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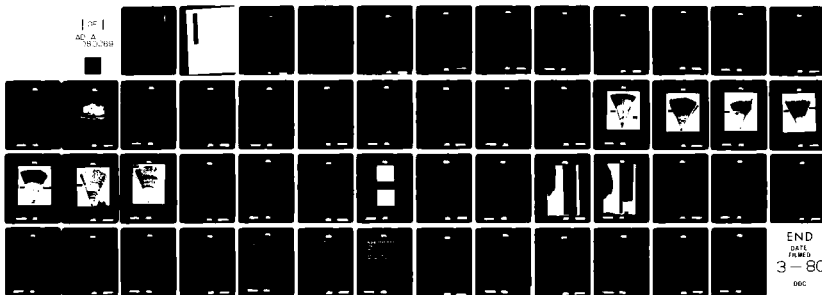
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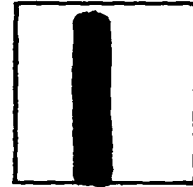
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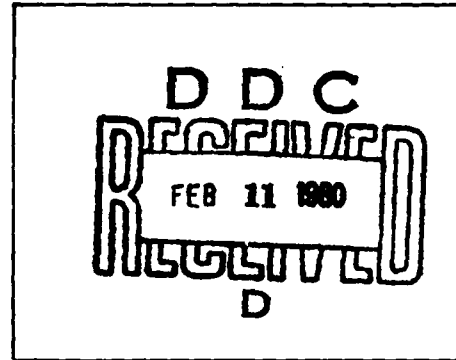
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OPERATION SNAPPER

Project 6.4

OPERATIONAL TESTS OF RADAR
AND PHOTOGRAPHIC TECHNIQUES FOR IBDA

REPORT TO THE TEST DIRECTOR

by

Harry F. Boone
Lt Col USAF

21 August 1951

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ABSTRACT

Encouraging IBDA results from previous atomic tests prompted the extension of an invitation to the Strategic Air Command to assist WADC in making some operational IBDA tests during TUMBLER-SNAPPER. The SAC provided three B-50D aircraft with flight and maintenance crews. These aircraft were equipped with AN/APQ-24 radars modified to present slant range marks; K-17C aerial cameras modified to cycle once per second; and two Edgerton, Germeshausen and Grier bhangmeters. The 4925th Test Group (Atomic), AFSWC installed two E G & G time of fall indicators in the drop aircraft at the request of Project 6.4. In addition, a photometer was installed at the site, and operated by project personnel.

The general plan was to secure all-weather ground zero and height of burst from radar; height of burst from the time of fall indicators; and yield from the bhangmeters and the photometer. Simultaneously, K-17C visual cameras were to be tested for their ability to provide ground zero and height of burst under conditions of good visibility. Analysis of data obtained with the foregoing devices indicates that, under operational conditions, ground zero can be determined by radar to an absolute value of 750 feet and height of burst to ± 400 feet. Yield may also be determined by radar to an accuracy which is presently unknown. The time of fall indicator will give height of burst to ± 300 feet. Visual photography will give ground zero to an absolute error of 500 feet and height of burst to ± 200 feet.

It was concluded that SAC has an immediate, though limited, all-weather IBDA capability. Further, that the interim IBDA system, presently under development, has been proved a proper approach. The experimental bhangmeter will require major modifications before it is incorporated into the interim system.

A test, not associated with IBDA, was performed by the project when one of the B-50D's penetrated an atomic cloud three times. The purpose of the penetrations was to observe the effects of a highly ionized atmosphere on radar operation. Radar operation was not affected, but all film aboard the aircraft was radiation fogged to a marked degree.

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PREFACE

Project 6.4, Operation TUMBLER-SNAPPER, utilized, for the first time, all elements of an airborne Indirect Bomb Damage Assessment system. In fact, the interim IBDA system presently under development at Wright Air Development Center, is essentially comprised of the equipments and techniques about which this report is written. Accuracies attained in making desired test measurements are indicative of accuracies attainable during actual operations. The report is therefore of interest to those personnel who are concerned with either the development, or the operational use, of IBDA systems. Above all, it is believed that those who are concerned with the correlation aspects of IBDA should carefully review their program to insure compatibility with the data gathering system that is almost in being.

The quantity of data obtained during a series of shots is necessarily limited. Moreover, in order to insure the greatest benefits to the majority of projects participating, an individual project sometimes has restrictions imposed which render a truly operational test impossible. The above is not a criticism, but a statement of fact to explain why some of the conclusions reached in this report are based equally upon established data, personal opinion, and past experience, and cannot be specifically proved by data obtained from the project at hand. To illustrate, it is concluded that the drop aircraft can displace itself from ground zero far enough to obtain satisfactory radar data. This was not specifically proved, because project aircraft did not drop any of the bombs. However, it is believed that all conclusions reached in this report are prudent; perhaps conservative.

Little or no effort was made to investigate theoretical aspects of observed phenomena. As the project title states, these were operational tests designed to investigate the present state of the art. However, it is essential that more tests be devoted to theory, because the heart of the interim system is the radar return from an atomic explosion. The cause of this return has not been conclusively established. Then too, basic research may open new avenues of approach which would greatly simplify the presently complex IBDA problem.

Project 6.4 enjoyed the utmost in support and cooperation from all agencies either directly, or indirectly associated with it. Specific thanks are extended to members of the 509th Bomb Wing, SAC; 4925th Test Group (Atomic), AFSWC; Operations Analysis Offices of Hq SAC and Hq AFSWC; "West Lab", Sandia Corp; SAC Liaison Office at Kirtland AFB, New Mexico; Western Electric Technical Representatives at Kirtland AFB; Program 6; and three agencies of WADC, namely, Aircraft Radiation Laboratory, Photographic Reconnaissance Laboratory, and Armament Laboratory.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

The Strategic Air Command's primary mission is to destroy an enemy's strategic installations. Such operations normally require deep penetrations into heavily defended territory. One round trip is costly enough, but during World War II it was necessary after each bombing mission to dispatch photographic reconnaissance missions so that damage assessment could be made. Reconnaissance missions suffered attrition, and were costly timewise.

In order to obviate the necessity for reconnaissance missions after atomic strikes, Headquarters USAF has directed the development of an Indirect Bomb Damage Assessment (IBDA) system. As presently envisioned, this system will consist of two distinct phases. Phase I requires recording, at the time of an atomic explosion, data necessary for the determination of:

Ground Zero
Height of Burst
KT Equivalent (Yield)

Phase II requires the correlation of these data to obtain an estimate of damage to enemy installations.

Military characteristics specify that the Phase I portion of the system shall be all-weather and operate from the drop aircraft, or any aircraft up to 40 miles distance from ground zero. Strategic Air Command representatives have verbally stated that operation from the drop aircraft is of primary importance, and that an operating range of something less than 40 miles would be satisfactory to their Command.

1.2 OBJECTIVE

The objectives of Project 6.4, which were all concerned with Phase I data, follow:

- a. To test immediately available IBDA devices under near operational conditions.
- b. To test experimental IBDA devices.

c. To provide operational crews of the Strategic Air Command with an opportunity to use the devices, and to prove that the Command has an immediate IBDA capability.

1.3 HISTORICAL AND THEORETICAL

1.3.1 Radar

Radar plan position indicator (PPI) photographs obtained during Operations CROSSROADS, 1946; SANDSTONE, 1948; GREENHOUSE, 1951; and BUSTER-JANGLE, 1951 proved that under proper conditions of yield and radar adjustment, an atomic explosion will register a return on the PPI scope. The physical cause of the return is not definitely known. However, there seems to be a relationship between the intensity of the return and the overpressure generated at ground zero. Moreover, it has been established that it is possible to obtain three types of returns from an atomic explosion. These are:

At detonation, a strong point return of short duration.
(See Fig 4.1)

A horseshoe return of possibly 2-3 seconds duration.
(See Fig 4.2)

A cloud shadow which is initially a portion of the horseshoe, but which persists much longer.

The point return is probably a direct reflection from the area of intense ionization which exists immediately after an atomic explosion. Registration of this return occurs when the antenna happens to be oriented on the bomb at the instant of burst, or scans past the area within approximately 0.2 second. Since for IBDA purposes the antenna is scanning a sector of approximately 60 degrees, such orientation occurs infrequently. This means that the point return does not provide a reliable means for obtaining IBDA data.

The horseshoe return occurs when the shock wave strikes the earth, and it persists for several seconds. Hence, this return provides an operational means of determining ground zero, if one assumes the center of the return is truly ground zero, and if at least one other identifiable radar target appears on the scope during the time of interest. As pointed out by Mr. James¹, the horseshoe return also provides a means for determining gross errors in height of burst, and possibly, gross errors in yield.

Prior to TUMBLER-SNAPPER, attempts to utilize radar measurements for IBDA suffered from two distinct limitations. First, a return had never been secured from the drop aircraft, or an aircraft simulating a drop aircraft. Second, even when a return was secured by

[REDACTED]

an escort aircraft, no suitable scale for measuring PPI scope distances existed. The project used a breakaway maneuver in order to place a simulated drop aircraft in a favorable position for obtaining a radar return, and modified radars, as described later in this report, in order to provide a PPI scale.

1.3.2. Visual Photography

Various Air Force cameras were used in past tests, and every time an atomic explosion plus surrounding terrain were photographed, either vertically or obliquely, ground zero and height of burst could be computed. However, no single installation was standardized. As a result, some photographs required a high degree of technical skill to interpret; a higher degree than it is believed exists in an operational interpretation unit.

In order to circumvent the above mentioned interpretation problem, a single method of camera installation was chosen, and interpretation aids were developed for the installation. Strategic Air Command representatives had stated, and WADC concurred, that a K-17C camera with 6-inch lens, mounted in the drop aircraft and tilted back 15° from the vertical, would secure pictures of ground zero regardless of aircraft maneuvers after the drop, provided that the aircraft was level at T_0 . There can be no standard installation for an escort aircraft, as each planned position for the escort presents a different camera pointing problem.

The Photographic Reconnaissance Laboratory, WADC, developed two transparent overlays to be used for the analysis of photographs secured with the 15° aft installation; one for height of burst and one for ground zero. In either case, the photograph is placed under the overlay and certain values read directly from curves or scales. These values may then be used in simple calculations which yield the desired answers. Overlays and instructions have been given to the Strategic Air Command.

1.3.3 Time of Fall Measurement

Many individuals have suggested time of fall measurements as a means of computing height of burst. Attractive features of this technique are simplicity, reliability, and an all-weather capability. However, the ultimate goal of such a device is accuracy, and this depends on measurement of the absolute altitude of the drop aircraft, true air speed, and several other parameters which affect time of fall. In addition, conflicting, informal information exists as to effects of aircraft accelerations, at the instant of release, on time of fall. In any event, the project chose to use some time of fall measuring devices

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developed by E G & G.

1.3.4 Bhangmeter

E G & G bhangmeters were successfully used in the drop aircraft during Operation BUSTER by members of the 4925th Test Group (Atomic). This instrument records, by means of a Land polaroid camera, a cathode ray tube trace of light intensity versus time. Time to minimum light intensity may be quickly determined and, by means of an empirical formula, yield may also be quickly determined.

Readers who are specifically interested in this instrument are referred to Bibliography reports 2 and 3.

1.3.5 Photometer

A photometer is a device for photographically recording light intensity versus time. Data are recorded by a pure photographic process, and hence data reduction is much more involved than in the case of the bhangmeter. First, the exposed film must be processed. Next, the processed film is analyzed by using a densitometer. For determination of yield, analysis is only carried to the first light intensity minimum. Time to this minimum is determined, and then correlated to yield.

The instrument (See Fig 1.1) used by the project drives 390 feet of 9.5 inch film, at approximately 1000 inches per second, past a 0.005 inch slit. Timing marks at the rate of 4000 per second are recorded on one edge of the film. This provides for excellent time resolution. A neutral density step wedge placed in the slit insures the best possible density readings regardless of light environment at shot time.



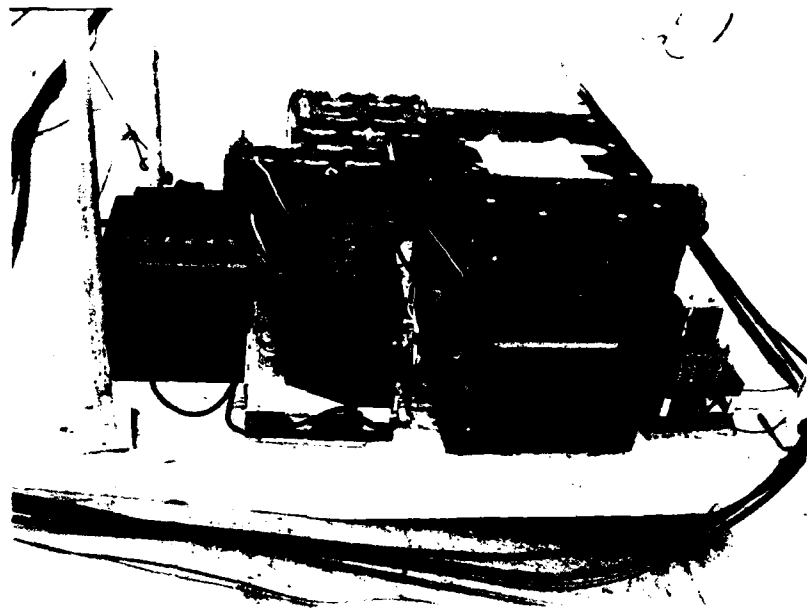


Fig 1.1 Experimental Photometer. To the left, and in the background, is the battery power supply. The middle box is an oscillator-amplifier for timing marks. The large box is the photometer proper and measures 20.5" X 13" X 17". To the extreme right is a relay-contact combination to receive site timing signals.

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CHAPTER 2

INSTRUMENTATION

2.1 GENERAL

Three Strategic Air Command B-50D aircraft were utilized by the project. All were equipped with the standard AN/APQ-24 radar and the standard K-17C visual camera. All radars and cameras were slightly modified as described below. In addition, two of the aircraft carried E G & G bhangmeters. A fourth B-50D belonging to the 4925th Test Group (Atomic), AFSWC, served as the drop aircraft, and carried two E G & G time of fall indicators for Project 6.4. The only equipment not airborne was a photometer which was installed at the site.

2.2 RADAR

Radar set AN/APQ-24 is an airborne navigational and bombing system operating in the X-band and consisting of Radar Set AN/APS-23 and Ground Position Indicator AN/APA-44. For Shot 1 all aircraft had "Unreliabilized" radars and all were modified in the same manner. For Shots 2 through 6, radars had undergone Project Reliable treatment, and two were modified in a different manner than existed during Shot 1.

2.2.1 Shot 1

The O-15 scope camera is standard equipment for photographing the AN/APS-23 PPI scope. With no modification, and with the radar on 60° sector scan, the camera operates on each CCW (counter clockwise) antenna sweep. This provides a picture approximately once per 1.4 seconds. Since the radar return from an atomic explosion is of such short duration, it appeared desirable to double the picture rate by modifying the camera to take pictures on both CW and CCW scans.

This was accomplished by the addition of one relay and a relay mounting bracket to the servo amplifier unit. The relay coil was connected across the antenna armature motor cushioning resistors, and the existing camera pulse lead was removed from relay K-104 and connected to a normally closed contact of the added relay. The other contact was connected to 28 volts D. C. A voltage is developed across the cushioning resistors for approximately 0.1 second at the end of each scan. This voltage is sufficient to pick up the added relay, which in turn allows the O-15 camera to recycle. The rate of camera exposure will therefore be twice the rate indicated by the setting of the exposure frequency control knob.

[REDACTED]

The above modification can be installed by a competent radar technician in approximately two hours. Once it is installed, no further relay adjustments are required. The modification prevents taking pictures on slow sector scan, but has no effect on 360° scan. The modifications performed faultlessly on three aircraft during two dry runs and the first shot. Two modifications were then removed, and the third functioned perfectly for the remainder of the project.

2.2.2 Shots 2 Through 6

For these shots, two radars were modified to show 1500-foot slant range marks on the PPI scope. The modification also provided CW, CCW 0-15 camera operation. Major items of equipment involved in the modification were Camera Control C-(XA-366)/APQ and a TS-102A/AP Range Calibrator. A complete description of installation and operation is given in a WADC Memorandum Report⁴. This project did not use the modification for bomb scoring, but rather for the computational features provided by the range marks.

2.3 VISUAL PHOTOGRAPHY

All aircraft were equipped with K-17C aerial cameras, two with 6-inch focal length lenses and one with a 12-inch lens. The only non-standard item in the cameras was a modified motor which provided for a cycling rate of once per second rather than the standard rate of a cycle per 1.25 seconds.

The two cameras with 6-inch lenses were mounted on A-27-A mounts and tilted back from the vertical 15°. The third camera was mounted on a modified A-27-A mount and was tilted forward from the vertical approximately 40°. All cameras were loaded with 25 feet of film per shot.

2.4 TIME OF FALL INDICATORS

Two Time of Fall indicators, developed and constructed by E G & G, were used during the tests. The 4925th Test Group (Atomic) installed the indicators in the drop aircraft, operated them, and provided Project 6.4 with resulting data.

The experimental instruments have the external appearance of a bhangmeter. The timer is started by the opening of the bomb shackle and stopped by the flash of the bomb. The timer clock is photographed by a Land polaroid camera, and may be read to 0.01 of a second. Technical details concerning the timer may be obtained from Bibliography report 5.

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2.5 BHANGMETERS

Bhangmeters were not permanently installed in the aircraft. Prior to each mission, one instrument was issued to the bombardier of the aircraft which generally was in an escort position, and the second instrument was issued to the right scanner of one of the aircraft which simulated a drop aircraft. Each placed the bhangmeter at his crew position and, at the proper time, turned power on and pointed the instrument head in the general direction of ground zero.

2.6 PHOTOMETER

The photometer was installed at the site. It was placed on top of the Control Point building, and operated on Shots 2 through 5. Site timing signals were used to initiate the device; $T_0 - 2\frac{1}{2}$ seconds for air drops and $T_0 - 1$ second for tower shots.

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CHAPTER 3

OPERATIONAL PROCEDURE

3.1 GENERAL

Flight and maintenance crews and three B-50D aircraft were provided by the 509th Bombardment Wing, Strategic Air Command. The 4925th Test Group (Atomic) was in operational control of the aircraft and assisted in some technical details of the operation. WADC provided and installed the modified K-17C cameras; made the previously mentioned radar modifications; supplied and operated the site photometer; and technically controlled the operation.

Since the three aircraft were instrumented somewhat differently, and performed different maneuvers, it seems necessary at this point to deal with specific aircraft. Henceforth, the three B-50D's will be referred to as Tiger 1, Tiger 2, and Tiger 3.

For Shot 1, aircraft instrumentation was:

Tiger 1: O-15 scope camera modified to take CW and CCW pictures, and a K-17C visual camera, 6-inch cone, tilted back 15° from vertical.

Tiger 2: Same as Tiger 1 except one bhangmeter, operated by right scanner, was added.

Tiger 3: Same CW, CCW modification, K-17 visual camera, 12-inch cone, tilted forward 36° , and one bhangmeter operated by the bombardier.

For Shots 2 through 6, Tiger 2 instrumentation remained the same. Tigers 1 and 3 had the 1500-foot slant range mark modification on their radars, and all else remained the same except that the K-17C on Tiger 3 was tilted forward $39-1/2^{\circ}$.

3.2 AIRCRAFT POSITIONING

On Shots 1 and 2, the drop aircraft was at 19,000 feet absolute. Tiger 1 was 1800 feet above and flying loose formation on the right wing. Tiger 2 was 1300 feet above and flying loose formation on the left wing. Tiger 3 was 800 feet above and 7 nautical miles in trail on Shot 1; 5 nautical miles in trail on Shot 2. Two seconds before "Bomb Away", Tiger 1 made a 40° turn to the right and Tiger 2 made a 30° turn to the left. Both turns were held until 8 seconds before T_0 at which time level-outs were initiated and K-17C's were actuated. Tiger 3 flew straight ahead for approximately 45 seconds after T_0 , and

[REDACTED]

then turned to leave the area. This positioning enabled Tigers 1 and 2 to simulate drop aircraft and Tiger 3 to simulate an escort aircraft.

On Shot 3, bombing altitude was 29,000 feet absolute, and Tigers maintained the same additive altitude displacements. Both Tigers 1 and 2 made 40° turns which were held until 10 seconds before T_0 . Tiger 3 was in trail 7 nautical miles, and flew straight ahead as before.

Shot 4 was dropped by a B-45 from 19,000 feet absolute. Two Tigers were in a very loose formation on the drop aircraft, and Tiger 3 was in trail 5 nautical miles. Absolute altitudes, in chronological order, were 20,800; 20,300; and 21,800 feet. Forty degree breakaways were to be made by Tigers 1 and 2 and held until T_0 -10 seconds. A bit of confusion resulted from a premature voice transmission of "Complete" by the drop aircraft. The transmission was approximately 10 seconds early and caught Tigers 1 and 2 by surprise. Both started turns, leveled out, and on the next "Complete" Tiger 1 accomplished a 60° bank with no ill effects on radar results.

Shot 5 was a pre-dawn tower explosion. Project 1.1 dropped parachutes before this shot, so the Tigers had to be positioned to one side. The original plan called for Tigers 1, 2, and 3 to fly in formation at absolute altitudes of 22,000, 22,500 and 23,000 feet, respectively. Tiger 1 was leader, 2 was to be on the right wing, and 3 on the left wing. Aircraft were to be 4 nautical miles south of the tower at T_0 . Visibility was poor, and Tigers 2 and 3 did not sight Tiger 1, however, all positions were made good. No breakaways were planned or made. Visual cameras were all pointed starboard for this shot.

Shot 6 was also a tower explosion, and occurred at 0400 PST. Tigers 1, 2, and 3 made individual simulated bomb runs at absolute altitudes of 22,000; 23,000 and 24,000 feet. The middle aircraft made a 40° turn to the left, and the other two made similar turns to the right. The mission was flown in an excellent manner; two of the Tigers hitting their simulated release point perfectly and the third in error only 5 seconds. All K-17C's were pointed 15° aft.

After the primary mission, Tiger 1 flew over the atomic cloud at an altitude displacement of approximately 1000 feet. It then penetrated the cloud three times. The purpose was to observe possible effects on radar operation.

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CHAPTER 4

RESULTS AND DISCUSSION

4.1 RADAR

4.1.1 Shot 1

None.

4.1.2 Shot 2

A possible one frame point return was obtained by both Tiger 1 and Tiger 3. These small returns, having no distinctive characteristics, would be of little or no value in actual operations. One could seldom be sure that a single point return, with no subsequent horseshoe and/or cloud shadow, was caused by an atomic explosion. Tiger 2 obtained negative results.

4.1.3 Shot 3

Tiger 1 obtained a possible return. The O-15 camera control was malfunctioning, and at T_0 pictures of CCW sweeps only were being obtained. This makes it impossible to examine the suspected return in detail, and consequently, it must be relegated to the doubtful category. Several frames of the cloud shadow were obtained some seconds after T_0 , but these have no operational value.

Tiger 2 obtained negative results.

Tiger 3 obtained a positive one frame return from the bomb explosion. Approximately 3 seconds later a very weak expanding ring was registered which is undoubtedly a result of the shock wave on the surface of the earth. The weak ring lasts for 4 frames, and would be difficult to definitely identify except for the previously mentioned point return. Cloud shadows were also obtained by Tiger 3.

4.1.4 Shot 4

Tiger 1 obtained a horseshoe which persisted for two frames and a cloud shadow which was still intense when it passed out of scope range at 10.1 nautical miles.

Tiger 2 obtained a doubtful one frame circular return and a definite cloud shadow some 6 seconds later. The O-15 camera malfunctioned at this time and no further pictures were secured. The

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radar was also malfunctioning in that the cross-hairs were not tracking properly.

Tiger 3 obtained a one frame, distorted horseshoe, followed by four frames of an expanding ring. A subsequent cloud shadow persisted for 38 seconds.

4.1.5 Shot 5

Tiger 1 obtained a two frame horseshoe. The cloud shadow existed for 12 seconds.

Tiger 3 obtained a medium intense expanding ring for 4 frames. Due to lack of radar painting in the background, no cloud shadow was observed.

4.1.6 Shot 6

Tiger 1 obtained a two frame expanding ring, and a cloud shadow which persisted for 15 seconds.

Tiger 3 obtained a two frame expanding ring, and a cloud shadow which persisted for 13 seconds.

4.1.7 General Comments

Shots 1 and 2 were so small that no radar returns were expected. Previous experience indicates that results could be obtained from yields of this size, only if the antenna happened to be pointed directly towards the bomb at T_0 . The fact that two aircraft may have secured returns during Shot 2 is merely of academic interest.

Although Shot 3 had a much larger yield, the extreme height of burst (3447 feet) apparently reduced overpressure at ground zero to a value which was marginal insofar as a radar return was concerned.

Shots 4, 5, and 6 were large enough and low enough to produce radar returns. The radar observer on Tiger 2 did not have the antenna pointed properly during Shot 5, but there is no explanation for his negative results on Shot 6.

Ignoring Shots 1 and 2 for reasons previously stated, the project obtained seven positive and two probable returns from 12 attempts. Positive, in this case, refers to a definite radar return which marks ground zero with either a horseshoe or a circle, and which could not be confused with any other radar return. (See Figs 4.1 to

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4.7 inclusive)

4.1.8 Calculations

Radar data were obtained for the primary purpose of establishing ground zero and the secondary purpose of computing height of burst. Unfortunately, only three sets of data which contained positive returns also contained identifiable terrain features, and only two sets contained radar returns in a form which permits height of burst calculations. Values obtained and aircraft and shots providing data follow:

	<u>Ground Zero Error</u>	<u>Height of Burst Error</u>
Tiger 1, Shot 4	290 feet	-340 feet
Tiger 1, Shot 5	525 feet	+200 feet
Tiger 3, Shot 5	450 feet	-----

The identifiable terrain object used for Shot 4 was the center of the asphalt mat. For both Shot 5 calculations, a corner reflector was identified. None of the calculations would have been possible except for the slant range mark modification on the radars.

It is of interest to observe aircraft altitude and ground range displacement from the bomb, each time a positive return was obtained.

	<u>Absolute Altitude (Ft)</u>	<u>Horizontal Range (Nautical Miles)</u>
Tiger 3, Shot 3	29,800	8.10
Tiger 1, Shot 4	20,800	4.80
Tiger 3, Shot 4	21,800	4.54
Tiger 1, Shot 5	22,000	4.20
Tiger 3, Shot 5	23,000	4.32
Tiger 1, Shot 6	22,000	2.34
Tiger 3, Shot 6	24,000	2.96

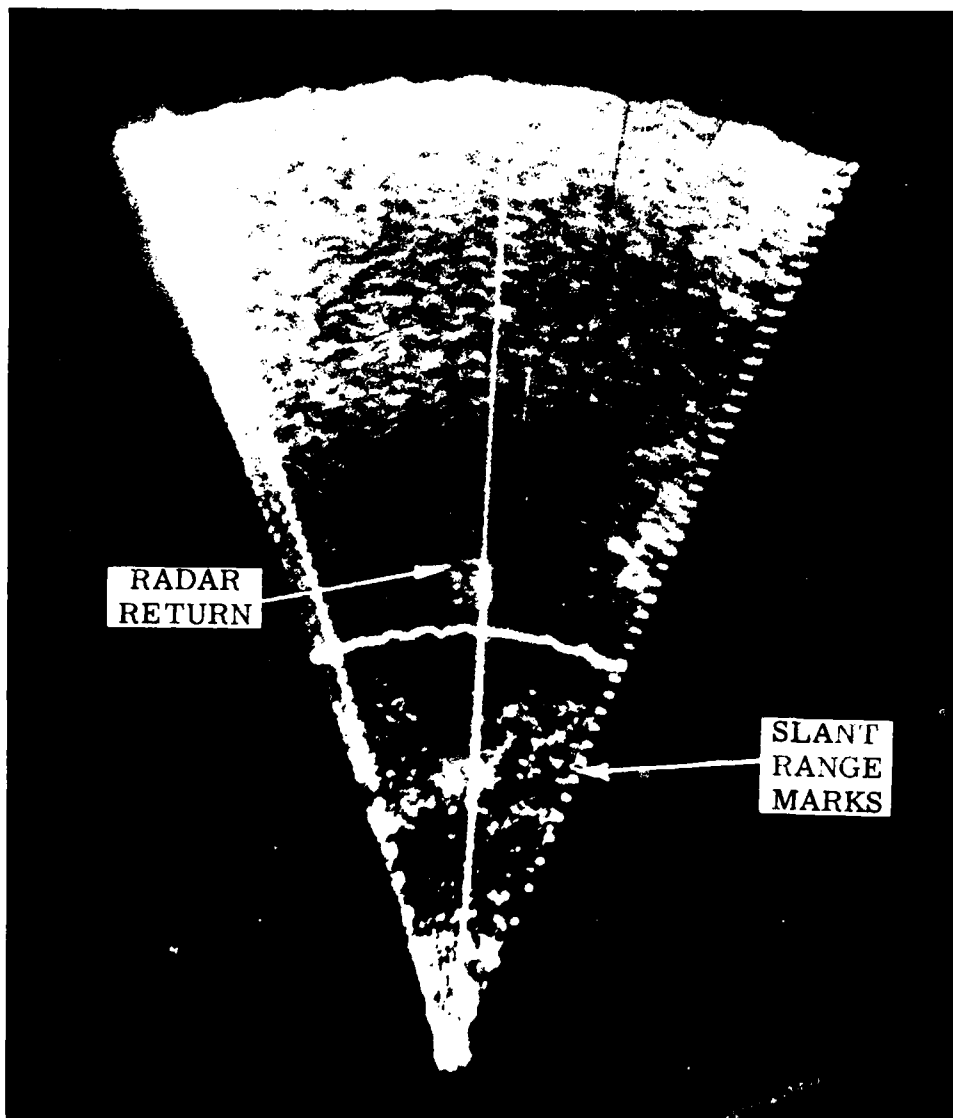


Fig 4.1 Radar Photography, Shot 3. This picture was secured by Tiger 3, and illustrates the type of return secured when the antenna happens to be oriented on the bomb at T_0 . Note the 1500-foot slant range marks on this and subsequent pictures.

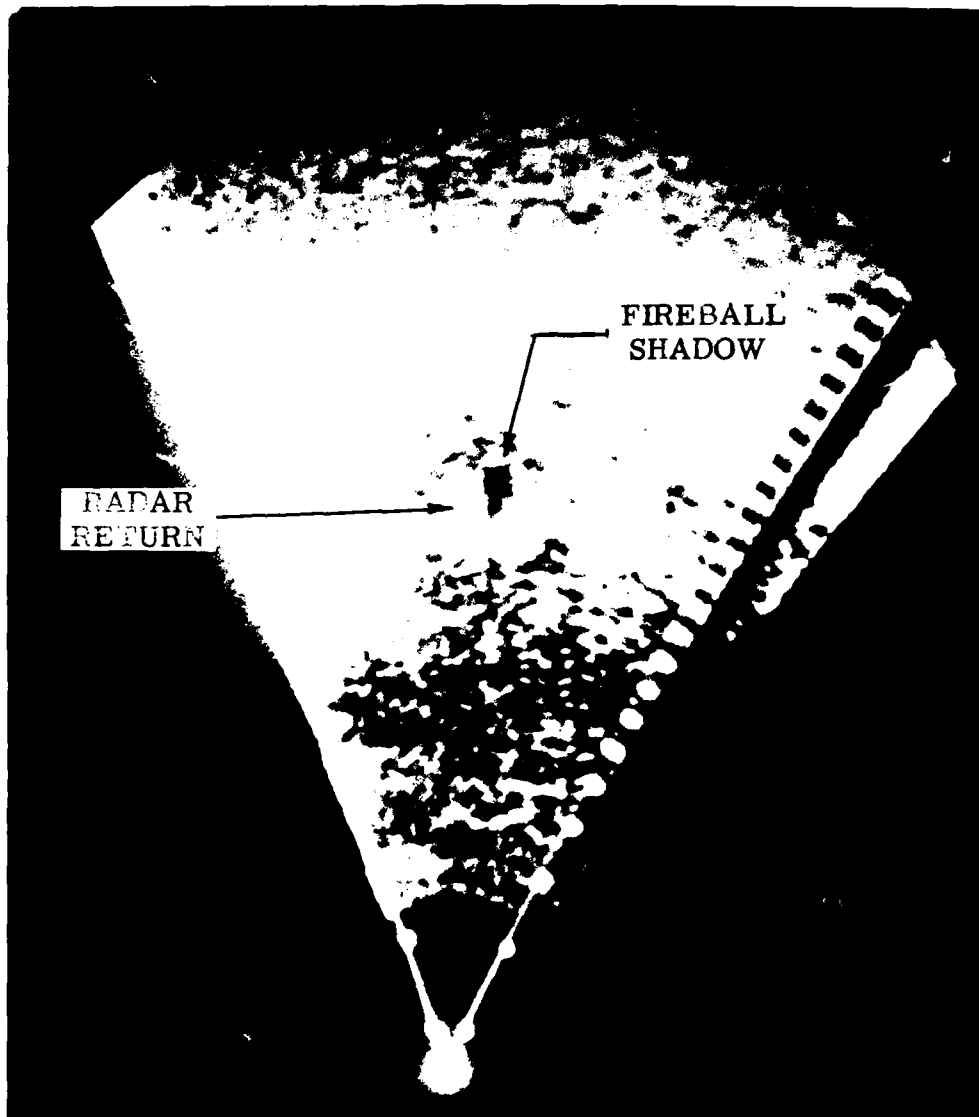


Fig 4.2 Radar Photography, Shot 4. This picture was secured by Tiger 1, and illustrates a so-called horseshoe return. All IBDA parameters may be secured from photography of this type, although attainable yield accuracy is presently unknown.



Fig 4.3 Radar Photography, Shot 4. This picture was secured by Tiger 3. It provides ground zero data but, due to distortion, is of little or no value for determining other parameters.

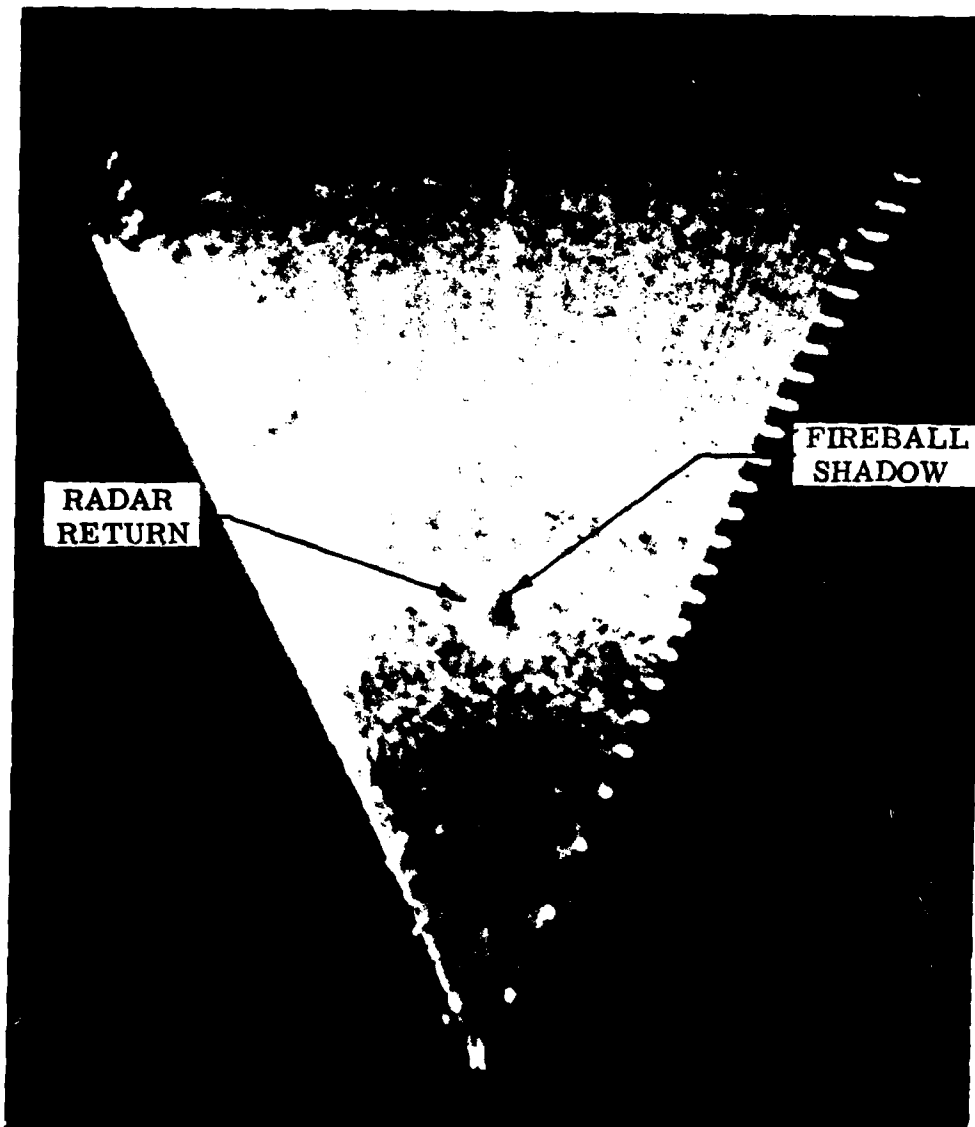


Fig 4.4 Radar Photography, Shot 5. This picture was secured by Tiger 1, and illustrates a so-called horseshoe return. All IBDA parameters may be secured from photography of this type, although attainable yield accuracy is presently unknown.

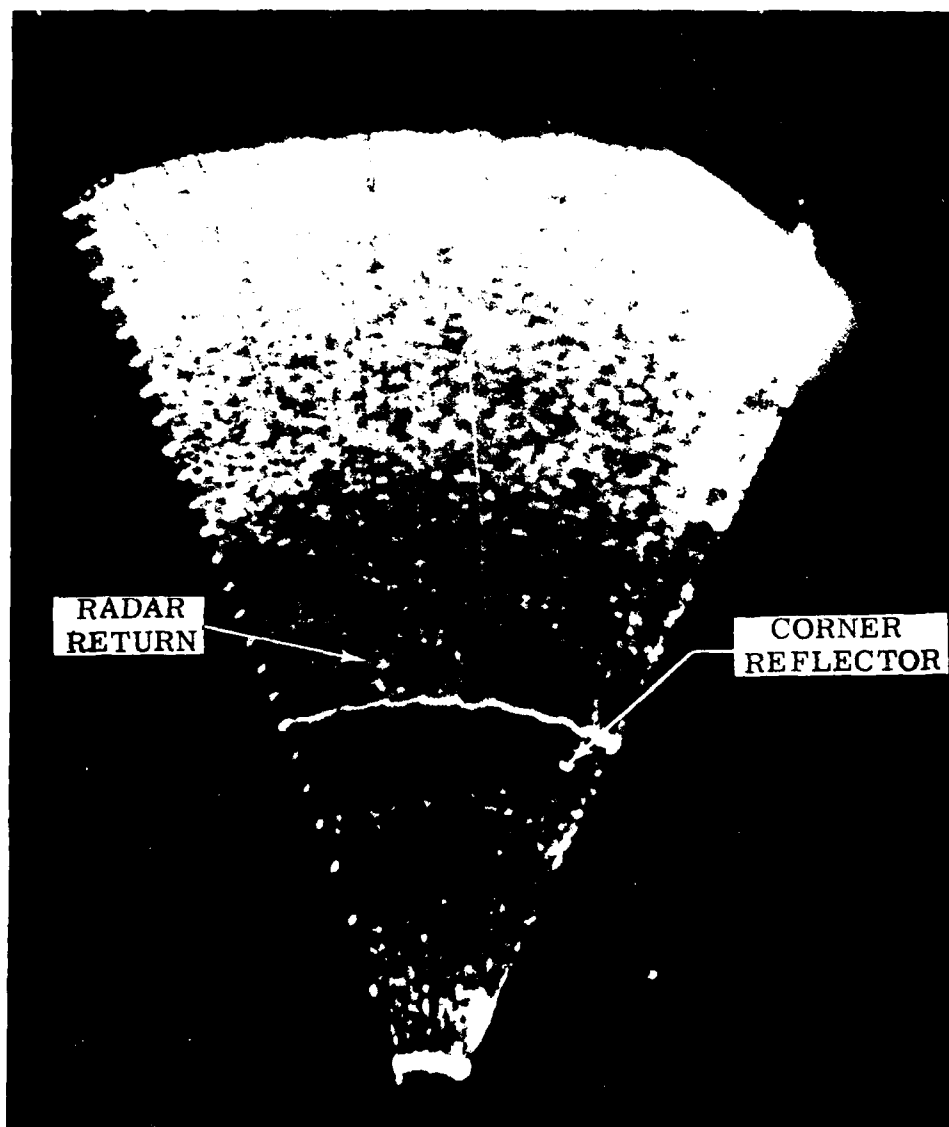


Fig 4.5 Radar Photography, Shot 5. This picture was secured by Tiger 3. Only ground zero may be determined from a circular return of this type. Note the excellent radar fix afforded by the return from a corner reflector.

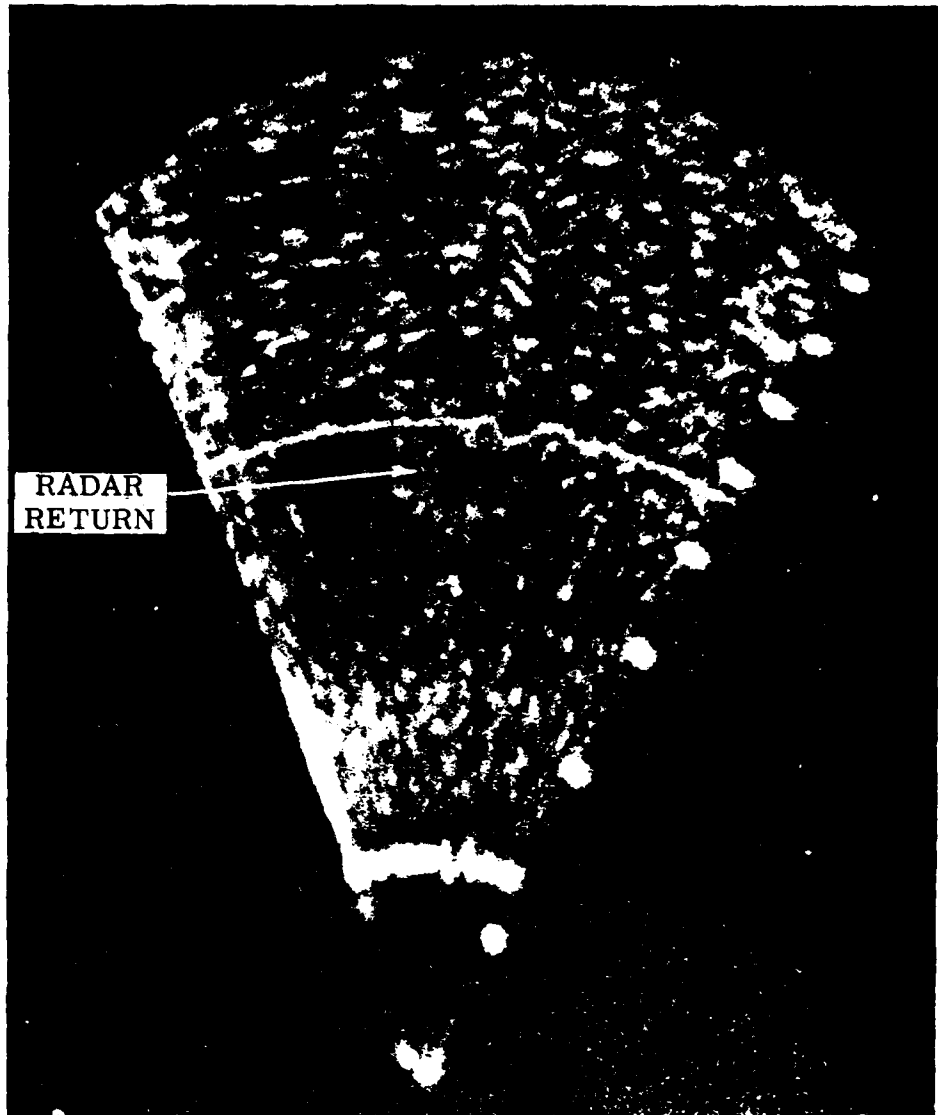


Fig 4.6 Radar Photography, Shot 6. This picture was secured by Tiger 1. Much detail has been lost in reproduction. Only ground zero may be obtained from a circular return of this type.

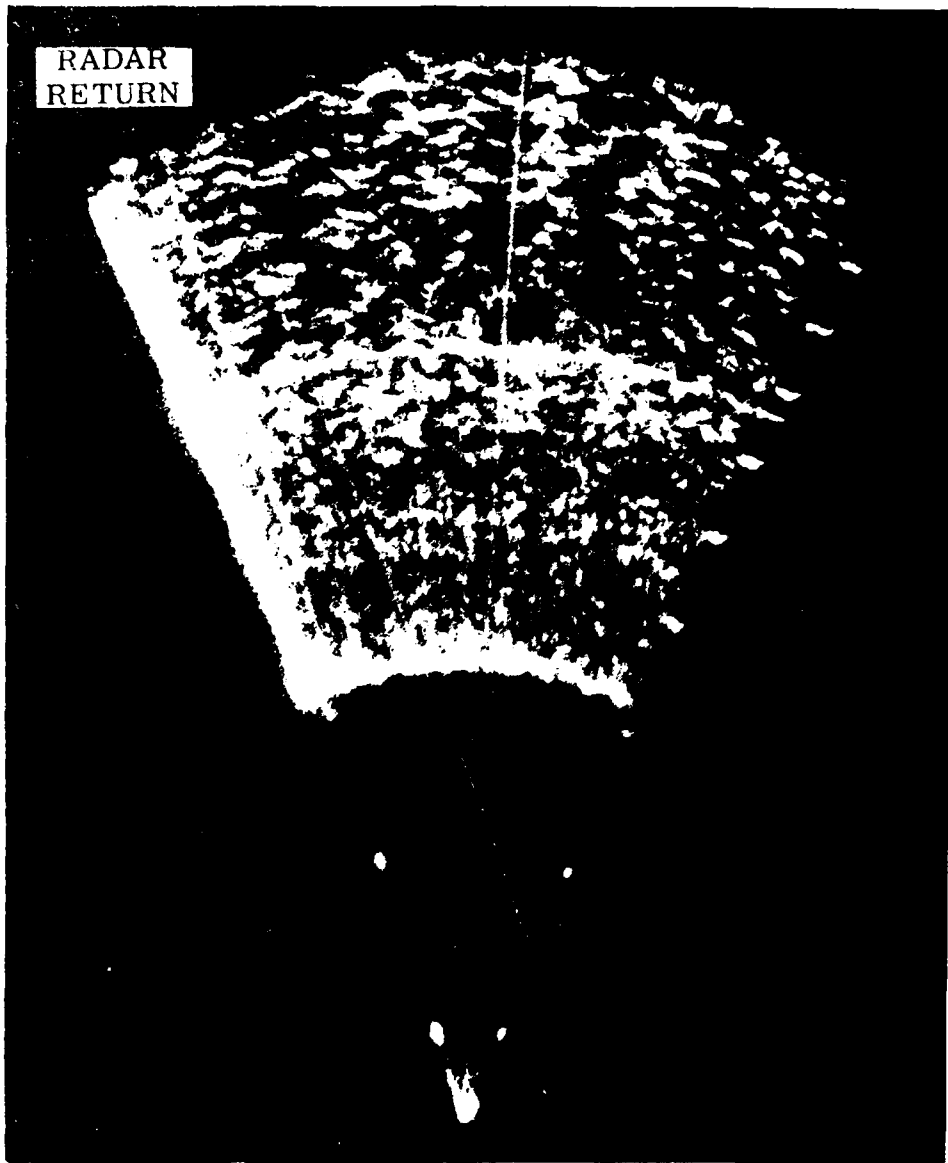


Fig 4.7 Radar Photography, Shot 6. This picture was secured by Tiger 3. This is a circular return which enables ground zero calculations, but the distortion would probably introduce an error on the order of several hundred feet.

[REDACTED]

Expressed in another manner, the above data indicate that an aircraft was in a favorable position for radar data when it was displaced in such a manner that the angle of depression from the aircraft to ground zero was on the order of 57° , or less. It is possible that the angle of depression could be larger, but no data exist to support this conclusion. The most favorable angle of depression, based upon this and other tests, appears to be on the order of 40-45 degrees.

Calculations from radar photography are cursed with inherent inaccuracies. To calculate ground zero, one must estimate the location of the center of the radar return; find an identifiable terrain return, and estimate which point on this return corresponds to a known point on a map; and measure the angle formed by the aircraft position and the two estimated points. More estimations enter the picture when interpolation between slant range marks is necessary. Height of burst calculations are particularly sensitive to slant range errors; more so than ground zero calculations.

It is the opinion of the author that, under adverse conditions, two people using the same radar data would differ by as much as 200 feet after making ground zero calculations and possibly 300 feet in height of burst calculations. In fact, the same person using identical data on different days will produce answers differing on the order of approximately half the above mentioned values.

4.2 VISUAL PHOTOGRAPHY

The number of useful visual photographs obtained by the project was unsatisfactory. Three cameras were used on each shot. This means that it was possible to secure 18 sets of useful photographs. Actually, only five useful sets were obtained. The escort aircraft, Tiger 3, accounted for three failures in that the camera was not properly pointed at T_0 . There were three instances of camera malfunctions. Tiger 1, due to a false "Complete", was in a bank at T_0 during Shot 4. Finally, all night photography, Shots 5 and 6, was useless.

Ground zero and height of burst were calculated from each of the five useful sets of photographs. Errors resulting when calculated values were compared with true values are listed below.

	<u>Ground Zero Error (Feet)</u>	<u>Height of Burst Error (Feet)</u>	<u>True Height of Burst (Feet)</u>
Shot 1	132	+ 162	795
Shot 2	218	+51	1109

	<u>Ground Zero Error (Feet)</u>	<u>Height of Burst Error (Feet)</u>	<u>True Height of Burst (Feet)</u>
Shot 2	450	+41	1109
Shot 3	240	+ 117	3447
Shot 4	225	+ 140	1040

Measurements of height of burst are complicated by the fact that one or more photographs are usually "burned out" by the intense light. This means that when a good photograph is finally secured, the fireball has risen by some amount. A rate of rise has to be calculated, and an appropriate value subtracted from the height of the fireball which was measured from the first usable photograph.

All cameras were properly pointed, and there were no malfunctions during the night shots. Unfortunately, the K-17C cannot cope with the light intensity produced by the bomb. All sets of photographs were the same; several photographs completely "burned out", and then 2-3 frames of the hot cloud with a very small area of terrain illuminated directly beneath. The camera settings used were F/6.3 and 1/50 second; film type was Class L Super XX. It could be argued that a smaller aperture and faster speed would prove useful. This is debatable, but it is believed that such settings would not alleviate the "burn out" problem, and could not utilize the comparatively dim light produced by the hot cloud.

4.3 TIME OF FALL INDICATORS

Two indicators were activated on Shots 2 and 3. No difficulties were encountered. Readings of 34.53 and 34.55 seconds resulted from Shot 2 and 42.28 and 42.32 seconds from Shot 3.

MK-4 Bombing Tables, dated December, 1950, were used to convert times of fall to heights of burst. Tables were entered with true air speed and release altitude in order to secure predicted time of fall. This figure was then corrected for target altitude and bomb weight deviation. The difference between the predicted time of fall and measured time of fall was then converted into a height of burst. One limitation of the tables used is that times of fall are given to the nearest 0.01 second; however, corrections for target altitude and bomb weight deviation are only given to the nearest 0.10 second.

Actual heights of burst for Shots 2 and 3 were 1109 and 3447 feet respectively. Calculated heights of burst resulted in the following errors:

<u>Shot 2</u>	<u>Shot 3</u>
+ 174 feet	+ 153 feet
+ 161 feet	+ 138 feet

In order to check on the general accuracy of converting times of fall into heights of burst, E G & G ground timing data were secured for Shot 1 from TUMBLER and Baker, Charlie, and Dog shots from BUSTER. These errors resulted for true heights of burst of 793; 1118; 1132; and 1417 feet respectively:

<u>TUMBLER-Shot 1</u>	<u>BUSTER-Baker</u>	<u>Charlie</u>	<u>Dog</u>
-90 feet	+142 feet	+88 feet	-7 feet

4.4 BHANGMETER

Bhangmeter performance was highly satisfactory. Twelve attempts, two instruments on each of six shots, were made to obtain yield data. Only one of these attempts failed. This failure was probably caused by a faulty photocell, plus the use of a Neutral Density 1 filter. In any event, the light intensity trace dropped down to the base line; and remained there. Consequently, no minimum could be determined. (See Figs 4.8 and 4.9)

One other minor difficulty was experienced with the bhangmeter operated by the bombardier of Tiger 3. It was discovered that it was necessary to ground the instrument to the aircraft in order to prevent the base line from oscillating. The cause of this interference was never discovered, and the scanner in Tiger 2 experienced no such troubles with his instrument.

Specifically, the following times to minimum light intensity were obtained. Also shown are yields computed from what is presently accepted as the best empirical formula.

	<u>TIGER 2</u> (Milli- seconds)	<u>TIGER 3</u> (Milli- seconds)	<u>TIGER 2</u> (KT)	<u>TIGER 3</u> (KT)
Shot 1	4.0	4.0	1.5	1.5
Shot 2	4.0	4.5	1.5	1.9

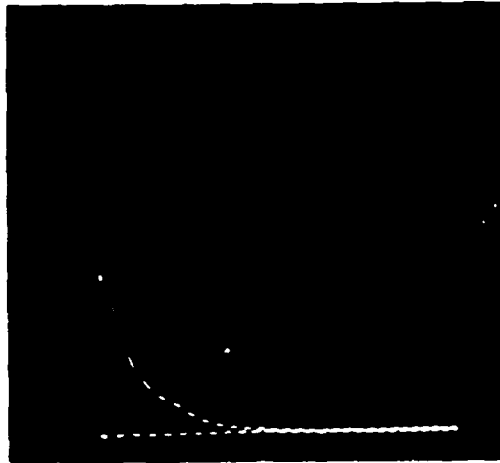


Fig 4.8 Bhangmeter Data, Shot 3.
This photograph demonstrates the
single failure incurred by Project 6.4

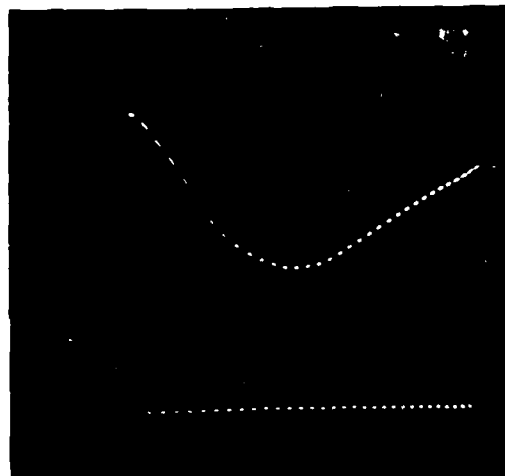


Fig 4.9 Bhangmeter Data, Shot 5.
This photograph demonstrates a
typical light intensity versus
time trace as obtained from an E G & G
bhangmeter. Time to minimum was read
as 13. 5 milliseconds.



	<u>TIGER 2</u> (Milli-seconds)	<u>TIGER 3</u> (Milli-seconds)	<u>TIGER 2</u> (KT)	<u>TIGER 3</u> (KT)
Shot 3	--	18.0	--	32.4
Shot 4	15.5	15.5	24.0	24.0
Shot 5	13.5	13.2	18.2	17.4
Shot 6	12.5	12.5	15.6	15.6

With one exception, all of the above readings were obtained with the instrument head pointed in the general direction of ground zero. The bombardier of Tiger 3 was going away from ground zero at T_0 during Shot 6. This resulted in the bhangmeter head being pointed in a most adverse direction. The fact that the instrument functioned properly demonstrated that pointing of the head is not critical.

The demonstrated ability of the bhangmeter to function regardless of the orientation of the head, plus the long distances from ground zero over which the instrument will function, impose severe problems in the case of multiple drops on a single target area. For example, if three aircraft made simultaneous drops on points separated by several miles, three airborne bhangmeters could not be relied upon to obtain separate intensity traces which could be identified as resulting from particular bombs. Then too, the present instrument could be triggered by a flash of lightning, or an exploding projectile. All of these problems, plus others, must be solved before an operational yield instrument can be produced.

4.5 PHOTOMETER

The photometer was actuated on Shots 2 through 5. No operational difficulties were experienced except on Shot 2, when timing marks failed to register on the edge of the film.

All film was processed during the tests, but no analyses were made until the project returned to its home base. This was necessary, but unfortunate. A densitometer is so sensitive that the least variation in film light depth, such as a processing spot, renders accurate analysis impossible. This situation was encountered when an attempt was made to analyze Shot 4 film. Extraordinary processing precautions would probably have saved these data, but the project did not realize such precautions were necessary.



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The foregoing misfortunes left two good rolls of film (See Figs. 4.10 and 4.11); those obtained from Shots 3 and 5. In each case, three different density bars were analyzed with a densitometer. Maximum time spread between each of the three minimums determined was 500 microseconds in the case of Shot 3 and 125 microseconds for Shot 5. A single reading can probably be made to an accuracy of one half the time between two timing marks, or to 125 microseconds.

Specific times to minima obtained were Shot 3, 18.36 milliseconds; and Shot 5, 14.12 milliseconds. In each case, these values were obtained by averaging the three different density bar readings. Values are degraded by the averaging process; the inability to read more precisely than 125 microseconds; and the fact that the start of the event registered on film as an indistinct, rather than distinct, line.

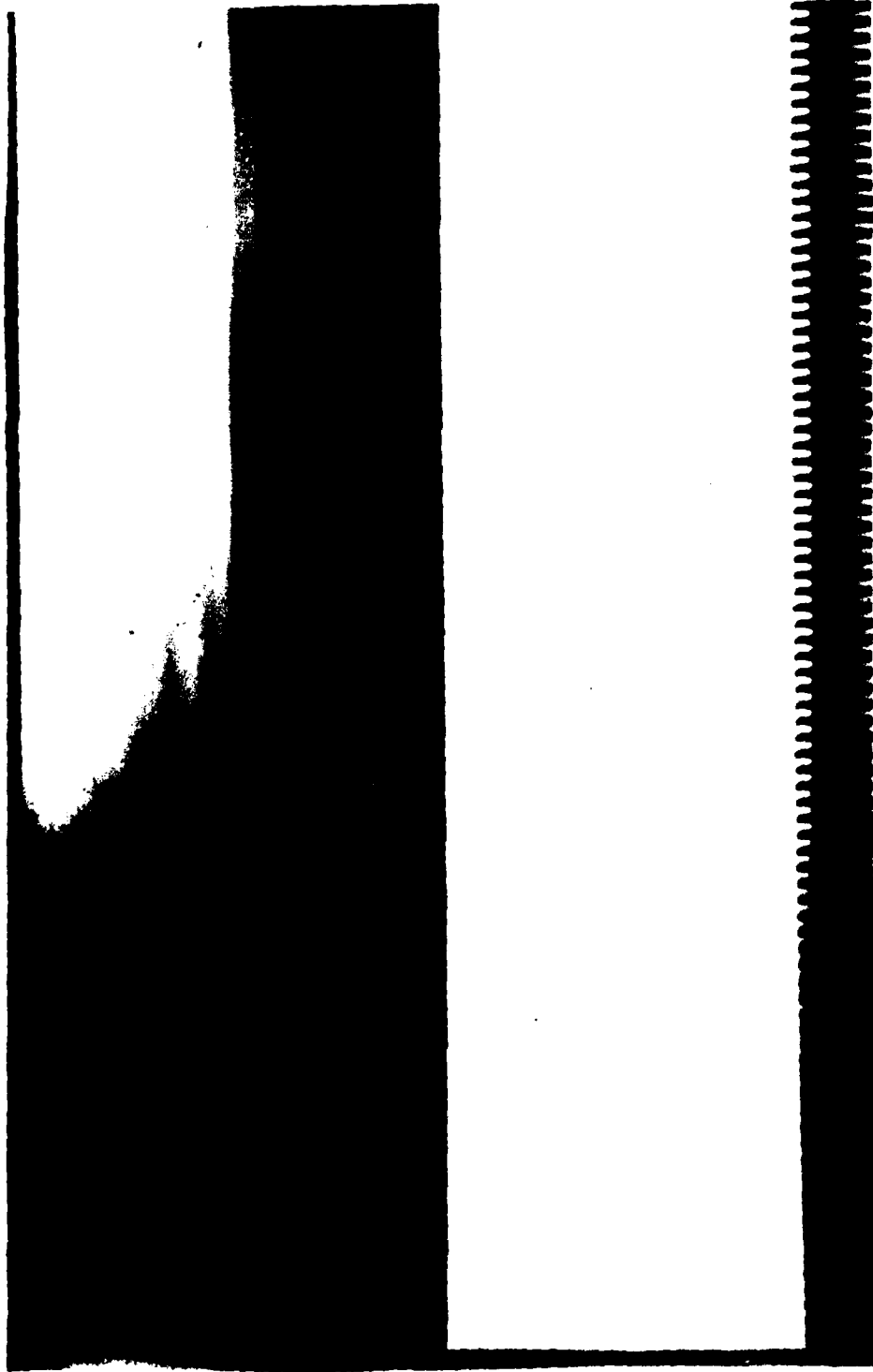


Fig 4.10 Photometer Film, Shot 3. This negative print depicts approximately 20 milliseconds of photometer data. T_0 is indicated by the boundary of the light and dark areas on the left. The bars of varying density are a result of the neutral density step wedge. Timing marks appear at the bottom. The white, rectangular area is caused by masking, and is not a part of these data.

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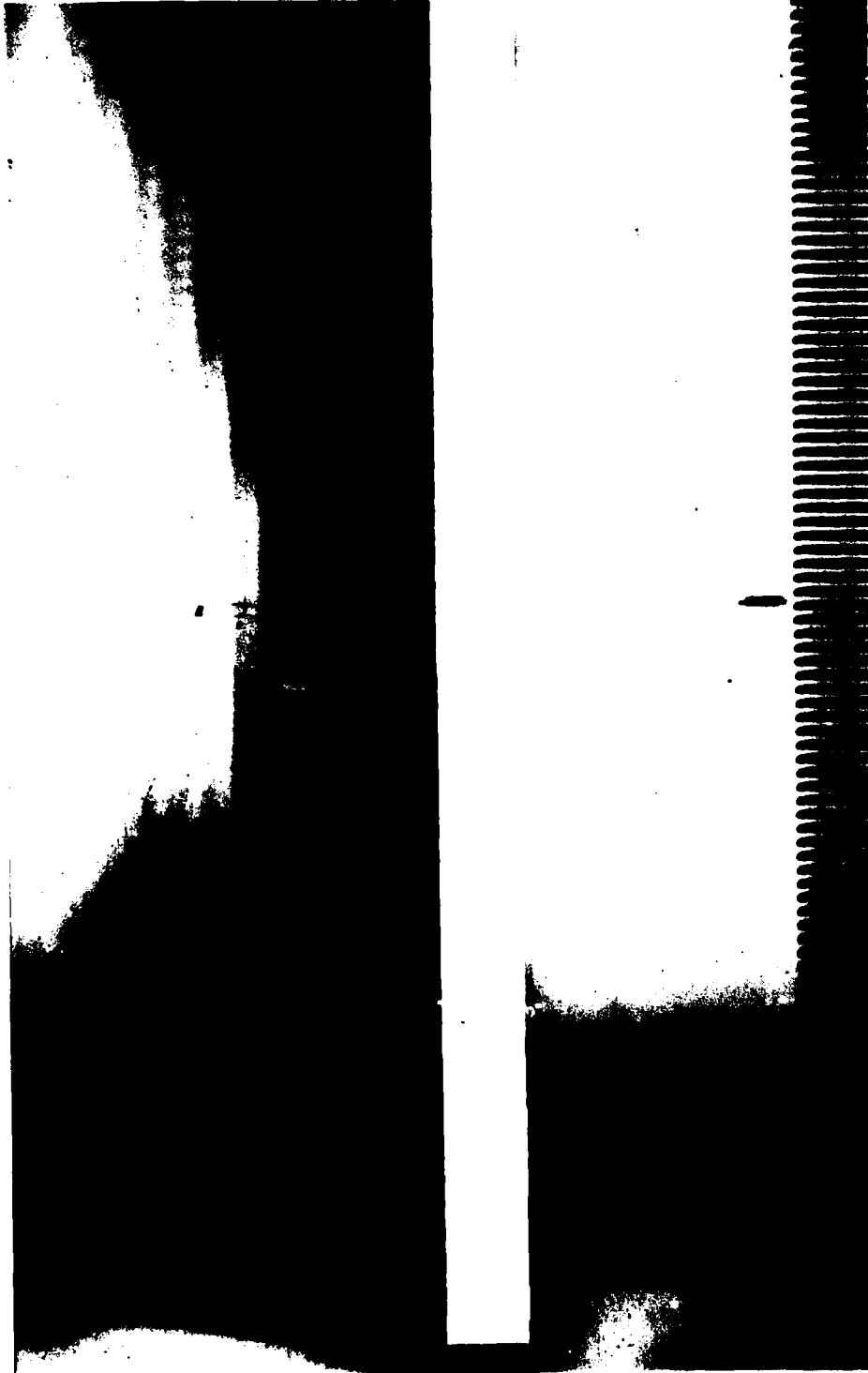


Fig. 4.11 Photometer Film, Shot 5. This negative print depicts approximately 22 milliseconds of photometer data. Note the decrease in light intensity to the vertical marks in the center of the print, and the build up to the right of these marks. Timing marks appear at the bottom. The small, white, rectangular area is caused by masking, and is not a part of these data.

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CHAPTER 5

CONCLUSIONS

5.1 RADAR

All conclusions pertaining to radar for operational IBDA systems are based upon the assumption that a stock pile weapon, dropped over a built up area, will produce some form of radar return which can be used to determine ground zero.

The Strategic Air Command, using standard bombing and navigation radar, has an immediate, all-weather, IBDA capability which exists in either a drop or escort aircraft. The capability is presently limited by the absence of PPI scope slant range marks. It is estimated that without this aid, ground zero could be calculated to absolute errors of from 800 to 1500 feet; dependent upon identifiable terrain features from which a scale may be obtained and the distance the aircraft is displaced from ground zero. Gross errors in height of burst and yield could be determined in those cases which are favorable to the establishment of a scale; providing that a horseshoe return is obtained.

The radar portion of the interim IBDA system is similar to equipment used in this project. Errors in determining ground zero are very dependent upon the terrain return which is used as a radar fix from which bearing and ground range may be measured to the atomic return. If a good radar fix, such as a bridge across a large river, were available, it is believed that all operational ground zero errors would fall within a radius of 750 feet. This error would increase proportionately as the quality of the radar fix deteriorated. Radar height of burst could be operationally determined to possibly ± 400 feet; however, this method of obtaining height of burst is not considered reliable since a radar return can be obtained which is not in the proper form for height of burst computations. Those returns which are of the proper form for height of burst computations also provide a means for determining yield to a presently unknown degree of accuracy. This is accomplished by measuring the fireball diameter during its early stages and comparing it with a curve showing yield versus fireball diameter. Preliminary investigations reflect favorably upon this method.

The radar techniques used by the project do not interfere with normal bombing procedures as advocated by SAC. However, the drop aircraft has no capability for obtaining radar IBDA data unless it executes an immediate breakaway with a bank on the order of 40° or greater.

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5.2 VISUAL PHOTOGRAPHY

The K-17C camera, when utilized as it was by this project, provides an operational, visual IBDA device for daylight operations. Test results indicate that ground zero errors should all fall within a radius of 500 feet, and that height of burst errors should be no more than ± 200 feet.

The camera is not satisfactory for night operations.

5.3 TIME OF FALL INDICATOR

The time of fall indicator is considered as the most desirable device presently available for all-weather height of burst determination. Under all-weather, operational conditions, this instrument should provide height of burst to ± 300 feet.

5.4 BHANGMETER

The experimental bhangmeter is a very satisfactory test device, and could be used operationally. However, it would not be truly satisfactory as an operational instrument, because it has no capability for recording multiple drops; it can be erroneously triggered by lightning and/or exploding projectiles; and its present battery-pack power supply would impose difficult logistic problems.

Timewise, the bhangmeter technique for measuring yield is far ahead of any other method which has been advanced to date. Pressure methods are dependent upon too many variables, and electromagnetic radiation techniques are still in the basic research stage. Investigation of all yield measuring techniques should be pursued, but it is believed that the bhangmeter will be the only operational instrument available for several years. It is definitely the only instrument available for the interim system.

5.5 PHOTOMETER

The photometer technique provides a very accurate means for recording light intensity versus time. However, data reduction is so complicated that the technique is not considered suitable as an operational means for determining yield.

5.6 INTERIM IBDA SYSTEM ACCURACY

Present plans for the interim IBDA system are considered sound. It will consist of a range mark generator for the PPI scope for radar determination of ground zero; a time of fall indicator for height of

[REDACTED]

burst; and a bhangmeter for yield determination. Present bhangmeter limitations will not exist in the production model. Expected accuracies are: ground zero, all errors within radius of 750 feet under conditions previously described; height of burst, \pm 300 feet; and yield, \pm 15 per cent.

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CHAPTER 6

RECOMMENDATIONS

Inasmuch as the interim IBDA system depends upon the radar return from an atomic explosion, and since SAC will be the eventual user of the system, it is recommended that SAC participate to as great an extent as possible in future atomic tests. Purpose of this participation would be to teach radar observers proper radar techniques for obtaining returns from atomic explosions.

It is essential that further investigations be made on the nature of radar returns from atomic explosions. Six years have passed since the phenomenon was first viewed, but conclusive proof of its cause is still non-existent.

It is obvious that a different method will be required for using visual photography at night. Present thinking involves a scheme for controlling the lens diaphragm so that immediately after the flash, an automatic control would adjust the aperture to optimum positions. It is not possible to test schemes for night photography unless night shots are provided. Development of a satisfactory night photography system is considered of extreme importance since most operational drops will be made under the cover of darkness.

No future effort should be expended on the photometer insofar as IBDA is concerned. The instrument would be of use to those individuals who are interested in several seconds of accurate data concerning light intensity versus time.

Radar corner reflectors did not provide as many radar fixes as anticipated. However, it is believed that all future IBDA projects should utilize the same, or improved devices, because there is little hope of securing a fix from any portion of the site terrain.

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APPENDIX A

ATOMIC CLOUD EFFECTS ON RADAR

A.1 OBJECTIVE

Reported malfunctions of Strategic Air Command airborne radars at tropopause levels led to speculations regarding the possible effects of ionized layers of atmosphere on the radar beam and the radar output. At the request of higher headquarters, Project 6.4's plan for Shot 6 was hastily revamped to include atomic cloud penetrations by Tiger 1, for the purpose of investigating the effects mentioned above.

A.2 INSTRUMENTATION

Equipment involved in the test consisted of a "Reliabilized" AN/APQ-24, an O-15 scope camera, an AN/APR-9, and an A-6 movie camera set up to record the oscilloscope of the APR-9. An APR-9 antenna was unavailable so an improvised antenna was constructed consisting of about 6 inches of welding rod; this connected to the APR-9 receiver by a properly matched coaxial cable. The antenna was physically mounted approximately 30 feet aft of the APS-23 radome. The APR-9 and A-6 camera were located in the radio operator's compartment. A radiological detection officer and equipment were located in the bombardier's position.

A.3 OPERATIONAL PROCEDURE

One pass was made over the top of the cloud, the top being approximately 1000 feet lower than the aircraft. Settings used were: range, 20 miles; 360° scan; and antenna tilt, - 15°. On this run and all others, radar controls were not touched once the run was initiated.

The first actual penetration was made with 0° tilt and 360° sector scan through the top thick portion of the cloud. The second penetration was through the estimated middle of the cloud with the same settings, and the third penetration was through the lower portion with the antenna at -3° and 60° sector scan. The cloud was estimated to be 5000 feet thick. Crew safety considerations prevented further penetrations.

A watch was mounted beside the scope of the APR-9 so that a record of signal amplitude versus time could be recorded. This watch was carefully synchronized with the watch on the O-15 camera data

board and with the radiological detection officer's watch. Data analysis would then involve quality of APQ-24 scope pictures, versus amplitude of energy as shown by the AFR-9, versus radiation intensity readings as recorded by the radiological officer. Shot time was 0400 PST. TAS of aircraft during the mission was approximately 300 knots.

A.4 DATA OBTAINED

A.4.1 Flight Over Cloud. Indicated Altitude 38,200 Feet.

<u>Intensity</u> <u>r/hr</u>	<u>Seconds After</u> <u>Penetration</u>	<u>Time of Reading(PST)</u> <u>hr - min - sec.</u>
Enter	0	04 - 48 - 50
1	30	04 - 49 - 20
5	50	04 - 49 - 40
3	76	04 - 50 - 06
2	80	04 - 50 - 10
1	90	04 - 50 - 20
Leave Cloud		04 - 51 - 10

A.4.2 First Penetration. Indicated Altitude 38,000 feet.

<u>r/hr</u>	<u>Elapsed Seconds</u>	<u>Time (PST)</u>
Enter	0	05 - 04 - 40
1	14	05 - 04 - 54
5	26	05 - 05 - 06
10	31	05 - 05 - 11
15	54	05 - 05 - 34
20	60	05 - 05 - 40
25	65	05 - 05 - 45
30	86	05 - 06 - 06
40	96	05 - 06 - 16
25	108	05 - 06 - 28
20	110	05 - 06 - 30
15	120	05 - 06 - 40
10	137	05 - 06 - 57
5	147	05 - 07 - 07
5	165	05 - 07 - 25
2	207	05 - 08 - 07
3	212	05 - 08 - 12
1	220	05 - 08 - 20
Leave Cloud		05 - 08 - 50

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A.4.3 Second Penetration, Indicated Altitude 33,400 feet.

<u>r/hr</u>	<u>Elapsed Seconds</u>	<u>Time (PST)</u>
Enter	0	05 - 14 - 10
1	20	05 - 14 - 30
5	46	05 - 14 - 56
6	58	05 - 15 - 08
5	76	05 - 15 - 26
8	106	05 - 15 - 56
10	119	05 - 16 - 09
15	131	05 - 16 - 21
20	137	05 - 16 - 27
20	149	05 - 16 - 39
15	179	05 - 17 - 09
10	185	05 - 17 - 15
5	199	05 - 17 - 29
1	229	05 - 17 - 59
Leave Cloud		05 - 18 - 15

A.4.4 Third Penetration, Indicated Altitude 34,600 feet.

<u>r/hr</u>	<u>Elapsed Seconds</u>	<u>Time (PST)</u>
Enter	0	05 - 24 - 00
1	20	05 - 24 - 20
5	30	05 - 24 - 30
10	41	05 - 24 - 41
15	63	05 - 25 - 03
15	87	05 - 25 - 27
20	110	05 - 25 - 50
30	125	05 - 26 - 05
20	132	05 - 26 - 12
10	138	05 - 26 - 18
5	145	05 - 26 - 25
1	150	05 - 26 - 30
Leave Cloud		05 - 26 - 35

A.4.5 Background Readings

Background readings in the aircraft were:

After flight over top : 0 r/hr

After penetration #1 : 0.48 r/hr

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After penetration #2 : 0.70 r/hr

After penetration #3 : 1.80 r/hr

A.5 RESULTS

All instrumentation operated normally. AFR-9 data revealed no changes in the amount of energy leaving the radome, and the scope pictures indicated that the ionized cloud had negligible effect on the operation of the APS-23. In fact, there is no discernible effect, but the film is quite fogged by radiation and some slight detail is lost. This means that slight loss of picture clarity by the APS-23 could not be detected. The fogging does not negate the utility of the scope photographs for reconnaissance or IBDA purposes.

In addition to the 35 mm film mentioned above, a second roll was carried in a spare O-15 camera, but was not used. The film which was exposed on the shot was processed within one day, but the unused roll was not processed until some months subsequent to the mission. Also carried on the mission, and processed within one day, was a roll of Super XX, K-17C film.

Density readings were made on all of the film. The following values were obtained from the formula $D = \log \frac{1}{T}$, where D is density and T is the fractional portion of light which the film will transmit:

	<u>Gross D</u>	<u>Normal Development</u> <u>D</u>	<u>Radiation</u> <u>D</u>
Super XX	0.92	0.10	0.82
35 mm (processed immediately)	0.66	0.18	0.48
35 mm (processed later)	1.17	0.18	0.99

It was also determined that the film had been exposed to a total of approximately 3.27 roentgens.

A generally accepted fact concerning visual photography is that total density readings greater than 0.4 are highly undesirable. Unfortunately, no fixed value can be stated for scope photography, but in this particular case the scope pictures appear to be on the threshold of suffering marked deterioration of quality.

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A.6 CONCLUSIONS AND RECOMMENDATIONS

Radiation intensities encountered in this test had no apparent effect upon the operation of the AN/APQ-24. The radar observer could have performed any type of radar mission in a routine manner.

The radiation had a very adverse effect on all film which was carried through the cloud. Slightly prolonged exposure of the film could well have ruined it.

It is recommended that no future radar tests of this type be conducted until the matter receives, if warranted, laboratory investigation under controlled conditions.

If it is contemplated that actual operations will result in film being exposed to greater quantities of radiation than were encountered in this experiment, it is suggested that thought be given to film shielding.



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