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PROJECT OFFICERS REPORT—PROJECT 7.6

FEASIBILITY EVALUATION OF AN AERIAL RADIAC SURVEY SYSTEM (U)

E. G. Hickson,, Jr., Captain, USA
Project Officer

J. P. Dietrich, Task Manager

U.S. Army Electronic Proving Ground
Fort Huachuca, Arizona

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ABSTRACT

An aerial radiac monitor system was evaluated in manned and drone aircraft to determine the feasibility of automatically correcting gamma radiation dose-rates measured at heights of 200 to 1,000 feet above terrain to the ground level (3-foot) dose-rate by the introduction of a correction signal from a radar altimeter. The radiac system consisted of a scintillation detector, logarithmic amplifier, summation circuit, radar altimeter, and recorder. A telemetry system relayed height-corrected information from drone aircraft to a ground station for recording. The equipment demonstrated tho feasibility of performing aerial radiological survey, with automatic height correction, in manned and drone aircraft of the surveillance types now in tactical use by the Armed Forces.

Information on air-to-ground correlation factors was also obtained.

PREFACE

Mr. Rodney Lewis, United States Army Electronic Proving Ground (USAEPG), was responsible for the development of the unique amplification, summation, and calibration circuits that were the heart of the instrumentation. PFC Brian Kuehn, PFC Robert Younkin, and Mr. Lewis assisted in data analysis.

Captain T. R. Cash, USMC, 1/Lt W. V. Dubinsky, USMC, and Gunnery Sgt C. P. Miller, 3rd MAG, Santa Ana, California, were the aircraft crew. Their professional ability and cooperative attitude were vital to the mission.

The assistance of the Defense Products Group, Minneapolis-Honeywell Corp., and of Emertron, Incorporated, in the adaption of their altimeters for this application contributed materially to the success of this evaluation.

This evaluation was performed under Department of the Army Sub-Task 3D22-09-001-02/01, U.S. Army Electronics Research and Development Activity, Fort Huachuca, Arizona.

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CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

The general objective of Project 7.6 was to test and evaluate experimental aerial radiac equipment in an actual nuclear environment. Specific objectives of this project were to: (1) test equipment designed and fabricated by the U. S. Army Electronic Proving Ground (USAEPG) to determine the feasibility of automatically correcting a gamma radiation dose-rate measured at any altitude from 200 to 1,000 feet above terrain, to the 3-foot (ground level) dose-rate by the introduction of an automatic correction signal from a radar altimeter, (2) determine feasibility of using the AN/USD-13 Drone Surveillance System as the platform for the aerial survey equipment, and (3) gather information on air-to-ground correlation over an actual fallout field.

1.2 BACKGROUND

The U.S. Continental Army Command (USCONARC) approved Military Characteristics for Aerial and Armored Vehicles on 16 December 1957. These military characteristics required that substantially the same equipment be used in aircraft and in land vehicles. A standard IM-108 Radiac Meter was modified and later designated the IM-133 for aerial use. This instrument, together with modification kit MK-394, was given the designation of AN/ADR-7, Aircraft Radiac Set, and was provided in an effort to afford an interim capability in this area. Service testing of this equipment by the U.S. Army Aviation Board during 1959 indicated that the equipment was unacceptable.

The USCONARC then reoriented the military characteristics to separate the aerial survey requirement from the armored vehicle survey requirement. The current military characteristics for an Aerial Radiac Survey System were approved by the Office of the Chief, Research and Development (OCRD) in August 1961. Additional military characteristics for an interim capability were approved in December 1961. The U. S. Army Electronic Proving Ground (USAEPG) initiated a task in July 1958 to determine the application of various nuclear surveillance sensors to surveillance drone aircraft under development by the U.S. Army Signal Corps. This is now Department of the Army sub-task 3D22-09-001-02/01, Drone Application of Radiological Sensory Devices.

In January 1960, a USAEPG-sponsored study report entitled "Measurement and Analysis of Residual Radioactivity Resulting from Nuclear Explosions", which dealt with detection of gamma rays from fallout, was completed (Reference 1). This report concluded that ground contamination could be measured by devices mounted in drones and recommended fabrication of an instrument to test the concept.

As a result of the above recommendation, an airborne radiac monitor was fabricated for USAEPG under contract and delivered in August 1960. Feasibility tests were initiated in accordance with Plan of Test, "Feasibility Test of Airborne Radiac Monitor", USAEPG SIG 930-171, subsequently published in November 1960 (Reference 2). Deficiencies in the equipment precluded completion of the tests as scheduled. During the period August to November 60, laboratory engineering tests and extensive studies of the concepts from which the system evolved were conducted, and an analysis of the system accuracy was completed. Based on these studies and tests, new models were designed and fabricated in USAEPG laboratories.

These models were completed in December 1961 and flight-tested over the Pelham Range radiological facility, Fort McClellan, Alabama, in January 1962. Although the limitations of the field as to size and composition did not permit definitive conclusions as to the air-to-ground correlation, the equipment provided predictable dose-rate contours. A detailed report of this test is being prepared (Reference 3).

In March 1962, the equipment was used to support the U.S. Army Nuclear Defense Laboratory in making radiation measurements in support of the Danny Boy Event. Again, though this was a limited radiation field, the equipment demonstrated the capability of rapid survey of relatively large areas.

By May 1962, the equipment had been reduced in size and sufficiently ruggedized and shock mounted to permit evaluation in the AN/USD-1B Drone Surveillance System.

1.3 THEORY

The equation describing radiation intensity above a large plane radiation source is generally accepted as:

$$I_G = KI_A \times \exp(\mu h) \qquad (1.1)$$

Where:

- I_G = radiation level at ground, or 3-foot level (Rad/Hour)
- K = buildup factor due to scatter
- I_A = radiation level at the detector (Rad/Hour)
- μ = gamma ray absorption coefficient in air (1/feet)
- h = height of detector above terrain (feet) $200' \leq h \leq 1000'$

$K \times \exp(\mu h)$ comprises the correction factor, i.e., what the air dose-rate must be multiplied by to equal the ground dose-rate. K and μ are essentially constant over the altitude range in which the equipment is designed to operate and are treated as constants, leaving h the only variable in the correction factor.

By taking the logarithm of both sides of the equation, we now have:

$$\ln I_G = \ln I_A + \ln K + \mu h \qquad (1.2)$$

Then set h' equal to the correction factor:

$$h' = \ln K + \mu h \qquad (1.3)$$

and substituting gives:

$$\ln I_G = \ln I_A + h' \qquad (1.4)$$

with h' the correction factor.

CHAPTER 2

PROCEDURE

2.1 OPERATIONS

Map References: Frenchman Lake Sheet 2857IV, 1:50,000

Las Vegas Sheet NJ 11-12, 1:250,000

An operations center and drone launch, control, and recovery point was established in the vicinity of grid coordinates 931783, approximately 3.5 miles northwest of ground zero. Helicopters were based at Indian Springs Air Force Base and were operated from a heliport located at CP-1. Helicopter flights were made at H+1½, H+5½ and H+22 hours. Drone flights were made at H+10, H+11, and H+15 hours. Telemetered and recorded data from manned and drone aircraft were evaluated and plotted at the operations center during and after each flight. The requirement for controlled air space limited the drone flights to an area northeast of ground zero. The data collected from the drone system was compared to that from manned aircraft.

2.2 INSTRUMENTATION

The Military Characteristics for an Aerial Radiac Instrument System (Reference Appendix) were used as a general guide in the design and development of equipment, but no attempt was made to meet every provision. The same basic system was used in both manned and drone aircraft, with the exception that on-board recording was accomplished during manned flight.

The basic equation which was instrumented is given by Equation 1.4, which is repeated here for convenience:

$$\ln I_G = \ln I_A + h'$$

Where: I_G = radiation intensity at 3-foot level (Rad/Hour)

I_A = radiation intensity at sensor (Rad/Hour)

h' = correction factor

The block diagram in Figure 2.1 shows the representative voltage signal from each major functional component. Figure 2.2 is a detailed schematic of the drone sensor; Figure 2.3 is a photograph of the AN/USD-1B Drone, and Figure 2.4 is a photograph of the drone sensor. Figure 2.5 is a detailed schematic of the manned aircraft sensor; Figure 2.6 is a photograph of the manned aircraft sensor.

2.2.1 Detector-Amplifier. The detector-amplifier consisted of a plastic fluor scintillator, a photomultiplier tube, and associated electronic circuitry designed to produce an output signal proportional to the logarithm of the gamma radiation incident on the fluor scintillator. The use of this logarithmic circuit facilitated the display of the data over a wide range of intensities and provided for ease of instrumentation. A 1½-inch diameter by ¼-inch long plastic fluor was used.

2.2.2 Radar Altimeter. Radar altimeters were used to determine the height of the aircraft above the ground and provide a voltage proportional to that height. An Emerson Model ERP-1180 was used in manned aircraft, and a Minneapolis-Honeywell Model 7091 was used in the drones. Both units consisted basically of a receiver, transmitter, indicator, power supply, electronic control unit, and receiving and transmitting antennas.

2.2.3 Summation Circuit. The purpose of this circuit was to add the logarithmic amplifier and radar altimeter signals to obtain height-correlated information. This circuit consisted basically of two CK533AX electron tubes and circuitry for calibrating the two input signals, which applied to the grids. The plates and cathodes were paralleled.

This circuit and the Detector-Amplifier were designed and fabricated by personnel at USAEPG.

2.2.4 Telemetry System. The telemetry system consisted of an airborne unit and a ground station. The airborne unit consisted of a TeleDynamics, Type 1004B transmitter, two each Bendix Type TOE-30 sub-carrier oscillators, and an antenna. The ground station consisted of a Nems-Clarke Type 1671 receiver and two each Electro Mechanical Research, Incorporated, Type 189F sub-carrier discriminators.

A signal voltage was applied to the sub-carrier oscillators and transmitted to the ground station. The receiver in the ground station detected the transmitted signal, and the discriminator returned it to the original voltage level form for recording.

2.2.5 Recorder. The recording units used for this evaluation were a Consolidated Electro-Dynamics Corporation Model 5-124 and a Midwest Instruments Corporation Model 603. These were fast-response oscillographic-type recorders with ultraviolet light reflected from a galvanometer onto photographic paper sensitive to this light region. No developing or fixing was required. A 4-decade logarithmic scale was traced on the paper simultaneously with the signal trace. The use of this logarithmic scale made direct reading of the ground radiation intensity possible.

2.2.6 AN/USD-1B Drone Surveillance System (SD-1). The AN/USD-1B Drone Surveillance System (SD-1) is controlled by visual or radar means. It has a 138-inch wing span, 162-inch length, and a speed of 160 knots with a 30 minute flight time. The drone is designed for zero length launching with jet-assisted takeoff (JATO) and is landed by means of a parachute either upon command from the Controller or automatically upon failure of the engine or interruption of the radio control carrier. The compartment size is 1.16 cubic feet and payload is 62 pounds.

The Control Radar used was an AN/MPQ-29, with an AN/DPN-62 Beacon Transponder mounted in the drone.

This is a tactical unit currently in use by the U. S. Army.

An SD-1 Drone is shown in Figure 2.3.

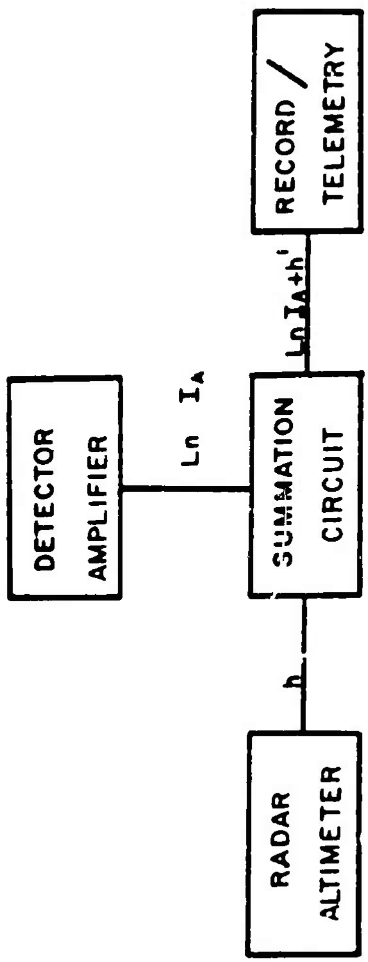

Figure 2.1 System block diagram.

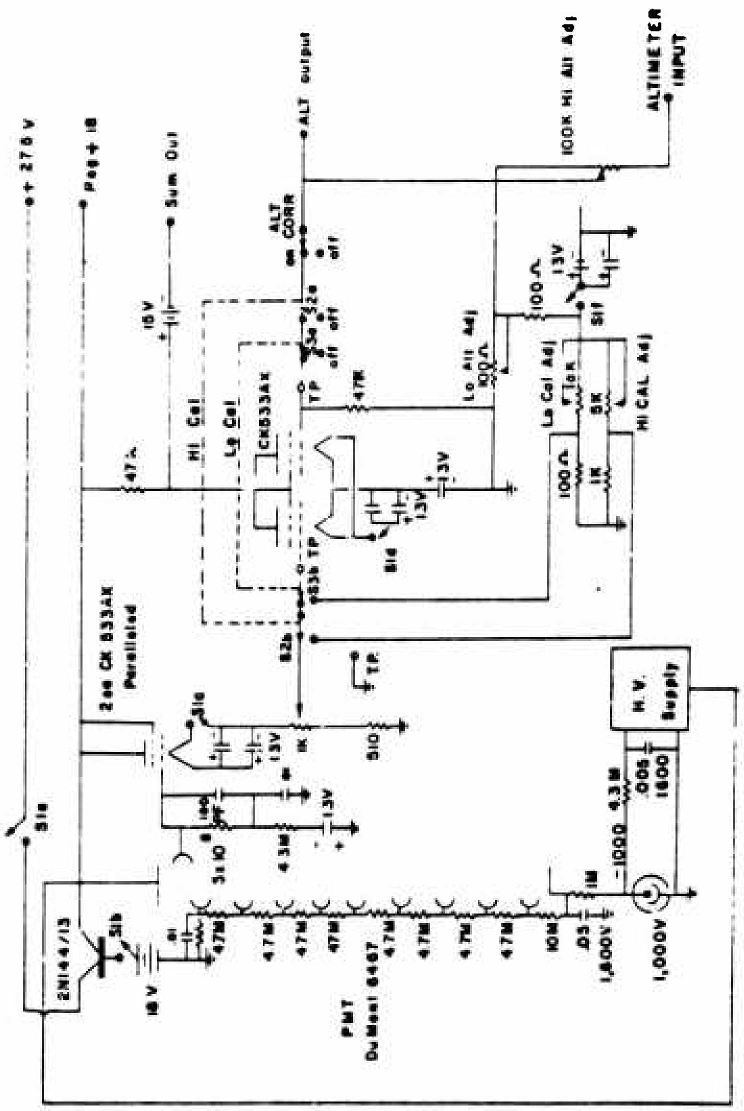

Figure 2.2 Drone unit schematic.

Figure 2.3 AN/USD-1B surveillance drone. (DASA 698-07-NTS-62)

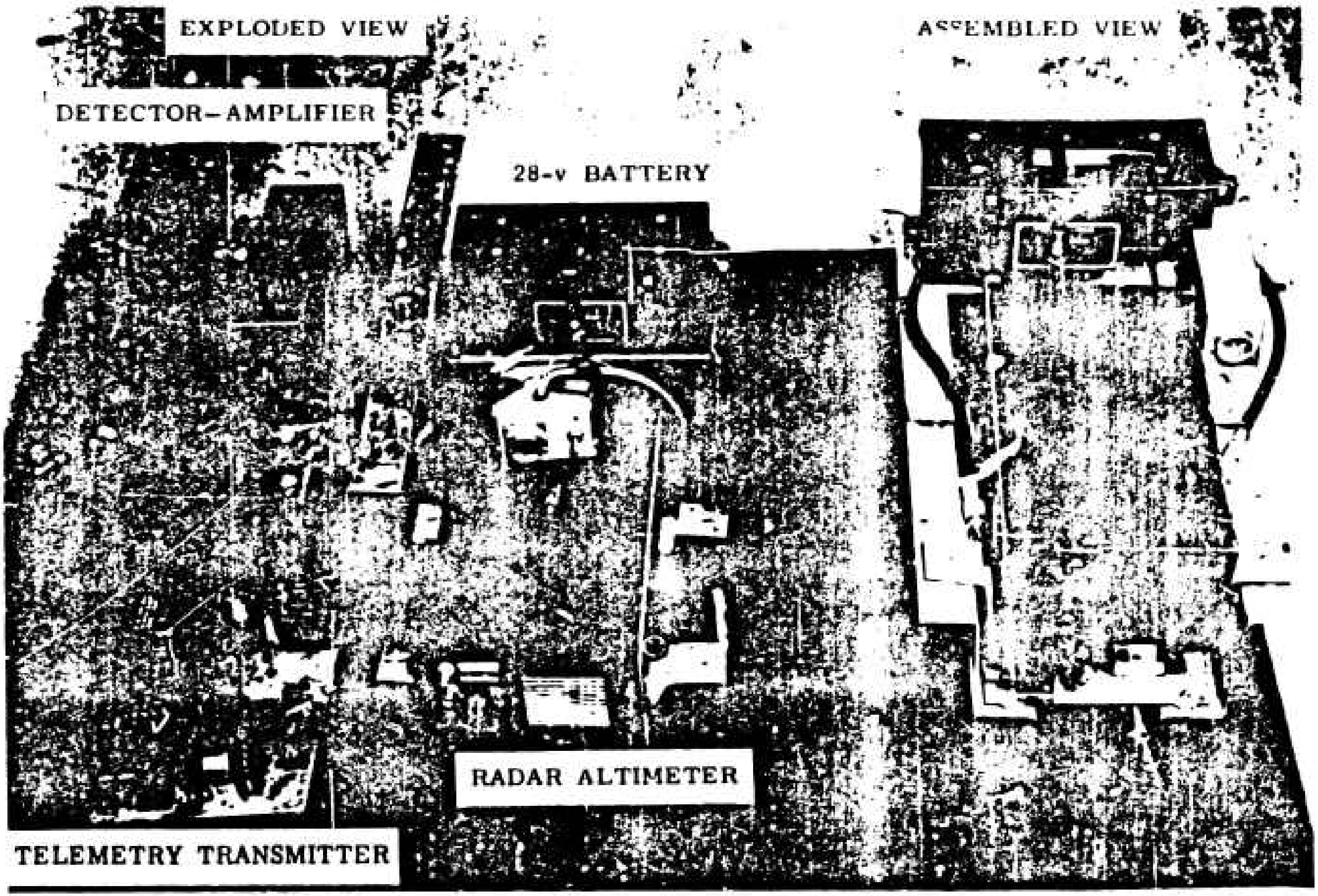

Figure 2.4 Drone airborne radiac sensor. (DASA 698-12-NTS-62)

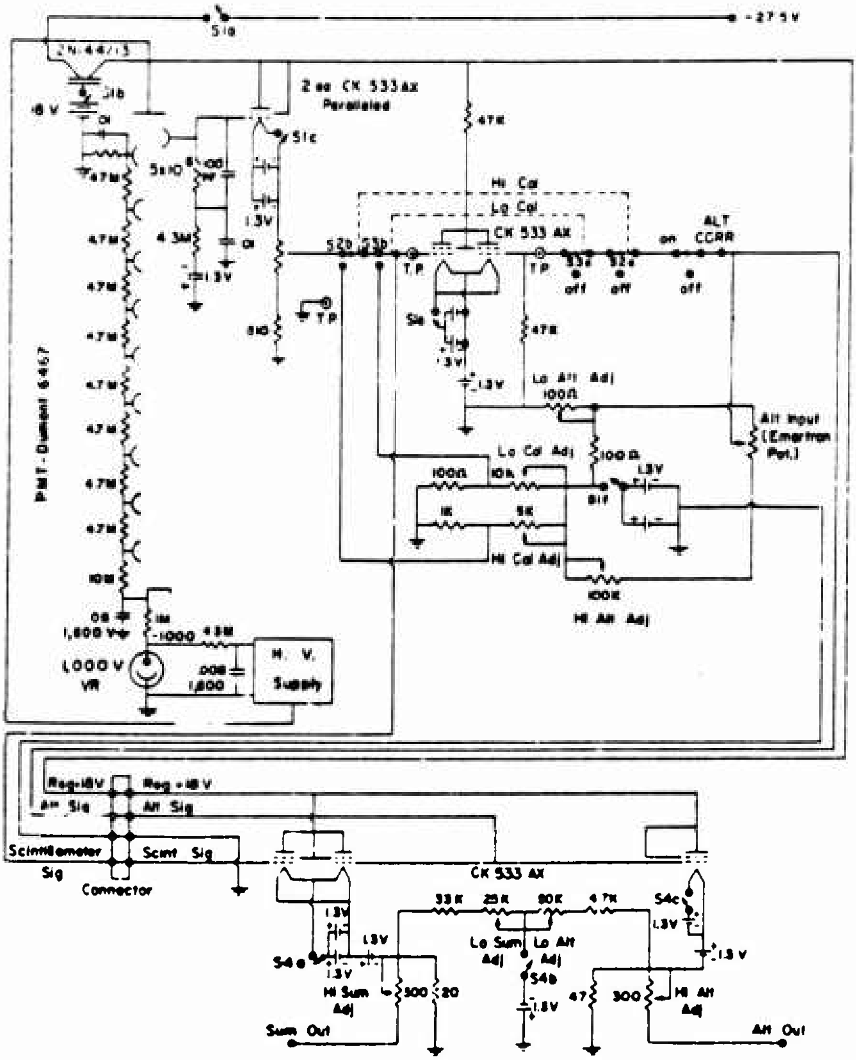

Figure 2.5 Helicopter unit schematic.

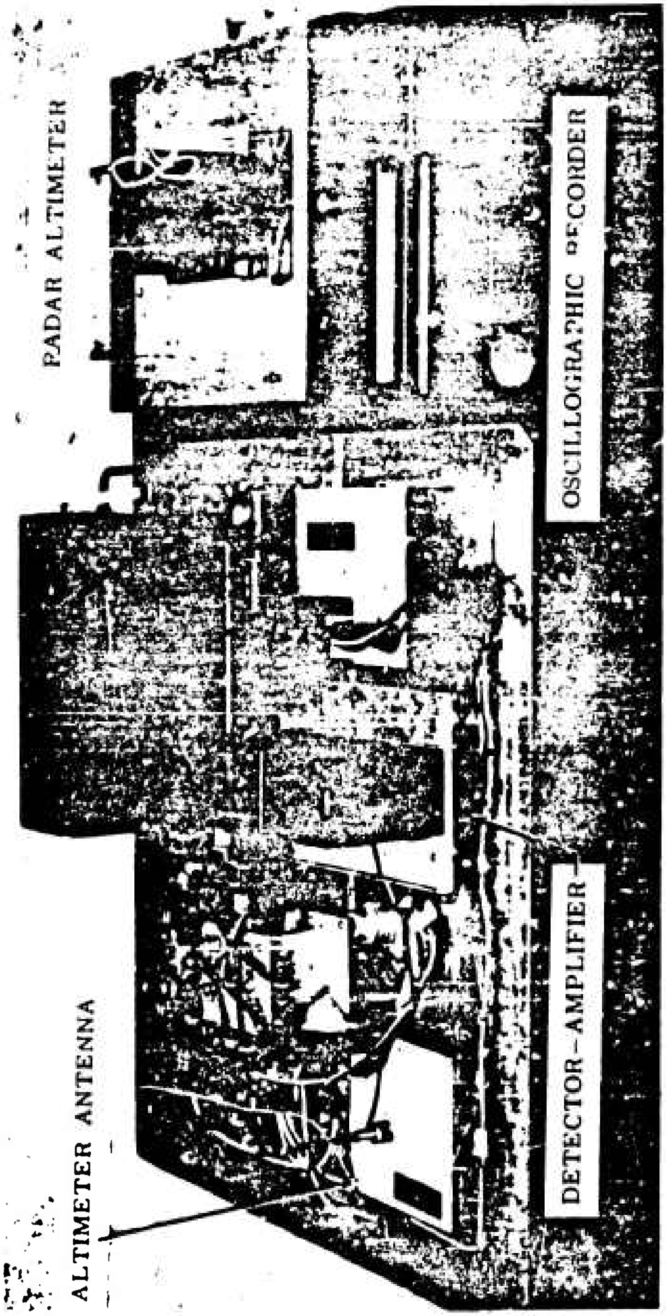

Figure 2.6 Manned aircraft sensor. (NASA 698-09-NTS-62)

CHAPTER 3

RESULTS

Helicopter flights were made over the fallout area at H+1.5 hrs, H+5.5 hrs, and H+22 hrs. Drone flights were made at H+11, H+12, and H+14 hrs. All flights were made in a sinusoidal pattern normal to the direction of fall-out dispersion.

Reduction of data from helicopter flight No. 1 (H+1.5 hrs) resulted in the corrected-to-ground isodose radiation contour shown in Figure 3.1. Tabulated data, unnormalized, for this figure is shown in Table 3.1. Normalization of this data to H+1 hr using standard decay ($t^{-1.2}$) gives Figure 3.2 and is tabulated in Table 3.2.

Data from helicopter flight No. 2 (H+5.5 hrs) (see Table 3.3) produced the unnormalized contour in Figure 3.3. Figure 3.4 is an expanded plot of a portion of the data from helicopter flight No. 1 and is included for comparison to the contour from flight No. 2. Flights were made over the M line (Figure 3.4) at various altitudes to collect air-to-ground correlation data. This data appears in Table 4.1.

No contour was plotted following helicopter flight No. 3 (H+22 hrs), as the radiation intensity over most of the fallout field was of lower intensity than the equipment had been calibrated to detect. The area around ground zero, although still radioactive, was too limited in size for valid aerial survey. This is discussed in Sections 4.3.2 and 4.3.3.

Drone flight No. 1 (H+11 hrs) failed after eight minutes due to a faulty control receiver in the aircraft. A limited amount of data was obtained from this flight.

Drone flight No. 2 (H+12 hrs) was terminated after twenty-six minutes. Reduction of data from this flight (Table 3.4) resulted in the unnormalized contour as shown in Figure 3.5. This flight indicated feasibility of aerial radiac monitoring from unmanned aircraft.

Drone flight No. 3 (H+14 hrs) was terminated after ten minutes. No data was taken due to low radiation intensities in the flight area.

TABLE 3.1 [illegible] FLIGHT NO. 1,
[illegible]

Intensity (Rad/Hr)	Distance from Check Point 1 (Meter)	Remarks	
1	410	Leg	[illegible]
3	601	Leg Length	3160 meters
10	885		
30	1010	Check Point 1:	1
100	1300	Check Point 2:	46
300	[illegible]		
300	1870		
100	2120	Direction of	
30	2240	Flight	South
10	2560		
3	2780	Time Start	1404
1	3040	Time Finish	[illegible]
1	1460	Leg	[illegible]
3	1630	Leg Length	5620 meters
10	1860		
30	2140	Check Point 1:	76
100	2190	Check Point 2:	1
300	2480		
300	2700	Direction of	
100	2980	Flight	North
30	3260		
10	3430	Time Start	1236
3	3600	Time Finish	1242
1	3770		
1	1320	Leg	[illegible]
3	1610	Leg Length	[illegible]680 meters
10	1710		
30	2000	Check Point 1:	1
100	2240	Check Point 2:	76
100	3120		
30	3560	Direction of	
10	3610	Flight	South
3	3810		
1	4050	Time Start	1242
		Time Finish	1248

TABLE 3.1 (CONTINUED)

Intensity	Distance from Check Point 1	Remarks	
(Rad/Hr)	(Meters)		
1	258	Leg	M
3	429	Leg Length	5500 meters
10	665		
30	880	Check Point 1:	85
100	1290	Check Point 2:	14
100	2550		
30	3350	Direction of	
10	3570	Flight	North
3	3840		
1	4080	Time Start	1248
		Time Finish	1254
1	0	Leg	K
3	440	Leg Length	5500
10	1020		
30	1590	Check Point 1:	51
100	2590	Check Point 2:	15
100	2960		
30	3840	Direction of	
10	4120	Flight	South
3	4450		
1	5130	Time Start	1254
		Time Finish	1301
1	4080	Leg	I
[illegible]	4520	Leg Length	7930 meters
10	4840		
30	6100	Check Point 1:	2
30	6420	Check Point 2:	28
10	7540		
3	8000	Direction of	
		Flight	North
		Time Start	1301
		Time Finish	1309

TABLE 3.1 (CONTINUED)

Intensity	Distance from Check Point 1	Remarks	
(Rad/Hr)	(Meters)		
10	163	Leg	G
10	645	Leg Length	4300 meters
3	2880		
1	3310	Check Point 1:	30
		Check Point 2:	16
		Direction of Flight	South
		Time Start	1309
		Time Finish	1312
1	5900	Leg	[illegible]
3	8350	Leg Length	14200 meters
3	8865		
		Check Point 1:	3
		Check Point 2:	5
		Direction of Flight	North
		Time Start	1312
		Time Finish	1320
1	3400	Leg	E
1	4950	Leg Length	11600 meters
1	5962		
1	8970	Check Point 1:	105
		Check Point 2:	64
		Time Start	1323
		Time Finish	1328

TABLE 3.2 ISO-RAD CONTOUR PLOT DATA HELICOPTER FLIGHT NO. 1.
14 July 1962, NORMALIZED

Intensity (Rad/Hr) H+1	Intensity (Rad/Hr) Actual	Distance from Check Point 1	Remarks	
3	0.855	385	Leg	U
10	2.85	591	Leg Length	3160 meters
30	8.55	840		
100	28.5	1062	Check Point 1:	1
300	85.5	1255	Check Point 2:	46
300	85.5	2125		
100	28.5	2320	Direction of	
30	8.55	2585	Flight	South
10	2.85	2835		
3	0.855	3060	Time Start	1404
			Time Finish	1418
1	0.765	1410	Leg	S
3	2.295	1590	Leg Length	5620 meters
10	7.65	1780		
30	22.95	1950	Check Point 1:	76
100	76.5	2170	Check Point 2:	1
300	229.5	2440		
300	229.5	2810	Direction of	
100	76.5	3020	Flight	North
30	22.95	3320		
10	7.65	3500	Time Start	1236
3	2.295	3660	Time Finish	1242
1	0.765	3960		
1	0.765	1360	Leg	Q
3	2.295	1500	Leg Length	4880 meters
10	7.65	1720		
30	22.95	1920	Check Point 1:	1
100	76.5	2170	Check Point 2:	76
100	76.5	3200		
30	22.95	3500	Direction of	
10	7.65	3680	Flight	South
3	2.295	3900		
1	0.765	4060	Time Start	1242
			Time Finish	1248

TABLE 3.2 (CONTINUED)

Intensity		Distance from Check Point 1	Remarks	
(Rad/Hr) H+1	(Rad/Hr) Actual	(Meters)		
1	0.705	197	Leg	M
3	2.11	364	Leg Length	5500 meters
10	7.05	577		
30	21.1	803	Check Point 1:	85
100	70.5	1140	Check Point 2:	14
100	70.5	2760		
30	21.1	3320	Direction of	
10	7.05	3660	Flight	North
3	2.11	3920		
1	0.705	4150	Time Start	1248
			Time Finish	1254
3	1.84	193	Leg	K
10	6.14	1080	Leg Length	5500 meters
30	18.4	1360		
100	61.4	1950	Check Point 1:	51
100	61.4	3330	Check Point 2:	15
30	18.4	3900		
10	6.14	4240	Direction of	
3	1.84	4510	Flight	South
			Time Start	1254
			Time Finish	1301
1	0.614	3830	Leg	I
3	1.84	4170	Leg Length	7730 meters
10	6.14	4560		
30	18.4	5160	Checkpoint 1:	2
30	18.4	6880	Checkpoint 2:	28
10	6.14	7600		
			Direction of Flight	North
			Time Start	1301
			Time Finish	1309

TABLE 3.2 (CONTINUED)

Intensity		Distance from Check Point 1	Remarks	
(Rad/hr) H+1	(Rad/hr) Actual	(Meters)		
10	5.42	1455	Leg	G
10	5.42	2540	Leg Length	4300 meters
3	1.63	3080		
1	0.542	3380	Checkpoint 1:	27
			Checkpoint 2:	16
			Direction of Flight	South
			Time Start	1309
			Time Finish	1312
1	0.542	4720	Leg	Z
3	1.63	6520	Leg Length	14200
10	5.42	9195		
10	5.42	9525	Checkpoint 1:	3
3	1.63	10860	Checkpoint 2:	5
1	0.542	11590		
			Direction of Flight	North
			Time Start	1312
			Time Finish	1320
1	0.486	1800	Leg	E
3	1.46	3580	Leg Length	11600
3	1.305	8040		
1	0.435	9070	Checkpoint 1:	105
			Checkpoint 2:	64
			Direction of Flight	South
			Time Start	1323
			Time Finish	1328

TABLE 3.3 ISO-RAD CONTOUR PLOT DATA HELICOPTER FLIGHT NO. 2, 14 July 1962 NOT NORMALIZED

Intensity (Rad/Hr) Actual	Distance from Checkpoint #1 (Meters)	Remarks	
1	3660	Leg was from	GZ
3	3810	Tower to	
10	3990	Leg Distance	4280
30	4100	Checkpoint 1:	Tower
100	4200	Checkpoint 2:	GZ
		Direction of Flight	Southeast
		Time Start	1840
300	165	Leg GZ to Well	5
100	282	Leg Length	4030 meters
30	399		
10	516	Checkpoint 1:	GZ
3	681	Checkpoint 2:	Well 5
1	843		
		Direction of Flight	West
		Time Start	1844
3	1850	Leg	Y
10	1970	Leg Length	3870 meters
30	2190		
100	2350	Checkpoint 1:	2
300	2520	Checkpoint 2:	57
300	2750		
100	2980	Direction of	
30	3100	Flight	South
10	3340		
3	3500	Time Start	1710
		Time Finish	1712

TABLE 2.3 CONTINUED

Intensity	Distance from Checkpoint #1	Remarks	
(Rad/Hr) Actual	(Meters)		
10	98.3	Leg	W
30	196	Leg Length	1770 meters
100	305		
100	620	Checkpoint 1:	31
30	744	Checkpoint 2:	2
10	850		
3	975	Direction of	
1	1120	Flight	North
		Time Start	1712
		Time Finish	1715
1	853	Leg	U
3	1030	Leg Length	3160
10	1200	Checkpoint 1.	1
30	1360	Checkpoint 2:	46
30	1870		
10	1930	Direction	
3	2310	of Flight	South
1	2500		
		Time Start	1717
		Time Finish	1718
1	1810	Leg	Q
3	2030	Leg Length	4880 meters
10	2440		
10	2980	Checkpoint 1:	1
3	3460	Checkpoint 2:	76
1	3660		
		Direction	
		of Flight	South
		Time Start	1720
		Time Finish	1722

TABLE 3.3 (CONTINUED)

Intensity (Rad/Hr) Actual	Distance from Checkpoint #1 (Meters)	Remarks	
1	660	Leg	M
3	990	Leg Length	5500
10	2060		
3	2840	Checkpoint 1:	85
1	3350	Checkpoint 2:	14
		Direction of Flight	North
		Time Start	1723
		Time Finish	1725
1	743	Leg	I
3	1260	Leg Length	5500 meters
3	1960		
1	2580	Checkpoint 1:	51
		Checkpoint 2:	3
		Direction of Flight	South
		Time Start	1728
		Time Finish	1730

TABLE 3.4 ISO-RAD CONTOUR PLOT DATA DRONE FLIGHT NO. 2,
14 July 1962 NOT NORMALIZED

Time 1 Rad/Hour Encountered on Radar Plot (Min after Radar Track Started)	Grid Coordinates	Remarks
3.42	007767	Time Flight Started 2240
3.88	060780	
4.03	026751	
4.05	027752	Time Flight Completed 2306
4.53	030770	
5.35	037770	
5.73	043755	Map Reference;
6.60	053762	Army Map Service
6.87	052773	Frenchman Lake
7.40	065765	2857 IV
9.18	077768	
9.42	060766	
11.1	026751	
12.0	007766	
14.2	985752	
14.6	998740	
15.3	974733	
15.9	956742	
17.3	989755	
18.4	020770	
19.6	996765	
20.2	000743	
20.4	985740	
20.8	969744	
22.7	986743	
22.9	967731	
23.8	981748	

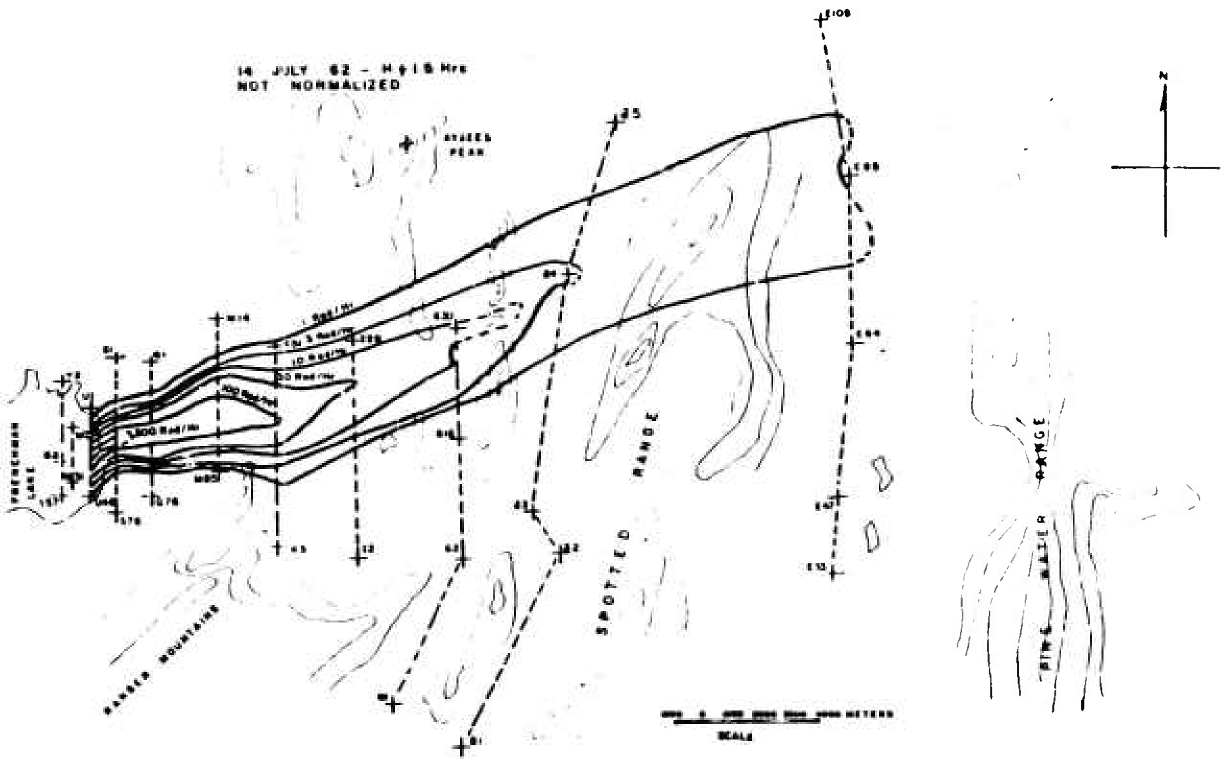

Figure 3.1 Lorad contour plot of helicopter Flight No. 1

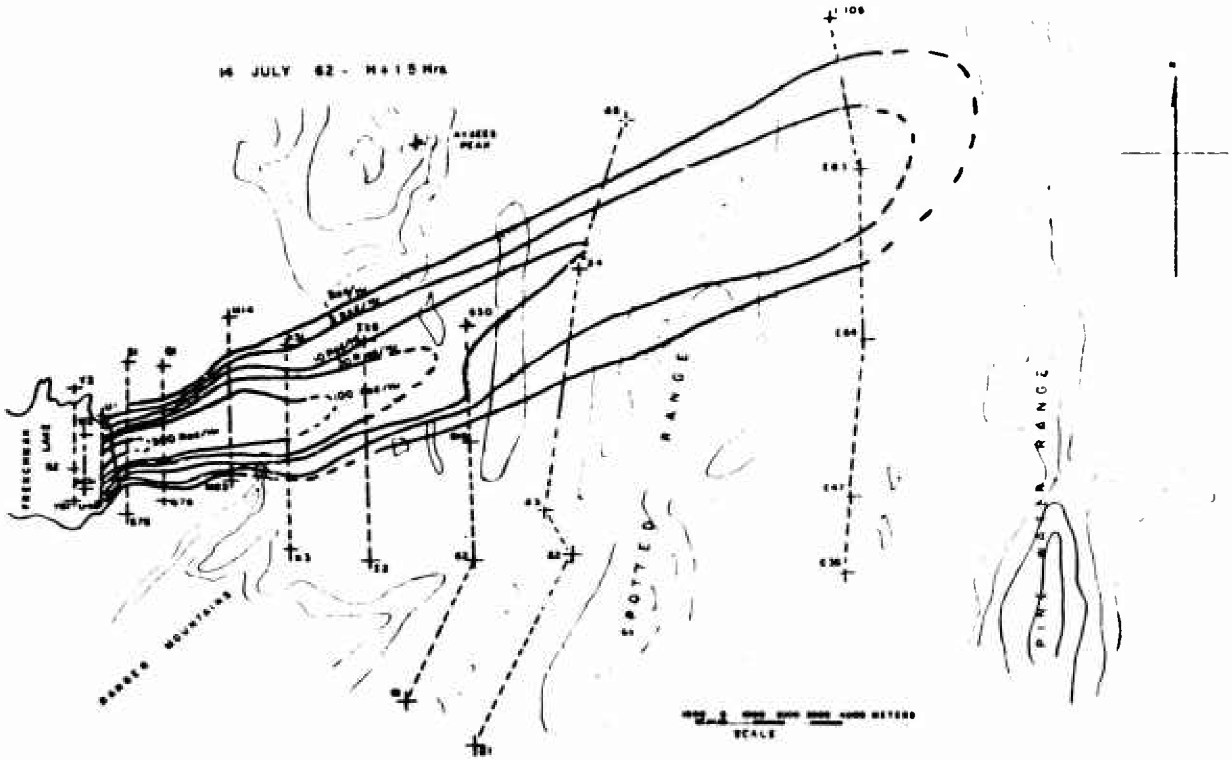

Figure 3.2 Isorad contour plot of helicopter Flight No. 1 normalized to H+1

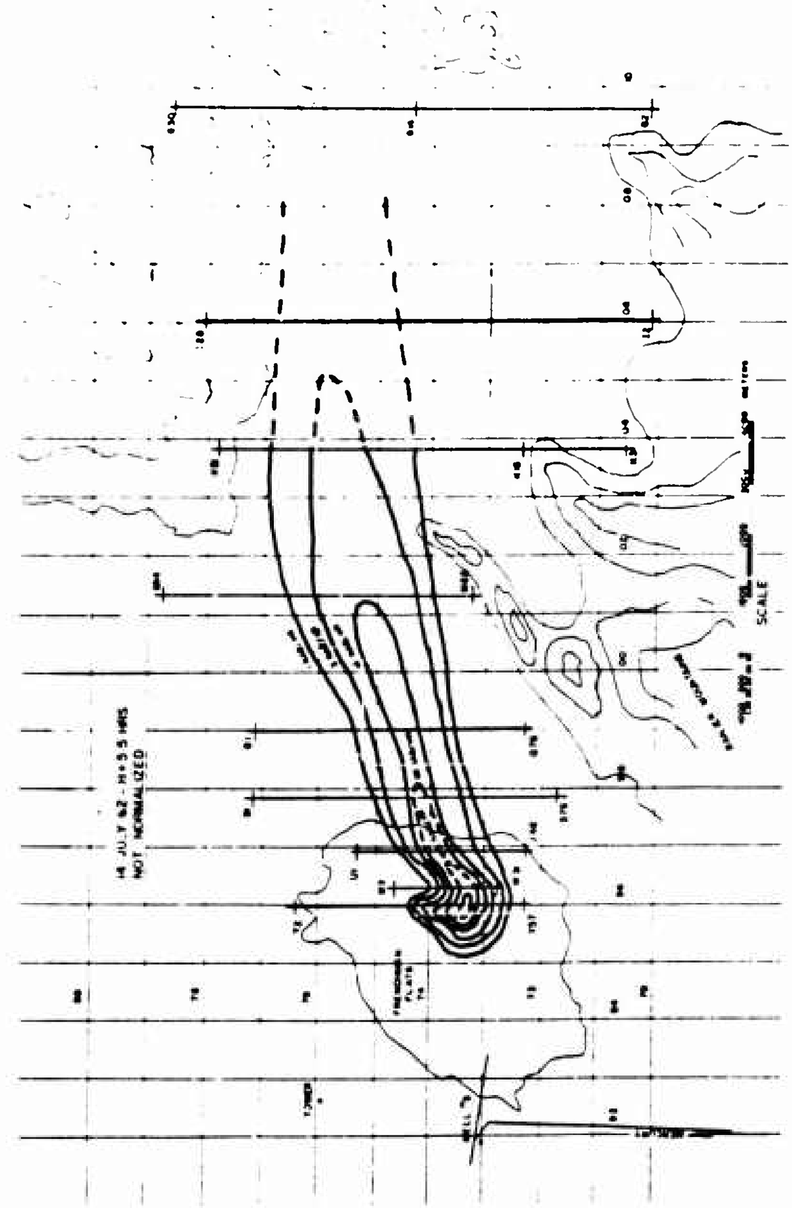

Figure 3.3 Isorad contour plot of helicopter Flight No. 2

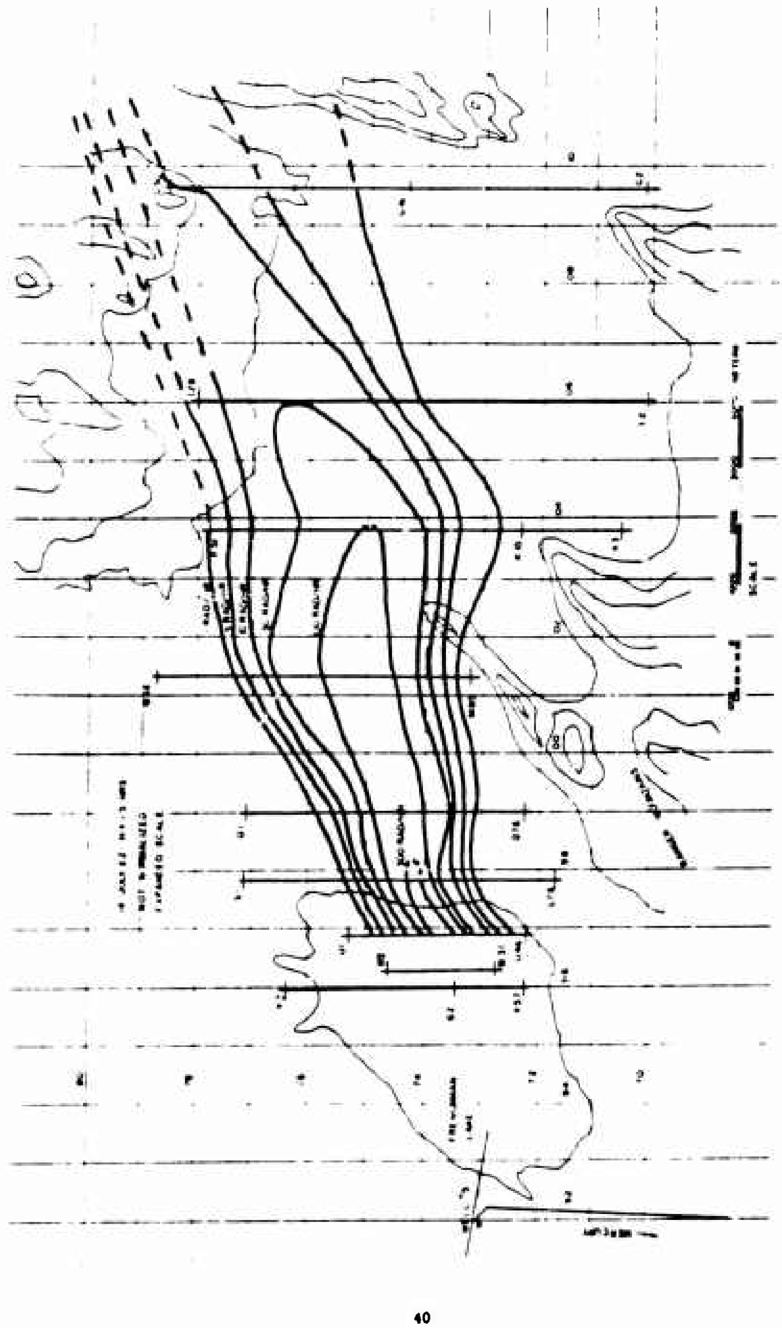

Figure 3.6 Isorad contour plot of helicopter flight No. 8 (first 9 legs only)

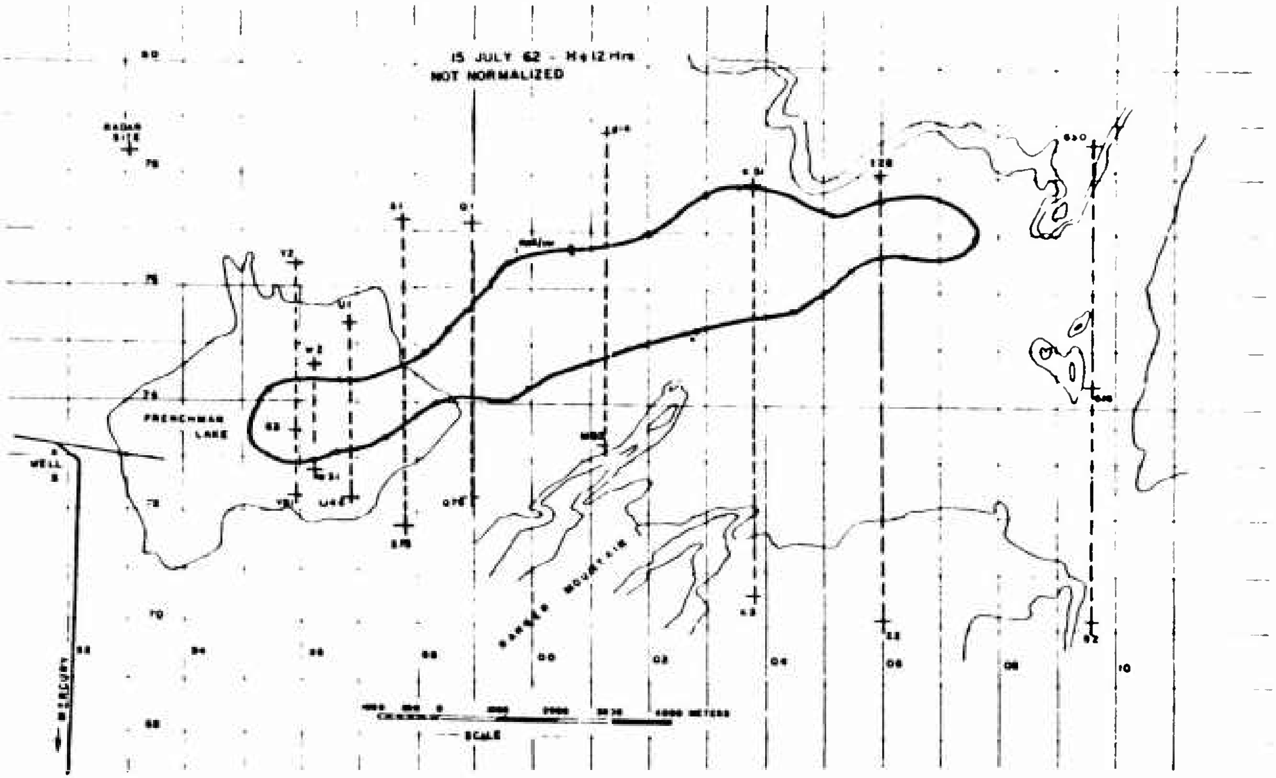

Figure 3.5 Isorad contour plot of drone Flight No. 2

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CHAPTER 4

DISCUSSION

4.1 AERIAL RADIOLOGICAL SURVEY

The primary purpose of aerial survey of radiologically contaminated areas is to provide a commander a basis for planning in the shortest possible time. A choice between alternate routes of march, for example, could properly be determined from aerial survey information. Aerial survey is primarily concerned with relatively high ground dose-rates, 1 to 1,000 Rad/Hour, as commanders operating in a nuclear warfare environment will necessarily be more concerned with casualty-producing radiation doses rather than long term considerations which govern peacetime operations.

Exact dose-rates at specific locations can best be determined by vehicular or dismounted survey.

4.2 FALLOUT FIELD INTENSITY

In pretest planning for this detonation, it was predicted that the fallout field would be formed to the east of ground zero with the 1-Rad/Hour line extending 30 to 50 miles downwind and that this field would decay by the standard rate ($t^{-1.2}$). Based on these predictions, the instruments were calibrated and flight schedules were arranged to allow survey of the field prior to excessive loss of intensity due to decay.

Initial manned aircraft flights indicated that the actual 1 Rad/Hour line extended approximately ½ the predicted distance. Data from later manned flights indicated that the fallout did not decay at the standard rate but seemed to decay at a faster rate. Decay curves were plotted from data taken on Flights 1, 2, and 3. These decay curves are shown in Figure 4.1. In an attempt to verify these curves, ground sensor data supplied by Reynolds Electric and Engineering Company (REECO) and ground survey data supplied by Nuclear Defense Laboratories (NDL) was plotted. The resultant curves did not show a single decay rate but varied widely, depending on location of reading, time of reading, and recording instrument. It was impossible to establish a definite decay rate from the data available, so normalization of all contours was not attempted. The normalization discussed in Section 3.1.1 was done for comparison only, and the resultant contour may be in error due to the uncertainty in decay constant.

4.3 MANNED AIRCRAFT FLIGHTS

4.3.1 Flight Number 1. The objective of flight number 1 was to determine the extent of the 1 Rad/Hour line by flying in a sinusoidal pattern normal to the direction of the movement of the fallout. The course legs flown are shown on the isodose contour plots. These plots were made by connecting points of equal radiation intensity on the course legs. Course legs near ground zero were not flown on this mission because of obliteration of marker panels on the W-line and excessively high radiation intensities along the Y-line, which passed directly through ground zero. The contour could have been filled out with data collected on flight number 2, but this was not accomplished due to uncertainty about the decay.

The iso-rad contour plot for this flight (Figure 3.1) shows some irregularities in the pattern, particularly on the K-line. The displacement of the pattern on this leg may be due to pilot errors rather than an actual displacement of the fallout field. These pilot errors are caused by improper marking of check points, variations in aircraft speed, and lateral displacement of the aircraft along the course leg. It has been observed that pilot error is the major source of error in the manned aircraft method of airborne radiological survey.

4.3.2 Flight Number 2. The objective of flight number 2 (H+5½ hrs) was to determine the extent of the radiation pattern out to the K-line and to make repeated flights at different altitudes over the M-line to determine the validity of the air-to-ground correlation factors used in this test. Figure 3.3, an unnormalized plot of the data from this flight, substantiates the general fallout pattern obtained from flight No. 1 but shows lower dose rates than had been anticipated. The close-in portion of the flight No. 1 contour was plotted to the same scale as Figure 3.3 for comparison purposes (Figure 3.4). This comparison showed the fallout field had contracted more than calculated, apparently due to an accelerated decay rate, see Section 4.2.

The radiation dose-rate in the vicinity of ground zero was low enough at the time of this flight to permit a survey of this area. Aerial readings in the immediate vicinity of ground zero cannot be accurately related to ground readings because the air-to-ground correlation factors (AGCF'S) are based on an infinite plane field, while ground zero represents an intense point source.

Repeated passes along the H-line demonstrated that automatic correlation of air dose-rates to ground dose-rates can be accomplished within the altitude range 100 to 850 feet. Table 4.1 shows the data collected on these passes. The corrected-to-ground dose rate reading varies only over the range 9.25 to 10.15 Rad/Hour between 100 and 850 feet. Over this considerable altitude spread, the deviation from the mean value is approximately 5%. This indicates that the air-to-ground correction formulas and techniques used were applicable over the ranges of height and dose rate encountered during the tests. See Section 4.5 for a further discussion of air-to-ground correlation.

4.3.3 Flight number 3. Manned aircraft flight number 3 was made at H+22 hours to determine the close-in contour pattern. The fallout had decayed to the extent that appreciable intensities could be detected only in the immediate vicinity of ground zero. Repeated runs were made over U-25 at different altitudes to gather additional air-to-ground correlation data, and a final run was made over ground zero for comparison to earlier runs. The data obtained was too limited to permit either further evaluation of the fallout field or determination of the air-to-ground correlation factor. Some point source data was used in an attempt to establish a decay rate.

4.4 DRONE AIRCRAFT FLIGHTS

The previous instrumented helicopter flights over the fallout field were used as the basis for the drone flight pattern. Instrumented drone flights were made at H+11, H+12 and H+14 hours.

Drone Flight No. 1 failed after eight minutes, due to a faulty control receiver in the aircraft. During this flight period the instrument telemetry system indicated that the radiation field was very weak. No attempt was made to plot an isodose contour from the limited data available.

Drone Flight No. 2 confirmed the low readings from the initial flight. As a sensor check, the flight pattern was modified to include runs closer to ground zero, where the radiation intensity was known to be within the range of the system. Near ground zero, the system indicated radiation, which confirmed sensor operation. The drone was then flown over the original flight pattern, where it again indicated a very low radiation level. A normal recovery was made after a twenty-six minute flight, and the sensor package was checked for proper calibration. This complete calibration check indicated the system was operating normally and as intended. The resultant isodose contour (Figure 3.5) defined the direction of fallout and the extent of the 1 Rad/Hour line. The field had decayed to such an extent that the sensors were operating near their lower calibration limits; thus, 10, 30 and 100 Rad/Hour isodose rates were found only very close to ground zero, and no attempt was made to plot them. The radar tracking technique used for positioning the drone permitted flights to be made over previously surveyed areas; thus, single points were surveyed several times during this flight to check repeatibility. An example of this repeatibility may be seen on Figure 3.5, near coordinates 0375 where three 1 Rad/Hour readings were obtained within a 100-meter radius. Another example may be seen near coordinates 0177, where two more 1 Rad/Hour readings were obtained during separate legs of flight over the same area.

Drone Flight No. 3 was made after a thorough system checkout and calibration had been accomplished on the alternate sensor pack. This flight was confined to the original flight pattern. A very low level of radiation was detected during this run, which confirmed the earlier flight data. The third flight was terminated by normal recovery after ten minutes, due to the lack of sufficient detectable radiation.

4.5 AIR-GROUND CORRELATION FACTOR (AGCF)

The theory of AGC is described in Section 1.3. To test the accuracy of this theory, several flights were made over the M-line at different heights above terrain and in opposing directions. Table 4.1 summarizes the results of this test. Maximum intensity readings for each pass are tabulated, as are the recorded altitudes above terrain as determined by the radar altimeter. The maximum intensity points were chosen for comparison in an attempt to minimize pilot positioning error in the direction-of-flight. Pilot positioning error perpendicular to flight direction was not removed but was considered to be small because the pilot was following a road. The detection system was carefully checked for calibration prior to this test. The results of this experiment indicated that the correction factor is essentially a straight line function when plotted on semi-logarithmic graph paper, and that automatic AGC affords consistantly accurate results.

All readings were automatically corrected by the equipment, and radar altimeter altitude information was recorded simultaneously. Although the pilot attempted to fly at a constant height above ground on each leg, it was noted that the altitude varied as much as ± 100 feet. If a constant altitude had been assumed and the appropriate correction factor been applied manually, large errors would be introduced into the corrected readings. An example of the magnitude of this error is as follows:

Assume the aircraft is attempting to maintain 600 feet above terrain but actually deviates plus or minus 100 feet. Assume a 1 Rad/Hour field at the aircraft. From Figure 4.2, the correction factors for 500, 600, and 700 feet are 9.2, 12.0, and 15.6 respectively. By using the correction factor for 600 feet, the ground dose-rate is indicated to be 12.0 Rad/Hour, whereas it may be anywhere between 9.2 and 15.6 Rad/Hour. Automatic correction produces considerably less error, as is illustrated by Table 4.1.

4.6 ESTABLISHMENT OF AUTOMATIC AIR-TO-GROUND CORRELATION FACTOR

In order to use the output of the radar altimeter to automatically correct all altitudes between 200 feet and 1,000 feet, the corrective circuits must be adjusted for each individual sensor.

First, a calibration curve is made for the sensor as shown by Figure 4.3, and the recorder is adjusted to give a direct reading of Rad/Hour.

From Figure 4.2 the correction factor at 200 feet is 4.2; at 1,000 feet it is 34.5.

A constant source of radiation is then applied to the sensor, and a ground test set is used to simulate altitude on the radar altimeter. The additive circuitry is then calibrated to add properly for 200 and 1,000 ft. When these upper and lower points have been adjusted, the altimeter is set at 530 feet which should provide an indicated dose-rate 10 times the uncorrected reading. The error at this point does not exceed 5 percent.

This method of automatic correction can be used to instrument any correction factor, so long as it is essentially a straight-line plot on semi-logarithmic graph paper. The plot of correction factors from Glasstone (Reference 4), shown in Figure 4.2, could be incorporated by a ten-minute recalibration as could any other straight-line logarithmic plot.

4.7 SYSTEM IMPROVEMENT ANALYSIS

The equipment used in this test is described in Section 2.2. It was developed and fabricated at USAEPG. The time available prior to this test did not permit the incorporation of some obvious improvements to the system. These are discussed below.

4.7.1 Output Signal Drift. The output signal drifted as much as ± 10% during this test. This drift was controlled with balance controls and repeated gain checks. This system was suitable for test purposes, but a tactical unit will require stable circuitry over long periods of time. Minor circuit changes can eliminate this problem.

4.7.2 Output Signal Presentation. The recorded data from the system at times was difficult to interpret because the output signal is composed of contributions from the scintillometer and the radar altimeter, and in the absence of a signal from the scintillometer, the altimeter signal alone can give an operator the false impression that radiation exists at the sensor. This problem can be solved by use of a squelch circuit that will cut off all output signal until a preset signal level from the scintillometer exists.

4.7.3 Calibration Source. The present system requires the use of an active radiation source for calibration. A means of electronic calibration can be built into the system by insertion of a reference electronic signal at the input of the log amplifier stage. This will test the circuit and act as a reference for calibration.

4.8 FUTURE DRONE USE

The development of a drone radiac sensor package by USAEPG has been directed toward the time frame of development of the

AN/USD-2 Low Endurance, Multipurpose Drone System, currently in the R&D stage. This drone has an integrated guidance and control system for radio line of sight operation plus an airborne programmer for mission operation beyond line of sight. It also has a larger sensor compartment, greater speed, and a radar altimeter.

The advantages of using a drone for aerial radiological survey include: (1) protection of personnel from extremely high radiation doses and dose-rates, (2) availability to the Division Commander to use as an integral part of his aviation resources, (3) aerial radiological survey could be performed concurrently with other intelligence gathering missions, such as photography, and (4) all weather capability.

TABLE 4.1 TEST DATA FOR AIR-TO-GROUND CORRELATION FACTOR THEORY

Peak Radiation Intensity (Rad/Hr) (automatically corrected to ground level)	Sensor Height above Terrain (Feet)	Remarks
10.05	100	Leg M
9.75	200	Time
9.50	470	1723-1800
9.25	525	
10.00	630	14 July 62
9.50	640	
10.10	850	
10.05	200	
10.15	115	
9.25	330	

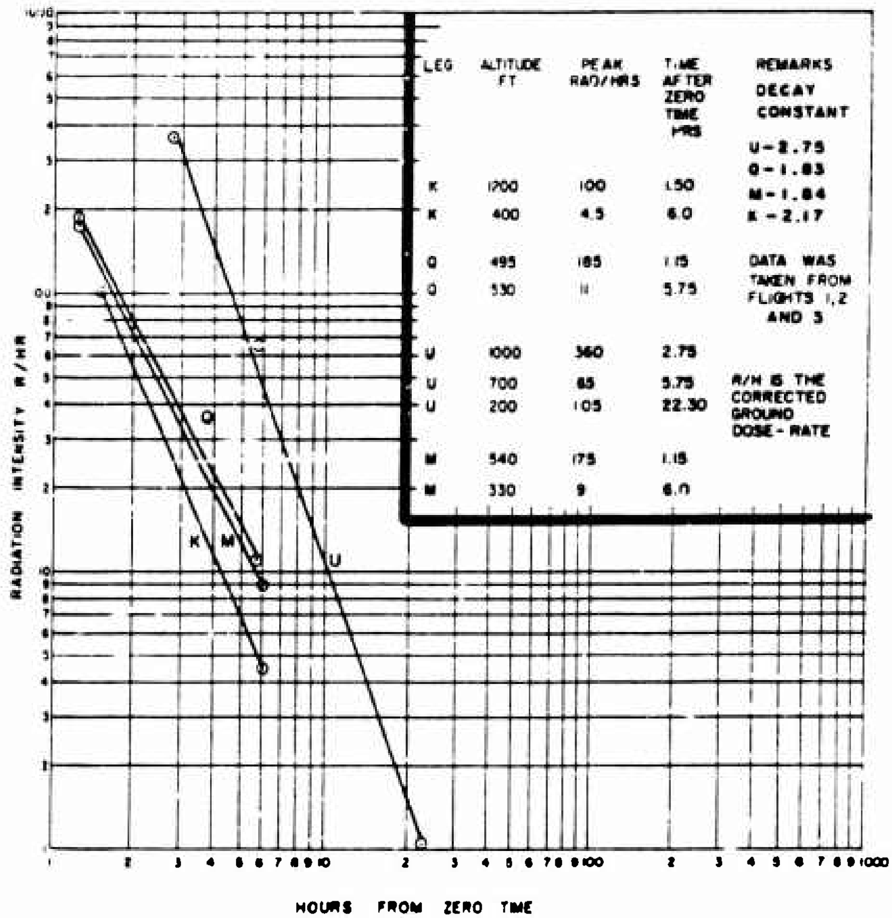

Figure 4.1 Decay curves.

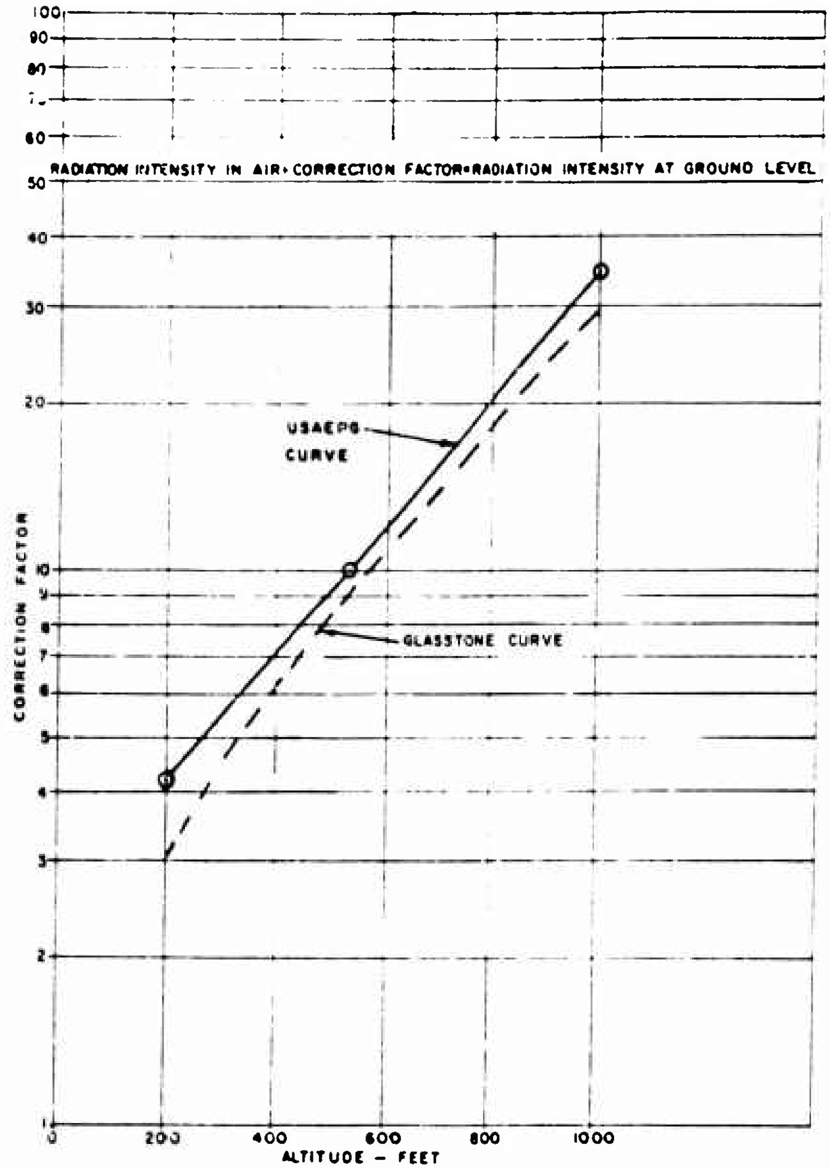

Figure 4.2 Correction factor curve.

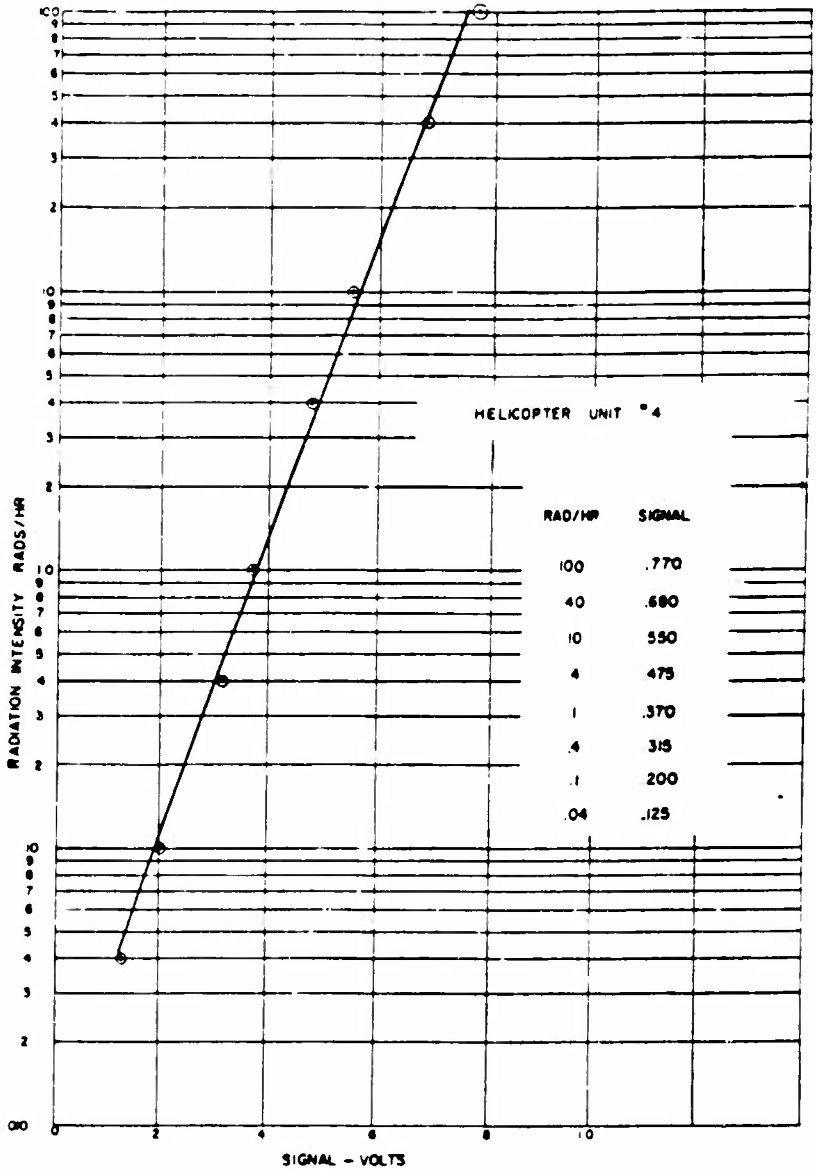

Figure 4.3 Sample calibration curve.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Automatic air-to-ground correlation of dose-rate intensities over the altitude range 100 to 1,000 ft above terrain is feasible.

An aerial survey system employing automatic air-to-ground correlation can be used effectively in the AN/USD-1B Drone Surveillance System.

The air-to-ground correlation factors used for this evaluation were substantially correct.

In its present form and under controlled conditions, the equipment is capable of reliably performing aerial survey of large radiologically contaminated areas with minimum maintenance.

Dependance upon pilot proficiency to maintain a constant height above the ground in manned aircraft surveys is a major source of error when prescribed manual correction methods are used.

5.2 RECOMMENDATIONS

A systems design analysis should be performed to simplify and integrate the electronic circuitry. This should include provision for utilization of radar altimeters that are scheduled for incorporation in many US Army manned and drone aircraft.

Development of tactical airborne radiac monitors should continue. This development should include their integration into the AN/USD-2 Drone System.

Advantage should be taken of future weapons effects tests to evaluate the equipment as it progresses in the developmental cycle and to provide additional data on aerial survey of fallout fields.

Agencies such as the Atomic Energy Commission (AEC) and Public Health Service, who may have a requirement for monitoring radiologically contaminated areas under more or less controlled conditions, should consider the adoption of a manned aircraft model of the USAEPG Airborne Radiac Monitor.

APPENDIX

MILITARY CHARACTERISTICS
FOR AN AERIAL RADIAC INSTRUMENT SYSTEM

Section I - General

1. Statement of Requirement. - A standard aerial radiac instrument system to be mounted in Army aircraft of the observation and utility type and drones for the purpose of determining ambient dose rates of gamma radiation.

2. Operational Concept. - This set will be used for aerial radiological detection and rapid aerial survey of large areas to provide data for contamination charts, to determine ground radiation dose rates in advance of troop movements, and to survey areas inaccessible to ground troops because of high radiation dose rates. In order to accomplish this, this equipment and auxiliary devices must be capable of:

a. Providing a continuous record, or a continual record based on horizontal spatial intervals not exceeding 100 meters, of radiation dose-rate at the 3 foot ground level beneath the survey air vehicle. This capability should be from flight altitudes which are optimum within the constraints of flight vehicle operational characteristics and the ability to correlate the instrument probe radiation environment with that at the 3 ft. level.

b. Providing a ground position record compatible with 2a, above.

c. Direct telemetering of height-corrected (3-ft.) dose rate readings and position readings to a receiving station, provided, however, that the provision for telemetering will not result in undue complexity, cost, or delay. It is expected that existing telemetering equipment or such equipment under development for other purposes will be used.

d. Using existing navigation, position-determining, and data transfer capabilities where possible.

e. Providing a visual and audio warning when a pre-settable dose rate of gamma radiation (height-corrected) is reached.

f. Providing a suitable visual readout in those applications involving manned aircraft.

3. Organizational Concept. - This equipment will be organic to all units equipped with Army Aircraft or drones.

4. Consideration of Tripartite, Navy, Air Force, and Marine Corps Development Activities. - United Kingdom, Canada, and the US Marine Corps have a stated requirement for aerial survey radiac equipment. US Marine Corps concurs and the Canadian Army generally concurs in these military

characteristics.

5. Feasibility of Development. - If during the development phase it appears to the design agency that the characteristics listed herein require the incorporation of certain impractical features and/or unnecessary expensive and complicated components and devices, costly manufacturing methods and processes, critical materials or restrictive specifications which would serve as a detriment to the military value or unduly delay the availability of the item, such matters should be brought to the attention of the Chief of Research and Development, Department of the Army, and Headquarters United States Continental Army Command for consideration before incorporation into a final design.

6. Background. - The feasibility of making aerial radiological surveys was studied by the US Army Chemical Corps in conjunction with the US Army Aviation School. In the US Army Chemical Corps Final Report, Aerial Survey Feasibility Study (revised in February 1957), it was concluded that while aerial radiological survey was feasible using standard instruments, no instruments then standard or under development were ideally suited to this purpose. In December 1957, USCONARC approved the military characteristics for a Radiac Instrument and Ancillary Equipment for Aerial and Armored Vehicle Survey. These were subsequently adopted

by Signal Corps Technical Committee Item 4437, Meeting No. [illegible]908, 29 September 1958. The Radiac Set AN/ADR-7 developed on the basis of these military characteristics was service tested by the US Army Aviation Board. Based on the report of this test, USCONARC concluded that the development of an aerial tactical radiation ratemeter should be disassociated from a vehicular tactical radiation ratemeter and that separate military characteristics should be prepared.

Section II - Operational Characteristics

1. Configuration.

a. (Essential) The ratemeter and all ancillary equipment shall be as light and small as possible consistent with the other military characteristics specified herein.

b. (Desirable) The controls shall be designed to permit operation when heavy gloves are worn.

c. (Desirable) Dials and controls would be integral with the equipment.

d. (Essential) Mounting hardware shall be provided as necessary, for mounting equipment in Army aircraft, helicopters, and drones.

e. (Essential) The equipment shall be designed for quick, easy installation in Army aircraft, helicopters and drones.

f. (Essential) A pre-settable warning device based on ground level dose rates shall be provided.

g. (Essential) The auxiliary probe, if used, shall be shaped so as to minimize vibration due to air turbulence when mounted outside the aircraft.

h. (Desirable) A telemetering system for transmitting dose rate data shall be provided, using an existing link if feasible.

2. Performance.

a. (Essential) The equipment shall have a range for measuring, height-correcting, and recording gamma radiation from 1.0 rad per hour to 1,000 rad per hour at the aircraft ground position.

b. (Essential) When calibrated and operated at absolute altitudes between 100 and 500 feet (50 to 1000 feet desirable), this equipment shall measure and record the dose rate of gamma radiation corrected to the 3 ft. level above ground with an instrument accuracy from probe to readout of plus or minus 20 percent over its entire range (plus or minus 10% desirable), and with the maximum "3 ft. level to probe" accuracy consistent with physical and other limiting factors.

c. (Essential) The equipment shall be capable of measuring the dose rate of gamma radiation within the energy range of 80 kev to 3 mev in rad per hour.

d. (Essential) An integral calibration source, if used, shall be long lived, shall give no background reading on the instrument meter when being used for the operational check, and shall not cause a radiation field in excess of 1 millirad per hour on the surface of the meter.

e. (Essential) The equipment shall be affected to the least degree practicable by its positioning in the aircraft.

f. (Essential) The equipment shall be affected by non-ionizing radiation to the least degree practicable.

g. (Essential) The meter where required shall be direct reading. Calibration curves are not acceptable.

h. (Essential) The equipment shall be capable of continuous operation.

i. (Essential) The equipment shall be capable of operation within 2 minutes after being turned on.

j. (Essential) The equipment shall be capable of a "zero check" and "zero adjust" in a radiation field if not designed so that absolute zero stability can be maintained without drift.

k. (Essential) When suddenly exposed to changes in gamma radiation intensities, the equipment shall respond to within 10 percent of the final reading within 0.1 second, except that mechanical meter movements used for visual readout may respond on the slower time scales suitable for such use.

l. (Desirable) The telemetering system shall be capable of transmitting a position indication simultaneously with a dose rate datum.

m. (Desirable) The equipment shall be designed to permit adaption for remote operation and transmission of readings through the data-link system of appropriate aerial drones. (See subparagraph p, below).

n. (Desirable) The equipment shall be capable of operation for at least 60 days without recalibration.

o. (Essential) If recalibration is required at frequent intervals, an internal calibration device shall be incorporated in the equipment.

p. (Essential) If simultaneous telemetry of position and dose rate data is impractical, a simple means of recording this information must be provided in order to correlate a measured dose rate with a particular position.

q. (Essential) Variations in power supply output will have minimum effect on functioning of equipment.

3. Durability and Reliability.

a. (Essential) The equipment shall have storage life of at least 5 years.

b. (Essential) The equipment shall have storage life of at least 5 years.

c. (Desirable) The equipment shall normally be capable of operation for 400 hours without necessity for field maintenance.

4. Associated Equipment.

a. (Desirable) The equipment shall be compatible with existing or developmental aircraft positioning devices.

b. (Essential) The equipment shall be designed to operate from the standard internal power supply of Army aircraft.

c. (Essential) The equipment shall be compatible and useful with existing or developmental absolute altimeters.

Section III - Special Characteristics

1. Environmental and Terrain Requirements.

a. (Essential) The equipment shall be designed to conform to the requirements of Spec MIL-E-5400 and Spec MIL-E-5422. It shall be usable in air temperatures from -65°F to 125°F and storable in air temperatures from -65°F to 155°F. In addition it must be capable of operation under atmospheric pressures prevailing at 20,000-ft altitude above sea level and transportation under atmospheric pressures prevailing at 50,000-ft altitude above sea level.

b. (Essential) The equipment shall be capable of withstanding without damage, normal ocean atmospheric corrosion.

c. (Essential) The equipment shall be weatherproof, dustproof, and fungusproof.

d. (Essential) All exposed components shall be resistant to corrosive gases to the maximum degree practicable.

2. CBR and Atomic Requirements. (Essential) Design shall be such as to minimize contamination by chemical or biological agents or radio-active materials. The equipment shall be readily capable of decontamination with minimum effect on its proper operation.

3. Maintenance and Interchangeability Requirement.

a. (Essential) The equipment shall be designed for the minimum practicable preventive maintenance and in-storage maintenance.

b. (Essential) If an integral calibration source is used, calibration shall be performed at organizational maintenance level; otherwise calibration will be performed at field maintenance level.

c. (Essential) All components and assemblies of the equipment shall be marked so as to be readily identifiable.

d. (Essential) Standard components shall be used where practicable. Maximum practicable interchangeability of components shall be provided.

e. (Essential) Operation and maintenance instructions shall accompany all service equipment. Where the instructions are printed on the equipment, these instructions shall be applied so that they are not subject to obliteration by repainting of the equipment or by abrasion of normal field use.

f. (Essential) The equipment shall be designed to provide readily accessible test points.

g. (Desirable) The equipment shall be constructed on a sub-assemble principle to facilitate maintenance through replacement of inoperable sub-assemblies that can be determined by test points provided in the equipment.

h. (Essential) Maintenance shall require standard general purpose equipment and tools.

4. Human Factors Engineering Requirements.

a. (Essential) The equipment shall be designed in conformity with human factor engineering principles with particular attention to the items below.

b. (Essential) The number of controls shall be a minimum. Controls shall be located so as to promote maximum efficiency of operation and to reduce to a minimum the possibility of accidental movement. Function of controls shall be clearly marked on or near the controls.

c. (Essential) The equipment shall be capable of operation by Army aircraft pilots and observers after a minimum of instruction.

d. (Essential) Operating personnel shall be adequately protected against high voltages and any self-contained radioactive materials used as a calibrating source.

e. (Essential) The indicating meter shall be located for easy observation of readings.

f. (Essential) The meter shall be provided with a light or luminous scale to permit operation during darkness, but suitable for operations under blackout conditions.

g. (Essential) When installed, the equipment shall not hinder pilot flying efficiency.

Section IV

1. If any of the required characteristics are incompatible with each other to the extent that significant compromises are required, the Commanding General, USCONARC, shall be

consulted as to the degree of compromise acceptable and the merits of revising the relative priorities which otherwise will be as here listed.

a. Performance

b. Durability and reliability.

c. Associated equipment.

d. Configuration.

e. Environmental and terrain requirements.

f. Maintenance and interchangeability requirements.

g. Human factors engineering requirements.

h. CBR requirements.

2. End item unit production cost should not exceed $3,000.

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47 U S ARMY SIGNAL R&D LABORATORY
48 U S ARMY TRANSPORTATION COMBAT DEVELOPMENT GROUP
49 THE RESEARCH & ANALYSIS CORP
50 NUCLEAR DEFENSE LABORATORY
51 U S ARMY AIR DEFENSE COMBAT DEV AGENCY

NAVY ACTIVITIES

52- 53 CHIEF OF NAVAL OPERATIONS OP03EG
54 CHIEF OF NAVAL OPERATIONS OP-0985
55 CHIEF OF NAVAL OPERATIONS OP-75
56 C[illegible] OF NAVAL OPERATIONS OP-922G2
[illegible] CHIEF OF NAVAL PERSONNEL
58- 59 CHIEF OF NAVAL RESEARCH
60 BUREAU OF NAVAL WEAPONS DLI-3
61 BUREAU OF MEDICINE & SURGERY
62 BUREAU OF SHIPS CODE 423
63 BUREAU OF SHIPS CODE 372
64 BUREAU OF YARDS & DOCKS
[illegible] NAVAL RESEARCH LABORATORY
[illegible] NAVAL ORDNANCE LABORATORY
68 MATERIAL LABORATORY CODE 900
[illegible] U S NAVAL RADIOLOGICAL DEFENSE LAB
73- 74 U S NAVAL CIVIL ENGINEERING LAB
75 U S NAVAL ACADEMY
76 U S NAVAL SCHOOLS COMMAND TREASURE ISLAND
77 U S NAVAL POSTGRADUATE SCHOOL
78 U S NAVAL SCHOOL PORT HUENEME
79 NUCLEAR WEAPONS TRAINING CENTER ATLANTIC
80 NUCLEAR WEAPONS TRAINING CENTER PACIFIC
81 U S NAVAL DAMAGE CONTROL TNG CENTER
82 U S NAVAL AIR DEVELOPMENT CENTER
83 U S NAVAL MEDICAL RESEARCH INSTITUTE
84 DAVID W TAYLOR MODEL BASIN
85 U S NAVAL SUPPLY R&D FACILITY

AIR FORCE ACTIVITIES

86- 89 U S MARINE CORPS CODE AO3H
90 HQ USAF AFROC-AE
91 HQ USAF AFRDR-NJ
92 HQ USAF AFOCE
93 HQ USAF OPERATIONS ANALYSIS OFFICE
94- 98 HQ USAF AFCIN-3D1
99 AC OF S INTELLIGENCE
100 DC OF S RESEARCH & TECHNOLOGY
101 THE SURGEON GENERAL
102 TACTICAL AIR COMMAND
103 ALASKAN AIR COMMAND
104 AIR DEFENSE COMMAND
105 AIR FORCE SYSTEMS COMMAND
106 AIR FORCE BALLISTIC SYSTEMS DIVISION
107 PACIFIC AIR FORCES
108 SECOND AIR FORCE
109-110 AF CAMBRIDGE RESEARCH CENTER
111-115 AFSWC KIRTLAND AFB NMEX
116-117 AIR UNIVERSITY LIBRARY
118 LOWRY AFB
119 SCHOOL OF AVIATION MEDICINE
120-122 AERONAUTICAL SYSTEMS DIVISION
123-124 USAF PROJECT RAND
125 ELECTRONIC SYSTEMS DIV ESAT
126 AIR TECHNICAL INTELLIGENCE CENTER
127 OFFICE OF AEROSPACE RESEARCH

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

128 DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING
129 ASST TO THE SECRETARY OF DEFENSE ATOMIC ENERGY
130 MILITARY LIAISON COMMITTEE
131 WEAPONS SYSTEM EVALUATION GROUP
132 ASST SECRETARY OF DEFENSE INSTALLATION & LOGISTICS
133 INDUSTRIAL COLLEGE OF THE ARMED FORCES
134 ARMED FORCES STAFF COLLEGE
135-138 DEFENSE ATOMIC SUPPORT AGENCY
139 FIELD COMMAND DASA
140 FIELD COMMAND DASA FCTG
141-142 FIELD COMMAND DASA FCWT
143-144 DEFENSE INTELLIGENCE AGENCY
145 U S COAST GUARD
146 JOINT TASK FORCE-8
147 COMMANDER-IN-CHIEF EUCOM
148 COMMANDER-IN-CHIEF PACIFIC
149 COMMANDER-IN-CHIEF ATLANTIC FLEET
150 STRATEGIC AIR COMMAND
151 CINCONAD
152-154 ASST SECRETARY OF DEFENSE CIVIL DEFENSE

ATOMIC ENERGY COMMISSION ACTIVITIES

155-157 AEC WASHINGTON TECH LIBRARY
158-159 LOS ALAMOS SCIENTIFIC LAB
160-164 SANDIA CORPORATION
165-174 LAWRENCE RADIATION LAB LIVERMORE
175-178 NEVADA OPERATIONS OFFICE,LAS VEGAS

FOR CIVILIAN DISTR CAT. B 3

179 UNIV OF CALIF LOS ANGELES CALIF
180 ISOTOPES WESTWOOD NEW JERSEY
181 STANFORD RESEARCH INST MENLO PARK ATTN VAILE
182 RAND CORP SANTA MONICA CALIF
183 US WEATHER BUREAU WASHINGTON ATTN FERBER
184 SPERRY RAND CORP LONG ISLAND N Y
185 DTIE OAK RIDGE,MASTER
186-215 DTIE OAK RIDGE SURPLUS