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

Technical Report

KEWEENAW RESEARCH RANGE

Harold F. Allen

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Abstract

The Keweenaw Research Range is located at the eastern end of the Keweenaw Peninsula in Northern Michigan, with rocket impact areas in Lake Superior. Surface surveillance is accomplished from chartered aircraft, and air surveillance is carried out by the 665th Radar Squadron of the Air Defense Command. Rockets up to Nike-Cajun in performance can be launched from the Range without danger of crossing the international boundary. Higher performance sounding rockets may involve areas in Canadian waters.

The Range is remote from populated areas, yet easily accessible by all forms of commerical transportation. The climate is mild in summer, severe in winter, with heavy snowfall. It is therefore a good site for environmental tests, winter operational tests, or hazardous experiments. The magnetic field intensity is high and the dip angle is 77^{o} so that it is an excellent place for ionospheric investigations. The location of the range near the center of the North American land mass is important from the standpoint of the Meteorological Rocket Network, or for synoptic measurements of any sort, and for tests requiring a mid-latitude site, or one remote from marine influences.

The Range is owned by the University of Michigan, with operational assistance available from Michigan Technological University at Houghton, Michigan. There are no permanent installations at the range, as only the small Arcas rockets have been launched as a summer project. Tracking radar, Rawinsonde GMD-1A, a portable telemetry station, launchers, etc., can be made available as required.

Keweenaw Research Range

Description

The Keweenaw Research Range is located at the east end of the Keweenaw Peninsula, which extends like a curved finger from the northern part of Michigan almost to the center of Lake Superior (Figure 1). The Keweenaw is a rocky, forested wilderness, with elevations ranging up to 1500 feet above sea level. There are no permanent habitations and no public highways east of the vicinity of Copper Harbor, a village ten miles west of the Range. Most of the land on the peninsula is owned by the lumbering division of a copper mining company. The Range is ideally adapted as a site for rocket launching, environmental testing, hazardous investigations, or any other type of project requiring a remote location, yet one easily accessible by commerical transportation, and within the limits of the continental United States.

Summers are mild, and winters severe. The temperature very seldom exceeds 90^{o} F, while temperatures of 40^{o} F and lower may be encountered during ten months of the year. Minima below -10^{o} F can be expected occasionally during the average winter. Precipitation is fairly uniform, with slightly more in summer than in winter. Summer precipitation occurs principally during showers of short duration. There are an average of six electrical storms per month during June, July, and August, with an annual total of 29 thunderstorms per year, mostly between May and September. Much of the winter precipitation is in the form of snow, which can occur during five to seven months of the year. The total annual snowfall sometimes exceeds 200 inches per year, and the maximum depth of snow on the ground frequently exceeds two feet between November and March. The prevailing wind direction is generally westerly or northwesterly. There are few severe storms, although the average wind velocity is fairly high. Wind chill factors of 1600 to 1800 are not uncommon in winter.

The Range comprises two pieces of land, as shown in Figure 2. The 183 acre launch site extends for 3/4 mile along the shore of Lake Superior at 47° 26' N. latitude and 87° 42' W. longitude. The 20 acre radar site occupies the top of a hill 3 1/2 miles WNW of the launch site and 700 feet above the lake. Figure 3 is a vertical aerial photograph of the launch area before the Range was established, and Figure 4 is a topographic map of the launch site.

The rocket impact areas are located in Lake Superior, as shown on Figure 1. Impact areas for the small rockets are clear of commerical shipping channels, and since there is little or no pleasure boating or fishing on that portion of the lake, these areas are usually clear at all times. The impact area for Nike-Cajun rockets includes portions of the main ship channel, and for larger rockets, may include areas of the lake north of the international boundary. Launching of such rockets may involve some delays due to ship traffic during the navigation season, which usually lasts from May to December. In winter, all areas are likely to be clear continuously. Surface surveillance of impact areas is carried out by chartered aircraft operating out of Houghton-Hancock Airport, about 40 miles west of Copper Harbor.

There is considerable military and some commerical air traffic in the area. All IFR traffic is under the control of the Minneapolis Air Route Traffic Control Center, which monitors all rocket countdowns, and routes all flights so as to avoid the area. There is little or no VFR traffic. Air surveillance over the area is carried out by the 665th Radar Squadron of the Air Defense Command, at Calumet Air Force Station, about 22 miles west of the launch site.

Immediate access to the Range is provided by private logging roads extending eastward from Copper Harbor. These roads are unimproved, but are passable for cars and trucks. They are kept open in winter near the range, as required by logging operations. Airline, rail, and marine transportation

facilities are available at Houghton, Michigan about 40 miles from Copper Harbor via U.S. Route 41. Motel, restaurant, and shopping facilities are operated at Copper Harbor during the summer, but are sharply curtailed in winter. An all-year resort area is planned, but not yet in operation.

All power required at the Range must be generated locally, as there is no power or public telephone service east of Copper Harbor. Communication is generally by radio to Copper Harbor or to Calumet Air Force Station. A private telephone line owned by the U. S. Coast Guard crosses the site, and is available for emergency use. K. I. Sawyer Air Force Base of the Strategic Air Command is located near Marquette, Michigan about 80 miles south of the Range.

There are no permanent installations at the Keweenaw Research Range at present other than a few unheated metal buildings as only temporary projects have been carried out, and only the small Arcas rockets have been launched to date. Enclosed rocket launch facilities will be provided eventually, for year-round operation. An SCR-584 tracking radar and a Nike launch rail are owned by the Range, and are currently in storage at Ann Arbor. A mobile telemetry station, a van-mounted rawinsonde GMD-1A set, a 75 foot telescoping tower, and such items as portable generators, radio transmitters and receivers, etc., are assigned to the University, and are available when not required by other projects.

The surplus SCR-584 radar which has recently been received from the NASA Wallops Island will be reconditioned and modified at the High Altitude Engineering Laboratory to serve as a precision tracking radar. This radar can be used with the modern meteorological payloads for the Arcas and similar rockets, to improve the data recovery capability of the Range. Furthermore, this radar is capable of tracking the larger two-stage rockets, such as the

Nike-Cajun and Nike-Apache. With the Nike launch rail, and the mobile telemetry station, the capacity of the Range can be expanded to include these rockets. Unofficial inquiries have been received relative to the launching of these rockets larger than the Arcas, and it is hoped that these will develop into actual projects at the Keweenaw Research Range.

Geophysical and Related Aspects

The most compelling reason for establishing a range on the Keweenaw Peninsula is its central location on the North American land mass, as shown in Figure 5, which makes it highly desirable as a station on the Meteorological Rocket Network. It is 925 miles from the Atlantic Ocean to the eastward and 1700 miles from the Pacific Ocean to the west, or 1700 miles from salt water in the direction from which the prevailing winds blow. It is 450 miles from Hudson's Bay to the northeastward. Its latitude, 47 1/2° N, places it very near to a true mid-latitude position.

The geomagnetic coordinates of the range are 58° N, 335° E. The magnetic variation is 0° 15' W. The total intensity of the magnetic field is .59 oersted. The horizontal intensity is .13, and the vertical intensity is .54, which corresponds to a dip angle of approximately 77°. The area of maximum magnetic intensity surrounding the north magnetic pole extends southward in a narrow band almost to the Keweenaw, as shown on Figure 6. The magnetic field intensity at the Range is nearly as great as at the magnetic pole itself, and it is the most southerly region in North America where the dip angle is this large.

The visible auroral activity is about 10% of the maximum at Fort Churchill, and there are from 5 to 20 bright auroras per year. Occasional auroras appear to extend from Fort Churchill in a southerly direction to the vicinity of the Keweenaw, with the maximum intensity well south of Fort Churchill.

This may be related to the magnetic anomaly discussed above.

Quantitative data on the concentration of natural aerosols in the atmosphere over the Keweenaw Peninsula are lacking, but it is probable that the density is very low. There are no smoke-producing industries on or near the peninsula, and few areas where dust can be produced. The remoteness from salt water leads to very low concentrations of sea salt. The atmosphere is considered to be comparatively free from pollen or other allergens.

The climate of the Keweenaw is discussed in an earlier section of this report, and in Appendix I.

Possible Range Users

The location advantage of the Keweenaw Range as a station on the Meteorological Rocket Network has already been mentioned. For similar reasons, the range could be utilized in connection with synoptic or near-synoptic measurements of any meteorological or other atmospheric phenomena.

The Range is attractive to aeronomers wishing to conduct atmospheric experiments in a continental area, remote from oceanic influences and salt spray, or at a mid-latitude location. It has special significance for ionospheric investigators. Recently it has been observed that ionospheric events of pronounced importance occur in regions where the magnetic dip angle exceeds 70º The dip at the Keweenaw is approximately 77,º which places it well within the area of major interest. The Range is adequate for launching rockets with apogees sufficiently high for ionospheric experiments.

The Range has many possible functions aside from its use as a sounding rocket launch site. The necessity of launching radiosonde balloons in connection with rocket firings implies the presence of major items of a standard weather station. The remoteness of the Range from populated areas makes it an excellent location for hazardous investigations of all sorts, for operational tests of missiles or other weapons systems, or for environmental

tests. The winter climate is not as severe as at Fort Churchill, Manitoba, where the U. S. Army formerly maintained an Arctic Test Center; but the Keweenaw is far more accessible, whether by air, surface, or marine transportation. A brief comparison of weather at Fort Churchill and Houghton, Michigan at the foot of the Keweenaw Peninsula is contained in Appendix I.

Initially, large rockets were not considered for launching from the Keweenaw Range, because of the presence of inhabited areas in Canada north of Lake Superior. However, the population density is not large, and there are no large cities. In a 40^{o} sector, 20^{o} on each side of a north line through the Range, there are only half a dozen towns or cities with populations exceeding 1000 (none of these is over 5000) and about a dozen towns between 500 and 1000. With a single exception, the northernmost of these towns or cities is less than 200 miles north of the Keweenaw. The exception is Fort Churchill, an established rocket range with excellent tracking facilities and a large impact area. Fort Churchill is about 700 miles north of the Keweenaw. If a necessity ever arises for launching a satellite into a north polar orbit, no existing range in the United States posesses the safety aspects of the Keweenaw Range, provided that international agreements can be worked out to cover this situation.

History

It was first suggested early in 1962 that the south shore of Lake Superior, in northern Michigan, might be a good location for a rocket range. There are many places between Sault Ste. Marie and the Wisconsin border with very low population densities, where such a range could be safely located. The lake itself could serve as an impact area.

A Legislative Committee was formed, and a preliminary investigation was conducted which appeared to substantiate this conclusion. An

intensive technical feasibility survey (Reference 1) was carried out by the University of Michigan, at its own expense, late in 1962. The study indicated that the tip of the Keweenaw Peninsula was the most advantageous location, considering all pertinent factors, and that small and medium range sounding rockets could be safely launched from this point on a year-round basis; although there were a few problem areas, such as ship traffic on Lake Superior, and the lack of electric power and telephone communication. The possible launching of large rockets was not considered in this study, because of the presence of inhabited areas in Canada north of Lake Superior. It should be noted, however, that the population density in these areas is generally small.

An informal survey of establishments in the United States and Canada which are engaged in upper atmospheric investigations of various kinds, indicated that a sounding rocket range at Keweenaw Point could provide data at a latitude of considerable significance. In particular, the Meteorological Rocket Network would derive special benefit from such a station. Figure 5 shows the position of the Keweenaw Research Range in relation to other stations of the Meteorological Rocket Network. This point is farthest from salt water, and nearest to the center of the continental land mass.

On the basis of the above investigations, a proposal for a complete scientific range (Reference 2) was prepared. This proposal was submitted to the NASA, on the basis of informal expressions of interest on the part of this agency, but no action has been taken to support the proposal.

Rocket Operations in 1964

During the summer of 1964, the Range was activated on a temporary basis, and a few meteorological rockets were launched, using a minimum of facilities and personnel. The State of Michigan, through the Department of Economic Expansion, provided a grant of $52,850 for this purpose, and the

Goodman Lumber Division of Calumet and Hecla, Incorporated, donated 203 acres of land to the University of Michigan. Access easements were granted by Calumet and Hecla, and by the Copper Range Company. Site preparation, access roads, and the transportation of some items of equipment to the site were arranged by the Keweenaw County Board of Supervisors and the County Highway Commission. Five Arcas rockets and five AN/DMQ-6 meteorological payloads were furnished by the United States Weather Bureau. Two Arcasonde II payloads were supplied by the Pacific Missile Range of the U. S. Navy. Both types of payload were manufactured by Atlantic Research Corporation, but are no longer in use at any established range. The reason for their use in this case is that no tracking radar was available for range determination. The DMQ-6 and Arcasonde II were intended to provide continuous wave ranging information, using an auxiliary ground based transmitter, and a remitter in the payload.

An Arcas rocket launcher was loaned by the U. S. Army Research and Development Activity at White Sands Missile Range, New Mexico. A van-mounted Rawinsonde GMD-1A set, a power generator, and a 75 foot telescoping tower assigned by the U. S. Army to the Willow Run Laboratory of the University of Michigan were loaned to the Range. The tower was used as an antenna mount and also for wind profile measurements required for determining launcher settings. Project personnel included three regular employees of the University of Michigan, two from Michigan Technological University at Houghton, Michigan, and two from the White Sands Missile Range. One of the latter returned to White Sands following the second rocket launching. U of M and MTU personnel were trained in rocket operations at WSMR and at Wallops Island range of the NASA. The above represents the bare minimum of crew and equipment sufficient for small rocket operations.

Surveillance of air traffic over the impact area was provided by the Air Defense Command, through the 665th Radar Squadron at Calumet Air Force

Station. Surface and low level air surveillance was carried out by chartered aircraft operating from Houghton-Hancock Airport. The launchings were accomplished under the terms of a waiver of Part 45 of the Federal Air Regulations, as authorized by the Detroit and Minneapolis Air Traffic Supervisors. The waiver defined the impact area, and authorized launchings on three specified days each week, during daylight hours, and in clear weather. Twenty-four hour advance notice of each launching was furnished to the Minneapolis Air Route Traffic Control Center through the FAA Flight Service Station at Houghton. The Center then monitored the countdown and issued final clearance ten minutes before launch time. Communication with the ARTC was carried out through Calumet Air Force Station. Communication between the launch site, the GMD tracking station, and the Calumet Air Force Station was by the two-way radio. The Coast Guard telephone line was used as back-up.

The five Arcas rockets were launched during August and September, 1964, at intervals of about ten days. Figures 7 to 11 are photographs of typical activities at the Range. There were some delays due to cloudiness, as the temporary FAA waiver specified clear weather, and designated only certain days on which launchings could take place. There were a few delays due to surveillance problems, as it was necessary to coordinate the rocket schedule with the Air Force schedule of radar preventive maintenance, and with certain Air Force maximum training exercises. There was practically no lake traffic in the impact area.

While all rockets functioned perfectly, considerable difficulty was experienced with the payloads. The ranging signal usually disappeared at ejection of the payload from the rocket, which occurs at 125 seconds after launch, and on two flights there was complete loss of signal. Where ranging was available to ejection, and a consistent temperature signal was received, approximate altitudes were calculated from the known descent rate of the parachute. Results of a typical flight are given in Figure 12.

The parachute which is used to lower the payload after ejection is metallized to serve as a radar target. In all five cases, after the parachute had descended to altitudes less than 60,000 feet, it was picked up by Air Force radars, either at Calumet Air Force Station or K. I. Sawyer Air Force Base. In one case, it was possible to recover the payload, which landed near a state highway west of Munising, Michigan.

Following completion of the five Arcas launchings, the GMD and telescoping tower were returned to Ann Arbor, the launcher was shipped to the White Sands Missile Range for use on another project, and the Keweenaw Range was closed for the winter.

References

1. Keweenaw Point, Michigan, as a Possible Site for Firing Sounding Rockets. University of Michigan, College of Engineering, No. 0537-1-P. January 1963.

2. Upper Michigan Range. University of Michigan, Office of Research Administration. Preliminary Proposal. June 1963.

Appendix I

Brief Comparison of Climates
at Fort Churchill, Manitoba and Houghton, Michigan

Table I shows essential weather elements at Fort Churchill, in the Arctic, and Houghton, at the foot of the Keweenaw Peninsula in northern Michigan, during typical summer and winter months.

Maximum temperatures are comparable at both places, but the greater temperature range at Churchill results in lower average temperatures, and considerably lower minima. Wind velocities are generally higher at Fort Churchill than at Houghton, resulting in the higher average wind chill at Fort Churchill. A wind chill of 1200 is rated as bitterly cold, and it is estimated that wind chill values of 1600 to 1800 or higher will be encountered during the average winter at the Keweenaw Research Range. The writer has spent portions of several winters at Fort Churchill, and recalls few instances where the wind chill exceeded 2000 for appreciable intervals, although higher values do occur occasionally, and a maximum of 2490 has been recorded.

Snow conditions at the two places are comparable. The maximum depth of snow at Fort Churchill is not available. The total snowfall for the year was 43 inches, with 15 inches of this occurring in October and November, where temperatures above freezing are frequent, and considerable melting can occur. As a result, the maximum snow depth probably is comparable to that at Houghton, where the average annual snowfall is four times greater. Drifting is probably more severe at Churchill because of the higher wind velocities.

Two general conclusions are drawn from the above comparison:

1. The winter climate at the Keweenaw Research Range is somewhat less severe than at Fort Churchill. Therefore, if suitable equipment and facilities can be provided, year-round rocket operations at Keweenaw will present fewer problems than at Churchill, where many rockets are launched

every winter.

2. Although less extreme than at Fort Churchill, the winter climate at Keweenaw makes it a very good site for environmental tests. The average winter produces severe snow and wind chill conditions, yet it is easily and quickly accessible, by all forms of transportation, and the crossing of an international border is not involved.

Table I

1961 Temperatures and Winds at
Houghton, Michigan - Latitude 47° and
Fort Churchill, Manitoba - Latitude 58°

	January 1961		July 1961	
	Houghton	Churchill	Houghton	Churchill
Max. Temp.	+42° F	+39° F	+87° F	+96° F
Average Temp.	+12° F	-18° F	+58° F	+53° F
Min. Temp.	-12° F	-57° F	+42° F	+21° F
Average Wind Velocity	8.5 m.p.h.	15 m.p.h.	6 m.p.h.	12 m.p.h.
Max. Wind Velocity	35.0 m.p.h.	52 m.p.h.	30 m.p.h.	37 m.p.h.
Average Jan. Wind Chill	1250	1700 Kilogram calories/sq. meter/hr.		
Max. Depth of Snow	29 inches	---		
Total Snowfall, 1961	----	43 inches		

Average January Design Temperatures at Houghton, Michigan

1%* Design Temperature	-25° F
5	-15°
10	- 8°
20	0°
80	73°
90	77°
95	80°
99	84°

*Percent of time temperature is below given value.

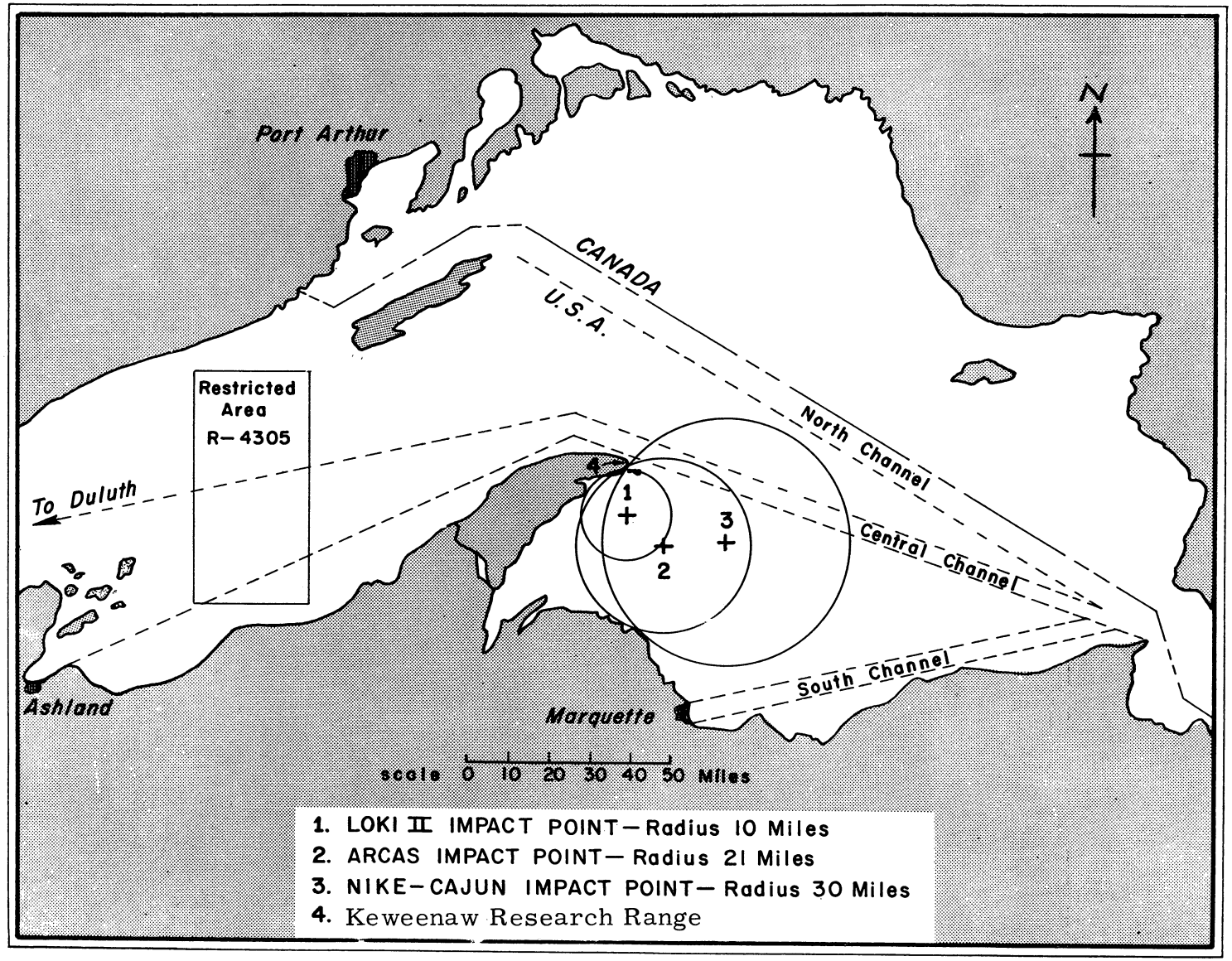

Fig. 1. Keweenaw Research Range, Lake Superior Ship Channels, and Rocket Impact Area

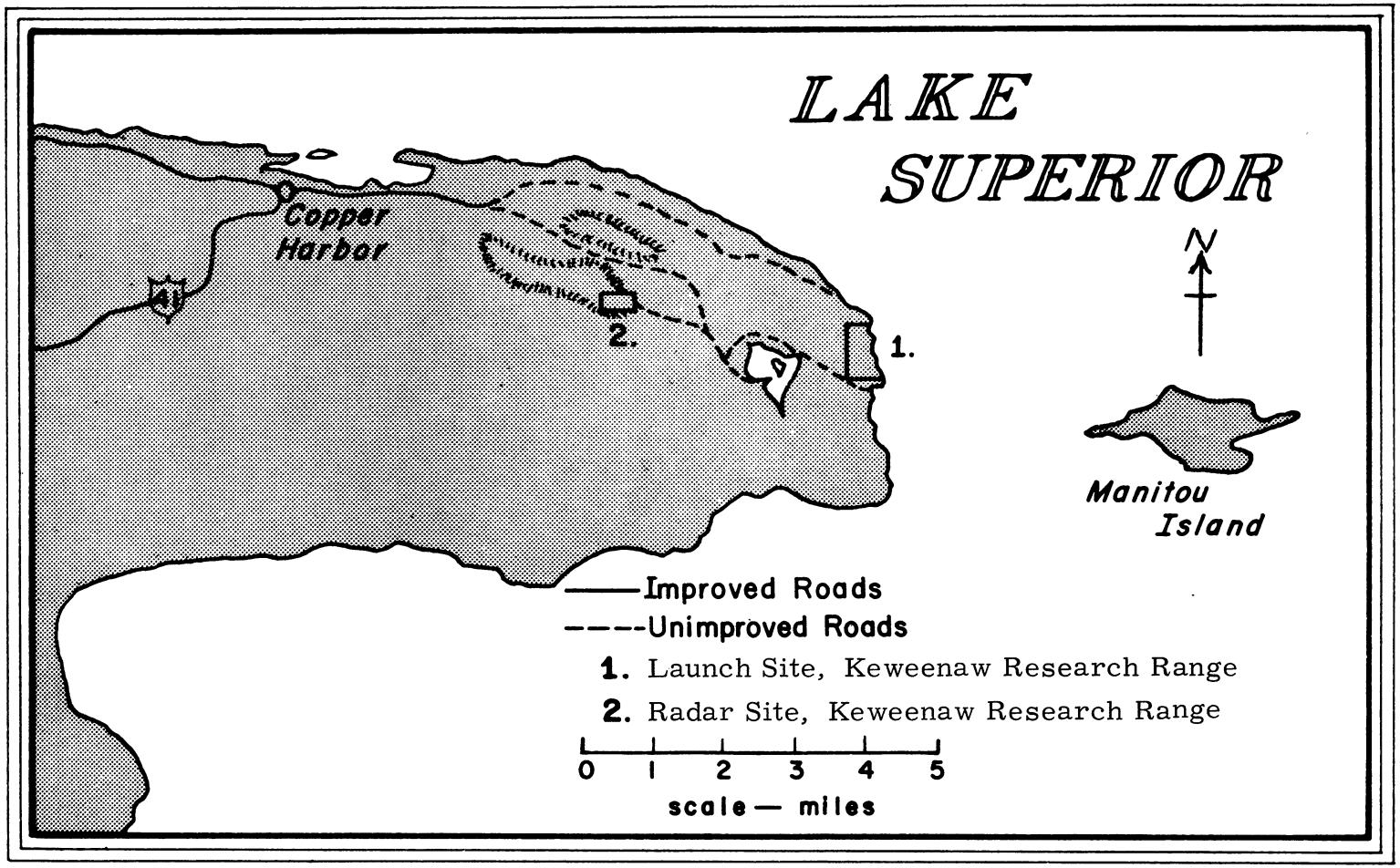

Fig. 2. East Portion of Keweenaw Peninsula, and Keweenaw Research Range

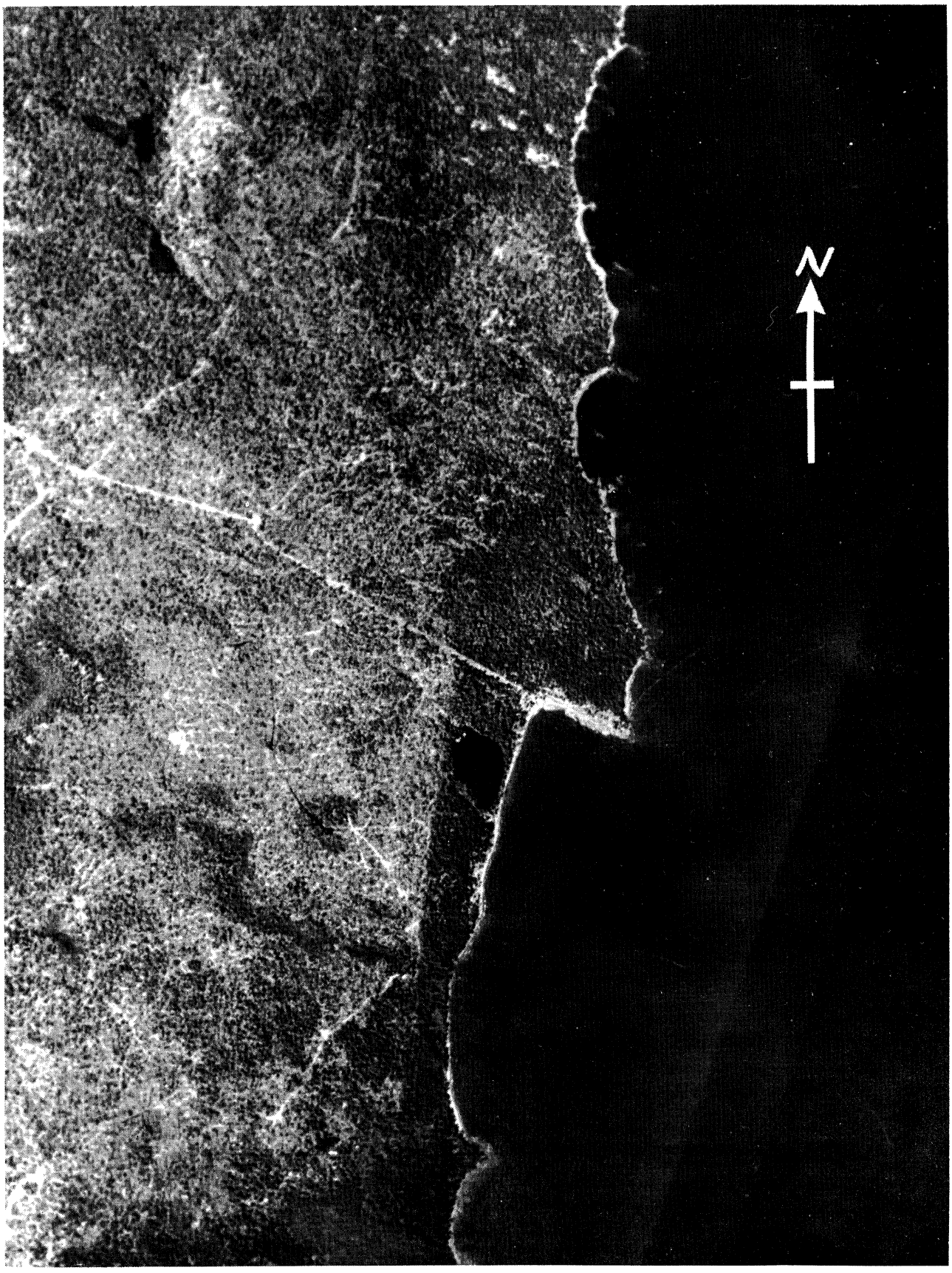

Fig. 3. Vertical Aerial Photograph of Proposed Launch Site

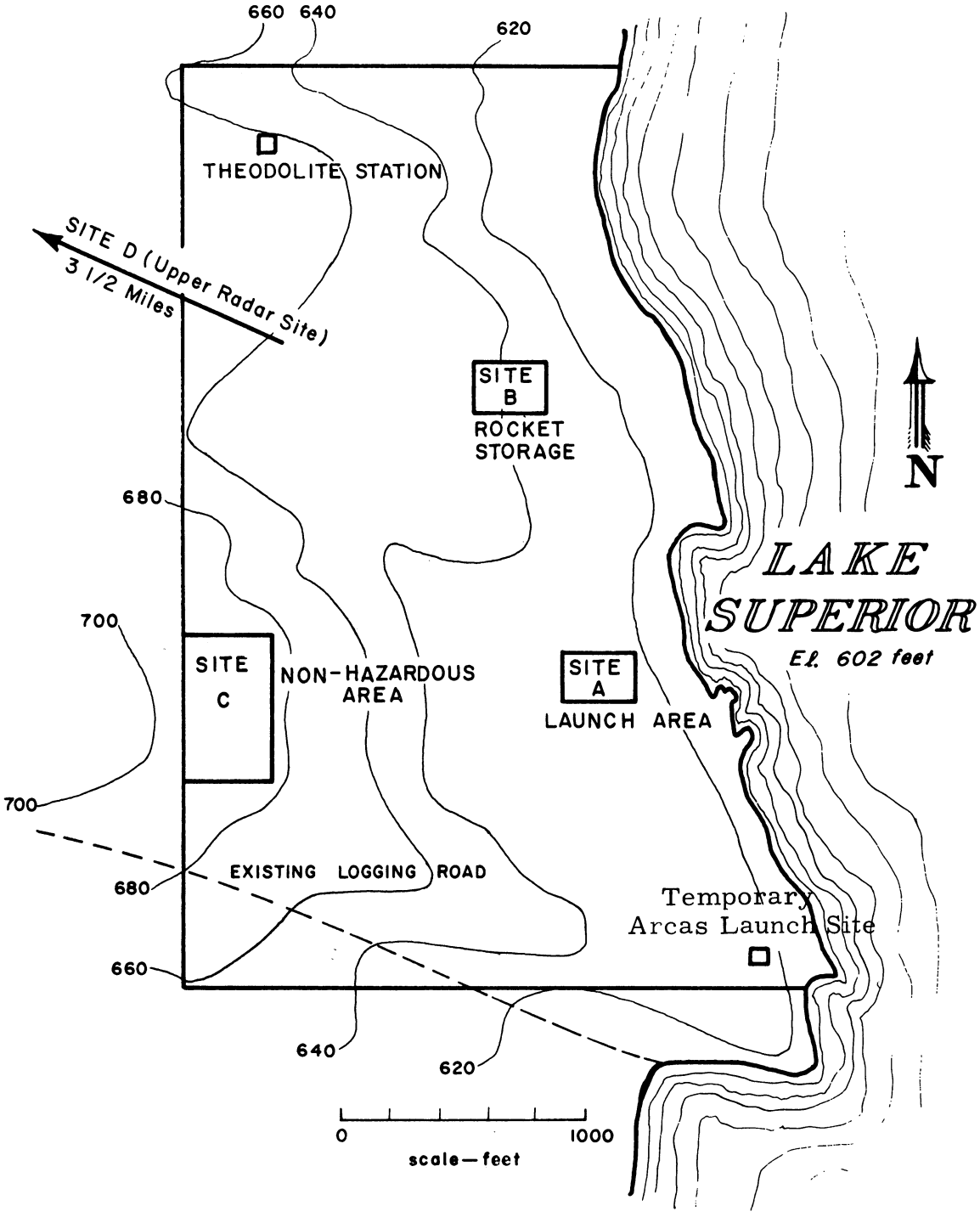

Fig. 4. Keweenaw Research Range with Proposed Site Locations

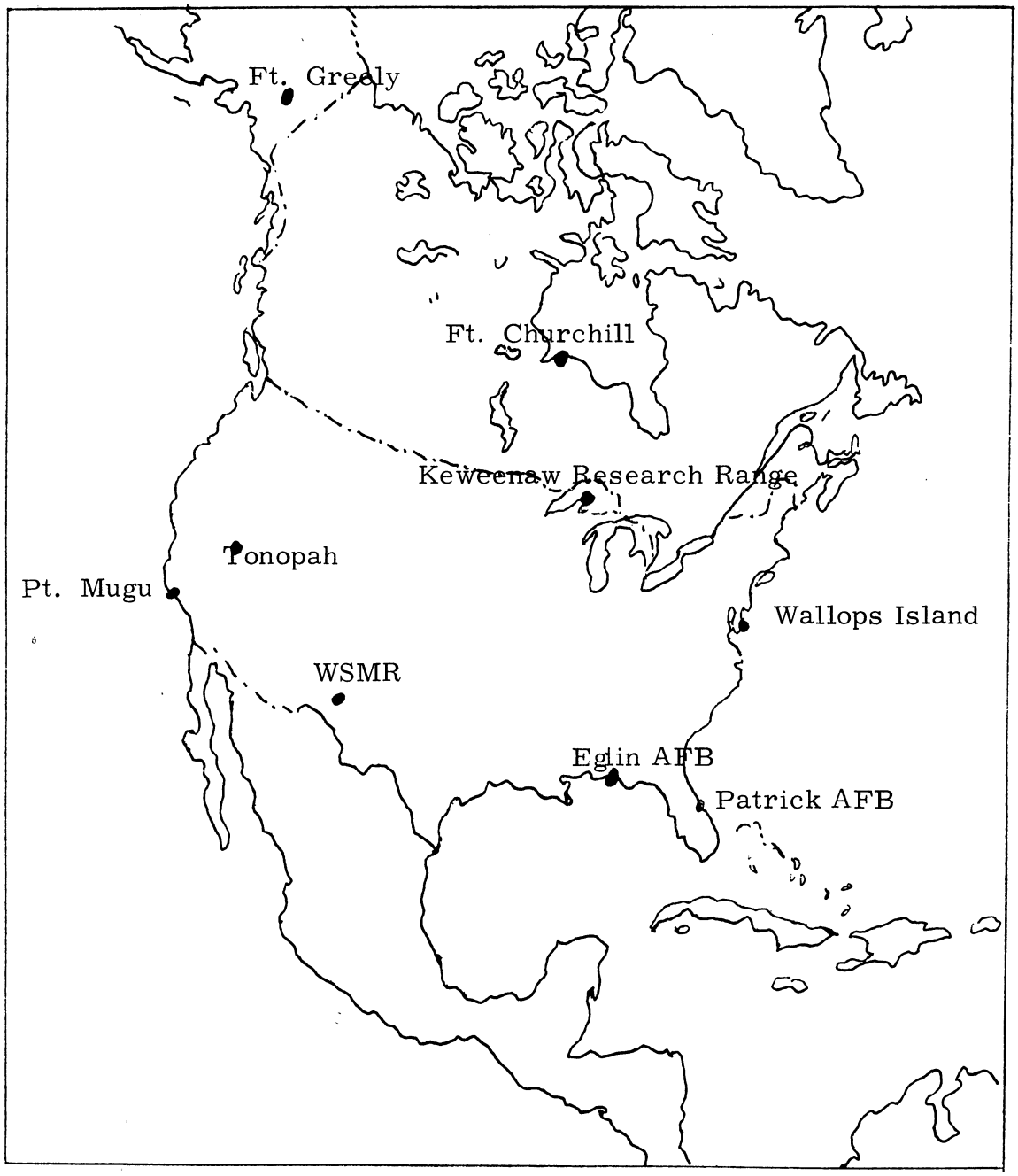

Fig. 5. Meteorological Rocket Network Stations

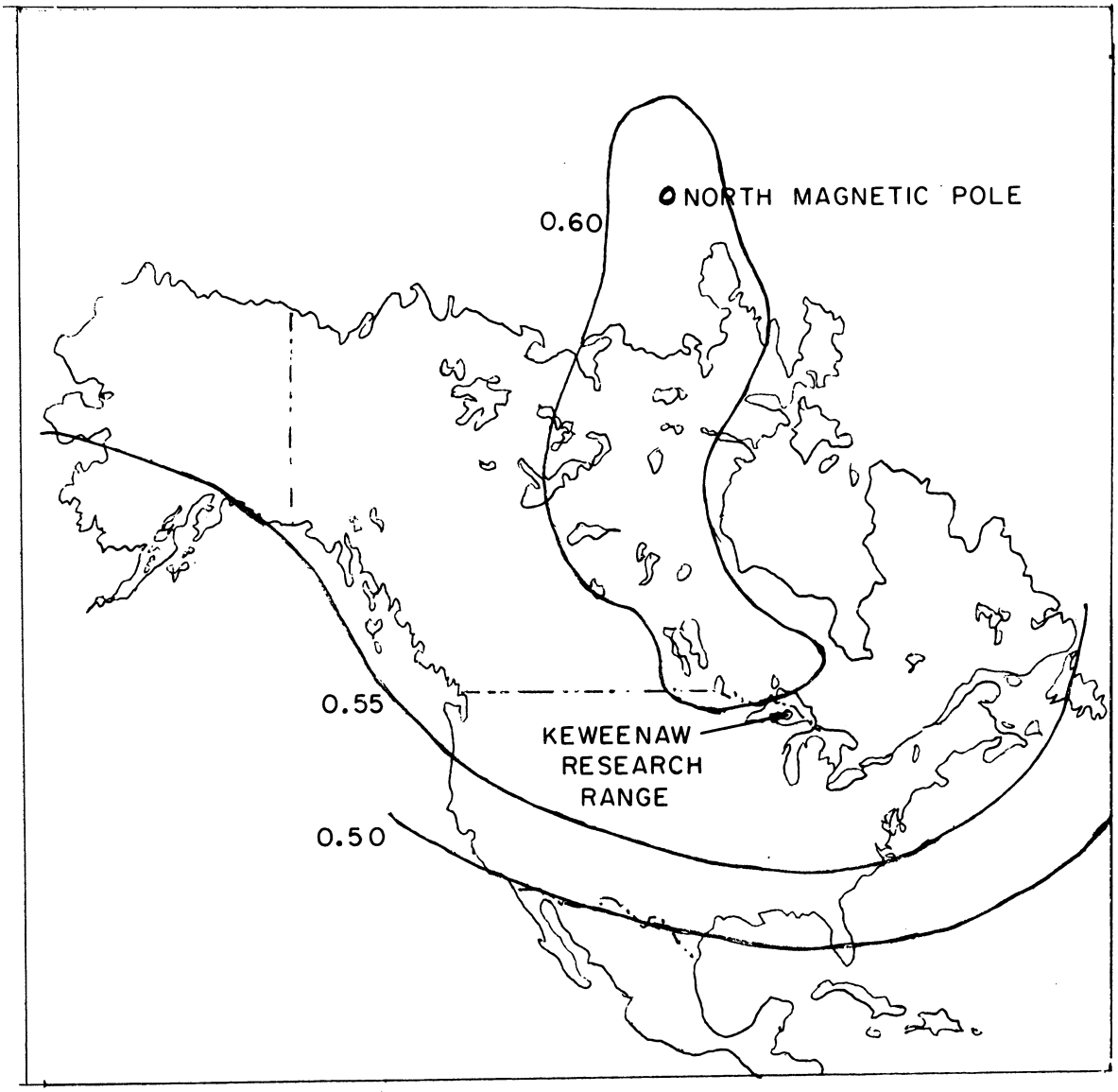

Fig. 6. Magnetic Field Intensity
(Oersteds)

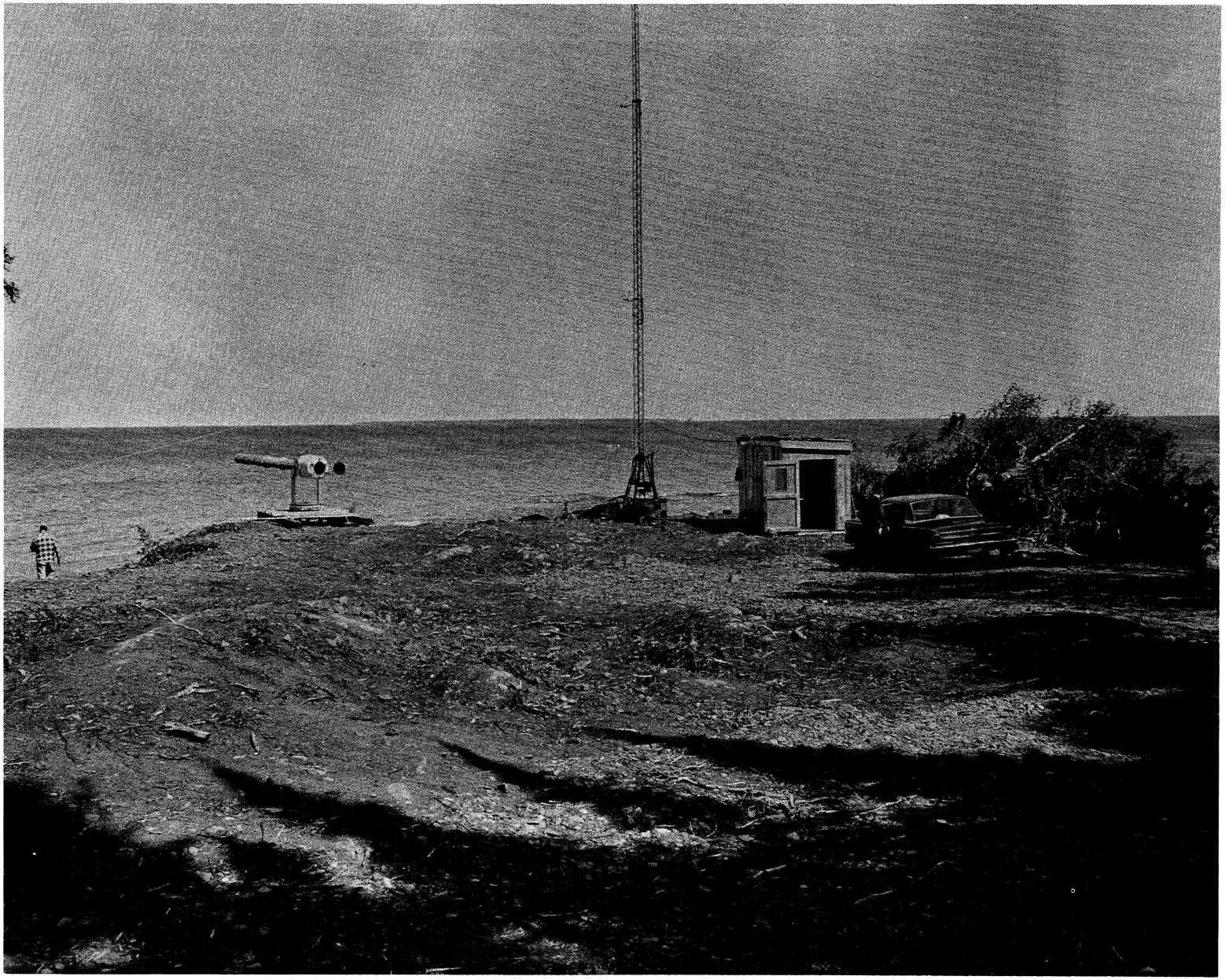

Fig. 7. Arcas Launch Site, Keweenaw Research Range

Fig. 8. Activities at the Tracking Site, Keweenaw Research Range

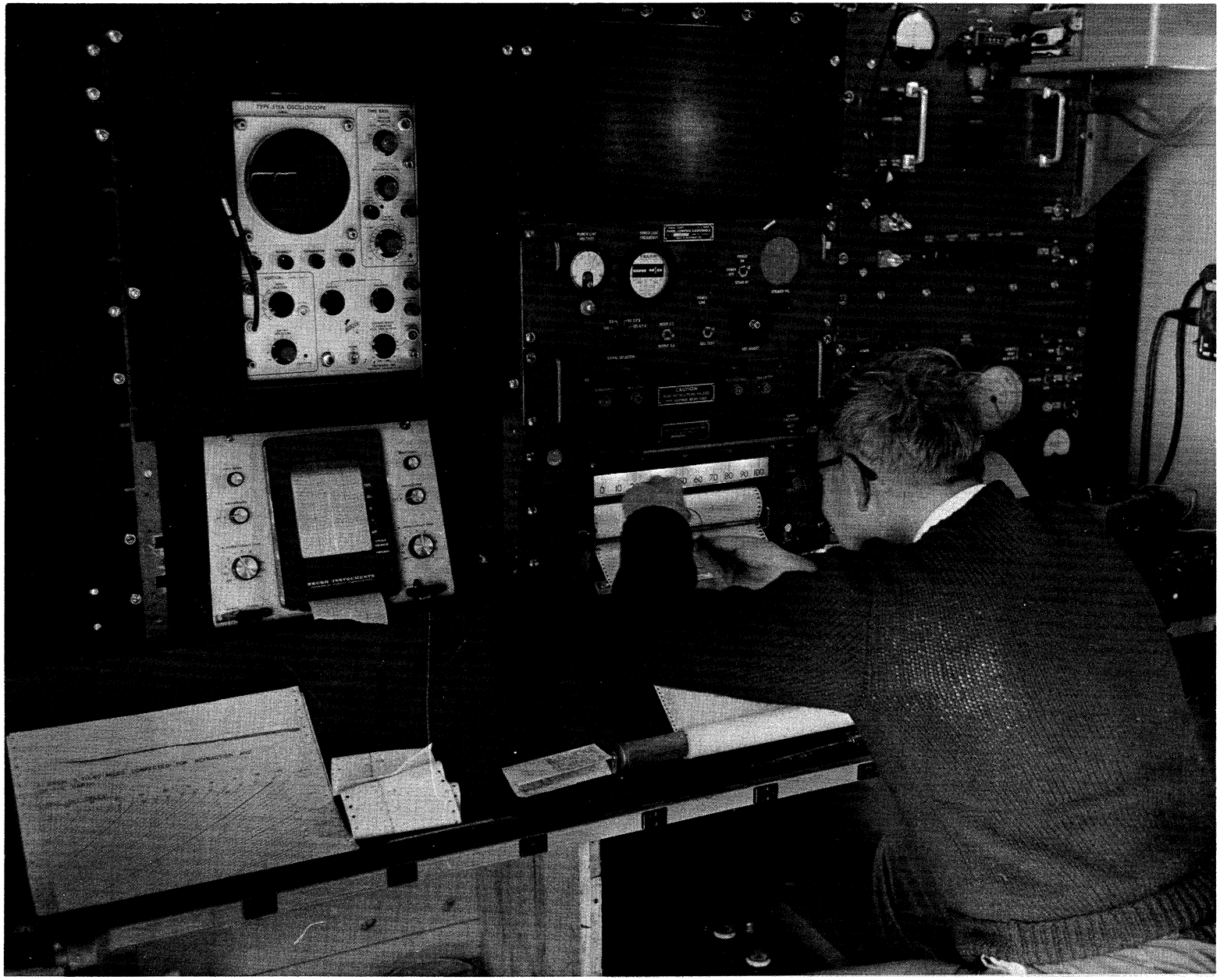

Fig. 9. Interior of Tracking Van at Keweenaw Research Range

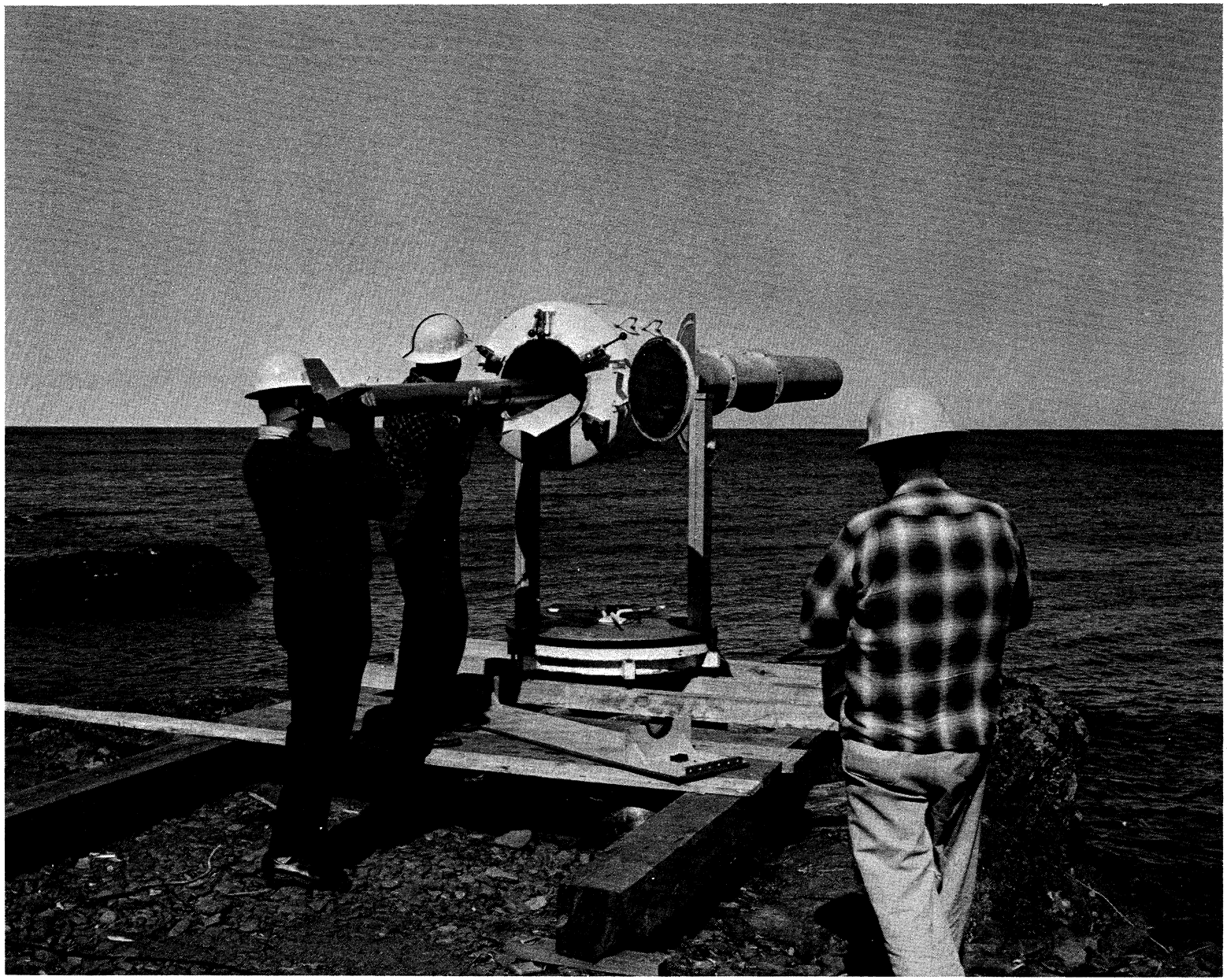

Fig. 10. Loading Arcas Rocket into Launcher at Keweenaw Research Range

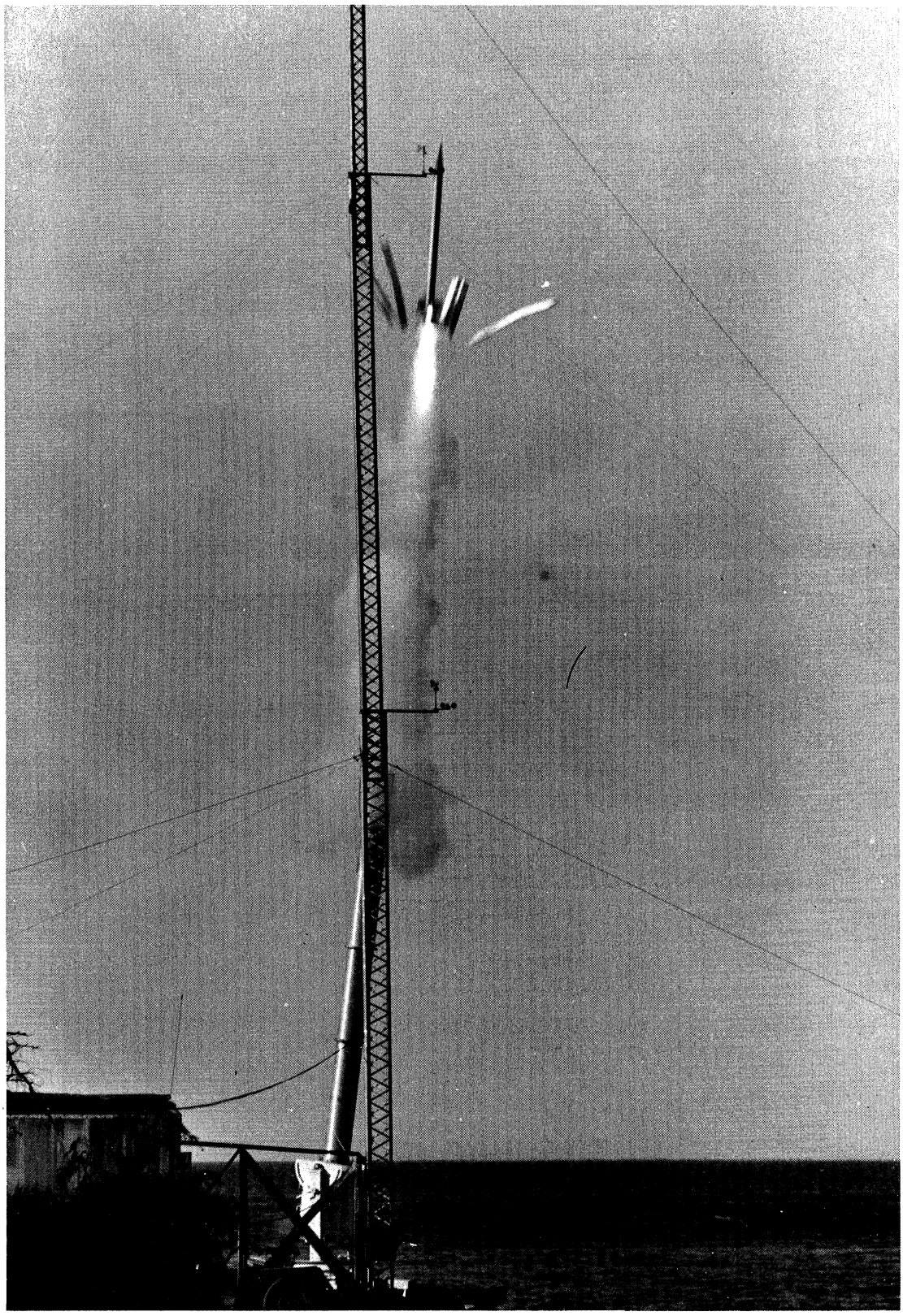

Fig. 11. Arcas Rocket Launching At Keweenaw Research Range

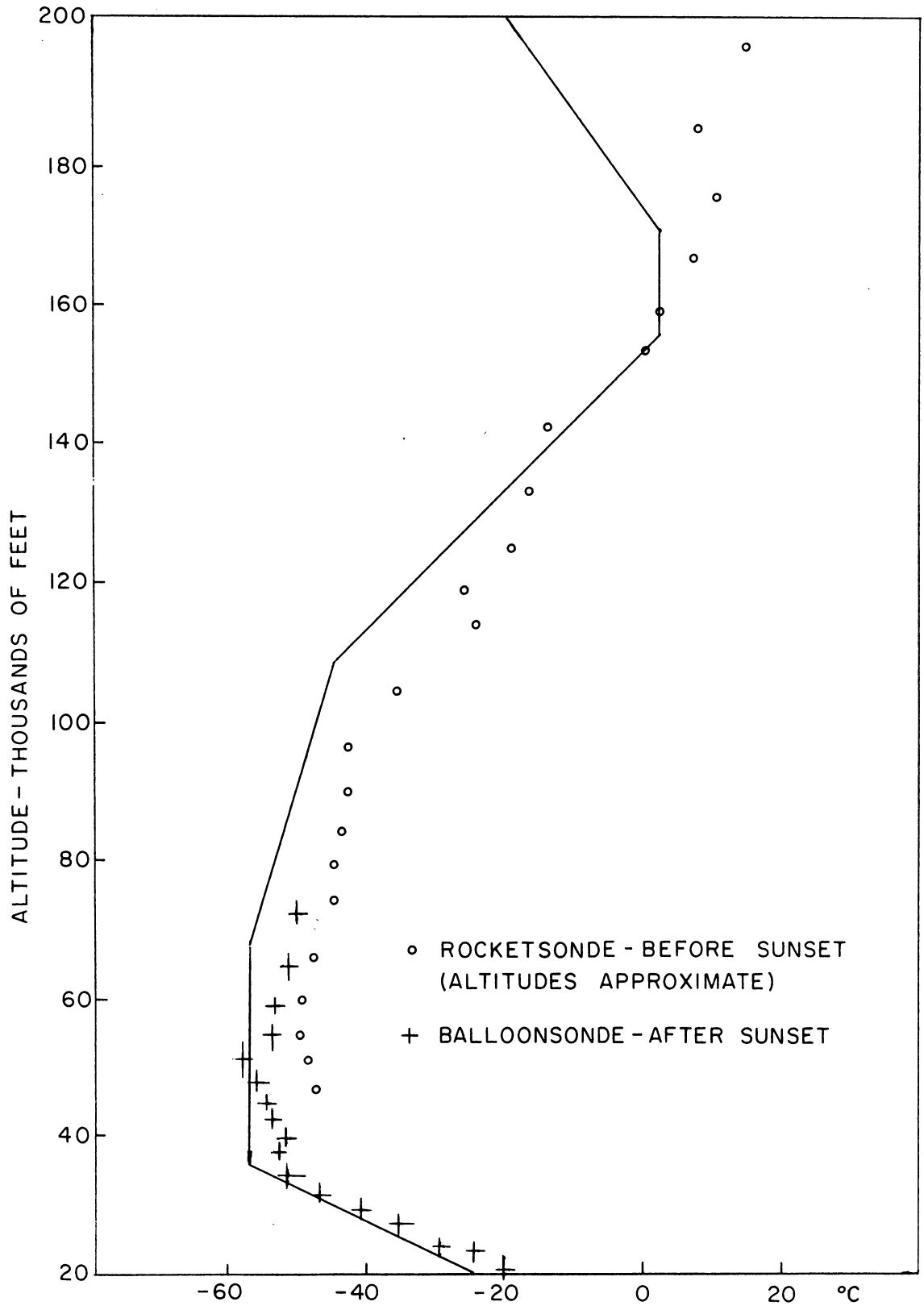

Fig. 12. Atmospheric Temperatures - Keweenaw Research Range - 14 August 1964