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UPPER ATMOSPHERE RESEARCH REPORT NO. III

Compiled and Edited

by

H. E. Newell, Jr. and J. W. Siry

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Washington, D.C.

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Carnegie Inst., - Att. Dr. Merle A. Tuve	"	(81)
Ord. Adv. Committee on GM - Gen'l. Radio Co., Cambridge, Att: Dr. H. B. Richmond	"	(82-83)
SIMN - Gen'l. Textile Mills - Att: Mr. L. P. Friedler	"	(84-85)
BAR - Glenn L. Martin Co., Att: Mr. Goddard; Mr. Vorhees; Mr. Routh	"	(86-88)
SINM - Harshaw Chemical Co., Att: Dr. H. O. Kremers	"	(89-90)
INM - Raytheon - Att: Dr. Edelfsen; Mr. H. T. Ashworth; Mr. H. Grant	"	(91-93)
INM - Sperry Gryoscope Co., Garden City, N. Y., Att: Mr. G. E. White	"	(94)

Foreword

The material contained in this Upper Atmosphere Research Report originally formed part of a report to the Joint Research and Development Board concerning the Naval Research Laboratory's program in this field. It provides a comprehensive review of the work, from its inception to the present time, and includes proposals for both the immediate and the long range programs in Rocket-Sonde Research. Much of the subject matter presented here has appeared in the Upper Atmosphere Research Reports I and II, and the more recent information will be given in greater detail in future reports of this series. The present survey is published since it makes available in convenient form the essential features of the entire program.

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ABSTRACT

The Naval Research Laboratory's upper atmosphere research program using rocket vehicles is described. In terms of the research already completed, in progress, and contemplated, the objectives, accomplishments, and proposed immediate and long term programs in various aspects of upper atmosphere study are set forth. In this manner the basic research programs in astrophysics, cosmic rays, the ionosphere, and the composition and physical characteristics of the atmosphere are treated. The supporting programs in telemetering, radio control, and warhead design and construction are also described.

CHAPTER I

THE ACCOMPLISHMENTS OF THE FIRST YEAR OF ROCKET-SONDE RESEARCH IN THE UPPER ATMOSPHERE

by

E. H. Krause

Introduction

The Naval Research Laboratory has been engaged in a large scale high altitude Rocket-Sonde research program for the past year. This program was the natural outgrowth of the Naval Research Laboratory's work on the upper atmosphere during the two decades preceding the War as well as the Laboratory's work on guided missiles during the War. For many years prior to the War various groups at the Laboratory had been doing research on the upper atmosphere, including: work on the ionosphere; pressure, temperature and composition measurements; sky brightness studies; atmospheric electricity studies; etc. The work of Gunn, Hulburt, Maris, and Taylor in these various fields since 1920 is too well known to need repeating here. It was natural therefore that the peacetime activity of the Naval Research Laboratory should include a program of upper atmosphere sounding with the aid of the long anticipated rocket vehicles which were finally reduced to practical devices during the War.

This report is a presentation of the Naval Research Laboratory's program in this field and discusses in detail its objectives, its accomplishments to date, and a proposal for the extension of the program into the future.

Objectives

The reasons for conducting a research program at high altitudes are many and varied. Perhaps the most important is the contribution to basic research which such a program makes. Although the specific applications are to a large extent unpredictable, the long range value of such research to the National Defense is certain to be great.

The basic fields of physics and astrophysics to which it is felt high altitude research can contribute the most are:

(a) Nuclear Physics. Fundamental nuclear studies are made possible by the high energy cosmic radiation existing above the atmosphere. The study of cosmic rays in the past has provided one of the richest sources of fundamental information in physics. For example, such fundamental particles as the positron and the meson were first detected and identified experimentally in the cosmic radiation. It will certainly be many years before these high energy particles and radiations can be artificially produced and studied in the laboratory. The study of solar phenomena is also likely to produce information on certain nuclear processes.

(b) Astrophysics. The study of solar phenomena also can contribute much to our knowledge of the sun in particular and the universe in general.

(c) Atmospheric Structure. A detailed study of the earth's atmosphere, including the variation throughout space of its composition, density, temperature, pressure, ionization processes, dissociation phenomena, etc., is fundamental.

In addition to the basic contribution which the Rocket-Sonde work will make, there are very specific applications to military problems which can be foreseen. These include:

(a) Aerodynamic Design. The design of aircraft or guided missiles of any kind which are to fly through the region of the upper atmosphere is predicated on a knowledge of the composition, temperature, density and pressure of that region. For example, the very practical problem of expected temperature rise on the surface of a guided missile for a given set of conditions must be known, both from a point of view of materials which must be used and precautions which must be taken for equipment or occupants aboard.

(b) Radio Guidance of Missiles. A knowledge of the electromagnetic properties of the atmosphere is essential so that the radio guidance of missiles, both short and long range, can be successfully and most efficiently accomplished. Similarly this information is also necessary from a purely defensive point of view for the detection and countering of enemy missiles.

(c) Weather Forecasting. The characteristics of the upper atmosphere and their contribution to weather conditions on the earth can be very significant to commercial and military applications. Meteorological forecasting at present is beset by many unknowns so that although predictions can be made several days in advance, sudden unaccountable wind shifts can upset the best predictions. Similarly, knowledge of the conditions responsible for the movements of ion clouds which seriously effect electromagnetic propagation may result from these studies.

(d) Aerial Photography. Photography from these high altitudes can prove very useful for meteorological studies of cloud formations as well as for general mapping purposes.

More detailed and adequate discussions of the various programs and the objectives involved are given in Chapter II as well as in Part II of this report.

The V-2 Program.

Initially the Naval Research Laboratory's Rocket-Sonde Program contemplated the procurement of a series of rockets for use in this program including that of a low performance "stop gap" rocket for immediate use. However, before this program got seriously underway the Army Ordnance's V-2 program entered the picture. The captured German V-2's which Army Ordnance contemplated firing were ideal vehicles for the Rocket-Sonde work and in addition, they would be available long before any American made rocket could be procured. Furthermore, the number of V-2's available would last over a sufficiently long period so that high performance high altitude sounding rockets could be developed in the meantime. Accordingly, since the programs dovetailed so nicely, an agreement was reached between Army Ordnance and the Naval Research Laboratory whereby the former would furnish and fire the V-2 rockets, while the latter would coordinate the upper atmosphere research to be done in the V-2's. To facilitate this coordination, a V-2 panel was set up, made up of members of various universities and agencies who were actually contemplating upper atmosphere work in the V-2. By mutual agreement between Army Ordnance and the various panel members, the technical decisions and the allocation of space in the V-2's were to be considered strictly on a scientific basis directly by the scientists on the panel. Army Ordnance agreed to stand by the recommendations of the panel insofar as possible. Early in the program it was felt by the Army and the General Electric Company (under contract to the Army) that the expenditure program should not be prolonged over too long a period because of the deterioration of various critical V-2 components.

From the beginning, the Naval Research Laboratory has supplied the entire V-2 program with specially designed warheads, complete telemetering equipment and services, and complete radio control equipment and services. A brief discussion of the warhead procurement program is given under Chapter III, Section A. Complete details about the present and proposed telemetering program, in which as many as 450 channels will be available, is given under Chapter III, Section B. Radio control has been very successfully used in the V-2 for emergency cutoff and for missile blow-up. The extension to other control functions is relatively simple and is presently contemplated for some of the experimental work. Details are given under Chapter III, Section C.

The basic philosophy of the V-2 Panel from the beginning has been to encourage as many participants in the V-2 program as possible so that the best brains in the country could be brought to bear on this admittedly very expensive program. However, to simplify the coordination problem it was agreed that any new participants should be brought in through one of the five agencies who had obtained the most experience and had adequate facilities to carry out this coordination. These five agencies were the Naval Research Laboratory, the General Electric Company, the Applied Physics Laboratory, the Air Materiel Command, and the Signal Corps. This plan worked out satisfactorily as time went along until today each of the five coordinating agencies supports and/or coordinates the work of numerous other universities and agencies. The Office of Naval Research has contracts with at least seven universities on this work, including Princeton, Harvard, Yale, Michigan, New Mexico A & M, Johns Hopkins University, and the University of Chicago. The Naval Research Laboratory is also working in very close liaison with the NACA on the problem of determining the physical characteristics of the atmosphere with a view to having the data obtained ultimately contribute to the NACA's Standard Atmosphere Tables. Similarly cooperative planning is being done at present with the Bureau of Standards which should lead to the performance of joint experiments on ionosphere propagation. In addition there is supporting work done by numerous industrial concerns.

It is felt that the V-2 program has been well coordinated by the V-2 Panel and that the method of allocating V-2's by the scientists of the panel is a good one and should be maintained. It is also believed that as many of the captured German V-2's as possible should be utilized for this upper atmosphere research program. According to data presently available from Army Ordnance the total number of such V-2's now available for upper atmosphere research work is approximately 75.

The development of rockets which will be more adequate to the requirements of the upper atmosphere research program has meanwhile been continued. The progress is described in detail in Part II of this report.

Accomplishments to Date

For the past year the Naval Research Laboratory's Rocket-Sonde research program has utilized the Army Ordnance's captured German V-2's as vehicles to attain altitudes between 80 and 170 kilometers. Although it was anticipated that the first year of work in this new field would be spent in the acquisition of techniques and "know-how", it is particularly gratifying to note that the results obtained in this first year of work represent great forward steps in at least three or four different scientific fields. Some of these results have already been published in numerous reports and yet others are in preparation. The reports, publications and talks by Naval Research Laboratory personnel on this subject are listed under Appendices II and III.

Briefly, the high altitude research at the Naval Research Laboratory has been highlighted by the following work.

(a) Astrophysics and Composition. On the basis of two different experiments, the known spectrum of the sun has been extended from 2900 Å down to 2300 Å. These spectra have shown that the sun does not act as a black body at 6000° K but that its energy falls off progressively from the black-body curve towards 2300 Å. Many new Fraunhofer lines have been observed and identified in this new spectral region. The upper limit of the ozone layer has been measured for the first time. The almost 100 spectrograms obtained to date have also provided interesting data on sky brightness. A more complete survey of the program and accomplishments in Astrophysics and Composition is given in Section A of Chapter II.

(b) Cosmic Rays. Four different cosmic ray experiments have been successfully performed to date in four different flights. At the present time four more experiments are in preparation for incorporation in flights during May and July 1947. The results of the first experiments have given more insight into the nature of the cosmic radiation. It has been definitely established that the greater portion of the primary radiation consists of "hard" particles (i.e. particles which will penetrate at least 12-15 cm of lead) and that about one out of every five such particles will produce a shower in 12 cm of lead. In addition it has been found that a non-primary soft component exists above the atmosphere (to the extent of about 30% of the total number of particles present) due presumably to radiation originating within the earth's atmosphere from the primary or secondary cosmic radiation. These results are particularly significant in that they were the first obtained above the atmosphere where the primary radiation could be studied directly. Heretofore the nature of the primaries could be inferred only from studies on the secondary or tertiary radiations. A more detailed discussion of the accomplishments and the program in cosmic rays is given in Section B of Chapter II.

(c) The Ionosphere. The ionosphere program has been beset by many electrical and mechanical problems brought about by the nature of a rocket and its flight characteristics. Because of these problems the initial experiments were not successful. However, data on the ionosphere was obtained for the first time on March 7, 1947 to an altitude of about 130 km (roughly the middle of the E layer). This data has not yet been sufficiently analyzed to present any definite results at this time. A further discussion of the results and the program on the ionosphere is given in Section G of Chapter II.

(d) Pressure and Temperatures of the Upper Atmosphere. Pressure measurements obtained up to 100 kilometers have provided the first good atmospheric pressure and temperature data above 30 Km. In addition, skin temperature for various types and thicknesses of skin have been obtained for Mach numbers up to 5. It is now possible to predict with reasonable accuracy the temperature at various points that a missile resembling a V-2 will reach for this range of Mach number.

(e) Aerial Photography. Photographs from the V-2 have provided overall views of cloud formations extending over an area in excess of one-half million square miles. Such data is of value for meteorological and cartographic studies.

Future Research

The proposed immediate and long range upper atmosphere research programs are detailed in Part II of this report.

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CHAPTER II

OBJECTIVES, ACCOMPLISHMENTS AND PROPOSED IMMEDIATE AND LONG RANGE PLANS IN THE BASIC RESEARCH PROGRAM

A. Astrophysics and Atmospheric Composition

by

E. Durand and R. Tousey

The main objectives of the research program are (1) to study the composition of an the physical processes in the sun, and (2) to determine the composition of the earth's upper atmosphere, using methods applicable to rockets.

Much of the research on atmospheric composition and all on solar composition and processes are being carried out by means of ultra-violet spectroscopic methods. Prior to the experiments conducted by this laboratory from the V-2 rockets, the ultra-violet spectrum of the sun was known only to about 2900 A. All measurable radiation below this wave length is absorbed by a layer of ozone in the earth's atmosphere located near 25 km. and by the upper air itself. Experiments from balloons have not succeeded in extending the ultra-violet spectrum appreciably since the ozone layer is too high to be penetrated except by rockets. The ultra-violet spectrum of the sun is of great interest to physicists, astronomers, and to the designers of high flying rockets. The following paragraphs give the principal fields in which knowledge gained under the foregoing objectives is of importance.

Physical Condition of and Processes in the Sun A great deal of interest centers in the physical condition, temperature and composition of the outer atmosphere of the sun. Spectroscopic evidence as well as radio noise measurements from the sun suggest that the outer atmosphere of the sun may be in a highly ionized condition such as would prevail at a temperature of over 1,000,000 degrees C. As a result a large quantity of short ultra-violet radiation should be radiated from the sun. If so, it is completely absorbed by the earth's high atmosphere. The cause of these high temperatures is not understood at present, but it is believed that they are produced by atomic energy release. A study of the ultra-violet solar spectrum possible from rockets will be of great assistance in understanding the processes of energy conversion in the sun.

The Ionosphere Radio transmission conditions are intimately related to the ionosphere. The ionosphere and changes in it are though to be produced by short ultra-violet radiation from the sun. It is expected that it will be possible by means of solar spectroscopy from rockets to prove that it is the solar ultra-violet which is responsible for the ionosphere. A great gain in understanding of the various layers of the ionosphere will result. The work will have a bearing on the prediction of radio transmission conditions.

Atmospheric Composition Direct determinations of composition have been made with balloon-borne instruments only up to 20 miles. Indirect evidence indicates the existence of a number of higher regions of great interest such as the ozone layer, the various layers of the ionosphere, and the region at very high altitude where oxygen disassociation sets in. Each of these regions results from the absorption of ultra-violet solar radiation and the energy transfer involved causes temperature and pressure changes. These matters are important to an understanding of the atmosphere and will have military value in connection with the design and use of high flying rockets.

Detailed direct studies of these regions are possible with rocket techniques. Ozone and several other gases may be measured by observing the changes in the solar spectrum as the region in question is traversed. Certain gases may be studied by emission or absorption spectroscopy using rocket-borne sources of radiation.

Non-spectroscopic methods are also useful. These include mass-spectrographs, sampling bottles, and composition-sensitive pressure gauges. Diffusion pumps or other condensing devices will be used to concentrate the gases, enabling the analysis to be carried out at higher altitudes.

Sky Brightness There is a need for measurement of the sky brightness at very high altitudes at various parts of the spectrum. This is of importance in connection with optical devices for missile control.

Altimeter for Rockets At present, research is in progress to measure the intensity of solar ultra-violet radiations of different wave lengths which reach different levels in the atmosphere. After this knowledge has been obtained it will be possible to use it as a method for measuring the altitude of a rocket. An optical altimeter may be the only device capable of measuring the altitude of a rocket when at the very highest levels.

Weather Prediction It has been suggested that the absorption of ultra-violet light high in the earth's atmosphere and possible variations in the ultra-violet light emitted by the sun may have a profound effect on the weather conditions on the surface of the earth. A pre-requisite to the proving or disproving of such theories is the measurement of solar ultra-violet and composition of the earth's atmosphere.

Accomplishments

Instruments A vacuum grating ultra-violet spectograph has been designed and built. As a result of a novel device, a lithium flouride bead, for admitting radiations, it has several features not found in any of the other instruments designed for rocket spectroscopy. These are:

1) Wide Range - 3400 to 1100 A. This is achieved by limiting the amount of absorbing material in the light path to the 2 mm sphere of lithium fluoride.

2) Large Acceptance Angle - 70 degrees from each of two mutually perpendicular axes. This is of great value since the rocket ceases to be stabilized at about 20 miles on the ascent.

3) High Speed - the efficiency of the bead as an illuminator is at least 300 times that of the ground quartz and slit arrangement used by others. Many short exposures are possible, so that composition may be studied at closely spaced altitudes. Film capacity is such that one exposure per second can be taken during the entire ascent. The high speed is also of great value in extending the short wavelength limit of observation, since the intensity of solar radiation falls off rapidly with wavelength below 2900 A.

<u>Experiments Performed</u> Ten instruments have been built. Four have been flown, of which two were successfully recovered and two destroyed on impact. Three are scheduled for flight in May, 1947, and the balance will probably be flown before the end of 1947.

<u>Results Obtained</u> In the two successful flights, nearly 100 spectra were recorded at various altitudes up to 125 Km. A single exposure covered the range from 130 Km to the top of one of the flights - 160 Km. Radiation was observed from 3400 A to 2100 A. Valuable contributions were made to several major problems:

1) Solar Spectral Energy Distribution. The curve of average radiant energy as a function of wavelength - the so-called black-body curve of the sun - was extended from the previous limit of 2900 A to 2300 A. It is shown in Figure 1. The ultra-violet intensities are much less than had been predicted.

2) Fraunhofer Line Analysis. A large number of fully and partly resolved absorption minima were observed in the region between 2950 and 2300 A. Nearly all observed minima are blends from two or more closely spaced lines, but the principal contributors have, in many cases, been identified.

3) Line Shapes. Line widths and intensities are important in determining excitation conditions in the sun, necessary to an understanding of the fundamental processes occurring there. Considerable information on this subject is contained in the spectra. Full analysis and evaluation of conditions in the sun will require another year or more of intensive work.

4) Ozone. The vertical distribution of ozone on 10 October 1946, is shown in Fig. 2. The results of the 1937 Explorer II balloon flight are shown for comparison. The balloon data above 22 Km. are based

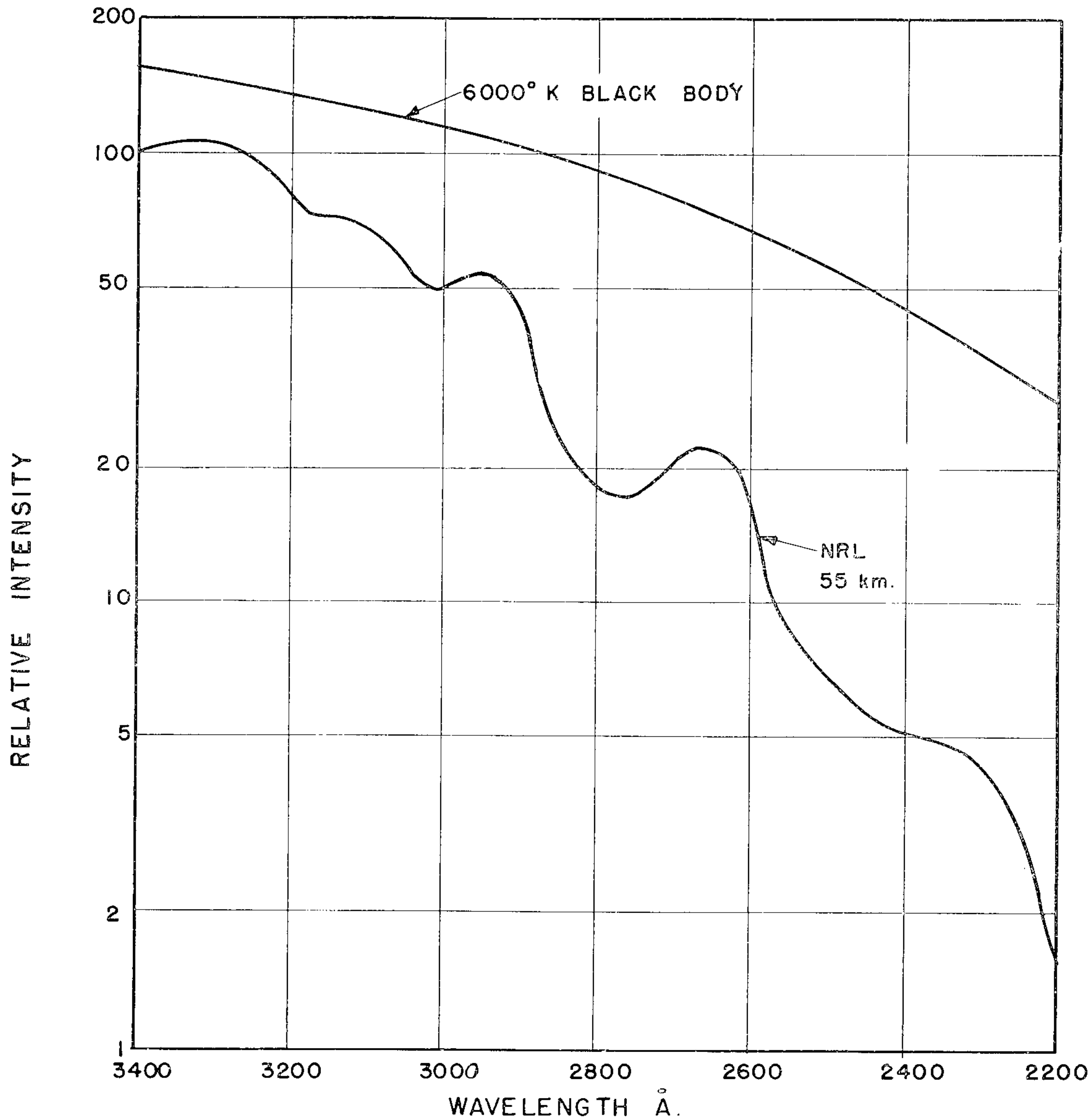

Fig. 1 - Preliminary Solar Intensity Distribution, 10 October 1946

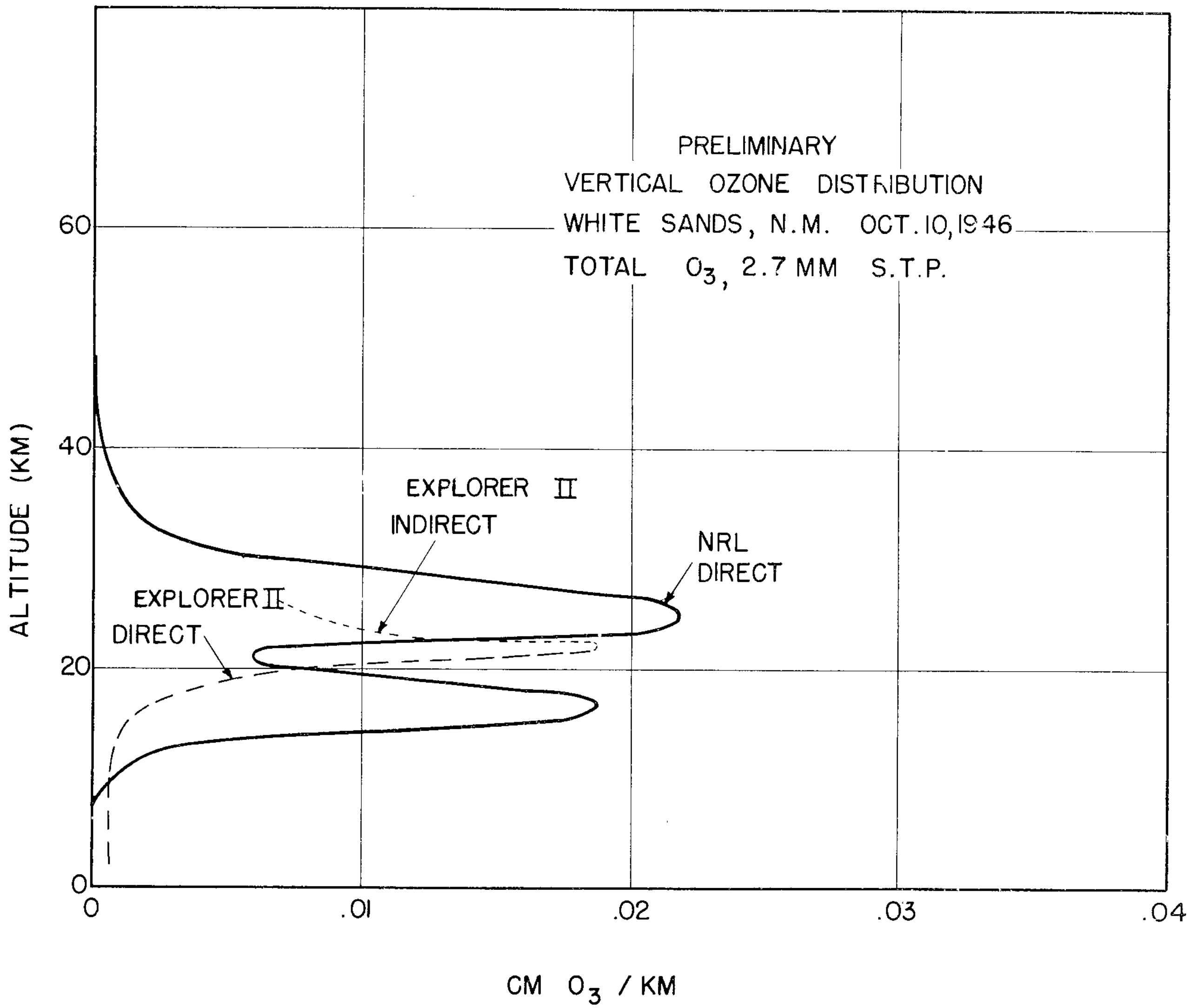

Fig. 2 - Preliminary Vertical Ozone Distribution

on an indirect method and lack the inherent accuracy of the direct method employed from the rocket. Further data are required to determine whether the disagreement is due to a real variation in the ozone or to experimental error

5) Sky Brightness. Some data in the ultra-violet are available. The experiments were not, however, designed particularly for this problem.

<u>The Future Program</u>

<u>Spectroscopic</u> The present instrument was designed to survey the whole spectrum and most of its potentialities are now known and have been realized. Work is underway on more specialized instruments. The aims are two-fold: (1) to extend the observations to shorter wavelengths, and (2) to obtain higher resolution in the regions already observed. Each is vital to the complete accomplishment of the objectives set forth in the introduction. The two aims are not entirely compatible with each other, so that specialized experiments and instruments adapted to the one or to the other will be required.

Concurrently with the development of new experiments, more experiments with the existing instrument are planned. Some extension of the spectrum and further data concerning ozone distribution will probably be obtained. Two spectographs will be launched in the 15 May missile, and others later, if needed.

On May 1, a new specialized experiment is scheduled, using a modification of the present instrument. The specific purpose is to observe the ozone layer through a long, slanting path, by launching the rocket near sunrise. The ability to detect traces of ozone and other suggested gases at a given altitude will be increased about 100 fold compared to a mid-day firing. This should confirm the tentative evidence that the top of the ozone layer was surpassed in the previous flights.

Another specialized experiment involving a modification of the present instrument is being contemplated. The bead illuminator system causes some loss of resolution in cases where the rocket orientation changes during the exposure. The modification consists of substituting a ground quartz plate and a slit for the bead. In spite of the great loss in speed, some increase in resolution will be achieved, and valuable data may be obtained in the spectral region just below the ozone cut-off.

The principal difficulties in the present experiment are caused by the roll, pitch, and yaw of the rocket during the exposure. The next major development will therefore be to stabilize a spectograph of the present type so that its axis always points to the sun. There should result a tremendous increase in effective exposure and a great extension of the spectrum into the vacuum ultra-violet is expected.

Some improvement in resolution will be obtained from this stabilization. However, still greater resolution is highly desirable. A spectrograph is being planned having ten times the dispersion of the present instrument. If not too bulky, it also will be stabilized. This is the second immediate major development.

Later developments will include a spectrograph in which the lithium fluoride bead is replaced by a small reflecting sphere, permitting observations in the region below 1100 A. Interferometric devices are being considered for the examination of small portions of the spectrum at very high resolution. The intensity ratio between the visible solar radiation and the radiation below 1200 A may be as high as 10^6. Therefore, in a conventional spectrograph, the longer wavelengths scattered because of the inevitable instrumental imperfections may fall on top of the shorter wavelengths, completely masking the latter out. This may be overcome by using selective detectors which do not respond to the longer wavelengths.

Such devices will usually be used without a dispersing device such as a grating, so as to avoid the energy loss involved. Their resolution, poor at best, will be determined by their inherent spectral response curve. Several types may be mentioned:

1) Photocells and Photomultipliers, used either with filters or with special photo-surfaces insensitive to the longer wavelengths.

2) Photosensitive crystals, such as thermoluminescent plates and the Pohl halogenoid crystals.

Non-Spectroscopic. The non-spectroscopic methods for determining composition were indicated in the introduction. Sample bottles are being tried by an outside group, but may be repeated, taking advantage of the ram compression at the rocket nose, and, perhaps, of the compression of a diffusion pump. An ionization pressure gauge with a palladium window for the detection of hydrogen has been considered, but appears to lack sufficient sensitivity. The mass-spectrograph has some promise, particularly if compression is used to obtain an adequate pressure in the ion source. There are great technical difficulties involved, however, and it will be some time before work can be started.

CHAPTER II

OBJECTIVES, ACCOMPLISHMENTS AND PROPOSED IMMEDIATE AND LONG RANGE PLANS IN THE BASIC RESEARCH PROGRAM

B. Cosmic Rays

by

E. H. Krause and G. J. Perlow

Objectives

At the start of the work on this subject it was apparent that two alternatives were possible. Either the identity or the reactions of the primary cosmic rays could be studied. It was decided to work on the identification problem first because this required fewer assumptions to get a useful result and second, because the experimental technique is more or less straightforward. It was known, for example, that if there were an appreciable electron component most of it would be well under 10^{8} e.v. in energy. If any ionizing rays were absorbed in 15 cms. of lead, they would be electrons.

Accomplishments

In a first experiment, the increase in counting rate in a flight was observed for counter tubes shielded with lead and relatively unshielded. It appeared from this that the high altitude radiation was entirely penetrating. However, a shower detecting arrangement showed large numbers of showers produced in the warhead and this threw doubt on the possibility of so simple a conclusion. The next experiment used coincidence counting and tested the penetrating properties again. It was then discovered that about 30% of the rays were not penetrating. A subsequent analysis of the geometry of the experiment showed that this figure could be even larger. The reason was that the penetrating radiation was found to be shower producing with about 20% probability of discharging a three-fold shower set under 15 cms. of lead. The production of these showers increased the apparent solid angle of the counter set defining the penetrating particles and led possibly to overestimating their numbers. Relatively then, the number of easily absorbed particles was underestimated.

In a third flight the previous experiment was repeated with better geometry. It was then found that (at a zenith angle of 45°) about 60% of the radiation was absorbable in a large thickness of lead (14 cm.). The other properties of the high altitude radiation were again verified, i.e., the large numbers of warhead showers, and the showers under 14 cm. of lead (28% in this measurement).

In the same flight another experiment was conducted and this gave greater insight into the properties of the radiation. The radiation was tested for penetration through two successive lead plates each only 2 cm. thick. It was then found that about 35% of the high altitude rays were stopped in either the first plate or penetrated it and stopped in the second. This indicated that at least this component was not primary (if the improbable case is excluded that it consisted of nuclei of high atomic number). It has been suggested by J. A. Wheeler that these are electrons which arise from the atmosphere below and are due to meson decay. The ones observed presumably originated above South America and spiraled around the magnetic field lines to reach the point of observations. The remainder of the radiation (i.e. 65%) was observed to penetrate the 4 cm. of lead, some of it producing showers in either the first plate, the second plate or both. An upper limit to the relative number of primary electrons is obtainable from this data. First, it cannot be greater than 65%-40% or 25% of the total radiation (including the Wheeler electrons). Second, it must be less than the relative number of events in which showers were produced below 2 and 4 cms. since some of these are ascribed to particles of high penetrating power. This reduces the possibility to 9% of the total or 18% of the primary radiation.

In another flight the penetration through 2, 6, and 12 cms. of lead was recorded. While this data is not completely analysed at this writing, it appears that the fraction of primary electrons allowable will be still lower. The Wheeler electrons were again found.

<u>The Immediate Future.</u>

At the present time three experiments are being prepared for two contemplated flights.

(a) The origin of the Wheeler electrons is to be checked by determining the upward intensity using an anti-coincidence method.

(b) M. Schein and his associates have reported the production of meson showers in paraffin. This will be checked in a simple experiment preliminary to any use of the paraffin technique.

(c) A maximum in the radiation penetrating 4 cms. lead as a function of altitude has been observed by the Naval Research Laboratory group. This could have been due to electrons of the soft component. A check will be made by a method due to Bhabha and to Hall in which electrons are ruled out by their shower production.

<u>The More Distant Future</u>

The counter technique has been the only one used thus far. Two additional techniques are being gotten ready for future flights. Fast ionization chambers will be constructed and filled according to a recipe of Rossi, and small cloud chambers are being designed from a large scale prototype. The Naval Research Laboratory group has succeeded in recovering film records on three flights. The outlook on recovery of cloud chamber photographs is therefore considerably more hopeful than it was early in the program. The use of thick emulsion film to record heavily ionizing particles directly does not appear promising in the rocket because of the short time of flight, and no effort will be made in this direction.

With the aid of whatever techniques and instruments are available at the time, the following program is contemplated.

(a) Measurement of the multiplicity and angular spread of the high altitude showers. The indications at present are that both of these quantities are large since this is required to explain the observed intensity and energy of the Wheeler electrons.

(b) Determination of the relative number of primary electrons. From the previous Naval Research Laboratory measurements 18% is an upper limit. If more than a few percent is present this should be determinable.

(c) Search for other groups in the primary radiation. N. Arley has suggested the existence of negative protons which should show up readily in a cloud chamber by the property of penetrating a lead slab without multiplication and producing an electron shower in a subsequent slab. By the same technique it may be determined whether in the process of meson production electrons are also produced.

It is, of course, not possible to commit a program of this nature very far in advance since it may be more desirable to follow up any given result than to proceed to a new problem. However, the outline of possible research with the rocket is permissible at this time since the scope of the technique is more clearly seen than it was originally. With the use of balloons and aircraft as adjuncts, the rocket program is capable of producing important results in the study of cosmic radiation.

CHAPTER II

OBJECTIVES, ACCOMPLISHMENTS AND PROPOSED IMMEDIATE AND LONG RANGE PLANS IN THE BASIC RESEARCH PROGRAM

C. The Ionosphere

by

T. R. Burnight and J. C. Seddon

Objectives

The physical characteristics of the ionosphere have in recent years assumed a very important position in the immediate affairs of civilization. Prior to World War II, the effect of the ionosphere on radio communications gave great impetus to this study. Now it is clear that continued rapid progress in the field of guided missiles, precision radio navigation, and communications, requires more precise and extensive knowledge of the ionosphere.

It is now possible to extend further our knowledge of the ionosphere by utilizing rockets to make measurements within this ionized region of the upper atmosphere. (See Fig. 3) The great value of this feature may not be immediately apparent when viewed only in regard to communications since the methods long in use give continuous 24 hour records of certain ionospheric conditions, whereas a rocket flight will last at present only 9 minutes, at the most.

The value of experimental methods utilizing rockets may be shown by a consideration of the parameters involved in the approximate expression for the index of refraction in an ionized medium neglecting the earth's magnetic field.

(1)
$$n = \sqrt{1 - \frac{4\pi \; Ne^2}{w^2 m}}$$

n: Index Refraction
N: Ion density
e: Charge on the ion
m: Mass of ion
w: Angular frequency of radiation

Radio pulse ionosphere height finding methods in wide use today can at most measure directly the index of infraction whereas rocket borne experiments may be designed to measure directly the ion density, N. Since in the E layer there is at present ambiguity as to the ratio of free

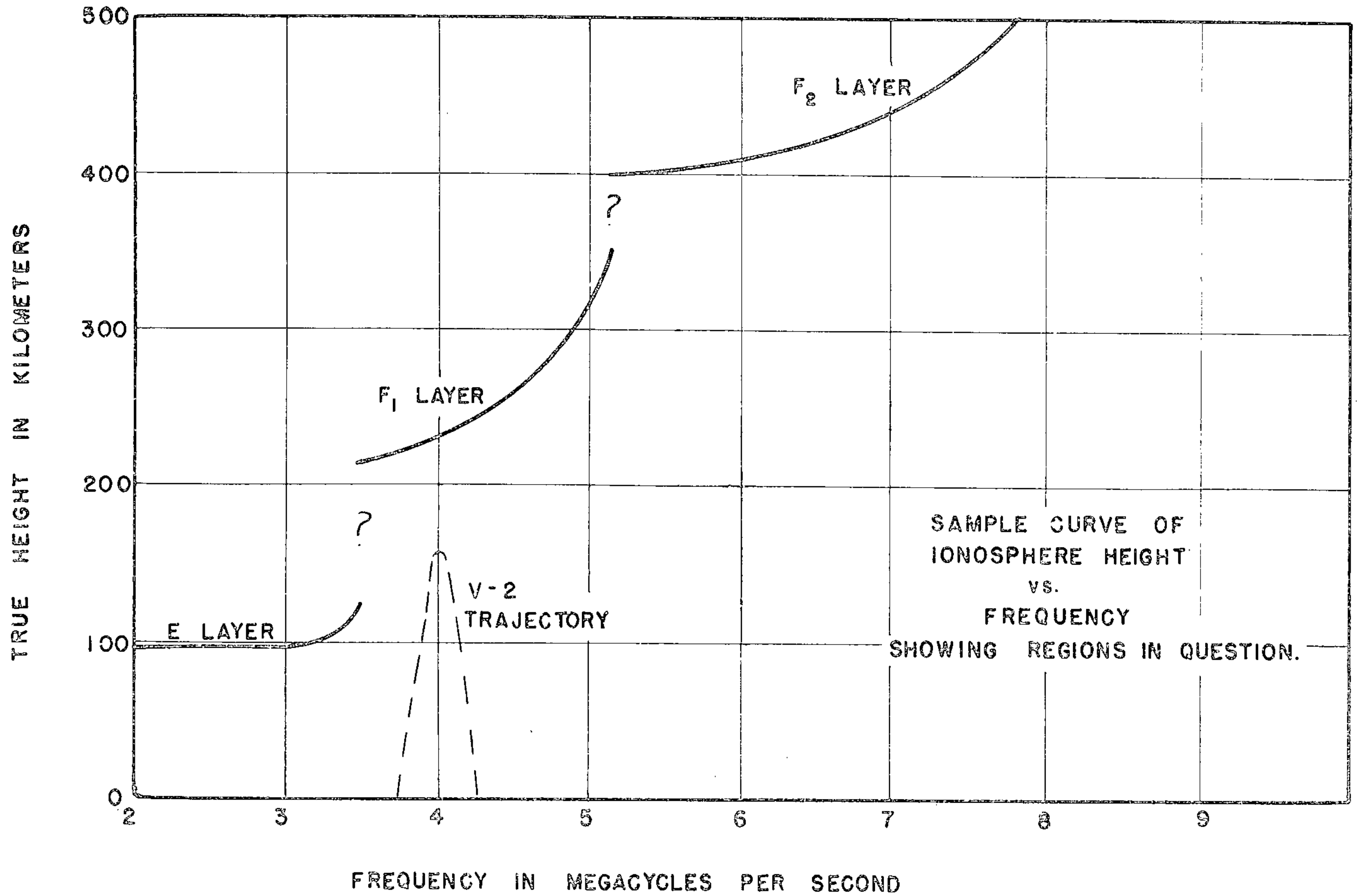

Fig. 3 - Sample Curve of Ionosphere Height vs. Frequency Showing Regions in Question

electrons and the ions in this region, rocket-borne experiments are the most direct way to determine whether the parameter on the right hand side of the expression should be in terms of electrons, ions, or a more complicated but correct relationship of both. A determination of data such as this will permit more accurate knowledge of many of the factors affecting long distance radio propagation such as delay times, velocities of propagation, phase shifts, intensities and numbers of modes, direction and arrival of wave fronts, ducting, multipath phenomena, and the actual rapidity of variations of these quantities. An example of the importance and interrelation of this study with guided missiles in clearly seen by considering the problem of guidance for an area target missile traveling at supersonic velocities and at ranges well beyond the line of sight. One of the fundamental requirements for this problem is the knowledge of missile position with respect to the known ground reference point or points, at any instant along the trajectory. To obtain this data by means of radio requires propagation through the ionosphere, possibly to or from the missile within the ionosphere. It is therefore important to be able to know and evaluate those factors which could result in rapid variations of the velocities of propagation through the ionosphere and which would introduce errors in an otherwise satisfactory system. It is this need for precision timing of the missile position, accurate to within tens of microseconds and precision determination of the relation between true bearing of the missile to the direction of arrival of radio waves with respect to the ground receiver stations that clearly shows the inadequacy of present knowledge of the ionosphere.

The basic research undertaken by the Naval Research Laboratory has been pointed toward more precise determination of the various physical parameters of the ionosphere, including measurements in those regions which it has been previously impossible to study directly.

Discussion of Present Experiments

At present the Naval Research Laboratory is investigating the following problems:

(a) Determination of the effective electron density as a function of altitude.
(b) Determination of the attenuation characteristics of the ionosphere as a function of altitude.
(c) Study of long range transmission from within the ionosphere.
(d) Direct measurement of electron and ion densities as a function of altitude.

Several methods of approach to the determination of these parameters are being pursued.

The Phase Beat Experiment This experiment permits the measurement of the effective electron density as a function of altitude and at the same time records the received signal strength so that the attenuation on specific frequencies may be studied. In essence the experiment consists of the transmission of two or more harmonically related crystal-controlled CW radio frequency signals from the rocket to special receiving and recording equipment at suitable locations on the ground. These frequencies of transmission are so chosen that one is sufficiently high that its velocity of propagation is essentially unaffected by the ionosphere, or rather, in Equation (1) the index of refraction remains essentially unity. The other frequency is chosen to be one slightly above the maximum critical frequency predicted for the regions into which the rocket will penetrate. For the latter frequency, as may be seen from Equation (1), the index of refraction will approach zero, and as a result the velocity of propagation will be greatly affected. If one considers the phase relation between the two radio frequency signals as received on the ground, it may be shown that as the rocket enters into the ionized region, the rate of change of phase is given by the following expression, neglecting the effects due to the earth's magnetic field:

$$(2) \qquad \dot{\phi} = \frac{M_W}{c} \; \dot{x} \; \left\{ n_{M_W} - n_W \right\} + \frac{M_W}{c} \; x \; \left\{ \frac{\partial \bar{n}_{M_W}}{\partial t} - \frac{\partial \bar{n}_W}{\partial t} \right\}$$

in which $\dot{\phi}$ is the rate of change of the phase relation between the reference frequency and the lower frequency multiplied by the harmonic integer, c is velocity of light, x is the radial distance from the ground station to the rocket, M_W is the high or reference frequency, n_W is the index of refraction for the low frequency, n_{M_W} is the index of refraction for the high frequency, $\bar{n}_{M_W}$ is the average index of refraction for the higher frequency, and $\bar{n}_W$ is the average index of refraction for the lower frequency. The first term of the right hand member of this expression is of primary interest in the experiment, inasmuch as the second term is concerned primarily with variations of the ionosphere with time. The importance of this term may become greater with further developments in this work; however, for the present purposes it will be considered to be zero and the time variations will be neglected. It is this phase beat or rate of change of phase with time which is recorded at the ground stations. The other parameters in the expression are determined by the design of the experiment and the knowledge of the rocket's trajectory. This allows, then, determination of the index of refraction for the low frequency as a function of altitude, with a suitable choice of the higher frequency. The ultimate sensitivity of this method is much greater than previous methods, permitting the determination of electron densities less than 1,000 per cubic centimeter. Further advantage lies in that if stratification in the ionosphere exists it can be easily detected by this sensitive method. Although this experiment could be performed with the receivers missile-borne, the advantage of studying long range transmission from within the ionosphere would not be possible. It is felt that transmission from within the ionosphere is prefereable for long range propagation studies, since no serious limit is imposed on the number or location of reception stations, whereas a missile-borne receiver could not readily be made to receive and identify signals from several transmitters.

The "phase beat" experiment has successfully recorded continuous data up to an altitude of approximately 110 km. and at several points above that up to 128 km. This may give us our first insight into the conditions existing between the E and F layers. At this time analysis of the records has not been completed. Many experimental problems have been encountered and solved and a great deal of invaluable experience as to suitable instrumentation for rocket investigation was acquired. It was soon found that the problem of developing suitable antennas for transmitting at low frequencies from the rocket was a major problem. The information on these subjects obtained to date will be of great value to other fields such as supersonic aircraft development and guided missiles.

In the March 7 V-2 firing an attempt was made to study the long range propagation of signals transmitted from the rocket. Arrangements were made with various Navy stations throughout the world, and with the Bureau of Standards Ionosphere Recording Stations to record the time at which signals, if any, might be received. No data was obtained because of the serious problem in alerting and coordinating these observers, since it is exceedingly difficult to launch a rocket exactly according to schedule. Further attempts of this nature will be made, and an effort made to improve the method of alerting the observers.

Immediate and Long Range Program

This problem of research involves a great deal of theoretical analysis of data and the coordinating of this data with existing and newly discovered data in related fields such as the temperature, pressure, composition and solar spectra in the upper atmosphere at various altitudes. A large amount of preliminary laboratory research and development is required for initiating new experiments or modifying and improving experiments presently in use. The phase beat experiment is amenable to a number of modifications each with various degrees of increased complexity, which will supply new and valuable data. The following are among those under consideration:

(a) A study of the velocity of propagation can be made by adding a receiver to the equipment in the rocket. A timing pulse transmitted to the receiver on a frequency unaffected by the ionosphere may be used to modulate the transmitters in the rocket. Hence, a comparison of the elapsed times of the two received signals recorded on the ground will supply the data on propagation velocity.

(b) A different study of the long range propagation may again be made by the addition of a receiver or receivers to the rocket equipment. The receiver or receivers in this experiment would be tuned to one or more of the frequencies transmitted for example by WWV. The timing pulses thus received in the rocket will be applied as a modulation to the transmitter frequencies as before. This would then permit a ground station at any point capable of receiving both the transmission from WWV and the rocket to record directly the transmission times. Such records obtained at several suitable ground stations would furnish a great deal of information on modes of propagation, multipath transmission, and serve to check maximum usable frequencies, etc. The received signal amplitudes at the rocket could be telemetered.

(c) By reversing the phase beat system, that is, put receivers in the rocket and the transmitter on the ground, this same method could be modified to include the differential absorption experiment proposed by the Bureau of Standards. The modifications on the basic system involved for the differential absorption experiment consists of transmitting a suitable frequency in such a manner that it is radiated alternately circularly polarized right handed and then left handed. The rocket-borne receiver then compares the received amplitude of the extraordinary and ordinary transmissions and a measure of the differential absorption is thereby obtained. From this it is possible to compute the ratio between free electrons and the ions present in the E layer. In addition, by suitably spacing the switching intervals of the transmitted r.f., the respective velocities of propagation for the ordinary and extraordinary modes can be measured by additional electronics in the vehicle. This data in addition to the phase beat data would then be telemetered to the ground.

(d) To study the long range propagation of microwave frequencies it is proposed to transmit high power pulses from a suitable 3 cm transmitter. The missile antenna used will be vertically directive but omnidirectional horizontally. During the major portion of the rocket trajectory if the rocket spins but does not tumble, then appreciable propagation path lengths through the ozone and E layer to receiving stations on the horizon can be obtained. This would permit a measurement of attenuation with long path lengths and also a determination of possible ducting effects at low angles of incidence. This will be of importance in long range detection or control systems.

Direct Measurement. Considerable theoretical and laboratory research has been carried out to establish the fundamental basis for a direct measurement of the electron and ion densities as a function of altitude. Several methods of instrumentation are under consideration and it is planned to perform the experiment in the July 10 Naval Research Laboratory V-2. The methods are similar in basic design being primarily a determination of the saturation current for electrons and positive ions respectively. The differences lie primarily in the geometry for best obtaining suitable electric field configurations and freedom from boundary layer disturbances.

An experiment to measure the electrical potential of the rocket will be run simultaneously in the flight. This will consist of a special generating voltmeter so designed that it will also be suitable aerodynamically. The data obtained from these experiments will be telemetered.

The information thus obtained directly will be used to check and strengthen data obtained by the phase beat method and the two kinds of data will be used to learn more about the true role of the ions and electrons respectively in the propagation of radio waves in the E layer.

CHAPTER II

OBJECTIVES, ACCOMPLISHMENTS AND PROPOSED IMMEDIATE AND LONG RANGE PLANS IN THE BASIC RESEARCH PROGRAM

D. The Physical Characteristics of the Atmosphere

by

N. R. Best and R. J. Havens

Objectives

Immediate. The immediate aim of the Naval Research Laboratory's program of investigating the structure of the upper atmosphere is to determine:

(a) Pressures, temperatures, and densities in the upper atmosphere. Most of the phenomena observed in the upper atmosphere depend in some way upon the pressure, the temperature and the density of the gases of which it is composed.

(b) Mechanical movements in the upper atmosphere. The amount of mixing is an important factor affecting the properties of the atmosphere and this is controlled by convection caused by heating of certain portions of the upper atmosphere.

Indirect. The attainment of these immediate objectives leads indirectly to the furthering of knowledge about

(a) The effect of solar radiation on the upper atmosphere. Solar radiation produces many changes in this medium. The existence and properties of the ionosphere are dependent upon solar absorption, and pressure, and temperature and density of the air. Disassociation of the molecules in other regions is caused by radiation.

(b) The ionosphere. The ionized regions of the upper air are of importance not only from the point of view of basic research, but also from the point of view of radio, guided missiles, etc. Knowledge of the effects of pressure, temperature, and density variations, as well as convection movements in these regions, is important.

(c) The aurora. Auroral phenomena are closely interrelated with the structural properties of the atmosphere.

(d) Radio transmission in the upper atmosphere. There is an obvious practical, as well as purely scientific value to studies which further knowledge about radio transmission.

(e) Meteorology in the lower atmosphere. Correlations between upper air and lower air phenomena may prove to be highly useful.

(f) Meteors. Increased accuracy in the pressure, temperature and density data about the upper atmosphere, can lead to increased accuracy in determination of sizes and speeds of meteors.

Applications. The upper air data obtained on pressures, temperatures, and densities are of direct value to many fields. Some of these are:

(a) Aerodynamic design. In the aerodynamic design of guided missiles and high altitude aircraft, such information is most important. The knowledge of the pressure and density will enable the calculation of drag and of structural stresses imposed on the missile due to its passage through the atmosphere. Furthermore, it will be possible to calculate the temperatures that the skin of the missile will reach and to make allowances for them. Lift to be expected in the case of high altitude aircraft can be calculated, as well as the possibility of obtaining oxygen for ram jets from the air through which the planes are to fly. Knowledge of the temperature of the air is necessary for certain aerodynamic calculations, such as the determination of Mach number. The engineering applications of this information are bound to become more important with the rapid expansion in such fields as these.

(b) Weather forecasting. Pressure patterns are known to have an effect on the weather. Studies of the upper atmosphere movement may lead to a better understanding of the conditions causing the weather. Motions of pressure areas may be the information that will lead to long range weather predictions over large regions.

(c) Radio transmission. The close relationship between radio transmission and weather in the troposphere is well known.

Similarly, it is to be expected that such transmission in the upper atmosphere will be strongly affected by the physical state of the medium traversed.

(d) Basic research. These data will have equal importance in the fields of basic science. For example, in the study of the ionosphere, it is extremely important to know the density of the gases in the various regions. This knowledge allows calculations to be made on the effectiveness of the ionization processes involved. The change of the effective height of the ionosphere is connected with the change in the vertical position of the maximum densities brought on by the presence or absence of solar radiation. Great accuracy is of value in such investigations.

Accomplishments.

Significant measurements have been made of the temperature and pressure of the atmosphere to about 110 kilometers, with accuracies from 2 to 20% depending on the altitude. These measurements have been made by applying techniques which take into consideration the high velocity of the rocket and even utilize the pressure ramming effect due to the rocket's motion, although this effect is many times the magnitude of the pressure change being measured. It has been possible to measure the temperature of the gas through which the rocket is passing by knowledge of the velocity of the rocket (as determined from other sources) and pressures measured on the rocket under two special conditions. Ambient pressure of the surrounding gas has been measured directly at places on the rocket which have been shown to read pressure independently of velocity.

In order to make these pressure measurements on the rocket, it has been necessary to make modifications, refinements, and adaptations of existing types of gages. Every attempt has been made to keep the gages as simple as possible since they must operate unattended. All of them have had to be redesigned to have electrical outputs suitable for telemetering.

The principal results obtained thus far in the program are presented in the accompanying curves, which are based on data obtained on 10 October 1946 and on 7 March 1947. Measurements up to 15 kilometers agree to within experimental error with balloon data obtained simultaneously, indicating reliability of data taken at high altitudes.

Temperatures calculated from the slope of the pressure curve and from ram pressure measurements are shown in the second figure. Data from

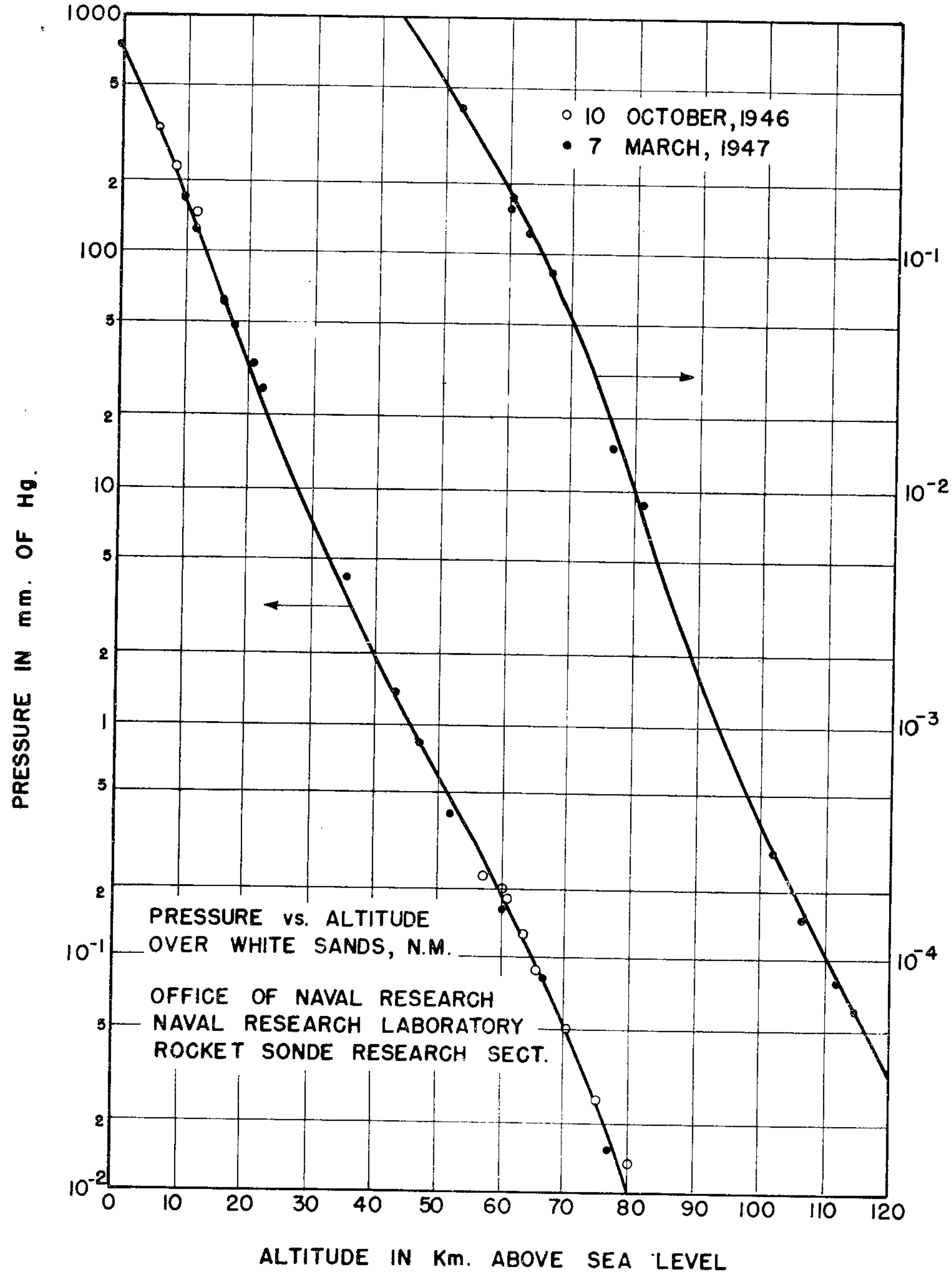

Fig. 4 - Pressure vs. Altitude over White Sands, N. M.

both methods were available at 65 km from the March 7 experiments, and agree within experimental error. The data show the temperature changes from 220° K at 20 km to about 320° K at 55 km and then drops to 200° K at 80 km. Above 90 km the temperature apparently rises to about 335° K at 120 km.

The skin temperature of the warhead was measured for skin thickness of 1/3 inch and 1/9 inch steel and for 1/9 inch aluminum. Temperatures obtained indicate that maximum temperature change in °C above initial temperature on ascent for a 100 mile high flight can be calculated from

$$T = \frac{10}{t}$$

where t is the thickness in inches of the steel warhead. The ratio of the temperature rises of the aluminum and steel was inversely proportional to the ratio of their heat capacities.

Between the forward section of the fins and the warhead the maximum rise (on ascent) above takeoff temperature of the 1/2 mm steel skin varied between 125°C and 200° C.

Future Research.

The future program contemplated for this phase of Rocket-Sonde Research is the following:

(a) Continuation and extension of the present pressure and temperature measurements. It is planned to continue the present program to gather sufficient date on the conditions in the upper atmosphere to be handled statistically. Check experiments will be devised and performed to eliminate errors in the present instruments and methods as well as to measure the extreme pressures and temperatures that are experienced. Data will be gathered to establish the magnitude of the average daily and seasonal variations which are known to occur. Pressure, temperature, and density measurements will be extended to the maximum altitudes reached by the sounding rockets.

(b) Further development and improvement of the types of gages now in use. The Pirani gages are to be improved to read pressures in the range where the Philips gage is now used,

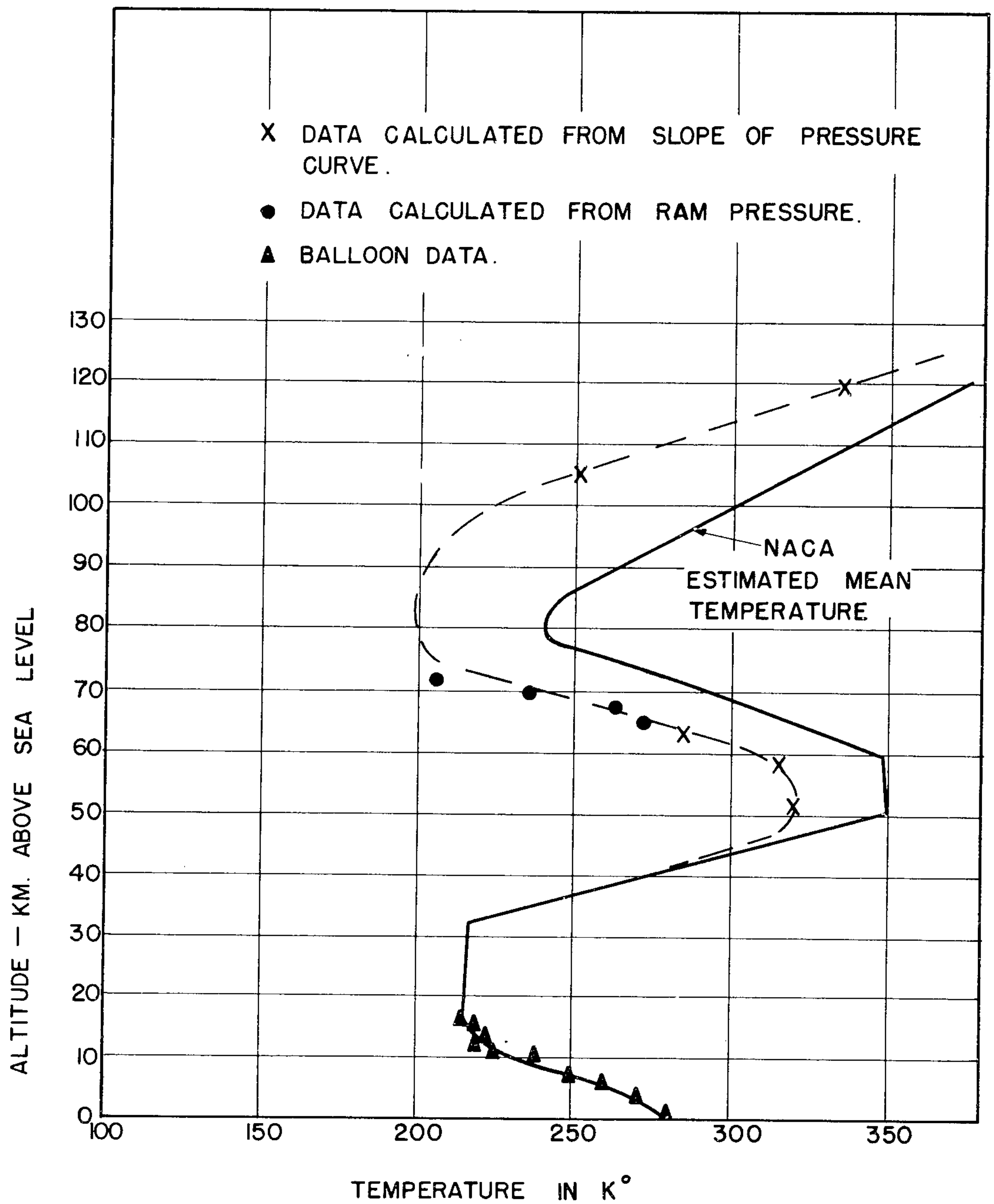

Fig. 5 - Temperature vs. Altitude, 7 March 1947

that is to about 10^{-5} mm Hg., with resultant simplification of the installation. Attempts will also be made to decrease the time constant of this type of gage. And in the case of all of the gages reading at pressures less than one micron of mercury, efforts must be made to decrease the amount of gas given off by the gage mounting during the flight. This problem becomes more serious as the measurements are made at lower and lower pressures.

(c) Measurements of partial pressures of the constituent gases of the upper atmosphere. It will be attempted to devise means to measure the partial pressures of the various constituent gases, and to develop techniques and instruments for differentiating between the molecular and atomic states of the gases.

(d) Development and application of new techniques. It is expected that new techniques will have to be developed to make pressure and density measurements at the highest altitudes where mean molecular spacings are so great that the effects of individual or small groups of molecules will have to be considered, rather than the statistical effects usually measured at higher pressures.

CHAPTER III

PROGRESS AND PROPOSED DEVELOPMENTS IN THE SUPPORTING PROGRAM

A. The V-2 Research Warhead

by

T. A. Bergstralh

The use of the V-2 for upper atmosphere research requires a special warhead to carry the needed experimental equipment. To meet this need for the entire program, the Rocket-Sonde Research Section of the Naval Research Laboratory undertook to design and procure a warhead suitable for this purpose. Accordingly, a design was prepared and a contract let to the Naval Gun Factory for the construction of twenty-five warheads to be used with the first V-2 series. This contract was let on 1 March 1946, and the first warhead delivered to the Naval Research Laboratory on 1 May 1946. Subsequent deliveries were made on a schedule of approximately one per week, and warheads were supplied to the participating agencies as required. A sufficient number of these warheads are on hand to supply all scheduled firings through 24 July 1947.

A second design has been prepared and a second contract let to provide twenty-five additional warheads to be used with the second V-2 series. The first of the new warheads will be delivered on 1 May 1947, and the balance at two week intervals.

The first design was for a three section warhead comprising: a nose tip, a nose section, and a main body. This entire warhead was constructed of 3/8" cast steel and weighed approximately 1000 lbs. empty. The nose tip is 12 inches long and has a base diameter of three inches. This unit has normally been used for pressure and temperature measurements of the atmosphere. The nose section is 22 inches long and has a base diameter of 12.37". It was originally designed to house a solar spectrograph. The main section is 57 inches long and has a base diameter of 37.625". This main section is equipped with three access doors, there being two 15" x 17" access doors starting 16 3/4" forward of the warhead base, and one 12" x 12" door 42 1/8" forward of the base. The principal share of the electronic and other equipment used in research assemblies was placed in this main warhead section which was sealed at ground level to maintain a pressure of one atmosphere throughout the flight. The accompanying photograph, Figure 6, shows one of these warheads.

The second warhead design calls for a two section unit comprising a nose cone and a main body. The main body is constructed of 3/8" cast steel, is 33" long with base diameters of 23.87" and 37.625". This section is equipped with two large access doors identical with those on the first model. At the upper end of this body is a pressure bulkhead to permit individual pressurization of the two sections. The upper section, or nose cone, is 49.87" long with a base diameter of 23.87" and is constructed of 1/8" aluminum. It is completely removable from the main warhead body for ease of installation of experimental equipment. This design is similar to a modification made for the 7 March 1947 firing, which modification is shown in Figure 7. However, in the future warheads the nose cone will be constructed entirely of aluminum instead of a steel and aluminum cone as shown.

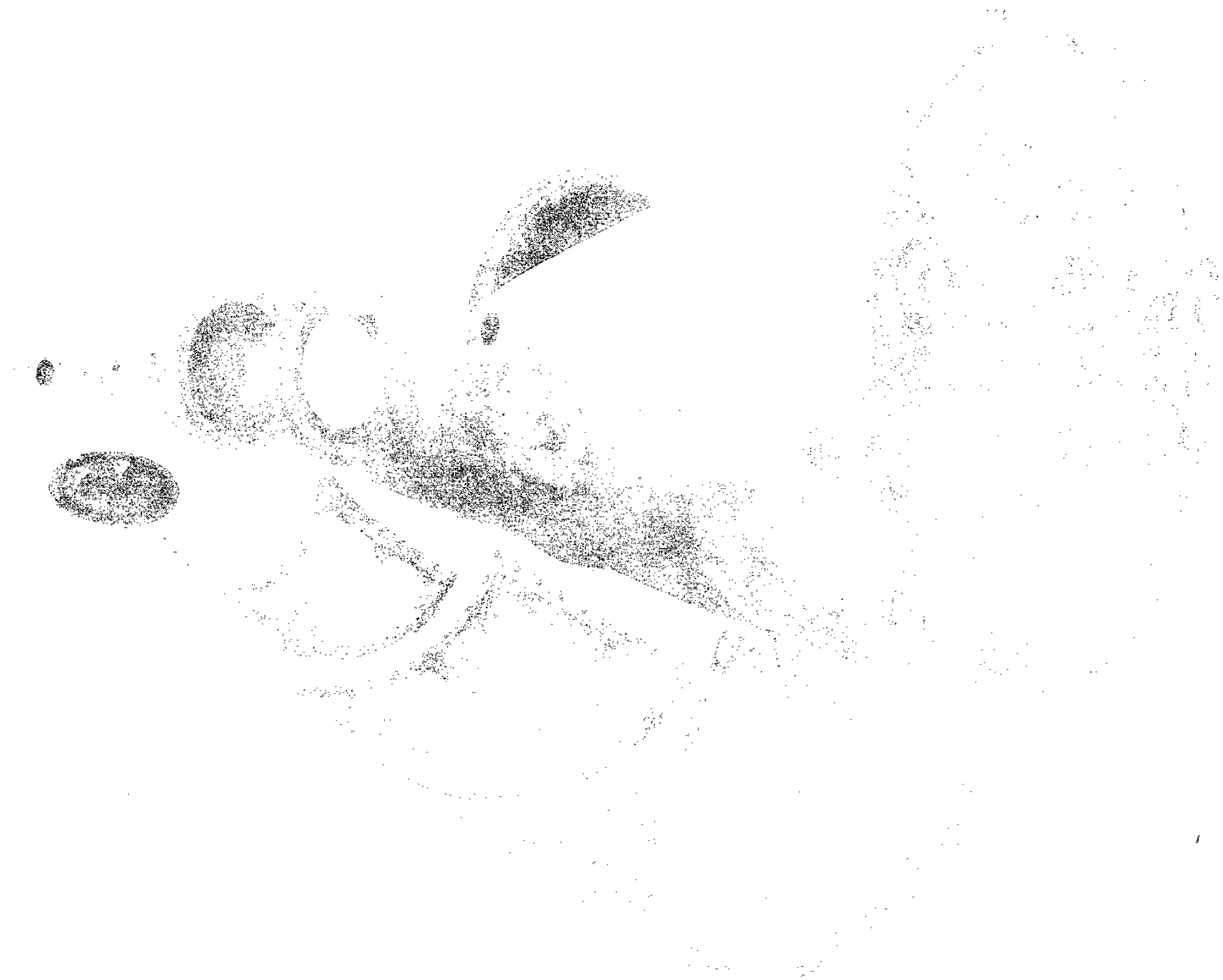

Fig. 6 - The V-2 Warhead Shell Employed on 28 June 1946

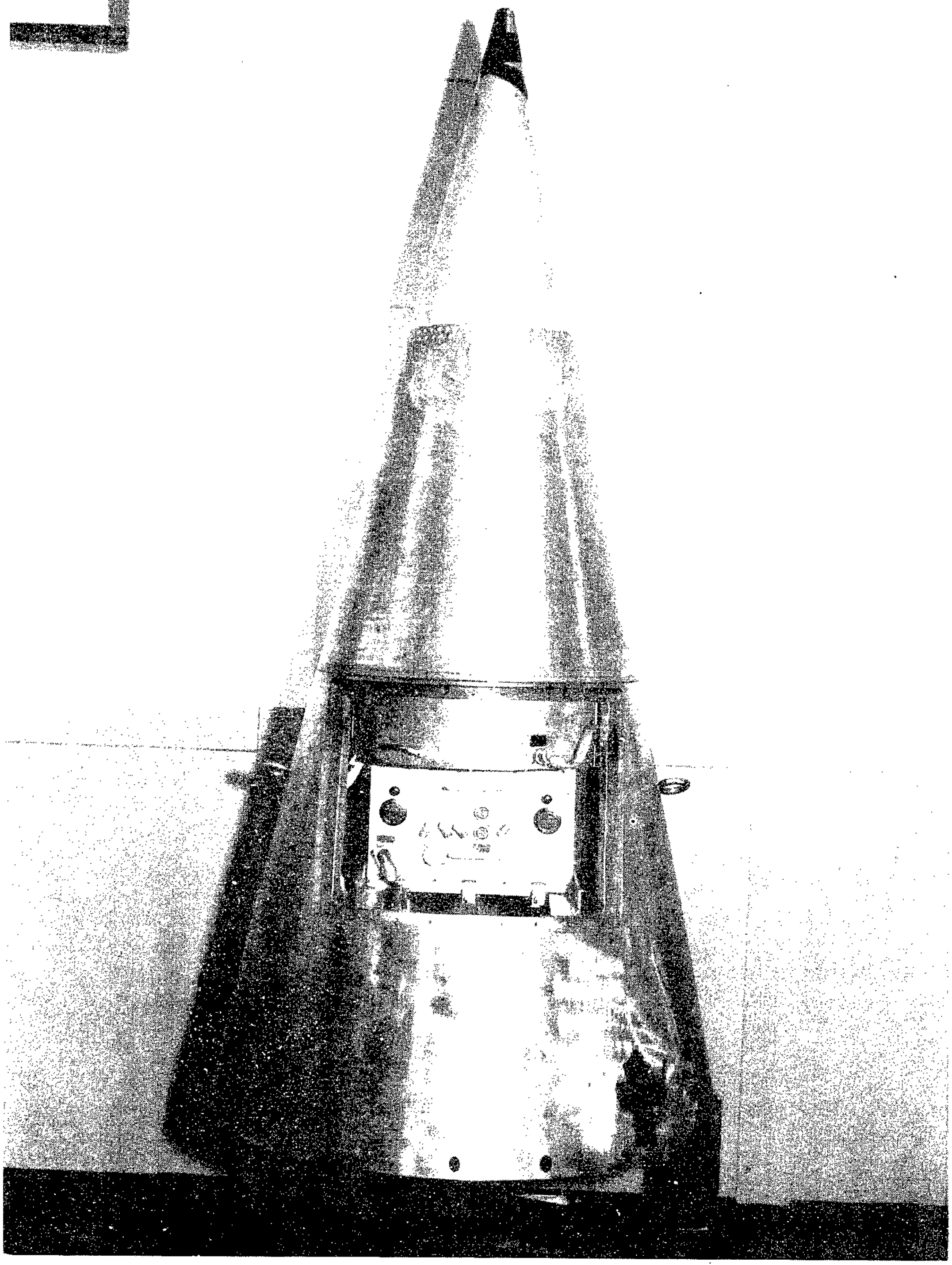

Fig. 7 - The V-2 Warhead of 7 March 1947

CHAPTER III

PROGRESS AND PROPOSED DEVELOPMENTS IN THE SUPPORTING PROGRAM

B. Telemetering from Rockets

by

C. H. Smith, Jr.

Introduction

The Naval Research Laboratory has designed, installed and operated all of the telemetering equipment used in the V-2 flights at the White Sands Proving Ground since the initiation of the High Altitude Research Program. There has not been a single failure of the 23-channel pulse time modulated telemetering system during this operating period from the first telemetered flight on 29 May 1946 to the present. In addition, the Laboratory has contracted for the processing of all telemetering film records and for the analysis of these records when requested by any V-2 participating agency. Also, a new type of pulse time modulated telemetering system has been designed, developed and tested, which is superior in number of channels, freedom from noise and reduction of cross talk. This new system is now being constructed and will be available to all V-2 program participants by late 1947. The telemetering ground station facilities at the White Sands Proving Ground have been made available to other agencies utilizing this system under the technical direction of the Naval Research Laboratory.

Historical Background

The group at the Naval Research Laboratory now working on rocket telemetering has been actively engaged in the telemetering field since January 1945. During the war this group, while working on the Guided Missiles Program, developed a pulse time modulated telemetering system with ten independent channels for use in the JB-2 program (the JB-2 is the Navy version of the German V-1). The rocket telemetering program was first envisioned as permitting at least one year of development work prior to the first flight, as it was planned to design and construct suitable rocket vehicles for the research studies. It was soon learned that, of the 100 V-2's brought to this country from the European Theatre, at least 25 would be fired at the White Sands Proving Ground by Army Ordnance. Subsequent arrangements were made which permitted the use of these rockets for high altitude research. Thus, the development of suitable telemetering equipment became a crash program.

It was the accepted philosophy of the Naval Research Laboratory at that time that the primary reliance for the recovery of data from the V-2 must be placed upon telemetering. Although numerous methods of recovering physical data have since been suggested and tried, the first decision to place the major responsibility upon telemetering equipment has proven to be a wise one. Recovery methods have been uncertain, and slow in developing. The Naval Research Laboratory has been particularly fortunate in recovering camera film, spectrograph film, cosmic ray recorders, and other items by separation of the warhead with an explosive charge. This charge has been detonated by a timing mechanism in the rocket or by a radio link. The tail section has proven by experience to be the best location within the rocket for recovery purposes. These methods have been and still are considered only supplemental to telemetering for recovery of information obtained during flight.

Within a three-month period of the initiation of the V-2 Program, the design and development of a complete telemetering system had been completed and a contract let for airborne telemetering units. Both airborne and ground station equipments were made available for the first V-2 flight in which telemetering was required on 29 May 1946. This system was a sequential pulse time modulated system in which channel intelligence was contained in the time spacing between successive pulse groups. The peak r. f. output power was 700 watts at 1000 megacycles.

The first airborne units were constructed under a contract with the Raytheon Manufacturing Company and are being used at the present time in much the same form as originally designed. A picture of one of these units is shown in Figure 1. The first ground station equipment consisted of two completely mobile stations mounted in K-65 type trailers, towed by a truck containing a 25 kilowatt generator. In each trailer was carried a 1000 megacycle receiver, a video amplifier, a decoding unit, the necessary recording equipment, the auxiliary monitoring test equipment, communication receivers and transmitters, and the timing devices.

Since the introduction of this equipment, the Naval Research Laboratory has installed and operated all telemetering equipment used with the V-2 rockets. Early experience showed that the signal was lost due to cross polarization whenever the rocket rolled, so the original dipole antennas, shown in Figure 1, were replaced on the 5 December firing with circularly polarized tripole antennas. At this time the ground station antennas were likewise converted. Figure 2 is a view of the ground station antenna. Excellent opportunity was provided by the use of these antennas to observe the improvement afforded by them in the 9 January flight in which the rocket rolled after 47 seconds of burning. Although no loss of signal was observed after burning, a definite roll period of about one second was established from roll gyros installed as a part of the experimental equipment carried in this particular flight.

Present Status

The present telemetering system includes a 23-channel sequential pulse time modulated airborne transmitter having a peak r. f. output power of 1200 watts at 1000 megacycles. The external appearance of this unit has not been changed from that shown in Figure 1. Power is obtained from dry batteries for the high voltage supplies and from storage batteries for the filaments.

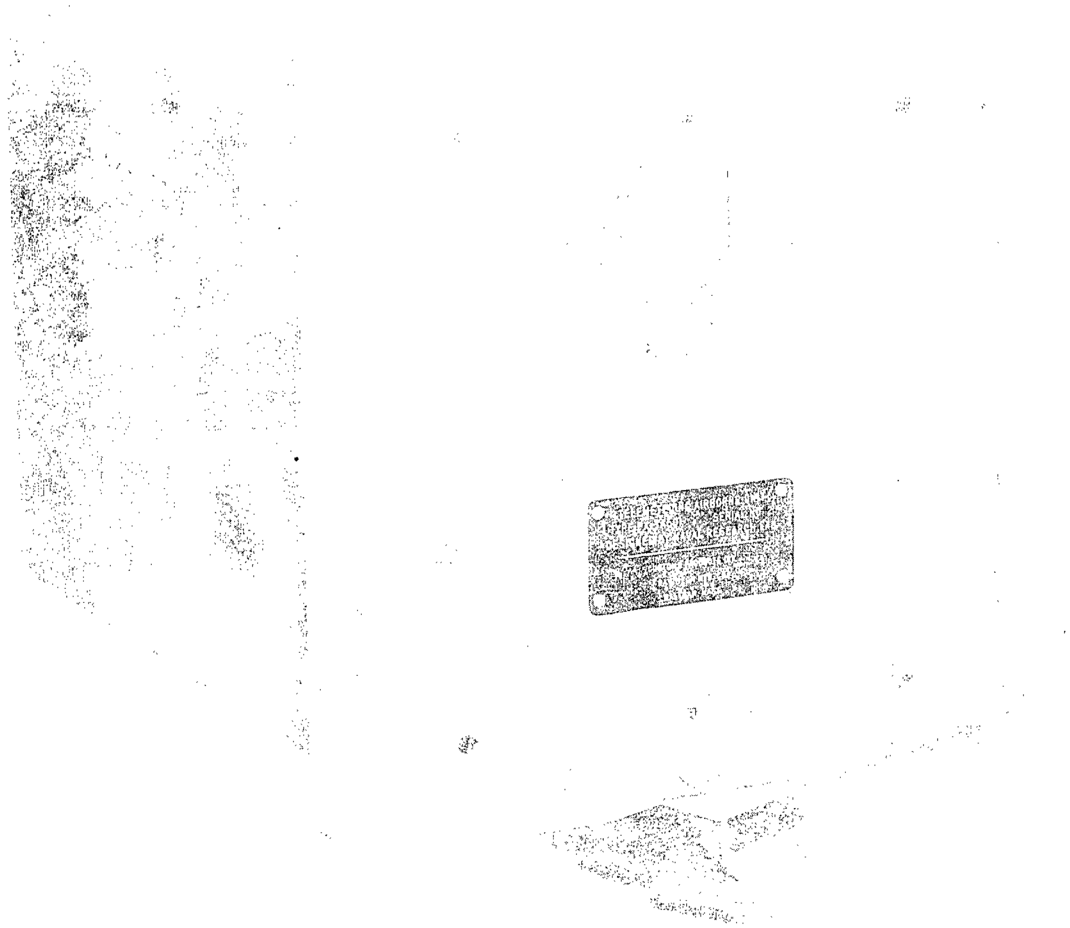

Fig. 8 - Telemetering Airborne Unit with Dipole Antenna

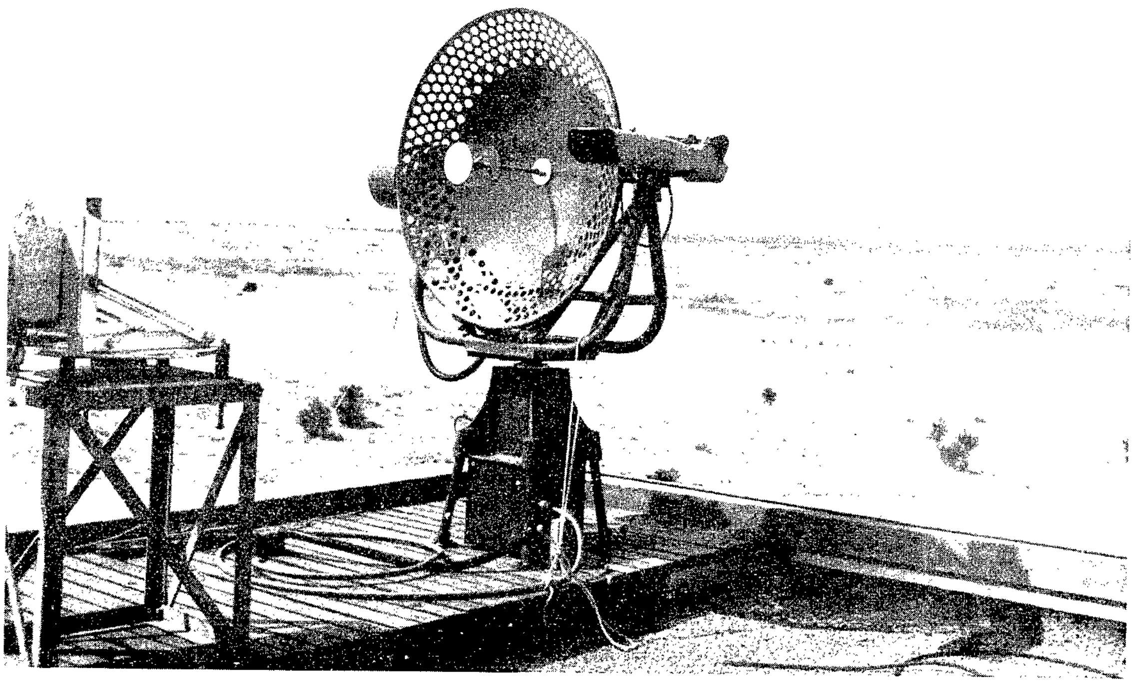

Fig. 9 - A Telemetering Receiving Antenna Installed On the Roof of the Ground Station at White Sands

The total weight is less than 150 pounds and the size is approximately 14" x 14" x 22". The complete unit is mounted in a pressurized case. The channel input voltage requirement is from zero to + 5 volts for full modulation. Optional overvoltage protection is available. For the telemetering of slowly varying phenomena, such as pressures and temperatures, mechanical subcommutators are provided. These subcommutators were originally developed by the Naval Research Laboratory and were manufactured by the Hathaway Instrument Company. They are presently available as stock items for use in future flights. By means of these units, 15 channels can be subcommutated on a single channel. This would allow a total of 345 channels to be telemetered at a sampling rate of about one cycle per second. By means of a motor-driven calibrator unit, each channel can be calibrated at zero and 3-1/2 volts alternately throughout the flight at about 15 second intervals. This allows an overall calibrated accuracy of 2 to 3%.

The antennas used with the airborne unit at the present time are of the circularly polarized turnstile type of Figure 10 which are superior to the circularly polarized tripole type previously used because of their more uniform circular field pattern. Field non-uniformities have thus been reduced from 7 db to 1-1/2 db.

For the ground receiving and recording installations, the Naval Research Laboratory maintains and operates a 30' x 30' permanent concrete block building, Figure 11, approximately six miles north of the launching site in a position directly in the line of fire. The two telemetering ground installations are of similar design, each consisting of a 1000 megacycle antenna, receiver, video amplifier, 23-channel decoding unit, and recording equipment, as shown in Figure 12. In addition to housing two complete and independent telemetering ground installations, this building houses complete radio communication facilities, operating and testing space, and a complete photographic darkroom for processing film records obtained during test periods. The directional receiving antennas are similar to those of Figure 9 and consist of pedestal mounted 4' parabolic reflectors with circularly polarized antenna feeds. These pedestals are mounted on the roof of this building and are operated in asimuth and elevation by means of servo control from either an optical tracker or a manually-operated director oriented by means of the level of the received telemetering signal. By means of a cross patching arrangement, either of the two stations can feed any combination of the five multichannel oscillograph film recorders shown in Figure 13. Two time reference markers are provided for each of these recorders: one from the master time signal generated at the blockhouse, initiated at the instant the rocket leaves the firing platform; and another from a chronometer controlled second-marking time bus from within the telemetering building. In this way, the utmost flexibility in the ground recording of the telemetered information is afforded. The two stations are always operated simultaneously during an actual flight in

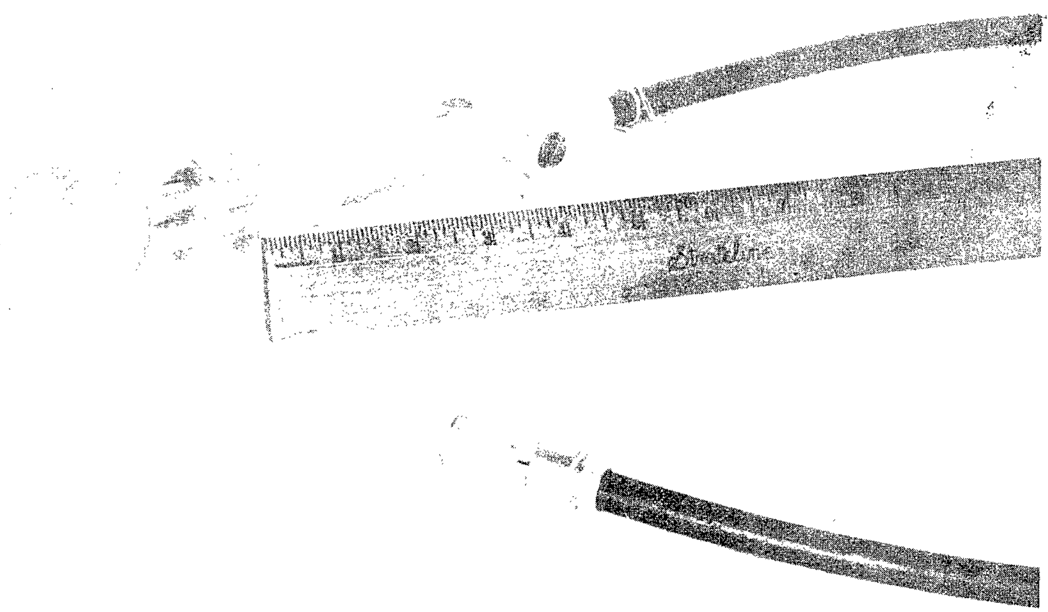

Fig. 10 - Turnstile Antenna and Mount

Fig. 11 - The Telemetering Ground Station at White Sands

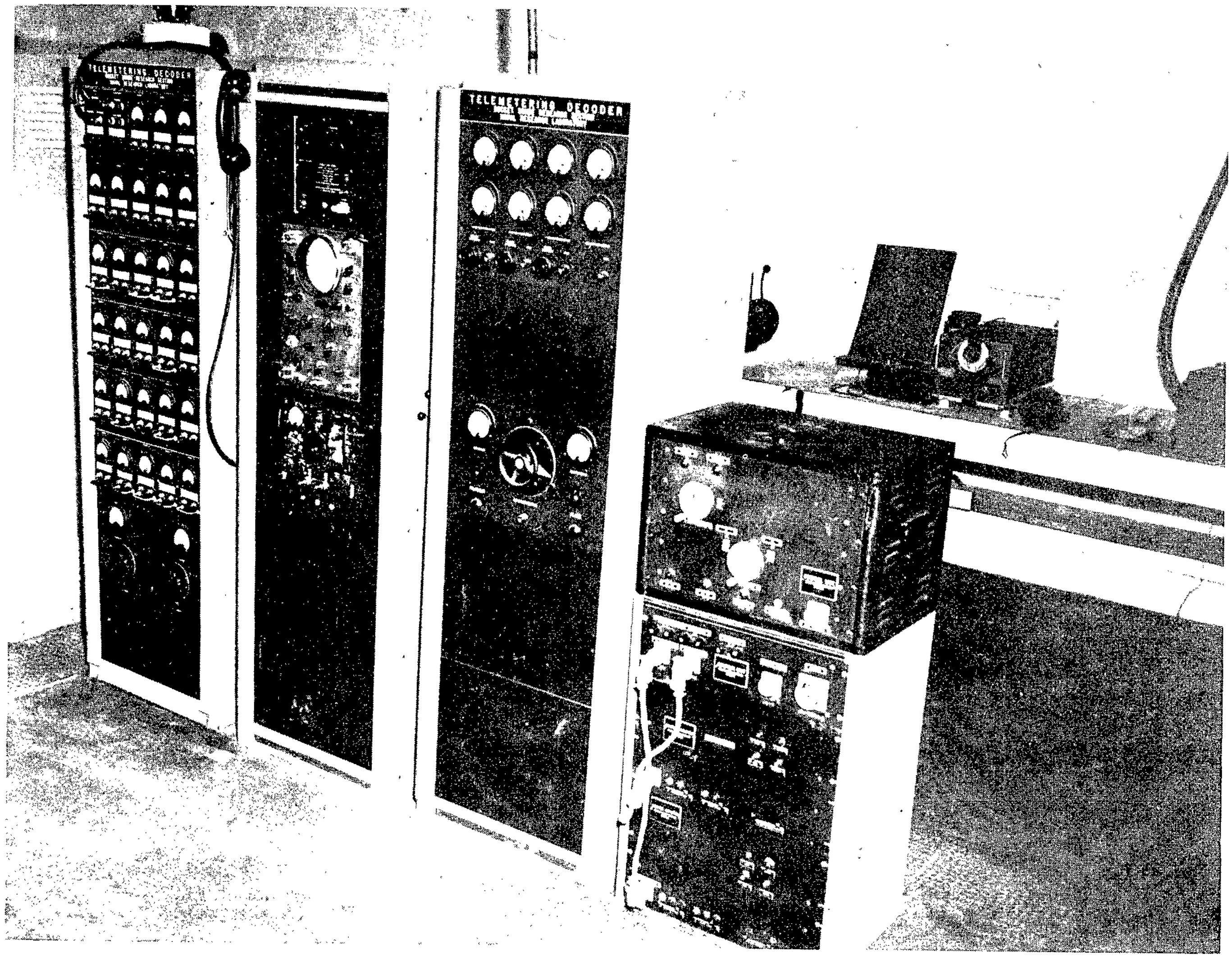

Fig. 12 - Interior of the Telemetering Ground Station

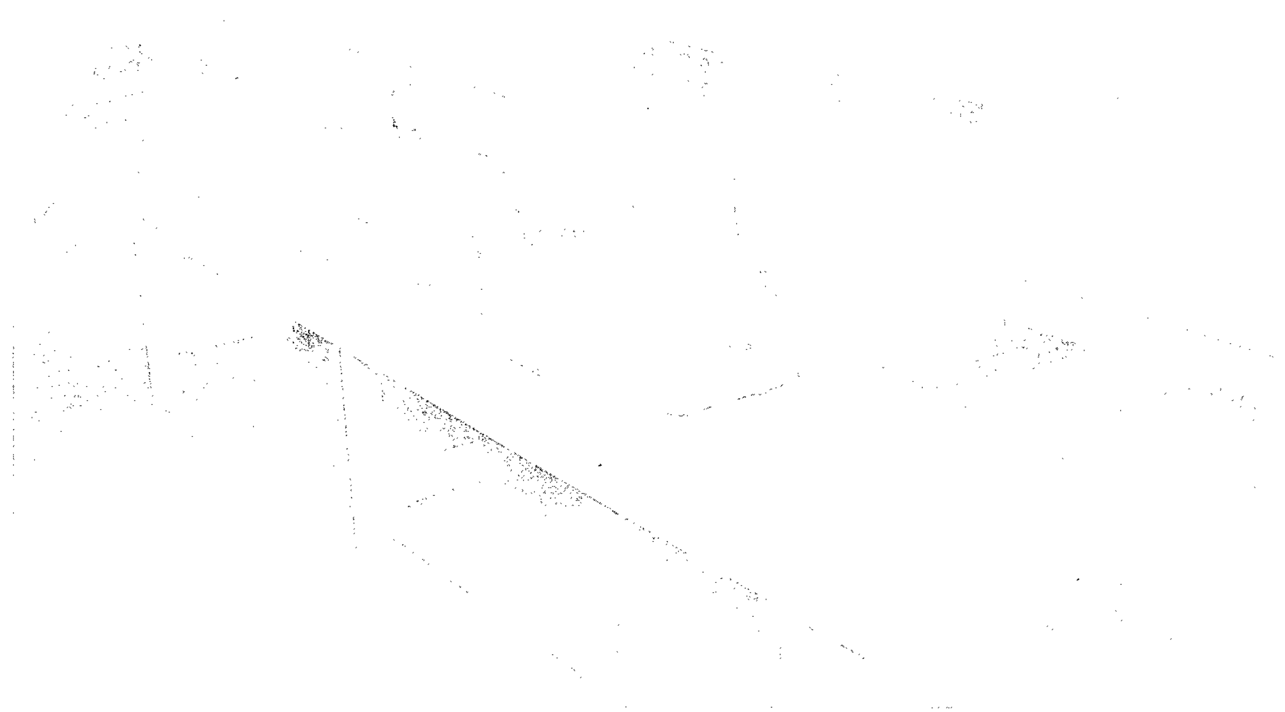

Fig. 13 - Oscillograph Film Recorders Installed in the Ground Station

order to guarantee complete telemetering records in case of tube or component failure in either station. A mobile trailer houses one of the original telemetering ground installations and radio communication units which have been modified by improvements resulting from operational experience. This station is used for special tests and to provide training for new personnel in a manner that will not jeopardize the overall telemetering setup during an actual flight.

In addition to these ground receiving installations, a telemetering receiving station is maintained in the blockhouse for monitoring rocket performance prior to and immediately after the start of every firing. An additional laboratory is also maintained for the modification, alignment, and testing of all airborne units prior to any flight.

The Naval Unit, White Sands, has provided the Naval Research Laboratory with certain supporting facilities and assisting personnel since their establishment in the fall of 1946.

For processing and printing the large amount of film record obtained from each flight, often amounting to over one thousand feet of 9-1/2" film, the Naval Research Laboratory has a contract with the New Mexico College of Agriculture and Mechanical Arts. The College develops the film immediately after each firing, making available preliminary prints of the records obtained to the interested activities within a period of 48 hours. In addition, this contract allows for detailed analysis by the College of any record obtained when so requested by the participating agency involved.

Future Plans

Recognizing that the present sequential telemetering system, which was developed on a crash basis within a three month period, inherently includes some details that can be modified for greater freedom from noise, reduction of cross talk, and higher accuracy, the Naval Research Laboratory undertook the development of an improved system during the summer of 1946. This system is a 30-channel matrix pulse time modulated system having a minimum of 3 kw peak r. f. output power at 1000 megacycles. The sampling rate will be over 300 cycles per second. The pulse time modulation is applied to the r.f. carrier. The modulation process consists of a series of equally spaced marker pulses interleaved with a succession of channel information pulses. Channel intelligence is contained in the time spacing between the channel information pulse and its corresponding time reference marker. All marker pulses are suppressed during transmission with the exception of one during each sampling period. This is a triple pulse, suitably coded in time spacing so as to distinguish it from the channel information pulses, which furnishes the basis for synchronization of the ground station.

This system has now been developed to a point where a contract is being let with the Hazeltine Electronics Corporation for the production of 70 airborne units. The ground equipment, as in the case of the older system, will be constructed at the Naval Research Laboratory. Subcommutation will be permissible as in the case of the present system, extending the total number of telemetered channels to 450. By virtue of the definite time space for each channel, this system will be inherently noise free to a degree not approachable in the present system.

Receivers designed on the basis of the best 1000 megacycle practice will increase the overall system r.f. sensitivity by a minimum of 10 db over that presently obtained. The major part of this improvement results from the use of an improved input cavity, the use of grounded grid IF amplifier stages, and automatic gain control. Cross talk in this system will be far less than in the present system inasmuch as each channel is triggered from an individual time reference marker rather than from the previous channel. The new system will utilize a calibrator consisting of step voltages of zero to 5 volts in six steps recurring at a 5 second period. In this way, an overall accuracy of better than 1% will be obtainable.

The ground station will incorporate specially designed cathode ray tube camera recorders operating directly from the output of the video amplifier and eliminating all of the necessary decoder channels utilized in the present system. This method of recording is made possible because of the definite time of initiation of each channel utilization period which is independent of time periods of previous channels.

Present expectations are for the complete overall testing of this system to begin at White Sands by October 1947 and for actual use of the V-2 Program as a whole by December 1947. In this manner, the V-2 High Altitude Research Program will be provided with the most modern telemetering system available, designed and developed on the basis of long-term operational usage and analysis of the present sequential system. Additional improvements anticipated in the ground installation at the White Sands Proving Ground include the introduction of commercial power, a 15-pair telephone line leading to the Army blockhouse, the Navy blockhouse and the camp area, complete automatic heating, ventilating and air filtering systems at the house, and automatic tracking of the antennas on the maxima of the received telemetering signal.

Availability to Other Agencies

Prior to the letting of the contract for this new system, the Naval Research Laboratory submitted invitations to all other agencies in this field to participate in this procurement. Requests have been received from other agencies for these units and the contract was extended to include these request

The telemetering ground station facilities at the White Sands Proving Ground, which are maintained by the Naval Research Laboratory, have been made available to other agencies utilizing this system.

CHAPTER III

PROGRESS AND PROPOSED DEVELOPMENTS IN THE SUPPORTING PROGRAM

C. Radio Control

by

J. T. Mengel

The firing of a rocket like the V-2 demands, from a safety standpoint, the inclusion of some type of radio control by which the thrust may, at any time during the launching and flight, be cut off at the discretion of operating personnel. Component failure, especially during the early part of the flight, can result in such erratic operation that the impact point will lie anywhere inside or outside the firing range. From the very first flight the Naval Research Laboratory has provided, installed and operated on each shoot a modified version of the ARW-17, frequency modulated, radio control receiver for this function of emergency fuel cutoff.

The function of warhead blowoff, to aid in recovery of data, has also been performed with the same control system, using two of the five available channels. A sufficient quantity of ARW-17 receivers has been obtained to last at least through missile #40, at which time it is intended to substitute ARW-37 receivers. The ARW-37 is also a frequency modulated five channel receiver, very similar in characteristics but operated at a slightly higher frequency. One of the presently used receivers in its pressurized case can be seen at the top of the V-2 control chamber shown in the figure.

While the emergency cutoff receiver has been installed in every flight, its use has been necessitated upon only four occasions: firing #2, 16 April 1946 when one fin fell off; 15 August 1946, steering control failure; 22 August 1946, gyroscope failure; and 7 November 1946, cause of failure undetermined. In each case the equipment functioned properly and fuel cut-off was accomplished, permitting the rocket to land within a safe area.

Warhead blowoff was first attempted on firing #5, 13 June 1946, and again on firing #6, 28 June 1946. Positive indication was obtained on the latter flight that the explosive charge was successfully detonated, but separation was, in both cases, unsuccessful. The first successful warhead separation was obtained on firing #9, 30 July 1946, and, while the warhead itself was never located, the afterbody of the rocket was found in fairly good condition. Since this time, there have been a number of successful attempts at warhead blowoff. The extension of the use of remote control to other control functions has been considered.

The ground station, which was powered by a portable gas engine generator and battery system, is to be replaced as soon as possible by a semi-permanent rack and panel type installation in a K-65 type trailer. Conversion to 110 volt, 60 cycle operation, powered from a PE-95 gas engine power supply, will be accomplished at the same time. General improvements in antenna installation will be attempted, and duplicate transmitter installations in the trailer will be provided for standby service.

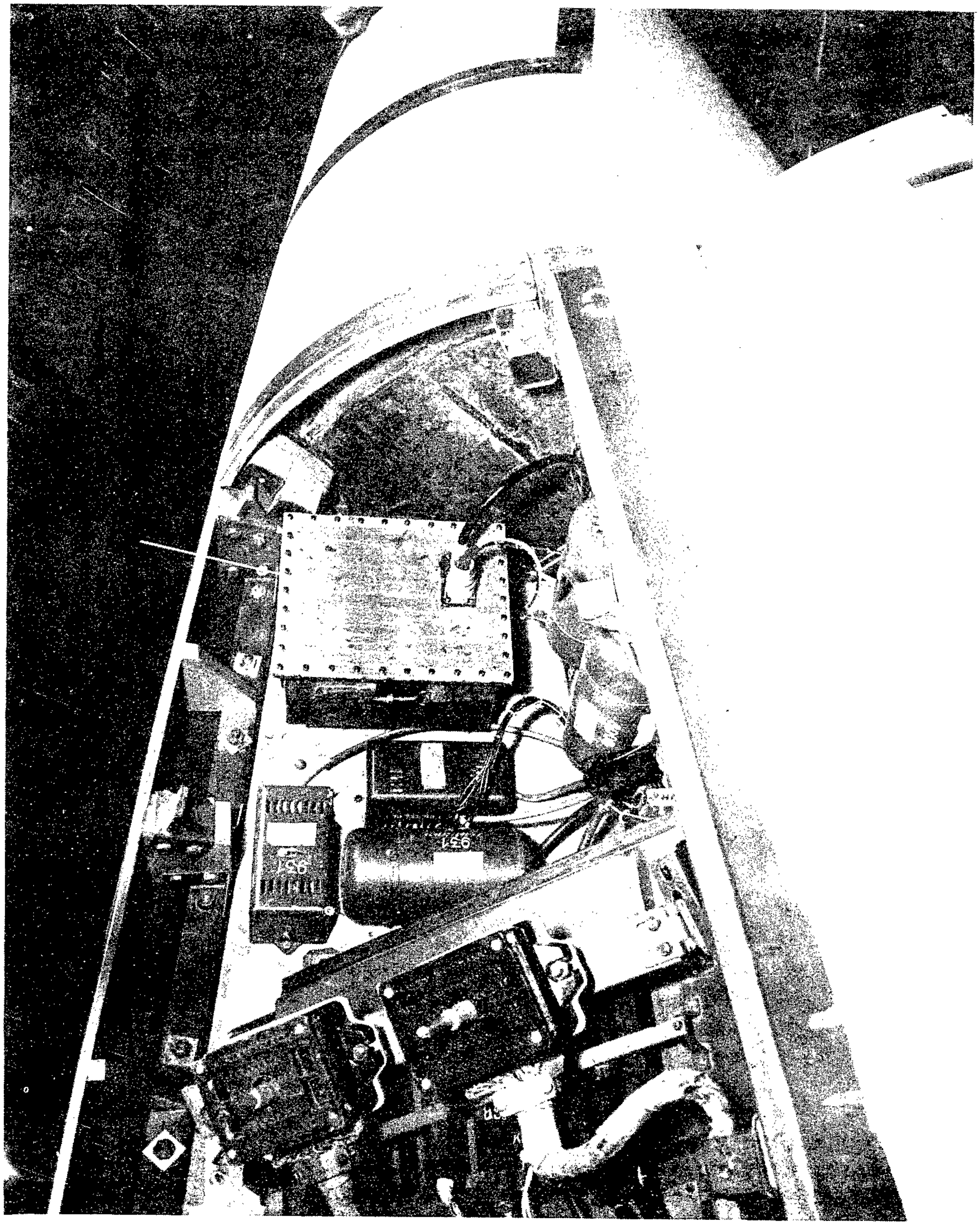

Fig. 14 - Emergy Cutoff Receiver Installed in the V-2 Control Chamber

APPENDIX I

V-2 FIRING SCHEDULE*

COMPLETED FIRINGS

FIRING	DATE	COGNIZANT RESEARCH AGENCY
	A. Preliminary Firings	
1	1946 15 March	Static firing
2	16 April	General Electric Company
3	10 May	General Electric Company
4	29 May	General Electric Company
5	13 June	General Electric Company
	B. The First Cycle	
6	1946 28 June	Naval Research Laboratory
7	9 July	General Electric Company
8	19 July	General Electric Company
9	30 July	Applied Physics Laboratory
10	15 August	Princeton University
11	22 August	Air Materiel Command
	C. The Second Cycle	
12	1946 10 October	Naval Research Laboratory
13	24 October	Applied Physics Laboratory
14	7 November	Princeton University
15	21 November	Air Materiel Command
	D. The Third Cycle	
16	1946 5 December	Naval Research Laboratory
17	17 December	Applied Physics Laboratory
18	1947 10 January	Naval Research Laboratory
19	23 January	General Electric Company
20	20 February	Air Materiel Command
	E. The Fourth Cycle	
21	1947 7 March	Naval Research Laboratory
22	1 April	Applied Physics Laboratory
23	8 April	Applied Physics Laboratory
24	17 April	G. E. Co. - Signal Corps

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*The firing schedule was modified slightly by the V-2 Panel (cf. p. 3) as this report went to press. The information here given contains these changes and is, accordingly, accurate as of 7 May.

APPENDIX I

V-2 FIRING SCHEDULE

DEFINITELY SCHEDULED FIRINGS

FIRING	DATE	COGNIZANT RESEARCH AGENCY
	F. The Fifth Cycle	
25	1947 15 May	Naval Research Laboratory
*	29 May	Ft. Bliss (tentative)
26	12 June	G. E. Co. - Signal Corps
27	26 June	Air Materiel Command - Signal Corps
28	1 July	Signal Corps - Naval Research Laboratory
	G. The Sixth Cycle	
29	1947 10 July	Naval Research Laboratory - Signal Corps
30	24 July	Applied Physics Laboratory - Signal Corps
*	31 July	Ft. Bliss (tentative)
31	7 August	General Electric Company - Signal Corps - Air Materiel Command
	s u m m e r v a c a t i o n	
32	25 September	Air Materiel Command
33	9 October	Signal Corps
*	23 October	Ft. Bliss (tentative)
	H. The Seventh Cycle	
34	1947 6 November	Naval Research Laboratory
35	20 November	Applied Physics Laboratory
36	4 December	General Electric Company
37	18 December	Air Materiel Command
**	1948 8 January	

*Denotes additional firings by Army Ordnance. V-2 Panel has first call on these dates, if exigencies demand.
**Denotes reserved for exigencies.

APPENDIX I

V-2 FIRING SCHEDULE

DEFINITELY SCHEDULED FIRINGS

FIRING	DATE	COGNIZANT RESEARCH AGENCY
	I. The Eighth Cycle	
38	1948 22 January	Naval Research Laboratory
39	5 February	General Electric Company
40	19 February	Applied Physics Laboratory
41	4 March	Air Materiel Command
**	18 March	
42	1 April	Signal Corps
	J. The Ninth Cycle	
43	1948 15 April	Naval Research Laboratory
44	29 April	General Electric Company - Air Materiel Command
45	13 May	Applied Physics Laboratory
46	27 May	Air Materiel Command
**	10 June	
	K. The Tenth Cycle	
47	1948 24 June	Naval Research Laboratory
48	8 July	General Electric Company - Air Materiel Command
49	22 July	Applied Physics Laboratory
50	5 August	Air Materiel Command
	L. The Eleventh Cycle	
51	1948 September	Air Materiel Command
52		Air Materiel Command

**Denotes reserved for exigencies.

APPENDIX II

REPORTS AND PUBLICATIONS BY NAVAL RESEARCH LABORATORY PERSONNEL ON UPPER ATMOSPHERE RESEARCH

"Cosmic Radiation Above 40 Miles" by S. E. Golian, E. H. Krause, and G. J. Perlow, The Physical Review, August 1 and 15, 1946.

"Upper Atmosphere Research Report No. I", by various authors, Naval Research Laboratory Report No. R-2955, 1 October 1946.

"Telemetering From the V-2", by V. L. Heeren, C. H. Hoeppner, J. R. Kauke, S. W. Lichtman, and P. R. Shifflett, Naval Research Laboratory Report No. R-3013, 1 October 1946.

"Additional Cosmic-Ray Measurements with the V-2 Rocket" by S. E. Golian, E. H. Krause, and G. J. Perlow, The Physical Review, November 1 and 15, 1946.

"Solar Ultraviolet Spectrum to 88 Kilometers" by W. A. Baum, F. S. Johnson, J. J. Oberly, C. C. Rockwood, C. V. Strain, and R. Tousey, The Physical Review, November 1 and 15, 1946.

"Pressure and Temperature Measurements in the Upper Atmosphere" by Nolan R. Best, Eric Durand, Donald I. Gale, and Ralph J. Havens, The Physical Review, December 1 and 15, 1946.

"Upper Atmosphere Research Report No. II", by various authors, Naval Research Laboratory Report No. R-3030, 30 December 1946.

"Solar Spectroscopy at High Altitudes" by Charles V. Strain, Sky and Telescope, February, 1947.

"Non-Primary Cosmic-Ray Electrons above the Earth's Atmosphere" by G. J. Perlow and J. D. Shipman, Jr., The Physical Review, March 1, 1947.

"Telemetering from V-2 Rockets" by V. L. Heeren, C. H. Hoeppner, J. R. Kauke, S. W. Lichtman, and P. R. Shifflett, Electronics, March, 1947 and April, 1947.

"Photography from The V-2 at Altitudes Ranging Up To 160 Kilometers", Naval Research Laboratory Report No. R-3083, by Thor A. Bergstralh, April 1947.

"Exploration Of The Upper Atmosphere By Means Of Rockets" by H. E. Newell, Jr., The Scientific Monthly, June 1947.

"Solar Absorption Lines between 2950 and 2200 Angstroms" by E. Durand, J. J. Oberly and R. Tousey, The Physical Review, June 1, 1947.

PAPERS ACCEPTED FOR PUBLICATION

"Eccles-Jordan Scale-of-N Circuits" by B. Howland, Electronics.

PAPERS SUBMITTED FOR PUBLICATION

"Electronics for Cosmic Ray Experiments" by B. Howland, C. A. Schroeder and J. D. Shipman, Jr., The Review of Scientific Instruments.

"Further Cosmic-Ray Experiments above the Atmosphere, by S. E. Golian and E. H. Krause, The Physical Review.

"Pressure and Temperature of the Atmosphere to 120 Km" by N. Best, R. Havens, and H. LaGow, The Physical Review.

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APPENDIX III

TALKS BY NAVAL RESEARCH LABORATORY PERSONNEL ON UPPER ATMOSPHERE RESEARCH

Topics	Time	Place	Speaker
Electronics in the V-2	30 Oct. 1946	American Institute of Electrical Engineers, Washington, D. C.	E. H. Krause
Spectroscopic Results from the Oct.10 V-2	27 Oct. 1946	Johns Hopkins Univ. Chapter of Sigma Xi Baltimore, Md.	R. Tousey
Exploration of the Upper Atmosphere by means of Rockets	7 Dec. 1946	Wash. Philosophical Society, Cosmos Club Washington, D. C.	H. E. Newell, Jr.
Radio Pulse Tele-metering	10 Dec. 1946	Am. Society for Experimental Stress Analysis, New York, N. Y.	C. H. Hoeppner
High Altitude Re-search with V-2 Rockets	28 Dec. 1946	Am. Association for the Advancement of Science, Cambridge, Mass.	E. H. Krause
The Solar Ultraviolet Spectrum from a V-2 Rocket	30 Dec. 1946	Am. Astronomical Society, Cambridge, Mass.	R. Tousey
Solar Spectroscopy	10 Jan. 1947	Journal Club, Ap-plied Physics Laboratory, Johns Hopkins University, Silver Spring, Md.	R. Tousey

Topic	Date	Place	Speaker
Pressure Measurements in the Upper Atmosphere	30 Jan. 1947	Joint Meeting of the Meteorological Society and the Inst. of the Aeronautical Sciences, N.Y.	N. E. Best
The Pressure and Temperature of the Atmosphere as Measured from the V-2	5 Feb. 1947	Wash. Phys. Colloquium George Washington University, Washington, D.C.	R. J. Havens
Rocket Spectroscopy Above the Ozone Layer	19 Feb. 1947	Wash. Phys. Colloquium, National Bureau of Standards, Washington, D.C.	C. V. Strain E. Durand
The Upper Atmosphere of the Earth	21 Feb. 1947	Optical Society of America, New York, N.Y.	E. O. Hulburt
Solar Spectrograph for V-2 Rocket	21 Feb. 1947	Optical Society of America, New York, N.Y.	R. Tousey
The V-2 Upper Atmosphere Research Program	3 Mar. 1947	Winners of the Science Talent Search, Dept. of Interior, Washington, D.C.	H. E. Newell, Jr
The NRL Telemetering System in Use at White Sands Proving Ground in Connection with the V-2 Firings.	13 Mar. 1947	New Mexico-West Texas Section of the Am. Inst. of Electrical Eng., El Paso, Texas.	H. A. Brown, (N.M. College of A. & M.A.)
Cosmic Ray Research in the V-2	19 Mar. 1947	Wash. Phys. Colloquium, National Bureau of Standards, Washington, D.C.	E. H. Krause
Results of the Cosmic Ray Experiment in the January 10, 1947 Rocket	21 Mar. 1947	Princeton Cosmic Ray Seminar, Princeton, N. J.	G. J. Perlow

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Topics	Time	Place	Speaker
High Altitude Research with V-2 Rockets	25 April 1947	Am. Philosophical Society, Philadelphia, Pa.	E. H. Krause
Cosmic Rays Above the Atmosphere	25 April 1947	Princeton Cosmic Ray Colloquium, Princeton, N. J.	E. H. Krause
Ozone Distribution from a V-2 Rocket by E. Durand, F. S. Johnson, J. J. Oberly, J. D. Purcell and R. Tousey	29 April 1947	Am. Geophysical Union, Meteorology Section, Washington, D. C.	R. Tousey
Absorption Lines in the Solar Spectrum from 2950-2300 A. by E. Durand, F. S. Johnson, J. J. Oberly and R. Tousey	29 April 1947	Am. Geophysical Union, Terrestrial Magnetism and Electricity Section, Washington, D. C.	E. Durand
V-2 Photographs up to 100 Miles Altitude	29 April 1947	Am. Meteorological Society Annual Meeting, Washington, D. C.	T. A. Bergstralh
Pressure and Temperature of the Upper Atmosphere from a V-2 Fired on March 7, 1947	29 April 1947	Am. Meteorological Society Annual Meeting, Washington, D. C.	R. J. Havens
V-2 Ionosphere Studies by the Naval Research Laboratory	29 April 1947	Am. Geophysical Union, Terrestrial Magnetism and Electricity Section, Washington, D. C.	T. R. Burnight

TALKS SCHEDULED FOR THE NEAR FUTURE

Topics	Time	Place	Speaker
Further Cosmic Ray Experiments Above the Atmosphere	3 May 1947	Am. Physical Society, Washington, D. C.	E. H. Krause
A V-2 Cosmic Ray Experiment	3 May 1947	Am. Physical Society, Washington, D. C.	G. J. Perlow
A Diode Coincidence Circuit	3 May 1947	Am. Physical Society, Washington, D. C.	J. D. Shipma
Rocket Observations of the Ionosphere	9 May 1947	National Bureau of Standards, Radio Propagation Conference, Washington, D. C.	T. R. Burnig
A Year of Upper Atmosphere Research by Means of Rockets	13 May 1947	Renesselaer Poly-technic Institute, Troy, N. Y.	H. E. Newell
Upper Atmosphere Research with the V-2	20 May 1947	Science Fair, District of Columbia Schools, Washington, D. C.	H. E. Newell

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