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THE TURQUOISE BOOK

OPERATION IVY

Classification changed to [redacted] Edman 9/26/79
by authority of the U.S. ERDA

Per DORIS H. DENNING
(Person authorizing change in classification and date)

By Evelyn Stephenson 6/8/79
(Signature of person making the change and date)

Compiled by:

Major Paul G. Galentine, Jr., USAF

Assisted by:

Major Robert E. Keegan, USAF
Capt. Milton D. Sprinkel, USAF

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J-12366

Headquarters
Task Group 132.1
Los Alamos Scientific Laboratory
15 May 1952

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Major General P. W. Clarkson
Commander, Joint Task Force 132
Washington, D. C.

Dear General Clarkson:

One of the missions assigned the Commander Task Group 132.1 for Operation IVY is that of conducting technical measurements programs for the Atomic Energy Commission and the Department of Defense. The Turquoise Book attempts to "tell the story" behind these programs - the why as well as the where, when and how. Our Scientific Deputy, Dr. William E. Ogle, and his staff, have reviewed the material contained herein, in order that its readers may be assured that the why is correct and that the how is up to date as we go to press. In addition, Dr. Alvin C. Graves has indicated his agreement with the underlying philosophy of the individual presentations.

The basic purpose of such a publication is to present, in a form acceptable to prospective readers representing varied professions, the object of each experiment and the general manner in which it is to be conducted. It is true that we have included miscellaneous allied information as to project ownership and approximate personnel involved; however, as a word of caution, the Turquoise Book cannot be considered as a document for accurate personnel and fiscal accountability, nor does it present a definitive account of Atomic Energy Commission and Military support. There are established sources for these types of supporting information.

In the intervening period, prior to boarding the USS ESTES during the early morning hours of MIKE Day, changes in the detailed methods of conducting individual projects will undoubtedly be made. As you well appreciate, this is the way of scientific experimentation. All we can say now is that this is how we see the fifty-eight experimental projects on Thursday, 15 May 1952, M-169. Subsequent changes will be reflected in the official reports and history of the operation.

S. W. Burriss

S. W. BURRISS
Commander, T.G. 132.1

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FOREWORD

The experimental effort associated with Operation IVY is divided into eleven programs, and each of the latter is further divided into projects. The following pages are devoted to a brief discussion of those projects in turn.

Overall supervision of the programs is the responsibility of Headquarters, Task Unit One - commanded by Dr. William Ogle of LASL. Each program is supervised by a director, to whom the Project Officers of that program are responsible. For the benefit of those interested in such details, the names and addresses of the Program Directors are as follows:

Program Number	Program Director	Address	Phone
1	Dr. Roderick W. Spence	P.O. Box 1663 Los Alamos, N. Mex.	2-4357
2	Dr. Bob E. Watt	P.O. Box 1663 Los Alamos, N. Mex.	2-5272
3	Dr. Gaelen L. Felt	P.O. Box 1663 Los Alamos, N. Mex.	2-5296
4	Dr. Clyde L. Cowan	P.O. Box 1663 Los Alamos, N. Mex.	2-2844
5	Dr. John S. Malik & Dr. Newell Hart Smith	P.O. Box 1663 Los Alamos, N. Mex.	2-4106
6	Dr. Everett F. Cox &	Weapons Effects Dept. Sandia Corporation Sandia Base Albuquerque, N. Mex.	Alb. - 6-4411 Ext. - 2-7156
	Lt. Col. Francis B. Porzel	P.O. Box 1663 Los Alamos, N. Mex.	2-2766

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Program Number	Program Director	Address	Phone
7	Mr. Walter Singlevich & Lt. Col. Paul R. Wignall	Hq. USAF Office for Atomic Energy, DCS/O ATTN: AFOAT-1 Washington 25, D.C.	Liberty-5-6700 Ext. - 6-1123 Ext. - 6-5400
8	Dr. Leslie B. Seely	P.O. Box 1663 Los Alamos, N. Mex.	2-2130
9	Col. Leland H. Stanford	Headquarters, JTF 132 Washington 25, D.C.	Liberty-5-6700 Ext. - 6-5709
10	Mr. Herbert E. Grier	Edgerton, Germeshausen, & Grier, Inc. 160 Brookline Ave. Boston 15, Mass.	Copley-7-3520
11	Dr. H. Kirk Stephenson	P.O. Box 1663 Los Alamos, N. Mex.	2-4380

The decimal page numbering system is used throughout the body of the report. For instance, a page numbered 6.3.2 is the second page of the discussion devoted to Project 3 of Program 6. A title outline is included in lieu of the usual table of contents. The subdivision of Project 2.1 is artificial, and was made by the author in the interests of clarity.

It should be clearly understood that much of the information contained herein is subject to change. It is manifestly impossible to describe a field experiment, complete in every detail, five months prior to its execution. All that can be said of this book is that it is as accurate and complete as we can make it at this time.

The personnel information presented with each project writeup is approximate, and should not be construed as being accountable.

Los Alamos, New Mexico
May, 1952

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IVY EXPERIMENTAL PROGRAM BY PROJECT TITLE AND SPONSORING AGENCY

PROJECT NUMBER	TITLE
	PROGRAM 1 - RADIOCHEMISTRY
1.1	Yield Measurements.
1.2	Internal Nuclear Detector Measurements.
1.3	Sample Collecting.
	PROGRAM 2 - PROGRESS OF THE NUCLEAR REACTION
2.1a	Alpha of the Fission Phase.
2.1b	KING Alpha
2.2	Timing in the Fission Phase.
2.3	Rise of the Fusion Reaction.
2.4	Propagation of the Fusion Reaction.
2.5	Measurement of Transit Time.
	PROGRAM 3 - SCIENTIFIC PHOTOGRAPHY
3.1	Ball-of-fire Yield.
3.2	Cloud Phenomena.
3.3	Hot-spot Observation.
3.4	Bomb Case Motion.
3.5	Illumination as a Function of Time, with GR-Slit Cameras.
3.6	Bhangmeters.
3.7	Preliminary Photographic Crater Survey.

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PROJECT NUMBER	TITLE
3.8	Burst Position.
	PROGRAM 4 - NEUTRON MEASUREMENTS
4.1	Slow Neutron Observations.
4.2	High Energy Neutron Observations.
4.3	Neutron Spectrum - Nuclear Emulsions.
4.4	Neutron Intensity as a Function of Time.
	PROGRAM 5 - GAMMA-RAY MEASUREMENTS
5.1	Total Dose.
5.2	Gamma Intensity as a Function of Time.
5.3	Fall-out Gamma Intensity.
5.4a	Fall-out Intensity and Particle Size.
5.4b	Close-in Particulate Cloud and Fall-out Study.
	PROGRAM 6 - BLAST MEASUREMENTS
6.1	Pressure vs Time on the Ground.
6.2	Air Mass - Motion Studies.
6.3	Shock Wind and Afterwind.
6.4a	Water Wave Motion - Shallow Water - Photographic.
6.4b	Sea Waves.
6.5	Ground Motion - Seismic Measurements.
6.7a	Underwater Pressures as a Function of Time and Peak Water Pressure as a Function of Distance.

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PROJECT NUMBER	TITLE
6.7b	Underwater Pressures - Along Reef.
6.7c	Acoustic Pressure Waves in Water.
6.9	Air Density.
6.10	Free Air Pressure as a Function of Time (Manned Aircraft).
6.11	Free Air Pressure as a Function of Time Utilizing Parachute Suspended Canisters.

PROGRAM 7 - LONG RANGE DETECTION

7.1	Electromagnetic Effects from Nuclear Explosion.
7.2	Airborne Low-frequency Sound from Atomic Explosion.
7.3	Calibration Analysis of Close-in A-Bomb Debris.
7.4	Propagation of Seismic Waves.
7.5	Transportation of Airborne Debris.
7.6	Detection of Fireball Lights at Distances.

PROGRAM 8 - THERMAL RADIATION MEASUREMENTS

8.1	Integral Thermal Radiation.
8.2	Thermal Intensity as a Function of Time.
8.3	Spectroscopy.
8.4	Air Attenuation.
8.5	Thermal Radiation as a Function of Time in Free Air Utilizing Manned Aircraft.

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PROJECT NUMBER	TITLE
	PROGRAM 9 - ELECTROMAGNETIC PHENOMENA
9.1	Electromagnetic Signals.
9.2	Effects on the Ionosphere with Respect to the Propagation of Radio Waves.
9.3	Measurement of the Effects of an Atomic Explosion on Radio Propagation.
9.4	Evaluation of Indirect Bomb Damage Assessment Techniques.
	PROGRAM 10 - TIMING AND FIRING
10.1	Timing and Firing.
10.2	Release tone.
	PROGRAM 11 - PRELIMINARY GEOPHYSICAL SURVEY OF THE TEST AREA
11.1	Soundings of the Ocean Side of Eniwetok Reef.
11.2	Scaled Ground Shock Tests.
11.3	Deep Drilling to Base Rocks.
11.4	Seismic Surveys.

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PROGRAM 1

RADIOCHEMISTRY

Project No: 1.1 Project Title: Yield Measurements.

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Dr. Roderick W. Spence
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-4357

Conducting Agency: Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian	2	M-7	M+1

Support Required:

(1) Sample collection by Project 1.3.

(2) Priority airlift for samples, from Kwajalein to Los Alamos.

* Plus two additional civilians from K-7 to K+1.

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Object of the Experiment:

In the discussion of this project, it seems most appropriate to separate our subject matter into two quite distinct groups, as follows:

GROUP A: The importance of post-shot knowledge as to the energy release of every atomic weapon.

GROUP B: The interrelationship between primary (absolute) and secondary (relative) methods of yield determination - and the importance of both. We shall discuss these groups in order.

Any experimental program built around the detonation of an atomic weapon is clearly dependent upon post-shot yield knowledge. Regardless of whether the weapon is a stockpile model or a radical new design, its actual yield is essential to the theoretician. In the former case, the available behavior statistics (upon which predictions of weapon behavior in the field are based) are increased and usually strengthened. In the latter case, either substantiation or denial of the design theories may be obtained - whereas they certainly will not be obtained without any yield information. In addition, the person who is conducting other experiments in the program requires yield knowledge for a proper interpretation of his results. We need not depend upon experimental programs for our justification of yield knowledge existence, however. The planning for our nation's defense offers far more spectacular examples, of which we shall mention three:

(1) The ability to determine the nuclear efficiency of another nation's atomic explosions is useful in deducing that nation's state of advancement relative to our own, in the development of atomic weapons.

(2) Knowledge of what energy releases may be expected from atomic weapons employed against us during wartime is invaluable to those charged with the responsibility of defense planning, both civil and military.

(3) Post-shot knowledge of what yield was obtained during the wartime employment of an atomic weapon against the enemy by us is useful to the field commander in determining what the immediate future course of action will be.

At present, there are two general approaches to the problem of yield determination - both of which are indirect, in that the determination of yield from them is dependent upon having additional information. The first involves the measurement of weapon efficiency (that

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fraction of the total available fission energy which was utilized), and hence needs only the amount of bomb material as supporting information. Such an approach is an absolute one for experimental programs such as IVY, since the supporting information required (the amount of fissionable material in the bomb) is readily available. The second approach is a relative one, and supplies the user with numbers proportional to the yield.* No direct method exists for determining the yield of an "unknown" weapon - one whose construction details are not available, such as a bomb detonated by another country. For our purposes the term primary shall denote the above mentioned absolute method, whereas secondary shall denote all relative methods. This classification is used to stress the fact that relative methods could not exist without an absolute method (in the same sense of usefulness that they do at present) because no method of evaluating the proportionality factors would be available.

This experiment is concerned with the radiochemical analysis of post-shot radioactive samples - the only absolute method of efficiency determination available to us at present. The above is intended to indicate why such a complex and expensive project must be included in operation IVY, and, if at all feasible, in every other weapons testing program.

Method and Procedure:

A. For fission weapons, the energy released by an explosion, and the nuclear efficiency of the bomb in utilizing the most valuable ingredients of its core, is rather directly (by means of established conservation of energy principles) related to the number of fissions which take place during the explosion. In order to get the number of fissions (F) occurring in the bomb during detonation, one recovers a sample (see the discussion of Project 1.3) representing some small fraction (ϕ) of the bomb. F is then given by:

$$F = \frac{f}{\phi}$$

where f is the number of fissions which took place in the material represented by the sample. Both f and ϕ must be determined by laboratory analysis of the sample.

The quantity f is determined by analyzing radiochemically for one of the active products of nuclear fission. The radioactivity of such a product at any given time after the explosion is proportional to the number of fissions which have taken place - and the constant of

* See the discussion of Projects 3.1 and 3.6.

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proportionality is capable of laboratory determination.

The quantity ϕ is determined by measuring the recovery of one of the constituents of the bomb and correcting for changes in the amount of that constituent, due to nuclear reactions during the explosion. These corrections can result from either production of the material or destruction thereof. If M is the original amount of material being used as monitor, and m is the amount in the sample, then:

$$\phi = \frac{m}{M}\left(1+\bar{X}-\bar{Y}\right)$$

where:

$\bar{X}$ is the amount of monitor material lost (expressed as a fraction of the amount left) and, $\bar{Y}$ is the amount of monitor material produced by nuclear reaction (also expressed as a fraction of the amount left).

Or finally:

$$F = M\left(\frac{f}{m}\right)\frac{1}{1+\bar{X}-\bar{Y}}$$

For fusion weapons, the problems are essentially the same but somewhat more complex in detail. For our purposes, it is sufficient to state that the MIKE shot yield will be determined in the following manner, if possible:

(a) The fission yield will be determined by the method outlined above.

(b) The fusion yield will be found by radiochemical determination of the neutron-induced activity of properly collected gas and particulate samples - this activity being theoretically related to the total number of neutrons arising from all nuclear processes. From the total population, that portion due to the fissions will be subtracted (dependence on part (a) above is thus seen). The remaining population will be theoretically related to the energy released by the thermonuclear reaction.

(c) The sum of the fission and fusion yields will give the total energy release.

B. The experimental procedures involved herein are essentially the laboratory analysis techniques mentioned above. The collection of the necessary samples, and the immediate dispatching of these samples

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to the Los Alamos laboratories, will be discussed under Project 1.3.

Remarks:

(1) A careful examination of the analysis methods outlined above will indicate the dependence of this project upon good statistics. To be most useful, a bomb debris sample must be representative of the overall bomb debris distribution. To the extent that it is not, conclusions based upon its analysis will be in error.

An attempt is made to minimize this effect by the collection of many samples - in order that averages can be used. It is conceivable, however, that unique conditions may preclude the existence of a representative sample at any feasible collection time, or may make the probability extremely small that such a sample will be found. In this case, the Radiochemistry analysis program is operating at a tremendous disadvantage, and results cannot be guaranteed. The term which describes such unique conditions as are mentioned above is "fractionation". For details of this problem, the reader is referred to the Project Officer.

(2) In the event that the fusion yield for MIKE shot is not capable of radiochemical determination (with acceptable error estimates), the fireball photography method (Project 3.1) will be used to obtain the total yield. The fusion yield will then be obtained by subtracting the fission yield from the total.

Such an alternate method has the disadvantage of requiring a large extrapolation from the fireball yield calibration data, but it does offer a "backup" to the radiochemistry - should it be needed.

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PROGRAM 1

RADIOCHEMISTRY

Project No: 1.2

Project Title: Internal Nuclear Detector Measurements.

Shot Participation: MIKE

Sponsor: AEC

Project Officer:

Name: Dr. George A. Cowan
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-3481
2-4357

Conducting Agency: Group J-11
Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer			
Enlisted			
Civilian	2	M-7	M/1 *

Support Required: Sample collection by Project 1.3.
Priority airlift for samples, from Kwajelein to Los Alamos.

* Plus two additional civilians from K-7 to K/1

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Object of The Experiment:

We have seen, in the discussion of Project 1.1, how radiochemical analysis of bomb debris samples make possible the post shot deduction of energy release and weapon efficiency. It is also feasible to gather diagnostic information as to the detailed nuclear processes of the weapon during the detonation period, by similar techniques. Hence we have an important subsidiary purpose for the use of radiochemistry in connection with experimental programs such as IVY. In composite bombs, for example, it is useful to know what fraction of the fissions took place in each of the components - knowing this, one can hope to optimize designs in the direction of conserving the more expensive fissionable materials (such as plutonium and U^{235}). In pure plutonium bombs it is important to know what fraction of the energy release is due to fissions in the U^{238} tamper, for the same reasons. Besides these, many other nuclear processes need experimental documentation before the science of weapon design can be said to have left the "cut and try" phase completely - this being particularly true where the design of thermonuclear weapons is concerned.

To further such a line of endeavor, an ingenious method of augmenting the classical radiochemistry techniques has been devised. Selected amounts of various substances are included in, or placed in the immediate vicinity of, the bomb. These substances have little or nothing to do with the primary nuclear processes of the exploding weapon - but serve only as remote indicating "tracers". The existence of a tracer substance in or near the exploding bomb is assurance that such a tracer will be bombarded with neutrons and gamma rays. If the substance has been properly selected, and if the tracer has been located sufficiently near the bomb to be thoroughly mixed with the bomb debris, such a bombardment will result in easily detectable activity in every subsequently analyzed sample. Careful positioning of tracer substances can hence furnish us with information as to the detailed action of some particular portion or component of the weapon design.

For maximum utility, a tracer substance or element must comply with the following requirements:

(a) It must not occur in the dirt, sea water, or coral (that are picked up by the explosion and mixed with the bomb debris) in appreciable amounts (~1%).

(b) If the by-products produced by its nuclear bombardment are stable, they must be sufficiently rare that the chance of introducing them extraneously during sample collection or

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analysis is small. If those by-products are unstable, the problem of sample contamination is not serious.

(c) It must give rise to by-products (either stable or unstable) that are readily amenable to laboratory analysis.

This project is designed to document various processes of the detonation, using the techniques outlined above.

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The collection of the necessary particulate samples, and the immediate dispatching of these samples to the Los Alamos laboratories, will be discussed under Project 1.3.

Remarks:

See the discussion (under "remarks") of Project 1.1.

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PROGRAM 1

RADIOCHEMISTRY

Project No: 1.3   Project Title: Sample Collecting.

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Dr. Harold F. Plank
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-3458

Conducting Agency: Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area: *

	Approximate Number	From	To
Officer	6	M-21	K/6
Enlisted	2	M-21	K/6
Civilian	2	M-21	K/6

Support Required:

* Plus short visits to Eniwetok by 2 officers and 2 civilians.

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Object of the Experiment:

At first glance it may seem strange to classify sample collection as an independent experimental project. We have seen in the discussions of Projects 1.1 and 1.2 that the collection of bomb debris samples is mandatory for the use of radiochemical analysis techniques in the laboratory. We have also discussed the tremendous importance of these analyses for an experimental program such as IVY. Thus far, the implication has been that "adequate samples will be collected", and it might seem that we could dismiss the matter by considering the collection of samples to be simple operational support for Projects 1.1 and 1.2. This is far from the true situation! The actual collection of adequate post-shot bomb debris samples, both particulate and gaseous, is one of the most complex and expensive projects associated with any atomic bomb detonation.

Let us consider the laboratory requirements for a so-called "adequate" sample. It must:

(a) Be of sufficient size. No matter how refined the laboratory technique, there is a sample size below which no analysis is possible.

(b) Be uncontaminated by collection and shipping procedures. The analyst has no way of knowing whether a particular element is present in the sample because of the bomb or because of the container in which the sample was shipped.

(c) Contain sufficient nuclear activity. An inert sample is hardly amenable to radiochemical analysis. This requirement and that of (a) above are not truly independent. The writer has listed them separately to make it completely clear that the laboratory needs activity samples - not just globs of matter.

(d) Be capable of relatively immediate recovery and delivery to the laboratory.

The best available source for such samples is the atomic cloud. Hence the problem of obtaining adequate samples is capable of simple statement - as are so many difficult problems. First a usable cloud sampling device must be developed, then an adequate carrier vehicle for the device must be provided. This problem has received a great deal of attention in the past, and the various experimental programs have allowed the field testing of several proposed solutions. Fundamentally, the program is based on a quantitative correlation between the sample size desired, the predicted energy release of the bomb, the

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performance characteristics of the aircraft and filter device used, and the radiation exposure permitted during the operation. We, however, shall not herein trace the development of what is now thought to be the best solution - the reader interested in such details is referred to the Project Officer. For our purposes, it suffices to state that the IVY sampling technique and procedures outlined below represent the culmination of a great deal of field experience, and are the best thing available at present.

Method and Procedure:

A. Devices which collect atomic cloud samples can be separated into two general classifications, as follows:

(a) Those which take, and hold, a single "bite" of the cloud - to obtain what is essentially a gaseous sample. Such devices are referred to as "snap samplers", and from them the laboratory receives containers full of gas for analysis.

(b) Those which, upon their passage through the cloud, filter the entire path along which they pass - to obtain a particulate sample representative of the cylinder in space produced by the intersection of the cloud and the travelling filter mouth. These devices are naturally referred to as filters, and from them the laboratory receives pieces of filter paper upon which are deposited the particulate samples required for analysis.

Both of the above types will be used for this operation, and manned F84G's will act as carrier vehicles. The instrumentation of a typical carrier vehicle will be as follows:

(a) A filter will be installed in the forward section of each wing tip tank - the filter paper area in each case to be approximately one square foot. The filter mouth will be supplied with a shutter which can be opened or closed by the pilot, to preclude the possibility of rain-washing the paper.

(b) A snap sampler (consisting of a poly-ethylene bag in a metal case, with a valve controlled inlet probe) will be mounted in the nose of the aircraft.

(c) An ionization chamber will be mounted in the right tip

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tank filtering unit - to act as the detector for a dose rate meter in the cockpit. This meter will give the pilot an indication of particulate sample strength thus far collected.

(d) A second intensity rate meter, with its associated detector, will be mounted in the cockpit. In this case the detector will have shielding equivalent to that afforded the pilot, and the meter will give a direct reading of dose rate to which the pilot is subjected at a given time.

(e) A total-dose meter assembly will also be mounted in the cockpit - with shielding similar to that mentioned in item (d) above. This meter will give the pilot a direct indication of how many roentgens of gamma he has received.

By correlating the information presented to him by the meters mentioned in items (c), (d) and (e), above, the pilot should be able to so plan his mission that a maximum of sample strength is obtained for a minimum of personnel hazard.

B. Sixteen F-84G "carriers" will be maintained on Kwajalein, in order that a minimum of twelve will be operational for each test. A total of twelve filter samples are considered essential for the analysis required by Projects 1.1 and 1.2. Two papers from a given aircraft constitute a single sample. Since these carriers are required to have a flight capability of five hours, some half dozen KB-29P air refueling tankers will be maintained (also on Kwajalein) for support purposes. Two B-29's will be used as primary and alternate operational command posts, or traffic controllers, for the project.

The samples will be collected as high as possible in the cloud stem (50,000 feet, the operational ceiling of the F-84G) to maximize the possibility of obtaining a good "hot" sample without dangerous exposure of the pilot.

<u>Remarks:</u>

(1) As soon as an adequate sample is obtained (or the carrier pilot has received the allowed total dose - whichever occurs sooner) the carrier will return to its base on Kwajalein. The samples will then be removed and prepared for shipment to Los Alamos. Two MATS aircraft will be standing by at Kwajalein, and at intermediate refueling points, to insure the "rush" status of this air shipment.

[redacted] [redacted]

(2) At zero time, two of the spare jets will be in the shot area - ready to perform reconnaissance as required to establish:

(a) Base of the upper cloud.

(b) Lowest altitude of prominent features of the cloud created by wind shear.

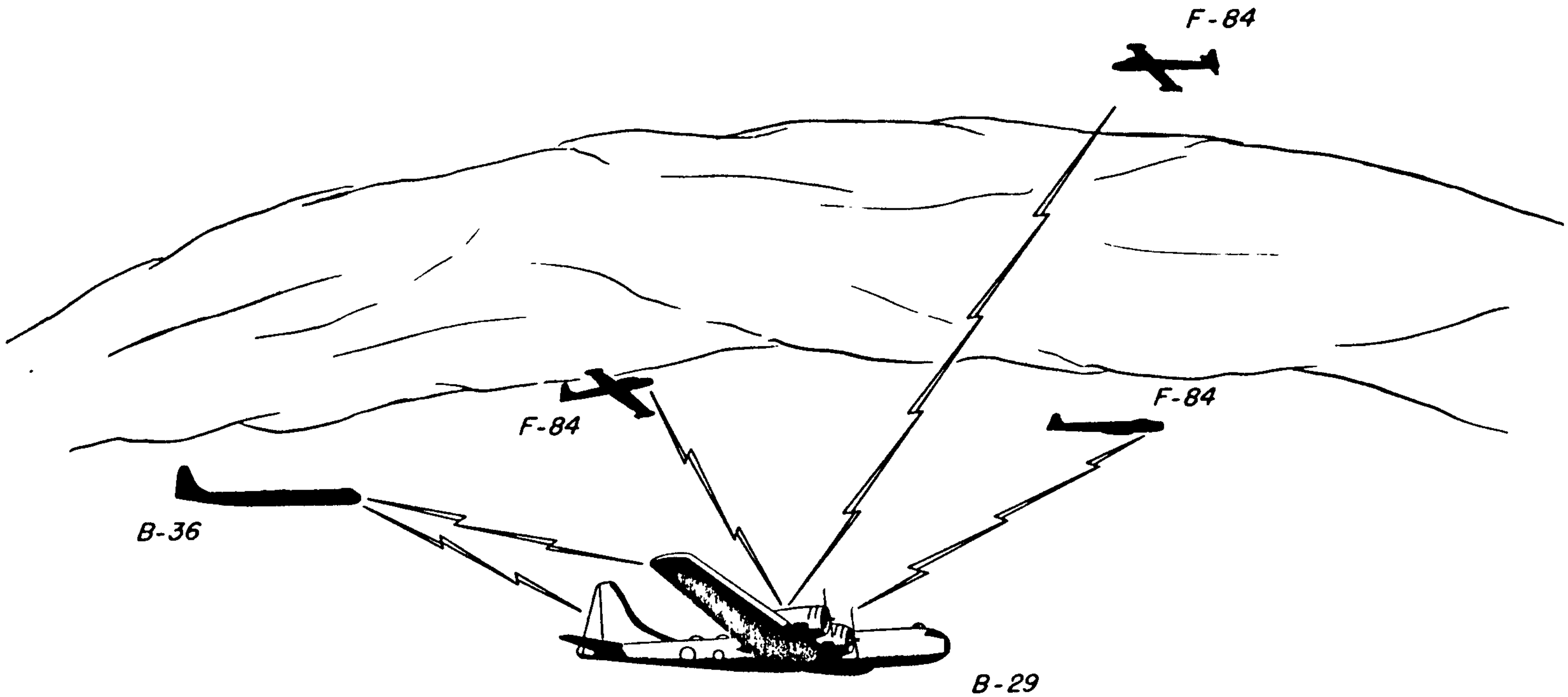
(c) Lowest altitude at which a useful radiation intensity is present.

This information will be relayed to the control aircraft, and will be used to determine proper take off times and flight altitudes for the twelve carriers.

(3) A much larger component of "soft" gamma radiation is expected to be present in the cloud radiation flux from MIKE shot than one would expect from "normal" bombs. Fortunately, much of this soft component is around 70 KEV in energy and can be "screened out" by a relatively thin layer of an absorbing material such as lead. The pilot and his radiation measuring instruments will therefore be shielded by a protective covering which should reduce the soft component by a factor of about sixteen. In the low energy region both radiation measuring instruments and radiation film badges are known to be markedly energy dependent in their response. Special efforts have been necessary to design a total radiation dose instrument, and a method of film badge interpretation, in such a way that a reliable correlation can be obtained between the operational measure of exposure given in flight, by the total dose instrument, and the final measure given by the film badge.

(4) To protect the carrier pilot from ingestion of radioactive material, adequate precautions will be taken to filter any air that enters the pressurized compartment.

[redacted] [redacted]



(not to scale)

Fig. 1.3.1
Airborne Sample Collecting

28

PROGRAM 2

PROGRESS OF THE NUCLEAR REACTION

Project No: 2.1a   Project Title: Alpha of the Fission Phase.

Shot Participation: MIKE

Sponsor: AEC

Project Officer:

Name: Dr. Ernst H. Krause
Address: Radiation Division
Naval Research Laboratory
Washington 25, D. C.

Phone: Johnson 3-6600
EXT. 864

Conducting Agency: Radiation Division
Naval Research Laboratory

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian			

Support Required:

* See "Remarks" on page 2.1a.4.

[redacted]

Object of the Experiment:

Regardless of whether the desired thermonuclear reaction takes place, it is important that we have information as to how the fission phase operated. To obtain such information, it is natural to fall back on the classical diagnostic measurements for fission weapons, such as the measurement of alpha and yield. Fission yield measurements will, of course, be without significance in the presence of a large scale thermonuclear reaction. Hence one must rely upon the measurement of alpha as a primary indication of the proper functioning of the fission aspect of the reaction.

Method and Procedure:

A. The number of neutrons present at a given time in any array of fissionable material can be shown to be approximated by:

$$N = N_0 e^{\alpha (t - t_0)}$$

in which N_0 represents the number of neutrons present at time t_0. The number is a measure of the neutron multiplication rate in the array - and a positive alpha is indicative of a supercritical array. The alpha of an implosion weapon is not truly constant, but varies with the degree of criticality produced by the implosion and subsequent explosion. In fact, there is no true alpha immediately after initiation - the magnitude of the neutron population being governed by the statistical behavior of individual neutrons. Very soon, however, the total number of neutrons present becomes sufficiently large that the statistical behavior of individual particles represents a small percentage of the overall effect. Then equation (1) becomes valid, and alpha increases until the assembly is most critical - remains relatively constant throughout the so-called "incubation" period - and decreases to negative values as the weapon disassembles and becomes sub-critical. Documentation of alpha versus time, and particularly the value of alpha during the incubation period, is an extremely valuable tool for use in post-shot deduction of how a fission weapon behaved.

The classical method of measuring alpha is an indirect one, involving the measurement of gamma-ray fluxes. This is feasible since the number of gamma rays given off is proportional to the neutron population, which is in turn proportional to the number of fissions - and nuclear theory supplies us with these proportionality factors.

[redacted]

[redacted]

[redacted]

The gamma-ray flux during this period of interest is determined by placing a phosphor-photocell detector near the case of the device. The phosphor is a quantity of material that fluoresces with high efficiency under gamma ray bombardment. The fluorescing process, of course, creates a light source which is observed by the photocell. The light output of the phosphor, and hence the signal produced by the photocell used to measure this light, is proportional to the instantaneous value of the gamma-ray flux. This signal is piped through coaxial cables to a relatively distant oscilloscope and applied to the horizontal plates. A constant high frequency sinusoidal signal is applied to the vertical plates of the scope to supply a time record, and the combination of these signals supplies a scope trace from which alpha can be measured. The combination of phosphor and photocell which generates the alpha signal is known as a scintillation detector.

B. Two scintillation detectors will be placed outside the case. The signals from these detectors will be fed to a recording station 3000 yards distant, on the Island of Bogon. A permanent record will be obtained by photographing the face of the recording oscilloscope.

Remarks:

The Radiation Division of the Naval Research Laboratory is responsible for four distinct projects (2.1, 2.2, 2.3, and 2.4) of the program entitled "Progress Of The Nuclear Reaction". The work loads imposed by these projects, however, are not separable. As a result, the NRL personnel under Dr. Krause's supervision will devote their efforts to all projects equally. In lieu of listing personnel requirements for the individual projects, the following table is presented; to represent the total proposed forward area requirements for the above mentioned four projects:

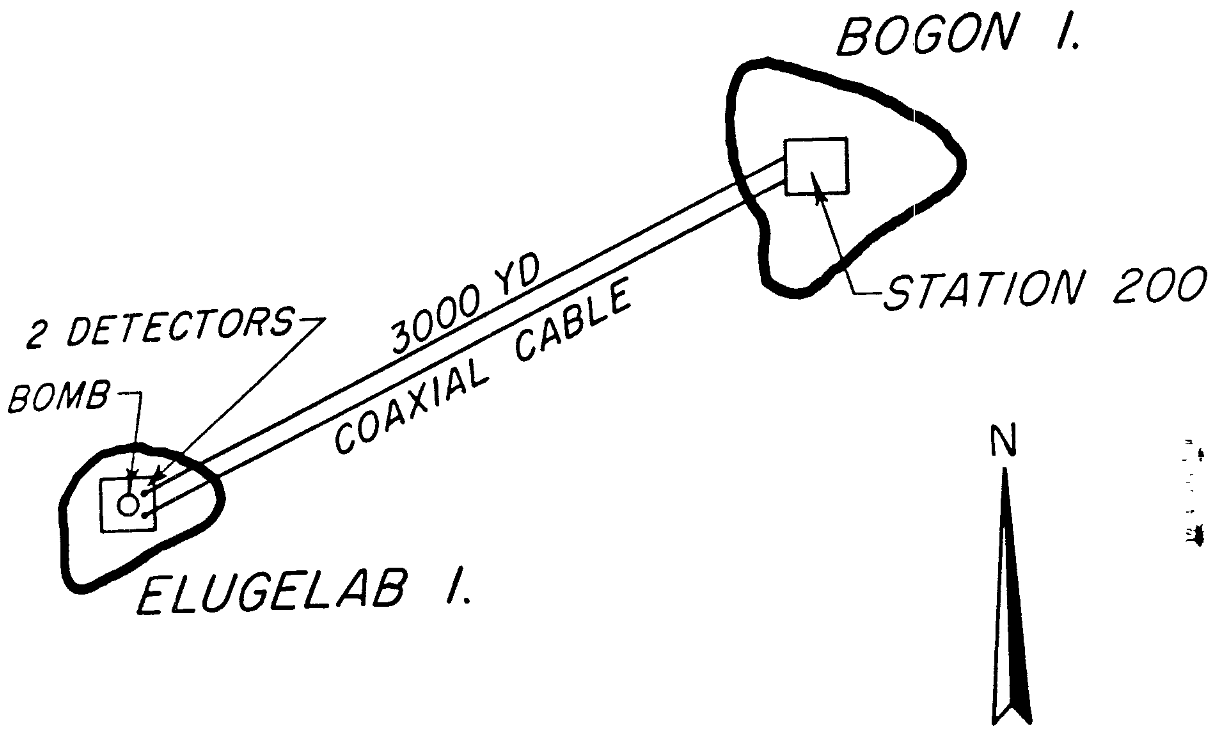
Officer	Enlisted	Civilian	No Name*	From	To
		1		M-153	M-138
		1		M-138	M-67
1	2	8	3	M-123	M-41
		4	2	M-123	M/15
		1		M-108	M-77
		1		M-77	M-16
		2		M-72	M-0
			6	M-72	? ** **
			29	M-51	?
		1		M-46	M/15
			10	M-36	? **
	1	1		M-22	M/30

[redacted]

[redacted]

* As of 16 May 1952, the proper classification (officer, enlisted, or civilian) of these personnel was not known.

** As of 16 May 1952, the date that these personnel will return to the Z.I. could not be estimated with reasonable accuracy.



(not to scale)

Fig. 2.1a.1
Mike Shot

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PROGRAM 2

PROGRESS OF THE NUCLEAR REACTION

Project No: 2.1b

Project Title: King Alpha

Shot Participation: KING

Sponsor: AEC

Project Officer:

Name: Dr. Ernest H. Krause
Address: Radiation Division
Naval Research Laboratory
Washington 25, D. C.

Phone: Johnson 3-6600
EXT. 684

Conducting Agency: Radiation Division
Naval Research Laboratory

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian			

Support Required:

* See "Remarks" on page 2.1a.4

[redacted]

[redacted]

Object of the Experiment:

As was mentioned in the discussion of Project 2.1a, the measurement of alpha is a classical diagnostic experiment for fission weapons. Since the KING shot device is designed to exhibit heretofore unobtainable efficiency, a reliable and relatively complete alpha-versus-time measurement is particularly important to theoretical people in the field of weapon design.

Method and Procedure:

A. The method used herein is identical in principle to that outlined for Project 2.1a. An air drop, however, precludes the use of detectors placed near the bomb case. For KING shot, we are also interested in obtaining more of the alpha-versus-time curve than is required for MIKE shot. In particular, we are interested in the gamma intensity-versus-time curve from four or five generations before the break to the peak. The break point is that point at which the slope of the intensity curve starts to decrease. This implies measuring the constant alpha (of the incubation period) for four or five generations - then following the decrease of alpha from that value to zero.

Since a given scintillation detector and recording mechanism has a limited useful range of response to gamma intensity, and since the above mentioned portion of the intensity curve spans a wide range of intensities, a number of detectors must be used. Each detector and recorder combination is arranged to cover a small portion of the desired range - the arrangement being a matter of obtaining desired attenuations, either with lead shielding or physical location. We thus have a method for documenting the entire gamma-ray intensity-versus-time curve, as follows:

(a) For the early-time low-intensity portion of the curve, we place our detectors very near the bomb case. The low intensities of the early portion of the curve (many generations before the break) will still be high compared to the minimum detectable signal on the recorder - having been attenuated very little.

(b) For later-time high-intensity portions of the curve, we place our detectors at varying distances from the weapon, the distances being chosen in terms of the intensity range desired and the known air attenuation of gamma rays. The recorder may indicate a signal of the same strength as before, but correcting the signal for both air and distance attenuations will indicate that such a recorder deflection was caused by a signal of considerably greater intensity. If it is desired to cover two intensity ranges at one distance, one of the detectors can either be surrounded with a lead shield to achieve more known attenuation or be recorded with a lessened sensitivity.

A difficulty is inherent in the method we have outlined, however. Our arrangement of detectors to "see" various intensity ranges has involved only attenuations - that is, we started near the bomb and moved away. What do we do when our nearest available detector position is already far from the bomb - as in the case of a high air drop? The answer there is clear; either we amplify the attenuated signal somehow, or lose the early-time low-intensity portion of the record. Such amplification techniques are being developed, and a feasibility test was conducted quite recently at the Nevada Test Site - they are not sufficiently reliable as yet, however, to warrant depending upon them to furnish the very important KING shot alpha record. We now see why KING shot is being fired at such a low altitude (1500 - 2000 feet), when effects measurements would be greatly facilitated (especially from the viewpoint of tactical use) by its being a much higher (5000 - 6000 feet) burst.

B. The bomb will be fired at some 5700 feet north of station 250 on Runit, at the altitude prescribed above. Two detectors will be placed on the north end of Runit, and their signals will be piped through three inch coaxial cable to recorders in station 250. Hence the nearest detectors will be some 2000 feet from the bomb, and will start their measurement at approximately five generations before the break. Five or six more detectors will be placed near station 250, in order that the remainder of the intensity curve can be documented. The recorders for the latter will also be in station 250, and various recording sensitivities will be used to prevent gaps in the curve.

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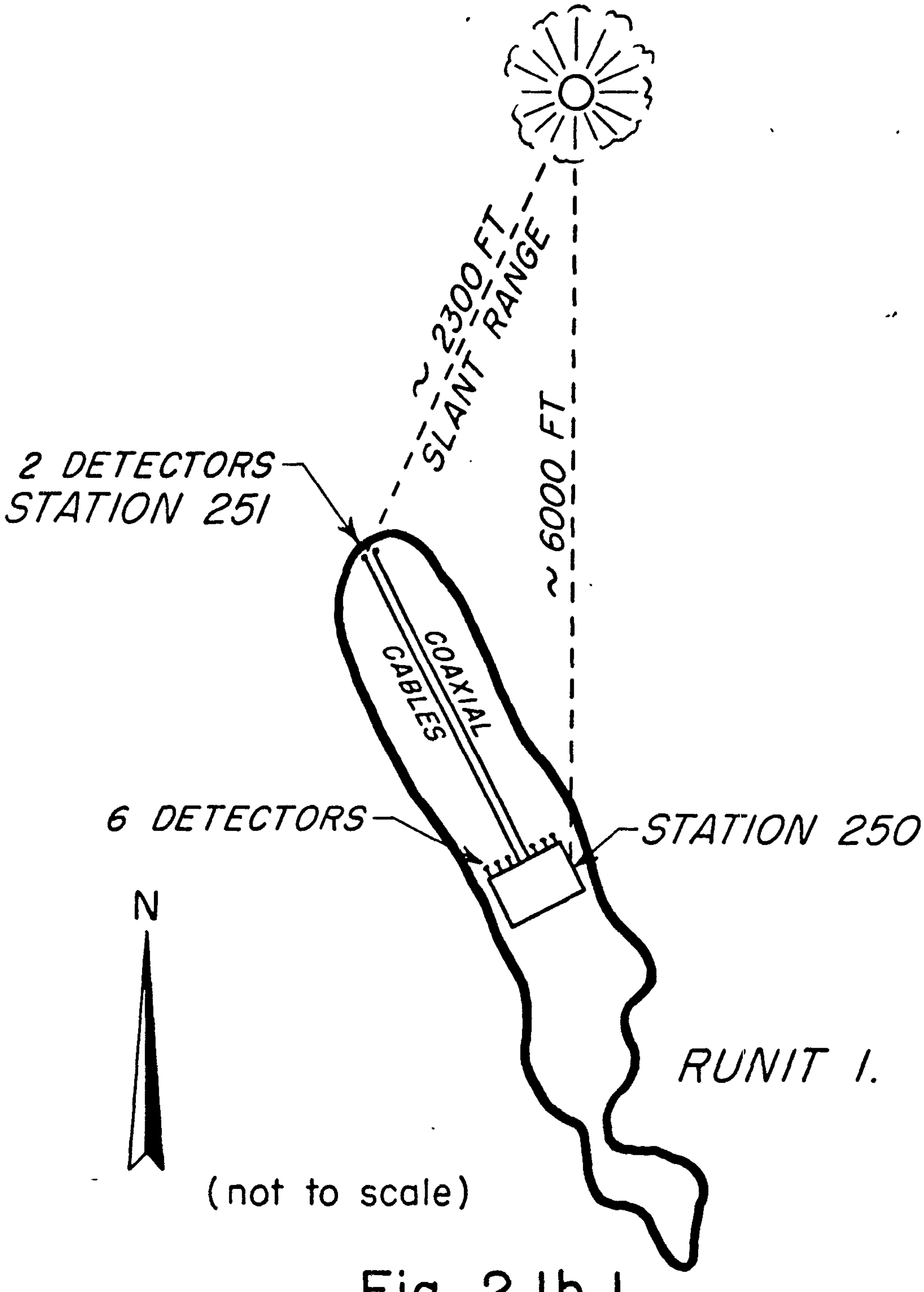

Fig. 2.1b.1
King Shot Alpha

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[redacted]

PROGRAM 2

PROGRESS OF THE NUCLEAR REACTION

Project No: 2.2 Project Title: Timing in the Fission Phase.

Shot Participation: MIKE

Sponsor: AEC

Project Officer:

Name: Dr. Ernst H. Krause
Address: Radiation Division
Naval Research Laboratory
Washington 25, D. C.

Phone: Johnson 3-6600
EXT. 864

Conducting Agency: Radiation Division
Naval Research Laboratory

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian			

Support Required:

* See "Remarks" on page 2.1a.4

[redacted]

Object of the Experiment:

Consistent with the idea of obtaining as much diagnostic information about the thermonuclear reaction as possible, this experiment is designed to determine the timing of the fission phase. Knowledge of this time is important as it tells us whether or not the process took place in the predicted fashion.

Method and Procedure:

DELETED

At this writing, the feasibility of detecting primary neutron signals (rather than the secondary neutron-induced gamma ray signals) is being studied. If such a technique is feasible it may be adopted for IVY.

B. The above mentioned signals will be observed directly with scintillation detectors (see discussion of Project 2.1a) at the 3000 yard recording station on Bogon, and indirectly by means of light detectors at Bogon which observe phosphors located on Elugelab. In either case the photocell signal is applied to the vertical deflection plates of a cathode-ray tube in a sweep oscilloscope. The signal which must be applied to the horizontal deflection plate circuit of the tube, the sweep signal, may be obtained from the alpha signal of Project 2.1a (either directly or after having been passed through a fixed-time-delay circuit). The combination of these signals will supply the face of the tube with a trace which can be photographed to obtain a permanent record. In order that these measurements may be time tied to the alpha measurement of Project 2.1a - to obtain the desired elapsed time as our final result - the signal will also be passed through a fixed-time-delay line to a pulse generator, which in turn supplies a "pip" to the vertical

[redacted]

plates of the tube.* In addition, it is expected that the direct observation detector on Bogon will also see the start of the fission reaction - if so, one record will contain the desired elapsed time without a time-tying requirement.

* Another time-tying technique involves the use of a precision delay (from the alpha signal) circuit. Either or both of these techniques may be used.

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PROGRAM 2

PROGRESS OF THE NUCLEAR REACTION

Project No: 2.3

Project Title: Rise of the Fusion Reaction.

Shot Participation: MIKE

Sponsor: AEC

Project Officer:

Name: Dr. Ernst H. Krause
Address: Radiation Division
Naval Research Laboratory
Washington 25, D. C.

Phone: Johnson 3-6600
EXT. 864

Conducting Agency: Radiation Division
Naval Research Laboratory

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian			

Support Required:

* See "Remarks" on page 2.1a.4

[redacted]

Object of the Experiment:

This experiment is a continuation of the diagnostic program for the MIKE device. It is designed to document the rise of the fusion reaction, in order that the theory upon which predictions of such phenomena are based may be substantiated.

Method and Procedure:

A. The activation of a chain fusion reaction will imply a flood of high energy neutrons. Many of these neutrons will be captured, and such capture will result in large numbers of high-energy gamma rays being produced. Documentation of these gamma rays will provide data which can be theoretically associated with the progress of the fusion reaction as a function of time. Observation of discrete non-intersecting areas of the case will also furnish information as to the space-wise development of the reaction.

B. A collimating shield will be placed close to the bomb to facilitate observation of small areas of the case. Present thinking conceives the collimator as consisting of two walls; the inner wall being six feet thick, fifteen feet wide, and thirty five feet high, of ordinary concrete, and with its inside face being separated from the case by two feet of air.

The collimated signals will be observed directly by means of scintillation detectors (see discussion of Project 2.1a) at the 3000 yard distant recording station on Bogon, and indirectly by means of light detectors at Bogon which observe phosphors located on Elugelab. As an indication of the electronic complexity of this experiment, let us consider the problems associated with obtaining permanent records of the above mentioned signals. When the fusion reaction takes place, a given signal will have an extremely high maximum value, and be existent for such a short period of time that excellent recording-time resolution is necessary to see it at all. The problem of recording the extreme maximum value of a signal, while retaining sufficient resolution for the detailed study of low magnitude results, is solved by using many scopes - each being adjusted to see only a portion of the total intensity range of the signal.

The signal is impressed on the vertical plate circuit of an oscilloscope, thereby causing a vertical deflection of the electron beam proportional to the impressed signal intensity. A voltage source (of sufficient strength that its "triggering" will cause the electron

[redacted]

[redacted]

beam to traverse the scope face in 2 to 5 microseconds) is available to the horizontal plate circuit. If this horizontal motion occurs at the proper time (when the experiment signal is available at the vertical plates), a two-dimensional trace will be produced on the face of the scope. This trace is a plot of the experiment signal and can be photographed to obtain a permanent record. We thus have introduced the auxiliary problem of triggering the horizontal sweeps at the proper time. This is essential as the sweeps are "one shot" affairs (a periodic sweep would supply a record most difficult of interpretation). The method of doing this is to trigger the horizontal plate voltage source with the experiment signal itself - then pass the experiment signal through a fixed-time-delay loop before impressing it on the vertical plates. However, this method has a serious drawback under certain conditions as we shall see below.

A qualitative picture of the over-all gamma-ray-induced signal from the device must now be considered. The fission phase will cause it to rise to a first maximum, after which it will fall off until the fusion phase starts. The latter burning will cause it to rise to a second maximum (the magnitude of which is determined by the "success" of the fusion process), after which it will fall off to zero. Uncertainties in the theoretical predictions of the magnitude of this signal, in the trough between the maxima, are such that the triggering of the low level scopes by their own signals is not feasible. The scope might be triggered too soon by the high background which follows the first maximum, and the record would be lost. By a low level scope we mean one which has been adjusted to see only the lower portion of the rise to the second maximum for the experiment. High-level scopes present no such problem, and can be triggered by their own signals, since no signal except the correct one can reach the intensities for which these will be set.

The low level scopes will therefore be triggered by passing the initial pulse (rise to initial maximum) through a time-delay circuit. As additional insurance, these low-level scopes may be duplicated, each having a different time delay in the triggering circuit, to take care of uncertainties in theoretical predictions.

The above is of course only a qualitative outline, and only partially indicates the complexities involved. It is presently estimated that four detectors, ten amplifiers and thirty oscilloscopes will be required for this experiment.

45

[redacted]

Remarks:

As an aid in the interpretation of results, additional "monitoring" observations will be made. For example, one phosphor will be "looking" at the sky, and one photocell will be observing an empty phosphor mounting.

8

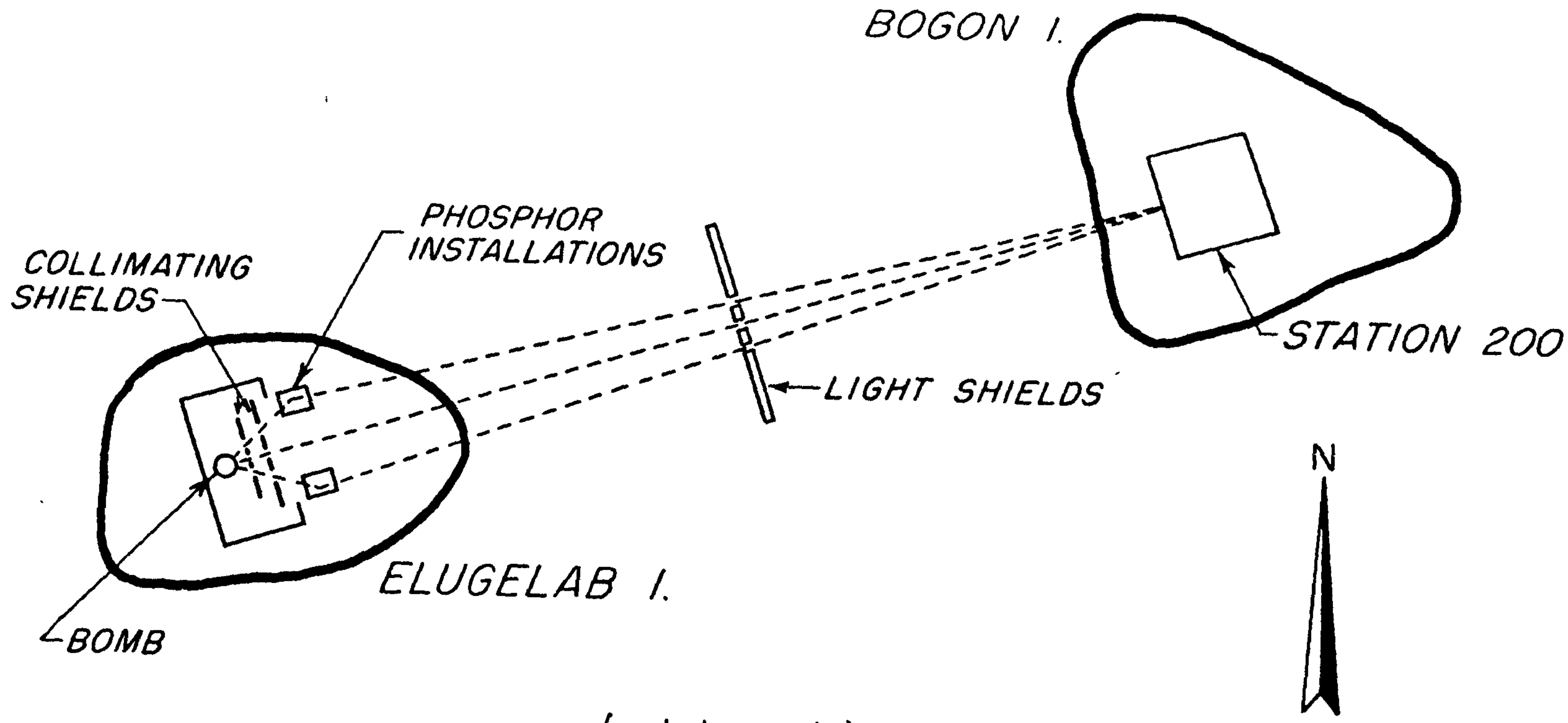

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Fig. 2.3.1
Mike Shot
Rise of the D-D Reaction

2.3.5

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PROGRAM 2

PROGRESS OF THE NUCLEAR REACTION

Project No: 2.4 Project Title: Propagation of the Fusion Reaction.

Shot Participation: MIKE

Sponsor: AEC

Project Officer:

Name: Dr. Ernst H. Krause
Address: Radiation Division
Naval Research Laboratory
Washington 25, D. C.

Phone: Johnson 3-6600
EXT. 864

Conducting Agency: Radiation Division
Naval Research Laboratory

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian			

Support Required:

* See "Remarks" on page 2.1a.4

[redacted]

[redacted]

Object of the Experiment:

Consistent with the idea of obtaining a maximum amount of diagnostic information from MIKE shot, this experiment is designed to measure the propagation of the fusion reaction throughout the device.

Method and Procedure:

A. The chain of events which makes these measurement possible is precisely the same as that outlined for Project 2.3.

B. The experimental procedures and the complexities involved herein are essentially the same as those outlined for Project 2.3. In this case, however, the collimation is arranged to observe different portions of the case. At the present time, some four positions are proposed. It appears that the recording oscilloscopes for this measurement can be triggered from the scopes of Project 2.3, since there will be no propagation to observe if the thermonuclear reaction fails. Present estimates indicate that four detectors, sixteen amplifiers, and thirty oscilloscopes will be required.

To insure sufficient collimation (and the absence of "cross talk" between independent signals) on the long-air line between phosphors on Elugelab and their associated photocells on Bogon, some 15 to 25 wooden light shields will be required.

Remarks:

1. Monitoring observations will be made for this experiment in a fashion similar to that mentioned for Project 2.3.

2. It may be possible to detect neutrons directly with the phosphor-photocell combinations, rather than the neutron-induced gamma rays. Such a technique is desirable, since it involves observation of the primary signal. Feasibility studies along these lines are being conducted at present.

[redacted]

[redacted]

PROGRAM 2

PROGRESS OF THE NUCLEAR REACTION

Project No: 2.5 **Project Title:** Measurement of Transit Time

Shot Participation: KING

Sponsor: AEC

Project Officer:

Name: Mr. C. B. McCampbell
Address: Code 5225-1
Sandia Corporation
Sandia Base
Albuquerque, New Mexico
Phone: Albuquerque 6-4411
EXT. 2-3215

Conducting Agency: Weapons Performance Division
Sandia Corporation

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	4	K-21	K+7
Enlisted			
Civilian	4	K-21	K+7

Support Required:

DOE

[redacted]

51

[redacted]

Object of the Experiment:

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DELETED

Method and Procedure:

A. The initial time pulse for transit time measurement is obtained electrically from the detonator firing system. The second, or terminal, pulse is obtained by detection of the initial flood of gamma radiation from the bomb.

B. For air drops such as KING shot, 2 small radio transmitters are installed within the ballistic case of the weapon. The signals from these transmitters are monitored by 4 receivers, two located in each of two aircraft which accompany the dropping plane. The signals are keyed by the electrical impulse which fires the detonators - thus supplying the initial time to the receivers. The flood of gamma radiation, which accompanies the start of the nuclear reaction, ionizes the air around the bomb and hence makes the transmission of radio signals impossible. Hence a phenomenon (namely, the interruption of a signal) is observable at the receivers to indicate the end of the transit time period. Both of these signal perturbations (the pulse and the interruption) are supplied to the vertical deflection plates of an oscilloscope. A time index is supplied to the scope by a horizontal sweep similar to that used in television receivers, upon which is

[redacted]

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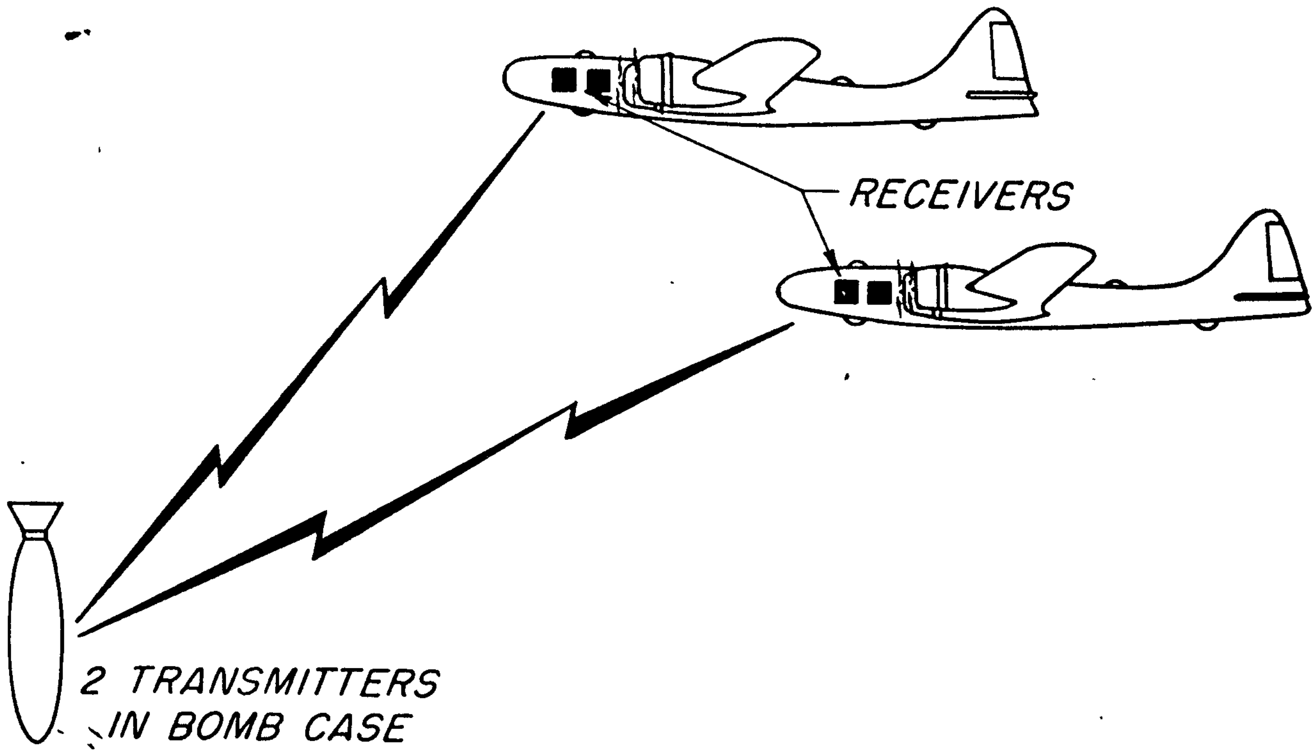
superimposed, by pulsing the vertical deflection plate circuit, a series of equally spaced (microsecond intervals) timing pips. The duration of the sweep is such as to include all reasonable transit time values for the weapon, and the sweep is triggered by the initial pulse. We thus obtain an oscillograph of the phenomena, which can be photographed for permanent record, with a built-in time scale.



(not to scale)

Fig. 2.5.1
King Shot Measurement of Transit Time

PROGRAM 3

SCIENTIFIC PHOTOGRAPHY

Project No: 3.1 Project Title: Ball-of-Fire Yield

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Mr. Herbert E. Grier
Address: Edgerton, Germeshausen, & Grier, Inc.
160 Brookline Avenue
Boston 15, Mass.

Phone: Copley 7-3520 (Office)
Bigelow 4-4956 (Home)

Conducting Agency: Edgerton, Germeshausen, & Grier, Inc.
160 Brookline Avenue
Boston 15, Massachusetts

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian	2	M-28	K/7

Support Required: Deck installation (on "Curtiss") of trailer type photographic laboratory.

* See note under "Remarks".

55

Object of the Experiment:

One of the basic requirements for any experimental program involving the detonation of an atomic weapon is the determination of whether or not the weapon behaved as predicted - and if not, why not. For fission weapons, the classical method of meeting this requirement has been to conduct a trio of so-called "diagnostic" experiments - the purpose of which was to determine the alpha (α), transit time (τ), and yield (W), of the weapon is question.

At this writing, the only available "absolute"* methods of determining yield are those which involve radiochemical analysis of bomb debris. The existence of hydrodynamical scaling laws, however, has made several "relative" methods of yield measurement available to us. One of these makes use of the fireball diameter at early times. By a relative method we mean one which gives as its result a number which is proportional to the yield. In this case the magnitude of the proportionality factor must be deduced from comparisons of fireball photography results with results of radiochemical analysis methods. Such comparisons have been made on previous experimental programs, with the result that the above mentioned proportionality factor is well established for yields up to 100 KT. [redacted] The IVY program will serve to supply more evidence in higher yield ranges.

The advantage of having complete and reliable information as to the size of this factor over as wide a range of yields as possible is clear. Operational use of atomic weapons will undoubtedly make immediate knowledge of weapon yield imperative, which precludes use of the time-consuming laboratory techniques of radiochemical analysis. Also, it may well be unfeasible to collect acceptable bomb debris samples in the face of enemy defenses. Fireball photography is a potentially feasible method for determining weapon yield quickly and under combat conditions. It is also conceivable that the nature of future experimental programs will be such as to preclude acceptance of the logistical problems associated with the collection of bomb debris samples. For such programs, fireball photography is a well established alternate method for determining yield.

* By an absolute method we mean one which gives, as its final result, the yield of the weapon directly - rather than a number proportional to the yield.

[redacted]

Method and Procedure:

A. The primary data to be obtained from this experiment are photographic records of the early fireball growth. These data will enable film analysts to determine the fireball diameter at certain specified early times. Such information, when combined with existing data on the above mentioned proportionality factor, will give initial estimates of the weapon yield. Later, when the results of radiochemical analysis are available, additional information as to the proper size of the proportionality factor for such yields will be available.

B. For MIKE shot six Eastman (~2000 frames/sec) motion picture cameras will be operated in a fall-out-proofed shelter on Parry island. Because of the earth's curvature, these cameras will obtain yield only in the event of a large energy release. Three additional Eastmans will be operated from Engebi (in shielded boxes on concrete pillars), to enable a yield determination if the energy release is small (50-300KT). A rapatronic (single frame, with very fast exposure, at a definite delayed time after zero) camera will be operated from the photo tower on Parry.

In addition to the above "primary" cameras, the Mitchell (~100 frames/sec) cameras mentioned under Project 3.2 will give some fireball growth data with much less time resolution.

For KING shot, six Eastmans and one Rapatronic will be operated from the photo tower on Parry. Again, additional long-time resolution data will be obtained from the Mitchells of Project 3.2.

Electronic devices will be used to supply the timing marks to the motion picture camera films, and to operate the Rapatronic at the proper time after zero. Theoretically, one picture at a known time after zero is all that is needed. In the past, however, it has been wise to use motion picture cameras, thereby increasing the probability of obtaining a good picture and increasing the accuracy of the final result by allowing an average to be taken over a multitude of results. The Rapatronic is included in the program to allow a yield estimate to be made from one picture, and to test the accuracy of such a "one picture" result.

It is hoped that sufficient reliability can be built into the Rapatronic technique, and that sufficient confidence can be developed for the scaling of its result, to enable the Eastmans to be eventually discarded in favor of the Rapatronic for this measurement. An obvious decrease in the cost and complexity of the experiment would result, and evidence already exists to support the opinion that no accuracy would be sacrificed. In fact, accuracy may be improved because of:

(a) The simple R-C network used to supply the necessary time delay to the Rapatronic is highly reliable and capable of excellent laboratory calibration, whereas the time at which a given Eastman picture is taken is not easily determined with the same precision.

(b) The short exposure of the Rapatronic "stops" the fireball growth better than the Eastmans, with the result that a given Rapatronic picture is "better" (a clearer record, capable of more accurate measurement) than any one frame of an Eastman film.

We thus see that the inclusion of the Rapatronics in this project constitutes both duplicate coverage and a feasibility test. If the inherent advantages of the Rapatronic technique can be shown to offset the increased statistics offered by the Eastmans, the ultimate experimental goal, (that is, to obtain a maximum of measurement accuracy and reliability with a minimum of effort and complexity) will be closer.

Remarks:

1. It is interesting to note, in the case of MIKE shot, that fireball photography may be forced to assume the role of a primary measurement for the first time. This possibility exists because of the relatively great uncertainties associated with determination of the fusion yield by means of radiochemical analysis. If it does turn out that a fusion yield is unobtainable with radiochemistry, that yield will be obtained by subtracting the radiochemical fission yield from the total yield given by ball-of-fire photography. Such a procedure does not imply high accuracy, because of the large extrapolation required (to determine the proportionality constant required by the ball-of-fire technique) but it does offer an available alternate method.

2. The firm of Edgerton, Germeshausen, and Grier, Inc. is responsible for five distinct projects (3.1, 3.2, 3.5, 3.6, and 3.8) of the Scientific Photography program. The work loads imposed by these projects, however, are not capable of complete separation. Therefore, most of EG&G's personnel will equally devote their efforts to all projects. As a result, only those personnel whose responsibilities are clearly associated with a particular project are listed under the personnel requirement of that project. In addition, eleven civilians will be available in the forward area for support of all five projects, as follows:

Number	From	To
1	M-42	M+2
2	M-42	K+7
1	M-42	K+10
2	M-28	M+10
1	M-28	K+2
4	M-28	K+7

[redacted]

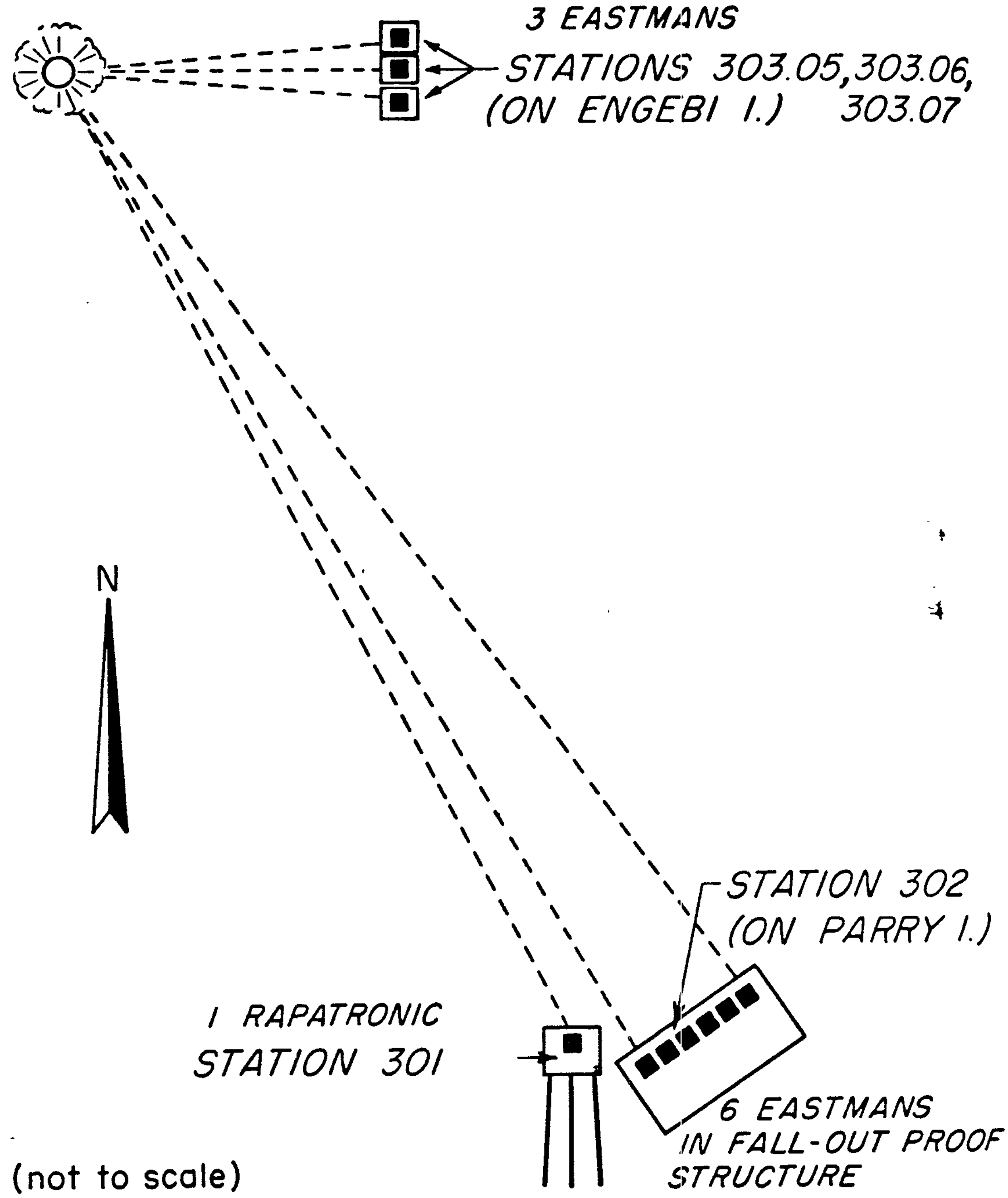


Fig. 3.1.1
Mike Shot Ball-of-Fire Yield

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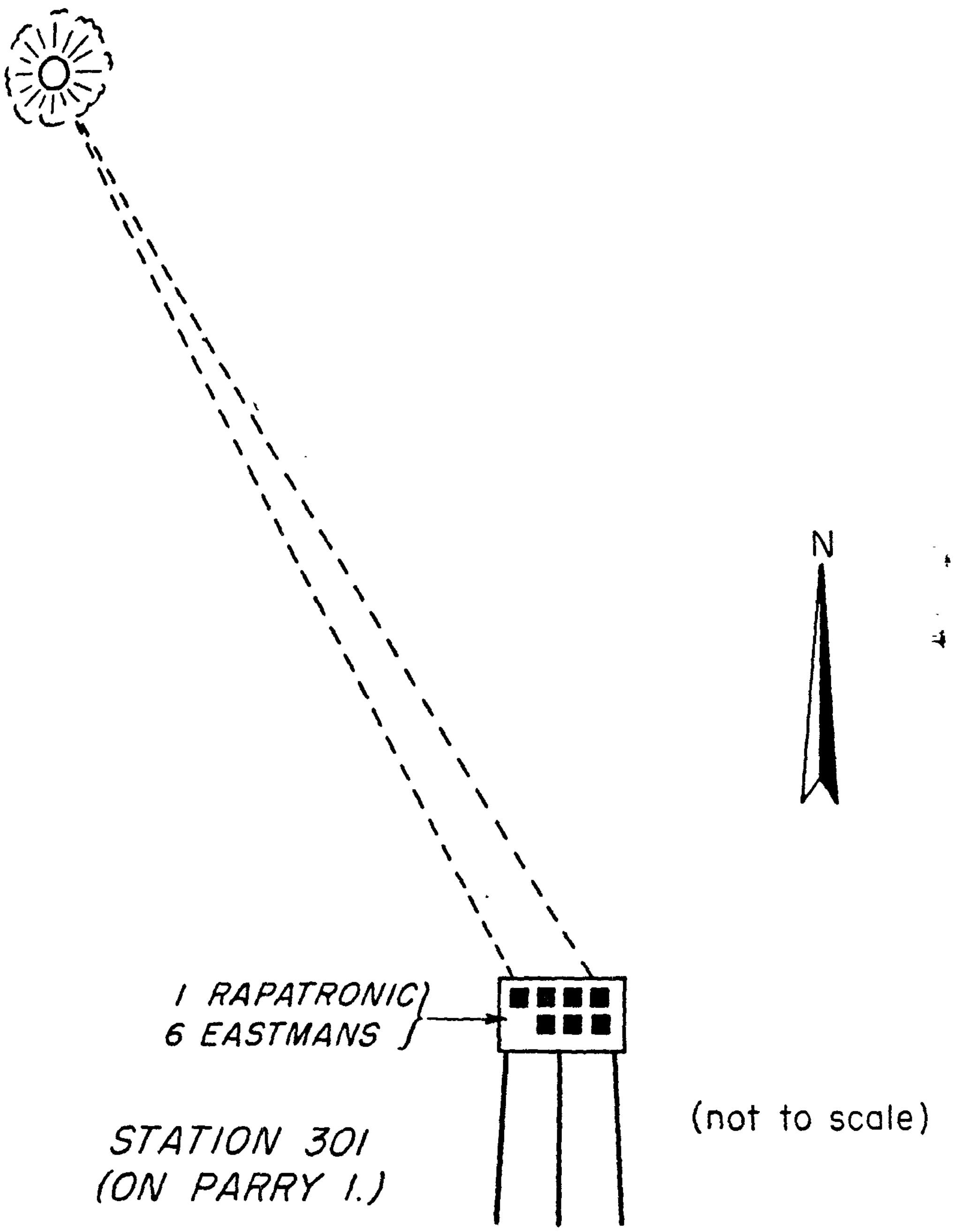

Fig. 3.1.2
King Shot Ball-of-Fire Yield

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PROGRAM 3

SCIENTIFIC PHOTOGRAPHY

Project No: 3.2 Project Title: Cloud Phenomena.

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Mr. Herbert E. Grier
Address: Edgerton, Germeshausen & Grier, Inc.
160 Brookline Avenue
Boston 15, Mass.

Phone: Copley 7-3520 (Office)
Bigelow 4-4956 (Home)

Conducting Agency: Edgerton, Germeshausen & Grier, Inc.
160 Brookline Avenue
Boston 15, Massachusetts

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian	1	M-28	K+7

Support Required: Deck installation (on "Curtiss") of trailer type photographic laboratory.

* See note under "Remarks" of Project 3.1.

63

[redacted]

Object of the Experiment:

To those interested in fallout hazards, tactical bomb delivery planning, or the planning for aerial collection of bomb debris, reliable answers to the following dependent questions are of paramount importance:

(a) What will be the maximum altitude of the top of the cloud, as a function of the yield of the weapon which produced it?

(b) What will be the size and shape of the cloud, as a function of (1) altitude, (2) time after zero, and (3) yield of the weapon?

(c) What is the vertical velocity of the cloud top, as a function of altitude and weapon yield?

Unfortunately the complexity of the physical phenomena involved (for instance, turbulence and mixing) have so far precluded the existence of a theory adequate to answer these questions. It is in fact, most improbable that a complete theory will ever exist. In the face of this fact, two alternative approaches to the problem suggest themselves:

(1) By making radical simplifying assumptions, derive an approximate theory - perhaps keeping one or two adjustable parameters in the result. Then substantiate (if possible) the approximate theory with experimentally observed facts, making whatever parameter adjustment is necessary. If substantiation is impossible, select somewhat different simplifying assumptions and try again.

(2) Using curve fitting techniques, deduce the necessary functional relationships from experimental data. These functional relationships may suggest a simplified theoretical approach of the type mentioned above.

For one to have confidence in predictions or plans based upon the answers to questions (a), (b), and (c) above, both a reasonable approximate theory and experimentally observed facts with which to substantiate a theory must be available. One without the other is interesting and useful, but it does not inspire the user with confidence. In this case we have several approximate theories available, and are lacking in a sufficient amount of good experimental data. The method for obtaining such data is available, and has been used in the past. This method is to take photographs of the cloud throughout the period of its rise to maximum altitude. Prior to BUSTER-JANGLE, However, such factors as poor lighting conditions, insufficient time resolution of photographic records, and obscuring cloud cover, made it extremely difficult to obtain the required documentation. The IVY cloud phenomena program is designed to extend this search for data, particularly in the high energy release range that is unavailable for II experiments.

Method and Procedure:

A. By obtaining photographs of the cloud, in a known field of view and at known times after zero, film analysis enables a time history to be drawn - not necessarily of the cloud itself, but of the cloud's projection on a plane perpendicular to the axis of the camera. The use of triangulation techniques (several cameras viewing the same phenomena - located on widely separated radial lines from zero), enables the position of the cloud in space to be determined with much greater accuracy.

B. For MIKE shot, eight Mitchell (~100 frames/sec) cameras will be operated - two operated in the fall-out-proofed structure on Parry island, two from the Parry photo tower, two from the photo platform on the Estes, and two from an airplane flying above Kwajalein. In addition, it is planned to operate four aero (~15 frames/sec) cameras - two from the photo tower on Parry, and two from a gyroscopically stabilized platform on the Estes. The cameras on Parry, of course, will be operated by remote control, and will hence obtain their records at the proper time regardless of photographic conditions. (Clouds obscuring the field of view, etc.) The others, however, will probably be hand operated in the hope that on-the-spot selection of exposure periods will enable at least a partial record to be obtained, even in the presence of local cloud cover.

For KING shot, two Mitchell and two Aero cameras will be operated (by remote control) in the Parry photo tower.

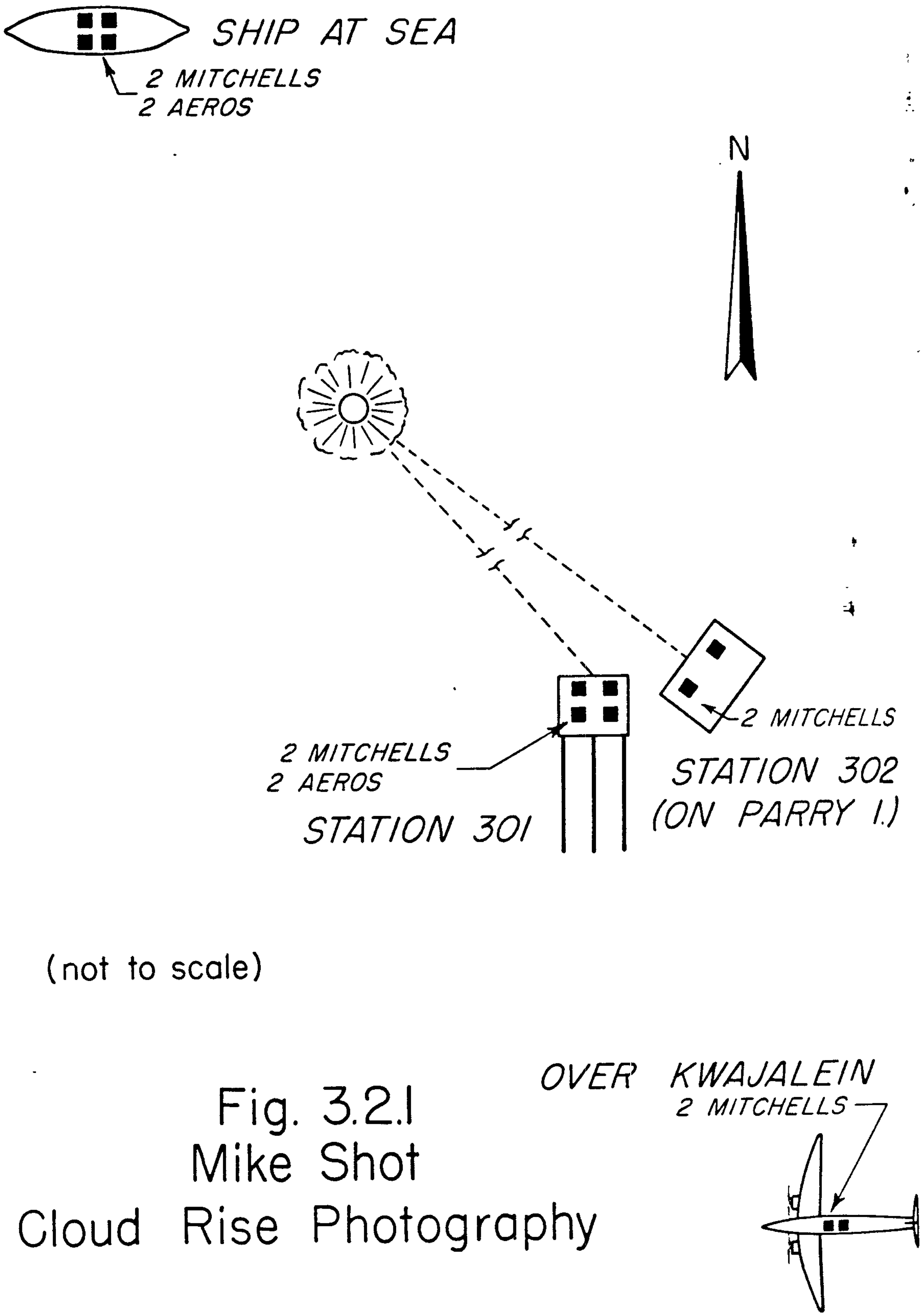


Fig. 3.2.1
Mike Shot
Cloud Rise Photography

PROGRAM 3

SCIENTIFIC PHOTOGRAPHY

Project No: 3.3 **Project Title:** Hot-Spot Observation

Test Participation: MIKE

Sponsor: AEC

Project Officer:

Name: Berlyn Brixner
Address: P. O. Box 1663
Los Alamos, New Mexico

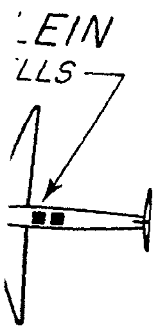
Phone: 2-3741

Conducting Agency: Group GMX-9
Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	1	M-30	K/10
Enlisted			
Civilian	2	M-30	K/10

Support Required:



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Object of the Experiment:

Laboratory design of a fusion bomb is strongly dependent upon the extraction of as much information as possible from each field experiment. The theoretician is fully as much interested in why a test model behaved as it did, as he is in how it behaved. As a result, the experimental program for MIKE shot includes a relatively large number of diagnostic experiments - each of which is designed to throw some light on the actual chain of events which immediately follow the fission phase. In some cases, completely independent experiments are designed to observe the same phenomenon, either directly or indirectly - thus increasing the probability of obtaining useful results.

One interesting piece of diagnostic information is the temperature distribution inside the gadget prior to disassembly, as the relative "success" of a fusion reaction is closely associated with temperature. This experiment is intended to supply some of that information in an indirect fashion.

Method and Procedure:

A. The time necessary for the explosion wave to traverse a known distance in metal is, of course, a direct indication of the speed of the wave. Knowledge of this, plus the known speed of a sound wave in a particular metal, enables one to deduce the "strength" of the explosion wave from hydrodynamic theory. This in turn is theoretically related to the temperature behind the shock wave in that region.

Three selected areas of the gadget case will be observed photographically by six cameras - the field of view of each camera being sufficiently large to include all of the three areas. In each area, two surfaces will be observed; the first being the outer surface of the case itself and the second being the outer surface of a one-inch-thick steel plate attached to the case.

The time difference between shock arrival at these two surfaces will then give the time required for the shock to traverse one inch of steel. The arrival of the wave at an observed surface will be indicated by a sharp rise in the light intensity seen thereon.

B. Six streak (fixed-film, moving image generated by rotating mirror) cameras, each having a time resolution of approximately 3 shakes (1 shake = 10^{-8} seconds), will be operated from a fall-out proofed shelter on Bogallua. The external areas of the gadget case

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selected for observation are (1) Near the top, (2) Just above the [illegible], and (3) Near the bottom of the assembly. The light from these areas will be directed to a line of mirrors angling lagoonward on the [illegible] side of zero, and thence reflected to the cameras. All cameras will have a sufficiently wide field of view to see all mirrors.

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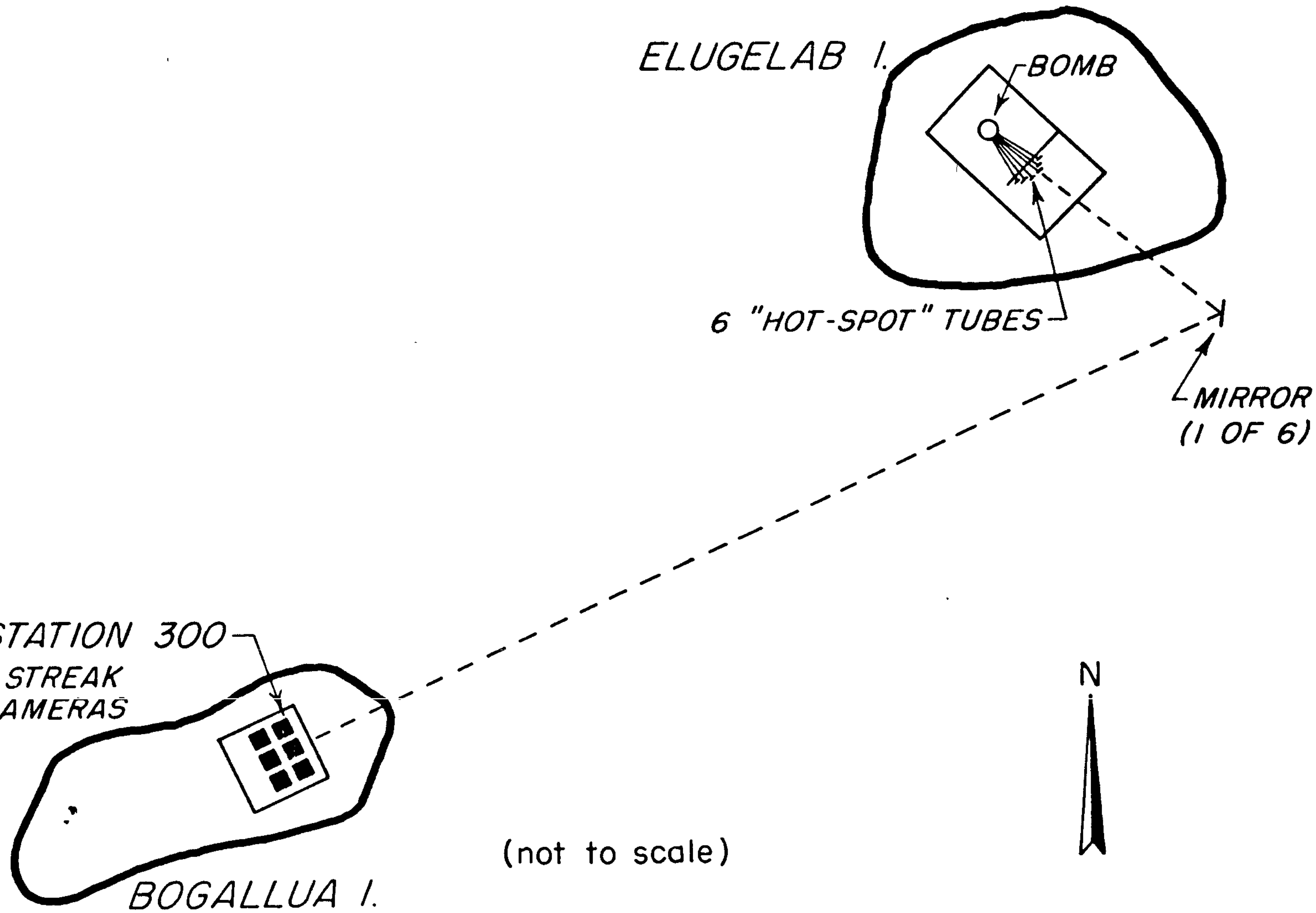

Fig. 3.3.1
Mike Shot Hot-Spot Observation

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Mike Shot Hot-Spot Observation

PROGRAM 3

SCIENTIFIC PHOTOGRAPHY

Project No: 3.4 Project Title: **Bomb Case Motion**

Shot Participation: MIKE

Sponsor: AEC

Project Officer:

Name: Berlyn Brixner
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-3741

Conducting Agency: Group GMX-9
Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer			
Enlisted	1	M-30	K+10
Civilian	2	M-30	K+10

Support Required:

[redacted] [redacted]

Object of the Experiment:

We have seen, in the discussion of Project 3.3, that several sweeping image ("streak") cameras will observe light intensity on the surface of the MIKE gadget case indirectly - by utilizing reflecting mirrors. This experiment is designed to supplement and extend such "early time" documentation by observing the case disassembly and initial fireball growth directly.

A detailed knowledge of how the gadget case disassembled is invaluable to those interested in internal temperatures, pressures, reaction rates, etc. The early formation of "jets" are also of great interest, as they are indicative of non-uniform expansion (or compression) and may explain the existence of temporary assymetries in the shock wave.

Method and Procedure:

A. The case will be observed directly with two groups of 3 cameras, the first group operating at a speed of 3.5 million frames per second and the second group operating at a speed of 90 thousand frames per second. The first group is designed to document the case disassembly, and the slower group will document the initial fireball development. The decreased time resolution of the second group will, of course, imply that records are taken over a longer period of time.

Since these cameras achieve their high time resolution by using the sweeping image technique (fixed film and rotating mirror), electronic timing devices must be used to close the shutters after the film has been swept once. Otherwise, multiple exposure would result. For lack of a better name, these cameras are called "frame" cameras.

B. The six cameras used in this experiment will be housed in a fall-out-proofed shelter on Bogallua - the same shelter as is used by Project 3.3.

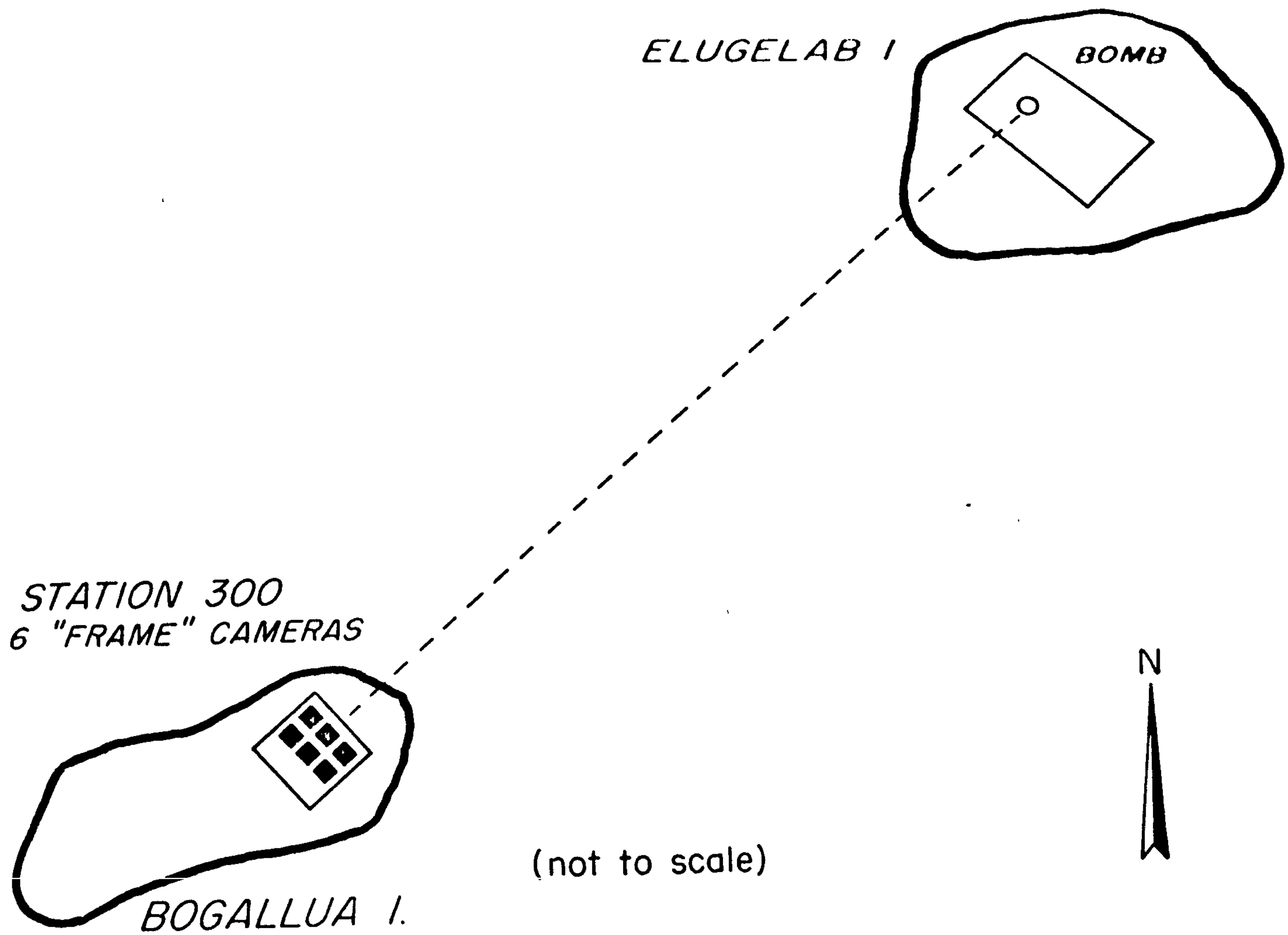

Fig. 3.4.1
Mike Shot Bomb Case Motion

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PROGRAM 3

SCIENTIFIC PHOTOGRAPHY

Project No: 3.5   Project Title: Illumination as a Function of Time, With GR-Slit Cameras.

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Mr. Herbert E. Grier
Address: Edgerton, Germeshausen & Grier, Inc.
160 Brookline Avenue
Boston 15, Mass.

Phone: Copley 7-3520 (Office)
Bigelow 4-4956 (Home)

Conducting Agency: Edgerton, Germeshausen & Grier, Inc.
160 Brookline Avenue
Boston 15, Massachusetts

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer	1	M-42	K+7
Enlisted			
Civilian			

Support Required:

* See note under "Remarks" of Project 3.1.

45

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Object of the Experiment:

This project is included in the Scientific Photography program to augment the collection of data on illumination as a function of time from exploding atomic weapons. One value of such data is discussed under Project 3.6. Another value is the establishment of a fund of information with which to design and adjust photographic equipment being used under the light conditions generated by atomic bombs. The success of such projects as 6.2 and 6.4a is completely dependent upon good photographic records being obtained - which implies that such things as film sensitivity, shutter speed, and auxiliary lenses (filters) must be selected with great care. Knowledge of the light intensities that will be experienced is essential in making these selections.

Method and Procedure:

A. Perhaps the simplest and most direct technique for measuring overall illumination as a function of time from an atomic bomb explosion is afforded by a device known as the GR (General Radio - the manufacturer) "slit" camera. It consists, essentially, of a rectangular aperture in front of a moving photographic film. The aperture is covered with a strip of neutral density (ND) filter material* - the strip being constructed in such a way as to make available a wide selection of ND filters. That is, as the aperture is traversed, a small section is covered with an ND-0 filter** - the next small section is covered with an ND-1 filter, and so on. The net result is that the photographic record will consist of a series of parallel streaks (dark lines) on the negative. Each streak will have been made by the bomb light; attenuated a known amount by the ND filter in front of that portion of the film. Some of the streaks will be completely overexposed (or underexposed) over a portion of their length. The multiplicity of the filtering available insures us that an adequate readable record can be found somewhere on the film, even if the bomb light deviates strongly from prognostications.

* A neutral density filter is one which is not color sensitive - that is, it attenuates all visible light by the same amount.

** An ND-0 filter attenuates the light not at all. An ND-1 filter attenuates the light by a factor of 10. In general, an ND-X filter attenuates the light by a factor of 10^X.

The density (opaqueness) of a streak at a given point along its length can be determined in the laboratory with a densitometer, and this is a measure of the light intensity falling on the film at the time that point was opposite the aperture. By multiplying this light intensity by an appropriate factor (determined by the filter), one obtains the bomb light intensity at that time. By combining the above information with the known starting time and linear velocity of the film, one can construct the required curve of illumination-intensity versus time.

B. For MIKE shot, two GR-Slit cameras will be operated on the Parry island photo tower.

For KING shot, one GR-Slit camera will be operated on the Parry tower.

In each case, the cameras will be started by means of an electrical pulse (timing signal) supplied by EG&G.

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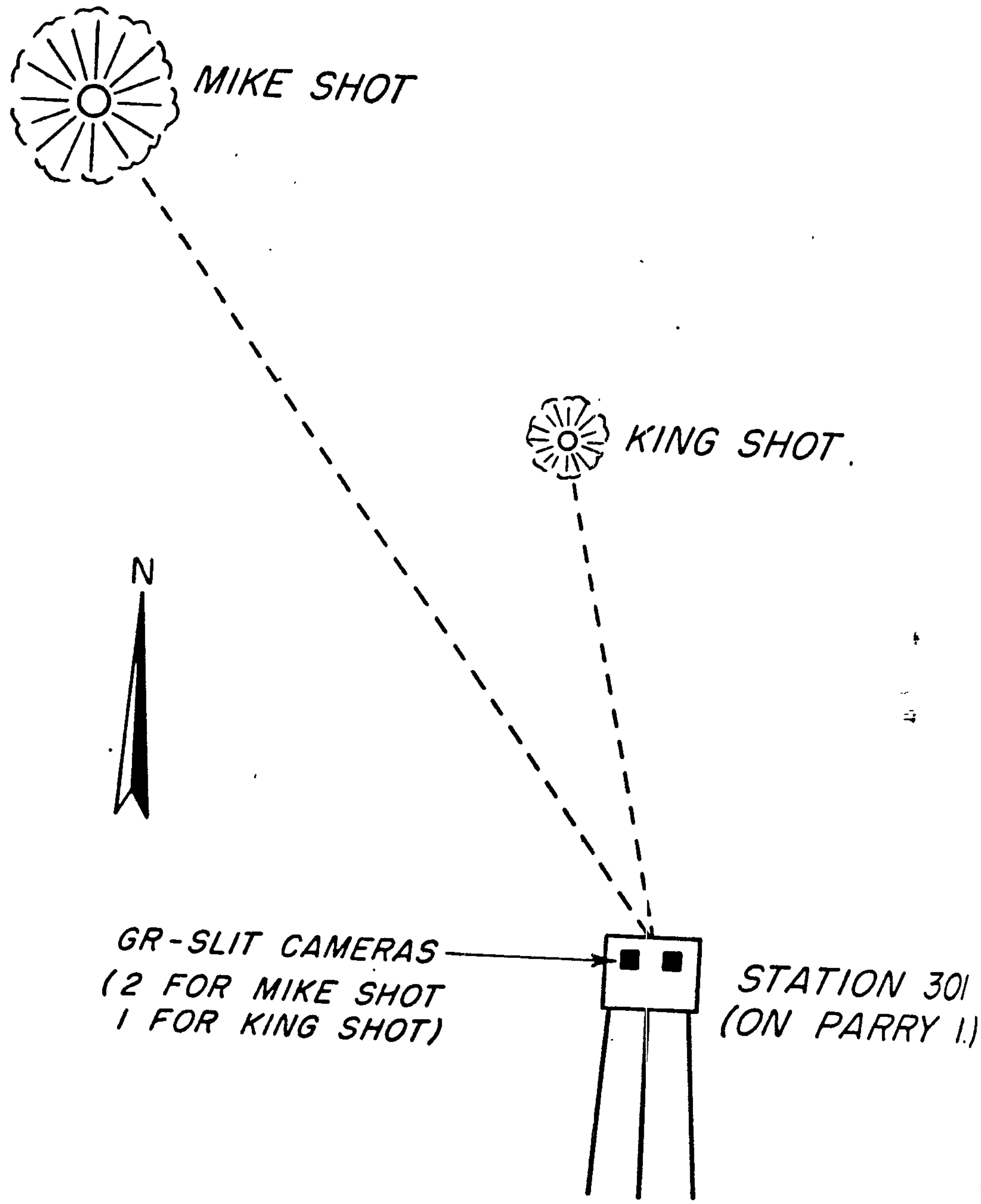

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Fig. 3.5.1
Illumination as a Function of Time for Mike and King Shots

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PROGRAM 3

SCIENTIFIC PHOTOGRAPHY

Project No: 3.6   Project Title: Bhangmeters

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Mr. Herbert E. Grier
Address: Edgerton, Germeshausen & Grier, Inc.
160 Brookline Avenue
Boston 15, Mass.

Phone: Copley 7-3520 (Office)
Bigelow 4-4956 (Home)

Conducting Agency: Edgerton, Germeshausen & Grier, Inc.
160 Brookline Avenue
Boston 15, Massachusetts

Personnel Requirements in the Forward Area: *

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	Approximate Number	From	To
Officer			
Enlisted	1	M-42	K+7
Civilian			

Support Required:

* See note under "Remarks" of Project 3.1

Object of the Experiment:

As was mentioned in the discussion of Project 3.1, there exists a definite requirement for a device capable of measuring weapon yield during tactical operations. Ideally, such a device will be:

(a) Small, light, and self-contained.

(b) Sufficiently rugged to withstand normal operational use without impairment of its operation or accuracy.

(c) Capable of being operated by its user at a relatively great distance from the explosion.

(d) Capable of supplying its user with a yield number in a minimum of time.

(e) Simple to operate.

The Bhangmeter represents an attempt to develop such an ideal device. In its present form it is a steel box; eighteen inches long, twelve inches wide, and five inches deep - weighing approximately thirty pounds.

The theory behind its operation can be described as follows: The light intensity emanated from an atomic bomb explosion first rises to a maximum with extreme rapidity. It then falls quite rapidly to a minimum and rises again, somewhat less rapidly, to a second maximum, the magnitude of the second maximum being very much less than that of the first. After passing through the second maximum, it falls off rather gradually (on a millisecond time scale) to background values.

If one assumes that the first minimum is indicative of a mathematical "similarity"* condition, it is simple to show by means of hydrodynamic theory that the weapon yield is proportional to the cube of the elapsed time between zero and the occurrence of the first minimum. Conversely, to the extent that the first minimum is not indicative of a similarity state, the so-called "cube-root" scaling law will fail to hold. Also, analysis of the equations involved tells us that no true scaling law other than the above mentioned cube root law is possible. We are thus faced with the following alternatives.

* For a precise definition of similarity, the reader is referred to the Project Officer. For our purposes it will be sufficient to consider the term as meaning "the same, except for a constant factor throughout."

(a) The first light minimum does label a state of actual similarity - therefore, the cube root scaling law <u>must</u> hold absolutely.

(b) The first light minimum does not label a similarity state at all - therefore no true scaling law exists.

The results of past experimental work are inconclusive. A large percentage of the experimentally determined light-minimum times give yield numbers within ten percent (the accuracy claimed for the Bhangmeter itself is 20%) of radiochemistry - a few do not. It is not felt however that case (a) has been completely denied as a possibility as there is a strong indication of color sensitivity in the light-intensity-measuring devices used. Careful laboratory analysis is indicated before final conclusions can be drawn. On the other hand, it appears that a rather good empirical fit can be made with past data by using something other than the cube root law. At first this may seem contradictory to both case (a) and (b); actually it is not. Case (b) does not deny the existence of any number of empirically determined scaling methods - it says only that no true <u>law</u> exists. A scaling law implies the invariance of a differential equation (or equations) under a given transformation- an empirically determined scaling method implies nothing but itself regardless of how useful it may be. Hence neither case (a) nor case (b) have been denied or substantiated.

Our problem then consists of continuing the development and calibration of the Bhangmeter, plus attempting to absolve anomalies in past (and perhaps future) data in such a way that either case (a) or case (b) above will be substantiated - and, if case (b) is substantiated, to find the best empirically determined scaling method available. Future users of the Bhangmeter will care little about the type of scaling used - as long as the results are sufficiently accurate (± 10%, probably) and dependable.

The inclusion of this project in Operation IVY will augment the above mentioned calibration, and hence continue what might be called the Bhangmeter feasibility studies, especially in the relatively high yield range.

<u>Method and Procedure:</u>

A. The Bhangmeter obtains the above mentioned elapsed time to first minimum for its user in the following fashion: A light-sensitive electronic valve observes the bomb light, the amount of current passing through the valve being proportional to the intensity of the light it sees. This current is used to deflect the sweep in a cathode ray tube so that a picture of the light intensity curve is drawn

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on the retentive fluorescent screen of the tube. A Polaroid "Land Camera" photographs this picture and hence provides a permanent record. An electronic timer which interrupts the cathode ray tube sweep momentarily every millisecond is included, so the picture is made up of a series of dots rather than a continuous line The elapsed time is then obtained by counting the dots from the start of the curve to the minimum.

B. For MIKE shot, one Bhangmeter will be installed on the Parry island photo tower, and another will be installed on the "Estes". In addition, others may be placed at more distant stations.

For KING shot, Bhangmeters will be installed on the Parry island photo tower.

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PROGRAM 3

SCIENTIFIC PHOTOGRAPHY

Project No: 3.7

Project Title: Preliminary Photographic Crater Survey.

Shot Participation: MIKE

Sponsor: DOD (USAF)

Project Officer:

Name: Lt. Col. James L. Gaylord
Address: Lookout Mountain Laboratory
8935 Wonderland Avenue
Hollywood, California

Phone: Hudson 2-1261

Conducting Agency: USAF Lookout Mountain Laboratory and Air Research and Development Command

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian			

Support Required: Part time use of the B-29 assigned to Documentary Photography coverage.

* Personnel for this Project are included in Task Unit 9 (Documentary Photography).

Object of the Experiment:

To obtain a preliminary photographic survey of the crater caused by MIKE shot, for use in the study of earth shock. It is also hoped that a correlation can be established between photographic evidence of surface perturbations and the fraction of the bomb's energy release that is "coupled" with the ground. Experience on previous tests has shown that early ground surveys of the crater are precluded by radiological hazards.

Method and Procedure:

A. A number of accurately surveyed ground points will be established close to Elugelab Island, with adequate marking of these points to assure contrast and definition when photographed. These positions must be so selected as to be easily distinguishable after the shot as well as before. Precise location of ground zero in relation to these positions is essential, and sufficient aerial photography of the shot island and adjacent islands prior to the explosion is planned to confirm the ground control.

B. The preliminary survey will be conducted from aircraft with vertical cameras as soon as practicable after the explosion of the MIKE device. The still cameras mounted in the documentary photography aircraft will be used only for oblique coverage on this project. Efforts will be made to obtain vertical and/or vertical stereoscopic photographs which will yield information on the size of the crater and the height of the material thrown out around the crater lip. Since considerable time must elapse before the crater can be surveyed in detail by personnel on the site, it is essential that the preliminary photographic survey yield as much data concerning the crater as is possible.

Remarks:

The experience of a similar project on Operation GREENHOUSE indicates that this photography should be done from an altitude of not less than 1000 feet. It was also found advantageous to process the film as soon as possible after the mission, in order that new photographs could be obtained in the event of equipment malfunction.

PROGRAM 3

SCIENTIFIC PHOTOGRAPHY

Project No: 3.8 Project Title: Burst Position.

Test Participation: KING

Sponsor: AEC

Project Officer:

Name: Mr. Herbert E. Grier
Address: Edgerton, Germeshausen & Grier, Inc.
160 Brookline Avenue
Boston 15, Mass.

Phone: Copley 7-3520 (Office)
Bigelow 4-4956 (Home)

Conducting Agency: Edgerton, Germeshausen & Grier, Inc.
160 Brookline Avenue
Boston 15, Massachusetts

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian	1	M-42	K/7

Support Required:

* See note under "Remarks" of Project 3.1.

Object of the Experiment:

Experimental air bursts, such as KING shot, impose the unique problem of determining their actual burst position in space. Prior to the shot, of course, a ground zero is selected and the detonation mechanism of the bomb is set for a given height of burst. The combination of bombing inaccuracy and the inherent inaccuracies of the detonation mechanism, however, make it extremely unlikely that the burst will actually take place at the preselected point in space. On the other hand, the success of many experimental projects is dependent upon knowing the bomb zero point with good accuracy. As a result, a rather precise photographic technique is used to locate the position (in space) of the light flash which characterizes the exploding bomb.

Method and Procedure:

A. Once the procedure for conducting this project is outlined, the details of the experimental method are obvious - hence we shall proceed directly to a discussion of the procedure.

B. The proposed bomb zero point is 1500 feet above the ground and 5700 feet due north of station 250 on Runit island. The region in space which includes this point will be observed photographically by two survey cameras, one located on Coral Head and one located in the Parry island photo tower. In addition to seeing the light flash from the exploding bomb, each camera will see two fixed points - the positions of which (with respect to the camera) are known with great accuracy. The distance between the images of these points on the film supplies the film analyst with a simple and accurate distance scale, with which to locate the burst point with respect to the fixed points. Measurement of a given film will then locate the burst point in a plane perpendicular to the axis of the camera - and having two such location planes will allow the burst point to be located in space.

The success of this project depends upon accurate information as to the camera positions, as well as the positions of the above mentioned fixed points, hence very precise surveying techniques are essential. Images of the fixed calibration points are obtained on the films by time-exposure, the night before the shot, to lights located at those points. The films in these cameras are actually glass plates, since the experimental error would be increased by the shrinkage of ordinary film. The image of the bursting bomb is obtained as a small dark spot on the negative (and hence the measurement errors are reduced) by greatly attenuating the bomb light with a strong ND filter (on the order of ND-9).*

Remarks:

1. The closer to proposed zero the bomb bursts, the more accurate is the location technique outlined above. This is because of the method used to obtain a distance scale on the film plate. The distance scale will be in error to the extent that the actual burst point is more or less distant from the camera than the fixed calibration points. The usual bombing error, however, is so small compared to the distance from zero to the camera that this effect is negligible.

* See the footnotes to the discussion of Project 3.5.

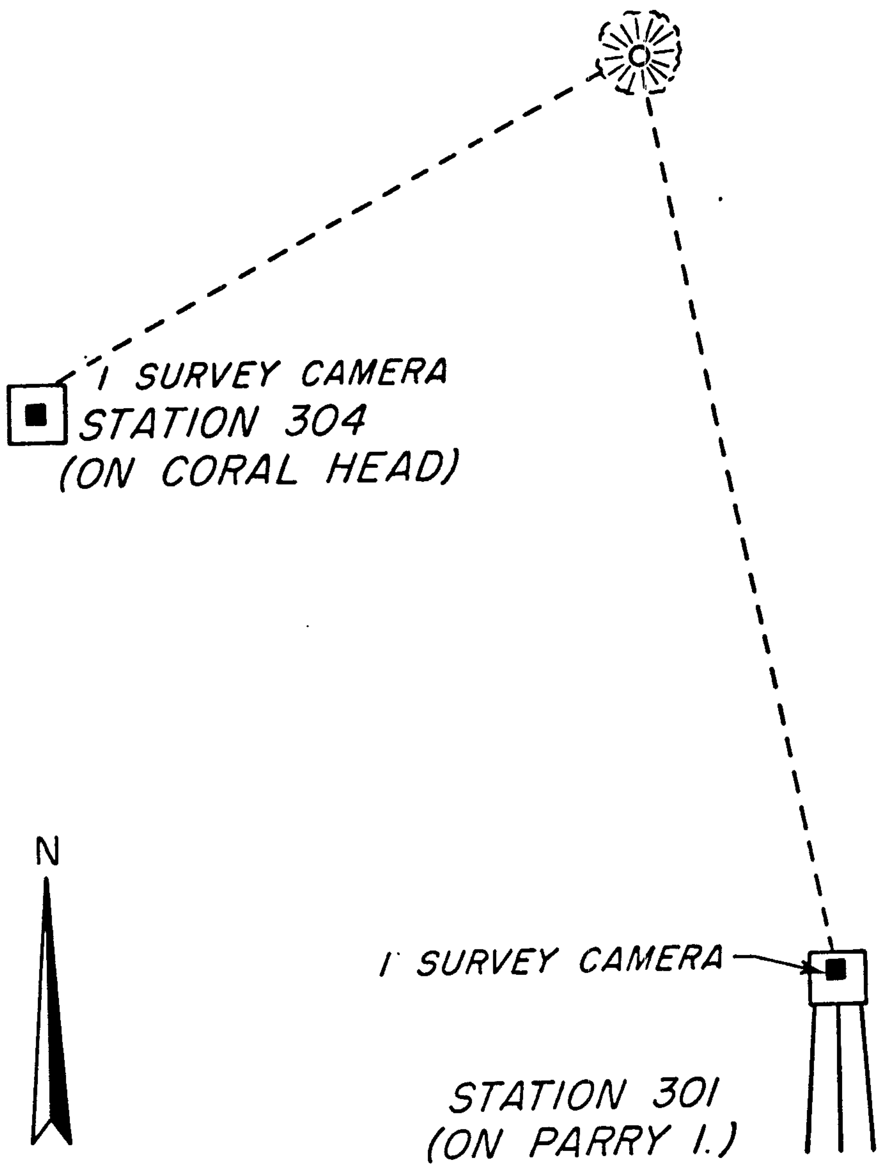

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Fig. 3.8.1
King Shot Burst Position

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PROGRAM 4

NEUTRON MEASUREMENTS

Project No: 4.1 Project Title: Slow Neutron Observation.

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Dr. Clyde L. Cowan
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-2844
7-4000

Conducting Agency: Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer			
Enlisted			
Civilian	2	M-35	K/1

Support Required:

[redacted] [redacted]

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Object of the Experiment:

The flood of neutrons which emanate from an exploding atomic device is of great interest to workers in at least two independent fields - that of bomb design (and the associated diagnosis of bomb performance) and that of "effects on things" (materials and animals, in particular). The neutron measurements program of Operation IVY is designed to augment existing data on neutrons and to continue the development of field measurement techniques - in order that the ultimate goal of complete documentation of neutron economy will be closer. In addition, especially for MIKE shot, it is designed to supply diagnostic information as to the "modus operandi" of the device.

In part, one is interested in the distribution of neutrons with respect to time, distance, and energy. Knowledge of the time dependence is primarily a theoretical requisite, but knowledge of the distance and energy dependence is as important to the soldier in the field as it is to the scientist. The neutron intensity-versus-distance curve tells us the lethal range of a neutron, and the energy spectrum at a given distance tells us the amount of shielding necessary for protection - not only of men, but of critical materials.

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If one knew the total number of neutrons emitted by an atomic bomb at explosion time, and the energy of each, neutron diffusion theory could be used to compute the subsequent neutron "field", with respect to both distance and time. In essence, such knowledge would supply the "initial conditions" for a set of integro-differential equations - and relatively straight-forward theoretical techniques could be used from there on.

Unfortunately these initial conditions are not known, and the problem must be approached in reverse. By making various measurements in the neutron field, one attempts to gain sufficient information for a deduction of "what the initial conditions must have been".

Every neutron liberated by an atomic bomb is ultimately captured by some element in the surrounding medium (air, ground, etc.) Some will be captured before losing any of their energy - others will be

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arrived only after losing some portion of their energy in one or more collisions. As a result, the existence of a neutron having energy E at a distance R from the bomb can indicate at least two possibilities:

(a) It may have left the bomb with energy E and traversed the distance R unmolested.

(b) It may have left the bomb with some energy greater than E and had its energy reduced by one or more collisions while traversing the distance R.

Each of these possibilities is associated with a definite probability of occurrence. Hence if one measures the total number of such neutrons (energy E at distance R), diffusion theory can be applied in reverse to indicate their probable ancestry at the bomb. A multiplicity of such measurements taken at different distances and for different neutron energies allow one to build a more complete, as well as consistent, model of the above mentioned "initial conditions".

This project is part of a continuing program to determine the space distribution of low energy neutrons liberated by various sizes and types of atomic bombs.

Method and Procedure:

A. Neutrons of energy in the range from thermal* to .25 electron volts (EV)** are essentially all captured by the element cadmium. Also, cadmium is quite transparent to neutrons of energy greater than .25 EV. These facts enable us to design a "target" which, when bombarded with neutrons of many energies, is capable of measuring the number of those neutrons in the energy range from .025 to .25 EV.

First we select an element which, upon being bombarded with neutrons, produces a radioactive by-product. Ideally, the element selected should be inert with respect to gamma radiation and the by-product should have a sufficiently long half-life to be amenable to laboratory analysis (counting) techniques. Two samples of this element are then prepared - one being coated with cadmium and the other left pure. These samples are together exposed to the neutron bombardment and subsequently placed in "counters" which measure the induced activity.

* Thermal neutrons are those with energies of the order of .025 EV.

** 1 EV = 1.602×10^{-12} ergs.

The difference in the induced activities of the two samples is then the amount of activity induced in the selected element by neutrons of energy in the range .025 EV to 0.25 EV. (This is usually referred to as the "cadmium difference"). Laboratory calibration of the element with neutrons of a known energy (for instance, as can be obtained with a Betatron) will then allow this cadmium difference to be interpreted in terms of numbers of neutrons (in the above mentioned energy range) striking a square centimeter of area of the "target" element.

This, in turn, finally allows one to deduce the total number of those neutrons which are existent (integral over time) at a given distance (the distance from zero at which the samples were exposed) from the particular bomb detonation. Such a measurement can be repeated at several distances to obtain an intensity-versus-distance curve for those neutrons.

The method outlined above is used in this project, the selected target elements being tantalum and gold.

B. For MIKE shot, pairs of tantalum and gold samples (one of each being shielded with cadmium at each station) will be placed on a line extending along the reef toward Bogallua. The first pair will be 100 yards from zero, and a pair will be placed every 100 yards from there to 2500 yards. Two sample recovery techniques have been proposed - one being to fasten the samples to a steel cable which can be hauled in after the shot; the other being to place the samples on fixed individual pylons and retrieve them after the shot by helicopter. In all probability, a combination of these methods will be used. After recovery, the samples will be shipped to Los Alamos for laboratory analysis.

For KING shot, the same technique will be used. The line of samples will start on the reef (300 feet from proposed ground zero) and extend down the center of Runit island to the region of the airstrip (7200 feet from proposed ground zero).

Remarks:

1. The samples must be collected as soon as possible after the shot, in order that the radioactive by-products will not decay any more than is absolutely necessary before laboratory analysis can be done. Also the near (to zero) sample containers are usually in extremely "hot" (radioactivity-wise) areas and may be "hot" themselves. Hence the recovery problems of this project are potentially very severe.

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7. The above outlined technique only allows deduction of the [illegible] of neutrons in a very limited energy range. For the theoretical "inverse approach" to be of appreciable value, measurements must be made in other energy ranges, so that a much greater percentage of the total ancestor distribution can be deduced. Project 4.2 is devoted to such measurements for energies greater than 3 million electron volts (MEV). A secondary objective of this project will involve attempts to document energies between .25 EV and 3 MEV. The techniques required for such measurements are not yet proven, so this portion of the experiment is primarily a feasibility study. In particular, it is hoped that the high cross section exhibited by Indium, for neutrons of [illegible] EV, will be useful.

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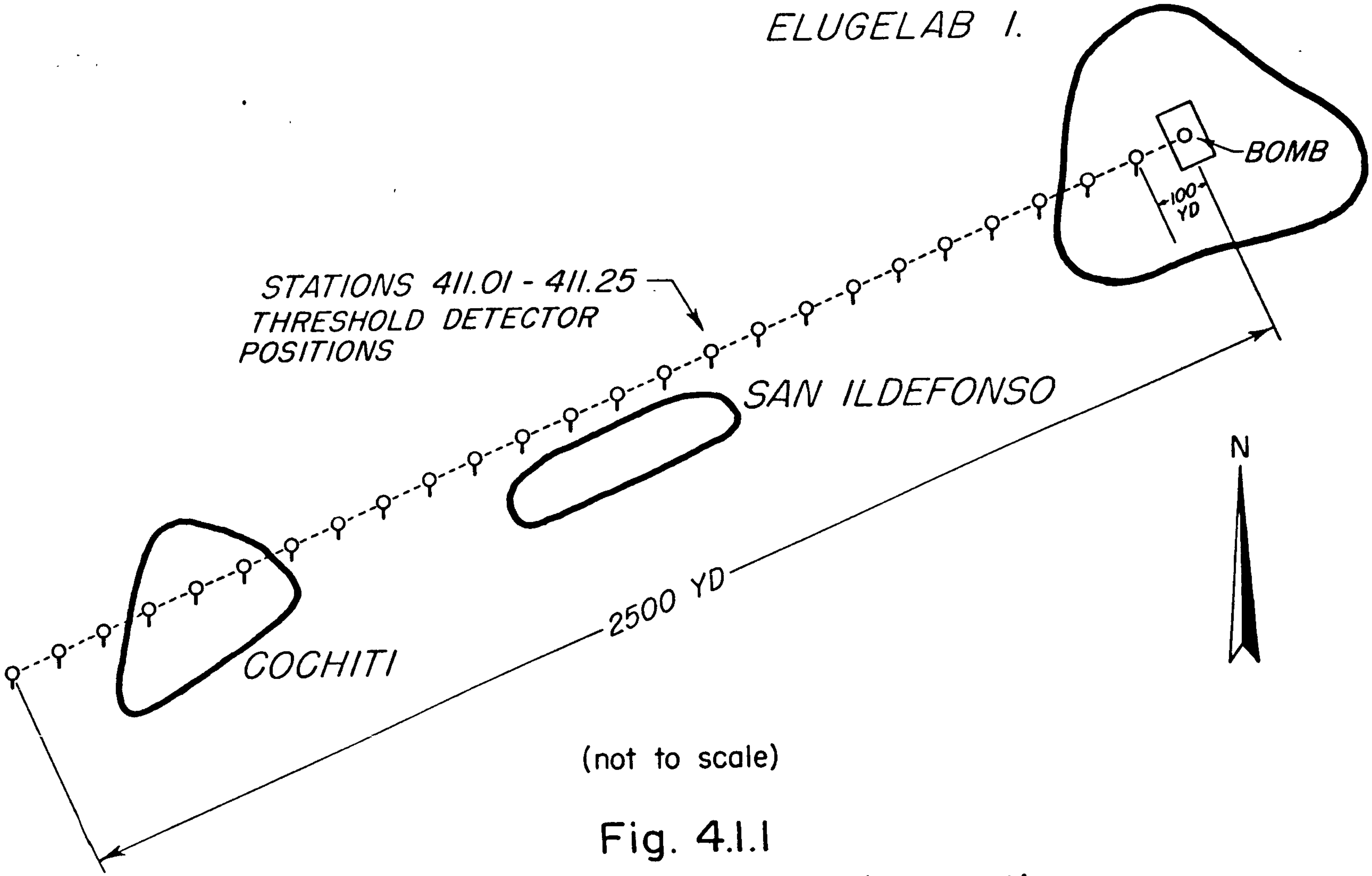

Fig. 4.1.1
Mike Shot Slow Neutron Observations

Fig. 4.1.1
Mike Shot Slow Neutron Observations

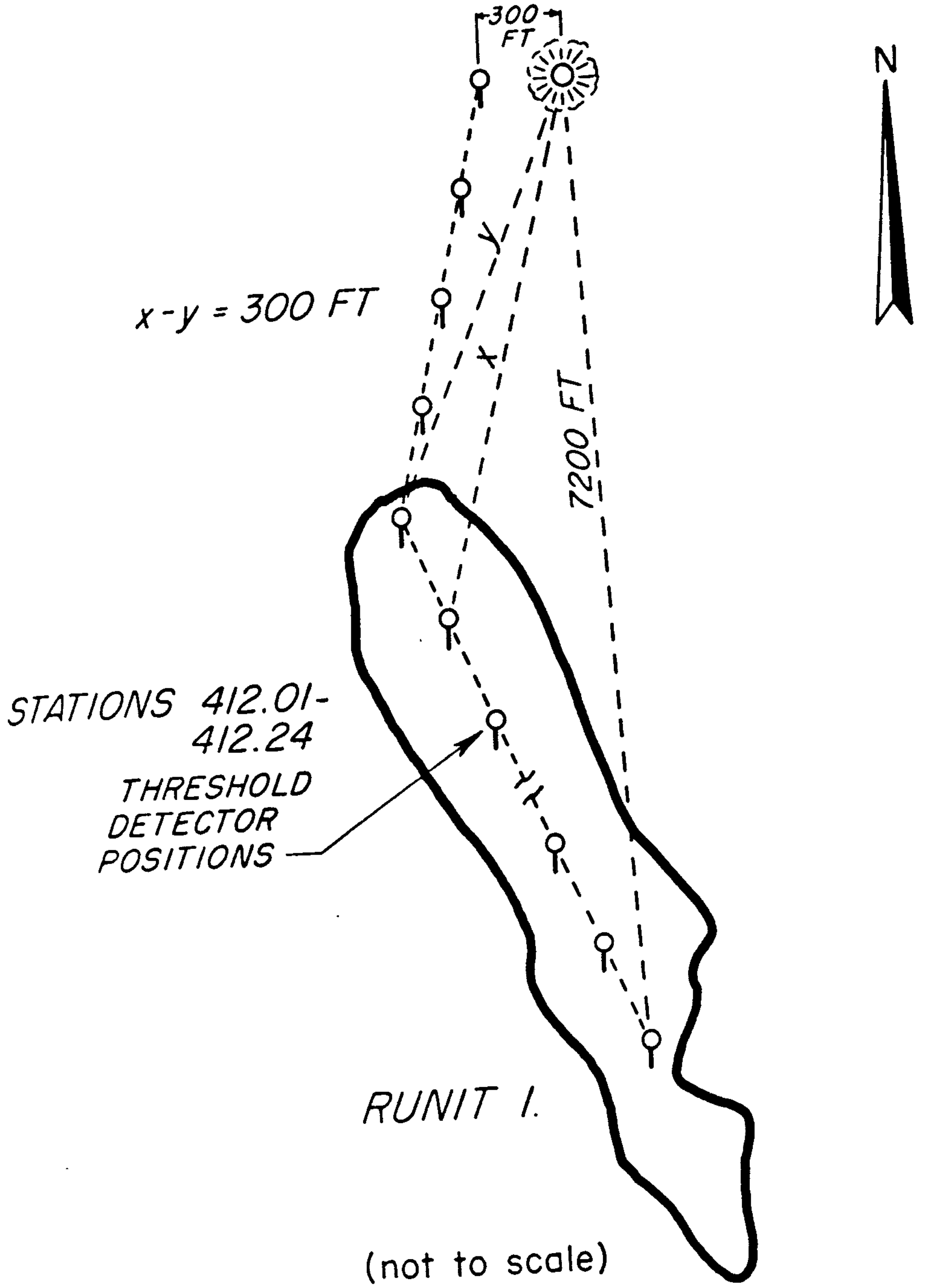

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Fig. 4.1.2
King Shot Slow Neutron Observation

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PROGRAM 4

NEUTRON MEASUREMENTS

Project No: 4.2

Project Title: High Energy Neutron Observations.

Test Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Dr. Clyde L. Cowan
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-2844
7-4000

Contracting Agency: Group J-12
Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer			
Enlisted			
Civilian	2	M-35	K/1

Support Required:

[redacted]

[redacted]

Object of the Experiment:

We have seen in the discussion of Project 4.1 the importance of obtaining as much information as possible regarding the distribution of neutron intensity with respect to distance and energy. This project is designed to extend the measurement started in Project 4.1, by documenting the flux of neutrons exhibiting energies considerably higher than .25 EV.

Method and Procedure:

A. The "cross section" of a substance with respect to a particular bombarding particle is a measure of the likelihood that the particle will react with the substance. A high cross section implies a high probability of reaction, and so forth. In general, the magnitude of this cross section is a function of the particle energy and type. As an example, consider the cadmium used in Project 4.1. We mentioned that cadmium absorbed essentially all neutrons having energies from thermal to .25 EV, and was "transparent" to those of energy greater than .25 EV. Cadmium thus has a very high cross section for neutrons in the .025 to .25 EV energy range, and a very low cross section for those of energy greater than 0.25 EV.

A threshold detector is a substance having an essentially zero cross section to particles of energy below a fixed level, and a finite cross section to particles of energy greater than that level. The fixed level is the threshold energy for that substance. Sulphur, iodine, and zirconium are examples of threshold detectors - each having quite different reaction characteristics and threshold energies. We shall discuss each of these in turn, with the view of indicating its usefulness to this project.

Sulphur (S^{32}) has a threshold energy of effectively 3 MEV. The reaction which takes place when sulphur is bombarded with neutrons of energy ≥ 3 MEV leads to the creation of a radioactive isotope of phosphorus (P^{32}). This active isotope in turn decays (with a 14.3 day half life)back to S^{32} by emitting 1.8 MEV beta rays. Thus, the specific beta activity of a sulphur sample measures the total number of neutrons with energies not less than 3 MEV that passed through the sample.

Iodine (I^{127}) exhibits a threshold energy of approximately 9.5 MEV. When it is bombarded with neutrons of energy greater than the threshold value, another isotope of iodine (I^{126}) is formed. The latter is radioactive, and decays (with a 13-day half life) to a stable isotope of Xenon (Xe^{126}) by emitting a 1.1 MEV beta particle

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and a 0.5 MEV gamma ray. Hence the specific activity (both gamma and beta) of the iodine sample is a measure of the total number of neutrons having energy in excess of 9.5 MEV which passed through the sample.

Zirconium (Zr^{90}) has a threshold energy of effectively 12.5 MEV. Its reaction, upon bombardment with neutrons of sufficiently high energy, produces atoms of Zr^{89} - a radioactive isotope of zirconium. This in turn decays (with a 78-hour half life) to a stable isotope of yttrium (Y^{89}) by emission of a 1 MEV gamma ray. The specific gamma activity of the zirconium sample is then a measure of the total number of neutrons (of energy $>$12.5 MEV) which passed through the sample.

An experimental procedure is thus indicated. Let us place samples of each of the above elements at some fixed distance from the bomb. Post-shot analysis of these samples will then supply three points on the curve of E (neutron energy) versus N(E), the total number of neutrons with energy at least as great as E. This curve is, of course, associated with the above mentioned distance. A family of such curves can be obtained by placing sets of samples at various distances. From such a family other curves can be derived - for instance those relating N(E) to distance, a different curve being drawn for each value of E.

B. For MIKE shot, sulphur, zirconium and iodine samples will be placed at the same positions mentioned under Project 4.1 (MIKE shot). In addition, a few zirconium samples may be placed on Elugelab - in line with the collimator holes mentioned under Project 2.3 - out to a distance from zero of approximately 800 yards. The placement of the latter is dependent upon space availability, as the collimation may be sufficiently "tight" to forbid extra material in the line of sight. The sample recovery and shipment (to the Los Alamos laboratories) procedures will be identical to those outlined for Project 4.1. For KING shot, sulphur samples will be placed at the same positions as the tantalum samples mentioned under Project 4.1 (KING shot).

Remarks:

1. The above discussion of sulphur, iodine and zirconium as threshold detectors has been over-simplified in the interests of brevity. In actuality, the specific activity of a sample may not be completely neutron-induced. Both iodine and zirconium also react to gamma rays in a very similar fashion. Hence the experimenter must separate the neutron-induced and the gamma-induced activities. One method of doing this is to duplicate such samples in the experimental set-up, one of each pair being surrounded by lead - lead having a very high cross

section for gamma rays and a very low cross section for neutrons. The difference in specific activity of two such samples is then the activity induced by the gamma rays, etc. The reader is referred to the Project Officer for details of this and other difficulties.

2. In addition to the above, it may be possible to obtain more points on the curve with the following threshold detectors - lack of documentation for which forces their use to be classified as feasibility tests:

(a) Neptunium (Np^{237}) with a .5 MEV threshold for fission.

(b) Uranium (U^{238}) with a 1 MEV threshold for fission.

(c) Arsenic with two thresholds, one at 10.5 MEV and one in the thermal range, the results of which can be separated with special analysis techniques.

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PROGRAM 4

NEUTRON MEASUREMENTS

Project No: 4.3

Project Title: Neutron Spectrum - Nuclear Emulsions.

Test Participation: MIKE

Sponsor: AEC

Project Officer:

Name: Dr. Clyde L. Cowan
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-2844
7-4000

Conducting Agency: Group J-12
Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer			
Enlisted			
Civilian	1	M-35	K/1

Support Required:

[redacted]

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Object of the Experiment:

The discussion of Project 4.1 pointed out the desirability of obtaining the total neutron spectrum (numbers of neutrons at every energy level) versus distance. However, the techniques of Projects 4.1 and 4.2 do not allow a determination of the entire spectrum. This project makes use of an experimental technique which, if successful, is capable of much more extensive documentation of the neutron energies existent at a given distance.

Method and Procedure:

A. Certain elements, upon neutron bombardment, undergo an (n,p) reaction. That is, the absorption of a neutron is accompanied by the ejection of a proton, the energy of which is proportional to the energy of the absorbed neutron. If the proton is allowed to travel through a photographic emulsion, it will produce a "track" of ionized particles and hence a track of "exposure". Upon development, the photographic negative will exhibit a dark line, the length of which is proportional to the proton energy. As a result, laboratory calibration of this technique allows the measurement of the resulting line in the negative to be interpretable as the energy of the incident proton.

This technique has a number of serious disadvantages, however. First, the film must be adequately shielded from both neutrons and gamma rays, as both are capable of producing "exposure" of the emulsion. Secondly, the proton source is also sensitive to gamma rays, and must be shielded from them if the experimental record is to be useful as a neutron indicator.

These difficulties are met, at least partially, by heavy shielding for the assembly (proton source and photographic plate) and strong collimation for the signal - with lead in the collimation line to keep the gamma rays away from the proton source. The necessary collimation creates more disadvantages, however. The experiment cannot be conducted on air drops because of the uncertainty in burst position, and the "good geometry" results are not applicable to the needs of those interested in the biomedical effects of neutrons. After all, it is most unlikely that the soldier in the field would be exposed to an atomic bomb in a collimated geometry.

B. For MIKE shot, one nuclear emulsion camera will be operated at 1300 yards from bomb zero. This is primarily a feasibility test for the equipment, as the gamma-ray level at such a distance from the gadget will be sufficiently high to make film-fogging marginal.

The camera cannot be moved further away, however, as the neutron signal strength at that distance is marginal (for obtaining a usable experimental record) on the low side.

Remarks:

At first glance, it might appear that the disadvantages associated with this experiment far outweigh the advantages to be gained from its success. This is not the case, however, as the spectrum information it may obtain would be of great theoretical value. Also, it can be simply and cheaply done with reclaimed GREENHOUSE equipment that has been kept in storage on Parry Island.

4.3.4

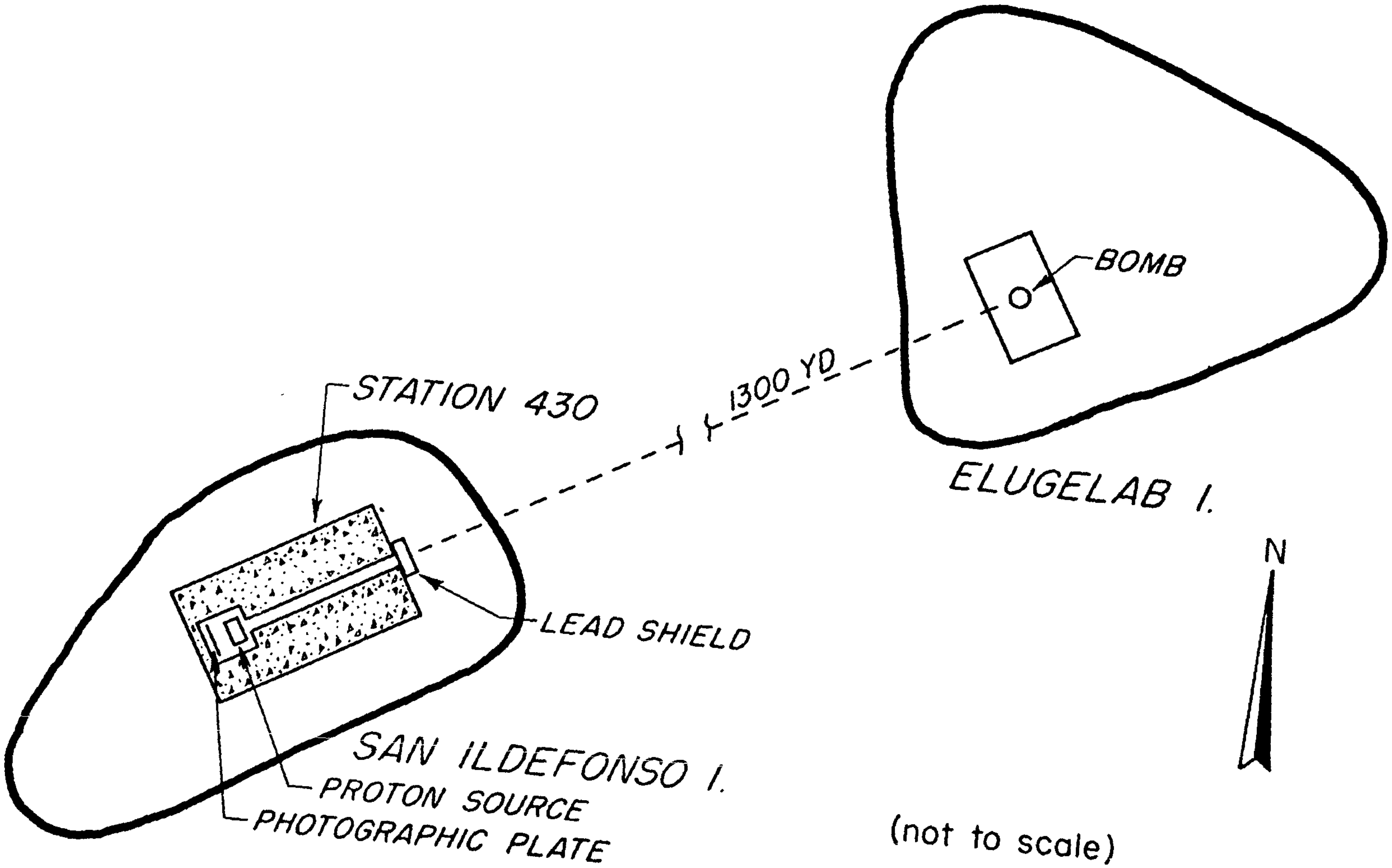

Fig. 4.3.1
Mike Shot Neutron Spectrum - Nuclear Emulsions

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Mike Shot Neutron Spectrum - Nuclear Emulsions

PROGRAM 4

NEUTRON MEASUREMENTS

Project No: 4.4

Project Title: Neutron Intensity as a Function of Time.

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Dr. Clyde L. Cowan
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-2844
7-4000

Conducting Agency: Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	1	M-35	K/1
Enlisted			
Civilian			

Support Required:

[redacted] CONFIDENTIAL

[redacted]

Object of the Experiment:

The neutron detection methods outlined in Projects 4.1 and 4.2 are essentially time integrating, and offer no information as to the time distribution of the original flood of neutrons. This project is designed to gain information as to the total number of arriving neutrons versus time at given fixed distances from bomb zero. The device which accomplishes this purpose is called a "fission-catcher camera" and its method of operation is discussed below.

Method and Procedure:

A. The fission-catcher camera consists essentially of a thin foil of fissionable material, behind which a cellophane strip is moved at a known rate. If the fissionable material is subjected to bombardment by neutrons of the proper energy, some of its atoms will undergo fission, and the by-products of these fissions will be thrown out as fission fragments. The fragments will be picked up by the moving cellophane strip, and their position on the strip will be a measure of when they were created. Since many fission by-products are radioactive, their presence on the strip can be detected by laboratory "counting" techniques. Hence by measuring the activity of the cellophane strip as a function of distance along the strip, one can, by using the known strip velocity and starting time, deduce the period of time over which fission producing neutrons arrived at the camera.

B. For MIKE shot, three fission catcher cameras will be located on San Ildefonso island approximately 1200 yards from zero. Foils of both uranium 235 and uranium 238 will be used as the fissionable material. the U^{235} being used both with and without cadmium shielding.* U^{235} has a thermal ($\sim$.025 EV) energy threshold for the fission reaction, and U^{238} has a similar threshold at 1 MEV.** Analysis of these cellophane "films" should then supply us with the following information:

(a) The time distribution, at 1200 yards from zero, of the neutrons in the energy range from 0.25EV to 1 MEV.

(b) The time distribution, at 1200 yards from zero, of those neutrons having energies in excess of 0.25EV.

* See the discussion of Project 4.1

** See the discussion of Project 4.2

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(c) The time distribution, at 1200 yards from zero, of those neutrons having energies in excess of 1 MEV.

In each case, these measurements will start at approximately 1 millisecond after zero and continue for 30 seconds.

For KING shot, an identical installation will be made on the north end of Runit island.

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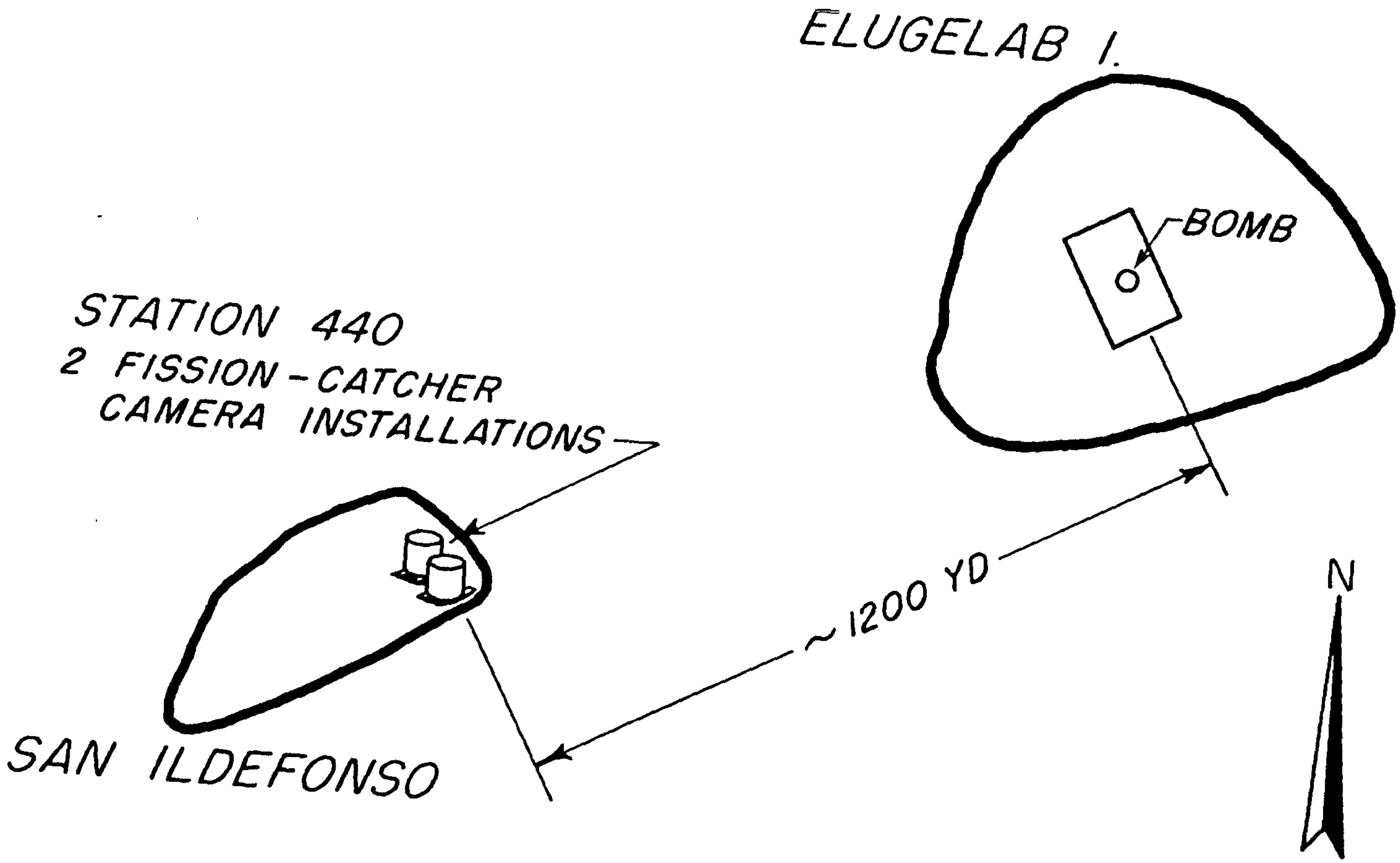

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Fig. 4.4.1
Mike Shot Neutron Intensity as a Function of Time

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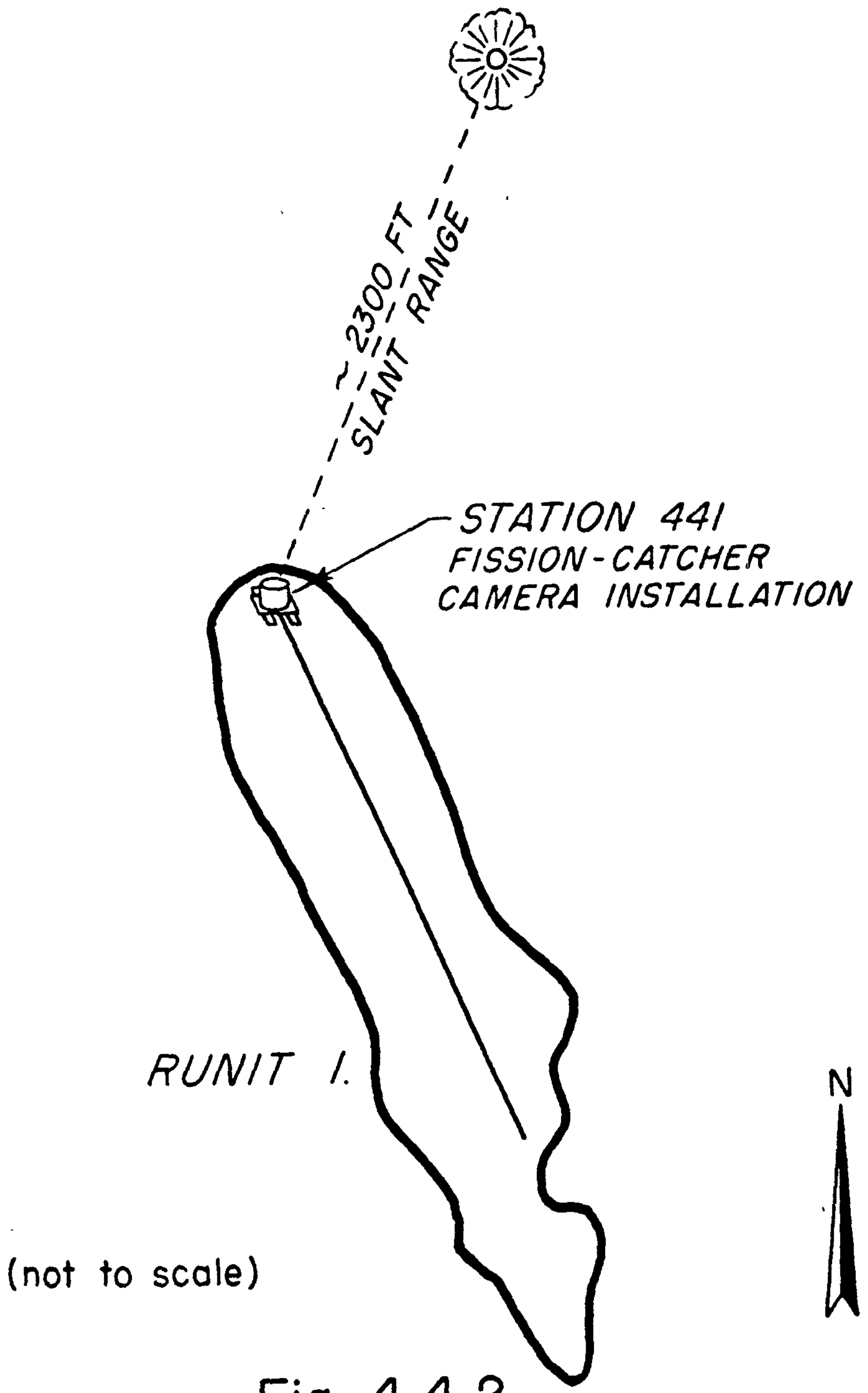

Fig. 4.4.2
King Shot Neutron Intensity as a Function of Time

Fig. 4.4.1
Mike Shot Neutron Intensity as a Function of Time

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PROGRAM 5

GAMMA RAY MEASUREMENTS

Project No: 5.1 Project Title: Total Dose.

Test Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Mr. Ellery Storm
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-3744

Conducting Agency: Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer			
Enlisted			
Civilian	4	M-21	K/10

Support Required: Courier facilities for returning film to the Los Alamos processing laboratories.

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Object of the Experiment:

In the field of atomic weapons effects, knowledge of the gamma radiation dose resulting from a bomb detonation - as a function of distance, energy release, time and weapon type (i.e., fission or thermonuclear) - is of obvious importance. Since a non-negligible fraction of the total energy involved is released as gamma radiation of various energy levels, we have a serious personnel hazard assured for some distance from bomb zero. The more knowledge we possess about this hazard, the better we can plan for defense against (and tactical use of) atomic weapons. As a particular example, consider the problem of telling the foot soldier how to prepare a fox hole in such a way that he will most efficiently utilize the time available to him in obtaining protective shielding from gamma rays. As another, we have the problem of where to plan the concentration of disaster relief team efforts for civil defense. This experimental project is part of a continuing program, the purpose of which is to obtain as much documentation as possible of the gamma radiation fields established by exploding atomic weapons. In particular it is designed to supply information as to the total gamma dose received by points located at various distances from bomb zero.

Method and Procedure:

A. It is common knowledge that photographic (silver halide) emulsions react to light in such a way that subsequent chemical reduction (development) of the emulsion causes opaque deposits of metallic silver to be produced - the relative opacity (density of silver deposit) being proportional to the original light intensity. Such a phenomenon might supply an experimental method for determining the strength of a light source, by carefully calibrating the emulsion, development technique, and negative density measurements - and by using known attenuators for very strong sources.

Consider, however, the fact that visible light represents but one small portion of the electromagnetic radiation spectrum. Other portions of that spectrum; for instance, X-rays and their more energetic brothers gamma rays, are capable of producing the same reaction in the silver halide suspension. Hence we have modern X-ray photography - and the film badge dosimeter.

The film badge dosimeter consists of a small packet containing several strips of photographic film - the packet being made light-tight to insure that "exposure" is due only to penetrating radiation. Quality control in the film manufacturing, and laboratory calibration of samples from each film batch used, insure that the field exposure of a packet will be interpretable directly in terms of roentgens of gamma ray dose received.

After the badge has been exposed, the analysis technique consists of first developing the film under carefully controlled conditions (that is, conditions precisely like those with which the film was calibrated), then measuring the opacity of the negative with a precision densitometer. The densitometer measurement will be interpreted as so many roentgens by the above mentioned laboratory calibration.

Exposure of the film, of course, tells us only that one or more gamma photons were there. It cannot, in itself, tell us when. Hence the film is a time integrating device, and measures only the total gamma dose received by it from the time it was made until the time it was developed. This fact indicates the absolute necessity of adequately shielding unexposed packets from extraneous radiation sources (for instance, fallout).

Photographic film, like all other gamma ray detectors, is somewhat energy sensitive - that is, the degree of "exposure" due to gamma ray passage is somewhat dependent upon the energy of the gamma. This effect, however, is essentially a calibration problem, and need not be considered herein. For such details the reader is referred to the Project Officer. For all practical purposes, one can give the final result of this measurement as so many roentgens of gamma - of energy sufficiently great to penetrate the protective covering of the packet.

The inclusion of several strips of film in each packet is an economy measure. The measurement of a fifty roentgen dose is more efficiently accomplished on a film strip that is strongly exposed by one hundred roentgens than it is on one which requires one thousand roentgens for strong exposure - the contrast between the correct densitometer reading and one slightly incorrect being much easier to detect. Hence the inclusion of only one film strip per packet would require several different packet models for the various distances from bomb zero (likely gamma exposure ranges) of interest. Packet standardization, in such a way that each packet is capable of use at any measurement station, effects an obvious logistical simplification.

B. For MIKE shot, two measurement lines will be established - one from Elugelab to the far end of Bogallua, and one from Elugelab to the far end of Engebi. The packet positions will be on land only, and will be spaced at one hundred yard intervals insofar as possible. Three film badges will be placed at each position, the first of which remains openly exposed to radiation until recovery. The second and third badges will be openly exposed initially, but will later drop into prepared shielded positions - the second dropping 0.2 seconds after the explosion, and the third dropping 60 seconds later. In this fashion, a crude time resolution of the total dose will be obtained - providing the shield corrections can be adequately made. In particular, the spreading of contamination by a "base surge" or "dust skirt" may be documented in this fashion.

For KING shot, a line of film badge stations will be placed down the middle of Runit - spaced at approximately one hundred yard intervals. Each station will consist of a post to which one or more film badges is attached. All badges will be openly exposed until recovery.

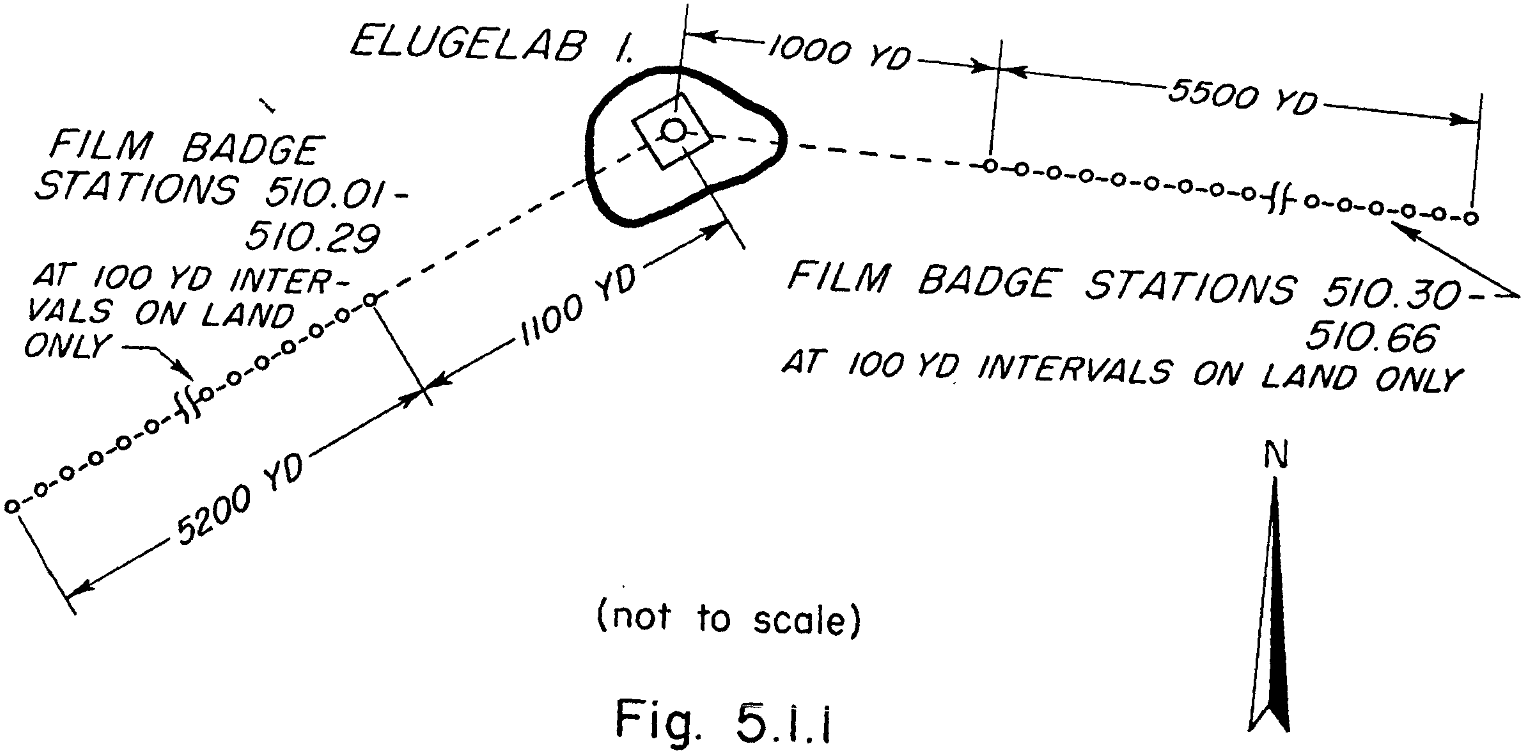

Fig. 5.1.1
Mike Shot Total Dose

5.1.5

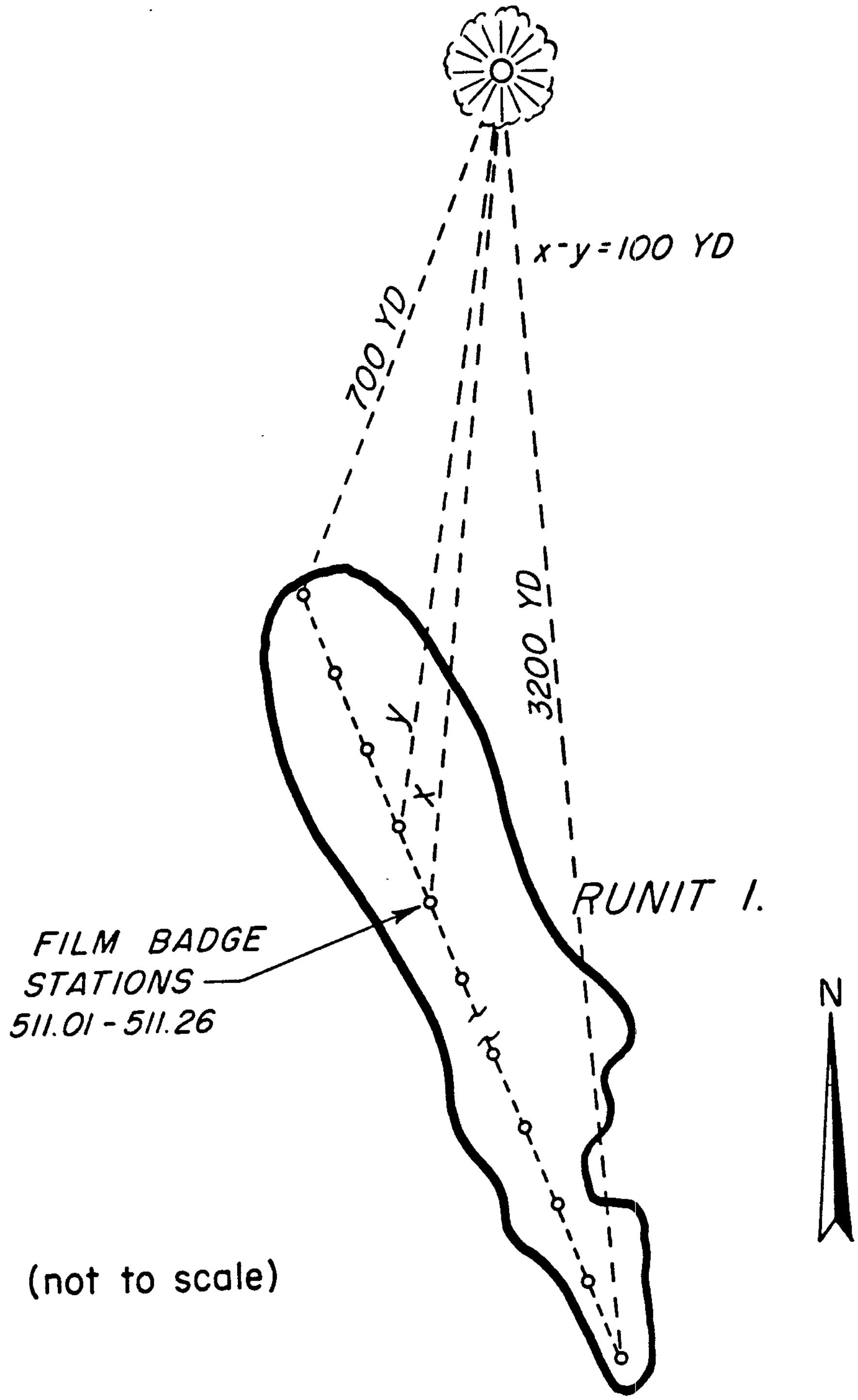

Fig. 5.1.2
King Shot Total Dose

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PROGRAM 5

GAMMA RAY MEASUREMENTS

Project No: 5.2

Project Title: Gamma Intensity as a Function of Time.

Test Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Dr. John S. Malik
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-4106

Conducting Agency: Group J-13
Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	1	M-45	K+15
Enlisted			
Civilian	3	M-45	K+15

Support Required:

[redacted] CONFIDENTIAL

[redacted]

SECRET

Object of the Experiment:

Consistent with the idea of eventually having complete documentation of the "field variables" associated with an atomic weapon detonation, this project is intended to measure the time dependence of gamma ray intensity (at certain fixed distances) from shortly after zero time to plus thirty seconds.

The gamma rays which are emanated from an exploding atomic bomb fall into two distinct classifications - "prompt" and "delayed". The prompt gamma rays are those created during the reaction time of the bomb - this time being dependent upon the bomb model, but usually being some fraction of a microsecond.

The delayed gamma rays come from two quite distinct sources, each source contributing approximately one-half of the total:

(A) Those liberated by the decay of the active fission fragments, their time dependence depending upon the fate of the fragments - when they are swept up by the rising fireball, or where they are deposited on the ground.

(b) Those arising from (n,γ) reactions in the soil and in the air around the bomb.

In any above-surface burst the vast majority of fission fragments will be carried up by the fireball; hence the greater portion of delayed gamma radiation occurs during the first few seconds after the explosion, although weak radiation may continue for a long time because of a few active fragments being deposited in the surrounding soil.

The time dependence of the prompt gammas is documented by the "Alpha" experiment, and will not be considered here. This experiment is designed to start at 0.2 microsecond (μs) for MIKE shot (1 millisecond (ms) for KING shot) and extend for approximately 30 seconds - thus measuring the time dependence of the major portion of the delayed gammas.

Method and Procedure:

A. The detection method used herein is essentially the same as that used in Project 2.1a. A "phosphor" (substance which fluoresces under gamma ray bombardment - to produce a light signal, the intensity of which is proportional to the intensity of the incident gamma radiation) observes the bomb, and is itself observed by a photocell (current

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generator - the magnitude of generated current being proportional to the intensity of the light signal it "sees"). The current signal from the photocell is converted to a voltage signal in a so-called "logarithmic attenuator" and applied to the deflection plates of an oscilloscope. The timing equipment is included in the horizontal deflection plate circuit of the scope in such a way that a given horizontal deflection of the electron beam is uniquely associated with a given elapsed time from zero. Hence the scope trace is a gamma intensity versus time record, the vertical scale of which is not gamma intensity itself but a known function of the gamma intensity - the known function being supplied by the experimentally determined characteristics of the logarithmic attenuator.

The logarithmic attenuator is an electronic device which, upon receipt of a signal of magnitude M, passes on a signal whose magnitude is proportional to log M. Hence it passes on small signals with little or no attenuation, whereas it attenuates large signals a great deal. Such a device is necessary in this experiment because of the tremendous range of gamma intensities involved. Since a given oscilloscope has a limited intensity range, direct recording of all gamma intensities involved herein would require a prohibitive number of scopes. The use of the above mentioned attenuator allows the use of only a few scopes, each covering several decades (powers of ten) of gamma intensity.

B. For MIKE shot, gamma intensity versus time measurements from 1 ms to 30 seconds (covering 6 decades of intensity) will be made on four islands - Cochiti, San Ildefonso, Bogombogo, and Ruchi. Hence four points will be obtained on the gamma intensity versus distance curves - each curve being associated with a given elapsed time after zero. In addition, on Ruchi island, measurements will be taken from 0.2 to 1000 μs, covering approximately 8 decades of intensity.

For KING shot, three measurement assemblies will be placed on Runit - at varying distances from bomb zero. The time coverage here will be from 1 ms to 30 seconds, and approximately 6 decades of signal will be recorded.

Remarks:

1. The retentive face of a cathode ray tube is caused to fluoresce by incident ionizing radiation - just as it is by the electron beam generated within the tube. Such a phenomenon can cause loss of experimental measurement, if it occurs during the time that a desired trace is being generated and photographed. As a result, recording oscilloscopes near the exploding bomb must be shielded from ionizing ra-

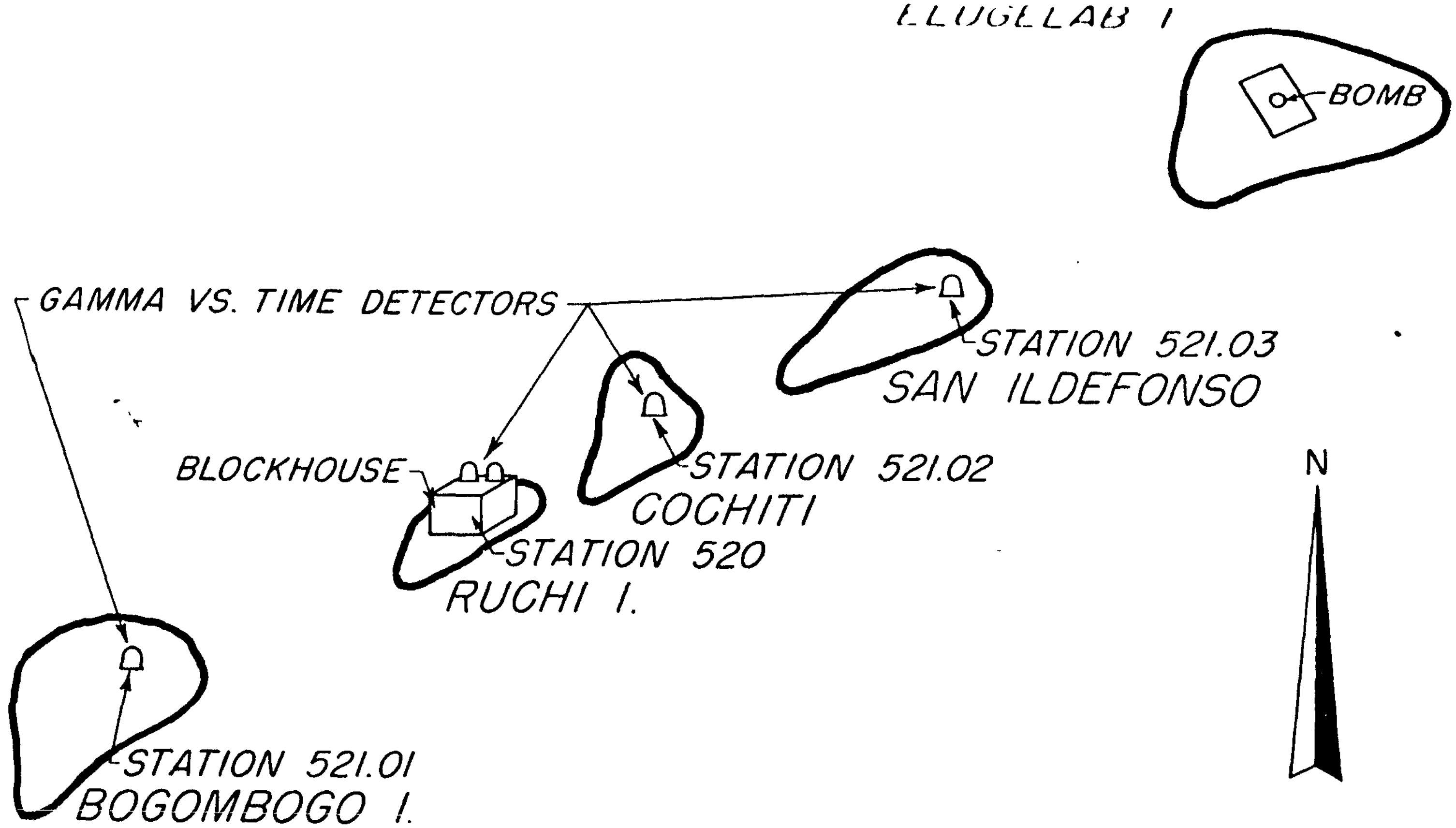
[redacted]

diation rather thoroughly.

As a result of this, the usual gamma-versus-time station consists of a hole in the ground - some 18 to 20 feet deep - at the bottom of which the recording equipment is placed. The hole is filled with water to obtain extra shielding, and the detector is placed above the surface of the ground. Hence the only outward manifestation of the stations existence is a bell shaped aluminum object (the detector cover) sitting on a steel plate (the hole cover). For this project, all stations not on Ruchi island will be as described above.

The Ruchi station will consist of a small blockhouse, in which a number of detectors for nearby recording equipment will be placed. This more complicated installation is made necessary by the greater time resolution (and attendant complexity of instrumentation) required of the Ruchi measurements.

2. The Ruchi blockhouse will be supplied with a timing signal by EG&G, to actuate the recorders. The self-contained units will be actuated by the "blue boxes".



(not to scale)

Fig. 5.2.1
Mike Shot Gamma Intensity as a Function of Time

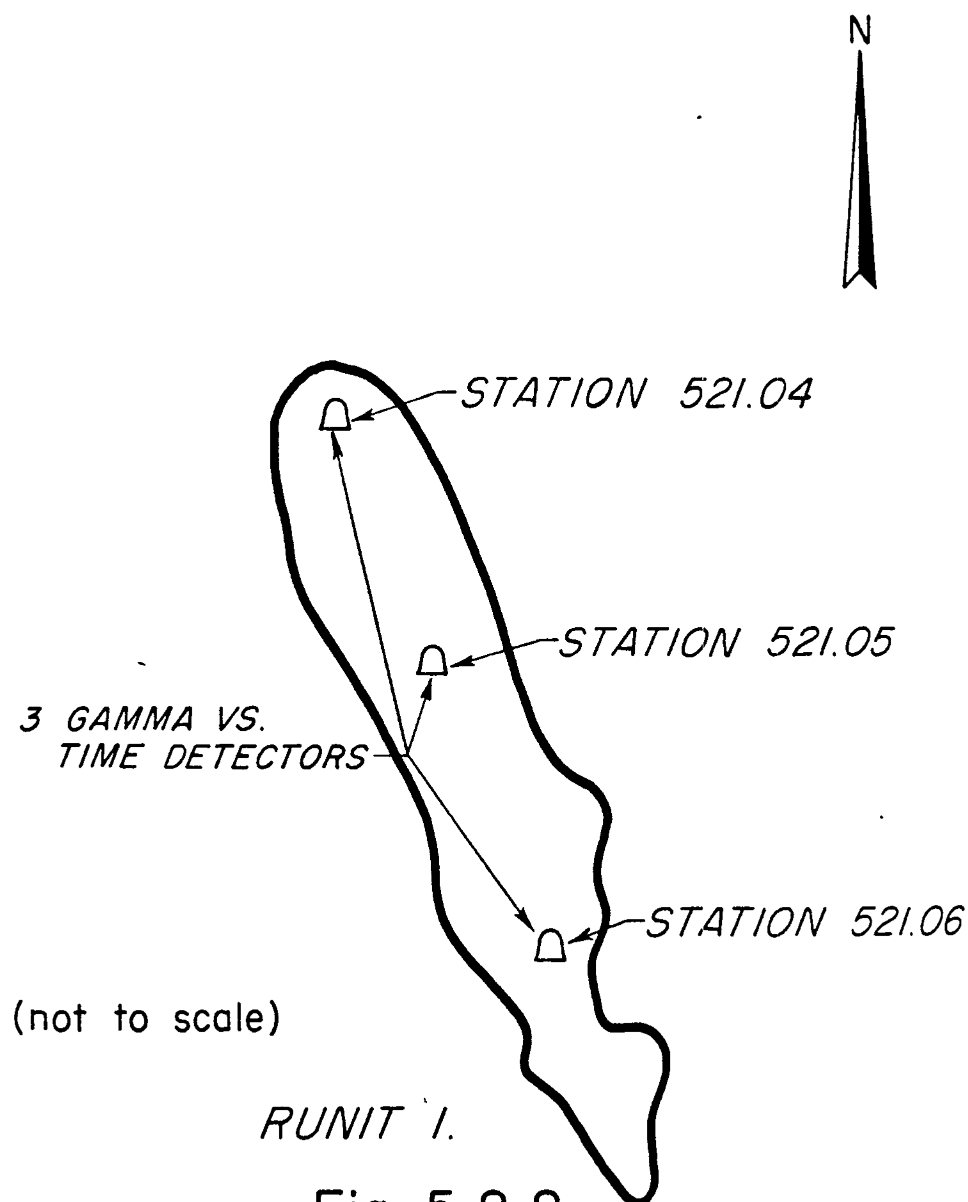


Fig. 5.2.2
King Shot Gamma Intensity as a
Function of Time

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PROGRAM 5

GAMMA RAY MEASUREMENTS

Project No: 5.3 Project Title: Fall-Out Gamma Intensity.

Shot Participation: MIKE

Sponsor: AEC

Project Officer:

Name: Dr. John S. Malik
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-4106

Conducting Agency: Group J-13
Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	1	M-45	K+15
Enlisted			
Civilian	1	M-45	K+15

Support Required:

:06

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Object of the Experiment:

The "fall-out" of radioactive particles from an atomic cloud presents a problem, the solution of which is potentially important to every living thing on our planet. Because of this phenomenon, a bomb burst over Nevada may require the evacuation of areas in another state - or a bomb burst over the enemy may endanger friendly troops many miles away. Of even more immediate interest to us at this time, MIKE shot may constitute a hazard to Runit island, Kwajalein, or perhaps even Oahu.

The winds of our atmosphere are primarily responsible for this ability of an atomic bomb to threaten at great distances. As a result of this fact, every experimental detonation made by this country to date has had its firing scheduled by the vagaries of nature - to minimize the possibility of hazardous fall-out. In time of war, however, (and particularly where the tactical deployment of atomic weapons is concerned) it may be necessary to forego a minimizing procedure in favor of a calculated risk - for defensive planning as well as offensive. Hence a relatively complete understanding (or a proven sufficiently accurate approximation thereto) of the fall-out mechanism is essential. A calculated risk is unworthy of the name if the risk cannot be calculated.

To better understand the above statements as to the importance of understanding fall-out, and to gain a feeling for how documentation of the phenomenon can be made more feasible, let us briefly consider a qualitative picture of what fall-out is and does.

As we mentioned in the discussion of Project 5.2, a vast majority of the radioactive fission particles are swept up to altitude by vertical winds - the winds being created by the rising fireball. These particles are of many types, and cover a wide range of sizes (for instance from a small fraction of a micron (μ)* to 1 millimeter (mm) in radius). They produce ionizing radiation of half-lives** ranging from a fraction of a second to thousands of years. The maximum altitude to which a particular particle is carried is a function of its size and the average vertical wind velocity to which it is subjected -

* 1 micron = 10^{-6} meters

** The half-life of a radioactive source is the amount of time necessary for it to decay to one-half its original strength.

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and hence of the yield of the weapon. After this maximum altitude is reached, the path of the particle is affected by the downward pull of gravity and whatever forces the atmospheric air motions (winds - both vertical and horizontal) may impose on it.* Hence its path in space will vary from nearly a simple parabola to extremely tortuous curves that defy analytical representation.

Regardless of what such a path may be, however, common sense tells us that it will intersect the ground sooner or later - sooner for large particles and later for small particles. After reaching the ground, a particular particle constitutes a personnel hazard - the magnitude of the hazard depending upon:

(a) The type of decay radiation produced by the particle - gamma, beta, or alpha, for instance.

(b) The energy of the decay radiation, which determines its effective range.

(c) The time after zero, which determines the source strength.

The ultimate theoretical goal in this field is the development of an adequate theory for prognostication of the fall-out-induced dose rate at any point. This can be naturally separated into two distinct problems, as follows:

(a) The problem of deducing particulate fall-out for a given point, and

(b) The problem of deducing the dose rate that will be experienced due to exposure to the above mentioned particles.

The second of these is adequately solved by using an empirically determined average decay rate for fission fragments - namely, that the dose rate is proportional to the inverse 6/5 power of time.

* Unless the particle is sufficiently small to undergo "Brownian movement". In this case, the dominating factor in its motion is bombardment by molecules of air, and its path in space will be dictated by chance. For the sake of simplicity, we shall ignore these particles (radius $<$ approx. $1/2\,\mu$), although it is by no means clear that such a simplification is justifiable from the viewpoint of contributing a negligible fraction of fall-out-induced radiation hazard.

The existence of the second, however, implies that we must know when the particle arrived at a point - the mere fact that it did arrive is not enough. A simple theory explaining the latter phenomena has been evolved, but it requires extensive corroboration and calibration before it can be used with confidence. Prior to BUSTER/JANGLE, the necessary experimental data was not available - since all fall-out measurements were time-integrating (for instance, film badges). This project is intended to further the documentation (started in conjunction with Nevada tests) of fall-out intensity versus time at various fixed points.

Method and Procedure:

A. The instantaneous dose rate at a given point will be measured with an ionization chamber - a device which produces a current signal upon the passage of ionizing radiation. A permanent record is obtained of this instantaneous measurement by using the current signal to drive a pen on a Esterline-Angus (or its equivalent) recorder. Measurement of the pen trace thus obtained will furnish radiation intensity versus time data - the lateral displacement of the pen being proportional to radiation intensity, and the longitudinal position of a point on the paper being a measure of time after zero.

B. Recording devices, of the above mentioned type, will be installed on Bogallua, Rigili, Parry, Biijiri, Engebi, Runit, and Bogon islands. The records from Engebi and Bogon will be telemetered to Parry, in order that the initial recovery teams (on Parry) may know the personnel hazard existent in the northern part of the atoll at that time. All units will be self-contained, and actuated by time clocks.

In addition, it is planned to install such monitoring devices on some ten other atolls in that portion of the Pacific.

PROGRAM 5

GAMMA RAY MEASUREMENTS

Project No: 5.4a

Project Title: Fall-Out Distribution and Particle Size.

Participation: MIKE

Sponsor: DOD (USN - BUSHIPS)

Project Officer:

Name: Lcdr. W. B. Heidt, Jr.
Address: c/o Code 348
Bureau of Ships
Department of the Navy
Washington 25, D. C.
Phone: Liberty 5-6700
EXT. 6-2422

Conducting Agency: U.S. Naval Radiological Defense Laboratory

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer	2	M-30	M/15
Enlisted	8	M-30	M/15
Civilian	2	M-30	M/15

Support Required:

(1) Boats to place rafts within the lagoon and ships to transport men and equipment to selected islands outside the atoll.

(2) Manpower to operate stations on board ship and on islands.

* Plus 2 additional civilians from M-60 to M/15.

Object of the Experiment:

In order to better predict fall-out patterns and probable external and internal hazards to personnel from radioactive fall-out, previous atomic weapons tests have mounted experiments to measure fall-out. As a result, after the SANDSTONE tests a secondary fall-out was reported at Kwajalein (400 miles distant) on YOKE plus 1 day. This fall-out occurred as radioactive rain which fell intermittently during a period of about 10 hours. The maximum activity reported was 6 mr/hr on exposed cloth and tent sides and 10 mr/hr in dried puddles. At Operation GREENHOUSE following DOG shot, a fall-out occurred over the southern half of Eniwetok Atoll. The fall-out on Eniwetok Island started approximately three hours after the shot and continued to build up for a few hours, reaching a peak in excess of 40 mr/hr by mid-afternoon. No secondary fall-out was observed through D plus 6 days. Within a few hours after EASY shot, a fall-out occurred which was restricted to the northern islands of the atoll, near Engebi. A small secondary fall-out occurred on E plus 1 day which was observed only on Aniyaanii, Parry and Eniwetok.

If the yield on MIKE shot approaches that which has been predicted, the cloud can be expected to rise considerably higher than that from any previous test. The gathering of fall-out data from this shot is therefore a logical extension of previous fall-out documentation. The data collected will have direct application in the appraisal of potential health hazards to personnel from external and internal exposure to the fall-out products. It will also furnish additional information for predicting fall-out patterns from other atomic detonations.

This experiment has been designed to accomplish the following objectives:

A. To extend the measurement of fall-out distribution and magnitude following MIKE shot to distances greater than those being documented by Project 5.3. For the most part, this will involve instrumentation of the sea areas around Eniwetok Atoll.

B. To determine, at a limited number of close stations, the rate of arrival of inert liquid or solid materials and associated radioactive materials.

C. To obtain data on size distribution and chemical nature of the active fall-out particles.

D. To correlate the fall-out pattern obtained with that predicted from a knowledge of meteorological conditions and atomic cloud behavior.

E. To calculate fall-out-induced radiation intensities (versus time) and total dose.

Method and Procedure:

The instrumentation to be utilized in securing the necessary data will include the following type of collecting devices:

Type A An integrating collector for both liquid and solid fall-out, comprising a collecting area funneling into a flask. The flask is so designed that it can be removed, from the collector, sealed and shipped.

Type B A liquid rate collector consisting of a modified recording type rain-gage. There will be two models of this instrument, one for recording over a period of one week and one for recording over a period of six hours.

Type C A differential fall-out collector which separates the liquid fall-out with respect to time of arrival at the station.

Type D A differential fall-out collector which separates the solid fall-out with respect to time of arrival at the station.

Type E Greased plates which will be replaced each 24 hours for a period of approximately one week after shot time.

The six-hour Type B collectors and Type D collectors will either be started manually or with blue boxes, depending upon their proximity to the weapon.

The land-based station array within the Atoll will consist of the following:

Land Station	Collecting Devices				
	Type A	Type B	Type C	Type D	Type E
Bogallua	1	1	1	1	
Engebi	1	1	1	1	
Yeiri	1	1	1	1	
Piiraai	1	1	1	1	
Runit	1	1	1	1	
Aniyaanii	1	1	1	1	
Parry	1	1	1	1	1
Eniwetok	1	1	1	1	1

It is currently planned that Type D and E collectors will be employed on certain islands outside the atoll. The exact islands to be used will be determined at a later date. Station installation at a selected island outside Eniwetok Atoll can be accomplished by a team of no more than two men - in a maximum of 24 hours. Subsequent operation of the station might be accomplished by personnel permanently assigned to that area - since it would require only 5 man-minutes per day during the period of interest.

It is also planned to use a number of anchored rafts as instrument stations within the lagoon. These raft stations will be assembled on land and towed to anchorage location.

Stations equipped with Type D and E collectors will be established aboard at least one vessel of each task force unit. This equipment can be delivered to the ship well in advance of proposed operations, and, where Project 5.4a personnel are not present, simple operating instructions will be issued to the ship's force.

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PROGRAM 5

GAMMA RAY MEASUREMENTS

Project No: 5.4b

Project Title: Close-In Particulate Cloud and Fall-Out Studies.

Test Participation: MIKE - KING

Sponsor: DOD (USA)

Project Officer:

Name: Mr. Elmer H. Engquist
Address: Chemical and Radiological Laboratories
Army Chemical Center, Maryland

Phone: Edgewood, Md. 1000
EXTENSIONS 4107, 7267

Conducting Agency: The Chemical and Radiological Laboratories of the U.S. Army Chemical Corps

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	2	M-25	K+7
Enlisted	4	M-30	K+7
Civilian	3	M-25	K+7

Support Required:

(1) The use of a liaison type aircraft or helicopter for the aerical survey.

(2) Rad-Safety monitors for survey recovery operations.

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<u>Object of the Experiment:</u>

At Operations SANDSTONE, GREENHOUSE and BUSTER/JANGLE, the Chemical Corps secured a great deal of data on the distribution of particulate matter in atomic explosion induced radioactive clouds. At Operations SANDSTONE and GREENHOUSE much of this data was obtained by using samplers on drone aircraft. It was used in determining the predominant sizes of gross and radioactive particulates, particulate activity per unit volume of the cloud, specific activity of particulate matter, fractionation of radionuclides with particle size, gross weight of fall-out per unit area as a function of distance and airborne activity contours in the area of cloud travel.

The object of this experiment will be to obtain the following specific data from the clouds produced by Operation IVY atomic detonations:

a. Total activity in the particulate material.

b. Rate of fall-out and the fall-out pattern on land areas of Eniwetok atoll.

c. Determination of the airborne concentration of the radioactive particulate matter near ground level over land areas of Eniwetok atoll.

d. Determination of size distribution of gross and radioactive particulate matter.

e. Distribution of activity with particle size.

f. Determination (with radiochemical techniques) of the presence of selected fission products in the particulate matter.

g. Determination of the adequacy of aerial survey systems in assessing the ground contamination situation.

These data will supplement the previous atomic bomb phenomena observations in the determination of the following:

a. The hazard to personnel resulting from residual fall-out and airborne activity.

b. The contamination of areas and structures.

c. The development of decontamination measures.

[redacted]

Method and Procedure:

The collection of the necessary samples will be accomplished by sampling aircraft for air samples and the Intermittent Fall-Out Sampler and Electrostatic Precipitator for ground samples. These methods and equipment will be discussed in detail below:

Air Sampling - Air sampling aircraft will collect a total sample of gaseous and particulate material from the cloud for the purposes of Project 7.3 and this project. This project will analyze the particulate sample for cloud particle size and distribution. The sampling will be accomplished by F-84G aircraft, each being equipped with a gas sampler. The latter will be installed in the nose of the aircraft with a probe extending forward of the nose through a gunport. The probe contains a solenoid operated valve and is attached to a flexible plastic bag. Initially the bag will be deflated and the valve closed. Upon entering the cloud following the detonation, and at a given radiation level, the pilot actuates a switch opening the solenoid valve. The probe samples the air isokinetically, to fill the bag within approximately ten seconds. The gas sample is subsequently pumped out through a filter into shipping bottles. Both bag and filter will finally be shipped to the ZI for detailed particulate analysis.

Intermittent Fall-Out Sampler - The intermittent fall-out samplers will be located on various islands of the atoll, and will operate in such a way as to document fall-out as a function of time. These samplers will be designed to the following specifications:

a. Initially water-tight to prevent entry of water.

b. Equipped with a Blue-Box with a time delay relay to start the sampling cycle at H-hour plus 5 to 10 minutes.

c. Total sampling time of six (6) hours.

d. The unit will sample fall-out intermittently, with a time interval between sample collections of fifteen minutes.

e. Battery, or spring-wound motor, operated.

f. Sampling surface readily removable from the equipment to facilitate shipment.

It is planned that one of these Intermittent Fall-Out Samplers will be located on each of the following islands of Eniwetok atoll:

Bogallua
Bogombogo
Ruchi
Bogon
Engebi
Muzin
Kirinian
Bokonaarappu
Yeiri
Aitsu
Rujoru
Eberiru
Aomon
Biijiri
Rojoa
Aaraanbiru
Piiraai
Runit
Aniyaanii
Japtan
Parry
Eniwetok
Igurin
Giriinien
Rigili
Coral Head
Artificial Island

Duplicate stations will be established at Engebi, Eberiru, Runit, Japtan, Parry, Eniwetok, Giriinien and Rigili.

Electrostatic Precipitator - These will collect samples of air-borne particulate material. Each precipitator is self-contained and similar to a portable electrostatic precipitator developed and manufactured by Mine Safety Appliance Company. The collecting surface will be modified to include electron microscope screens for particulate analysis. Such units will be located on Engebi, Eberiru, Biijiri, Runit, Japtan, Parry and Eniwetok.

Aerial Survey - These data will be obtained with survey meters in light aircraft or helicopters, with detailed data being taken with survey meters equipped with recorders. It is planned that these data be taken by a Rad-Safety monitor in each aircraft and made available to this project. Detailed information is required on the altitude, flight path, air speed, estimated ground speed, location relative to the ground, etc., to permit interpretation of the graphical data.

PROGRAM 6

BLAST MEASUREMENTS

Project No: 6.1 Project Title: Pressure vs. Time on the Ground.

Test Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Mr. Harlan E. Lenander
Address: Proving Ground Department
(Code 5230) Sandia Corporation
Sandia Base, Albuquerque, New Mexico

Phone: Albuquerque 6-4411
EXT. 7133

Conducting Agency: Proving Ground Department
Sandia Corporation

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian			

Support Required:

* See "Remarks" on Page 6.1.4

Object of the Experiment:

A complete understanding of blast phenomena involves many problems - very few of which can be adequately treated with theoretical methods alone. To the bomb design theoretician, knowledge of the free-air* pressure field that would be established in a homogeneous atmosphere by a given atomic explosion is sufficient. Such knowledge would imply an understanding of how the explosion energy is partitioned (between the various energy transport mechanisms) and how at least part of that energy is propagated. In the strict sense, the phrase "field variable" means just that when applied to pressure. Since no such homogeneous atmosphere exists, however, and we see that pressure can never be studied as a field variable in the strict sense, it seems logical to study pressure fields that have been perturbed only by atmospheric inhomogeneities. The discussion of Project 6.2 is devoted to explaining the proposed contributions of Operation IVY to such studies.

The next step in complexity involves studying the pressure field, near a reflecting surface, in order that one may understand how such a surface perturbs the field - as a function of pressure, time, characteristics of the reflecting surface, and characteristics of the atmosphere above the surface. This project is designed to augment the existing fund of experimental data on the latter - by measuring pressure as a function of time, on or near the earth's surface, at various fixed points around Eniwetok atoll for shots MIKE and KING. The value of such data to those interested in Weapons Effects is clear, since most objects that one might wish to destroy with (or protect from) an atomic bomb are located on or near the surface of the earth.

Method and Procedure:

A. One device which measures the instantaneous incident pressure is known as a Wiancko gauge. This instrument makes use of the pressure-induced deformation of a twisted "bourdon" tube to vary the inductance of a coil - thus generating an electric signal, the magnitude of which is proportional to the instantaneous value of the incident pressure. A permanent record of the signal is made electronically, either on magnetic tape, photographic film or paper. Each gauge thus supplies a record of pressure versus time at its location - and a pressure versus distance record is obtained by placing gauges at a number of different positions.

To obtain information as to azimuthal variations in the field, gauges are located on different radial lines from zero. To separate "surface" effects from the records, the gauges are mounted a few feet above the ground on small towers. When the latter is not feasible, the

* See the discussion of Project 6.2.

gauges are mounted flush with local surfaces (ground baffles).

B. For MIKE shot, Wiancko air pressure gauges will be placed at thirteen positions around the eastern side of the atoll, as follows:

Station Number	Island	Dist.from Zero (ft.)	Type of Gauge Mount
614	Teiteiripucchi	4422	Ground baffle
615.01	Bogairikk	5900*	Ground baffle
616.01	Bogairikk	5900*	Ground baffle
615.02	Bogon	8250**	Ground baffle
616.02	Bogon	8250**	Ground baffle
610	Site Noah***	11490	15 foot tower
611.01	Engebi	15900	15 foot tower
611.02	Muzin	21412	15 foot tower
611.03	Bokon	30130	15 foot tower
611.04	Aomon	47574	15 foot tower
612.01	Parry	-	15 foot tower
613.01	Aitsu	-	10 foot tower
613.02	Runit	74884	10 foot tower

In this way, an estimated peak pressure range of from 0.8 to 300 pounds per square inch (psi) will be covered. The recording will be accomplished in the following stations:

Station Number	Island	Type of Structure
600	Bogon	New concrete blockhouse
601	Engebi	GREENHOUSE station 301J
602	Muzin	" " 301H
603	Bokon	New concrete blockhouse
604	Aomon	GREENHOUSE stations 132a & b
605	Runit	" " 55
606	Parry	New wooden blockhouse

In every case, signal wiring is being kept to a minimum, both by recording at the nearest available recording station and by careful selection of gauge locations.

* Different radial lines.
** Different radial lines.
*** This is a small artificial island on the reef between Bogon and Engebi.

For KING shot the same type of gauge will be used, and two measurement lines will be established - one over water and one over land. For the former, the gauge mounts will be 15 foot towers, located at 2500, 3000, 4000, 5000, 6000, 7000, 10,000, and 15,000 feet from bomb zero. The line will extend along the reef to the south, an attempt being made to keep each instrument at least one hundred yards from land - in order that the measurements may be more nearly "over water". The land line will be established on Runit, and will consist of the following:

Station Number	Distance from Zero (ft.)	Type of Gauge Mount
6101.01	3000	Ground baffle
618	5000	15 foot tower
6101.02	5000	Ground baffle
619.01	7000	15 foot tower
6101.03	7000	Ground baffle
619.02	9678	15 foot tower
6101.04	9678	Ground baffle

Recording of these measurements will be accomplished in station 605. In addition to the above, one gauge will be mounted (on a 15 foot tower - station 612.02) on Parry - the measurements of which will be recorded in station 606.

Remarks:

The Proving Ground Department of Sandia Corporation is responsible for four distinct projects (6.1, 6.3, 6.5, and 6.7b) of the Blast Measurements program. The work loads imposed by these projects, however, are not separable. As a result, the Sandia Corporation personnel under Mr. Lenander's supervision will devote their efforts to all projects equally. In lieu of listing personnel requirements for the individual projects, the following table is presented; to represent the total proposed forward area requirements for the above mentioned four projects:

Officer	Enlisted	Civilian	From	To
		2	M-130	M+7
		1	M-99	M+7
		3	M-59	M+29
	12	21	M-44	M+29
		2	M-14	M+25

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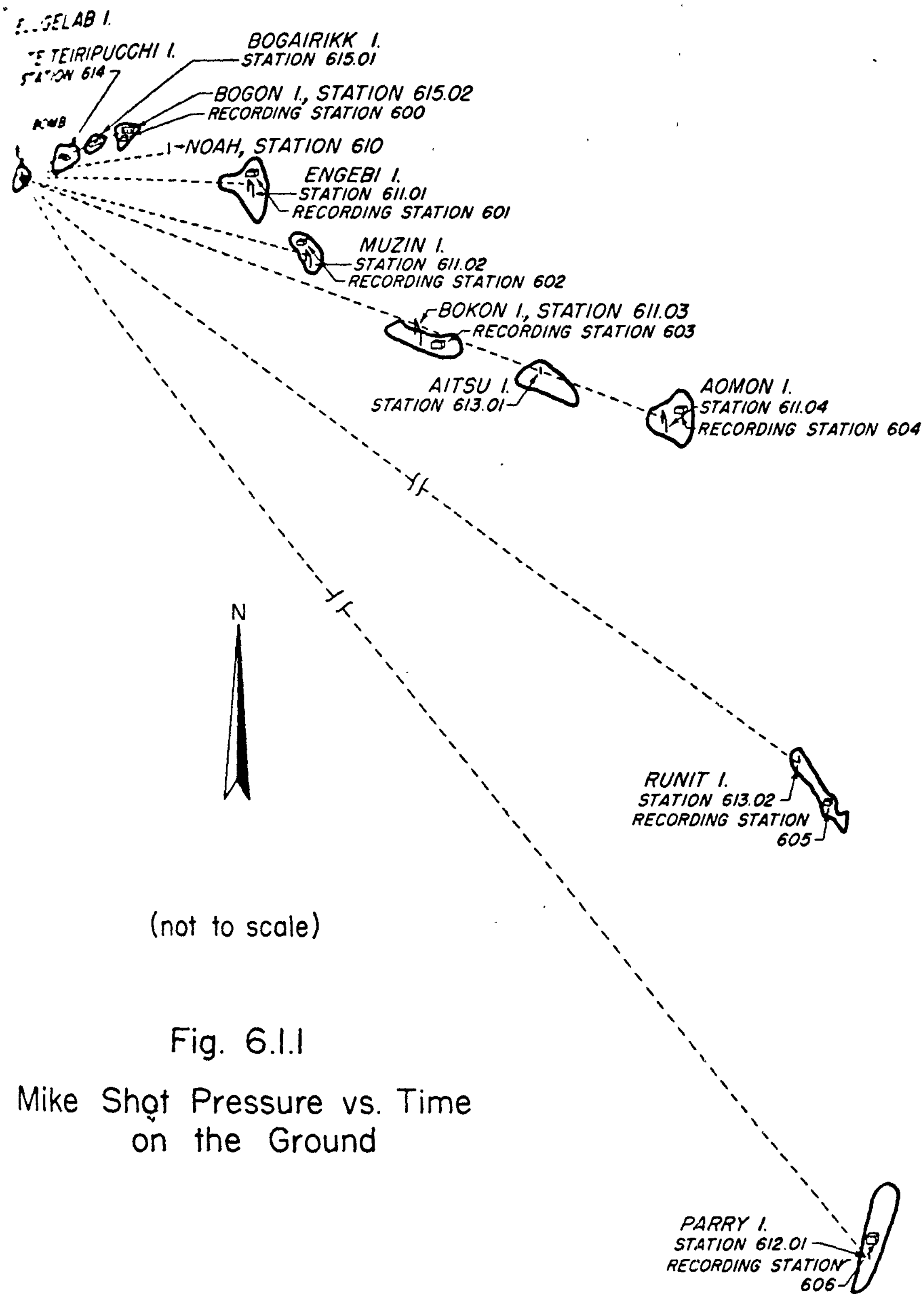
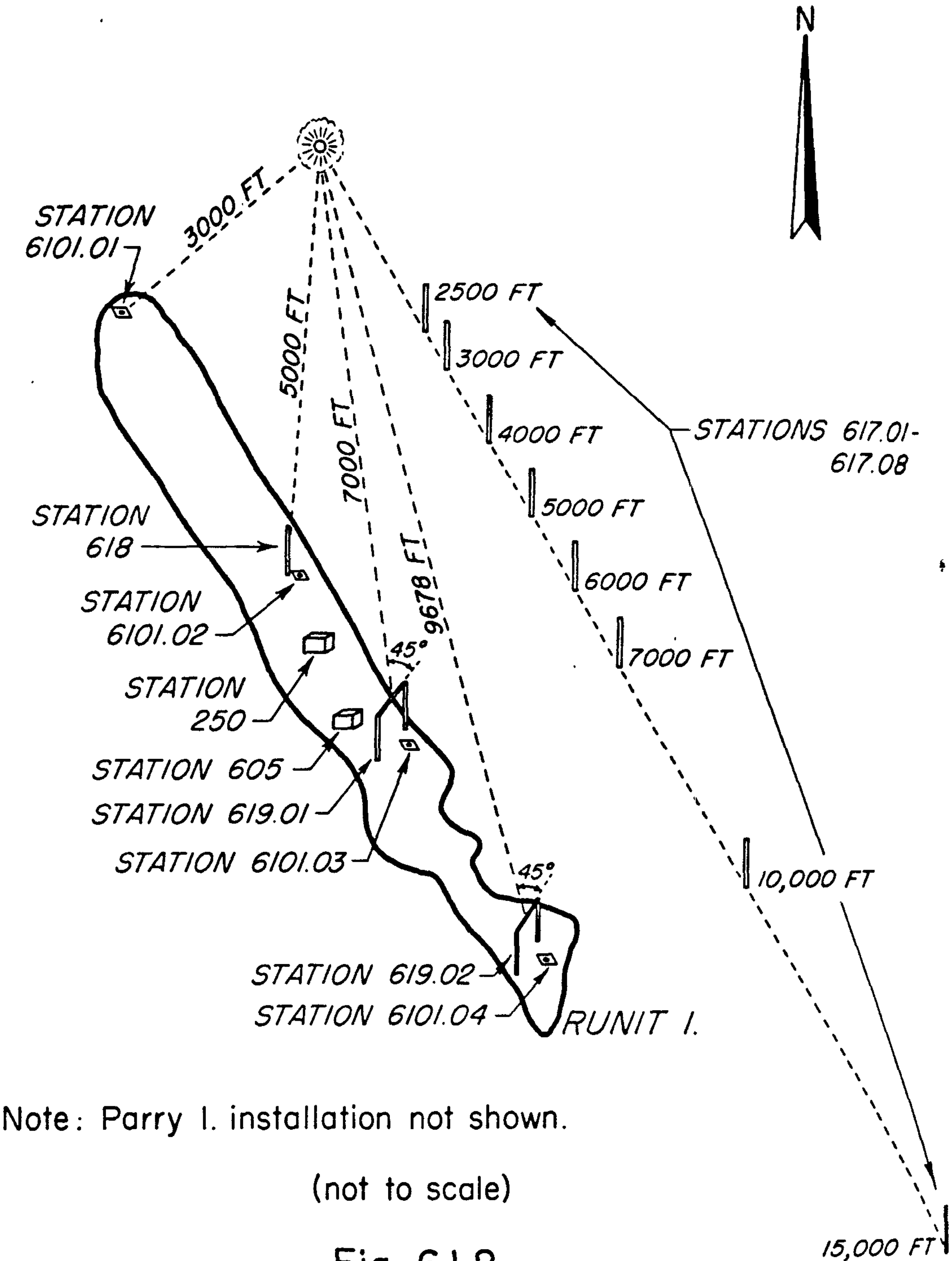


Fig. 6.1.1

Mike Shot Pressure vs. Time on the Ground



Note: Parry I. installation not shown.

(not to scale)

Fig. 6.1.2
King Shot Pressure vs. Time on the Ground

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PROGRAM 6

BLAST MEASUREMENTS

Project No: 6.2 Project Title: Air Mass Motion Studies

Test Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Lt. Col. Francis B. Porzel
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-2766

Conducting Agency: Group J-10
Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	1	M-60	K/15
Enlisted	6	"	"
Civilian	1	"	"

Support Required:

6.2.1

[redacted]

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Object of the Experiment:

One of the most perplexing problems in the field of atomic weapons effects is the obtainment of an accurate and complete free-air over-pressure versus distance curve. By complete we mean a continuous record of pressures from the relatively high (hundreds of pounds per square inch) to the very low (a fraction of a pound per square inch). Over-pressure, of course, is defined as absolute pressure less ambient pressure - and the term free-air implies the true absolute pressure existent at a point in the atmosphere, in the absence of such perturbing factors as measuring instruments, structures, aircraft, or the earth's surface.

Unfortunately, the hydrodynamical equations which describe this phenomenon completely can be written but not solved. An approximate solution has been obtained with IBM machines, under the simplifying assumptions of a homogeneous atmosphere and no radiative transport of energy - this solution, however, is of maximum value only when supplemented with experimentally determined facts, as it tells us nothing about the attenuation of the shock strength with passage to altitude.

The obtainment of such experimentally determined facts is fraught with difficulties, as will be seen from an examination of our definitions above. First one must develop an instrument which will document the passage of the shock wave without disturbing that passage in any way, otherwise the measurements will not be true "free-air". Then a system must be evolved for fixing these instruments at known positions in space.

The importance of having the above mentioned pressure versus distance curve cannot be overemphasized. For instance, in the field of atomic weapons effects alone, the correct answers to the following questions would come much closer to being a reality:

(1) What is the minimum safe target approach distance for a dropping aircraft, as a function of target altitude, aircraft altitude, and energy release of the weapon?

(2) What accuracy is required for the optimal use of atomic warheads in anti-aircraft projectiles, as a function of target altitude, target velocity, probable target dispersal (tactical deployment of aircraft formations), and energy release of the warhead?

(3) What is the optimal bomber formation for effective deployment against an enemy target which may be defended by atomic anti-aircraft projectiles?

At the present time, these questions (and many others, closely related) can be answered in an approximate way only - by making many simplifying assumptions. The availability of good free-air pressure versus distance information will decrease the number of those assumptions by at least one. This experiment attempts to supply some of this information, by employing an "ingenious device" to partially surmount the experimental difficulties mentioned above.

Method and Procedure:

A. One method of labeling the atmosphere is supplied by smoke puff photography. A puff of smoke is placed in the atmosphere - in the region of interest (the placement procedure will be discussed below). A motion picture camera has been previously aligned in such a way that the puff is well within its field of view, and the camera has been supplied with a device for placing timing "pips" on the film. Subsequent photography of the puff, and film analysis procedures, will supply the experimenter with a time history of the puff's motion and perturbation.* Use of one camera, of course, will only document the projection of the puff on a plane perpendicular to the axis of the camera. If one places the puff in a known plane initially, however, and makes wind corrections, a reasonable approximation to the three dimensional path of the puff can be obtained.

Such a method should supply us with the following information, with fair accuracy:

(a) The elapsed time from zero to the arrival of the shock at the puff. This combined with the Eulerian coordinates of the puff at that time (obtained from film analysis) will supply a point on the free-air shock time of arrival curve.

(b) The motion of the puff after passage of the shock. Such "mass motions" are theoretically associated with the variation of shock strength with time, and hence with the variation of shock overpressure with time in that region. This represents the primary measurement of the project.

* The puff itself may be thought of as a point in the Lagrangian coordinate system, and the technique outlined herein is a method of associating this Lagrangian point with both time and the Eulerian coordinate system.

B. For MIKE shot, low altitude ($\sim$ 400 feet) labeling of the air will be accomplished with exploding mortar projectiles. The distances from zero will be similar to those chosen for the Wiancko gauges of Project 6.1 - the actual positions, however, are quite different. Most of the mortars will be mounted on ten foot square rafts and placed in the lagoon, to allow photography from stations on the eastern side of the atoll. The four close-in mortars will have their firing mechanisms actuated with EG&G timing signals - the remainder will be actuated by means of "blue boxes". The mortar-produced puffs will be photographed by ten Mitchell (100 frame/sec) cameras - from vantage points on Engebi, Rojoa, Runit, and Parry. These cameras will be mounted in individual shielded steel boxes on concrete pillars.

In addition, the air will be labelled with smoke at ten altitudes above the bomb (5000, 6000, 10,000, 11,000, 15,000, 16,000, 20,000, 21,000, 25,000, and 26,000 feet) by means of bursting shells from guns. The guns will be placed on Engebi, and the bursts will lie on a line defined by the intersection of the following planes:

(1) A plane such that a horizontal line in that plane is perpendicular to the line from zero to the photo station on Rojoa. This plane makes an angle of 60 degrees with the horizontal, passing through zero and leaning toward Rojoa.

(2) A plane such that a horizontal line in that plane is parallel to the line from zero to the Rojoa photo station. This plane makes an angle of 75 degrees with the horizontal, passing through zero and leaning toward Bogollua.

The ten guns will be placed on Engebi, each gun assembly being mounted on a concrete pad (10 feet square and 8 inches thick). Since the lowest burst height is 5,000 feet, the choice of the above line (along which the bursts will lie) implies that no gun is aimed toward the bomb. If the velocity of a projectile be wrong, the nearest possible approach to the bomb is 1,000 feet. All guns will be fired with timing signals furnished by EG&G. The gun-produced puffs will be photographed by five Mitchell (100 frames/sec) cameras, from the photo station on Rojoa.

For KING shot, only the low altitude ($\sim$ 400 feet) air labeling technique will be used. Eight mortars will be placed on a line running approximately northwest from ground zero - the nearest being at 4,000 feet and the most distant being at 15,000 feet. The puffs will be photographed by Mitchell cameras from the Rojoa photo station.

Remarks:

1. A fundamental difficulty with this measurement is the fact that cloud coverage may result in complete failure to obtain data. Since this method is the simplest known way to obtain the information sought, however, it is felt that the chance is worth taking.

2. It should be clearly understood that high orders of accuracy in the obtainment of free-air pressure information are not essential to the present day "effects on things" planning. This is due to the fact that the response of the "things" to those pressures is not well understood. Such a fact, however, does not preclude the desirability of understanding the pressure field about an atomic bomb explosion as completely as possible. Future developments in the field of structural analysis may well make highly accurate pressure knowledge necessary.

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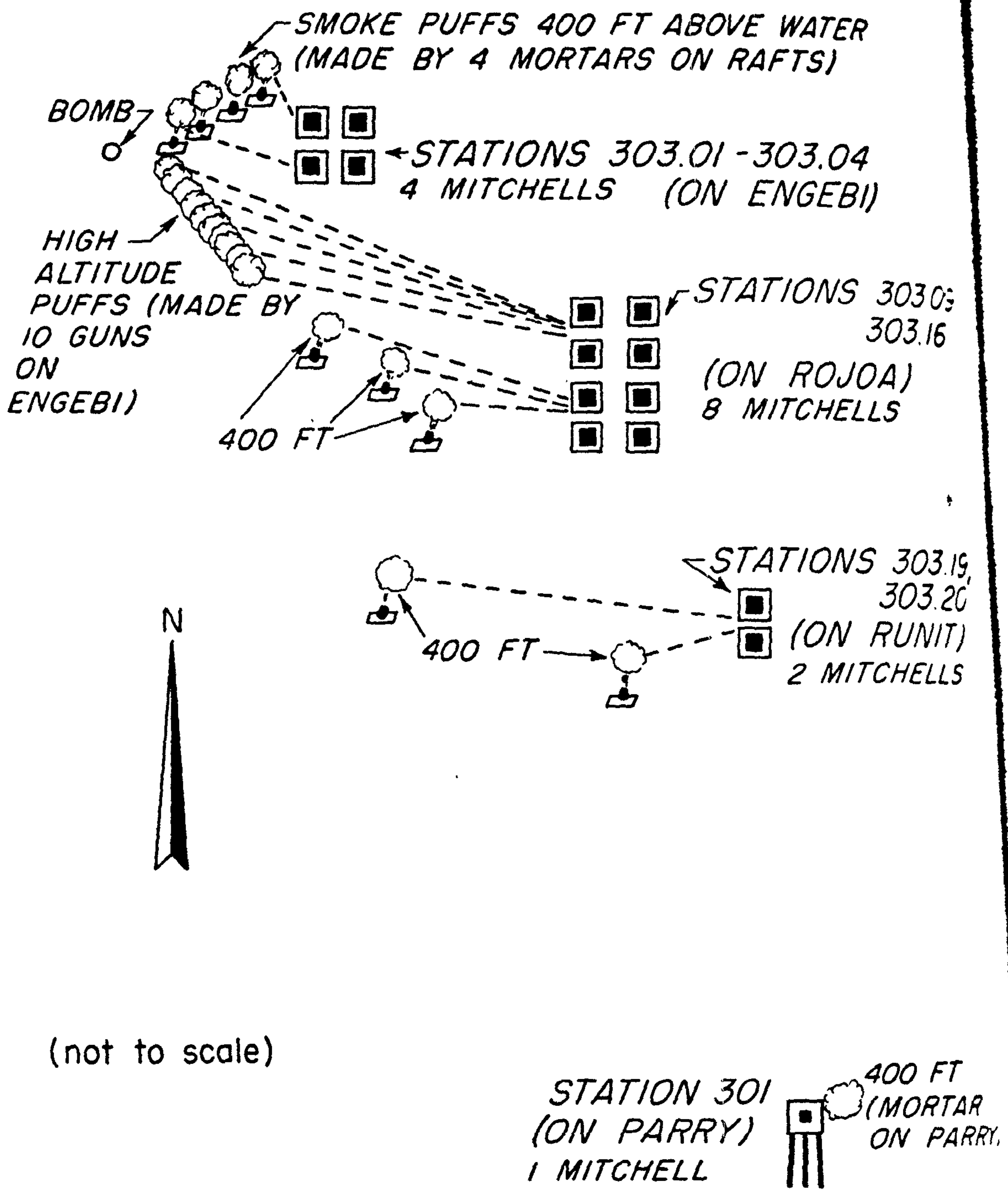

Fig. 6.2.1
Mike Shot Air Mass-Motion Studies

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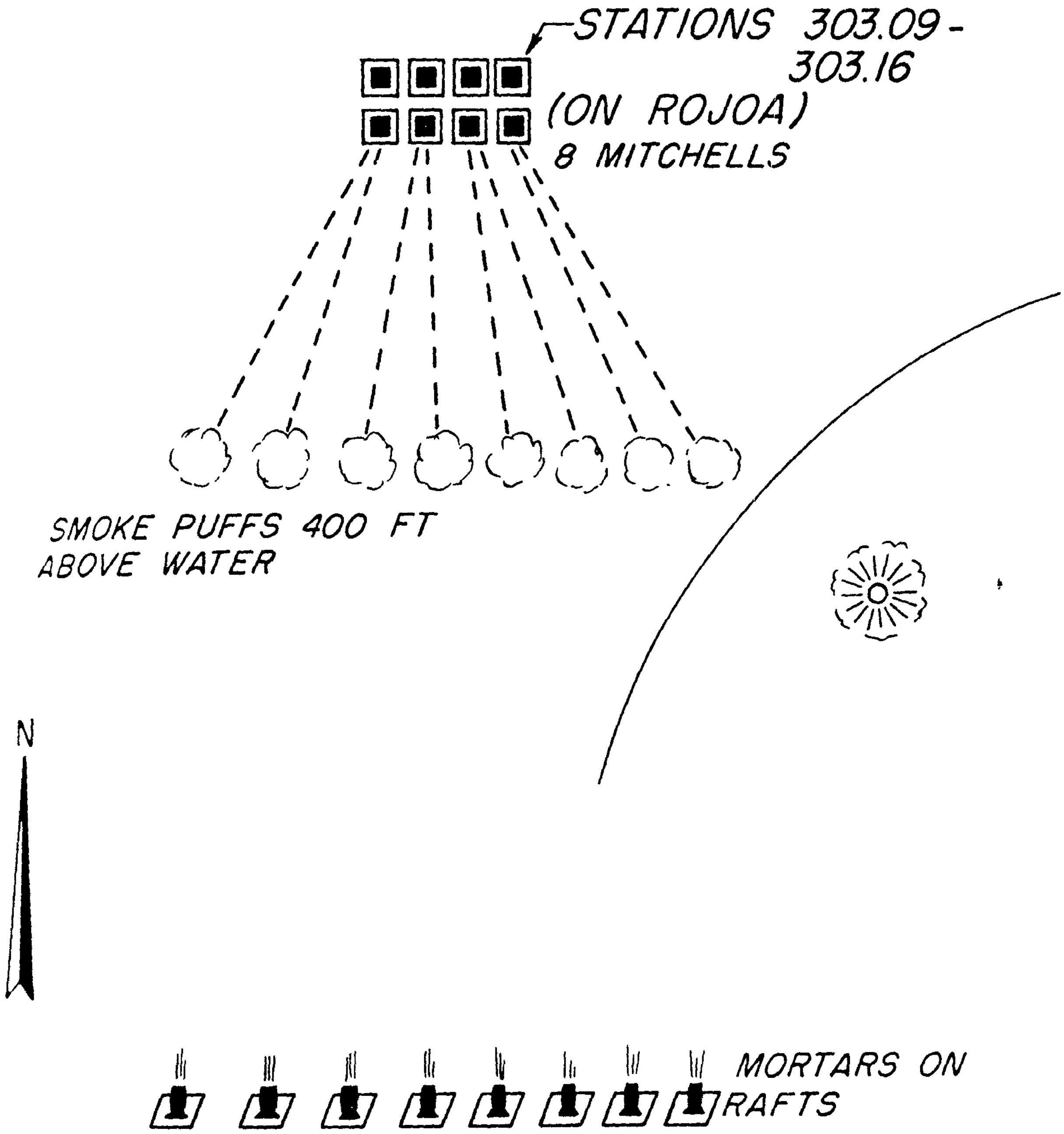

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Fig. 6.2.2

King Shot Air Mass-Motion Studies

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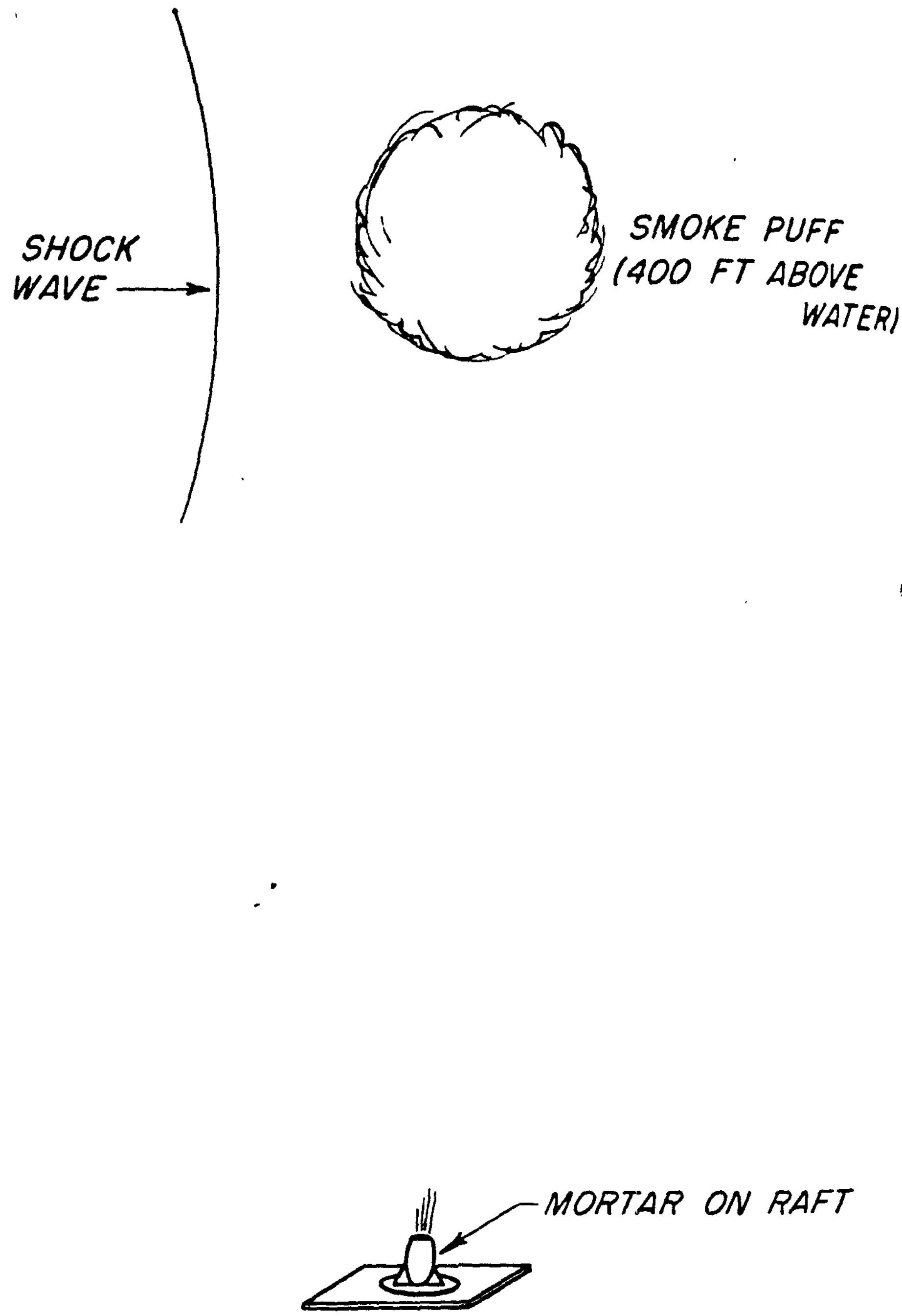

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Fig. 6.2.3
Detail for Low Altitude Smoke Puffs

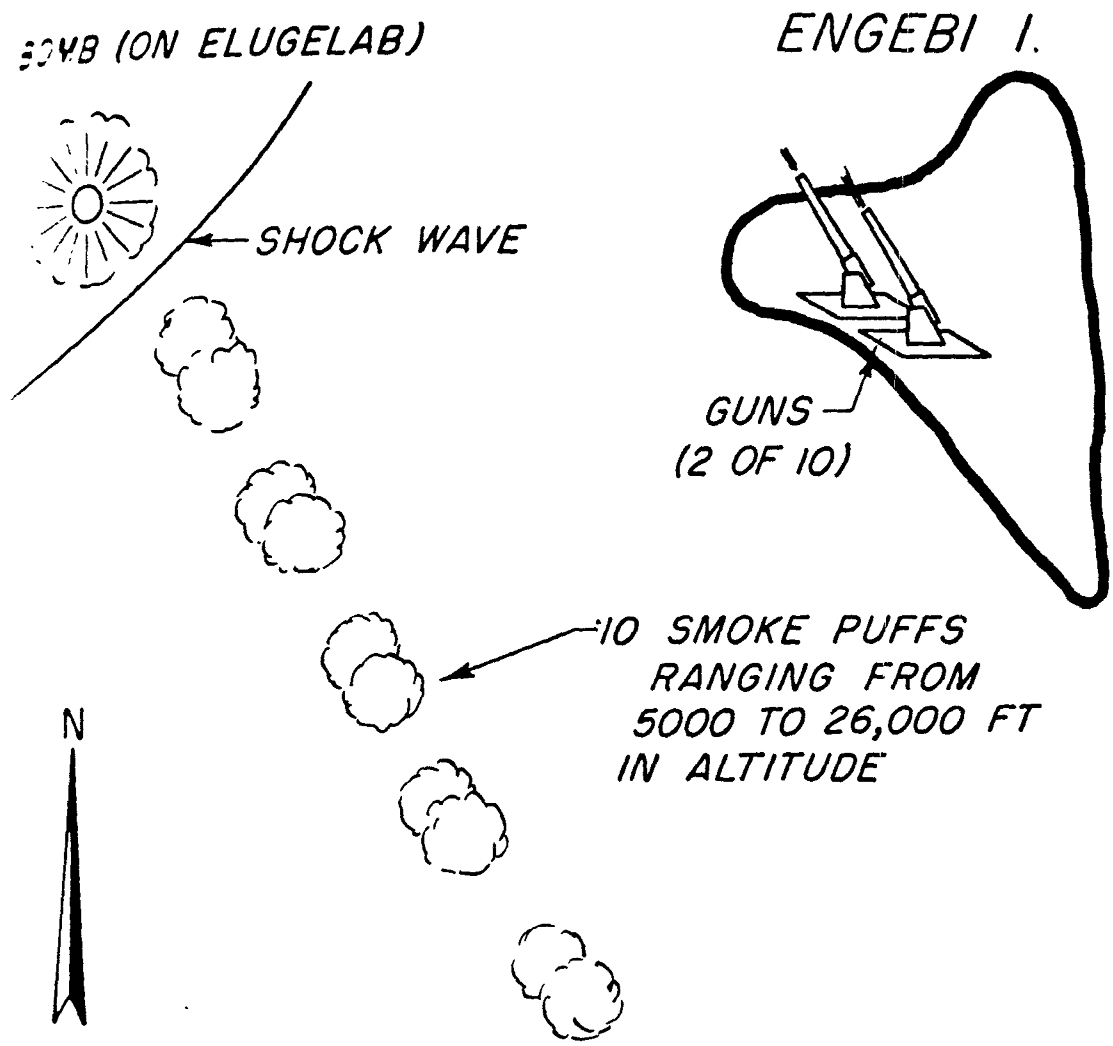

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Fig. 6.2.4
Detail for High Altitude Smoke Puffs

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PROGRAM 6

BLAST MEASUREMENTS

Project No: 6.3 | Project Title: Shockwind, Afterwind, and Sound Velocity.

Test Participation: MIKE - KING

Sponsor: AEC

Project Officer:*

Name: Mr. Harlan E. Lenander
Address: Proving Ground Department
(Code 5230) Sandia Corporation
Sandia Base, Albuquerque, New Mexico

Phone: Albuquerque 6-4411
EXT. 7133

Conducting Agency: Sandia Corporation
&
Group J-10
Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:**

	Approximate Number	From	To
Officer	1 (J-10)	M-45	K+7
Enlisted			
Civilian	1 (J-10)	M-45	K+7

Support Required:

* See "Remarks" on page 6.3.6

** See page 6.1.4

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[redacted]

Object of the Experiment:

The static pressure experienced by a fixed point in the blast field exhibits the following qualitative variation with time:

(a) Prior to shock arrival it remains relatively constant at its ambient value.

(b) Passage of the shock wave is accompanied by an abrupt pressure rise to some peak value. This peak value is determined in part by the distance from bomb zero and the energy release.

(c) After the shock passes the pressure falls (in something like an exponential fashion) with time from the above mentioned peak to below-ambient values. It subsequently passes through a minimum, and finally approaches the ambient value from below.

For a given point in space, the period during which the pressure is greater than ambient is known as the "positive phase" - and the period during which the pressure is below ambient is known as the "negative phase". The positive phase is characterized by a wind blowing radially outward (from zero) and the negative phase is characterized by a wind blowing radially inward toward zero. These are the shock winds. Material velocity behind the shock (one of the parameters entering into the equations used to describe shock propagation) is another name for the shock wind in that region.

The rising fireball creates a tremendous "updraft" in the vicinity of bomb zero. Such a vertical motion of an air column creates a low pressure region near the base of the column. This in turn causes outside air to flow into the lower portion of the column. The latter is called the "afterwind".* For a sufficiently small burst height (above the earth's surface), the above mentioned column rests on the ground - and the afterwind includes horizontal components at ground level, directed toward ground zero. The mechanisms which create an afterwind on the one hand and a "fire-storm"** on the other hand are essentially the same.

* The term "afterwind" may also be used to include the shock winds of the negative phase. In this case, the phrase "shock wind" applies only to the radially-outward winds associated with the positive phase.

** Similar to that following the Hiroshima detonation.

When an object is placed in a moving fluid, such as air, the pressure to which the object is subjected consists of two distinct components - the static pressure and the dynamic pressure. The former is the pressure that the object would "see" if it were moving with the fluid - the latter is the additional effective pressure on the object, produced by the fluid velocity. Which of these components is the larger depends on the particular conditions - and each is capable of destruction, as an inanimate object has no way of differentiating between them. Thus the above mentioned winds are potential destructive forces, and are worthy of study as such.

The ambient (unshocked air) sound velocity, the material velocity behind the shock, and the sound velocity behind the shock are all parameters which occur in theoretical shock wave descriptions. As a result, their experimental documentation for an actual wave is very valuable to a complete description of the phenomena associated with the wave.

The objectives of this project are thus seen to be two-fold, as follows:

(a) The measurement of shock winds and afterwinds at various distances from ground zero.

(b) The measurement of sound and material velocities, both prior to and after shock arrival, at various distances from ground zero.

Method and Procedure:

A. At this writing, feasibility tests of several instruments are being conducted at the NTS. Final decisions as to which of these instruments will be used for IVY will be forthcoming on or about 15 June. Among those instruments being considered are the following:

(a) A double-ended pitot head assembly. This instrument measures both total (static plus dynamic) and static pressures. It is made double-ended in order that both the positive and negative phase winds can be documented. Its mode of operation is identical to that of any aircraft pitot head.

(b) A so-called Sonic Interferometer. This instrument assembly consists of a pulsing mechanism, two sound wave generators, two receivers, a timing oscillator, an interval timer, and recording equipment. That portion of the assembly which actually is subjected to the blast wave is mounted on the cross bar of a "goal post" type tower, some 15 feet above the ground. The two sound wave generators are located at the center, and one receiver is attached to each end, of the bar. The goal post is oriented in such a way that the bar makes a 45 degree angle with the oncoming blast wave. Hence one receiver is upstream, and the other is downstream, of the transmitter head. The remainder of the assembly (pulsing mechanism, timing devices, and recording equipment) is mounted in a nearby recording station, to and from which the necessary signals can be carried by wires.

In brief, operation of the above instrument is as follows:

(1) The timing oscillator (set for 250 signals per second) triggers the pulsing mechanism and the interval timer simultaneously.

(2) The pulsing mechanism feeds a pulse to the transmitter head, which in turn generates two sound waves.

(3) Upon detection of a sound wave, a receiver notifies the interval timer and its associated recording equipment.

The basic data obtained by the instrument consists of elapsed time measurements - from the electronic initiation of each signal to its recording after detection by both receivers. Calibration allows these measurements to be interpretable in terms of the sound wave transit times over both upstream and downstream air paths. The latter information can in turn be theoretically related to both local sound velocity and wind velocity.

(c) Kiel-meters and Q-tubes. These instruments are commonly used for wind tunnel pressure measurements. Their operation is based on an application of Bernoulli's principle.

(d) A device known as the Sonic Anemometer, the name being derived from the fact that it is a wind velocity measuring instrument which probes the velocity field with sound waves. This interesting device, which was designed and developed by Group J-10, of LASL, measures the elapsed times between the creation of a sound wave

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(by a spark gap) and its arrival at two microphones. The path lengths in air (from spark gap to each microphone) are identical in length and oriented differently with respect to a radial line from bomb zero. The difference in wave arrival times, at the two microphones, is a measure of the relative motion of the air through which the wave passed - and hence of the local wind velocity. The time required for a wave to traverse a given path is a measure of the average sound velocity over that path.

A typical installation consists of a 24 inch (diameter) hole in the ground (16 feet deep) - around the mouth of which three steel pipes extend vertically some six feet above the ground. The pipes are located at the vertices of an isosceles right triangle, the altitude of which is perpendicular to a radial line from ground zero. The microphones are located at the tops of the pipes at either end of the triangle base, and the spark gap is located at the top of the pipe remaining. The air paths are thus the equal sides of the triangle - each being approximately one meter long. The electronic equipment, including a dual-trace recording oscilloscope, and a Warrick high speed camera which provides permanent records by photographing the scope face, are mounted in the hole - cheap shielding from ionizing radiation thus being obtained.

B. For MIKE shot, Group J-10 of LASL will measure both sound and inward directed wind velocities - using Sonic Anemometers. These measurements will start at the end of the positive phase (at a given station) and extend for approximately ten seconds. The instrument locations will be as follows:

Station Number	Island	Distance from Zero (ft.)
630.01	Engebi	19363
630.02	Kirinian	24104
630.03	Bokon	30764
630.04	Biijiri	51008

The possible participation of this group in the KING shot program is as yet unsettled.

The Proving Ground Department of Sandia Corporation, using one or more of the other instruments mentioned, will also measure sound and wind velocities for both MIKE and KING shots. Their instruments

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will be mounted on, and the recording for them will be done in, Project 6.1 stations* (15 foot towers and associated recording stations) - on Bogairikk, Bogon, Engebi, Muzin, Bokon, Aomon, Parry, and Runit. The two closest stations will not measure wind velocity directly, because of its great magnitude, but will measure pressure differences along a shaped surface - from which the wind velocity can be calculated. Shaped surface designs are not yet available, but they will probably be concrete walls 5 to 10 feet high and 20 to 30 feet long.

Remarks:

Major Jack E. Whitener, of LASL, is the Project Officer for the Sonic Anemometer portion of this experiment. For those interested in contacting him for additional details of his work, we offer:

Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-2766

* This includes the Sonic Interferometer goal posts - stations 611.01, 611.02, 611.03, 611.04, 619.01, and 619.02.

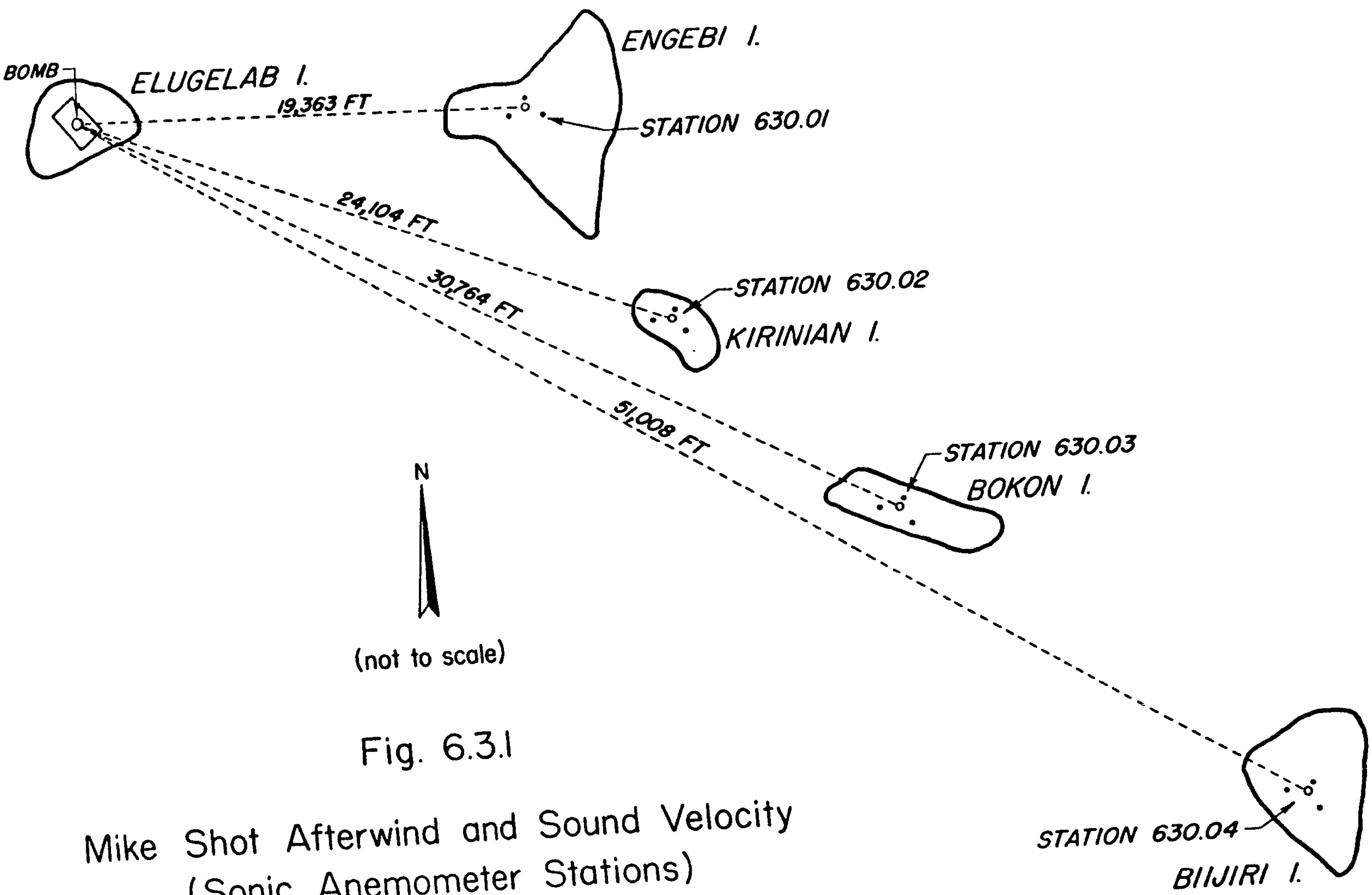

Fig. 6.3.1

Mike Shot Afterwind and Sound Velocity
(Sonic Anemometer Stations)

6.3.7

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PROGRAM 6

BLAST MEASUREMENTS

Project No: 6.4a | Project Title: Water Wave Motion - Shallow Water - Photographic.

Shot Participation: MIKE

Sponsor: AEC

Project Officer:

Name: Cdr. William D. Baker
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-2766

Conducting Agency: Group J-10
Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	1	M-45	M+1
Enlisted			
Civilian			

Support Required:

(1) Overseas shipment of floats.

(2) Small craft for laying floats.

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Object of the Experiment:

As a continuation of the studies outlined under Project 6.4b, this project is designed to document water surface motions within the lagoon.

Method and Procedure:

A. Both the wavelength and amplitude of lagoon water waves will be observed photographically. To make such a technique feasible, the water surface will be labelled with floats. Each float will be located within the fixed field of view of a Mitchell (~100 frames/sec) camera. Subsequent film analysis will allow the construction of a position-versus-time function for each float - and hence for those water surface points.

B. The fields of view of those Mitchell cameras arranged to observe mortar-produced smoke puffs (see Project 6.2) will include the water surface. Hence ten film records can be obtained for this project by the proper location of floats alone. In addition, to obtain further coverage, three Mitchells will have a primary mission of obtaining records for this project. The latter will be mounted in individual shielded steel boxes on concrete emplacements. One each will be located on Engebi, Runit, and Biijiri.

The above instrumentation will allow documentation of lagoon water surface motions in the vicinity of Parry, Runit, Rojoa, and Engebi.

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PROGRAM 6

BLAST MEASUREMENTS

Project No: 6.4b Project Title: Sea Waves.

Shot Participation: MIKE

Sponsor: DOD (ONR)

Project Officer:

Name: Willard Bascom
Address: Scripps Institution of Oceanography
La Jolla, California

Phone: Glencove 5-4214

Conducting Agency: Scripps Institution of Oceanography
(University of California)

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer			
Enlisted			
Civilian	12	M-15	M/2

Support Required: The conducting agency will use two of its own fleet type tugs. In addition, military support will be furnished by Joint Task Force 132 - for operations at and in the vicinity of Bikini atoll.

Object of the Experiment:

MIKE shot is expected to produce rather substantial waves on the surface of the surrounding water. This project is designed to document:

(1) The characteristics of the waves produced (number, height, period, length, and velocity).

(2) The amount of blast energy being transferred into wave-making.

(3) The nature of propagation and refraction of seismic-like waves over large areas of ocean.

Although many experiments which give a reasonably good picture of explosion-generated waves have been conducted, they have been for comparatively uncomplicated conditions. The principal problem is to ascertain the means by which energy is transferred from the explosion to the water (the impedance match). Such a problem is particularly difficult in this case because we have no comparable experiments upon which to base an estimate. For example, the "Seal" experiments by Leech indicated that there is a second critical depth, close to the water surface, at which a remarkably high percentage of blast energy goes into wave energy. In fact, the use of near-surface explosions is a promising means of deluging an enemy beach prior to an amphibious assault. This would lead one to assume that the MIKE waves will be high. On the other hand, the fact that the actual explosion will be over land suggests a poor impedance match and a low transfer of energy to wave making. There are at least six means by which waves may be produced:

(1) The existence of a high pressure area of considerable duration over the water surface near ground zero will give an initial outward impulse to the surrounding water.

(2) The pressure and tremendous heat will create a crater, the collapse of which may cause a second wave to start outward.

(3) A submarine landslide may be started by the blast, resulting in a tsunami (tidal wave) which, though a secondary effect, might make large waves at a distance.

(4) The air-pressure wave travelling across the water surface may be accompanied by a water wave of equal velocity.

(5) There may be a mass of rock and material lifted from the crater which will fall back into the sea - thus creating waves.

(6) Because of the assymmetry of the situation, with the shallow

lagoon (150 ft.) on one side and the deep ocean (12,000 ft.) on the other side, it is probable that the water crater will be much larger on the ocean side and that its collapse may throw a great mass of sea water into the lagoon - thus creating a secondary wave source.

Another very important, and highly indeterminate, fact is that under such circumstances these waves are likely to be of low amplitude in the deep ocean but may peak-up very considerably upon arriving at distant shores.

The value to the sciences of geology and geophysics of instrumenting a controlled seismic sea wave, perhaps the only one in history, can well be imagined.

Method and Procedure:

Waves are to be measured at four general types of locations:

1. In Eniwetok Lagoon.

2. In the open ocean nearby (undisturbed).

3. On the shores of islands at moderate distances (subject to some refraction and diffraction).

4. At great distances which are highly modified by the configuration of the bottom and the juxtapositions of islands.

The following specific locations and instruments have been chosen which, it is believed, will give the most satisfactory records of such waves:

(1) On Eniwetok island a shore recording station will receive electrical impulses thru a submarine cable from a pressure pick-up in about 60 feet of lagoon water. This is a tried and true instrument combination which has been used successfully in the past for measuring ocean swell.

(2) To the north of ground zero there are no suitable (nearby) islands at which the above "standard" instruments can be used. It is necessary, however, to measure waves reasonably close to ground zero in deep water. For this, a radical departure from previous methods of instrumentation will be required. A deep-sea mooring which utilizes the tops of undersea mountains (at 26 and 72 miles) will be tried; these flat-topped seamounts rise from 12,000 feet of water to within 4,000 feet of the surface and are thus in comparatively shallow water. A taut-line mooring with an underwater buoy for a pressure pickup station, connected by slack line to a spar-buoy containing the recording elements, will be used. Although this scheme is as yet untested, we believe it will be successful; and the eventual value of such an instrument-placing technique in undersea warfare can scarcely be overestimated.

(3) An installation on the seaward side of the westernmost islands of Bikini atoll, similar to that at Eniwetok, is necessary to measure waves at the third type of location. Here the first record of shoaling waves will be taken; diffraction will be measured and perhaps some indication of energy transfer can be obtained. Bikini will also have shore-recording wave meters cable-connected to pressure pick-ups in shallow water.

(4a) In order to measure waves at greater distances (500 - 2000 miles) a simple water-level recorder will be used which can be mounted on existing pier pilings. This instrument measures the differences in elevation of the water surfaces in two adjacent pipes which are suitably damped to exclude low frequency waves. Such installations are planned for Hawaii, Truk, Wake, and Midway.

(4b) It is quite possible that the MIKE-produced waves will be picked up by the U. S. Coast and Geodetic Survey recording-tide gauges which are distributed throughout the Pacific islands; copies of their records will be requested for study.

The University of California wave recorders on Guam, although not tuned for exact frequency response, will almost certainly get some sort of a record. These instruments will be operated continuously during the time at which waves may arrive at Guam.

Remarks:

As an aid in correlating water wave motion (and formation) with atmospheric pressure variations, microbarograph measurements may be made at Truk, Guam, Midway, and Wake islands. Such measurements would determine perturbation pressures established in the upper atmosphere by the nuclear detonation.

Each station would consist of two microbarophones installed on a radial line from Elugelab - the phones being approximately two miles apart. Measurement of the elapsed time between signal arrival at the two observation points allows a calculation of the angle from which the signal is coming.

It was originally planned that the Proving Ground Department of Sandia Corporation would make these measurements. Economy considerations, however, make it highly desirable that the Scripps Institution of Oceanography take the responsibility for them as a part of the parent project. At this writing, a final decision on this matter was not available.

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PROGRAM 6

BLAST MEASUREMENTS

Project No: 6.5

Project Title: Ground Motion - Seismic Measurements.

Shot Participation: MIKE

Sponsor: AEC

Project Officer:

Name: Mr. Harlan E. Lenander
Address: Proving Ground Department
(Code 5230) Sandia Corporation
Sandia Base, Albuquerque, New Mexico

Phone: Albuquerque, 6-4411
EXT. 7133

Conducting Agency: Proving Ground Department
Sandia Corporation

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian			

Support Required:

* See "Remarks" on page 6.1.4

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[redacted]

Object of the Experiment:

Of the total energy released by an atomic explosion, an indeterminate percentage is transported (radially outward from bomb zero) by the ground. The magnitude of this percentage is dependent upon the impedance match between the ground and the weapon during reaction time. For a high air burst, the impedance match is obviously poor, and the percentage is essentially zero. For a deep underground burst, conversely, it is 100%. Low air bursts, surface bursts, and shallow underground bursts represent intermediate situations.

The transport of this energy by the ground is evidenced by earth accelerations and resulting motions. Documentation of these as a function of distance from bomb zero may make possible the theoretical deduction of how much energy was ground-transported. This project is designed to supply such documentation. Data from the pre-shot seismic surveys and earth attenuation measurements of Program 11 will aid in the analysis and interpretation of results obtained herein.

Method and Procedure:

A. The basic instrument to be used for these measurements is a Wiancko accelerometer. An acceleration along the axis of the instrument causes unbalance of a mass-loaded lever arrangement. This in turn causes the inductance of a coil to be varied - which generates an electric signal. Laboratory and field calibrations allow the magnitude of the generated signals to be interpretable in terms of the instantaneous accelerations. These accelerations can be integrated; once to obtain velocity, and twice to obtain displacement.

Each measuring station will consist of three such accelerometers mounted in the ground, with mutually perpendicular measuring axes. The earth acceleration will therefore be measured in three components. The depth of the accelerometer mounts will depend upon local conditions - depth of the base rock foundation, if any, etc.

B. Measuring stations will be established on Parry, Biijiri, Bokon, Muzin, Engebi, and Bogon. Exact locations and individual station details are not available at this writing.

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PROGRAM 6

BLAST MEASUREMENTS

Project No: 6.7a

Project Title: Underwater Pressures Across the Lagoon and in Deep Water.

Test Participation: MIKE

Sponsor: DOD (USN)

Project Officer:

Name: Mr. James W. Smith
Address: Office of Naval Research,
Code 418, Navy Department,
T-3/2515, Washington 25, D.C.

Phone: Liberty 5-6700
EXT. 6-4476 or 6-6967

Conducting Agency: Office of Naval Research
Bureau of Ships (USN)

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian	6	M-60	M/15

Support Required: One P2V (or C-47) to carry airborne telemetering relay equipment. This will weigh approximately 300 pounds, occupy 16 cubic feet, and require one man to operate.

* Additional help will come from Scripps Institute of Oceanography personnel engaged on another project.

Object of the Experiment:

This project is designed to supplement the data obtained by the Sandia Corporation under Project 6.7b, by making a limited number of peak water pressure measurements along a line from ground zero through the center of the lagoon. In addition, the pressure-time history of the underwater shock wave, in the deep water immediately outside the reef northwest of the shot island, will be obtained. The data obtained may be of importance in determining the energy "coupling" coefficient*, as well as in predicting the effects of similar releases of energy on underwater ordnance and on vessels.

Method and Procedure:

A. A minimum of four pressure measuring and recording systems ("Tuna Cans") will be moored below the surface of the deep water immediately adjacent to the reef northwest of Elugelab. Each buoy for supporting the pressure pick-up is a completely independent unit containing the necessary power supply and recording system for the pressure-time instrumentation. A complete unit will weigh approximately 7½ tons. Pressure gauges will be suspended from the mooring cable at various depths to 2000 feet. In addition, suitable mechanical underwater pressure gauges will be utilized.

B. Scripps Institute of Oceanography vessels will position and permanently moor the pressure measuring instruments and the "Tuna Cans" during their operation in the Eniwetok area; then retrieve the records, and later the units intact, after the shot. A team of approximately six Navy scientists who have been doing underwater explosion research will be organized to accomplish the field work and analyze the data from this project. They will be based on the Scripps vessels.

The three outermost "Tuna Cans" will have surface buoy telemetering equipment (seven channels each), the signals of which will be relayed, by an airborne pick-up and relay telemetering station, to a ship plotting station. The aircraft involved has been requested and will probably be a P2V, whose position at shot time will be more than 2000 feet above the evacuation fleet.

* This is the ratio of energy transferred into the water to total energy incident upon the water.

Remarks:

The Sandia Corporation will place six underwater pressure gauges in the shallow water on the lagoon side of the shot island, under Project 6.7b, the data from which will be coordinated with the above.

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PROGRAM 6

BLAST MEASUREMENTS

Project No: 6.7b

Project Title: Underwater Pressures - Along Reef.

Shot Participation: MIKE

Sponsor: AEC

Project Officer:

Name: Mr. Harlan E. Lenander
Address: Proving Ground Department
(Code 5230) Sandia Corporation
Sandia Base, Albuquerque, New Mexico

Phone: Albuquerque 6-4411
EXT. 7133

Conducting Agency: Proving Ground Department
Sandia Corporation

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian			

Support Required:

* See "Remarks on page 6.1.4

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Object of the Experiment:

As a continuation of the underwater pressure field studies*, this project is designed to measure the pressure as a function of time in the shallow water of the lagoon. Various distances from bomb zero will be instrumented, in order that pressure attenuation with distance can be documented. These measurements are not considered worthwhile for KING shot. Since it is to be an air burst, one expects a poor impedance match between water and exploding weapon, with a correspondingly small amount of energy being transported by the water.

Method and Procedure:

A. The basic instrument to be used herein is a Wiancko gauge** modified for underwater use.

B. These gauges will be placed in the lagoon, 1/4 to 1/2 mile from land. The actual locations will be off Parry, Biijiri, Engebi, and Bogairikk. Recording of the data obtained by these instruments will be accomplished in nearby Project 6.1 recording stations, using standard equipment.

* See Project 6.7a

** See the discussion of Project 6.1

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PROGRAM 6

BLAST MEASUREMENTS

Project No: 6.7c

Project Title: Acoustic Pressure Waves in Water.

Test Participation: MIKE - KING

Sponsor: DOD (USN)

Project Officer:

Name: Mr. James W. Smith
Address: Office of Naval Research
Code 418, Navy Department
T-3/2515, Washington 25, D.C.

Phone: Liberty 5-6700
EXT. 6-4476 or 6-6967

Conducting Agency: Office of Naval Research,
Naval Electronics Laboratory,
Bell Laboratories

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer	None		
Enlisted	None		
Civilian	None		

Support Required: This project merely requires that existing stations be alerted to record, analyze, and submit a report on data obtained with their equipment.

* Normal SOFAR station complements.

[redacted]

Object of the Experiment:

This project is designed to make special observations, at several SOFAR (Sound Fixing and Ranging) stations in the Pacific (and possibly Atlantic) area, of acoustic signals propagated in deep water. It is believed that the MIKE shot yield can be crudely estimated from the characteristics of the received signal. It was demonstrated during Operation SANDSTONE that the relative yields of shots XRAY, YOKE, and ZEBRA could be established in this fashion. The poor impedance match (between ocean mass and exploding weapon) characteristic of an air burst will probably preclude the reception (at great distance) of such signals for KING shot.

Method and Procedure:

A. SOFAR is a method of detecting, and recording the characteristics of, acoustic signals propagated in a water layer which is approximately 500 fathoms under the ocean surface in the Pacific and 700 fathoms under the surface in the Atlantic. The transmission of sound waves in this layer is extremely efficient, apparently because of a temperature inversion at that depth. In fact, for MIKE shot, it is expected that the signal will travel through the layer around the tips of both Cape Horn and the Cape of Good Hope.

B. Navy SOFAR and SOFAR Research Stations, presently operating in the Pacific and Atlantic areas, will be used for special observation and analysis of the acoustic signals received during the shot period of Operation IVY. Installation of new pressure pick-ups and recording systems is being expedited at these stations. A specially trained observer will be attached to the normal staff of each of two such stations, to insure that observations are properly made and to analyze the available data. No new SOFAR stations will be established.

[redacted]

[redacted]

PROGRAM 6

BLAST MEASUREMENTS

Project No: 6.9 Project Title: Air Density vs Time

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Major Pedro R. FlorCruz
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-2766

Conducting Agency: Group J-10
Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	2	M-46	M/14
Enlisted			
Civilian	1	M-46	M/14

Support Required:

[redacted]

[redacted]

[redacted]

Object of the Experiment:

This project is designed to make special observations, at several SOFAR (Sound Fixing and Ranging) stations in the Pacific (and possibly Atlantic) area, of acoustic signals propagated in deep water. It is believed that the MIKE shot yield can be crudely estimated from the characteristics of the received signal. It was demonstrated during Operation SANDSTONE that the relative yields of shots XRAY, YOKE, and ZEBRA could be established in this fashion. The poor impedance match (between ocean mass and exploding weapon) characteristic of an air burst will probably preclude the reception (at great distance) of such signals for KING shot.

Method and Procedure:

A. SOFAR is a method of detecting, and recording the characteristics of, acoustic signals propagated in a water layer which is approximately 500 fathoms under the ocean surface in the Pacific and 700 fathoms under the surface in the Atlantic. The transmission of sound waves in this layer is extremely efficient, apparently because of a temperature inversion at that depth. In fact, for MIKE shot, it is expected that the signal will travel through the layer around the tips of both Cape Horn and the Cape of Good Hope.

B. Navy SOFAR and SOFAR Research Stations, presently operating in the Pacific and Atlantic areas, will be used for special observation and analysis of the acoustic signals received during the shot period of Operation IVY. Installation of new pressure pick-ups and recording systems is being expedited at these stations. A specially trained observer will be attached to the normal staff of each of two such stations, to insure that observations are properly made and to analyze the available data. No new SOFAR stations will be established.

Duplicate of 176

[redacted]

[redacted]

PROGRAM 6

BLAST MEASUREMENTS

Project No: 6.9 Project Title: Air Density vs Time

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Major Pedro R. FlorCruz
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-2766

Conducting Agency: Group J-10
Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	2	M-46	M/14
Enlisted			
Civilian	1	M-46	M/14

Support Required:

Duplicate of 177

[redacted]

[redacted]

Object of the Experiment:

In the discussion of Project 6.2 we pointed out the difficulty of measuring a blast parameter without perturbing the flow with the measuring instrument. We also indicated one approach to a solution of the problem posed by such a difficulty; namely, the "probing" of the blast field with particles so small that their presence in the flow would cause little or no perturbation. Under Project 6.3 we discussed a second approach to the solution - the use of sound waves to probe the field.

The probing method used herein is a continuation of the first approach, in that even smaller (than the smoke particles of Project 6.2) particles are used. This project is designed to document the air density at various fixed points in the blast field - prior to, during, and subsequent to the passage of the shock wave. Knowledge of the air density alone is insufficient to describe the shock wave development completely. Since all the blast parameters (pressure, temperature, density, velocity, etc.) are related theoretically by well substantiated expressions, however, the measurement of any one is useful in the determination of others. Also, if we measure more parameters than are necessary to make the equation system determinate, the obvious advantage of being able to cross-check our results is available to us.

Method and Procedure:

A. In addition to its function as a blast parameter, density controls the transmission properties of air - for both particulate and electromagnetic radiation. That is, the mean free path* of gamma-rays, neutrons, beta-rays (electrons), etc. in air is a function not only of their energy but also of the air density. In other words, the cross section** of air with respect to radiation of a given energy varies with air density. In particular, an increase of air density implies greater attenuation with distance (shorter mean free path - higher cross section) to radiation of a given energy level.

To accomplish its purpose, this project utilizes a device known as the Beta-ray Densitometer, the latter being designed to take advantage of the above mentioned variation of cross section with

* See page 8.1.3

** See page 4.2.2

180

[redacted]

density. In brief, its method of operation is as follows: A beta-ray source of known intensity is observed by a phosphor-photocell type of detector, the separation between source and detector being ~ 50 cm. An air density increase (decrease) over the path between source and detector causes a decrease (increase) in the intensity of beta radiation incident upon the phosphor - which in turn causes a decrease (increase) in the light output by the phosphor. The latter leads to a corresponding decrease (increase) in the current signal generated by the photocell. The current signal is used to perturb an electron beam in a cathode-ray tube, and the primary datum generated by the instrument is a photographic record of the tube face. Laboratory calibration of the assembly allows analysis of the above mentioned film to be interpretable directly as air density versus time along the path.

B. For MIKE shot, four Beta-ray Densitometers will be used, one on each of the following islands: Engebi, Kirinian, Bokon, and Aamon. The distances from bomb zero to these stations will be approximately 20,000, 25,000, 30,000, and 50,000 feet respectively.

At present, it is planned to use two densitometers for KING shot - both of which will be located on Runit. Detailed planning for this phase of the operation is not complete at this writing.

Remarks:

(1) The density versus time information obtained herein should be valuable as a data-interpretation aid for Project 5.2 (Gamma Intensity as a Function of Time). At a given instant of time the density contour between bomb zero and any fixed point in space will affect the gamma radiation incident upon the point. Hence humps or troughs in the gamma intensity versus time curves may be explainable in terms of shock wave position (and attendant air density variations) relative to the gamma detectors.

(2) For the primary data of the densitometer to exhibit high signal-to-noise ratios, the instrument must be located such that:

(a) The density variations experienced during and subsequent to shock passage are relatively high.

(b) The magnitude of the extraneous (to this experiment) light signals generated in the phosphor by incident gamma radiation and neutrons must be relatively small.

[redacted]

Hence we must place the station so close to the bomb that the shock strength is not too low when it reaches the instrument, yet sufficiently distant that the gamma-ray and neutron flux will be adequately attenuated. For small weapons, these conditions are mutually exclusive - for large weapons the situation is much better. The reader interested in determining why this is true needs only to compare the expressions for gamma-ray intensity versus distance and shock strength versus distance. Because of the above, MIKE shot presents the best opportunity to date for using the densitometer technique, and excellent results are expected. The smaller yield of KING shot will make a less desirable environment - not sufficiently less, however, to preclude its inclusion in the experimental program.

[redacted]

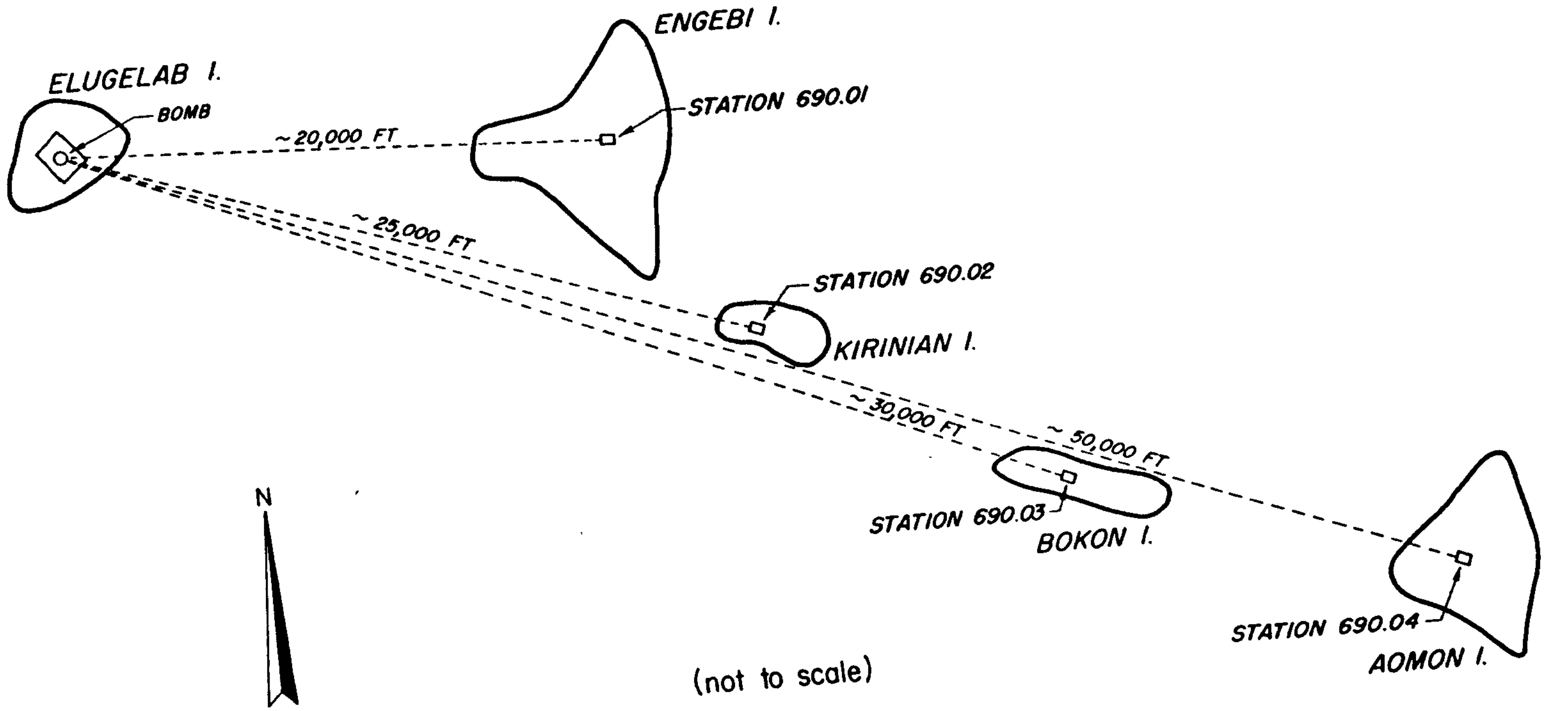

Fig. 6.9.1

Mike Shot Air Density vs. Time
(Beta-ray Densitometer Stations)

6.9.5

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PROGRAM 6

BLAST MEASUREMENTS

Project No: 6.10

Project Title: Free-Air Pressure as a Function of Time (Manned Aircraft).

Shot Participation: MIKE - KING

Sponsor: DOD (USAF)

Project Officer:

Name: Lt. Col. Rodney Nudenberg
Address: Wright Air Development Center
Wright-Patterson Air Force Base
Dayton, Ohio

Phone: Kenmore 7111
EXT. 2-2226

Conducting Agency: Wright Air Development Center

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	18	M-30	K+5
Enlisted	60	M-30	K+5
Civilian	4	M-30	K+5

Support Required: One B-36D and one B-47B, with spare parts, to be furnished by Wright Air Development Center. Crews to be furnished by Strategic Air Command.

[redacted]

Object of the Experiment:

To determine the free air pressure as a function of time using manned aircraft to position the measuring instruments in space, at altitudes significant to delivery aircraft. In addition, data on the dynamic structural response of aircraft will be obtained. The latter will be used as a basis for establishing structural design criteria, and for immediate use in planning delivery techniques for very high yield weapons.

Method and Procedure:

A. One B-36D and one B-47B aircraft will be instrumented for measurement of overpressures, induced loads (such as increased lift and structural strains in the wings and tail group), and the dynamic response of the complete airplane to the blast wave. Since the yield of MIKE shot may fall within broad limits, it will be necessary to instrument the aircraft with two distinct sets of pressure gauges to cover a pressure range of 0 to 10 psi. Strain gauges will be employed to determine deflections of individual aircraft components.

The data will be recorded on consolidated oscillographs with a total of seventy-two sensing channels. These data will be returned to the ZI for reduction and analysis. It is hoped that the final results will be useful for the establishment of criteria for tactical employment of currently available (or future) aircraft as delivery devices for high yield bombs.

B. The instrumented aircraft will orbit the zero point at a safe distance until just prior to the detonation, at which time they will turn so as to be flying directly away from ground zero at the time of detonation. These aircraft will be based at Hickam AFB, T. H., with the B-47B being phased in and out of Kwajalein.

The aircraft used, and results obtained, will be coordinated with those of Project 6.11. This project is also closely associated with Project 8.5, in that the thermal attenuation measurements are being made in the same aircraft. In addition, the B-36D will carry radar scope cameras for Project 9.4.

Remarks:

1. This project is a continuation of the previous work on the effects of blast upon aircraft, which has been conducted by the

[redacted]

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Massachusetts Institute of Technology under Air Force contract. Valuable data were obtained during Operation GREENHOUSE, and such results are reflected in the refined pressure-time and pressure-distance curves which are currently being used by the USAF for tactical planning. The positioning of all aircraft for IVY is being influenced by these curves.

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6.10.4

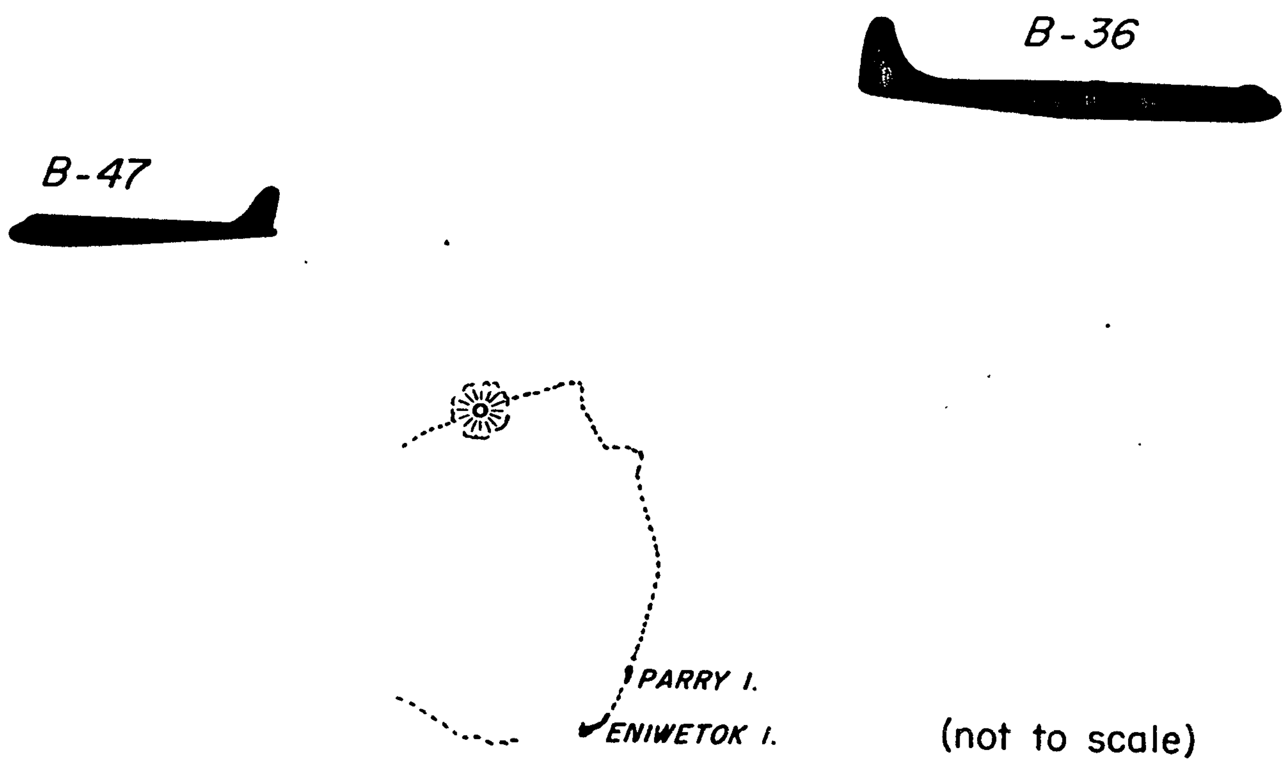

Fig. 6.10.1
Free Air Pressure as a Function of Time
(Manned Aircraft)

[redacted]

(Manned Aircraft)

PROGRAM 6

BLAST MEASUREMENTS

...ct No: 6.11

Project Title: Free-Air Pressure As A Function of Time Utilizing Parachute Suspended Canisters.

...rticipation: MIKE - KING

...: DOD (USAF)

...ct Officer:

...: Major James D. Vann, USAF
...ress: Air Force Cambridge Research Center
230 Albany Street
Cambridge 39, Mass.

...: Lexington 9-2200
EXT. 69 or 133

...cting Agency: Air Force Cambridge Research Center (AFCRC) of the Air Research and Development Command (ARDC)

...sonnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	14	M-30	K+5
Enlisted	27	M-30	K+5
Civilian	18	M-30	K+5

...port Required: Two ARDC B-29's operating from Kwajalein, unless Hickam is a feasible operating base. ARDC crews will be provided, and the planes must be modified to allow pre-heating of canisters.

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Object of the Experiment:

This project is designed to measure the free-air over-pressure versus time, at a number of different known altitudes and distances from an atomic bomb explosion. Data on the attenuation of a shock wave in a non-homogeneous atmosphere will be obtained to aid in the determination of safe (to flight crew personnel) procedures for aircraft delivery of high yield atomic weapons, and to verify (or deny) presently available theoretical approximation methods. In addition, free space thermal measurements will be obtained, under the conditions of severe reflection or absorption (due to cloud coverage) which may exist at shot time.

The effect of the ambient pressure and temperature gradients on a passing shock wave is almost completely unknown. Theoretical discussions of the effect exist, but there are no reliable experimental observations to test the resultant approximate theories. Such experimental data as do exist suggest that present theories are inadequate. The effects may be significant in determination of the optimum height of burst,* particularly for bombs of very large energy release. There is also an obvious application in the determination of minimum safe ranges and altitudes for dropping aircraft.

Method and Procedure:

A. For this project, the general plan of operation will be to obtain pressure and thermal measurements at twelve points along a radial line from the bomb - extending from the shortest range at which data can be obtained to approximately the operational range for manned aircraft. Twelve parachute-suspended canisters will be dropped on each shot, from two B-29 aircraft flying at approximately 32,000 feet. The altitude of the canisters at shock arrival time will vary from approximately 10,000 feet for the nearest to 30,000 feet for the most distant. The twelve instruments will be divided into two groups, one to give useful data in the event of a low yield and the other adjusted for documentation of a high yield. The two B-29's will each deploy six canisters, in such a way that a maximum of useful data will be obtained should either of the planes fail.

B. Each canister will contain a pressure sensitive element, a thermal sensing device, and a telemetering transmitter - it will be approximately 8 feet long, 14 inches in diameter, and will weigh 275 pounds.

* In the sense of maximizing the area subjected to a given peak pressure.

[redacted]

The position of each canister is to be determined by an electronic system known as MOTS (Multiple Object Tracking System), which is being developed by the Glenn L. Martin Company of Baltimore, Maryland. There will be two such MOTS installations, one on the southern end of Eniwetok Island and one on Runit Island.

The airborne telemetering system was developed by the Bendix-Pacific Division of Bendix Aviation Corporation. Each canister utilizes three telemetering channels; one for an altimeter, one for a preselected pressure range, and one for thermal radiation data. A separate sub-carrier frequency will be frequency modulated by two additional signals - one from an ambient pressure transducer and one from a differential pressure measuring device. The sub-carrier frequencies are mixed and in turn frequency modulate the radio frequency carrier. The thermal radiation sensing device is a thermocouple (or an array of thermocouples) arranged such that a nearly hemispherical sensitivity pattern is achieved. The omnidirectional characteristic is essential as there is no control of canister aspect. The time constant of the thermal sensing element is to be as small as practical (considering the time available for development of the system) and will be of the order of .08 seconds. The output of the thermal sensing device is to be impressed upon the input of a saturable reactor modulation element of the Bendix telemetering system. The sensitivity of the various sensing elements will be adjusted to allow for the anticipated variation in radiation flux with distance.

The telemetering station consists of receivers, carrier discriminators, amplifiers, and recording instrumentation for each canister. It is planned to have this station on board a ship. Transmission range is 25 to 30 miles.

Remarks:

The system proposed for this project was proved during Operations BUSTER/JANGLE and TUMBLER/SNAPPER, and the instrumentation is almost fully developed. Detailed dropping procedures for the canisters are being established by AFCRC, WADC, and TG 132.4. For KING shot, particular emphasis is being placed on flight-coordination with the strike aircraft.

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6.11.4

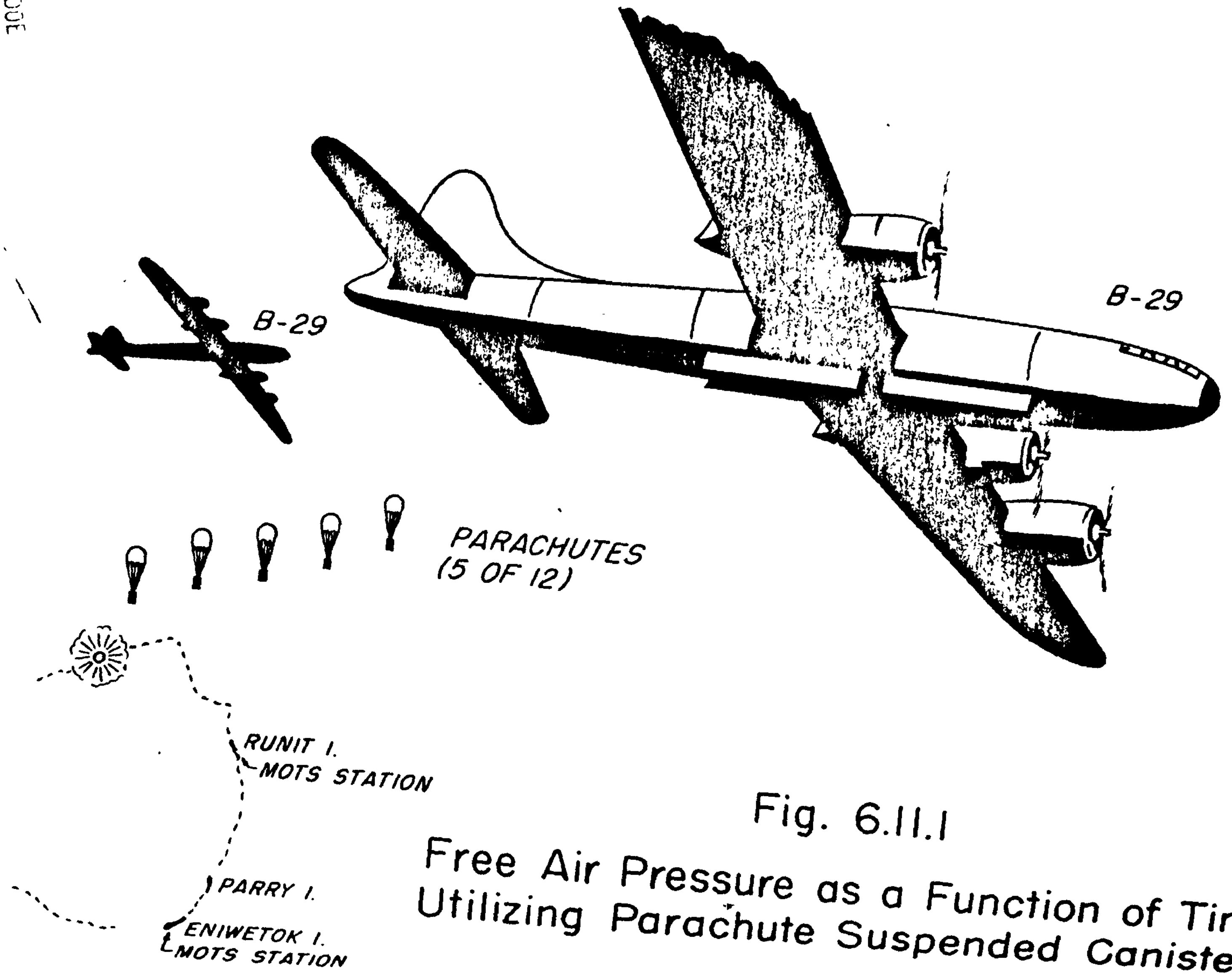

Fig. 6.11.1

Free Air Pressure as a Function of Time Utilizing Parachute Suspended Canisters

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PROGRAM 7

LONG RANGE DETECTION

Project No: 7.1

Project Title: Electromagnetic Effects From Nuclear Explosions.

Test Participation: MIKE - KING

Sponsor: DOD (USAF)

Project Officer:

Name:
Address:

DELETED

Phone:

Conducting Agency:

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	None		
Enlisted	None		
Civilian	None		

Support Required: Radio-transmitted timing signals.

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PROGRAM 7

LONG RANGE DETECTION

Project No: 7.2

Project Title: Airborne Low-Frequency Sound from Atomic Explosions.

Shot Participation: MIKE - KING

Sponsor: DOD (USAF)

Project Officer:

Name:
Address

DELETED

Phone:

Conducting Agency

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	None		
Enlisted	None		
Civilian	None		

Support Required:

(1) Notification of each proposed shot time at H-24 hours.
(2) Notification of any change in schedule.
(3) Confirmation of each shot.
(4) Time of shot, to the nearest second (WWV world-time), as soon as possible after detonation.

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PROGRAM 7

Project No: 7.3 **Project Title:** Calibration Analysis of Close-in A-Bomb Debris.

Shot Participation: MIKE-KING

Sponsor: DOD (USAF)

Project Officer:

Name:
Address:

Phone: DELETED

Conducting Agency:

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	2	M-20	K+10
Enlisted	4	M-15	K+10
Civilian	4	M-10	K+7

Support Required:

Additional airmen for peak loads right after shot time may be needed when counting facilities are being operated twenty-four hours per day.

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PROGRAM 7

LONG RANGE DETECTION

Project No: 7.4 Project Title: Propagation of Seismic Waves.

Shot Participation: MIKE - KING

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Sponsor: DOD (USAF)

Project Officer:

Name:
Address

DELETED

Phone:

Conducting Agency:

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	None		
Enlisted	None		
Civilian	None		

Support Required: Will require the time of detonation with relation to WWV world-time, with an accuracy of one-tenth (1/10) second, for each test in Operation IVY. This information will only be required "after-the-fact".

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PROGRAM 7

LONG RANGE DETECTION

Project No: 7.5

Project Title: Transportation of Airborne Debris.

Shot Participation: MIKE - KING

Sponsor: DOD (USAF)

Project Officer:

Name:
Address:

DELETED

Phone:

Conducting Agency:

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	1	M-25	K/10
Enlisted	None		
Civilian	None		

Support Required: Prompt transmission of cloud height and movement data to the Director, Program 7

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PROGRAM 7

LONG RANGE DETECTION

Project No: 7.6

Project Title: Detection of Fireball Light at Distances

Shot Participation: MIKE - KING

Sponsor: DOD (USAF)

Project Officer:

Name:
Address

DELETED

Phone:

Conducting Agency:

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	None		
Enlisted	8	M-14	K/7
Civilian	1	M-14	K/7

Support Required: Timing signals similar to those specified for Project 7.1 will be required.

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PROGRAM 8

THERMAL RADIATION MEASUREMENTS

ject No: 8.1 Project Title: Integral Thermal Radiation.

Participation: MIKE - KING

nsor: AEC

ject Officer:

Name: Dr. Harold S. Stewart
Address: Radiometry Section
Optics Division
Naval Research Laboratory
Washington 25, D. C.
Phone: Johnson 3-6600
EXT. 681

nducting Agency: Radiometry Section
Optics Division
Naval Research Laboratory

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer			
Enlisted	1	M-45	K/10
Civilian	2	M-45	K/10

Support Required:

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[redacted] [redacted]

[redacted]

Object of the Experiment:

The thermal radiation emitted by an atomic bomb represents still another subject that must be thoroughly investigated. In the field of weapons effects, both personnel and materiel can be jeopardized by exposure to the tremendous flux of heat - especially under ambient conditions of low density and/or high visibility. The latter considerations, of course, being advantageous for the use of atomic weapons against aircraft - or disadvantageous if one happens to be using the aircraft as a weapon delivery device. In the fields of weapon design and diagnosis of weapon performance, on the other hand, detailed knowledge of every energy transport mechanism is essential to an understanding of how an atomic explosion actually develops - and thermal radiation acts as a highly efficient transport mechanism under certain conditions.

The experimental projects of Program 8 are devoted to a study of thermal radiation as a "field variable".* This project, in particular, is devoted to documenting the total (integral over time) thermal radiation received at various fixed distances from an exploding weapon. To further clarify the above statements, consider the equation:

$$Q = \frac{FY}{4\pi} \frac{T}{R^2} \qquad (8.1.1)$$

in which:

(1) Q is the total incident radiation, at a distance of R centimeters from the bomb, in calories per square centimeter.

(2) Y is the total energy release of the bomb in calories.

(3) F is the fraction of the bomb's total energy that is in the form of thermal radiation.

(4) R is the distance in centimeters from the bomb to the surface upon which the radiation is incident.

* See "preface".

[redacted]

[redacted]

(5) T is that fraction of FY which reaches the surface under consideration - usually called the "transmission". A natural extension of this notation is the replacement of T by $e^{-R/\lambda}$ - where R is the same as above and λ is the mean free path* of the radiation for the particular medium (atmosphere) under consideration.

Equation 8.1.1 is not capable of theoretical justification as an exact description of the thermal radiation versus distance phenomenon. It does, however, appear to fit past data reasonably well - which is justification enough for its use in weapon effects planning. The knowledge of how thermal radiation affects things is sufficiently vague that an approximation device (such as the above equation) is quite adequate for the effects people.

The above equation is useful to the extent that we can determine F and T (or equivalently, λ) as functions of Y and the ambient atmospheric conditions respectively. This project is concerned with the determination of Q in equation 8.1.1, as a function of R, for both MIKE and KING shots.

Method and Procedure:

A. Two methods will be employed to measure total incident thermal radiation. The first of these is the conventional ballistic thermocouple technique. The output of an Epply thermopile is recorded by a GE photoelectronic galvanometer. The thermopile is essentially an electric current generator, the amount of current generated being proportional to the heat energy "seen" by the instrument - and a galvanometer is an electric current "sensing" device. Laboratory calibration of such a combination of devices allows the galvanometer reaction to be interpretable directly in terms of calories per square centimeter at the instrument.

The second method involves the use of so-called "black balls". For IVY, these will consist of black containers filled with some liquid - the color black being chosen to maximize heat absorption. The heat-induced expansion will move a diaphragm, and the motion of the latter will be recorded through a stylus linkage on a spring driven revolving drum. Laboratory calibration will again allow the peak expansion of the liquid to be interpreted as so many calories of heat per square centimeter falling on the instrument.

* Defined as the distance (in the same units as R) over which the radiation must travel in order to be attenuated by a factor of e. (e = 2.718···, the base of natural logarithms.)

[redacted]

[redacted]

B. For MIKE shot, six ballistic thermocouples will be operated - two from the Parry photo tower, two from station 801 on Engebi, and two from station 803 on Biijiri. In addition, "black ball" stations will be placed on Biijiri, Bogallua, Aitsu, Bokon, Kirinian, Engebi, and Bogon islands - and still another will be placed on a piling between Engebi and Bogon (at site Noah, a small artificial island).

For KING shot, six thermocouples will be used - two on the Parry photo tower, two in station 803 on Biijiri, and two mounted on a 12 x 12 foot platform (25 feet high) on Aniyaanii. In addition three "black ball" stations will be established near the north end of Runit. Each "black ball" station will consist of a pressure-tight case roughly two feet square and three feet high, to the top of which one or more balls (6" diam.) will be attached. The case will then be either buried (with the balls protruding above the surface of the ground, of course) or bolted to a concrete emplacement.

Remarks:

The tremendous amount of dust thrown up by a surface burst implies a strong variation of transmission with azimuth angle - and also the possibility of variations along a given radial line. As a result of this, one cannot be certain of adequate documentation of the total thermal radiation with a given number of measuring stations. In any event, the MIKE shot measurements will be characteristic of the weapon design, and of Eniwetok and the firing conditions - and hence may be of little use in predicting thermal effects from thermonuclear weapons in general.

The relatively dust-free light paths from an air burst are conducive to much more reliable documentation, hence the KING shot measurements may well be sufficiently complete and reliable to allow predictions to be made. The results of these measurements, when combined with past work on smaller yield bombs, will make air drop data available over the yield range of 1-500KT.

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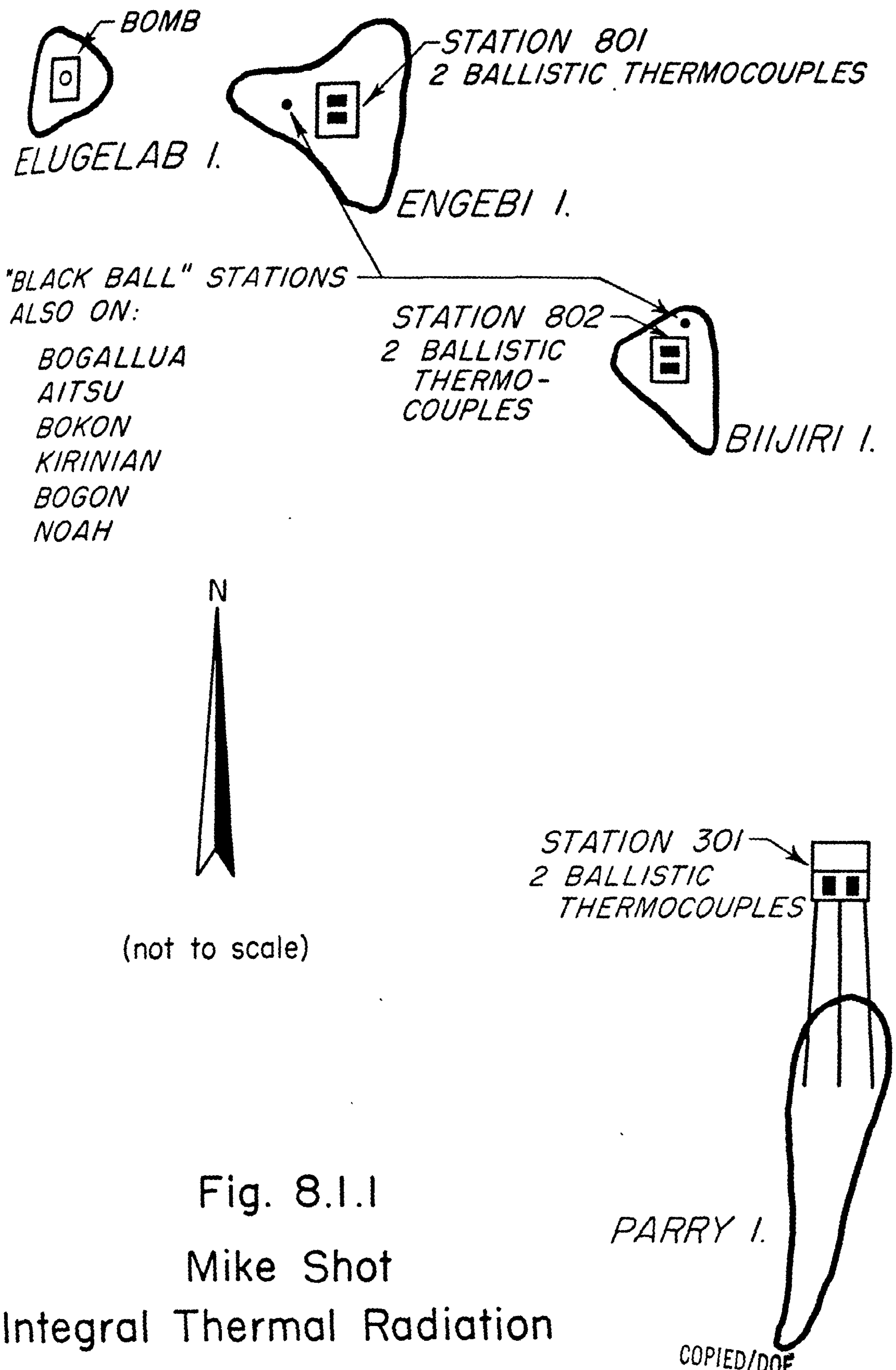

Fig. 8.1.1

Mike Shot

Integral Thermal Radiation

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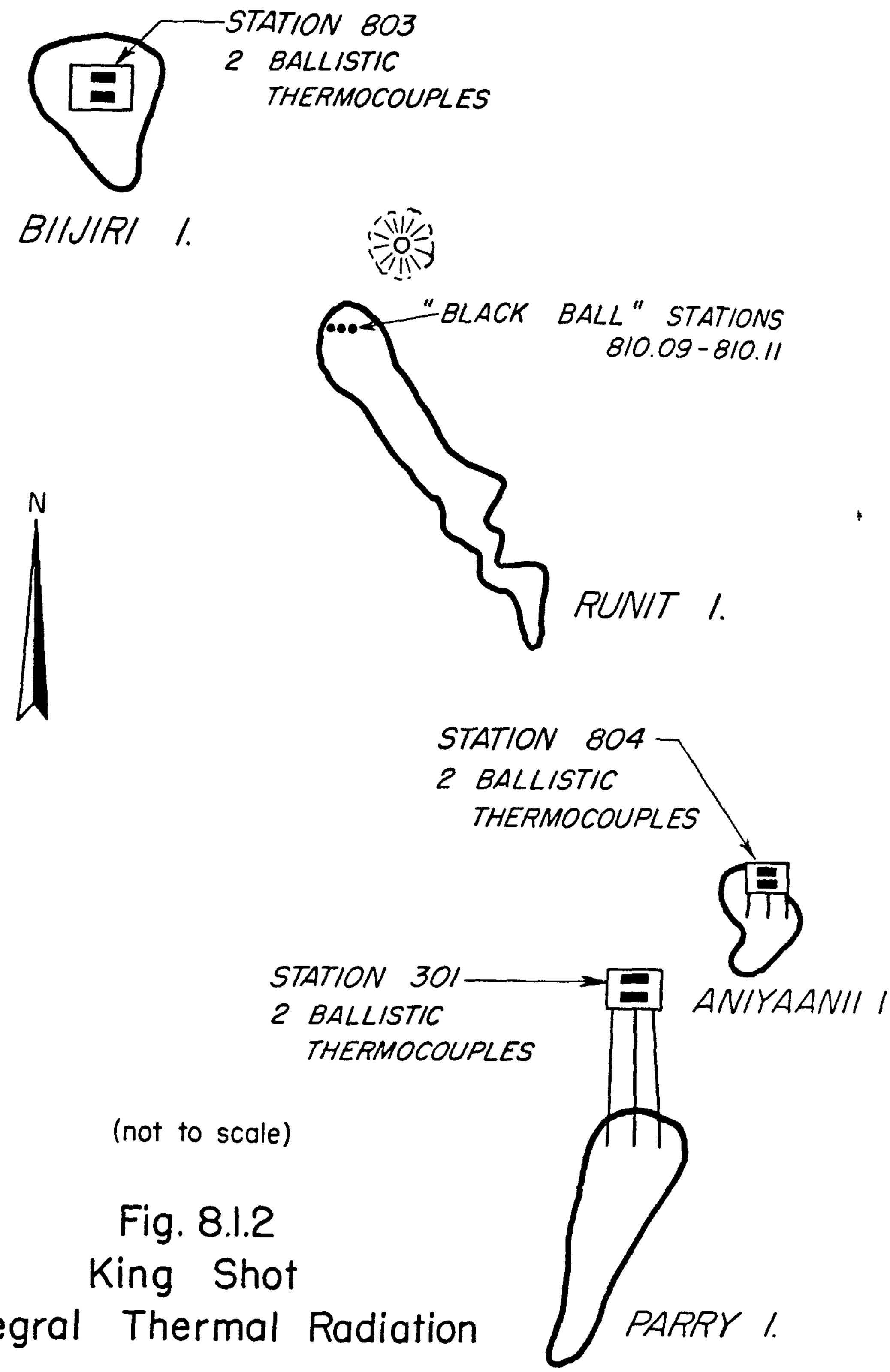

(not to scale)

Fig. 8.1.2
King Shot
Integral Thermal Radiation

[redacted]

PROGRAM 8

THERMAL RADIATION MEASUREMENTS

Project No: 8.2

Project Title: Thermal Intensity as a Function of Time.

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Dr. Harold S. Stewart
Address: Radiometry Section
Optics Division
Naval Research Laboratory
Washington 25, D. C.
Phone: Johnson 3-6600
EXT. 681

Conducting Agency: Radiometry Section
Optics Division
Naval Research Laboratory

Personnel Requirements in the Forward Area:

VII 1

	Approximate Number	From	To
Officer	1	M-45	K/10
Enlisted	2	M-60	K/20
Civilian	2	M-45	K/10

Support Required:

223

[redacted]

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Object of the Experiment:

To the soldier who may be exposed to thermal radiation from an exploding atomic bomb, perhaps the most important single question to be answered is "Can I duck it? - Is it possible to escape a large portion of its harmful effects by jumping behind a tree or rock, etc.?" To obtain the answer to such a question, we must investigate the time dependence of total thermal radiation.

To the weapon diagnostician, the early time dependence of thermal radiation is closely related to the fireball opacity and to the blast propagation near reflecting surfaces. Also, of course, it is important to the understanding of thermal radiation itself as a field variable. As an illustration of the latter, it can be combined with the spectrum versus time data to aid in the documentation of transmission* as a function of energy and atmospheric conditions.

Method and Procedure:

A. At IVY, three methods of measuring total thermal radiation versus time will be used, as follows:

(1) High speed bolometers, having approximately 25 μs time resolution, will be used to cover the period of time from just before to several seconds after zero - when the thermal radiation flux has returned to background values. The bolometer consists essentially of a small piece of blackened platinum wire that is exposed to the thermal radiation source, by means of a rotating chopper wheel, several thousand times each second. As the temperature of the platinum wire changes, its resistance changes - hence it is capable of supplying a signal to an electronic recording circuit, the magnitude of the signal being proportional to the temperature it "sees".

The bolometer assembly for this project consists of two such bolometers connected in push-pull electronically. Connected in this fashion, they generate a 24000 cycle AC signal, the amplitude of which is proportional to the radiant flux incident on the equipment. This AC signal is recorded on magnetic tape, using techniques which allow a dynamic range of one thousand times background (with a linear portion for 600 times background).

(2) Liquid flow meters, having a time resolution of approximately 1 ms, will be used to cover the same period of time as the

* See the discussion of Project 8.1.

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bolometer assemblies above. These meters have the advantage of being non-electronic (requiring no timing signals or power), and consist of a rigid chamber filled with an opaque liquid. A quartz window is placed in one wall of the chamber, through which the radiant flux may reach the liquid. This flux heats the liquid, with resultant expansion - and the rate of expansion is proportional to the rate of heating. In fact it can be shown that, to a fairly high degree of accuracy, the rate of flow (escape) of liquid from such a chamber is proportional to the rate at which radiant energy enters the quartz window. For this instrument, the rate of flow will be recorded on a revolving drum.

(3) For very early time coverage (0.1 μs to 100 μs), photocells will be used. These are nothing more than current generators having extremely good time resolution. The instantaneous current generated is a known function of the instantaneous radiant flux "seen" by the cell, and the known function is supplied by laboratory calibration. The current signals supplied by these instruments will be converted to voltage signals, attenuated if necessary, and recorded by oscillographs.

B. For MIKE shot, stations 800 on Engebi and 803 on Biijiri will each contain the following thermal radiation versus time measuring equipment:

(1) Two high speed bolometer assemblies.

(2) Two photocell recorders - one sensitive to the violet portion of the spectrum, and the other sensitive to the red portion.

(3) One or two of the above mentioned non-electronic instruments.

For KING shot, station 803 on Biijiri will be reactivated to take the same measurements as mentioned above for MIKE. In addition, these measurements will be duplicated from the 25 foot tower on Aniyaanii.

<u>Remarks</u>:

Contamination due to MIKE may make station 803 on Biijiri unavailable for KING shot thermal radiation measurements. If this should be the case, the Aniyaanii station will be depended upon for all time dependent total thermal measurements. Such a situation increases the probability of loss of data because of localized cloud cover.

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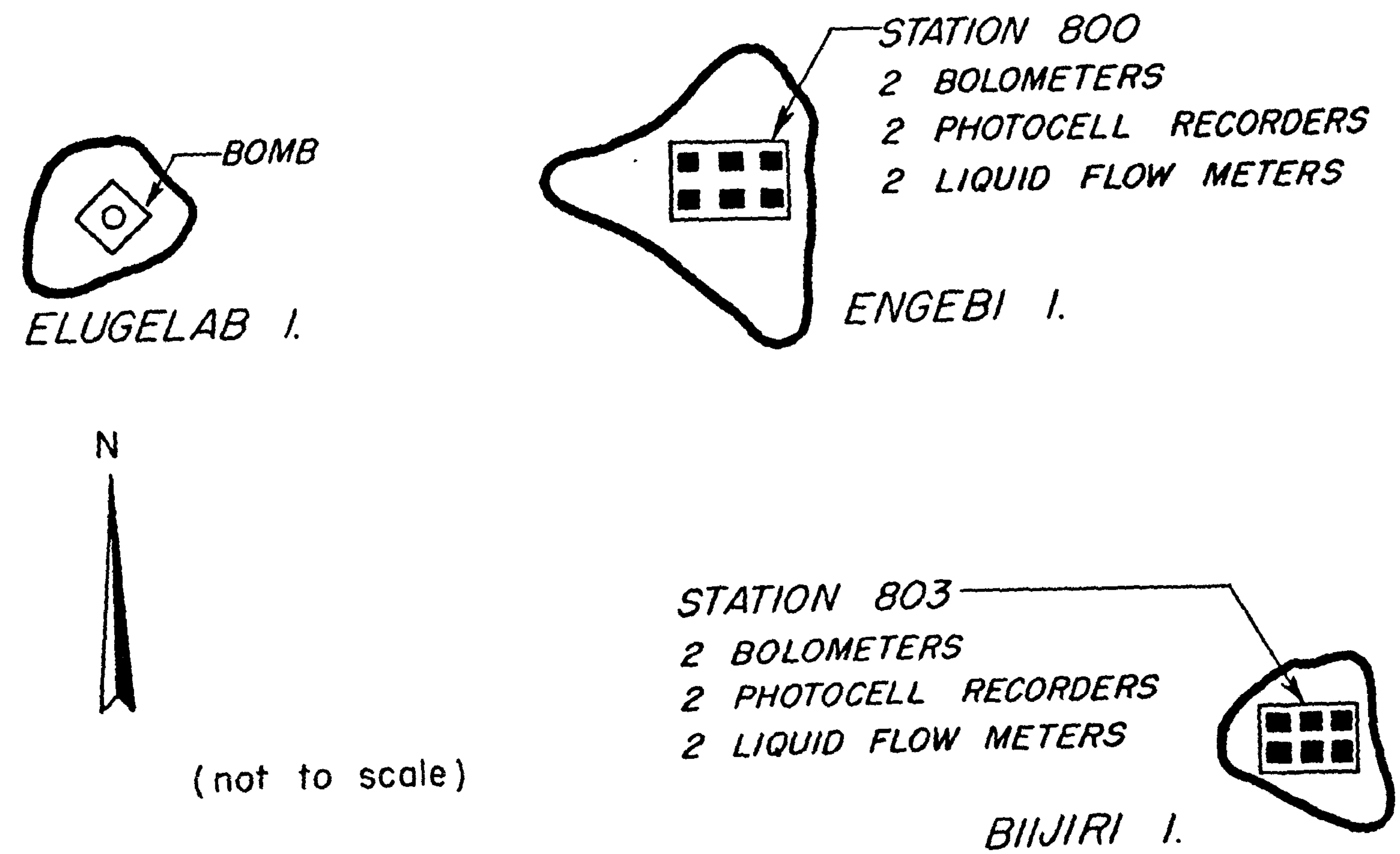

Fig. 8.2.1
Mike Shot Thermal Intensity as a Function of Time

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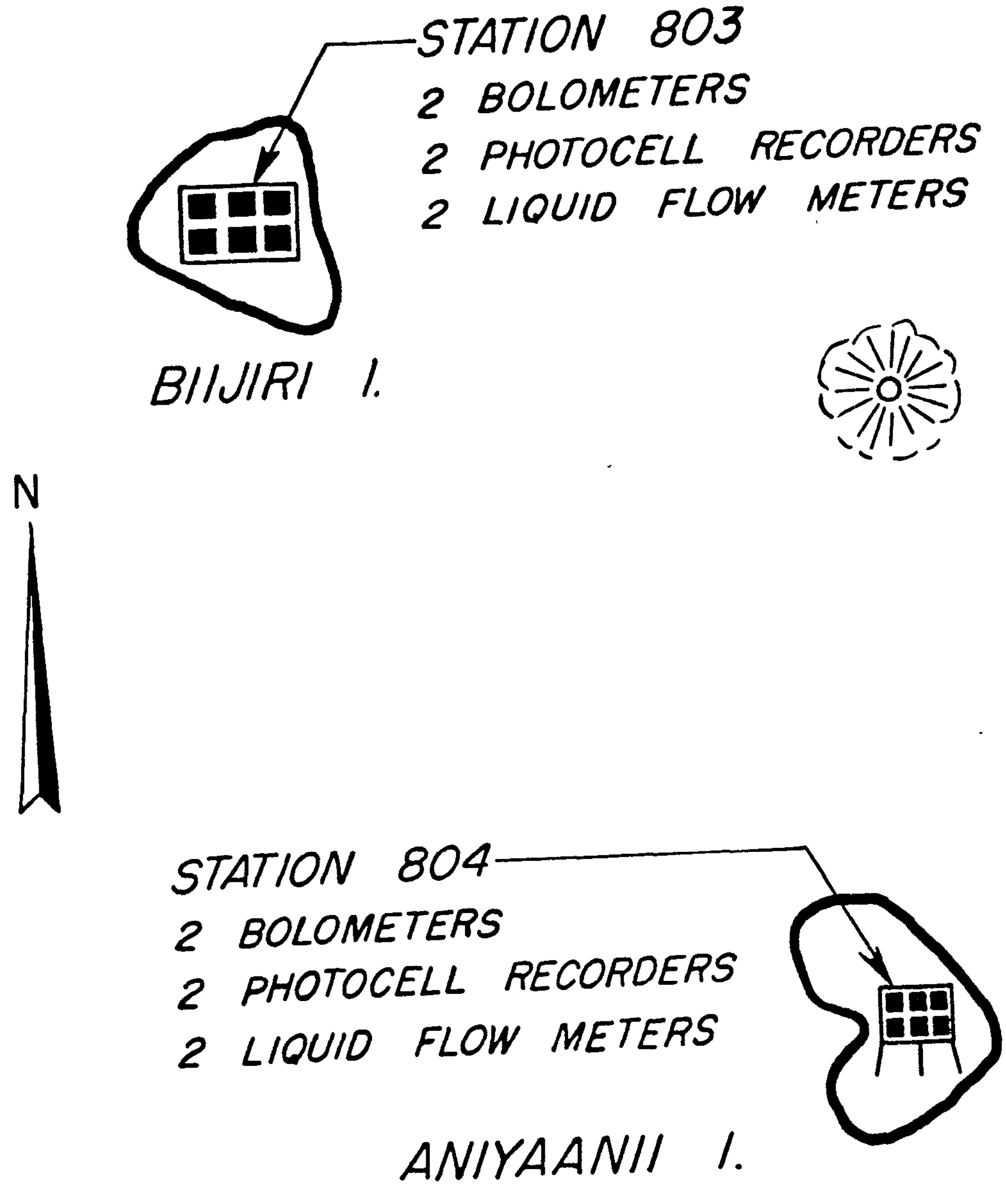

(not to scale)

Fig. 8.2.2

King Shot Thermal Intensity as a Function of Time

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PROGRAM 8

THERMAL RADIATION MEASUREMENTS

Project No: 8.3 Project Title: Spectroscopy

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Dr. Harold S. Stewart
Address: Radiometry Section
Optics Division
Naval Research Laboratory
Washington 25, D. C.
Phone: Johnson 3-6600
EXT. 681

Conducting Agency: Radiometry Section
Optics Division
Naval Research Laboratory

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer			
Enlisted			
Civilian	4	M-45	K+10

Support Required:

[redacted]

Object of the Experiment:

A complete documentation of thermal radiation as a "field variable" associated with exploding atomic bombs must include studies of the radiation energy spectrum. To the theoretician interested in weapon diagnosis, such information may explain an early phenomenon in the explosion development - or it may explain a connection between thermal radiation and another field variable, such as pressure. To the weapon effects theoretician, knowledge of a bomb's expected thermal spectrum will be an aid in predicting the penetrating power of the radiation - both through air and into more solid substances, such as human flesh.

This project is part of a continuing series of experiments, the purpose of which is to obtain as much information as possible concerning the thermal radiation spectrum associated with various sizes and types of atomic bombs - detonated under a variety of conditions. Both integral (summation over all time) and time dependent spectra will be measured. The relatively high yields expected from the IVY devices should insure a considerable extension of these data with respect to energy release.

Method and Procedure:

A. The classical method for measuring the energy spectrum of a radiation beam involves the use of an instrument known as a spectrograph. This instrument passes the beam through a "spreading" device (prism or diffraction grating) and then directs it to a photographic emulsion. The spreading device deflects each component of the incident composite beam by an amount dependent upon its energy. Hence the beam after spreading consists of a "fan" of smaller beams - each of the latter being essentially monoenergetic. These beams cause "exposure" in the silver halide of the emulsion - hence a dark line on the developed negative is associated with a particular energy level of electromagnetic radiation. The spectrograph record produced by a beam containing many different energies consists of many dark lines separated by lighter areas - the latter being associated with energy levels not represented in the beam.

Calibration of the instrument with known monoenergetic sources allows the experimenter to identify a given line on the record as being indicative of a given energy.

The above outlined technique does not, in itself, allow for time resolution. The record simply gives the integrated spectrum for whatever length of time the composite beam is incident upon the instrument. One way of obtaining the spectrum versus time is to add

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a shutter and moving film - then operating the spectrograph like a "motion picture" camera. A member of discrete integral spectra will thus be obtained, each covering a short period of time. The time resolution of such a system is fixed by the shutter and film speeds. Another way is to move only the film using no shutters. This technique supplies a continuous strip of spectrum (rather than a series of discrete spectra), each line of which is more or less dense as its length is traversed - depending upon the time variation of that particular energy.

For either of the above methods, timing marks are created on the film as it moves - in order that a particular spectrum can be identified with a given elapsed time from the start of the record.

B. For MIKE shot, moving film spectrographs will be installed at stations 800 on Engebi and 802 on Biijiri. At each of these stations measurements will be taken with two film speeds - one to obtain a spectrum every 2 milliseconds, the other to obtain a spectrum every 2 microseconds. The above mentioned "motion picture" technique will be used for the 2 ms resolution, whereas the continuous strip technique will be used for the $2 \mu s$ resolution. Each film frame of the slow speed record will contain 5 spectra. The first four of these are identical in content but with differing exposure levels, ranging from 1 to .03 on a relative scale, produced by the use of three ND* filters. The fifth is that of either a standard intensity source or a standard wave length source - whichever is most useful for calibration under the circumstances. The high time resolution will be produced by forming a 20 micron high spectrum of the source on a film moving at the rate of 25 meters per second. In this fashion, high time resolution is gained by sacrificing the range of intensities that can be covered.

In addition a high resolution of energies will be obtained on a integral spectrum. The instrument for this measurement will be installed in a small room directly below the photo tower cab on Parry island. Approximately 0.1 Angstrom (A)** wave length resolution will be obtained by using a 21 foot focal length 15,000 line grating in a Wadsworth mounting. The spectrum between 3800 and 8000 Å will be formed on a plate 30 inches long, and simultaneously (by means of filter separation) the spectrum between 1900 and 4000 A will be formed adjacent to it. This folding technique, of course, effects a great saving in space.

For KING shot, the above mentioned Biijiri and Parry install-

* See the footnotes on page 3.5.2

** 1 Angstrom = 10^{-8} cm.

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ations will be activated. The measurements taken from them will be identical to those taken for MIKE shot.

Remarks:

The relatively poor energy resolution obtainable in the high speed spectra makes analysis of them very difficult. As a result, the high energy resolution of the records obtained with the integrating spectrograph serves as an analysis aid. For instance, a group of lines on the high speed record may look like a single blur, yet the position of this blur will allow it to be identified on the integral spectrum record. The energy resolution of the latter is sufficiently great that we no longer have a blur, but a group of well defined and distinct lines.

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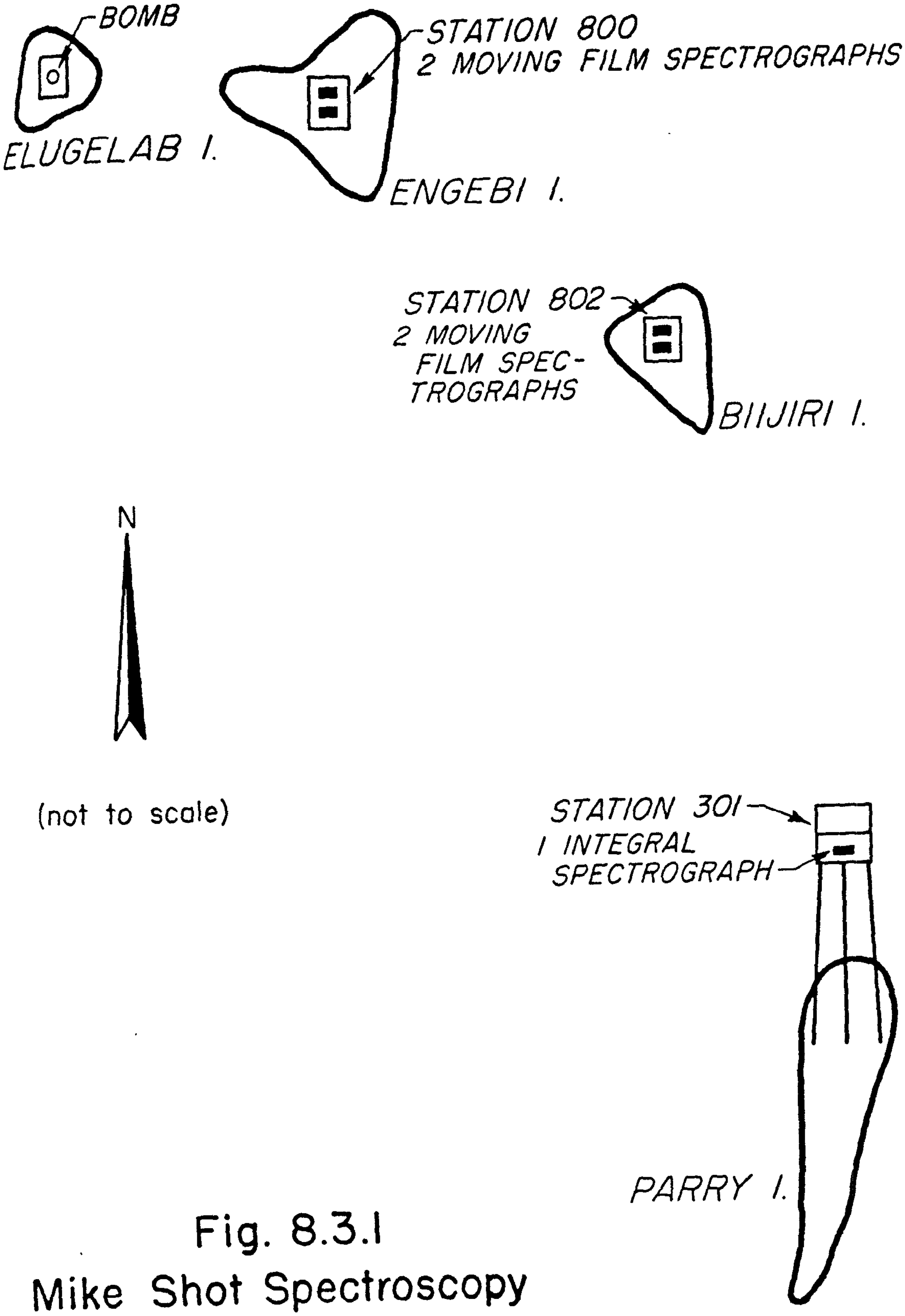

Fig. 8.3.1
Mike Shot Spectroscopy

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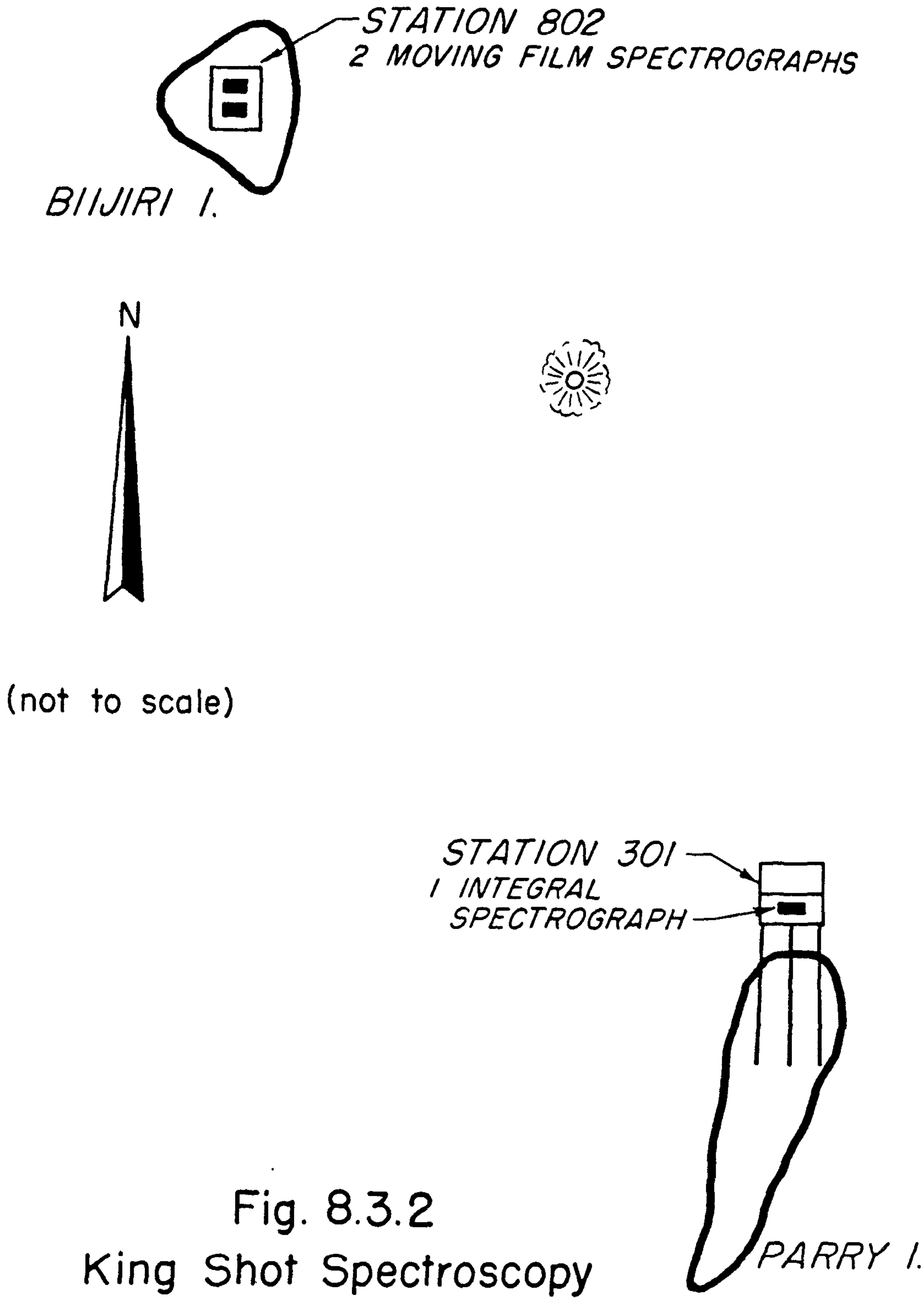

Fig. 8.3.2
King Shot Spectroscopy

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PROGRAM 8

THERMAL RADIATION MEASUREMENTS

Project No: 8.4 Project Title: Air Attenuation.

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Dr. Harold S. Stewart
Address: Radiometry Section
Optics Division
Naval Research Laboratory
Washington 25, D. C.
Phone: Johnson 3-6600
EXT. 681

Conducting Agency: Radiometry Section
Optics Division
Naval Research Laboratory

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	1	M-60	K+20
Enlisted			
Civilian	1	M-45	K+10

Support Required:

✓ 1.

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[redacted]

Object of the Experiment:

In the discussion of Project 8.1, we considered an equation (equation 8.1.1) of great potential usefulness for the prediction of incident thermal radiation versus distance. The use of this equation for making predictions implies that one must know F as a function of yield and T (or λ) as a function of the atmospheric conditions. To obtain the latter functional relationships experimentally, we measure Q as a function of distance (see Project 8.1) and mathematically determine the values of F and T which allow the best "fit" of equation 8.1.1 to the observed data. The value of F thus obtained can be related to the measured yield of the weapon, to obtain another point on the F versus W curve. The documentation of T, however, is much more complicated, since the range of electromagnetic radiation in any medium is dependent upon the energy (wavelength) of the radiation as well as the characteristics of the medium. We therefore must obtain information as to:

(a) The energy distribution (spectrum) of the radiation emanating from an atomic weapon.

(b) The effective range of electromagnetic radiation in the atmosphere, as a function of energy and the atmosphere's ambient conditions.

The primary purpose of this project is to add to the already existent fund of knowledge for (b) above. The secondary purpose is to satisfy an operational requirement - this will be discussed under "Remarks" below.

Method and Procedure:

A. The observation of a known monochromatic light source enables one to obtain data as to the transmission of a particular wavelength in the electromagnetic spectrum over the path from the source to the receiver. Laboratory calibration of the source allows us to determine the actual wavelength and total energy being radiated. Similarly, laboratory calibration allows us to interpret the detector reaction as so much radiation energy received.

A typical known light source for field use consists of a parabolic reflector with a tungsten lamp mounted at its focus. The light from the projector is modulated at 60 cycles per second by a shutter mechanism to make it easier for the detector to distinguish between the primary light signal and "noise" created by scattered light from other sources. A typical receiver (detector) consists of a

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parabolic mirror with a photocell mounted at its focus. The current generated by the photocell is proportional to the intensity of light seen, and this current signal is used (usually after amplification) to actuate various types of recording devices.

B. Transmissometer (source, detector, and recorder) assemblies will be operated over several light paths at Eniwetok atoll for IVY.

For MIKE shot, one light source will consist of two 60 inch searchlights with 4000 watt tungsten lamps at their foci. One light will be used, and the other will be on automatic standby (the failure of the first will automatically turn on the second). The 60 cycle modulation will be produced by rotating a sector disc between the bulb and the mirror - 100% modulation being obtained. The searchlights will be mounted approximately 100 feet above sea level on the Parry photo tower, and the associated receiver will be on Elugelab - the latter consisting of a vacuum phototube mounted at the focus of a 60 inch (focal length) parabolic mirror, and its associated recording equipment. A similar set-up will be used between Bogon and Bogallua, with a smaller searchlight (18") source on Bogon. This pair of transmissometer assemblies will monitor the air attenuation along their lines of sight at all times prior to the shot, and they will be made a part of the "go-no-go" system in the firing circuit.

For KING shot, an attempt will be made to measure air attenuation between bomb zero and the thermal stations on Parry (photo tower), Aniyaanii, and Biijiri (station 803), until some few hours prior to the shot. A helicopter will be used, if possible, to hold the light source at the proper position.

<u>Remarks</u>:

For MIKE shot the success of Programs 2 and 3 is dependent upon good air transmission of light at shot time. This is considered to be sufficiently important to warrant a postponement of the shot if localized rain conditions cause the transmission to drop below prescribed values ($\sim 20\%$). Such a postponement, if necessary, will be made automatic by the following circuitry: When the current signal generated by the detector phototube (at either Elugelab or Bogallua) falls below the prescribed value, and stays below for 20 seconds, a relay will be opened. When it rises above the prescribed value, and stays above for 20 seconds, the relay will be opened again. The firing circuit is such that this relay must be open for the bomb to be detonated. The twenty second delay period is included so that a highly transient disturbance to the light path (such as a bird flying in front of the detector) will not actuate the relay.

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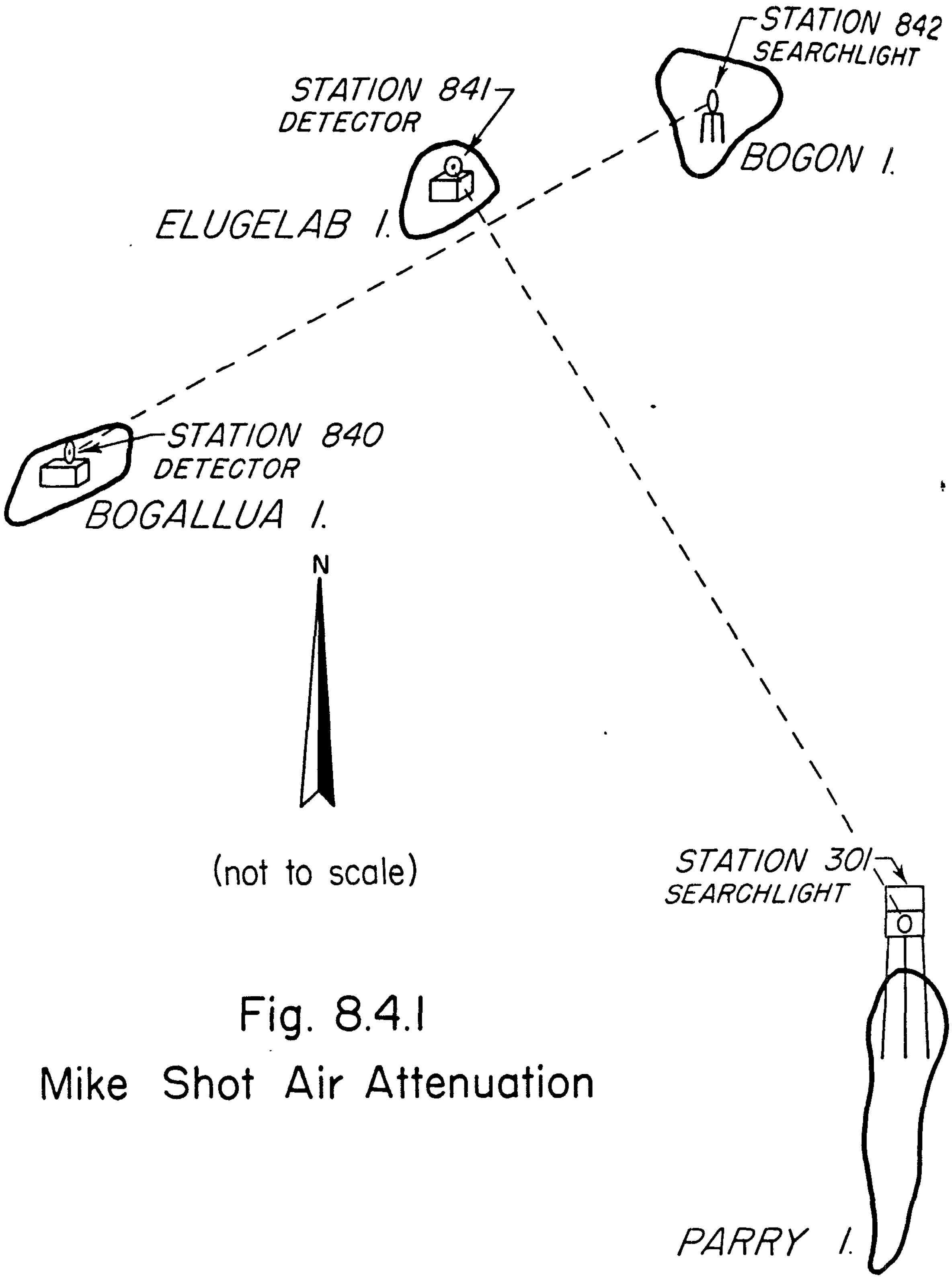

Fig. 8.4.1

Mike Shot Air Attenuation

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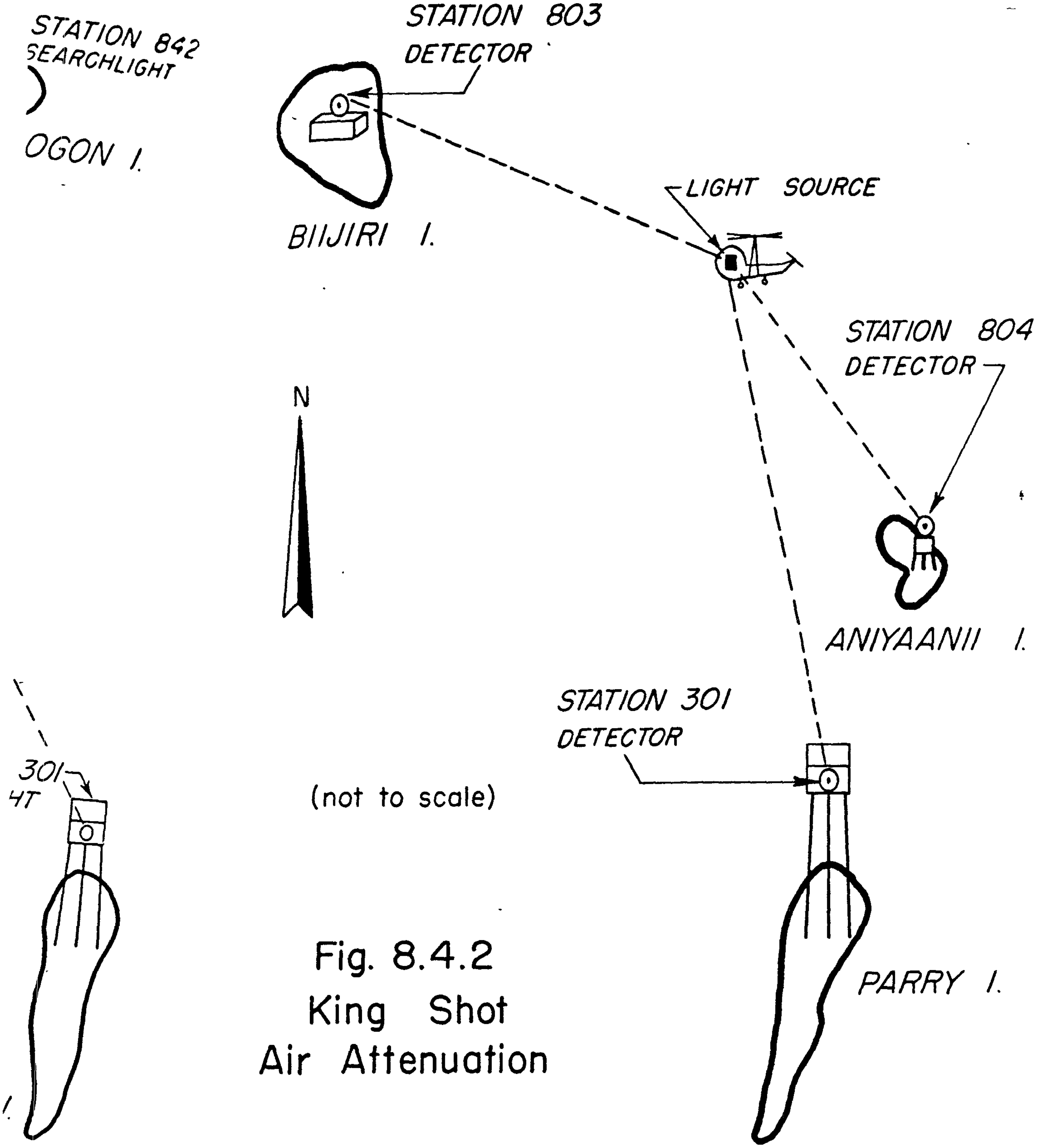

Fig. 8.4.2
King Shot
Air Attenuation

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PROGRAM 8

THERMAL RADIATION MEASUREMENTS

Project No: 8.5

Project Title: Thermal Radiation as a Function of Time in Free Air Utilizing Manned Aircraft.

Shot Participation: MIKE - KING

Sponsor: DOD (USAF)

Project Officer:

Name: Lt. Col. Rodney Nudenberg
Address: Wright Air Development Center
Wright-Patterson Air Force Base
Dayton, Ohio

Phone: Kenmore - 7111
EXT. 2-2226

Conducting Agency: Wright Air Development Center

Personnel Requirements in the Forward Area: *

	Approximate Number	From	To
Officer			
Enlisted			
Civilian			

Support Required:

(1) Utilization of the B-36D and the B-47B of Project 6.10.

(2) Use of one aircraft, preferably a B-29, for attenuation measurements and calibration; on a part-time basis only.

* Personnel for this project are reported under Project 6.10.

[redacted]

Object of the Experiment:

This project is designed to determine, in free air at altitudes significant to delivery aircraft, the thermal radiation intensity as a function of time, and the maximum associated radiation-induced aircraft skin temperature. Such information is essential to studies of safe aircraft delivery procedures.

Method and Procedure:

The maximum skin temperature of the B-36D and B-47B aircraft of Project 6.10 will be determined with skin patches - located on the inside surface of the skin. Thermocouples, properly located for representative measurements, will also be used. The temperature as a function of time will be correlated directly with the thermal radiation intensity measurements made with a directed phototube.

Attenuation measurements will be made over a two week pre-shot period, using similar equipment in a B-29, to determine the air transmission properties under conditions as nearly similar to those existing at shot time as possible. A strong mercury-arc light source will be operated on or near Elugelab island three weeks prior to MIKE shot and attenuation measurements will be made on a number of days, at about the same hour of the day as proposed shot time. Such measurements will also be made immediately prior to the shot. It is also planned to have a similar light source on Runit island, and as many pre-shot attenuation measurements as possible will be made during the time interval between re-entry into the atoll subsequent to MIKE shot and KING shot.

At shot time the light source will be destroyed, but prior to this it will serve as a point for alignment of the phototube mentioned above.

Remarks:

The attenuation data obtained in Project 8.4 will be of great value in final analysis of the data obtained herein.

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Project No
Shot Parti
Sponsor:
Project O:
Name:
Address
Phone:
Conducti
Personn
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PROGRAM 9

ELECTROMAGNETIC PHENOMENA

Project No: 9.1 Project Title: Electromagnetic Signals.

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Dr. Clyde L. Cowan
Address: P.O. Box 1663
Los Alamos, New Mexico

Phone: 2-2844
7-4000

Conducting Agency: Group J-12
Los Alamos Scientific Lab.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer			
Enlisted			
Civilian	1	M-35	K/1

Support Required:

[redacted]

Object of the Experiment:

We have seen in other project discussions that electromagnetic radiation acts as an important energy transport mechanism for atomic explosions. Those projects, however, have been concerned with short wave length portions of the electromagnetic spectrum - heat, light, gamma radiation, etc. It also has been well established that a longer wave length component of the spectrum is radiated, but very little is known about the details of the phenomenon.

Past experimental results indicate that a broad-band radio signal of very high intensity is emanated by exploding fission bombs. The frequency range of the band extends from very low audio (one or two cycles per second) to moderately high radio (~100 megacycle) frequencies, and the total duration of the signal is approximately two seconds.

Naturally, one hopes to take advantage of such a phenomenon in some way. Perhaps it can be used in the field of long range detection, helping us to penetrate the atomic energy security mantle of another nation. Perhaps it can be used to supplant more cumbersome methods of diagnostic experimentation in our own weapon test programs. This experiment is part of a continuing effort to understand how, why, and where this radio signal is generated.

Method and Procedure:

A. The ordinary radio is designed to receive a very narrow band of frequencies at a given time - in order that the user may separate a desired signal from the host of those not desired. Such a "selectivity" is achieved by tuning the antenna system to resonate at a given frequency. Conversely, an untuned antenna (one with no resonant frequencies) is capable of detecting a wide range of radio frequencies simultaneously.

This experiment makes use of such an untuned antenna as its detector, and proceeds to amplify the signal in the normal "radio" fashion. The purpose here is not to drive a transducer, however, but to deflect the sweep of a cathode-ray tube. The amplified signal is fed simultaneously to the vertical deflection plates of several such tubes, each having a different elapsed time horizontal sweep (covering the range of 2 μs to 2 sec., approximately). A number of oscillographs are thus obtained (by photographing the tube faces for permanent records) of the induced signal, each accentuating a different detail.

B. Recording equipment will be operated at Parry island and at Los Alamos, for both MIKE and KING shots.

[redacted]

PROGRAM 9

ELECTROMAGNETIC PHENOMENA

ject No: 9.2

Project Title: Effects on the Ionosphere with Respect to the Propagation of Radio Waves.

t Participation: MIKE - KING

nsor: DOD (USA)

ject Officer:

Name: Dr. C. M. Crenshaw
Address: Signal Corps Engineering Laboratories
Fort Monmouth, New Jersey

Phone:

nducting Agency: U.S. Army Signal Corps

ersonnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	2	M-30	K/10
Enlisted	4	M-30	K/10
Civilian	2	M-30	K/10

Support Required:

(1) One transmission from an aircraft (WB-29, P2V, or PBM) operating 250 miles west of Eniwetok.

(2) LST-lift into Bikini atoll.

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Object of the Experiment:

This project is designed to determine the effect of an atomic explosion on the ionosphere, with respect to the propagation of radio waves.

Method and Procedure:

A. The effects of atomic explosions on oblique incidence radio signals reflected from the ionosphere and the attenuation caused by the ionosphere layers will, if practicable, be observed. A vertical incidence ionosphere height recorder will be located as near to ground zero as practicable to observe near effects. Other recorders will be located at suitable distances to observe the undisturbed ionosphere for control purposes.

Radio signals from various widely separated transmission paths will be recorded in an effort to determine unusual disturbances which may be correlated with previous projects and experiments. The effect of atomic explosion-induced ionospheric disturbances upon the scattering of radio waves will be observed. Serious disturbances of the ionosphere, with consequent interruption of routine radio communications, have been observed at past tests. This project is devoted to improving our understanding of the phenomena.

B. Several HF sky-wave circuits will be keyed preceding, during, and following the shot. Observations will be made relatively close-in (50-200 miles) to determine the effect of the explosion on the circuits monitored.

Vertical incidence CRPL Type C-3 automatic ionospheric-height recorders will be operated at Parry and Bikini islands. Special recordings will be made on C-3 recorders at existing Army Signal Corps and Department of Commerce ionosphere observation stations. Back-scratcher ionosphere equipment will be operated to sweep the ionosphere azimuth-wise. Field intensity measurements will be made at Guam of WWVH transmissions from Maui, T.H., prior to and during the test.

A simulated practical communications system will be operated as follows:

(a) Transmit on about 3 megacycles at Eniwetok using an antenna with maximum radiation in an upward direction. The transmission will use radio teletype keying and will be on test tape. It will be observed, on a con-

[redacted]

uous basis, at Bikini and other mobile stations in the shot area.

(b) Transmissions will be made in the high frequency band from aircraft 250 miles west of Eniwetok, diametrically opposite Bikini. These will be observed at Bikini and other designated stations.

Observations will be made on long wavelength radio communication circuits originating at Guam, Honolulu, and other locations.

Remarks:

This project will be closely coordinated with Projects 7.1 and 9.3.

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PROGRAM 9

ELECTROMAGNETIC PHENOMENA

ect No: 9.3

Participation: MIKE - KING

sor: DOD (USA)

ect Officer:

ame: Mr. Peter Brown
ddress: Commanding Officer
Evans Signal Laboratory
Belmar, New Jersey

hone:

ucting Agency: U.S. Army Signal Corps

Project Title: Investigation of Electromagnetic Radiation Throughout the Radio Spectrum Caused by an Atomic Explosion.

sonnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	1	M-30	K/10
Enlisted	4	M-30	K/10
Civilian	2	M-30	K/10

port Required:

(1) Firing alert for remote stations.

(2) Timing signals for Runit and Parry island stations.

[redacted]

Object of the Experiment:

This project will attempt further quantitative investigations of the electromagnetic pulse caused by atomic explosions, recording sufficient data, over a wide band of search frequencies, to support a theoretical study of the phenomenon.

Method and Procedure:

A. Special close-in measurements of the radiated pulse spectrum will be made. In addition, radio receivers and recording apparatus will be employed at various distances to record evidence of the phenomenon, to determine field strength and establish the frequency distribution. Current investigations have been initiated to determine the validity of the phenomenon on theoretical grounds.

B. A spectrum analysis of the radiated pulse will be made on Runit and Parry islands. Observations will be made at Hawaii and Belmar, New Jersey, on 10 kilocycles (using sferics receivers). Observations will also be made at such stations as Adak, Okinawa, Bikini, Kwajalein, Guam, Japan, and Belmar, New Jersey, guarding optimum propagation frequencies.

Remarks:

This project will be coordinated with Projects 7.1 and 9.2. The data obtained herein will be complimentary to that obtained from the radar scope photography in Project 9.4, and each will aid in the analysis and interpretation of the other as techniques for indirect high yield weapon detection.

[redacted]

PROGRAM 9

ELECTROMAGNETIC PHENOMENA

ject No: 9.4 — Project Title: Evaluation of Indirect Bomb Damage Assessment Techniques.

t Participation: MIKE - KING

nsor: DOD (USAF)

ject Officer:

Name: Lt. Col. Rodney Nudenberg
Address: Wright Air Development Center
Wright-Patterson Air Force Base
Dayton, Ohio

Phone: Kenmore 7111
EXT. 2-2226

nducting Agency: Wright Air Development Center

ersonnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	1	M-30	K+5
Enlisted	5	M-30	K+5
Civilian	2	M-30	K+5

upport Required:

(1) Utilization of Project 6.10 aircraft, as well as any other aircraft within sufficient range and with adequate airborne radar equipment.

(2) Four Bhangmeters - to be supplied by EG&G.

[redacted]

Object of the Experiment:

It is planned herein to evaluate components of the IBDA which is installed in aircraft scheduled to participate in Projects 6.10 and 8.5.

Method and Procedure:

A. Photographs of radar scopes will be made during the atomic explosions, and a-detailed analysis will be made of the value of this technique as a measure of bombing accuracy, bomb damage, and weapon yield.

B. The basic radar equipment of the B-36D, the B-47B, and any available B-50's and B-29's will be utilized. These equipments are either complete AN/APQ-24 radar systems or APS-23 radar sets, the former incorporating the latter as part of the system. The response of the radar sets to each detonation will be observed and photographed on 35 mm film using standard O-15A camers (~15 frames/sec).

Indications of actual burst height and circular bombing error are to be obtained from the PPI presentations. In order that yield estimates can be obtained shortly after detonation (for correlation purposes), four Bhangmeters will be carried - two in each aircraft. The latter are described under Project 3.6.

Remarks:

1. Any radar sets and cameras equivalent to the above mentioned types that are airborne and within 50 to 75 miles from Eniwetok should be turned on and film should be made available to and later collected from each.

2. This project is a continuation of similar test projects conducted at GREENHOUSE, BUSTER-JANGLE, and TUMBLER-SNAPPER. Radar scope data is also available from CROSSROADS, SANDSTONE, AND RANGER. It is proposed that all these data be compiled and be the basis for a continuing Air Force study of this indirect bomb damage assessment method.

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PROGRAM 10

TIMING AND FIRING

Project No: 10.1 Project Title: Timing and Firing.

Shot Participation: MIKE - KING

Sponsor: AEC

Project Officer:

Name: Mr. Herbert E. Grier
Address: Edgerton, Germeshausen & Grier, Inc.
160 Brookline Avenue
Boston 15, Mass.

Phone: Copley 7-3520 (Office)
Bigelow 4-4956 (Home)

Conducting Agency: Edgerton, Germeshausen & Grier, Inc.
160 Brookline Avenue
Boston 15, Massachusetts

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer	3	M-42	K/7
Enlisted			
Civilian	1	M-42	M/10

Support Required:

* Plus seven additional civilians from M-42 to K/7.

[redacted]

Object of the Experiment:

This project is responsible for supplying all timing signals required by the IVY experimental program, and for supplying the firing pulse to the detonators of the MIKE shot weapon. Having such responsibilities, its most serious problem is that of maximizing the reliability of its equipment - a most perplexing problem indeed when one considers that Eniwetok atoll must be completely devoid of personnel for MIKE shot.

The importance of reliable timing signals for a complex experimental program of this type seems obvious. In fact, no exaggeration is involved in the statement that the success or failure of many experimental projects is heavily dependent upon their receipt of accurate and dependable pre-shot timing signals. Most measuring devices need to "get ready" just before they take a measurement - and many such devices need stopping before they try to measure too much. Timing signals are used to solve such problems.

Method and Procedure:

A. Consider an imaginary experiment station, S, which contains an assembly of experimental equipment, E. E is to be used for some measurement during an atomic explosion, and its proper operation depends upon the following sequence of events:

(a) 30 minutes prior to zero time an electric motor must be started.

(b) 5 minutes prior to zero time a voltage must be applied to the plates of a condenser.

(c) 1 minute prior to zero time the protective cover of a lens must be raised.

(d) 1 second prior to zero a shutter must be opened.

(e) At zero time the condenser must be discharged.

(f) 1 second after zero the shutter must be closed, the protective cover lowered, the voltage removed from the condenser plates, and the motor stopped.

The experimenter builds E in such a way that the closing of a switch is sufficient to cause each of the above to take place. He

[redacted]

...hen supplied with five relays (by those responsible for timing) ...h can be installed in S. The relays furnish the above mentioned ...ches for E, a separate relay being used for each circuit which re... ...res its switch to be closed at a different time. Signal wires ex... ...d from each relay to the nearest distribution station of the timing ...tem - which serves a number of experimental stations in addition ...S.

Each distribution station contains one relay for each time ...al available in the system - the closing of which actuates every ...erimental station relay intended to be closed at that time. Signal ...res extend from each distribution station relay to a corresponding ...tch in the central timing station. The latter is arranged to be ...rated either by hand or by a mechanically driven cam.

As an example, then, the sequence of events at 1 second prior ... zero is:

(a) The 1 second switch in the central timing station is closed - by a motor driven cam in this instance. This allows a signal to pass along the 1 second "line" to all distribution stations, where

(b) All 1 second distribution station relays close. This allows current to flow in the 1 second lines leading to experimental stations, where

(c) All 1 second experimental station relays close. This is the final desired result, and, in the case of E above, the shutter will open.

The above outline is perhaps over-simplified, but it will ...rve to identify the components in the IVY description which follows.

B. The timing signals which past experience has shown will meet ...e requirements of most experimenters are as follows:

[redacted]

(a) For a tower shot

Type	Time (with respect to zero	Error (with respect to actual zero)	Remarks
Manually operated	-60 min	0.5 sec	
"	-30 min	"	
Automatic (cam operated)	-15 min	0.1 sec	
"	- 5 min	"	
"	- 1 min	"	
"	-30 sec	.05 sec	
"	-15 sec	"	
"	- 5 sec	"	
"	- 1 sec	"	
"	ZERO	"	For "Dry Runs" only
"	≠ 1 sec	"	Cut-off for all relays

(b) For an air burst

Type	Time	Error (with respect to predicted zero)	Remarks
Manual	-15 min	See "Remarks"	
"	- 5 min	"	
Automatic	-30 sec	0.05 sec	
"	-15 sec	"	
"	- 5 sec	"	
"	- 2.5 sec	"	

(b) For an air burst (Continued)

Type	Time	Error (with respect to predicted zero)	Remarks
Automatic	- 1.5 sec	0.05 sec	
"	- 0.5 sec	"	
"	ZERO	"	For "Dry Runs" only
"	+ 3 sec	"	Cut-off for all relays

Two of the master switches are actuated by manual push buttons, and the remainder by an automatic sequence timer. The automatic sequence timer (or cam sequence timer) is a precision device driven by a synchronous motor. The timing cams operate mercury master switches in the proper sequence. For a tower shot, a sequence-start button (manually operated) places the cam timer in operation, and the timer shuts itself off after opening all the signal circuits after zero. For an air drop, a radio tone signal is interrupted at the time of bomb release, and controls the actual start of the cam timer.

Power to actuate all relays is supplied by batteries. In every case, the batteries are located in the station from which the signal comes - that is, the power to actuate the experimental station relays is provided by batteries located in the associated distribution station, etc.

All relays are type DN-11 railroad relays, which can operate on as low as 7.5 or as high as 100 volts. The operating time is essentially constant for voltages across the coil in excess of 25 volts. Four double-throw switches are available on each relay for the experimenters use. Two of these switches are rated at 10 amperes, and the remaining two are rated at 4 amperes.

Each relay circuit contains a monitoring milliammeter, in order that faulty operation of the circuit may be diagnosed. The criteria for meter location are identical with those mentioned above for battery location.

The fundamental limitation on the total number of basic time signals is the availability of lines from the control station. Since it is not feasible to string several miles of line for one additional time, the practice is for an experimenter to receive a standard signal and construct a delay line which will adapt it to his individual needs.

For an air drop, uncertainties in the release time and time-of-fall force all signals to be given with respect to predicted zero - and actual zero may vary from predicted zero by as much as 1.5 seconds either way. Thus no signal can be expected to exhibit an accuracy with respect to actual zero of better than ± 1.5 seconds. Signals given prior to release time (for example, a -15 minute signal) must obviously be given without knowledge of what the actual precise release time will be. It is quite possible for conditions on the ground or in the plane to delay, or cause an abort of, the planned bomb run. Approximately 25 minutes are required for the plane to make another run - hence such an eventuality will delay zero time by that amount. The practical significance of this is that batteries (for instance, a filament supply) that are turned on prior to expected release time should be capable of supplying current for the time necessary to make one or two extra bomb runs.

For pre-shot test purposes in the field, a practice (or "dry") timing signal run is made twice each day - with zero times at 1000 and 1500 hours local time. An experimenter receives any or all of these "dry run" signals, by his request only. Reliability considerations, of course, dictate his use of a maximum number of dry run signals.

C. In addition to the above system, "Blue Boxes" are available to those experimenters requiring them. The Blue Box is a device which responds to a very fast-rising (in intensity) light signal - and hence to the initial bomb light but not to extraneous sources. Its response consists of suppling either or both of two signals. The first of these is a voltage pulse rising to $\sim$200 volts within 100 μs after zero, and holding at $\sim$100 volts until manually reset. The second is a relay closure which is completed within 2 ms after zero. The relay includes one double throw switch, the contacts of which are rated at 2 amperes. The Blue Box is self-contained and weather proof. Models are available for both standard (110 volt) AC power line and battery operation.

D. Everything we have said thus far applies to timing systems in general, and only one restriction has been implied - the existence of a man at the central timing (control) station to actuate the manually operated switches. For MIKE shot, this restriction cannot be satisfied since the atoll will be completely evacuated - hence an additional link will be required in the system. The link will be supplied by radio control, and television monitoring, of the Elugelab central timing station from the "Estes" in the evacuation fleet. For details of the radio link operation, the reader is referred to the Project Officer.

E. The possibility always exists that experimental conditions will be such that a shot must be stopped and delayed. For air drops, radio contact is maintained between the control station and the dropping aircraft - and a verbal order to the bombardier can prevent release of the bomb if given early enough. For surface shots, a master disconnect switch is included in the system to allow manual stoppage after the sequence timer is actuated.

In addition, for surface shots, one wishes to allow for the necessity of a shot stoppage that can not (or need not) be subjected to the vicissitudes of human reaction. Two examples suggest themselves:

(a) If something untoward happens less than a second before zero, it may well be too late for a human to find out about it - or to decide what to do if he does find out - or pull the switch if he decides.

(b) Certain eventualities are so serious that their occurrence does not require a last-minute decision. If they do occur, the shot must be stopped.

One solution to the problem implied by these examples is the inclusion of one or more automatic master disconnect switches in the firing circuit. Such a system bears the name "go-no go", and will be included for MIKE shot. The discussion of Project 8.4 describes one of the go-no go installations. Another will be supplied by the cryogenics system.

F. Firing signals originate in the control station in the same manner as the cam timing signals, a separate "zero" cam being used. The master disconnect switch, and the remainder of the firing circuit, is isolated from the timing system for safety's sake.

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PROGRAM 10

Project No: 10.2 Project Title: Release Tone.

Shot Participation: KING

Sponsor: AEC

Project Officer:

Name: Mr. C. B. McCampbell
Address: (Code 5225-1) Sandia Corporation
Sandia Base, Albuquerque, New Mexico

Phone: Albuquerque 6-4411
EXT. 2-3215

Conducting Agency: Weapons Performance Division
Sandia Corporation

Personnel Requirements in the Forward Area:*

	Approximate Number	From	To
Officer			
Enlisted			
Civilian			

Support Required:

* The personnel requirements of this project are included in those of Project 2.5.

[redacted]

Object of the Experiment:

In the discussion of Project 10.1, we mentioned the use of a cam-driven sequence timer to actuate the majority of the timing signal master switches. We also mentioned that, for an air drop, the sequence timer is triggered (started) by the interruption of a radio tone signal when the bomb is released. This project is responsible for furnishing the starting signal to E.G.&G.'s sequence timer - in order that the complex timing-signal system described previously may be put into operation. Reliability is the most important boundary condition (to the design and operating techniques used herein) implied by such a responsibility.

Method and Procedure:

A. Knowledge of the objective to be achieved by this experimental project makes the basic method of achievement obvious. Prior to the release of the bomb, a radio tone signal is transmitted from the dropping aircraft. When the bomb leaves its shackle, this signal is interrupted. The line which supplies power to the sequence timer contains a relay-actuated switch, the relay coil being connected to a radio receiver which is tuned to detect the tone signal. As long as the tone signal is being transmitted, the switch is held open; the interruption of the tone, however, allows the switch to close. The latter starts the sequence timer and "the die is cast". The equipment duplication techniques, used to augment this basic method (see below), are indicative of the striving for reliability.

B. Two transmitters (transmitting on different frequencies) will be operated in the dropping aircraft, a normally-closed switch being located in the "ground" line of each (S_1 and S_2). These switches are opened (by remote control, utilizing sealed micro-switches) when the bomb is released. Two relay-actuated normally-open switches (in series) are located in the sequence timer power line (S_3 and S_4), - each relay coil being connected to an associated receiver. Each receiver is tuned to the frequency of one airborne transmitter.

The opening of S_1 and S_2 interrupts both tone transmissions. This in turn causes the receivers to pulse their respective relay coils, closing S_3 and S_4 - which allows current to flow to the sequence timer. The series connection of S_3 and S_4 implies that <u>both</u> tone signals must be interrupted before the sequence timer can start - hence the failure of one transmitter or one receiver cannot cause the timer to be actuated prematurely.

The above is a highly simplified representation of the equip-

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ment used by this project. The reader interested in a more detailed exposition is referred to the Project Officer.

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PROGRAM 11

PRELIMINARY GEOPHYSICAL SURVEY OF THE TEST AREA

Project No: 11.1

Project Title: Soundings of the Ocean Side of Eniwetok Reef.

Shot Participation: Pre-Shot

Sponsor: DOD (AFSWP & ONR)

Project Officer:

Name: J. W. Smith
Address: Office of Naval Research
Washington 25, D. C.

Phone: Liberty 5-6700
EXT. 6-4476

Conducting Agency: Hydrographic Office
U.S. Navy Department
Washington 25, D. C.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	4	M-150	M-120
Enlisted	60	M-150	M-120
Civilian	3	M-150	M-120

Support Required:

(1) Placement of targets on islands for surveying ship location.

(2) Use of photographic facilities ashore.

(3) Minor use of laboratory and shop facilities ashore.

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Object of the Experiment:

Although many water depth soundings have been made in Eniwetok lagoon and in the deep ocean water outside the island ring, the configuration of the close-in oceanside profile of the reef is unknown. Because of the expected magnitude of MIKE shot, there is some possibility that the reef may be shattered and breached in the vicinity of the shot island. It is therefore important that the reef configuration be determined before the shot. Such soundings will also provide information necessary for possible model studies of the atoll, to aid in the interpretation of shot-time measurements.

Method and Procedure:

The Navy Hydrographic Office has agreed to make the necessary soundings. The method employed will be a modified acoustic sounding system, whereby a vertical "fan" of acoustic pulses will be directed against the ocean side of the reef, the echoes being recorded by photography of oscillograph traces. The work will be done from the COCOPA (ATF-101), supported by a 42-foot boat for close-in measurements. Detailed sounding profiles, to a depth of several hundred fathoms, will be taken at 500-yard intervals for a distance of five miles either way from Elugelab and at intervals of about one mile for the remainder of the reef perimeter. This work will be accomplished during June, 1952.

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PROGRAM 11

PRELIMINARY GEOPHYSICAL SURVEY OF THE TEST AREA

Project No: 11.2   Project Title: Scaled Ground Shock Tests.

Shot Participation: Pre-Shot

Sponsor: DOD (AFSWP)

Project Officer:

Name: H. K. Stephenson
Address: P. O. Box 1663
Los Alamos, New Mexico

Phone: 2-4380

Conducting Agency: Los Alamos Scientific Lab.

U. S. Coast and Geodetic Survey
Washington 25, D. C.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	1	M-225	M-195
Enlisted			
Civilian	3	M-225	M-195

Support Required:

(1) Two seismic stations on San Ildefonso (Sta.11) and Rigili (Sta.13).

(2) Logistic support within the atoll.

(3) Occasional use of heavy equipment such as tractors, bulldozers, trailers.

(4) Support from Task Group 132.2 consisting of 15-man team (to handle high explosives) and approximately 10 radio operators.

 [redacted]

Object of the Experiment:

Predictions as to the ground shock at any given distance from an explosion may be based on scaling laws, which have in turn been based either on theoretical assumptions or on actual measurements for a series of shots of different yields. For a particular geological setting measurements in situ must be made. It was therefore decided to make a series of ground shock measurements at Eniwetok. Such measurements can serve as a check on predicted scaling laws and also as a measure of ground shock attenuation under the particular sub-surface conditions at the atoll.

Method and Procedure:

A series of scaled shots for ground shock measurement were made at Eniwetok during March and April, 1952. The high explosive charges for these consisted of a combination of Composition C-2 and Tetrytol. Five shots were fired, these being the equivalent of 1, 5, 10, 15 and 20 tons of TNT.

The shots were arranged in a "beehive" configuration, the base of which was placed at the saturated sand level on the shoreline of Elugelab near proposed MIKE zero point. Motion pictures of each shot were taken, for a study of wave action.

Seismic recordings for ground shock measurements were made at five stations around the atoll, with seismographs provided by the U. S. Coast and Geodetic Survey. These stations were at San Ildefonso (1200 yards), Engebi (6000 yards), Runit (25,100 yards), Rigili (27,800 yards), and Eniwetok (41,700 yards).

The records of both the seismic and photographic measurements are being analyzed at the present time.

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PROGRAM 11

PRELIMINARY GEOPHYSICAL SURVEY OF THE TEST AREA

Project No: 11.3 Project Title: Deep Drilling to Base Rocks.

Shot Participation: Pre-Shot

Sponsor: DOD (AFSWP & ONR)

Project Officer:

Name: Gordon Lill
Address: Office of Naval Research
Washington 25, D. C.

Phone: Liberty 5-6700
EXT. 6-2346

Conducting Agency: Drilling and Exploration Company,
Abilene, Texas

U. S. Geological Survey
Washington, D. C.

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	2	M-165	M-135
Enlisted	12	M-165	M-135
Civilian	20	M-180	M-120

Support Required:

(1) Heavy equipment for moving drilling rig, drill pipe, casing, etc. to first location (Sta. 1130, Elugelab), second location (Sta.113 Site Mack), and aboard ship.
(2) Support by 14-man Seabee team to build drilling platform of Navy T-6 pontoons on Site Mack. Heavy equipment support and some labor help for this team from Holmes and Narver.
(3) Military aid for handling and firing explosives to prepare Site Mack.

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Object of the Experiment:

Although coral atolls have been studied in one way or another for many years, much is still unknown about their structure. From various indirect evidence it is assumed that the rings of coral islands are built on eroded flat-topped platforms of volcanic origin and basaltic composition. The validity of this assumption has never been checked by drilling through the coral to the basement structure beneath.

Drill holes at selected locations on the atoll will give direct information on the geologic column which cannot be obtained in any other way. Deep drilling will give a direct measure of the depth of coral as well as determining the proportion of sand and rock layers. It will provide information necessary in the interpretation of the seismic refraction survey (Project 11.4) and will give an opportunity for determining vertical seismic profiles by velocity shooting.

Method and Procedure:

A deep-well rotary drill rig of the type used for oil wells will be used to drill two holes, each to an estimated depth of 5000 feet - or into the unaltered basement rock. Continuous samples of the drill cuttings will be taken, and at intervals cores of the rock will be cut for study.

The first drill hole will be near the shot point on Elugelab in order to determine subsurface conditions there before the disturbance created by the shot. The second hole will be drilled from a Navy steel pontoon platform on the shallow coral head (Site Mack) in the lagoon west of Runit. This second hole will provide information on subsurface conditions near the middle of the atoll structure and will be especially valuable in the interpretation of the seismic refraction survey.

It is expected that the drilling will be completed by early July, 1952.

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PROGRAM 11

PRELIMINARY GEOPHYSICAL SURVEY OF THE TEST AREA

Project No: 11.4

Project Title: Seismic Refraction Survey.

Shot Participation: Pre-Shot

Sponsor: DOD (AFSWP & ONR)

Project Officer:

Name: J. W. Smith
Address: Office of Naval Research
Washington 25, D. C.

Phone: Liberty 5-6700
EXT. 6-4476

Conducting Agency: Scripps Institution of Oceanography
La Jolla, California

Personnel Requirements in the Forward Area:

	Approximate Number	From	To
Officer	8	M-30	M-1
Enlisted	120	M-30	M-1
Civilian	25	M-30	M-1

Support Required: Erection of high targets for positioning ships up to 20 miles offshore.

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Object of the Experiment:

In order properly to interpret seismic measurement made in conjunction with high yield weapon tests, the seismic characteristics of the substructure in the region around the shot should be known. Measurements of these characteristics can be made by conducting a seismic refraction survey, of the same type as is used so widely in exploration for oil. In such a survey high explosive charges are fired at one point and the resulting refracted elastic wave is detected by a recorder at a second point. By varying the spacing between shots and recorder, the results can be interpreted in terms of the elastic constants and structure of the underlying rock layers.

Such a survey was recently completed at Bikini by an expedition from the Scripps Institution of Oceanography, and yielded much information indicating a rather complex structure under the atoll. The proposed survey at Eniwetok should yield more significant information because of the additional control provided by the deep-drill holes and experience gained during the Bikini survey.

Method and Procedure:

The refraction survey will be based on the technique worked out at Bikini, and the same group which conducted the Bikini survey will work at Eniwetok.

Two ships will be used, one for firing explosive charges, the second to act as recording point for the seismic waves. Detection of the waves will be by means of a hydrophone trailed behind the recording ship. In such a technique the water is considered as one layer of a multi-layer problem. Furthermore, the known seismic velocity for sea water is used to measure the separation of the two ships.

Measurements will be made along traverses criss-crossing the lagoon, and these will be interpreted in terms of the configuration of the subsurface layers under the atoll. The two deep-drill holes will give positive control for the interpretation of measurements.

Field work for the seismic refraction survey will be completed during the month preceding MIKE shot.

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