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PRELIMINARY REPORT

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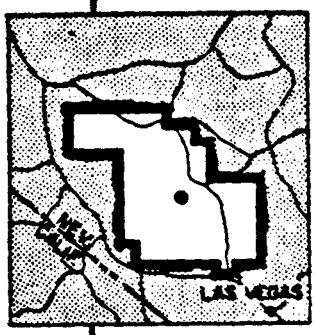

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Project 2.9

RAY F. COYLE, JR.
Lt Col AGC
Adjutant General

NUCLEAR RADIATION RECEIVED BY AIRCREWS FIRING THE MB-1 ROCKET

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DATE: 25 July 1994

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HEADQUARTERS FIELD COMMAND,
ARMED FORCES SPECIAL WEAPONS PROJECT
SANDIA BASE, ALBUQUERQUE, NEW MEXICO

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ITR-1418

OPERATION PLUMBBOB—PROJECT 2.9

NUCLEAR RADIATION RECEIVED BY AIRCREWS FIRING THE MB-I ROCKET

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Issuance Date: October 11, 1957

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ABSTRACT

Three F-89 interceptor aircraft participated in the delivery of a live MB-1 air-to-air rocket and were instrumented to measure the total gamma and neutron exposure received by the aircrew members.

Neutron dose was measured by fission-foil detectors, gold and sulfur threshhold detectors, chemical dosimeters, and the Los Alamos human counter. Gamma radiation dose was measured by chemical dosimeters, NBS film badges, and Rad-Safe film badges. Gamma dose rates were also measured in an initial-gamma-versus-time recorder that had been installed in the aircraft. Complete data and an analysis thereof appear in ITR-1414.

The values recorded by each of these instruments and devices were evaluated and interpreted in order to yield the most reliable estimate of the total exposures. These were then compared with values predicted on the basis of previous full-scale nuclear test operations.

Neutron and gamma doses did not exceed 5 rep and 3 r, respectively. Neutron exposures compared well with the predicted values, whereas gamma exposures were found to be somewhat lower than the predicted values. Part of the latter difference can be attributed to shielding by the airframe.

There is no doubt that an MB-1 rocket can be fired from an F-89 interceptor aircraft at an altitude of 19,000 feet MSL with a radiation dose to the delivery aircrew that is within acceptable limits.

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FOREWORD

This report presents the preliminary results of one of the 43 projects comprising the Military Effects Program of Operation Plumbbob, which included 28 test detonations at the Nevada Test Site in 1957.

For overall Plumbbob military-effects information, the reader is referred to the "Summary Report of the Director, DOD Test Group (Programs 1–9)," ITR–1445, which includes: (1) a description of each detonation, including yield, zero-point location and environment, type of device, ambient atmospheric conditions, etc.; (2) a discussion of project results; (3) a summary of the objectives and results of each project; and (4) a listing of project reports for the Military Effects Program.

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Chapter I

INTRODUCTION

The MB-1 rocket has become operationally available to the Air Defense Command of the United States Air Force. The MB-1 is an air-to-air rocket that carries a [redacted] nuclear warhead. Only limited information was available from past test operations from which to predict the radiation dose to which the crew of an aircraft delivering an MB-1 would be subjected.

1.1 OBJECTIVE

The objective of this project was to measure the radiation dose, both from neutrons and gamma rays, received by an aircrew delivering an MB-1 rocket. Secondarily, the same type of measurements were made at locations other than the crew compartment and on other aircraft in the delivery array.

1.2 BACKGROUND AND THEORY

Whenever a new weapon becomes available for operational use, its characteristics must be known and available to potential users. Before committing the MB-1 to use, an operational commander must have information on the radiation dose to be received by the delivery aircrew, as well as the blast effect on the delivery aircraft. The Joint Chiefs of Staff approved the conduct of a test as a part of Operation Plumbbob in order to obtain the necessary experimental measurements.

In order to be of value, radiation exposure and blast effects must be experienced under conditions as nearly like the operational situation as possible. Although ample data are available to document radiation dose as a function of distance for surface and low-altitude detonations, the unknown effect of the air-ground interface necessitated that a test be conducted at a relatively high altitude.

Experience in past test operations has shown the difficulty of establishing accurately positioned instrument stations at altitude. One satisfactory method had been found to be the use of aircraft that are tracked and positioned by MSQ-1A radar. This being the case, it was concluded that the best plan for this test would be an actual firing of an MB-1 rocket at a preselected point in space. The delivery aircraft, as well as any other participating aircraft, would serve as instrument stations for radiation measurements.

Data from previous test operations have been used to predict the exposure to be received by an aircrew during the delivery of an MB-1. The data, as well as the predictions made therefrom, are contained in References 1, 2, and 3. Since most of the data was obtained on the ground, the presence of the air-ground interface introduces an uncertainty into these predictions.

The delivery of an MB-1 could be expected to provide an experimental check point that would increase the degree of confidence in the theoretical computations or point out the need for additional information.

Chapter 2
PROCEDURE

The activities of this project were limited to Shot John, which was the MB-1 rocket test.

2.1 OPERATIONS

Modifications to the aircraft required for the installation of the instruments were made by the 4925th Test Group (Atomic) several weeks before the actual test. The instruments themselves were installed during the night prior to the test. After the detonation and the return of the aircraft to Indian Springs AFB, all instruments were removed at the earliest possible moment. The fission-foil neutron detectors and neutron threshhold detectors were flown immediately to the counting facilities established at the Nevada Test Site by Project 2.3. All of the fission foils were counted at least once by H + 58 minutes. The crews of the delivery and alternate delivery aircraft were flown to Los Alamos Scientific Laboratories (LASL) for counting in the human counter. This counting was accomplished by H + 5 hours.

Inasmuch as no time limitation existed, the other instruments were evaluated at a later time. The chemical dosimeters were read by Project 39.5 during the afternoon of shot day. The National Bureau of Standards (NBS) film packs were returned to Air Force Special Weapons Center (AFSWC). They were processed and interpreted on shot day. The results from Rad-Safe film badges were received through the normal Rad-Safe channels during the afternoon of shot day.

2.2 INSTRUMENTATION

The three aircraft that participated in the MB-1 delivery were instrumented. Identical sets of instruments were installed in four locations on each aircraft. In the delivery and alternate delivery aircraft, these four locations were the rear cockpit, left and right wing-tip tanks, and tail section of the fuselage. In the blast-effects aircraft, they were the rear cockpit, right wing-tip tank, tail section, and nose section of the fuselage. Each pilot and radar observer carried an NBS film badge, a Rad-Safe film badge, and a set of chemical dosimeters in the pockets of his flight suit. Instruments that recorded gamma dose rate as a function of time were installed in each aircraft by Project 2.5. A detailed gamma-time history, as well as a discussion of predicted gamma doses for the delivery aircraft, is reported in ITR-1414.

The location of primary interest was the crew compartment, since the objective of this project was to measure the radiation exposure of the flight crews. The additional instrument locations were chosen in an attempt to gain some information on the degree of shielding afforded by the airframe.

Fission-foil and threshhold neutron detectors were furnished by Project 2.3. These detectors, as well as the associated counting apparatus, were calibrated at LASL prior to the beginning of the test operation. Details of this calibration can be found in Reference 4.

Chemical dosimeters were obtained from Project 39.5 through the USAF School of Aviation Medicine, Randolph Field, Texas. For the purpose of mixed irradiation dosimetry,

single-phase and half-phase dosimeters were exposed simultaneously. The single-phase system yielded the gamma and fast-neutron dose, while the half-phase system yielded the gamma dose only. Some of these dosimeters were placed in lithium shields fabricated by the Oak Ridge National Laboratories. The purpose of this was to render the dosimeters independent of energy down to about 90 kev and to eliminate the response to thermal neutrons. These devices were calibrated extensively before the test operation began. Details of this calibration and further information on the functioning of the dosimeters can be found in Reference 5.

Two standard types of personnel film-badge dosimeters were used to measure the gamma-radiation exposure. The National Bureau of Standards film badges were obtained from Project 2.5. These were calibrated with gamma radiation from a 10-curie Co^{60} source at AFSWC. Rad-Safe film badges were furnished by the Nevada Test Site Rad-Safe Organization. The exposures recorded by the Rad-Safe film badges are reported as returned by the unit at the test site.

The aircrews from the delivery and alternate delivery aircraft were flown to LASL within 5 hours after the time of detonation for counting in the whole-body counter operated by the H-4 group of LASL. By measuring the induced gamma radiation from Na^{24} in the body, this operation gives a measure of the neutron exposure. A background level for the radiation emitted by each crew member had been established by a count taken 6 weeks prior to shot day. This background level does not change appreciably over a period of several months. At the time of the postshot counting, each individual was also scanned by a crystal scintillation counter. The spectral analysis from this operation made certain that any increase in gamma radiation emitted by the body was from Na^{24} and not from fission-product contamination, either external or internal. Details of the construction, calibration, and use of the Los Alamos human counter can be found in Reference 6.

2.3 DESCRIPTION OF REQUIRED DATA

The data required for the purpose of this project consisted of the total gamma and neutron exposure as measured by the instruments and devices described in the previous section.

For both gamma and neutron measurements, the reliability and accuracy of the data depend on the magnitude of the exposure. Film measurements of gamma radiation are normally considered to be accurate to ±20 percent. The chemical dosimeters furnished by Project 39.5 are accurate to ±20 percent for gamma exposures above 5 r. They are not sufficiently sensitive to measure exposures below this value. The threshhold for neutron measurements using chemical dosimeters is about 10 rep. Above this level they are reliable to ±20 percent.

Fission-foil detectors for fast neutrons have a lower limit, which is dependent on the amount of exposure and the time between exposure and evaluation. For the present case, this lower limit was about 5 rep. The thermal-neutron threshhold detectors will measure a thermal-neutron exposure of 10^7 neutrons/cm^2. Above these lower limits, the detectors are accurate to ±20 percent, but they are not usable below these limits.

Neutron-dose measurements made in the human counter at LASL are presently considered accurate to within a factor of two. This level of confidence may be improved by more-extensive calibration of the counter, but this will not be completed for several months. This method of measurement has the unique capability of detecting fast-neutron exposures of the order of magnitude of 0.1 rep and can be considered to be the best method presently available for the evaluation of small neutron exposures.

Since all of the instruments were amenable to postshot evaluation and interpretation, no special methods or devices were used to record, reduce, or correlate the data.

The location of the burst and the position of each aircraft relative to the burst had to be known with as great a degree of accuracy as possible. The point of burst was obtained from Program 9 and is considered to be correct to ±100 feet in space. The aircraft were controlled and positioned by MSQ-1A radar. Their positions at the time of detonation were obtained through Project 5.5. The aircraft-position values were determined graphically from the chart presentation and are correct to within ±100 yards. More-accurate values will be available from Boeing data-box records and will be incorporated in the final report.

Chapter 3

RESULTS and DISCUSSION

The radiation measurements are recorded in Table 3.1. No values are shown for the chemical dosimeters or neutron detectors, since in every case the exposure was below the threshhold value for these instruments. Even though no precise measurements of the dose were obtainable from these devices, they served to establish an upper limit of 5 r for gamma exposure and 5 rep for neutron exposure.

Because of the limited amount of calibration work for neutron exposures that has been done with the Los Alamos human counter, the exact counting rates are of little significance to this report. Only generalized statements may be made concerning the neutron doses received. If more extensive calibration is completed before the preparation of the final report for this project, the exact counting rates and more precise dose measurements will be included. A total neutron exposure of approximately 3 rep for the crew of the delivery aircraft is indicated. This is the dose which corresponds to the whole-body count of 12 times the background level. The crew of the alternate delivery aircraft counted approximately 1 ½ times the background level. This indicates a neutron dose of about 0.2 rep. No differentiation between the exposure of the two crew members was possible in either instance. These measurements were made at about H + 5 hours. The counts were corrected for decay of Na^{24} activity before the neutron dose was calculated.

A secondary objective of this project was to observe the shielding afforded by different parts of the airframe. From the values shown in Table 3.1, it can be seen that the gamma exposures of the wingtips were essentially the same. This is to be expected, inasmuch as the wing tips are of identical configuration. The orientation of the aircraft with respect to the point of burst is of no significance, since it was at a distance of several mean free paths from the burst. At this distance the geometry for the radiation is essentially nondirectional (4π). The gamma dose in the rear cockpit is only one third that of the wingtips. This difference is attributable to the shielding provided by the airframe.

The pilot in each aircraft received a gamma radiation dose about 30 percent greater than that of the radar observer in the rear cockpit. This can be accounted for by the greater amount of shielding from prompt radiation given to the rear cockpit by the jet engines. It is interesting to note this is the exact opposite of the situation that arises when the aircraft becomes contaminated with fission products by flight through the radioactive cloud. In the latter situation, the radar observer receives the greater exposure, because the jet engine is the primary source of residual radiation.

Table 3.2 shows a comparison of the measured gamma and neutron doses compared with predicted values for the same distances from a 2-kt device. The aircraft and the burst point were all at an altitude of approximately 19,000 feet MSL. The measured gamma doses were less than the predicted doses for the distances of concern. This difference can be attributed, in part, to the facts that shielding by the airframe was not considered in the computation of the predicted doses [redacted] Field measurements of neutron exposures of this magnitude using techniques available to this project are somewhat uncertain. This uncertainty is at least as great as the difference between the predicted and measured values. A more-detailed analysis of predicted and actual doses will appear in the report of Project 2.5 (ITR-1414).

[redacted]

TABLE 3.1 SUMMARY OF GAMMA DOSES

Aircraft	Closest Approach To Burst	Location of Instruments	Dose Measured By Rad-Safe Film Badge	Dose Measured By NBS Film Badge
	yards		mr	mr
Delivery	2,400	Rear Cockpit	1,200	930
		Left Wingtip	3,600	2,250
		Right Wingtip	3,730	3,290
		Tail Section	2,370	1,880
		Pilot	1,530*	1,250
		Radar Observer	1,210*	940
Alternate Delivery	3,000	Rear Cockpit	235	235
		Left Wingtip	625	430
		Right Wingtip	640	460
		Tail Section	595	350
		Pilot	320*	255
		Radar Observer	230*	200
Blast Effects	2,000	Rear Cockpit	1,560	1,180
		Right Wingtip	5,570	3,900
		Nose Section	2,840	2,100
		Tail Section	3,420	2,750
		Pilot	2,720*	1,620
		Radar Observer	2,190*	1,420

* These values are the average of two film badges. One was issued through the normal Rad-Safe channels. The second was attached to the case of the NBS film badge and was issued through this project. However, both were processed and interpreted by the Rad-Safe unit.

TABLE 3.2 COMPARISON OF PREDICTED AND MEASURED DOSES*

Aircraft Crew Member	Distance From Burst Point	Predicted Dose		Measured Dose	
		Neutron	Gamma	Neutron	Gamma †
	yards	rep	r	rep	r
Delivery Pilot	2,400	~2	2.1	~3	1.5
Delivery RO	2,400	~2	2.1	~3	1.2
Alternate Pilot	3,000	< 1	0.3	~0.2	0.3
Alternate RO	3,000	< 1	0.3	~0.2	0.3
Blast Effects Pilot	2,000	~2	6.5	< 5	2.7
Blast Effects RO	2,000	~2	6.5	< 5	2.2

* Predicted doses based on a device yield of 2 kt and a coaltitude delivery at 19,000 feet MSL.
† These values are the average of two film badges. One was issued through the normal Nevada Test Site Rad-Safe channels. The second was attached to the case of the NBS film badge and was issued through this project. However, both were processed and interpreted by the Nevada Test Site Rad-Safe unit.

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CONCLUSIONS

The MB-1 rocket can be delivered in an operational situation at an altitude of 19,000 feet MSL with a radiation dose to the delivery aircrew within acceptable limits. For the three distances from the burst that are considered in this report, the theoretical predictions of the gamma-radiation exposure to be received by the aircrew are on the conservative side. The predicted neutron doses agree with the measured doses within the uncertainty of these measurements. The difference in the case of the gamma dose is attributed to the shielding provided by the airframe. Although no definite statements can be made concerning altitudes other than 19,000 feet MSL, it is felt that theoretical predictions made for other altitudes would hold equally well.

[redacted]

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131 Commander, Crew Training Air Force, Randolph Field, Tex. ATTN: 20TS, DCS/O
132-133 Commandant, Air Force School of Aviation Medicine, Randolph AFB, Tex.
134-135 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, O. ATTN: WCOSI
136-137 Commander, Air Force Cambridge Research Center, LG Hanscom Field, Bedford, Mass. ATTN: CRQST-2
138-140 Commander, Air Force Special Weapons Center, Kirtland AFB, N. Mex. ATTN: Library
141 Commander, Lowry AFB, Denver, Colo. ATTN: Department of Special Weapons Training
142 Commander, 1009th Special Weapons Squadron, Headquarters, USAF, Washington 25, D.C.
143-144 The RAND Corporation, 1700 Main Street, Santa Monica, Calif. ATTN: Nuclear Energy Division
145 Commander, Second Air Force, Barksdale AFB, Louisiana. ATTN: Operations Analysis Office
146 Commander, Eighth Air Force, Westover AFB, Mass. ATTN: Operations Analysis Office
147 Commander, Fifteenth Air Force, March AFB, Calif. ATTN: Operations Analysis Office
148 Commander, Western Development Div. (ARDC), PO Box 262, Inglewood, Calif. ATTN: WDSIT, Mr. R. G. Weitz
149-153 Technical Information Service Extension, Oak Ridge, Tenn. (Surplus)

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

154 Asst. Secretary of Defense, Research and Development, D/D, Washington 25, D.C. ATTN: Tech. Library
155 U.S. Documents Officer, Office of the U.S. National Military Representative, SHAPE, APO 55, New York, N.Y.
156 Director, Weapons Systems Evaluation Group, OSD, Rm 2E1006, Pentagon, Washington 25, D.C.
157 Armed Services Explosives Safety Board, D/D, Building T-7, Gravelly Point, Washington 25, D.C.
158 Commandant, Armed Forces Staff College, Norfolk 11, Va. ATTN: Secretary
159 Commander, Field Command, Armed Forces Special Weapons Project, PO Box 5100, Albuquerque, N. Mex.
160 Commander, Field Command, Armed Forces Special Weapons Project, PO Box 5100, Albuquerque, N. Mex. ATTN: Technical Training Group
161-165 Commander, Field Command, Armed Forces Special Weapons Project, P.O. Box 5100, Albuquerque, N. Mex. ATTN: Deputy Chief of Staff, Weapons Effects Test
166-176 Chief, Armed Forces Special Weapons Project, Washington 25, D.C. ATTN: Documents Library Branch
177-181 Technical Information Service Extension, Oak Ridge, Tenn (Surplus)

ATOMIC ENERGY COMMISSION ACTIVITIES

182-184 U.S. Atomic Energy Commission, Classified Technical Library, 1901 Constitution Ave., Washington 25, D.C. ATTN: Mrs. J. M. O'Leary (For DMA)
185-186 Los Alamos Scientific Laboratory, Report Library, PO Box 1663, Los Alamos, N. Mex. ATTN: Helen Redman
187-191 Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: H. J. Smyth, Jr.
192-194 University of California Radiation Laboratory, PO Box 808, Livermore, Calif. ATTN: Clovis G. Craig
195 Weapon Data Section, Technical Information Service Extension, Oak Ridge, Tenn.
196-215 Technical Information Service Extension, Oak Ridge, Tenn (Surplus)