

THE UNIVERSITY OF MICHIGAN  
COLLEGE OF ENGINEERING  
Department of Aeronautical and Astronautical Engineering  
High Altitude Engineering Laboratory

Final Report

ATMOSPHERIC PHENOMENA AT HIGH ALTITUDES

(April 14, 1955, to January 31, 1960)

Submitted for the Project

by  
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UMRI Project 2387

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## ABSTRACT

The tasks specified and the reports of results achieved in a five-year program of measuring atmospheric phenomena at high altitudes with the use of rockets are summarized.

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## FINAL REPORT

In April, 1955, The University of Michigan entered into a research contract for the primary purpose of adapting the rocket-grenade experiment for upper-air temperature and winds to Arctic conditions to carry out measurements at Fort Churchill during the IGY. Various supplementary tasks were added to the contract from time to time. The research and development was carried out in the High Altitude Engineering Laboratory of the Department of Aeronautical and Astronautical Engineering of the University.

The various tasks specified are listed below together with the contractual document in which they were specified. All the tasks were accomplished and, with one exception in the case of a classified program, were reported in various reports. The reports which describe in detail each major task are also listed. In addition, all the monthly letter-type and quarterly reports required by the contract were submitted.

Signal Corps Technical Requirements No. SCL-5070 dated 20 January 1955 entitled "Upper Atmosphere Research in the Arctic." The tasks specified by this document were as follows:

### "3. REQUIREMENTS

3.1 By performing the rocket-grenade experiment covered by this specification the atmospheric temperatures, the wind speeds and directions shall be measured in the arctic regions at altitudes between 30 and 90 km. Approximately 8 Aerobee rocket firings carrying the rocket-grenade instrumentation shall be conducted at Fort Churchill, Manitoba, Canada during the International Geophysical Year 1957-58.

3.2 Emphasis shall be placed on the following matters:

- a. A fundamental design-of-the-experiment study directed toward making the experiment (1) simpler and more reliable and (2) an 'all-weather' day and night experiment.
- b. A thorough study of the feasibility and problems of conducting the rocket-grenade experiment in the arctic.
- c. The design, construction, purchase, assembly and test of the instrumentation and equipment required for the conduct of the experiment.
- d. The instrumentation and firing at WSPG of Aerobee rockets carrying the redesigned rocket-grenade experiment under simulated arctic operational conditions to prove out the redesign. These test firings are to take place not later than the Fall of 1956.

- e. The planning and construction at the arctic test site of the special facilities required for the experiment and not provided through the range-instrumentation operations.
- f. A necessary and sufficient reliability program for parts, components, and systems."

The over-all objectives of the above requirements (Sec. 3.1) were completely achieved in a cooperative effort with USASRDL. Nine Aerobees (SM 1.02 - SM 2.10) were instrumented and fired at Fort Churchill during IGY. They were completely successful and yielded temperatures and winds in the region 30 to 90 km. The results were presented at the 5th Reunion of CSAGI in Moscow, Aug. 1958<sup>1</sup> and have been submitted for publication in the Journal of Geophysical Research<sup>2,3</sup>. The accomplishment of tasks 3.2 a, b, c, and f is described in the Quarterly Reports. The instrumenting and firing of a prototype experiment was accomplished successfully with Aerobee SM 1.01 at Fort Churchill in November, 1956,<sup>4</sup> rather than at WSPG as specified in item 3.2d. Task 3.2e was accomplished by the Special Committee for the IGY of the Technical Panel for Rocketry of the U. S. National Committee for the IGY. The authors were attached to this committee. See the final report of this committee entitled The U. S. IGY Upper Atmosphere Rocket Operations by J. R. Siewert.<sup>5</sup>

The results of those phases of the grenade-experiment research not covered in detail in the final "temperature and wind" papers are described in detail in the quarterly reports, technical reports, and papers in the general literature. The topics thus reported on are:

1. The effect of finite-amplitude propagation on the rocket-grenade experiment.<sup>6,7,8</sup>
2. A simplified method for computing temperatures and winds in the grenade experiment.<sup>9</sup>
3. The details of the method used to calculate the DOVAP trajectory data.<sup>10,11</sup>
4. The effect of varying index of refraction on the accuracy of the DOVAP data.<sup>12</sup>
5. The determination of upper-air densities from the measured characteristics of shock waves due to grenade explosions.<sup>13</sup>

By Modification No. 3 to the contract dated February 9, 1956, Amendment No. 1, dated January 12, 1956, to the work statement contained in Signal Corps Technical Requirements No. SCL-5070 was added. The amendment called for:

- "g. Various samples of air from the region 60 to 100 km will be collected and analyzed by Techniques stated in Technical Requirements No. SCL-2370, 19 Jan. 1954 and developed under contract DA 36-039-sc-56737 with the University of Michigan.
- h. Not more than two Aerobee rocket firings will be carried out at White Sands Proving Ground for this sampling purpose specified in 3.2g above. These firings are in addition to and separate from those specified in 3.2.d."

In fulfillment of these tasks Aerobee rockets SC-34 and SC-35 were launched at WSPG on 9 and 10 August 1956, respectively. The samples collected were analyzed on a new analyzer constructed at Michigan to complete the sampling work. A complete report of this work as well as a summary of the results of the overall sampling program was presented in a paper given at the 5th Reunion of CSAGI, Moscow, August, 1958.<sup>14</sup>

By Modification No. 11 to the contract dated Jan. 16, 1958, the following task was added.

"Item 7 - Design and fabrication of twelve (12) each NOSE CONES for the NIKE-CAJUN; in accordance with University of Michigan unnumbered drawing, (except the rear instrument section shall be one (1) inch longer than indicated in drawing), together with installation and testing of auxiliary wiring of Nose Cones."

This work was undertaken on an emergency basis at the urgent request of the Signal Corps. The Michigan nose cones were designed to accommodate electronic gear provided by Raytheon and the Signal Corps for a classified experiment. The nose cones were delivered complete on the date specified, and it is our understanding that rocket-vehicle performance was successful in every case, from which it may be inferred that the nose-cone design was adequate with regard to structure and aerodynamics. No reports were prepared by the University on this work.

Contract Modifications 13 (May 19, 1958), 14 (June 16, 1958), and 16 (June 27, 1959) specified work on the Guam grenade experiment program as follows:

From Modification 13 dated May 19, 1958:

"ITEM 8 - To design, develop and fabricate a ground station capable of tracking rockets carrying the grenade instrumentation with DOVAP and Ballistic Camera equipment. The station shall consist of two (2) vans (Government furnished equipment) plus instrumentation, some of which will be Government furnished and the remainder is to be procured by the Contractor. Specifications covering the general outlay of the ground station, as it pertains to the overall rocket experiment, will be provided by the United States Army Signal Research and Development Laboratory.

"ITEM 9 - Check out and operate the ground station provided for under Item 8 to ensure its functional use and the availability of sufficiently trained personnel to operate the station in the field by 1 August 1958.

"ITEM 10 - Fourteen (14) Nike-Cajun rocket vehicles, except for nose cones. The rocket motors will be standard Cajun units as supplied by Thiokol Chemical Corporation with modifications specified by United States Army Signal Research and Development Laboratory.



The Contractor will inspect the components of the vehicle but will not carry out pre-firing checks."

From Modification 14 dated June 16, 1958:

"ITEM 11 - Engineering Services, necessary for assembling, operating and maintaining the equipment to obtain doppler and ballistic camera tracking data in connection with the Rocket Grenade experiments to be conducted in Guam during the latter part of 1958. Tracking data on these firings shall be obtained and included in Report Nos. 14, 15 and 16 (Final Report) under Item 6; in accordance with Technical Guidelines for PR&C No. 58-ELE/R-2110. Report No. 16 (Final Report) to contain the evaluation of both the Fort Churchill and Guam firings."

From Modification 16 dated June 27, 1959, and Technical Guidelines for PR&C 59 ELS/D-1628, dated 25 March 1959:

- "1. In order to accomplish the overall objectives of this program, the following tasks are required:
  - a. The contractor shall be responsible for counting two tracks DOVAP cycles for each of the nine rocket firings at Guam. Slant ranges shall be calculated from these DOVAP data. The DOVAP data shall be combined with ballistic camera data and existing survey data from which grenade positions in space shall be computed.
  - b. The camera and survey data will be furnished to the contractor by this Laboratory and no more than the necessary spot checks shall be carried out on these data."

The objectives of the above work statements were achieved with complete success. The work involved in the assembly and operation of the Guam ground station is reported on in detail in the quarterly reports.<sup>13,15-17</sup> The analysis of the trajectory data is covered in the technical report Single-Station DOVAP-Ballistic Camera Tracking Reduction for Grenade-Experiment Rockets S.S. 12.50 - S.S. 6.58.<sup>18</sup>

During the course of the research program certain analytical investigations of general interest to upper-air research were pursued by V. C. Liu. These were reported in Refs. 19-30.

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