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NAVWEPS REPORT 7733
NOTS TP 2689
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HISTORY OF THE NOTS RESEARCH PROGRAM ON THE PHYSICS OF THE UPPER ATMOSPHERE

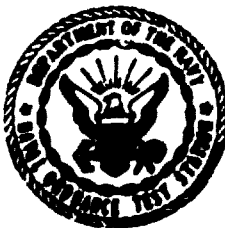
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ABSTRACT. This report is a summary of the activities of the Naval
Ordnance Test Station in the field of research on the physics of the
upper atmosphere.

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U. S. NAVAL ORDNANCE TEST STATION

China Lake, California

31 May 1961

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U. S. NAVAL ORDNANCE TEST STATION
AN ACTIVITY OF THE BUREAU OF NAVAL WEAPONS

W. W. HOLLISTER, CAPT. USN
Commander

WM. B. McLEAN, PH.D.
Technical Director

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NOTS Technical Publication 2689
NAVWEPS Report 7733

Published by Weapons Development Department
Manuscript 40/MS 61-27
Collation Cover, 12 leaves, abstract cards
First Printing 165 numbered copies
Security Classification UNCLASSIFIED

FOREWORD

There has been an active program of research in the physics of the upper atmosphere at the Naval Ordnance Test Station since July 1946. This research program may be conveniently divided into three phases. The first phase is associated with the U. S. Army Air Force--Navy program using three B-29 aircraft as flying laboratories. This program was initiated by the Naval Office of Research and Invention in the spring of 1946. In July 1946, the Office of Naval Research sponsored the program, and the Naval Ordnance Test Station acted principally as a service facility for the B-29's and the visiting scientists. The second phase of the research program was associated with the selection of a site and the construction of the White Mountain Research Station. Two years after this high-altitude observatory was established, its control was transferred to the University of California. The third phase is associated with an active program of basic research in the physics of the upper atmosphere. This report is a historical account of all three of these phases of activity.

This report has been reviewed for authenticity by G. J. Plain and M. H. Hunt.

F. H. KNEMEYER
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the authority of:

WM. B. MCLEAN
Technical Director

INTRODUCTION

A historical account of the activities of an organization in the field of basic research serves two purposes. First, it gives recognition of the achievements of the group, and second, it assists the directors of the program to look at the long-term trends in the research program. The Naval Ordnance Test Station has had a group active in the field of research in the physics of the upper atmosphere since 1946. This note is a historical summary of the activities of this group.

No history of the work done on the physics of the upper atmosphere at the Naval Ordnance Test Station would be complete, however, without an acknowledgement of the important support and cooperation given by the Office of Naval Research from 1946 through 1950, and again in 1961. This support was more than financial. The staff of the Office of Naval Research (Washington, Pasadena, and San Francisco) at all times gave enthusiastic and efficient support and encouragement.

This history consists chiefly of an objective listing of personnel, publications, awards, and special events insofar as the availability of records permit. There are, however, subjective factors that are also important. For example, the number of publications can be determined approximately. The quality of the publications is difficult to assess; however, the awards and general recognition given to the authors are one clue.

The Office of Naval Research and the Naval Ordnance Test Station sponsored basic research on the upper atmosphere through three distinct programs: (1) the high-altitude flying laboratory (B-29), (2) the White Mountain high-altitude observatory, and (3) the Atmospheric Physics Branch. In addition to these explicitly basic research programs, the Aviation Ordnance Department and the Weapons Development Department of this station have made significant contributions in the study of the physics of the atmosphere.

PROJECT APOLLO: The High-Altitude Flying Laboratory

On 8 July 1946 a conference was held in the Main Navy Building, Washington, D. C., on the subject "Joint AAF/Navy Upper Atmosphere Research Program" (see Minutes of Conference, 8 July 1946, Planning Division, Office of Research and Invention). Those present at the conference, from the organization indicated, were:

Office of Research and Invention (ORI), Planning Division

CAPT R. D. Conrad
U. Liddel
LCOL R. C. Walton
LCDR D. F. Rex

LCDR J. W. Smith
R. C. Bryant
LTJG J. D. Rough

Naval Research Laboratory (NRL)

R. Touscy
M. Katzin

Los Angeles Office of Research and Invention

CDR E. Bollay

Bureau of Aeronautics

J. B. Matthews, Jr.
LCDR H. H. Stuart

National Bureau of Standards

C. A. Douglas

Naval Ordnance Test Station (NOTS)

W. H. Barkas
W. R. Brode

Applied Physics Laboratory, John Hopkins University

J. A. Van Allen

U. S. Weather Bureau

C. Harmantas
B. C. Haynes

Massachusetts Institute of Technology (MIT)

B. Ross
M. Sands
A. D. Sard
M. M. Hubbard

California Institute of Technology

P. E. Lloyd

University of California

R. B. Brode

At this conference a tentative operational plan was proposed. Three B-29 aircraft were to be based at NOTS, starting 1 August 1946. Limited laboratory facilities, storage space, housing, and general

support were to be supplied by NOTS. Dr. Lloyd, Dr. R. Brode, Dr. Van Allen, and Dr. Ross all submitted lists of specific experiments and cloud chambers, cosmic ray telescopes, and other instruments that either were ready or would soon be ready for installation in the B-29's. Each of the other scientists had specific experiments ranging from the measurement of the composition of the atmosphere to terrestrial radiation, earth's magnetic field, etc. (The Office of Naval Research took over the functions of the Office of Research and Invention in 1946.)

Although the records of the research done with the aid of the B-29 aircraft are incomplete, there is evidence that at least the following scientists were active in the program:

W. C. Barber, University of California
 R. B. Brode, University of California
 R. R. Brown, University of California
 W. B. Fretter, University of California
 D. C. Moore, University of California
 G. E. Plummer, University of California
 W. E. Hazen, University of California and MIT
 S. B. Jones, University of California and MIT
 R. V. Pyle, University of California and MIT
 R. V. Adams, California Institute of Technology
 Carl D. Anderson, California Institute of Technology
 A. T. Biehl, California Institute of Technology
 E. W. Cowan, California Institute of Technology
 John Strong, John Hopkins University
 J. A. Van Allen, John Hopkins University
 John A. Simpson, University of Chicago
 Sigmund Fritz, U. S. Weather Bureau
 T. H. MacDonald, U. S. Weather Bureau
 H. W. Baldwin, NOTS and University of Chicago
 R. A. Anthony, NOTS
 E. V. Ashburn, NOTS
 C. L. D'Oogie, ONR Liaison
 MAJ Wayne Gustafson, Air Force Operation of B-29's.

Dr. R. B. Brode kindly loaned his files on the cosmic ray program to the author. These files indicate that the physicists from the University of California at Berkeley used the following equipment at some time during the cosmic ray program:

1. Eight-inch cloud chamber
2. Twelve-inch cloud chamber
3. Set of three cloud chambers to measure momentum and range of cosmic ray particles
4. Geiger counter system to study east-west effect
5. Nuclear research photographic plates

6. Mesotron mass spectrometer
7. Cosmic ray counter telescope

The University of California equipment was first flown on 9 and 10 October 1949. The B-29's were flown from the equator to the arctic and to altitudes up to 40,000 feet.

There were three major tragedies associated with Project Apollo. H. W. Baldwin, physicist on leave from NOTS to the University of Chicago, was killed in September 1948 when he failed to pull the rip cord on his parachute in an emergency jump. One B-29 sank in Lake Mead after an emergency landing on the lake. A second B-29 was destroyed by fire caused by a short circuit in a cloud chamber while the aircraft was on the ground at Armitage Field (NOTS).

In Project Apollo, the principal role of NOTS was that of a service organization. However, the personnel at NOTS profited from the outstanding opportunity to be associated with some of the nation's leading physicists. An extensive list of publications grew out of the B-29 research program. Certainly NOTS and the Navy received recognition for their part in this successful scientific program.

WHITE MOUNTAIN RESEARCH STATION

The White Mountain Research Station was first suggested by C. T. Elvey, Research Department of NOTS. R. S. Estey selected the site and supervised the construction of the first two buildings at 3 km and 3.2 km elevation. The Research Station was established under the sponsorship of NOTS and ONR in 1949. Approximately two years later, the White Mountain Research Station was placed under the direction of the University of California. The National Science Foundation and the Rockefeller Foundation for Medical Research added their support, and in 1955 buildings were erected at the Mt. Barcroft site at 4 km elevation and at the summit (4.6 km) of White Mountain. Dr. Nello Pace of the Physiology Department, University of California, at Berkeley is Director of the Laboratory. The White Mountain High-Altitude Research Station has received nationwide publicity in recent years, but to the author's knowledge, there has never been any mention of NOTS' role in its founding.

ATMOSPHERIC PHYSICS BRANCH

In 1946, A. L. Bennett suggested that the Research Department, NOTS, should support a small group to study the physics of the upper atmosphere. Edward V. Ashburn was the first member of the group which was established in September 1946. In July 1947, the group was expanded and placed under the direction of C. T. Elvey and

F. E. Roach. Under their leadership and through the cooperation of the Office of Naval Research, an active program of research on the night airglow was initiated. Daniel Barbier of the Institut d'Astrophysique, Paris, joined the group for 6 months in 1948. David R. Bates of University College, London and Queens College, Belfast, and Marcel Nicolet, l'Institut Royale Météorologique Belgique, joined the group for 6 months in 1949. John Irwin, Indiana University, joined the group for the summer in 1948 and 1949. In 1948, a site was selected by the group for the construction of an observatory on Cactus Peak, a volcanic cinder cone on the northwestern part of the Naval Ordnance Test Station. (Fig. 1). The Peak Observatory, constructed under supervision of Dr. Estey, is shown in Fig. 2.

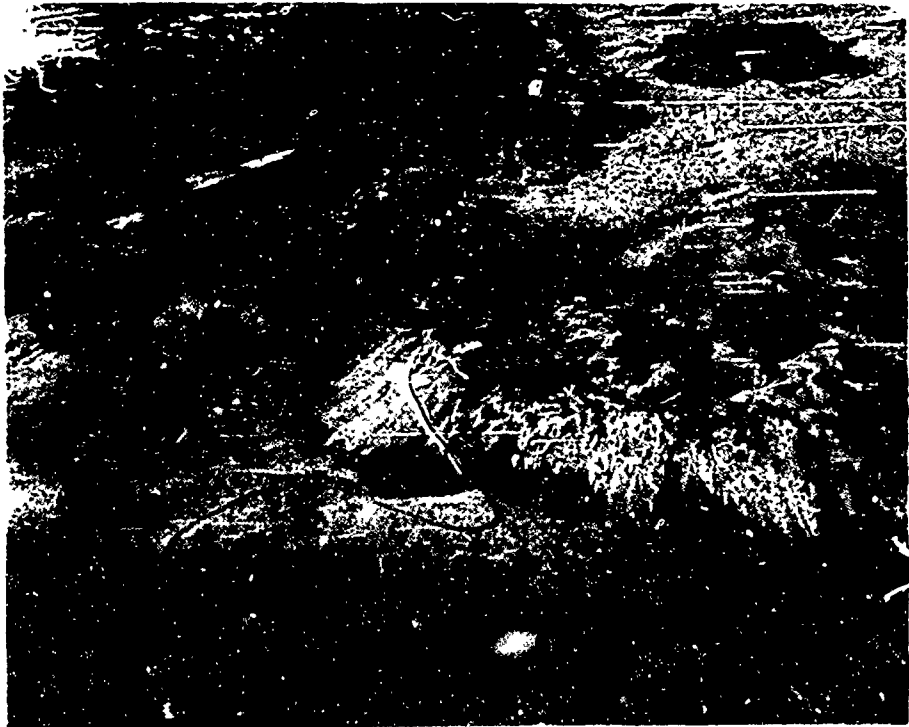


FIG. 1. Site of Cactus Peak Observatory.

With these leading authorities in the field of atmospheric physics, for a short time NOTS became one of the outstanding centers in this field in the nation.



FIG. 2. Cactus Peak Observatory.

The following is a partial list of the distinguished atmospheric physicists who visited the NOTS Atmospheric Physics Group:

V. A. Bailey	Marcel Nicolet
Daniel Barbier	Marcus O'Day
David Bates	D. M. Packer
L. V. Berkner	Rudolph Penndorf
Sydney Chapman	Edison Pettit
Kinsel Coulson	Jean Piccard
W. A. Elsasser	Jeanette Piccard
J. W. Evans	W. O. Roberts
J. L. Greenstein	M. J. Seaton
Beno Gutenberg	Z. Sekera
Levi Herman	Polidore Swings
E. O. Hulburt	M. A. Tuve
J. H. Irwin	S. V. Venkateswaran
Joseph Kaplan	G. L. Weissler
C. Lock	F. L. Whipple
Aden Meinel	Oliver Wulf
D. H. Menzel	

In addition, distinguished scientists such as R. B. Brode, L. B. Loeb, K. J. Buettner and others visited the group incidental to their stay at NOTS.

A symposium on the "Physics of the Upper Atmosphere" was held at the California Institute of Technology and at NOTS in 1950 under the sponsorship of the Office of Naval Research. The attendance at the NOTS sessions, shown in Fig. 3, was as follows:

Warren Arnquist, ONR
Edward V. Ashburn, NOTS
David R. Bates, NOTS
Lloyd V. Berkner, Carnegie Institute of Technology
Sydney Chapman, Chairman, IGY
C. T. Elvey, NOTS
J. L. Greenstein, Mt. Wilson Palomar, Observatory
Beno Gutenberg, California Institute of Technology
Joseph Kaplan, UCLA, Institute of Geophysics
Aden Meinel, U. of Chicago, Yerkes Observatory
Marcel Nicolet, NOTS
Marcus O'Day, Geophysical Research Directorate, USAF
Rudolph Penndorf, Geophysical Research Directorate, USAF
F. E. Roach, NOTS
F. T. Rogers, NOTS
Merle Tuve, Carnegie Institute of Technology
G. L. Weissler, U. of Southern California, Los Angeles
Oliver Wulf, California Institute of Technology



FIG. 3. Attendance at NOTS Symposium on "Physics of the Upper Atmosphere". (L to R, Front Row: Aden Meinel, Rudolph Penndorf, Marcel Nicolet, David Bates, J. L. Greenstein; Second Row: Beno Gutenberg, F. T. Rogers, Joseph Kaplan, Marcus O'Day, F. E. Roach, Oliver Wulf, Lloyd Berkner, Sydney Chapman; Back Row: Edward Ashburn, unidentified person, G. L. Weissler, C. T. Elvey, and Warren Arnquist. Not Shown: Merle Tuve.)

C. T. Elvey left NOTS in 1952 to become Director, Geophysical Institute, College, Alaska. F. E. Roach moved to the National Bureau of Standards in 1954. Pierre St. Amand became Head of the NOTS group when Dr. Roach departed. In 1958, Dr. St. Amand was asked by the U. S. State Department to teach at the University of Santiago, Chile, for two years, because of the Chilean earthquake in 1960, his stay was extended 6 months. F. K. Odencrantz headed the group during this period.

During the past 14 1/2 years, there have been organizational changes at NOTS within the Research Department, and the atmospheric physics group has been transferred to three different divisions. The name and size of the group has varied. The number of scientists active at any one time has varied from one to about eight as shown in Table 1. Thirteen scientists have been a co-author of at least one publication. Ashburn, Bates, Barbier, Moore, Nicolet, Pettit, Roach, St. Amand, and Williams were authors or co-authors of five or more publications, and Ashburn and Roach have published fifteen or more papers (see Bibliography).

F. E. Roach (1952) and Pierre St. Amand (1953) each received Fulbright Research Fellowships to the Institut d'Astrophysique in Paris. Dr. St. Amand has published significant work in the field of geology as well as in the field of the upper atmosphere. Through St. Amand's interests, Roland Von Huene, a geologist, joined the Atmospheric Physics Branch in 1955. Von Huene received a Fulbright Student Fellowship to the University of Innsbruck, Innsbruck, Austria, in 1957, and was awarded his PhD in 1960 from UCLA on the basis of his work at NOTS.

Z. Sekera and his group in the Meteorology Department, University of California at Los Angeles, have taken an active interest in the work done by the Atmospheric Physics Branch. In fact, Dr. Sekera was a co-author of NAVORD Report 2061 containing Tables Relating to the Scattering of Light by the Atmosphere. In 1960, the personnel at NOTS collaborated with S. V. Venkateswaran of the Institute of Geophysics, UCLA, in the study of atmospheric ozone. This collaboration, with the support and encouragement of C. E. Palmer of the Institute of Geophysics resulted in a significant paper by S. V. Venkateswaran, J. G. Moore, and A. J. Krueger.

TABLE 1. Program Participation of Atmospheric Physics Group

Year	Program	Visiting scientists active in program	NOTS scientists, including junior prof. trainees	Number of NOTS publications
1946	B-29 Labs	15	1	0
	Atm. Physics	--	1	0
1947	B-29 Labs	15	2	0
	Atm. Physics	--	5	0
1948	B-29 Labs	15	1	--
	Atm. Physics	3	7	3
1949	B-29 Labs	15	0	--
	Atm. Physics	4	8	6
	White Mtn.	?	1	--
1950	Atm. Physics	3	9	17
	White Mtn.	?	1	--
1951	Atm. Physics	1	6	13
1952	Atm. Physics ^a	--	4	8
1953	Atm. Physics ^b	--	4	4
1954	Atm. Physics	2	5	4
1955	Atm. Physics	--	4	10
1956	Atm. Physics	--	4	4
1957	Atm. Physics ^c	--	4	2
1958	Atm. Physics	--	5	0
1959	Atm. Physics	--	5	2
1960	Atm. Physics	1	4	3

^aFulbright Fellowship to Dr. Roach

^bFulbright Fellowship to St. Amand

^cFulbright Student Fellowship to Von Huene

Further activities of the personnel of the Atmospheric Physics group worthy of note are as follows:

1. 1949--Daniel Barbier and D. R. Williams obtained spectra of the aurorae at the Geophysical Institute, College, Alaska.
2. 1950--D. R. Williams was detailed to l'Institut d'Astrophysique, Paris, to collaborate with Daniel Barbier on the study of the aurorae and air glow.
3. 1953 and 1954--E. V. Ashburn made photometric measurements of the aurorae at the Geophysical Institute, College, Alaska.
4. 1956--J. G. Moore and E. V. Ashburn measured the infrared and ultraviolet emission of the aurorae at the Geophysical Institute, College, Alaska.
5. 1957--J. G. Moore was the only person in the world to report photometric observations of Sputnik II.
6. 1957 and 1958--S. R. Smith, E. V. Ashburn, and W. C. White installed air collection sample bottles and radiation measuring devices on the ONR "Stratolab" (Fig. 4) for flights No. 2 and 3. The Stratolab flights were manned balloon flights to 25.6 km (84,000 ft.). The launch for flight No. 2 is shown in Fig. 5.
7. 1960--W. C. White was detailed to the Smithsonian Institute and the Dearborn Observatory, Northwestern University to make astronomical observations from a balloon at 25 km. White will make the first of a series of ascensions in the balloon in June 1961.
8. The personnel of the atmospheric physics group presented talks to national or international meetings of at least the following organizations:

The International Astronomical Union
The American Physical Society
The American Meteorological Society
The Optical Society of America
The American Astronomical Society
The American Geophysical Union
The International Union of Geodesy and Geophysics

Other NOTS Organizations who have contributed to upper atmospheric studies are the Weapons Development Department and the Aviation Ordnance Department. Since July 1960, the Weapons Development Department has supported one full-time physicist for research

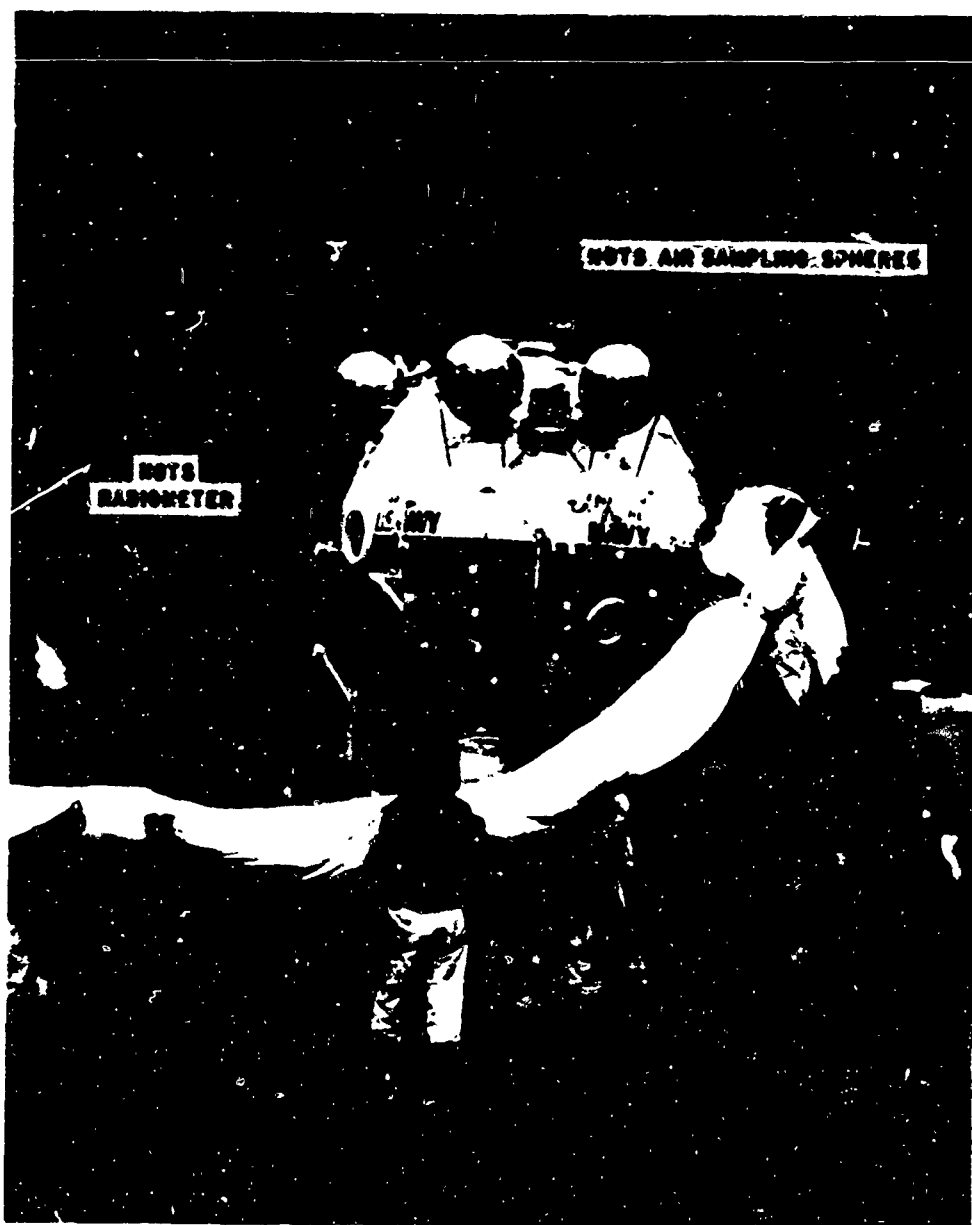


FIG. 4. The ONR "Stratolab".

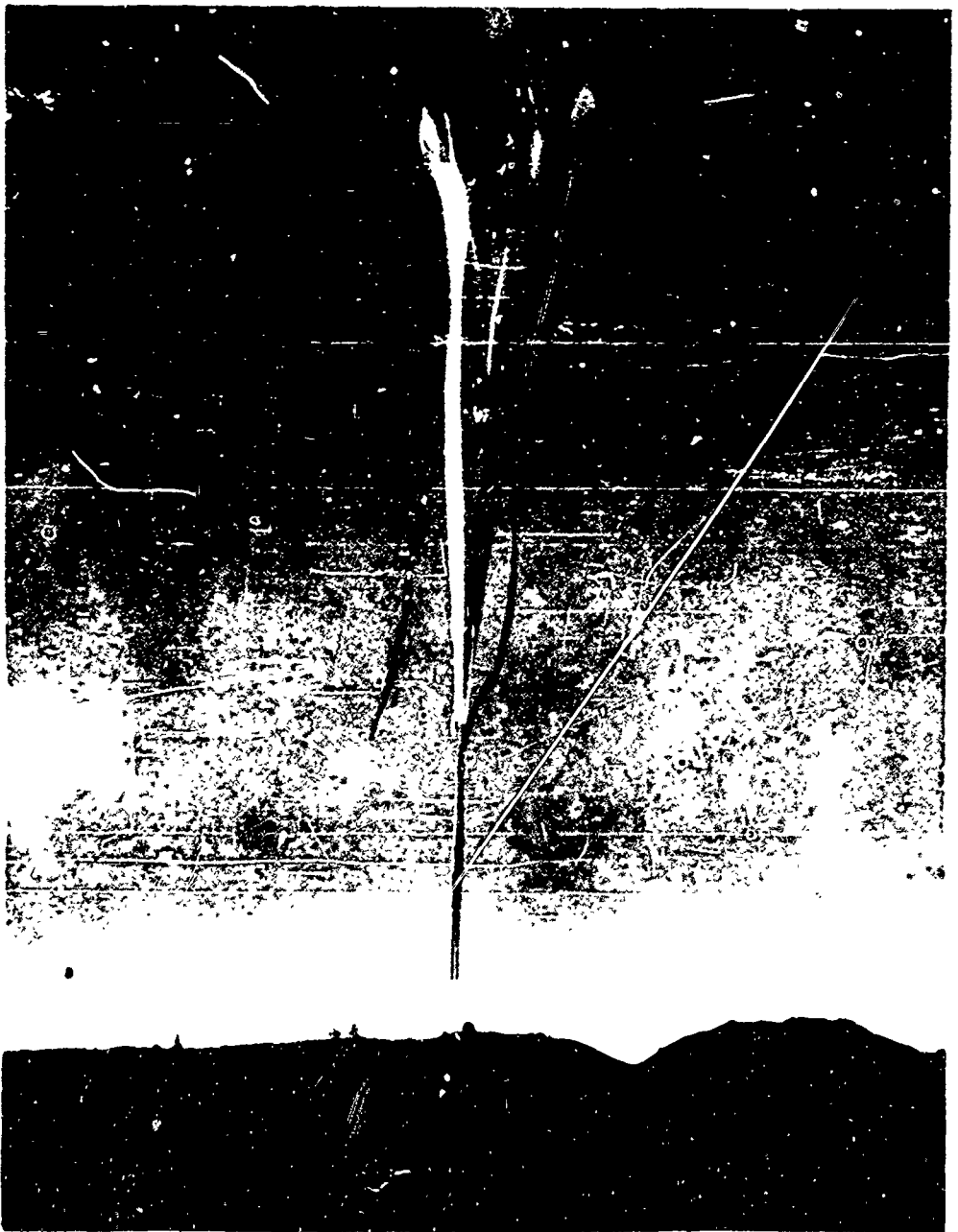


FIG. 5. Launch of Stratolab, Flight No. 2.

in atmospheric physics. In addition, a program of measuring the infrared irradiance from the ground and atmosphere has been initiated. Two unclassified reports (NAVORD Report 3465 by Dowell Martz and Howard Smnicht and NAVORD Report 7050 by Gordon C. Augason) relating to the properties of the atmosphere have been published by the Aviation Ordnance Department (see Bibliography).

As a result of the work at this Station, the Office of Naval Research (after a lapse of ten years) is once again supporting research work at NOTS in the upper atmosphere.

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ACKNOWLEDGEMENT

Dr. R. B. Brode, Professor of Physics, University of California loaned the author complete files on the University of California B-29 cosmic ray program. Most of the material on the B-29 program is based upon Dr. Brode's files. Dr. Warren Arnquist, C. L. D'Oogie, and Dr. F. E. Roach also assisted in the gathering of the basic facts relevant to this history. Dr. L. T. E. Thompson suggested that this historical survey be written.

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