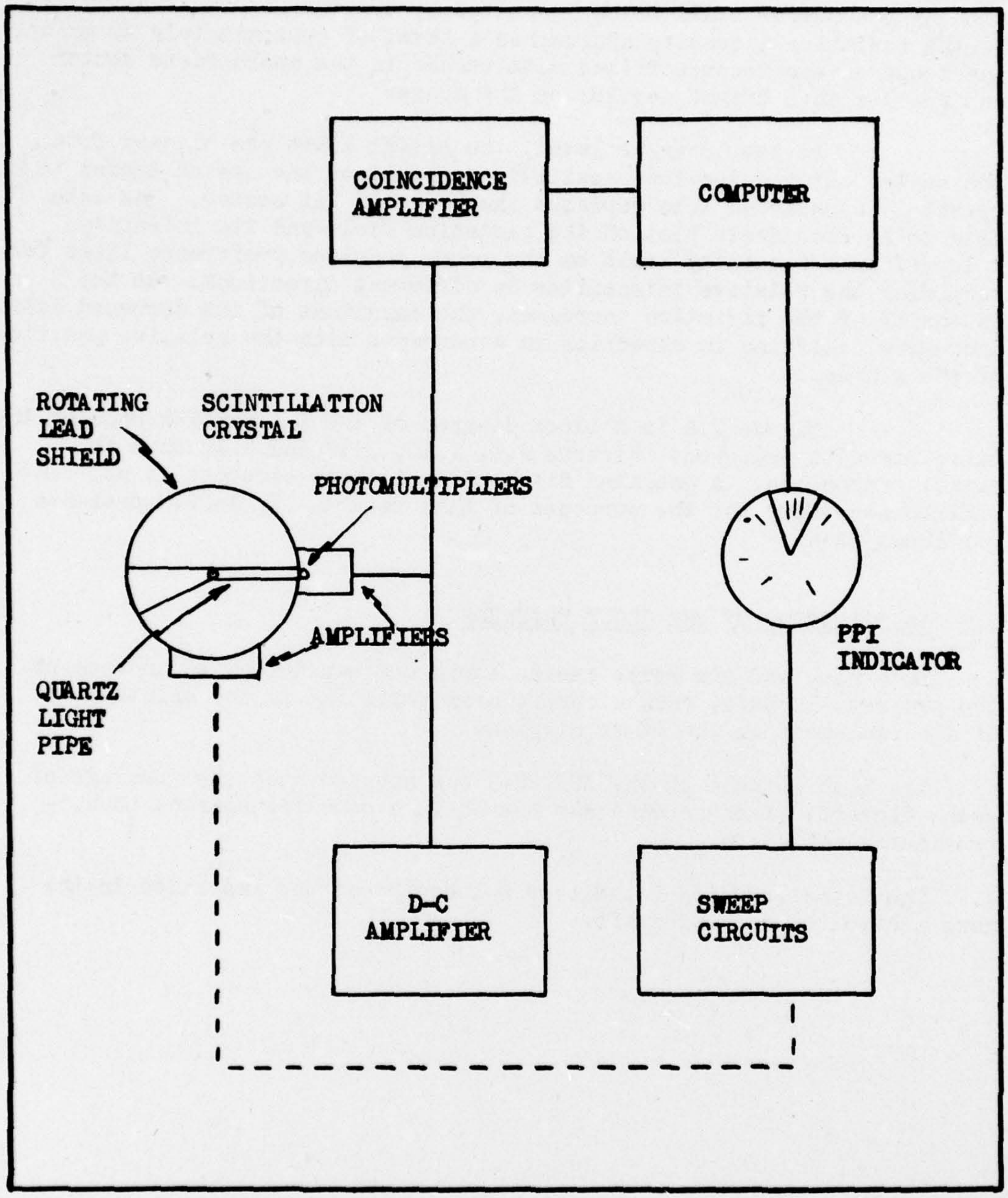

Figure 2.8 Block Diagram of Type D-1 Radioactive-cloud Tracker

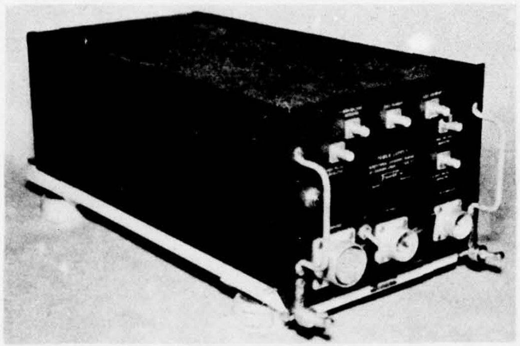

Figure 2.9 Power-supply Unit

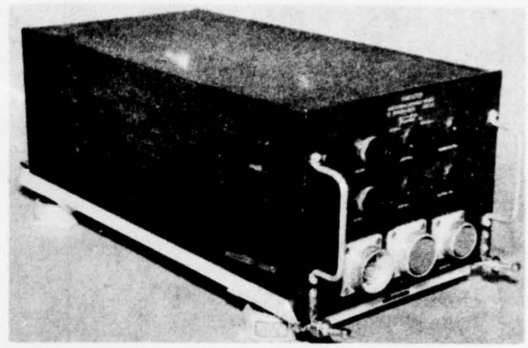

Figure 2.10 Computer Unit

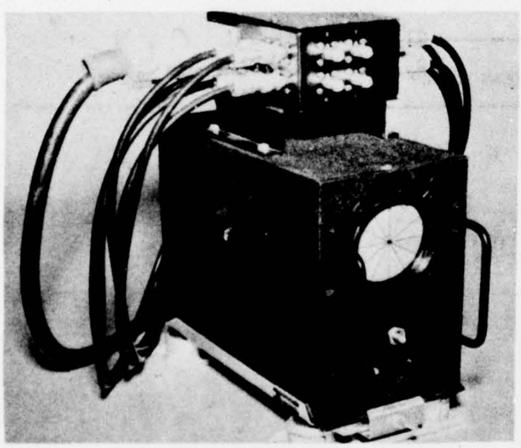

Figure 2.11 Indicator Unit

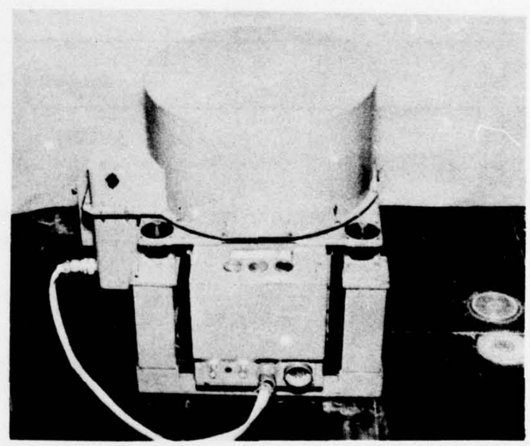

Figure 2.12 Detector Head

TABLE 2.2

Data for Type D-1 Radioactive-cloud Tracker

Physical Data				
Unit	**Weight (lb)**	**Height (in.)**	**Width (in.)**	**Depth (in.)**
Detector head	150 or 300	16	16	18
Computer	25	22	10	10
Indicator	10	12	6	12
Power-supply	25	22	10	10
Power Requirements				
DC		**AC**		
28 v 300 w		115 v, 200 va 400 cps		
Miscellaneous Data				
Type presentation . . . . .PPI The unit weighing 300 lb has greater directivity than the 150 lb unit. The detector heads in both units are interchangeable.				

CHAPTER 3

OPERATIONS

3.1 CLOUD DETECTION

The two project aircraft were based at Kirtland Air Force Base, Albuquerque, New Mexico, throughout the duration of the tests, proceeding to the Nevada site on shot day. On arrival at the site, each aircraft occupied its specified orbit approximately twenty miles from the zero point. The P2V-2 usually orbited at about 8000 feet above the terrain, the B-17 at about 10,000 feet.

At zero time each aircraft was on a specified heading at twenty miles range. Efforts were made to detect the cloud at this range for ten to fifteen minutes. Permission was then received from the control station to proceed in toward the cloud to determine the maximum range at which the cloud could be detected. As a rule the course selected was down-wind of the cloud and in such a direction as to keep the sun out of the field of scan of the AN/ADR-3 cloud tracker.

3.2 GROUND SURVEY

Upon dissipation of the cloud or its drift out of the test area, operations were discontinued insofar as the cloud trackers were concerned and the aircraft requested permission to undertake aerial survey of the ground at zero point, employing dosimeter AN/ADR-1 and ground survey equipments AN/ADR-4 and F-1.

The P2V-2 and the B-17 made alternate passes over ground zero at altitudes between 2000 and 500 feet. A pattern of parallel passes was obtained which covered the area around ground zero for a half mile on each side. Upon completion of these surveys (about one hour), both aircraft returned to Kirtland Air Force Base.

Further mention of the ground survey operations and data made in this report is brief since they are best understood and evaluated in conjunction with the data obtained in Operation JANGLE. Reference to them can be made in the report on Project 2.1c-2, Aerial Survey of Local Contaminated Terrain, of Operation JANGLE.

CHAPTER 4

RESULTS

4.1 AN/ADR-3 AND TYPE D-1 RADIOACTIVE-CLOUD TRACKERS

No quantitative data on the cloud trackers performance was recorded due to the essentially negative results. The distance at which reliable directional indications were first obtained with the two types of cloud trackers was of the order of two to three miles approximately twenty to thirty minutes after shot time. These distances are not considered sufficient for a high-speed aircraft to undertake evasive action.

4.2 AN/ADR-4 AND TYPE F-1 GROUND SURVEY EQUIPMENT

Slight indications of ground contamination were picked up on these equipments in passes over the crater areas resulting from shots Baker and Charlie. Passes were made at altitudes ranging from 2000 to 500 feet. Marked indications were obtained on shot Dog and somewhat less on shot Easy. These results are noted in more detail in the report on Project 2.1c-2, Aerial Survey of Local Contaminated Terrain, of Operation JANGLE.

4.3 AN/ADR-1 RECORDING DOSIMETER

Readings on this equipment were obtained during the ground-survey operations and on close (0.5-1.0 miles) approaches to the atomic cloud. Values of 3 mr/hr were observed on shot Charlie at a distance of 0.5 miles approximately fifteen minutes after zero time. The ground survey associated readings for shot Dog are considered in the report on Project 2.1c-2, Aerial Survey of Local Contaminated Terrain, of Operation JANGLE.

CHAPTER 5

DISCUSSION

5.1 PRELIMINARY

The present status of the AN/ADR-3 and Type D-1 cloud trackers is believed to be reasonably stated as follows: They are capable of detecting and roughly defining an atomic cloud at a distance of some fifteen to twenty miles from zero time to about one hour later provided the yield from the shot is of the order of forty kilotons or larger. For bombs of lower yield they are ineffective, the maximum range being of the order of three miles or less, falling off rapidly with time.

5.2 JUSTIFICATION FOR CLOUD TRACKERS

In 1948, when the initial procurement of the two types of cloud trackers was started, an atomic cloud was more or less an unknown hazard insofar as aircraft operations were concerned. Estimates could be made, but they were tenuous extrapolations at best.

It was known that the radiation intensity in the atomic cloud was high and that fission products constitute a dangerous inhalation problem. Little was known, however, of the actual dosages to be expected by an airplane passing through the cloud at various altitudes, at varying distances from the zero point, and at varying time intervals after the shot. Accordingly, the two services realized that warning equipment should be developed in anticipation of the possibility that an atomic cloud was found to be a major constraint on operations. The data from Operations GREENHOUSE and BUSTER indicate, however, that the need for these cloud trackers should be re-examined in the light of their probable use.

5.3 CRITICISM OF CLOUD TRACKERS

First, and obviously, the cloud trackers are entirely too heavy and too large to be considered for any general installation. Their use would, in any event, be confined to aircraft of bombing or transport dimensions having a specific mission in a bombed area. The question therefore arises as to the probable hazard represented by an atomic cloud to an aircraft in its vicinity. Specifically, we may visualize a bomb-carrying strike aircraft approaching an area in which one or more bombs have been dropped some fifteen minutes previously. Under such circumstances, the following observations are pertinent:

(a) If the mission is made in daylight, the clouds will be seen and the cloud trackers are superfluous. If the mission is conducted at night, the cloud trackers will provide directional information only at distances too short to take evasive action if the yield has been of the order of 40 kiloton or below. For yields above 40 kiloton, they will give directional, but no range, information. The trackers are not radars.

(b) The likelihood of an approaching aircraft entering an atomic cloud during the initial stages, when the concentration of radioactivity is high, is very small. At twenty miles, a cloud one mile in diameter subtends an angle of about three degrees. The likelihood of an aircraft being on a heading in that particular sector is small. Later, when the cloud is diffused and subtending a larger angle, the radioactivity is greatly decreased.

(c) In the event that an airplane is unfortunate enough to pass through the center of the cloud at an early stage, the radiation dose received should not be lethal. An aircraft traveling at 400 miles per hour would pass through a cloud one mile in diameter in a matter of ten seconds. Available Operation GREENHOUSE data indicate that dose rates of the order of 12,000 r/hr may be expected. An exposure of ten seconds at this rate (assuming uniform intensity) would result in a dose of some 40 r. Admittedly, residual contamination of the aircraft might occur which is subsequent flight might increase the dose. But such contamination is largely in the engines and on leading edges which are some distance from the air crew. Moreover, during ground survey operations by the aircraft of this project, it has consistently been noted that the dosage recorded in the fuselage of the aircraft is less by a factor of ten than that recorded in the nose section. The estimated dosage of 40 r should therefore be reduced by a factor of at least five in general operations.

(d) The cloud tracking equipments are heavy, involving penalties in terms of aircraft performance, require the maintenance associated with all complex electronic equipment, and require the services of a crew member to operate it. Aircraft crewmen on a strike mission are not likely to accept reduced performance to avoid a hazard which is likely to be least of their worries. Nor can they afford to devote the attention of one member of a limited and overburdened crew to such equipment during the critical phases of a strike.

(e) Finally, and this criticism is relevant only to the AN/ADR-3, the scanning antenna receiving the 8.5-centimeter radiation cannot scan below an elevation of about 20° without receiving spurious signals from the horizon. This means that at a minimum angle of elevation the detected cloud will be above the actual flight path of the airplane; at twenty miles the observed readings would be due to a cloud hazard which was some seven miles above the flight path. Clearly, such information is not of interest. To be sure, this problem would decrease with increasing altitude as the horizon receded, but it would not vanish and while not insoluble, the existing design does present this difficulty. (It should be noted that the AN/ADR-3 is an experimental design and that this deficiency is not the result of an oversight).

CHAPTER 6

CONCLUSTIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The present cloud tracking equipments are not sufficiently sensitive to detect and track the clouds resulting from low-yield shots of the order of 40 kilotons at a sufficient distance to take evasive action in high-speed aircraft. The Operation GREENHOUSE results indicate that they might be of value at ranges up to twenty miles against shots of higher yield as late as one hour after detonation.

6.2 RECOMMENDATIONS

6.2.1 AN/ADR-3 RADIOACTIVE-CLOUD TRACKER

Further development of this equipment is being abandoned and no substitute investigation or alternative design is proposed. A service need for this equipment does not exist.

6.2.2 TYPE D-1 RADIOACTIVE-CLOUD TRACKER

Further development of this equipment is being abandoned and no substitute investigation or alternative design is proposed. A service need for this equipment does not exist.

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