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WEBROCK Final Report

WEATHER BUOY ROCKET
FEASIBILITY STUDY

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Prepared for:	Office of Naval Research Physics Branch (Code 421) Washington, D.C. 20360
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Abstract

The work reported spans a period commencing 15 June 1965 through 15 February 1967. An experimental buoy was constructed, capable of launching sounding rockets automatically and remotely. Firings are controlled to assure that the quadrant elevation of each launch is never less than 80° despite the buoy motions. The rocket used during the tests (2.75" FFAR) is capable of projecting the rocketsonde payload to 22,500 feet. As the rocketsonde commences its parachuted descent, receivers aboard the buoy automatically acquire the signal and record the data. Although rocketsondes were not available during the period covered, simulation testing was performed by substituting balloon launched radiosondes (AN/AMT-11). Tests were conducted at the University of Michigan Keweenaw Rocket Range on Lake Superior and at the contractor's facility.

Acknowledgements

Space/Defense Corporation is indebted to the following organizations and individuals for the valuable assistance rendered during the course of the program:

1. Dr. H. Allan, University of Michigan, Ann Arbor.
2. Dr. E. Niemi, Michigan Technological University, Houghton, Michigan.
3. Commandant, 9th Coast Guard District, United States Coast Guard, Cleveland, Ohio.
4. Commanding Officer, 665th Radar Squadron (SAGE) (ADC), United States Air Force, Calumet, Michigan.
5. ONR Field Representative, Universityoof Minnesota, Minneapolis 14, Minnesota.
6. Calumet Division, Calumet and Hecla, Calumet, Michigan.

Other personnel participating, but not specifically noted here, were numerous and they contributed significantly to the success of the program. The manuscript preparation and proof-reading was undertaken by Mrs. Julia A. Bugera.

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I. INTRODUCTION

The research program has been directed toward proving the feasibility of launching meteorological rockets from remotely located ocean platforms. Ultimately an operational system would be capable of automatic operation over long periods with replenishment of projectiles and routine maintenance being scheduled to occur every six months. For purposes of identification the program was unofficially designated "Project WEBROCK," the term being an acronym for Weather Buoy-Rockets.

More specifically the program effort has been oriented to prove feasibility of the following hypothesis:

A. That sounding rockets stored aboard unmanned buoys, located in the oceans, can be launched regularly and automatically at preset intervals;

B. That the rocket head instrumentation will sense and transmit pressure, temperature and humidity information from the surrounding atmosphere during the parachuted descent; and

C. That the transmitted rocketsonde data can be received aboard the buoy, processed and retransmitted to a monitoring shore station automatically.

Proof of the first part (A) of the hypothesis was undertaken during the initial phase of the program. The second part (B) is presently being tested at the Naval Air Development Center, Johnsville, Pennsylvania. The third part (C) was investigated, in part, during the closing portions of the contract effort. All three parts of the hypothesis are vital to success of the overall program.

Initially the contract was for a period of nine months commencing 15 June 1965 through 15 March 1966. During this time feasibility was to be determined of parts (A) and (B) of the hypothesis. It was necessary to construct an experimental buoy in which to house a cluster of rockets and the supporting electronic equipment. Subsequently, during the first test period (November/December 1965), since instrumented rocket heads were not available, dummy heads were substituted. The program was due to conclude during March 1966 with demonstrable evidence of the feasibility of parts (A) and (B) of the hypothesis. Part (C) was to be the subject of a subsequent study phase.

However, due to the inconclusiveness of the preceding tests, the contract was extended and the effort revised so that parts (B) and (C) could be tested simultaneously. The program was completed 15 February 1967. Tests were undertaken during January 1967 but since the rocketheads were still under development, radiosondes had to be substituted for rocketsondes. Thus, the balloon launched radiosonde (AN/AMT-11c) was released adjacent to the launcher tubes and the receiving equipment aboard the buoy switched on.

An ancillary test was undertaken during the same period to determine the feasibility of a closed breech firing. Normally a rocket launcher tube is open at both ends and hence the rocket exhaust during firing cannot generate high pressures within the tube. However, since a closed breech design offers some important advantages, tests were carried out to determine feasibility and detrimental effects, if any, of this type of launch.

The automatic launch technique, as described in Section IIB, could not be adhered to because of Federal Aviation Agency (FAA) requirements. Despite the issuance of NOTAM's it was necessary to have positive control on the firing circuits at all times. Therefore, an additional circuit was introduced overriding the automatic sequencing, but not the mercury switches. A 1000 foot electric cable, supported by ¼ inch diameter steel mooring cable, ran from the shore to the buoy. By this method negative control of the test launches was exercised; that is, the rockets could be prevented from firing by onshore control. However, the rocket firing circuit would only energize (even with the onshore circuitry closed) when the mercury switches sensed a correct buoy attitude. There were further complications due to the continuing bad weather during the test period, but these are discussed in the Test Procedures, Section IIC.

II. DEVELOPMENT

A. Equipment Description

The present WEBROCK Buoy was not designed for U.S. Navy operational use; it was constructed only to demonstrate feasibility of the concept. Therefore costs have been minimized where possible to develop an adequate but utilitarian unit.

For the test rocket the 2.75" FFAR (Folding Fin Aircraft Rocket) was selected. Some of the reasons for this choice were: availability; reliability; and ease of handling. Also, the Navy has developed a rocketsonde primarily for use with this rocket motor. Presumably the rocketsonde will adapt to other types of sounding rocket.

A prototype buoy was constructed, see Figure 1, incorporating eight 55 gallon oil drums arranged around the periphery in an octagonal configuration. One additional drum is located at the center of the buoy with its long axis vertical. The central drum contains the instrumentation, batteries, and four rocket launching tubes. The buoy is assembled by use of eight aluminum beams radiating from a pair of circular plates situated below the central drum. One inch thick wood flooring partially covers the outer drums allowing the central drum to project through. The buoyancy of the floating platform is approximately 3750 pounds; the total weight of the structure including rockets is 1140 pounds. The assembled buoy has a 12 inch draft and appears to ride quite stably.

Equipment contained in the central drum for the first test series (November/December 1965) consisted of the following: a radial array of eight mercury (N.O.) switches connected in parallel to sense buoy attitude; a timer and selector switch to complete the firing circuit to a specific rocket at a given time. A pair of 12 volt automotive batteries coupled in parallel supply the power and a special skyward facing camera was installed to record buoy motions during the test launches. The mercury switch array allows the floating buoy to deviate only within prescribed limits during a rocket launch; if the buoy motion exceeds 10° the mercury switch array will deactivate the firing circuit.

Four open breech launch tubes are welded into the central drum and project through the drum at the ends. Both ends of the launch tube are taped to prevent moisture entering prior to firing and the central drum has a 12 inch diameter waterproof access panel bolted into the top. Contained in the drum are three tiers of equipment; the batteries at the bottom, the camera at the top with the lens projecting through a sealed aperture in the access panel, and the middle layer contains the mercury switches, timer and electronic gear.

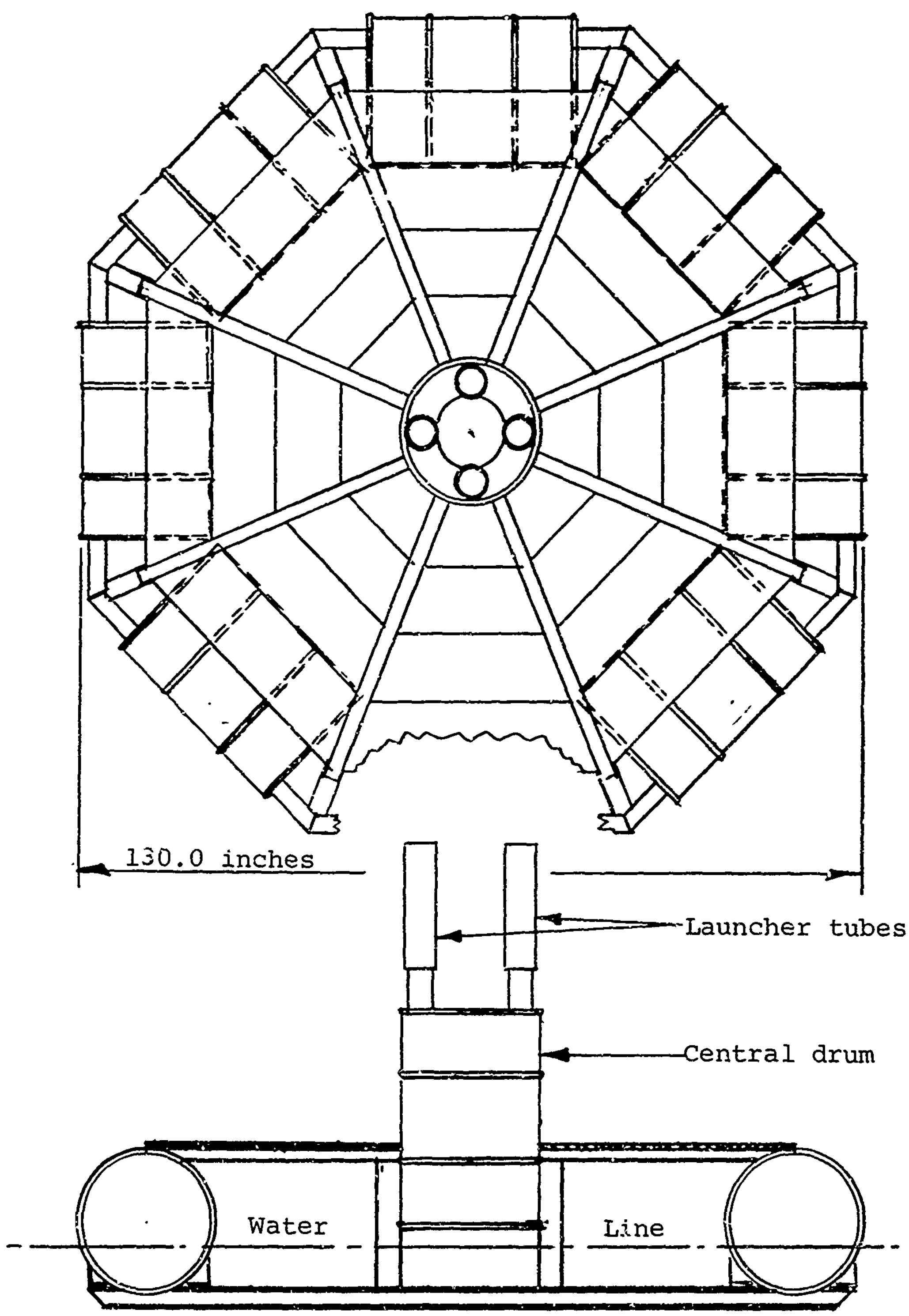

Figure 1. Prototype Buoy WEBROCK Program

B. Automatic Launch Technique

The basic equipment employed to energize the firing circuit for a selected projectile consists of a battery powered sequence timer, a thirty position rotary selector switch, and the attitude sensing mercury switches.

The timer has a single cam with three lobes spaced six hours apart in their operation. Each lobe controls a separate switching function. The first lobe energizes the stepping switch for a rocket selection; six hours later the second lobe energizes the firing circuit to that rocket. After ten minutes the lobe releases the switch deactivating the circuit. The final lobe reactivates the firing circuit via a separate switch six hours later. At that time the rocket either does or does not eject from the launch tube. In either event the lobe motion causes the circuit to be deactivated after ten minutes. The sequence recommences in twelve hours when the first lobe causes the rotary stepping switch to move on to the next contact point for a different rocket.

Lobes 2 and 3 also activate the skyward viewing camera for a sixty second period. The camera has a pulsing unit that causes an exposure rate of one frame per second. Figure 2 shows the circuitry in detail. The rotary stepping switch can accommodate up to thirty projectiles. The original intent was to fire two rockets and then allow the equipment to simulate rocket launches for twenty-six days during which time the system would be exposed to the environment. On the twenty-ninth and thirtieth days two more rockets were to be launched.

The 1000 foot shore line is extraneous to the needs of the circuitry for an automatic launch, therefore the connecting lines have been in dotted form rather than solid.

C. Rocketsonde Operational Technique

The rocketsonde development forms no part of the study and is referenced here, briefly, only for purposes of continuity.

The rocketsonde instrumented package, as shown in Figure 3, monitors the temperature, humidity and pressure of the surrounding atmosphere during descent. At peak altitude the instrument package is ejected from the rocket head and transmission commences while an attached parachute controls the descent

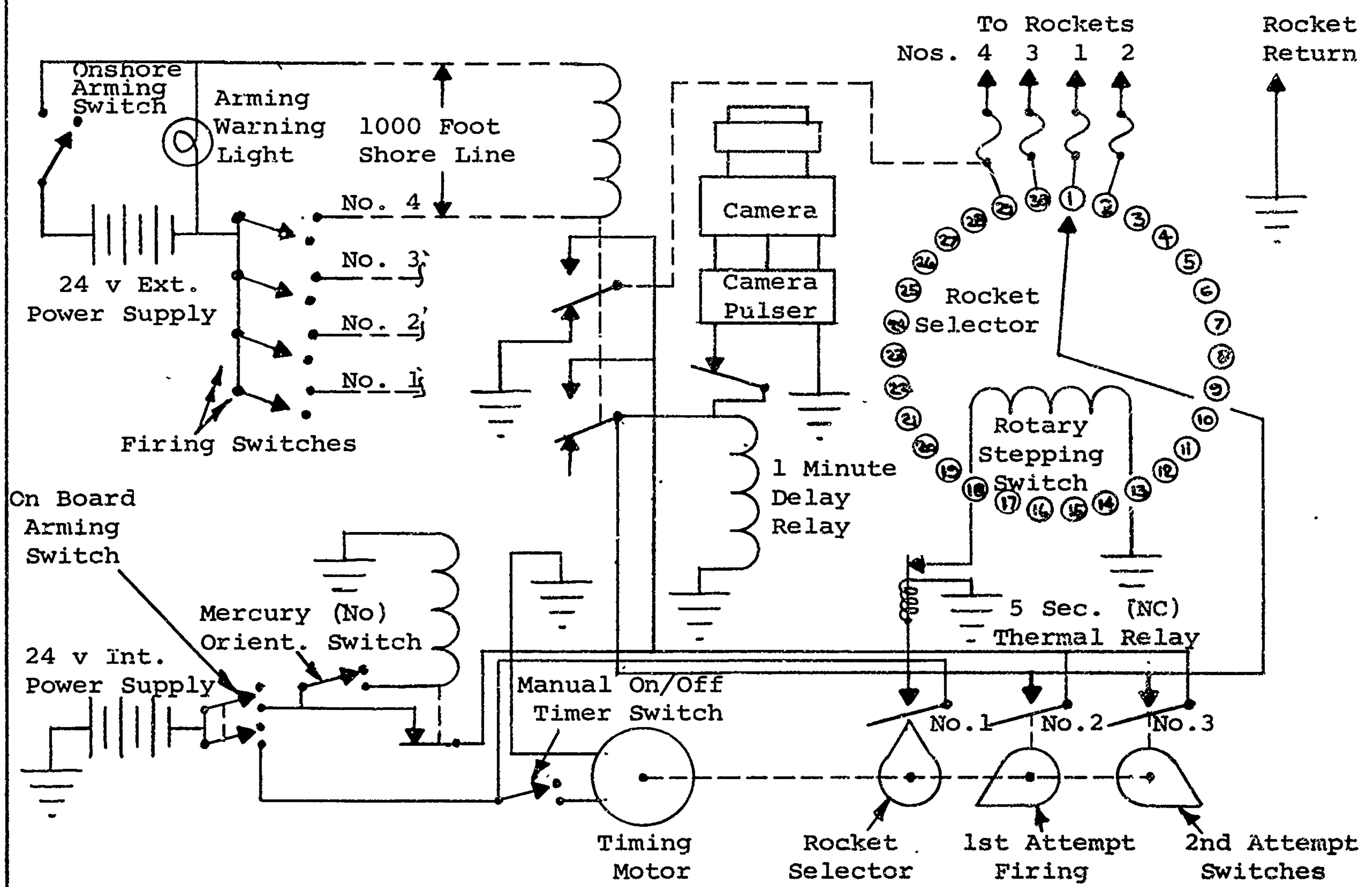

Figure 2. Automatic Sequencing Circuitry with FAA Hard-Line Circuitry

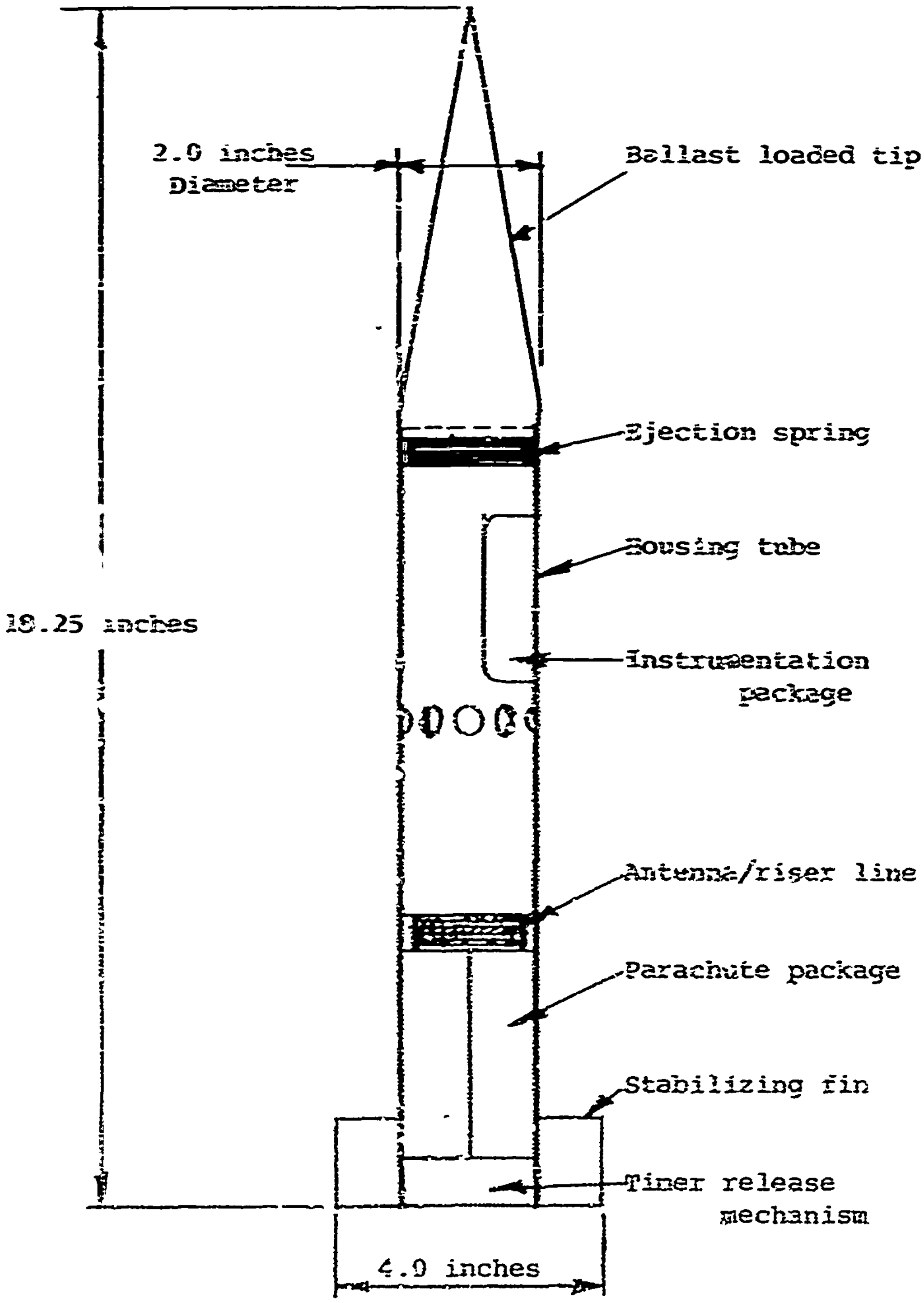

Figure 3. NADC Instrumented Meteorological Rocket Head

rate. The rocketsonde operates on a nominal frequency of 403 mc. and contains an audio oscillator operating on a range of 25 to 225 cycles per second. A mechanically operated commutator continually monitors the three sensors (pressure, temperature and humidity); interspersed with the sensors are three reference resistors. The rotation of the commutator is held to between 2 and 3 rpm and the resulting transmission pattern is as shown:

1. Reference signal..................53 $\pm$3 cps
2. Pressure sensing measurement......5 to 1060 mb
3. Reference signal..................175 $\pm$9 cps
4. Temperature sensing measurement...+50°C to -60°C
5. Reference signal..................110 $\pm$5.5 cps
6. Humidity sensing measurement......10% to 95% R.H.

The proposed rocketsonde is currently under development by the Naval Air Development Center, Johnsville, Pennsylvania. The NADC rocketsonde is the only unit, currently under development, capable of operating in the desired manner and suitable for integration with the WEBROCK concept.

D. Receiving and Recording Apparatus

For the initial study (June 1965-March 1966) the equipment installed on the buoy was sufficient to prove feasibility of Hypothesis "A". Following the contract extension (March 1966-February 1967) it became necessary to supplement the electronics contained in the central drum. To validate Hypothesis "C" in its entirety was considered impractical and uneconomic at the time. Therefore it was decided to concentrate on receiving the transmitted rocketsonde signals and recording the information aboard the buoy. The justification for this approach was based on the premise that eventually the system will be integrated with the NOMAD buoy. The latter is already equipped with a powerful transmitter and is considered adequate for retransmission of the rocketsonde signals to a monitoring shore station. Figure 4 indicates the modified circuitry.

The skyward facing camera was removed from the central drum and a receiving unit plus a small portable tape-recorder substituted. The opening in the drum top (for the camera lens) was sealed off and an antenna mount was welded to, and slightly above, No. 4 Rocket Launch Tube in such a manner as to ensure water tightness of the installation.

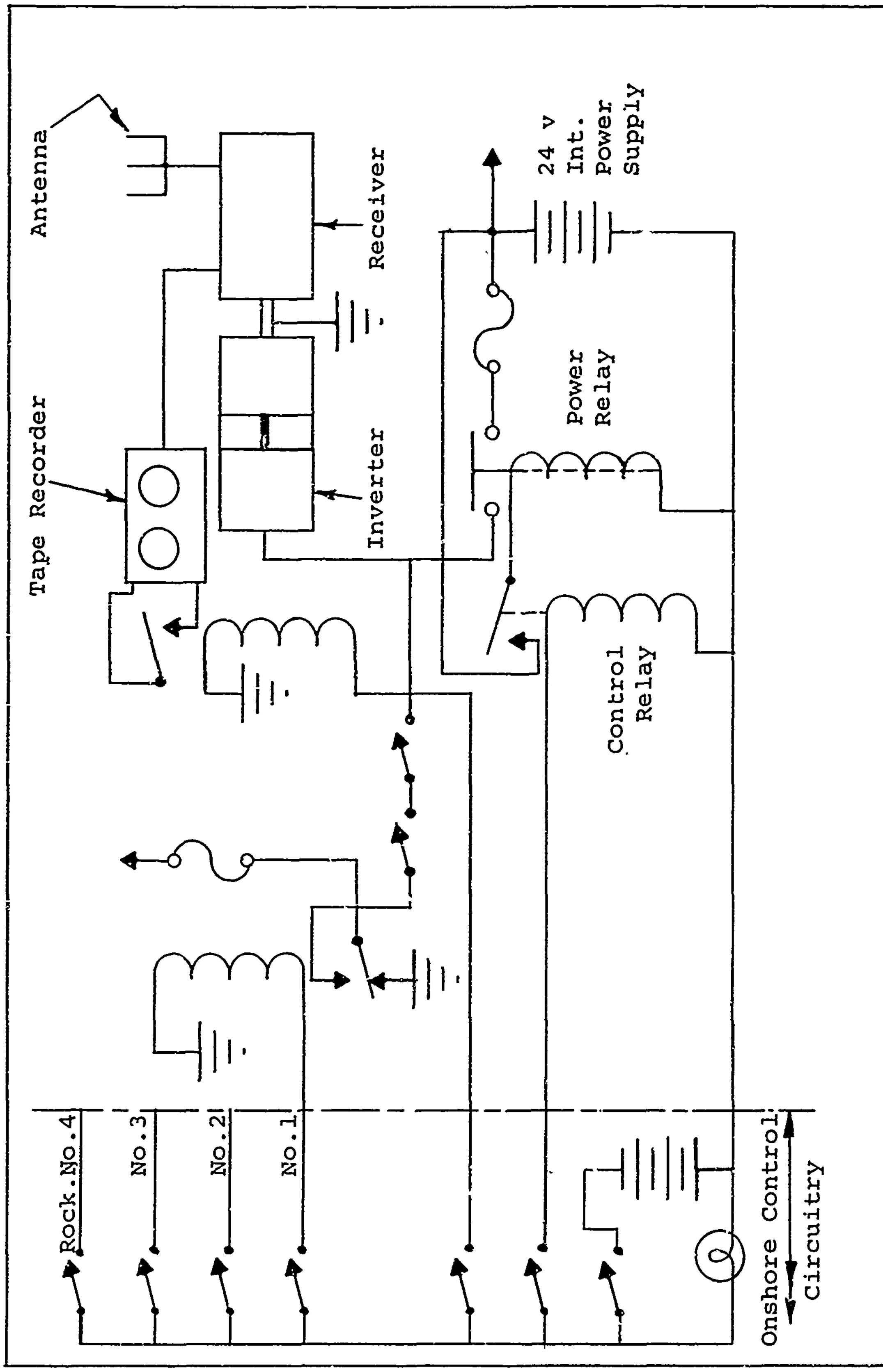

Figure 4. Modified Circuitry Showing the Additional Receiving/Recording Equipment

1. Receiver Installation

Rather than incur the expense of designing a completely automatic receiver, it was decided to investigate the availability of suitable equipment. After examining several alternatives it became apparent that the most suitable was the receiving unit incorporated in the AMQ-19 system. This system, designed for the USAF under contract No. AF30(635)-35029, is used for airborne weather surveys, and it operates in conjunction with the AN/AMT-13 radiosonde. This radiosonde operates on a nominal frequency of 403 mc. and contains an audio oscillator with a range of 2450 to 6050 cycles per second and pulse widths of 14 to 18 microseconds. It was necessary to adapt the unit to operate with an AN/AMT-11( ) series radiosonde, which for all practical purposes is very similar in characteristics to the rocketsonde ultimately to be used. The AN/AMT-11( ) radiosonde produces a 403 mc. signal and is modulated with a repetition frequency of 8 to 225 cycles per second.

The AMQ-19 receiver automatically and repetitiously scans between 400 to 406 mc. until a signal is detected. Upon acquisition the receiver "locks on" to the incoming signal. It was necessary to modify the low pulse repetition rate injection circuit so that the unit would accept (not reject) the low audio frequencies emitted by the AN/AMT-11( ) radiosonde. Some relatively simple changes to the circuits were made and it was possible to track audio frequencies down to 25 cps. Below that value, however, the receiver tends to reject and recommence scanning. To effect the complete acceptance of all audio frequencies (down to 8 cps) would have entailed a major modification. This was considered unnecessary since, in actuality, the minimum audio frequency of the rocketsonde is 25 cps.

The power input requirement for the receiver is 115 V. single phase 400 cps. It was therefore necessary to install an inverter for conversion of the 24 vdc power supply. Nominally the receiver/inverter equipment may be switched on approximately fifteen seconds before operation if the ambient temperature is not too low. (For aircraft operation, where presumably the ambient temperature can be -60° F, the handbook recommends a thirty minute warm-up period.)

Due to the heavy demand on the batteries when the inverter is in operation it was decided to have onshore control.

Thus, if FAA requirements dictate a last minute delay in launching, the inverter can be switched off.

2. Recorder

The tape recorder is a small self-contained battery powered unit capable of accepting 5.0 inch reels. One mil magnetic tape at a recording speed of 3.75 inches per second allows a recording time of approximately 80 minutes per side. An onshore control for the tape recorder was designed into the system to conserve power and tape. Figure 5 indicates the onshore control panel schematic.

E. Closed Breech Launcher

As an independent study it was decided to determine the feasibility of launching a 2.75" FFAR from a tube with the aft end sealed. Since this (apparently) had never been attempted, it was not known what the result would be.

Primarily it was unknown if the confined heat at the base of the rocket motor would damage the folding fins prior to ejecting from the launch tube. The reason for considering a closed breech launch, rather than the conventional open tube, was the possibility of damaging surrounding equipment if the rocket tubes were installed in a confined space. Even if the rocket blast did not cause damage, after ejection the open tube could allow water to enter and this might present worse problems. The closed breech configuration is shown in Figure 6. The outer tube was primarily a safety precaution in case the inner tube burst. Analysis indicated the inner tube would be subjected to a tensile stress of 30 kips. In actuality the outer tube proved to be unnecessary.

III. EXPERIMENTAL PROCEDURES

A. Te: . Site

The Keweenaw Rocket Research Range is located at the eastern tip of the Keweenaw Peninsula in Upper Michigan. The site is immediately adjacent to Lake Superior and sufficiently remote (See Figure 7) from populated areas to permit hazardous operations. By road it is approximately 550 miles from Space/Defense Laboratories.

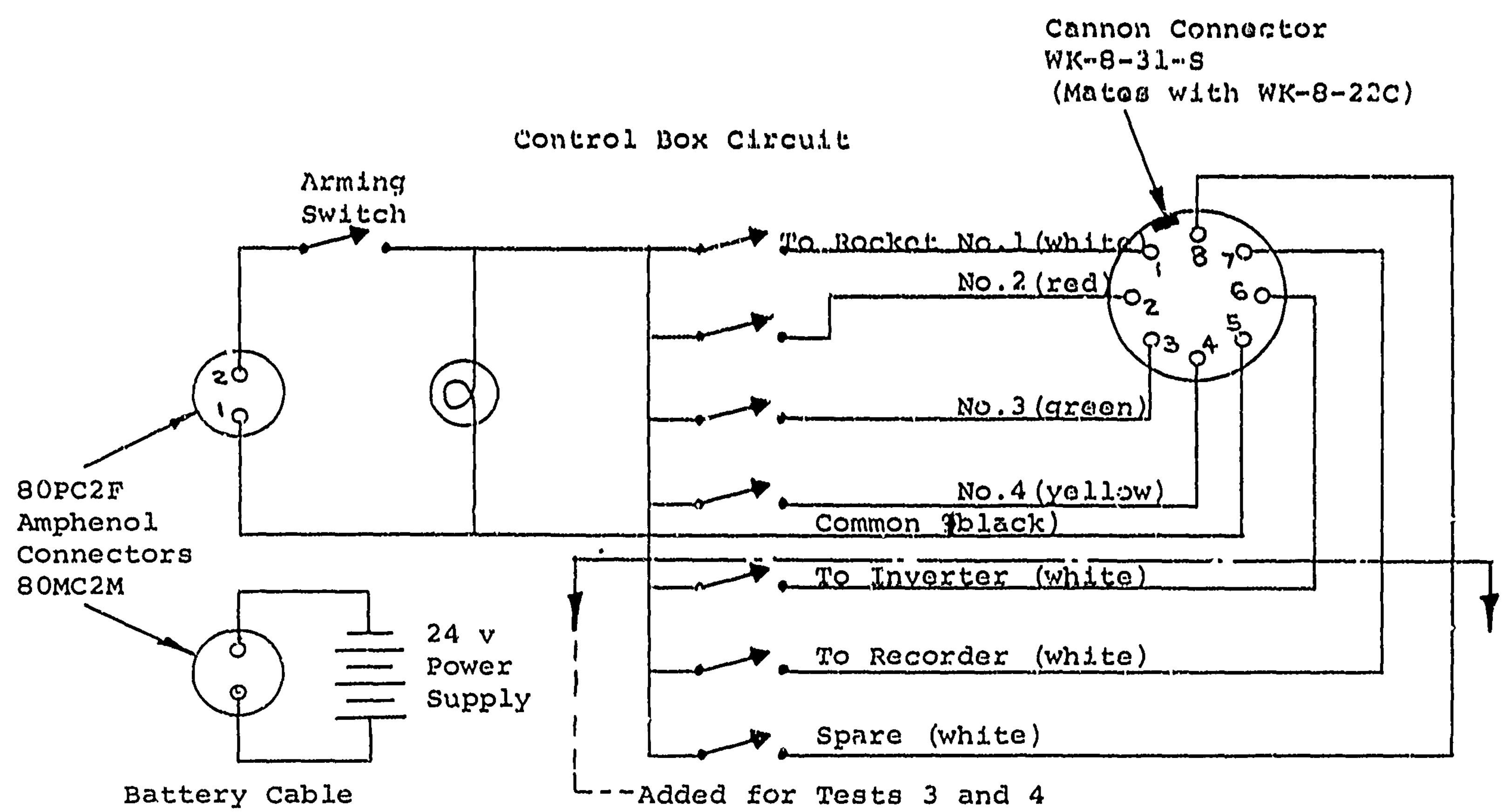

Figure 5. Onshore Control Panel Circuitry

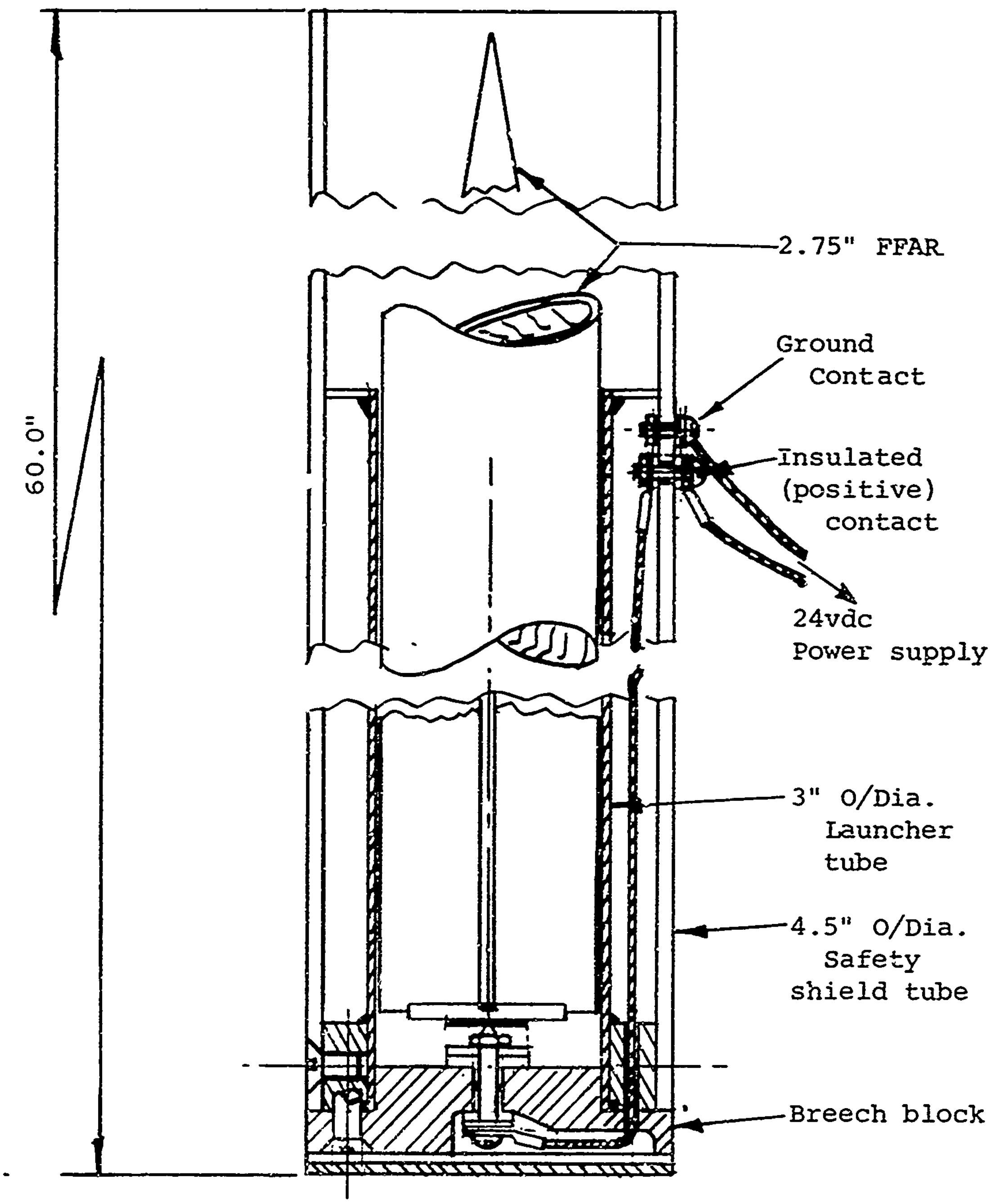

Figure 6. Closed Breech Launcher Tube

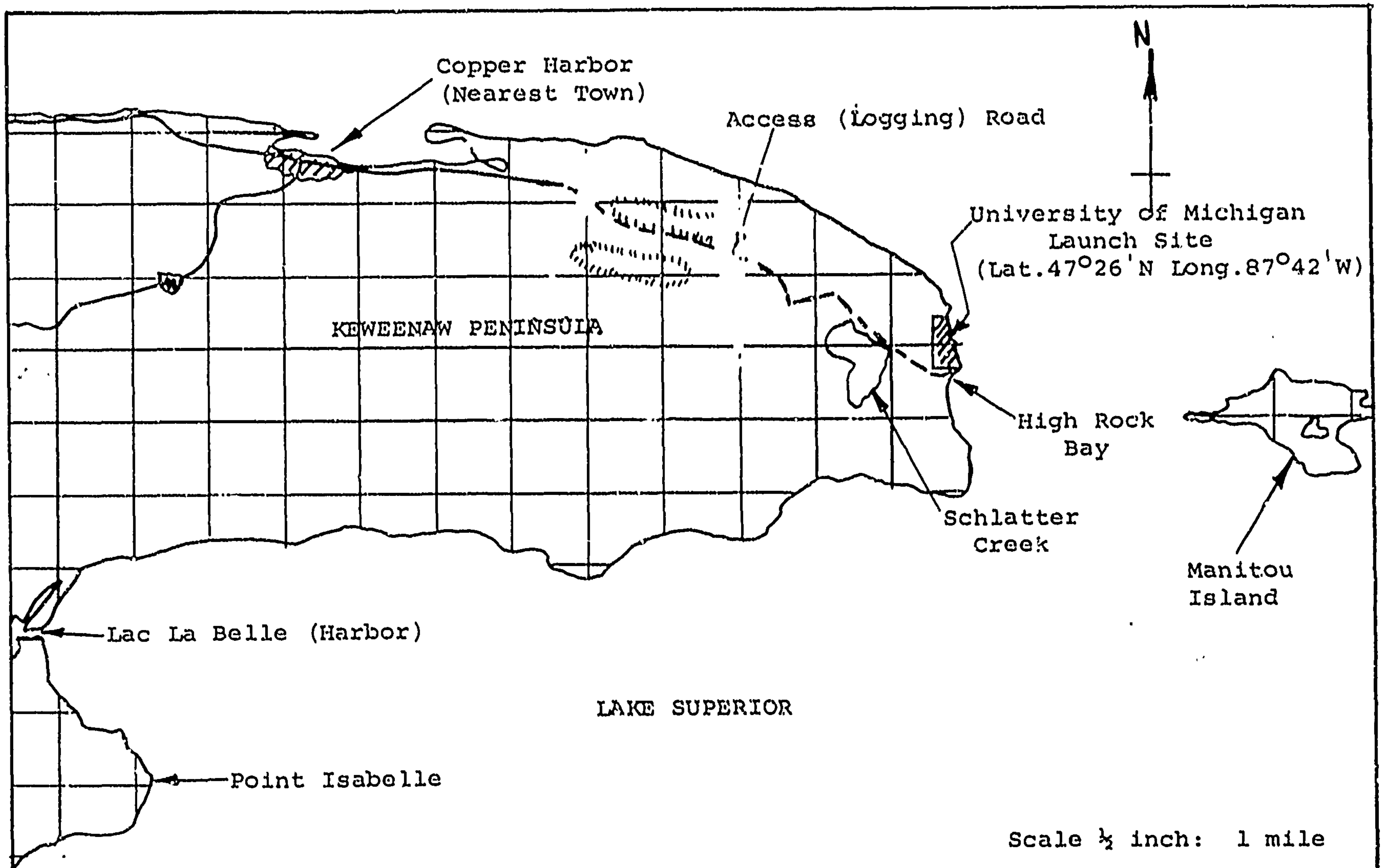

Figure 7. Physical Location of Keweenaw Research Range

The Range is owned and operated by the University of Michigan with assistance available from Michigan Technological University. There are no permanent installations at the range and no utilities although plans have been prepared for future development. The site is accessible by traversing six miles of logging road.

Air surveillance is accomplished with the assistance of the 665th Radar Squadron of the Air Defense Command which is located at the nearby Calumet Air Force Station.

Twenty-four hour advance notice of each launching was furnished to the Minneapolis Air Route Traffic control (ARTC) Center through the FAA Flight Service Station at Houghton Airport, Michigan. The Center then monitored the countdown and issued a final clearance ten minutes before launch time. Communication with ARTC was relayed through Calumet Air Force Station. Communication between the launch site and Calumet Air Force Station was by two-way radio. On subsequent tests it was found to be more convenient to use a portable telephone and tap into the Coast Guard pole-line. The pole-line carries a single pair of wires to the Coast Guard Station on Manitou Island (see Figure 7) and is usually available upon request.

B. Rocket Loading Preparations

Prior to inserting the rockets in the launcher tubes of the central drum, certain checks are undertaken. A dummy rocket is placed successively in each of the four tubes and the firing circuits tested against a small test lamp. If the power is insufficient the lamp will not light; conversely, excessive power would destroy the fuzed circuits. With the firing circuits deactivated the system is again checked to ensure no power at the contacts. A master safety switch, water-tight, mounted on the outside of the central drum, and coupled directly to the batteries, must be on before the firing circuitry can be energized.

The preceding checks are made with the safety switch on; the circuitry is again tested with the master switch locked-off. For this test the contacts should not energize despite the activation of the firing circuit switches. After verification of the circuitry, and with the master switch still in the locked-off position, the rocket motors together with rocket heads may be inserted in the launcher tubes.

In retrospect, it would have proven advantageous to have checked to determine that the rocket motor was seated firmly on the positive contact at the base of the launcher tube. This check is performed by use of a circuit igniter tester and is a special piece of equipment expressly designed for that purpose. However, it was not possible to obtain this test apparatus prior to the first test firings.

After the rockets were installed, the open end of the launcher tubes were sealed using thin polyethylene film and adhesive tape. Finally, the master switch is unlocked, switched-on, and relocked in that position.

C. Test Histories

In those tests where it was necessary to launch rockets, FAA regulations dictated the use of a hardline control to, when necessary, prevent rocket ignition. Thus, as previously described, an electric cable ran from the buoy to the shore.

The time mechanism was set to activate the rocket selector switch circuit at 04.30 hours and the initial launch time was scheduled six hours later at 10.30 hours. The same circuit would reactivate six hours later at 16.30 hours allowing the rocket motor (if still in the launcher tube) a second attempt.

As a safeguard it was decided to incorporate four onshore switches to bypass the timer mechanism. Since FAA regulations stated cloud cover could not exceed 50% for a launch, it was considered somewhat restrictive to limit the potential launch time to ten minutes in the morning and afternoon. In the event that nominal conditions prevailed at some time other than the selected firing periods a launch could still be attempted. Therefore, referring to Figure 2, three additional firing switches were included in the buoy to shore cable and jumper wires installed in the central drum to bypass the timer and selector switch. The complete series of tests undertaken are as shown in Table I. The first test series were those tests undertaken for the initial contract phase (June 1965 to March 1966) and the second test series resulted from the contract extension. The account of the first test (Test 1) is described in some detail; the remaining tests are covered more selectively relating only the nonrepetitious facts for each test.

TABLE I. Test Program and Schedule

	Test No.	Purpose	Location and Period	Results	Remarks
1st Test Series	1	To Validate Hypothesis "A" and Verify Hypothesis "B"	Lake Superior (Keweenaw Rocket Range) Nov.-Dec. 1965	Hypothesis A Satisfactory Hypothesis B Unproven	Rocketsondes Unavailable
	2	Duration Test of the Automatic Sequencing Apparatus	S/D Laboratories Dec. 65 thru Apr. 66	Equipment Performed Reliably	Time Drift From Nominal Setting 2 Seconds Per Day Tested Over 120 Days
2nd Test Series	3	To Validate Hypothesis "C" and Verify Hypothesis "B"	Lake Superior	Unproven (See Test No.4)	Test Cancelled Rocketsondes Unavailable
	3A	To Determine The Practicality of acClosed-Breech Launch for the 2.75" FFAR	Keweenaw Rocket Range Nov. 66	Successful	Closed Breech Firing Indicates No Detrimental Effects on Rocket (or Tube)
	4	To Test The Receiver/Record. Equipment Under Simulated Launch Conditions	S/D Laboratories Jan. 67	Satisfactory	Equipment Tested Using Balloon Launched Radiosondes

1. Test 1

It was initially planned to perform the test during late summer-early fall of 1965 before the onset of winter, since the logging road to the launch site is not kept open. A University of Michigan truck was loaned to Space/Defense Corporation to transport the equipment including the dismantled buoy to the launch site at Keweenaw. The buoy was to be assembled at the site, slid into the water and anchored in High Rock Bay about 300 feet offshore.

The truck, which is equipped with electric heaters, would serve as launch headquarters, containing the telemetry receivers and other ancillary equipment. A communications van (four-wheel drive carryall) supplied by the ONR Field Office, Minneapolis, would supply the two-way radio link to Calumet Air Force Station.

An FAA waiver was issued by Minneapolis ARTC allowing launch attempts for Mondays, Wednesdays, and Fridays up to mid-December 1965. Added stipulations required the launches to be attempted in the hours of daylight and with no more than 50% overcast.

The test plan was delayed until mid-November awaiting delivery of the NADC rocketsondes. At that time it was thought inadvisable to delay further since the weather was becoming less favorable.

The revised test plan required the four rockets to be launched with dummy payloads in place of the rocketsondes. This would serve to check the buoy equipment and complete tests would have to be postponed until a later date (after Winter).

Accordingly, the truck was loaded during the second week of November and left the Space/Defense facilities on Sunday, 14 November. Remaining Space/Defense and University of Michigan personnel departed the next day in a station wagon with back-up communications equipment. The unexpected onset of heavy snow, high winds, and hazardous driving conditions delayed the arrival and consequently the entire group did not reach Copper Harbor (temporary headquarters) until Wednesday.

It was not possible to drive the truck to the launch site because of deep snow on the last three miles of the logging road, and also a washout at Schlatter Creek (ref. Fig. 7), although the four wheel drive vehicles (the ONR truck and a Michigan Technological University Jeep) were able to penetrate all the way to the site. It was therefore decided to assemble the buoy at a launching ramp at Lac La Belle, on the south side of the Keweenaw Peninsula, and tow it from there to High Rock Bay, with the assistance of the U.S. Coast Guard. The buoy was not intended to be towed over long distances, but it was believed that it could withstand the twenty mile journey without ill effect.

On Thursday, 18 November, a snowplow of the Keweenaw County Highway Commission cleared the parking area at Lac La Belle and assembly of the buoy commenced. University of Michigan and ONR personnel proceeded to the launch site and erected a guyed mast for the anemometer and wind vane. Initial tests on communication links between the site and Calumet Air Force Station were checked and appeared satisfactory.

The Minneapolis ARTC was advised through the Houghton Airport Flight Service Station that a launching was scheduled for Friday, 19 November, since the weather prediction indicated broken overcast. The U.S. Coast Guard Cutter, a 44 foot vessel, left Portage Coast Guard Station at Hancock Thursday afternoon and arrived in Copper Harbor four hours later.

On Friday morning assembly of the buoy was completed at Lac La Belle while the Coast Guard cutter made the run around the Keweenaw Peninsula. The buoy was slid down a ramp into the water and a channel chopped through the ice to deep water. The cutter arrived at mid-day, breaking ice to reach the buoy, and departed an hour later with the buoy in tow Space/Defense personnel remained aboard the cutter to determine the effects of the tow. It was observed that the buoy could not be towed at speeds in excess of about four knots since at that speed it tended to plane under; although structurally there were no problems. Communications with the Coast Guard cutter were maintained via the ONR carryall and Calumet Air Force Station.

Remaining project personnel proceeded to the launch site preparing to carry out wind-weight procedures for the scheduled launch. However, the predicted break in the weather did not materialize and the rocket-firings had to be postponed. The

Coast Guard cutter and buoy arrived at High Rock Bay at 1700 hours and, in view of the deteriorating weather conditions, it was thought prudent not to anchor the buoy. Therefore, it was decided to continue the tow and fetch-up in Copper Harbor until the weather improved. The cutter arrived in Copper Harbor after dark at 2200 hours and the buoy was moored between two adjacent docks. Subsequently the cutter departed for Portage.

A logging company was operating west of the launch site at a distance of about 3½ miles. There are no other personnel east of Copper Harbor except the Coast Guard Station on Manitou Island (situated six miles east of the launch area) and that station is abandoned during the Winter months. Since the buoy was to be towed to the launch site, it was decided to control the firing from the Coast Guard cutter. Accordingly, permission was sought and granted by the Commanding Officer of the local Coast Guard unit to proceed as stated. If the firing is conducted at least a mile off-shore and to the northeast of the site there is no possibility that a rocket can impact near the logging crew or the Manitou Island Coast Guard Station. Wind-weight calculations could, therefore, be omitted. For this reason during the Saturday forenoon the guyed mast at the site was dismantled and stowed in the University of Michigan truck at Copper Harbor.

In view of the strong possibility of continued bad weather with very short intervals of clearing, FAA authorities at Chicago were asked to modify the waiver restrictions. This was granted verbally so that launchings could be scheduled any day, and if necessary, with more than 50% overcast, provided it was possible to ascertain visually no V.F.R. aircraft were in the area. A policy was initiated of issuing daily notices to airmen from Houghton Airport Flight Service Station and these were cancelled only when it was obvious the weather was not suitable.

The weather remained formidable through 29 November with frequent gales and snow. Clearing was predicted for 30 November, so arrangements were made for the Coast Guard cutter to tow the buoy to the selected launch area. Meantime the rockets were removed from the buoy and the system checked out (as described in Section IIIB). Everything appeared in order and the rockets were reloaded aboard the buoy. The cutter arrived and took the buoy in tow; at that time gale warnings were in existence and it was estimated there was a sea state of 6 to 7. Weather conditions were marginal, with a broken cloud deck at

12,000 feet and a high thin overcast. Direct radio communication from the cutter to Calumet Air Force Station was possible once the vessel cleared Copper Harbor. However, as a back-up, the ONR carryall was stationed at Point Isabelle to act as a relay if required.

At 1530 hours when the cutter arrived at the designated launch area, vapor trails of high flying military aircraft were visible through the thin cloud cover. It was therefore considered that acceptable launch conditions prevailed despite the overcast at 12,000 feet. Final clearance was obtained from ARTC at 1645 hours and the firing switches actuated. The launch was unsuccessful and the buoy returned to Copper Harbor. On subsequent examination of the systems it was determined that the electric cable between the buoy and the vessel had parted. The electric cable was taped to a steel cable at about six foot intervals, but due to the violence of the Lake conditions had worked loose and formed a loop. The loop had caught on the buoy during the passage out and the subsequent strain caused the cable to part.

The weather appeared to improve during the evening, so the cutter remained at Copper Harbor overnight. The electrical cable was repaired and tied again to the steel cable. The firing system was rechecked and everything appeared satisfactory as before. Next morning, 1 December, the weather deteriorated once again and the projected launch had to be cancelled. The cutter left and returned to Portage.

The weather remained overcast until Saturday, 4 December, when broken overcast was predicted, although gale warnings remained in effect. The Coast Guard cutter was not available at this time, but a commercial fishing boat operating out of Copper Harbor was. The owner of the vessel, the "Charles J" agreed to tow the buoy, if it was possible in the high waves. After a trial run outside the harbor it was determined conditions were no worse than on 30 November when the Coast Guard had towed the buoy. However, during the subsequent preparations for departure, the weather again closed in with blizzard conditions prevailing and it became necessary to cancel out.

On Monday, 6 December, there was a broken overcast which was predicted to improve during the day with clear skies remaining through Tuesday. Unfortunately, gale warnings were still in effect on the western part of the Lake and this prevented the

Coast Guard cutter from leaving Portage; therefore, the "Charles J" was prevailed upon to perform the tow which, after a trial run outside the harbor, the owner agreed to do.

The operations got under way at 1400 hours with Space/Defense, University of Michigan and Calumet Air Force Station personnel onboard. A heavy layer of ice coated the entire surface of the buoy, but this was not considered detrimental to the launching. At 1620 hours the tow had reached the designated area and final clearance to launch was granted by Minneapolis ARTC. None of the rockets ignited when the firing circuits were actuated. It was subsequently determined that continuity existed through the entire circuitry down to the actual contacts on which the rocket motors rested. The buoy was returned to Copper Harbor, the rockets unloaded, and the central drum was removed for examination. Some water had found its way inside the drum, but this did not effect the operation of the relays or the circuit continuity. On examination of the positive contact at the bottom of the launcher tubes a layer of ice was observed. At the time this was incorrectly interpreted as the reason for the misfires. The real reason was subsequently determined to be more basic. The rocket motor casing has three spring loaded ground contacts installed around the upper rim of the case. When each rocket was loaded into its tube, the spring loaded contacts were binding on the lip of the launcher tube. This held the rocket away from the bottom contact by approximately one half inch. Inability to check continuity with the actual rockets installed had prevented this condition from being detected prior to making the attempt to fire the rockets.

In view of the long delay experienced due to weather conditions and the continuing uncertainty it was decided to adopt a different approach. The buoy and associated equipment had survived a fairly vigorous three week period and was still in good working condition. Simulated rocket launches had been made during this period with the buoy moored in Copper Harbor; each time the equipment performed satisfactorily. To obviate further delays, it was decided to haul the central drum, containing the electronic instrumentation, rocket launching tubes, and the rockets to Keweenaw Point by Snow-Cat. Since by this time more than two feet of snow was on the ground, this was the only practical means of reaching the Point. When in position all was in readiness to fire in the event breaks occurred in the overcast. (A boat towed launch took approximately seven hours advance notice.) Once in position at "the Point" it was possible to wait for suitable conditions with a finger on the fire button.

The trip was made to the Point on 7 December and adequate conditions existed. After firing two rockets in succession the rocket launching tubes became angled slightly beyond the 10^{o} cut-off. The central drum with the launcher tubes was jostled slightly from its fixed position by the reaction of the two launches; consequently there was a misfire on No. 3 rocket, confirming the operational adequacy of the 10^{o} cut-off constraint. The can was then repositioned so that the launching tube angle was reduced to slightly less than 10^{o} and the remaining two rockets were fired without incident.

After firing, the flotation part of the buoy was beached at Copper Harbor and the central can containing the instrumentation was returned to the Space/Defense Corporation laboratories.

2. Test 2

The second test comprised a duration test of the automatic sequencing apparatus contained in the central drum. The 1000 foot land line was disconnected and the internal electronic gear returned to truly automatic sequencing. The skyward viewing camera was left in place and the two 12 volt batteries recharged prior to the commencement of the test. The rotary selector switch was set to No. 1 contact point and the simulated launches were set to occur at 1030 hours and repeating six hours later at 1630 hours. The rotary selector switch sequenced to the next contact at 0430 hours each day.

It was possible to determine the precise time of launch each day by the noise of the shutter action on the unloaded camera, which commenced simultaneously with the actuation of the firing circuit. The camera would continue to operate for sixty seconds until automatically timed out. Each day the rotary selector switch was visually checked to ensure it had progressively sequenced to the next contact.

The rotary selector switch contact numbers 1, 2, 29 and 30 control the firing circuits to the rocket launcher tubes numbers 1, 2, 3 and 4 respectively. On days when the selector switch was contacting any of those numbers a dummy rocket with the test lamp was inserted in the appropriate launcher tube. This was a positive check on the circuitry and available power at the rocket contact.

On a random basis the central drum was sometimes placed outside the laboratories and other times left inside. The test was continuous from 15 December 1965 through 15 April 1966; thus the electronic equipment was exposed to temperature variations between 75° F to 0° F.

At conclusion of the test the timer was actuating the firing circuit 4.5 minutes later than the original setting. The drift was approximately linear during that time, although days of severe temperature change did produce greater variation than the nominal drift rate.

3. Tests 3 and 3A

Test 3 was intended to be similar to, though more comprehensive than, Test 1. The electronic equipment contained in the central drum was modified to include a 403 mc. receiver and a small portable tape recorder (See Section IID).

The buoy equipped with four rockets and rocketsondes was to be anchored in High Rock Bay (Lake Superior) and the rockets launched via the land line. Just prior to launch the inverter (and receiver) would be activated and just subsequent to launch the tape recorder would be switched on.

In this manner it was intended to acquire a recording of the transmitted signals from the descending rocketsonde. However, since it was not possible to obtain the rocketsondes, it was impractical to proceed. Therefore, the test was abandoned and Test 4 introduced as a partial substitute.

Test 3A was a separate experiment to be undertaken at Keweenaw Peninsula during the same period as Test 3 was in progress. It consisted of firing four rockets with dummy payloads from the closed breech launcher tube (ref. Figure 6).

The entire unit was comprised of the launcher tube, a 75 foot length of two-conductor stranded wire cable, a toggle action firing switch mounted in a small weather-proof metal box, and two 12 volt batteries coupled in parallel to supply the 24 vdc power supply.

After the decision was made to abandon Test 3 it was decided to proceed with Test 3A immediately. Accordingly, on Monday, 17 October 1966, the equipment was loaded into a small panelled

Chevrolet truck loaned by the University of Michigan, and the drive to Copper Harbor was completed in one day. The launch crew consisted of two Space/Defense personnel and one University of Michigan representative. At Copper Harbor on Tuesday morning it was apparent that the weather was not suitable for a launch that day. Therefore, the test was cancelled, but arrangements were made for the following day, Wednesday. During the remainder of Tuesday, Space/Defense personnel borrowed a portable telephone unit from the U.S. Coast Guard at Portage and drove to the launch site at Keweenaw Point.

Permission was previously obtained to tap into the existing telephone line adjacent to the site. It was possible to dial Calumet Air Force Station and thus communications were established. All other arrangements regarding communications and necessary clearances were as described in Test 1.

The empty rocket launcher tube was set up on the beach at the University of Michigan launch site and left in position overnight. On Wednesday morning the weather was good and the launch crew drove to the site with the four rockets. The radar station at Calumet supplied one of their personnel to act as the communications link at the launch site.

The launcher tube circuitry was tested with a dummy rocket and operated satisfactorily. Communications were then established with Minneapolis ARTC via Calumet Air Force Station. After final clearance was granted the first rocket was loaded itno the tube and launched without incident.

Before each subsequent launch, the launcher tube was inspected for signs of damage (none were apparent) and the circuitry retested. After each launch it was necessary to up-end the tube to eject the contact ignition cap released by the rocket motor.

All four rockets were fired in quick succession and all four trajectories, as indicated by the smoke trails, appeared normal.

The launch crew personnel returned to Birmingham on the following day, Thursday, 20 October 1966. Upon subsequent detailed examination of the launcher tube no damage could be detected. It may reasonably be concluded that neither the rockets nor the launcher tube were adversely affected by the closed breech launch technique.

4. Test 4

The purpose of Test 4 was to replace, in part, the cancelled Test 3. A hand-launched balloon carrying an AN/AMT-11(Dx) radiosonde was used in place of the NADC Rocketsonde.

A test of this nature may be conveniently performed at Space/Defense Laboratories, since the inflated balloon and suspended payload are sufficiently small not to be considered a hazard to aircraft.

The test was undertaken in the parking lot adjacent to the Space/Defense Laboratories and the apparatus was as shown in Figure 8. On the day of the test, 18 January 1967, the temperature was 6^{o} F. and it was necessary to allow the equipment an ample warm-up period. A monitoring station, the Radiosonde/Receptor AN/SMQ-1A was set-up adjacent to the test receiving apparatus contained in the central drum.

Simultaneously with the balloon inflation, the battery powering the radiosonde was water activated. With the parachute, radiosonde, battery and antenna suspended from the balloon there remained approximately 0.5 pounds of free lift.

Before releasing the balloon with its payload a check was made to ensure both pieces of ground equipment were receiving the transmitted signal (i.e., the receiver/recorder in the central drum and the monitoring radiosonde/receptor). No adjustments were required for the receiver/receptor unit although it was necessary to move the receiving antenna a greater distance from the drum. The antenna was picking up noise from the inverter and this tended to conceal the signal. For the monitoring unit it was necessary to tune in initially and thereafter to periodically readjust the controls as the balloon ascended.

The tape recorder was set in motion and the balloon released. Both units continued to receive the signal until switched off 45 minutes later. Figure 9 indicates the predicted horizontal distance covered by the balloon during ascent. The prediction was based on a wind data plot for that day obtained from the U.S. Weather Bureau at Flint, Michigan (40 miles distant). The altitude plot was obtained by counting the number of reference signals emitted by the radiosonde during the ascent and comparing with the calibration sheet.

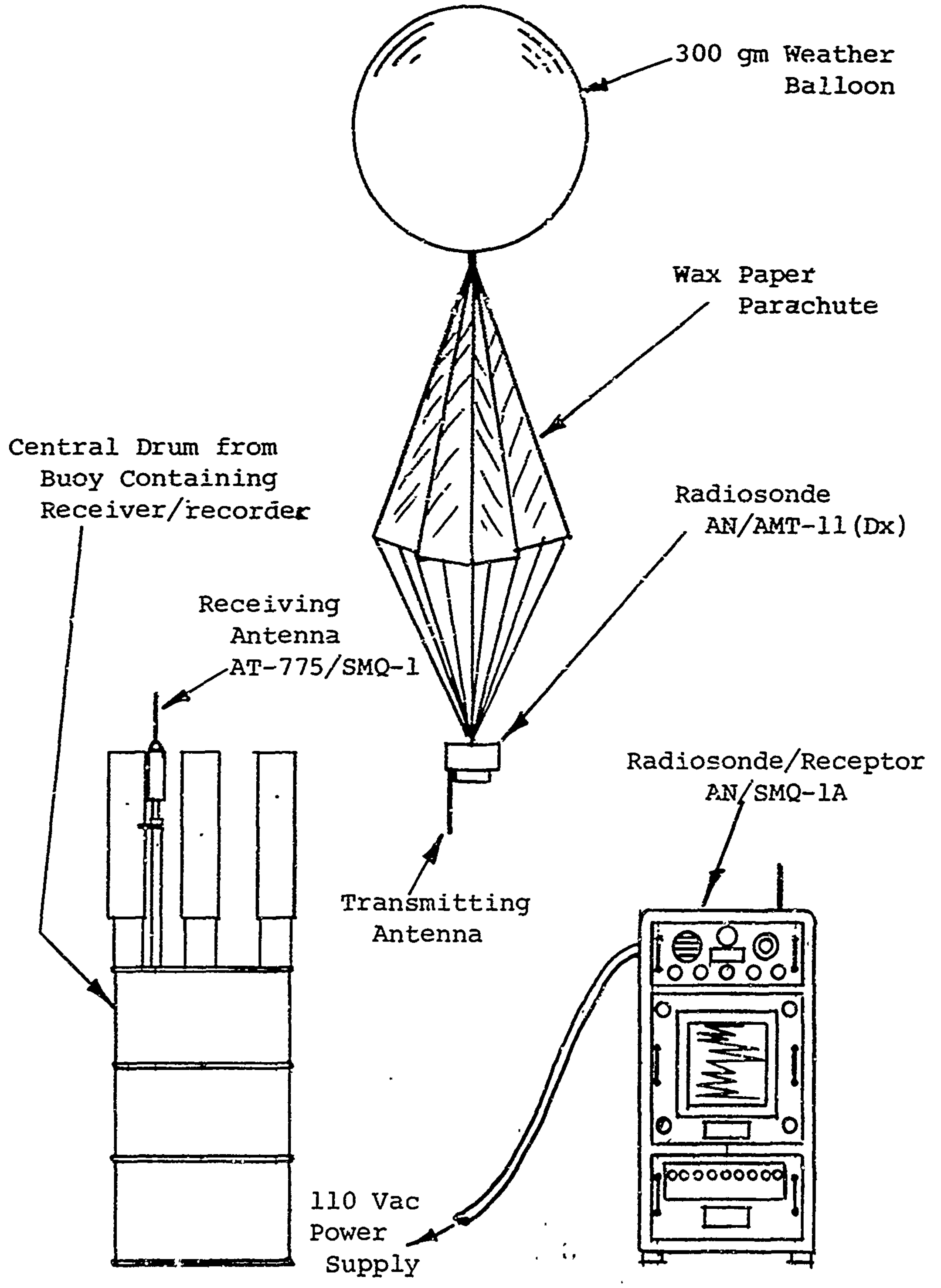

Figure 8. Test 4 Apparatus

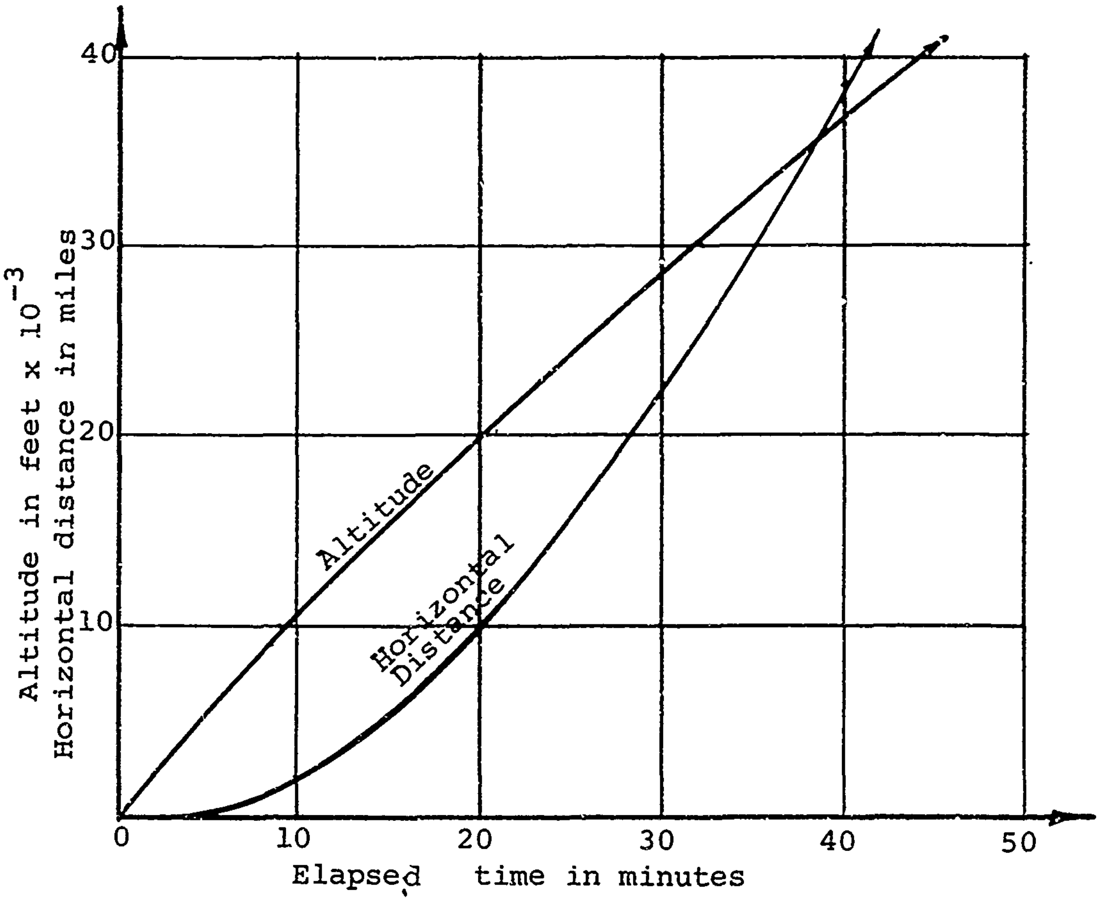

Figure 9. Physical Displacement of Radiosonde to Receiver

Some difficulty was encountered when the radiosonde was entering the troposphere. The rapid decrease in temperature caused the audio frequency to drop below 25 cps and for a brief period the receiver/recorder unit rejected the temperature signal and returned to the scan cycle. However, when the temperature increased shortly thereafter, the system returned to its normal output. A similar condition occurred at around 35,000 feet altitude when the data started to generate audio signals below 25 cps. From there to the cut-off point five minutes later the signal gradually deteriorated.

The test illustrated the ability of the receiver/recorder unit contained in the central drum to perform as required. When the NADC rocketsonde becomes available (with its stronger transmission signal) no problems are anticipated for the reception.

IV. CONCLUSIONS AND RECOMMENDATIONS

As a result of work performed under the contract requirements, an experimental buoy has been developed. Laboratory and field tests have indicated adequacy in most respects. However, FAA regulations prevent the testing of a truly automatic system without override control. The deviation from truly automated sequencing is considered a minor perturbation and the effect can be discounted when assessing the overall system feasibility.

The azimuth at launch can be selected to within precise limits. Automatic launch and signal reception are also both feasible and practical. It remains to develop a system of converting the data aboard the buoy and retransmitting to a monitoring shore station. Since there are buoys presently in existence equipped for handling data in a similar manner it is necessary only to adapt rather than develop. The retransmission of the signal will present no difficulties since this is presently standard procedure.

It is therefore recommended that the next steps in development of the Upper Atmosphere Automatic Weather Station be:

A. Integrate WEBROCK with an existing NOMAD buoy placing as many rockets on board that vessel as may be conveniently handled without incurring major modifications.

B. Utilize the existing power, data handling techniques, and available retransmission equipment. Install the electronic processing apparatus capable of handling a six-month operation, despite the physical limitation placed on the number of projectiles.

C. Subject the prototype unit to a six month duration test of truly automatic launches. Because of the limited number of projectiles that can be presently accommodated on the buoy, the launch routine will be stretched to fire approximately one rocket a week. This should not affect the validity of the test.

D. After the successful conclusion of items A through C a new and extended buoy should be designed to accommodate the total number of rockets desired and a power source developed other than batteries per se.

E. A new and more powerful rocket should be selected to obtain greater altitude than the present 2.75" FFAR.

F. Finally, studies should be initiated toward the development of a suitable buoy "ground" tracking station which would permit the determination of wind data from the descending rocketsonde to supplement the pressure, temperature and relative humidity data now acquired.

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13. ABSTRACT

The work effort related in this report spans a period commencing 15 June 1965 through 15 February 1967. An experimental buoy was constructed capable of launching sounding rockets automatically and remotely. Firings are controlled to assure that the quadrant elevation of each launch is never less than 80° despite the buoy motions. The rocket used during the tests (2.75" FFAR) is capable of projecting the rocketsonde payload to 22,500 feet. As the rocketsonde commences its parachuted descent, receivers aboard the buoy automatically acquire the signal and record the data. Although rocketsondes were not available during the period covered, simulation testing was performed by substituting balloon launched radiosondes (AN/AMT-11). Tests were conducted at the University of Michigan Keweenaw Rocket Range at Lake Superior and at the contractor's facility.

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WEBROCK Weather buoy Rocketsonde						

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