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OPERATION TEAPOT—PROJECT 6.5

Report to the Test Director

TEST OF AIRBORNE NAVAL RADARS FOR IBDA (U)

R. Zirkind

Bureau of Aeronautics
Department of the Navy
Washington, D. C.

Issuance Date: August 2, 1957

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SUMMARY OF SHOT DATA, OPERATION TEAPOT

Shot	Code Name	Date	Time*	Area	Type	Latitude and Longitude of Zero Point
1	Wasp	18 February	1200	T-7-4†	762-ft Air	37° 05' 11.6866" 116° 01' 16.7306"
2	Moth	22 February	0545	T-3	300-ft Tower	37° 02' 52.2654" 116° 01' 15.6067"
3	Tesla	1 March	0530	T-9b	300-ft Tower	37° 07' 31.5737" 116° 03' 51.0077"
4	Turk	7 March	0520	T-2	500-ft Tower	37° 06' 10.4044" 116° 07' 03.2070"
5	Hornet	12 March	0520	T-3a	300-ft Tower	37° 02' 36.4043" 116° 01' 31.2074"
6	Bee	22 March	0505	T-7-1a	500-ft Tower	37° 05' 41.3860" 116° 01' 25.5474"
7	ESS	23 March	1230	T-10a	67-ft Underground	37° 10' 06.1263" 116° 02' 37.7010"
8	Apple	29 March	0455	T-4	500-ft Tower	37° 05' 43.0200" 116° 06' 00.9040"
9	Wasp'	29 March	1000	T-7-4‡	740-ft Air	37° 05' 11.6866" 116° 01' 16.7306"
10	HA	6 April	1000	T-5§	36,620-ft MSL Air	37° 01' 43.3642" 116° 03' 26.2634"
11	Post	9 April	0430	T-9c	300-ft Tower	37° 07' 19.6365" 116° 02' 03.8060"
12	MET	15 April	1115	FF	400-ft Tower	36° 47' 52.6867" 115° 56' 44.1006"
13	Apple 2	5 May	0510	T-1	500-ft Tower	36° 03' 11.1095" 116° 06' 09 4937"
14	Zucchini	15 May	0500	T-7-1a	500-ft Tower	37° 05' 41.3860" 116° 01' 25.5474"

* Approximate local time, PST prior to 24 April, PDT after 24 April.
† Actual zero point 36 feet north, 426 feet west of T-7-4.
‡ Actual zero point 94 feet north, 62 feet west of T-7-4.
§ Actual zero point 36 feet south, 397 feet west of T-5.

ABSTRACT

This test was designed to determine the suitability of unmodified operational naval radar sets for Indirect Bomb Damage Assessment (IBDA) purposes and to provide fleet personnel with experience in the analysis of IBDA data.

The Navy AJ-2 aircraft with a standard ASB-1 radar bombing system and an R4D-5Q aircraft equipped with an APS-31 radar set simulated attack aircraft during five shots. At the time of detonation, the aircraft were in a head-on flight about 7 miles from ground zero. The presentation of the nuclear detonations on the radar scope was photographed from approximately time zero to ten seconds after detonation. Positive results were obtained from Shots 8 and 13. A detailed analysis of the available data indicates that an interim IBDA capability may exist with present equipment with minor modification, provided special attention is given to the features which produce good photographs for IBDA; that is, correct gain setting and sufficient identifying details to plot aircraft location.

FOREWORD

This report presents the final results of one of the 56 projects comprising the Military Effects Program of Operation Teapot, which included 14 test detonations at the Nevada Test Site in 1955.

For overall Teapot military-effects information, the reader is referred to the "Summary Report of the Technical Director, Military Effects Program," WT-1153, which includes the following: (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; (4) a listing of project reports for the Military Effects Program.

PREFACE

The writer wishes to express his gratitude to the Commanding Officers of the Fleet Airborne Electronics Training Unit (FAETUPAC) and Composite Squadron SIX, and the men of their respective commands for their efforts to make this project a fruitful one. In addition the writer expresses his thanks to LCDR H. Fortner for his diligent effort in handling the air-operations phase of this project.

CONTENTS

TEST OF AIRBORNE NAVAL RADARS FOR IBDA

INTRODUCTION

The purpose of Indirect Bomb Damage Assessment (IBDA) is to provide strike forces an all-weather technique to estimate target damage prior to a post-strike reconnaissance. A proven technique (Reference 1) is radar-scope photography. With suitable radars and bomb yields, data can be obtained which may give ground zero and height of burst. Operationally, the height of burst can be obtained from a time-of-fall device, or reliance can be placed upon the fuze system which has an accuracy greater than that provided by interpretation of radar-scope photographs. Yield can be obtained by other means; e.g., fireball photography, Bhangmeter, or time to the second maximum of the thermal pulse. Thus, the location of ground zero is the only parameter for damage assessment which must be evaluated reliably from radar photography.

Objectives. The main objective of this project was to test the IBDA capability of airborne radars in naval aircraft and determine the steps required to improve this capability. Radars tested were unmodified versions of the APS-31 search radar and ASB-1 bombing system. The latter has an APS-30 series radar with associated computers.

A secondary objective was to provide operational experience for fleet personnel, to develop IBDA operating techniques for inclusion in fleet doctrine, including in-flight procedure, instructions for radar operation, and interpretation of radar photography.

Background and Theory. In all previous tests since Operation Greenhouse, the United States Air Force (USAF) has explored various means to develop an all-weather IBDA capability (References 1, 2 and 3). A significant portion of this work was centered around radar-scope photography; that is, photographing the radar presentation during the early times after the detonation (times less than 30 seconds). These photographs exhibit a point return at zero time (provided the antenna is pointing nearly directly at the zero point), a horseshoe pattern for about 10 seconds after zero time, and a less-descriptive return for the next 30 seconds. From them, height of burst and ground zero can be obtained with sufficient accuracy to be of operational importance.

The earlier tests indicated that the desirable radar frequencies for IBDA work are X and K_μ bands. Although radar sets operating in the latter band had a scan rate greater than the X-band sets, no particular advantage was obtained with this equipment over the standard X-band variety (Reference 3). Further, it appeared that the optimum aircraft positioning was obtained when the antenna axis was at a 50° angle to the horizontal plane containing the zero point.

The presently accepted explanation for the mechanism which gives the radar return is that the earth or water broken up by the shock wave increases the reflective properties of the matter around the fireball and thereby enhances the return (Reference 4). Recent work (Reference 5) indicates that a stronger return can be obtained from an ionized region exhibiting considerable turbulence. More work must be done to provide a complete explanation.

PROCEDURE

Participating aircraft were under the command of Air Force, Pacific Fleet, and were based at the Naval Air Station, San Diego. The AJ-2 aircraft were attached to Composite Squadron, VC-6, and the R4D-5Q to the Fleet Airborne Electronics Training Unit. The AJ aircraft were equipped with an ASB-1 radar bombing system and the R4D with an APS-31 radar, both possessing only a forward-looking antenna.

Radar. The two radar systems used operate in the X-band at a frequency of 9,375 megacycles; their characteristics are given in Table 1. The ASB-1 is capable of an extremely rapid scan rate, 600 "looks" per minute, when the 25-degree sector scan is

TABLE 1 RADAR CHARACTERISTICS

Radar Set	APS-31, ASB-1
Frequency	9375 ± 55 Mc
Peak Power	52 kw (minimum)
Pulse Width	0.5 μsec or 4.5 μsec
Pulse Repetition	800 or 200 pulses/sec
Antenna	Parabolic with horn
Scan Rate:	
Fast	40-50/min at 150° sector
	90-100/min at 60° sector
	230/min at 25° sector
Slow	16-20/min at 150° sector
	45-55/min at 60° sector

used in conjunction with the precision expanded view. Under normal operation, the radar presentation is displayed on a 5-inch PPI scope and is photographed with a Fairchild CR-1a camera; when the 25-degree expanded position of the ASB-1 is utilized, the "B" scope is photographed.

The APS-31 radar was operated at 150-degree sector scan for Shots 4, 8, and 12, and at 25-degree sector scan for Shot 13. The ASB-1 equipment was operated on 25-degree expanded view for Shot 4 and on 150-degree sector scan on Shots 6, 8, and 12.

Radar Photography. The cameras associated with either system are capable of automatic and manual operation. On automatic operation, the ASB-1 camera-cycle time is 10 frames/minute, and on manual operation is 40 frames/minute. With the APS-31 set, the cycle time for automatic operation is 20 frames/minute and as high as 120 frames/minute on 25-degree sector scan. To improve the cyclic rate and reliability, two cameras were installed on the APS-31 radar for all events except Shot 4. One camera was operated automatically on the complete sweep, while the other was manually operated on the half sweep. This procedure permitted scope photography on the clockwise and counterclockwise portions of the sweep.

Initial interpretation of the film was performed by FAETUPAC and VC-6 personnel. The final analysis was performed by radar interpreters at the Naval Photographic Interpretation Center, Anacostia, D. C.

Aircraft Positioning. The participating aircraft were flown from San Diego by navigational aids to the Nevada Test Site vicinity. The final positioning of the AJ aircraft was accomplished by the ASB bombing system in conjunction with ground-radar reflectors and beacons. The R4D positioned itself by radio and visual fix whenever possible over Indian Springs Air Force Base and continually by airborne-radar fixes in conjunction with radio bearings to H-hour position.

The position of each aircraft is described in the following paragraphs by event and summarized in Table 2. It should be noted that the positioning of the R4D was dictated by service ceiling and aircraft safety. The maximum of this aircraft is 14,000 feet msl.

Shot 4. The AJ-2 flew at an altitude of 30,000 feet msl on a 090-degree true heading inbound and was located on a point 7 miles west of ground zero at H-hour. The aircraft continued on this course for about 30 seconds, executed a 90-degree right turn, and returned to San Diego via Las Vegas.

The R4D flew at an altitude of 11,500 feet msl on a 327-degree true heading and was located at a horizontal range of 7 miles at H-hour. The aircraft continued on this course for about 32 seconds, executed a 90-degree right turn, and returned to San Diego via Las Vegas. In this shot and all others, the aircraft maintained an inbound heading until shock arrival and then executed the necessary right turns.

Shot 6. Two AJ aircraft were to participate in this event; however, one aborted due to mechanical difficulty. The other flew at an altitude of 34,000 feet on a 311-degree true heading inbound and was positioned at 10 miles southeast of ground zero at H-hour.

TABLE 2 SUMMARY OF AIRCRAFT POSITIONING

Shot	Altitude feet msl	Heading	Ground Distance feet	Aircraft	Radar
4	30,000	090° true	35,000	AJ-2	ASB-1
	11,500	327° true	35,000	R4D-5Q	APS-31
6	34,000	311° true	53,000	AJ-2	ASB-1
8	30,000	090° true	35,000	AJ-2	ASB-1
	11,500	300° mag.	35,000	R4D-5Q	APS-31
12	31,000	317° true	35,000	AJ-2	ASB-1
	12,000	295° mag.	53,000	R4D-5Q	APS-31
13	12,000	300° mag.	35,000	R4D-5Q	APS-31

Shot 8. The flight pattern described under "Shot 4" was repeated for this shot.

Shot 12. One R4D aircraft flew at an altitude of 12,000 feet msl on a southeast heading (295-degree magnetic) and was located at 10 miles from ground zero at H-hour. One AJ-2 aircraft flew at an altitude of 31,000 feet msl on a 317-degree true heading and was located 7 miles from ground zero at H-hour. The other AJ aircraft aborted due to mechanical difficulties.

Shot 13. One AJ aircraft aborted due to mechanical difficulties and the other missed the target sufficiently to give negative results. The R4D aircraft was in position.

RESULTS AND DISCUSSION

This project represented the first attempt to use Naval Aircraft radar systems to obtain IBDA radar-scope photography. Although some data was obtained, equipment failures often curtailed flights and data collection. In addition, the operational procedures for use of the radars were not optimized for IBDA photography, especially for kiloton-range detonations at the Nevada Test Site.

Radar Photography. Shot 4. The camera magazine jammed shortly before zero time on the APS-31. However, the radar operators did not observe any results on the scope.

On the ASB-1, the radar was set on the 25-degree precision expanded view (see

Figure 1 ASB-1 presentation on 25° expanded view. Shot 4. The circled section is ground zero.

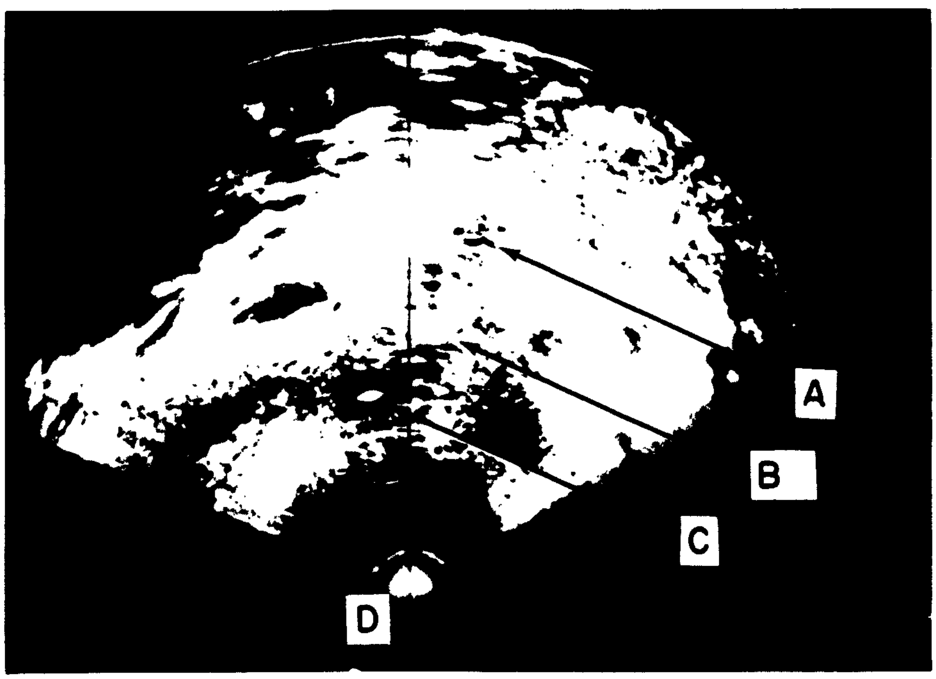

Figure 2 APS-31 presentation of Shot 8. Points A, B, C, and D are: Shot 4 area, blast return, radar reflector and Shot 13 tower, respectively.

Figure 1 for result). Due to low gain and high distortion the result was negative.

Shot 6. Only one of the two participating AJ aircraft reached the target area. Due to low gain and a camera-cycle time of 10 seconds (manual operation), no results were obtained.

Shot 8. In this event, two cameras were used to photograph the scope of the APS-31. The two radar operators reported seeing the burst on the radar screens at H + 0.1 seconds (see Figure 2). One and a half seconds later, there was no evidence of the burst—again pointing out the necessity for a high-gain setting. The visual observations on the ASB-1 indicated that at H + 0.5 seconds, a horseshoe formation was discernible on the radar-scope; however, due to low radar power (about 50 percent of normal) the image rapidly disappeared.

Shot 12. On the APS-31 two cameras were again employed; however, one magazine was not properly engaged to the camera. This camera gave negative results. Radar malfunction did not permit sector sweeps, and photographs were obtained by hand triggering during a portion of the total sweep. No results were obtained.

One AJ aircraft reached the target area and obtained negative results because of low gain settings.

Shot 13. Only the R4D participated in this event. The two cameras photographed the presentation on the APS-31 radar-scope at the rate of 2 frames/second. Evidence of the burst was discernible on the scope for several seconds (see Figures 3 and 4), but the narrow sector precluded an analysis to determine the location of ground zero.

Discussion. The data was subjected to an analysis by radar-photo evaluators, utilizing procedures outlined in OPNAV Instruction 03150.8A. The results were unsatisfactory. Insufficient photographic coverage (time-wise) of the burst, poor distribution of the targets on the radar-scope, and improper gain settings (resulting in poor target definition) made it extremely difficult to plot the photographs of the radar-scope. As a result, ground zero could not be determined within an acceptable margin of error.

To a large degree these difficulties can be attributed to insufficient experience and inadequate equipment. For the kiloton-range detonations observed, the burst presentation had a short lifetime on the scope, and therefore, the system must be capable of recording at least one picture per second. Secondly, the terrain of the Nevada Test Site presents a most difficult radar problem, in that the area is barren of identifiable targets for plotting and provides considerable ground clutter. The short-duration condition imposes the requirement of a narrow sector scan, about 30 degrees, which is in conflict with adequate area coverage for mapping purposes.

Also, to obtain satisfactory pictures for IBDA, a medium to high gain should be employed to distinguish the burst return from ground clutter. The results of a high-gain return are shown in Figures 3 and 4. Although the return is recognizable, insufficient mapping data was obtained to make a satisfactory analysis.

CONCLUSIONS

The results clearly confirm previous USAF tests that to obtain good IBDA photographs a high-gain setting must be utilized in conjunction with a camera speed of about 120 frames/minute. For the radar equipments tested, it appears that a 25-degree sector scan is the most desirable for the first five seconds after the detonation, followed by return to maximum available coverage, preferably 360 degrees.

With proper crew indoctrination and operating procedures, either radar set may provide an interim IBDA capability.

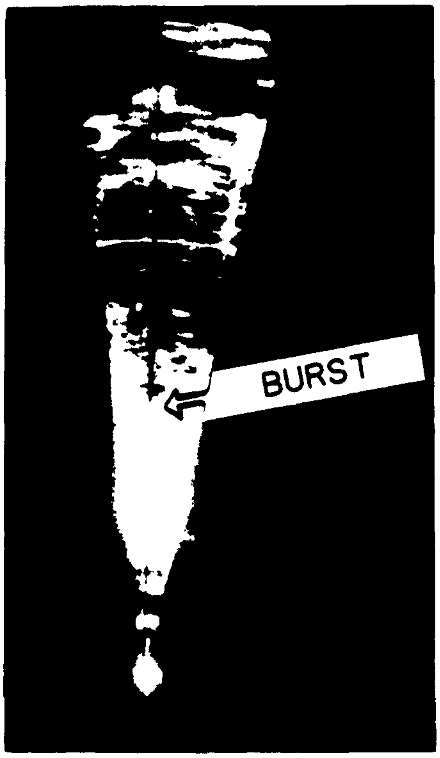

Figure 3 APS-31 Radar photography, Shot 13.

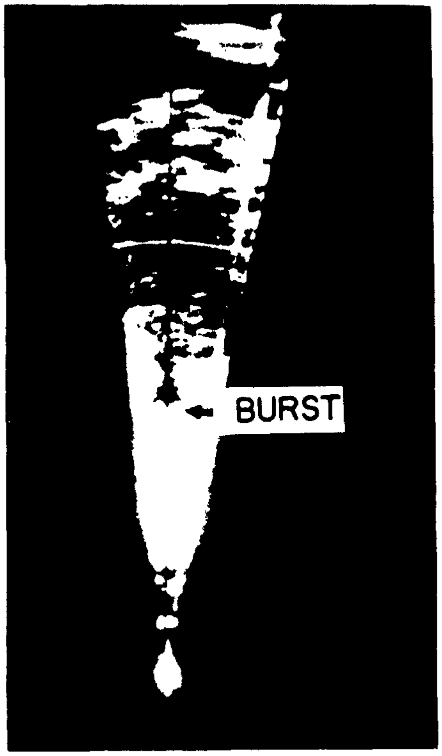

Figure 4 APS-31 Radar photography, Shot 13. one frame later than Figure 3.

To observe the burst directly at early times, for kiloton-range detonations, a sweep rate of 0.2 seconds and equivalent film speed (10 frames/second) would be required.

RECOMMENDATIONS

Further participation and experimentation is required by the Navy before an operational IBDA capability can be attained.

A standard operating procedure for each tested radar set should be prepared for fleet use.

Additional research into the phenomenology associated with the radar return is required.

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124 Commander, Tactical Air Command, Langley AFB, Va. ATTN: Documents Security Branch
125 Commander, Air Defense Command, Ent AFB, Colo.
126-127 Research Directorate, Headquarters, Air Force Special Weapons Center, Kirtland Air Force Base, New Mexico. ATTN: Blast Effects Research
128 Assistant Chief of Staff, Installations, Headquarters, USAF, Washington 25, D.C. ATTN: AFCIE-E
129 Commander, Air Research and Development Command, PO Box 1395, Baltimore, Md. ATTN: RDDN
130 Commander, Air Proving Ground Command, Eglin AFB, Fla. ATTN: Adj./Tech. Report Branch
131-132 Director, Air University Library, Maxwell AFB, Ala.
133-140 Commander, Flying Training Air Force, Waco, Tex. ATTN: Director of Observer Training
141 Commander, Crew Training Air Force, Randolph Field, Tex. ATTN: 2GTS, DCS/O
142-143 Commandant, Air Force School of Aviation Medicine, Randolph AFB, Tex.
144-149 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, O. ATTN: WCOSI
150-151 Commander, Air Force Cambridge Research Center, LG Hanscom Field, Bedford, Mass. ATTN: CRQST-2
152-154 Commander, Air Force Special Weapons Center, Kirtland AFB, N. Mex. ATTN: Library
155 Commander, Lowry AFB, Denver, Colo. ATTN: Department of Special Weapons Training
156 Commander, 1009th Special Weapons Squadron, Headquarters, USAF, Washington 25, D.C.
157-158 The RAND Corporation, 1700 Main Street, Santa Monica, Calif. ATTN: Nuclear Energy Division
159 Commander, Second Air Force, Barksdale AFB, Louisiana. ATTN: Operations Analysis Office
160 Commander, Eighth Air Force, Westover AFB, Mass. ATTN: Operations Analysis Office
161 Commander, Fifteenth Air Force, March AFB, Calif. ATTN: Operations Analysis Office
162 Commander, Western Development Div. (ARDC), PO Box 262, Inglewood, Calif. ATTN: WDSIT, Mr. R. G. Weitz

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

163 Asst. Secretary of Defense, Research and Development, D/D, Washington 25, D.C. ATTN: Tech. Library
164 U.S. Documents Officer, Office of the U.S. National Military Representative, SHAPE, APO 55, New York, N.Y.
165 Director, Weapons Systems Evaluation Group, OSD, Rm 2E1006, Pentagon, Washington 25, D.C.
166 Armed Forces Explosives Safety Board, D/D, Building T-7, Gravelly Point, Washington 25, D. C.
167 Commandant, Armed Forces Staff College, Norfolk 11, Va. ATTN: Secretary
168 Commander, Field Command, Armed Forces Special Weapons Project, PO Box 5100, Albuquerque, N. Mex.
169 Commander, Field Command, Armed Forces Special Weapons Project, PO Box 5100, Albuquerque, N. Mex. ATTN: Technical Training Group
170-171 Commander, FC, AFSWP, PO Box 5100, Albuquerque, N. Mex. ATTN: Chief of Staff, Weapons Effects Tests
172-182 Chief, Armed Forces Special Weapons Project, Washington 25, D.C. ATTN: Documents Library Branch
183 Commanding General, Military District of Washington, Room 1543, Building T-7, Gravelly Point, Va.

ATOMIC ENERGY COMMISSION ACTIVITIES

184-186 U.S. Atomic Energy Commission, Classified Technical Library, 1901 Constitution Ave., Washington 25, D.C. ATTN: Mrs. J. M. O'Leary (For DMA)
187-188 Los Alamos Scientific Laboratory, Report Library, PO Box 1663, Los Alamos, N. Mex. ATTN: Helen Redman
189-193 Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: Martin Lucero
194-196 University of California Radiation Laboratory, PO Box 808, Livermore, Calif. ATTN: Clovis G. Craig
197 Weapon Data Section, Technical Information Service Extension, Oak Ridge, Tenn.
198-225 Technical Information Service Extension, Oak Ridge, Tenn. (Surplus)