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FIVE-INCH GUN METEOROLOGICAL SOUNDING SITE, HIGHWATER, QUEBEC

by

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July 1968

U.S. ARMY ABERDEEN RESEARCH AND DEVELOPMENT CENTER
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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BALLISTIC RESEARCH LABORATORIES

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RDT&E Project No. 1T025001A616

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EDBoyer/sjw
Aberdeen Proving Ground, Md.
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ABSTRACT

The use of a meteorological gun-probe in a confined area has been demonstrated. A program utilizing the 5 in. HARP system at Highwater, Province of Quebec, near the Vermont state border, is described. Wind soundings were made to altitudes of 230,000 ft with a ground impact area limitation of 1 sq mi for the spent projectile.

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INTRODUCTION

One of the distinct advantages of a meteorological gun-probe system is the small impact area required. This low dispersion potential was demonstrated in an early phase[1*] but was never seriously utilized in subsequent operations at Wallops Island,[2] Virginia; White Sands Missile Range,[3] New Mexico; Barbados,[4] West Indies; Fort Greely,[5] Alaska; and Yuma Proving Ground,[6] Arizona. The use of the range at the Highwater Laboratory, however, did seriously depend on close control of the impact area.

The Highwater site is located at Highwater, Quebec, Canada, on the Vermont-Quebec border, latitude 45°1'19" North; longitude 72°28'12" West at a height of 1200 ft. The range is owned and operated by the Space Research Institute of McGill University.** The primary function of the range is the horizontal testing of components for the 16 in. system (Figure 1). There is a total land area available to the range 2 mi wide and 5 mi long. This amount of area is consistent with the predicted performance of the 5 in. system and it seemed very reasonable to establish a meteorological site in this area. The U. S. Army Electronics Command, Atmospheric Sciences Laboratory (ECOM-ASL), of White Sands Missile Range has been interested in data from this area and partially supported soundings in February 1967 to June 1967. The utilization of this site is the first inland sounding site east of the Rockies, illustrates the value of the highly accurate gun system, and should pave the way for other useful sites with impact areas too small for conventional sounding rockets.

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*References are listed on page 26.

**In January 1968, the Space Research Institute was incorporated as a nonprofit corporation under the control of Norwich University of Northfield, Vermont, and all guns, radars, and associated equipment were transferred by the U.S. Army to this corporation.[7] Border check points are to be moved to allow unrestricted access to the Highwater Laboratory from the United States.

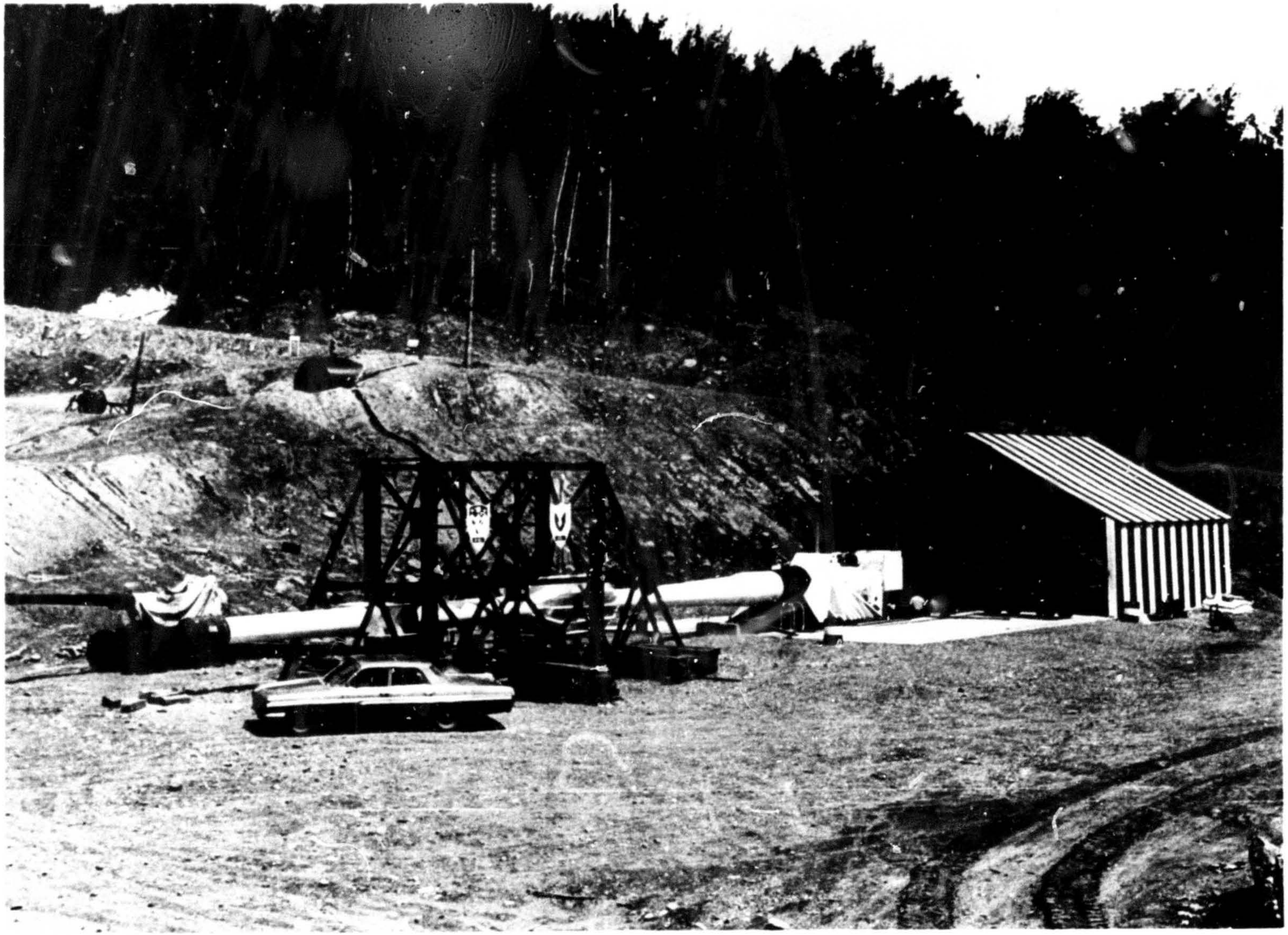

Figure 1. 16-inch Gun

GUN AND TRACKING EQUIPMENT

The gun system used was the 5 in. system in the form previously reported at the other sites. The components were winterized to the specifications for -70°F operation to meet the possibility of the extreme weather conditions occurring in Quebec during the winter series.

The 5 in. HARP system has a launch tube consisting of two 120mm T123 tank gun units. The major portion of the second tube is connected to the first and the assembly smoothbored to form a nominally 5 in. bore gun tube 41 ft in length. In order to reduce the added flexibility of the long jointed tube, a truss rod stiffening system is used. This tube is mounted in a 155mm M2A1 towed field carriage. The complete unit is placed on a 30-degree inclined ramp, to allow elevations to 90 degrees (Figure 2). Basic loading equipment consists of a model holder and hydraulic cylinder to ram the model 66 in. forward into the tube. With the present equipment, this loading procedure takes 15 min and requires a two man crew (Figure 3).

An objective of the series was to obtain data during the yearly warming trend that passed through the area usually during February.

The Space Research Institute (SRI) was in the process of securing a Mod II radar for the site but it became apparent that this radar could not become available in time for February firings. To circumvent this problem, an MPS-19 radar unit was borrowed from the National Aeronautics Space Administration's (NASA) Wallops Island Station. The MPS-19 radar unit consisted of two vans (Figures 4 and 5) and was located on the firing azimuth, 3770 ft behind the gun.

TEST

The projectile to be used was the standard 5-1 projectile (Figure 6), with [illegible] m Mk33 aluminized metsonde parachute, a 1 m non-reflective chute, and a 120 sec ejection system. M30 powder was employed as the propelling charge.

Figure 2. 5-inch Gun

Figure 3. Model loading mechanism

Figure 4. MPS-19 radar

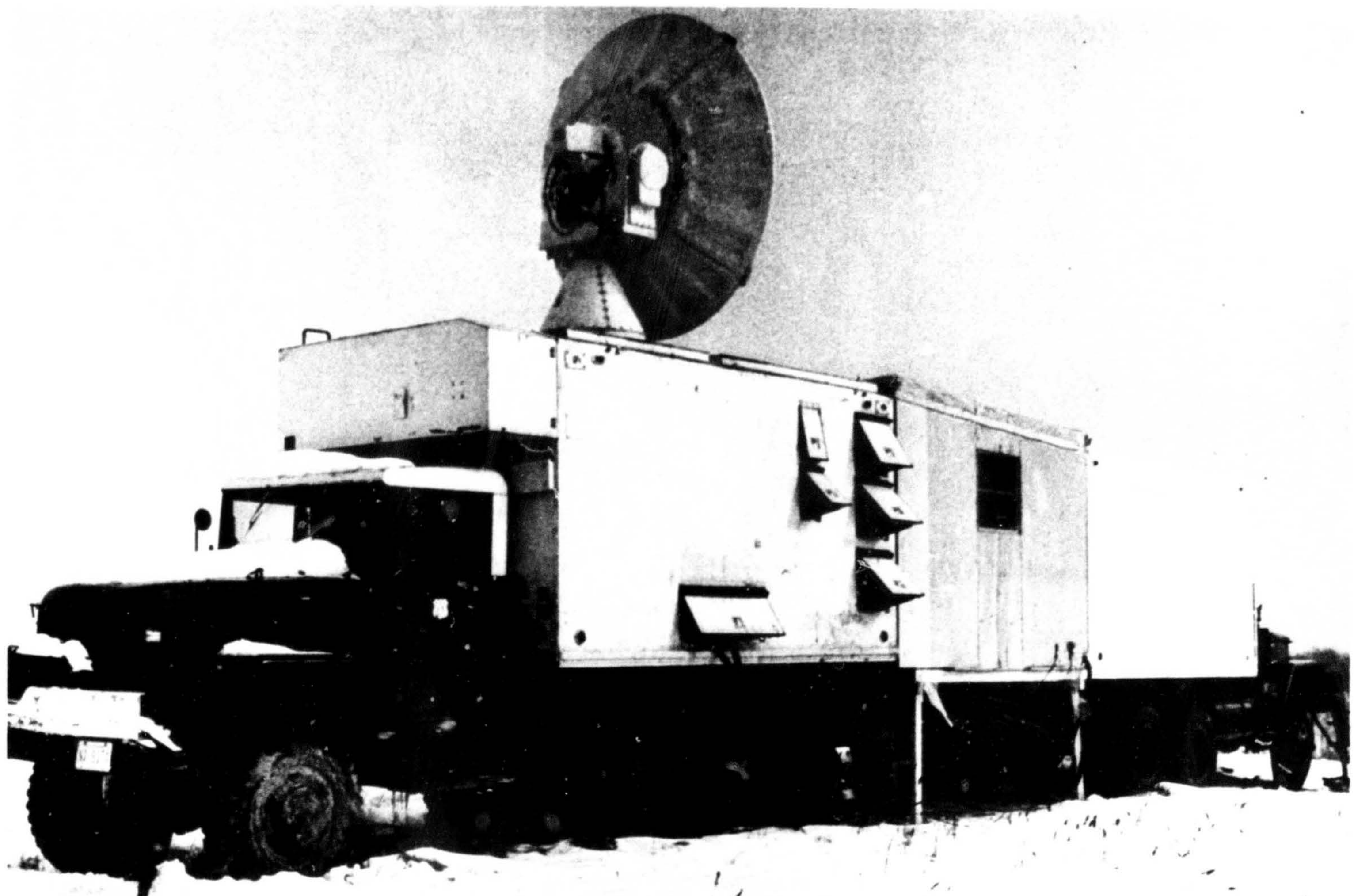

Figure 5. MPS-19 radar

HARP 5-I PROBE PROJECTILE

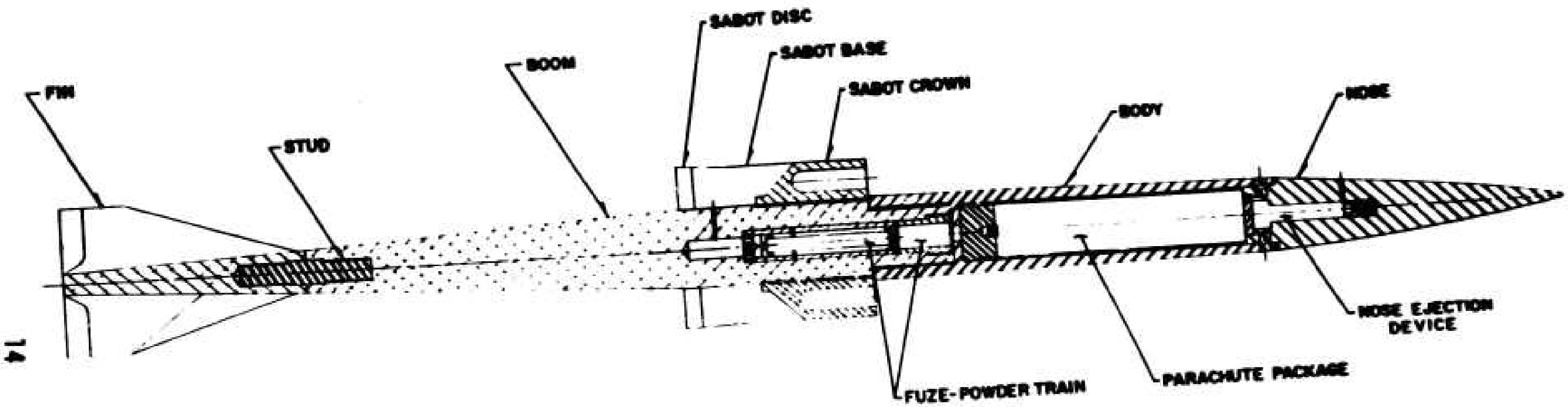

Figure 6

The limited range area, 2 by 5 mi, had dwellings along the perimeter, and this required that the gun be laid with great accuracy. Two other important factors which have to be considered are a Coriolis correction for the geographic site, and an allowance for the wind effects. To correct for the wind effects, it is desirable to have information as current to the time of firing as possible, although the relatively low wind sensitivity of the gun system is one of its advantages. Preliminary information was obtained, at the site, by releasing a chaff balloon and tracking it to 30,000 ft (balloon's capability). The surface and average winds to 30,000 ft account for approximately 60 percent of the projectile's wind deflection and is the major portion of the corrections employed. Another 33 percent of deflection would be accounted for by the wind profile up to 70,000 ft. The remaining 7 percent might be accounted for by winds above was not considered. Wind corrections to cover the region 30-70,000 ft were obtained by using radiosonde data from Maniwaki, Quebec. (lat. 45°1'19" N; lon. 72°28'12" W). Although the data was not very current and was taken 200 mi northwest of Highwater, it was considered adequate for the relatively low wind sensitivity of the gun probe.

The deflection from wind was based on a ballistic wind weighting factor equation of the form

$$D = D_a \sum W_{x_i} \left(\frac{\Delta x_i}{X}\right)$$

where W_{x_i} = the wind speed in miles per hour for altitude zone i

D_a = the deflection for unit constant wind for a given apogee

$\left(\frac{\Delta x_i}{X}\right)$ = weighting factor for the different altitude zones. The projectile configuration is as seen in Figure 6 (minus sabot) on the up leg of the trajectory, and is minus its nose cone on the down leg of the trajectory.

It is interesting to note that D_a for a 200,000 ft apogee trajectory is 111 ft/mph and, hence, a constant wind of 50 mph at all altitudes causes the very low deflection of about 1 mi for a total flight path length of

75 mi.[8-9] This deflection is for the projectile only and the control of the excess smaller parts, which are ejected during payload deployment, will be considered later. The atmosphere is broken up into zones of 10,000 ft intervals with weighting factors determined.

Zone	Altitude (k/ft)	$\left(\frac{\Delta x_i}{X}\right)$
1	0-10	0.241
2	10-20	0.220
3	20-30	0.162
4	30-40	0.124
5	40-50	0.086
6	50-60	0.059
7	60-70	0.036
8	70-	0.072

The nominal westerly Coriolis deflection X_c is determined from

$$X_c = \frac{8}{3} \omega \sqrt{2/g} \, (\cos \theta) \, z_a^{3/2}$$

where z_a = apogee

ω = 0.000073 rad/sec (earth's angular velocity)

θ = 45^o (latitude)

For an apogee of 200,000 ft, a Coriolis deflection of 3100 ft is predicted by this formula.

Knowing the wind conditions at the different zones and the displacement due to Coriolis force, the proper orientation of the gun can be determined. This is taken from the full vertical position of 90 degrees and for a desired impact 13,500 ft out along the azimuth (266 degrees) and 2200 ft north. The data for the 18 April shot is given on the following page.

Zone A	Wind True North (deg) B	Gun (deg) C	Cos θ D	Sin θ E	W_{x_i} (mph) F	$\frac{\Delta_{x_i}}{X}$ G	ΔR D-F-G	ΔA_z E-F-G
1	150	64	-0.438	0.899	11	0.241	-1.2	2.4
2	174	88	-0.035	0.999	27	0.220	-0.2	5.9
3	182	84	0.105	0.995	42	0.162	0.7	6.8
4	300	34	0.829	-0.559	20	0.142	2.1	-1.4
5	280	24	0.914	-0.407	27	0.086	2.1	-0.9
6	320	54	0.588	-0.809	16	0.059	0.6	-0.8
7	045	41	-0.755	-0.656	16	0.036	-0.4	-0.4
8	082	4	-0.998	-0.070	38	0.072	-2.7	-0.2
							1.0	11.4

Cos θ, function of range

Sin θ, function of azimuth

wind deflection ΔR = (1.0)(111) = 111 ft (East)

wind deflection ΔA_z = (11.4)(111) = 1260 ft (North)

Total layoff in feet

Range	=	13,500	Desired impact
		111	Wind deflection
		-3,100	Coriolis
		10,511	ft

Azimuth	=	2,200	Impact
		1,260	Wind deflection
		200	Coriolis (A_z = 266 deg)
		3,660	ft

The gun is set in mils. The impact point moves 800 ft/mil. Therefore,

Mil setting range

$$1600 - \frac{10511}{800} = 1586.8 \text{ mils}$$

Mil setting azimuth

$$\frac{3660}{800} = 4.6 \text{ mils south}$$

The impact point of the spent projectile was determined by sound ranging. Five observers with stop watches were stationed around the parameter of the impact area. They clocked the time from launch to sound impacts. With this data, it is possible to locate the actual impact.* A total of 20 rounds were fired and the impacts for all rounds were determined to fall within a circle of 5000 ft radius. Two rounds were recovered in July and were located within 1000 ft of the impacts designated by the sound ranging technique. This recovery was made by a troop of boy scouts on a hiking trip. The models impacted, through the snow, nose first with the last 10 in. remaining above ground (Figure 7). The recovery of these two rounds is some representation of the accuracy of the sound ranging technique and that the actual impact is within 1000 ft of that shown in Figure 8.

Although the impact of the major portion of the vehicle can be controlled, the problem still remains to control the ejected pieces of metal resulting from the deployment of the payload. These are the nose cone and two pieces of payload canister. It has been observed that if these pieces are allowed to float to the earth freely they are quite wind sensitive, they can remain aloft about 20 min and impact with a velocity of about 300 fps. The difficulty associated with these pieces is eliminated by

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**With a fixed array of microphones and a recording system, a number of other phenomena associated with the flight of 5 in. projectiles have been observed.*[10]

Figure 7. Recovered 5-1 probe projectile

SOUND IMPACTS

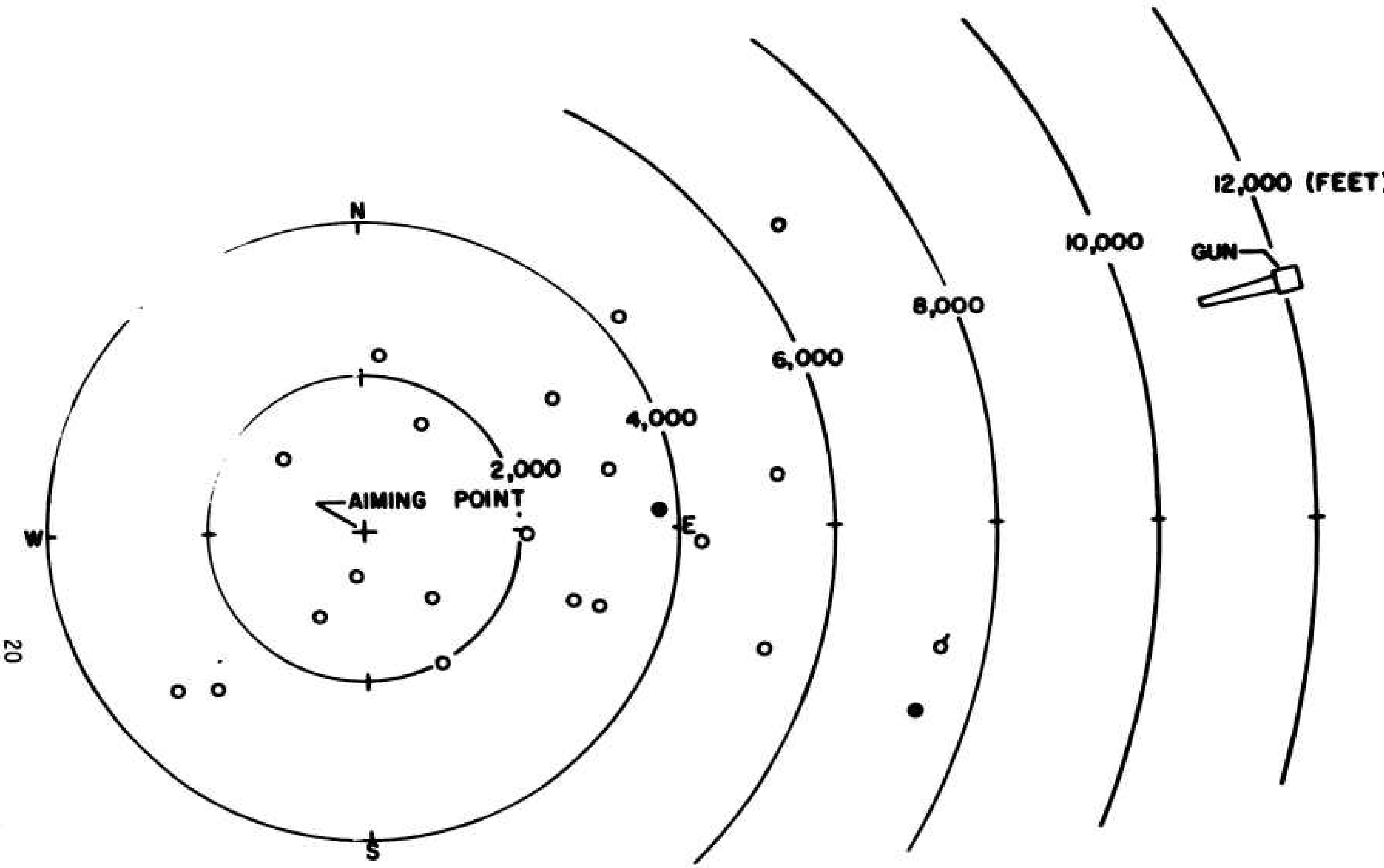

Figure 8

attaching them to a small second chute. This chute is 1 m^2, non-radar reflective (Figure 9) and reduces the impact velocity to less than 25 fps. The typical mission profile is depicted in Figure 10.

The initial three rounds of the series were fired without any payload deployment. These shots were used to verify the flight control and impact of the projectile. Having established this, the Mk33 metsonde parachute was employed. A total of 17 rounds were fired from March to June. Of course, one round failed to eject, two rounds had defective parachute, and one had a properly deployed chute with a radar failure.*

Good wind data were obtained for the other 13 rounds and have appeared in the Meteorological Rocket Network Data Reports. The complete data is given in the table. The wind data and plots for the 18 April shot are given in Figure 11.

CONCLUSIONS

It has been demonstrated that the gun system can be fired and controlled in a confined area. With the proper handling, it is possible to deploy a metsonde payload at altitudes above 200,000 ft on a routine basis.

**Since these firings, the ejection problems and those associated with the improper deployment of the metsonde have been resolved. A 100 percent success has been realized on the last 25 attempts at Wallops Island.*

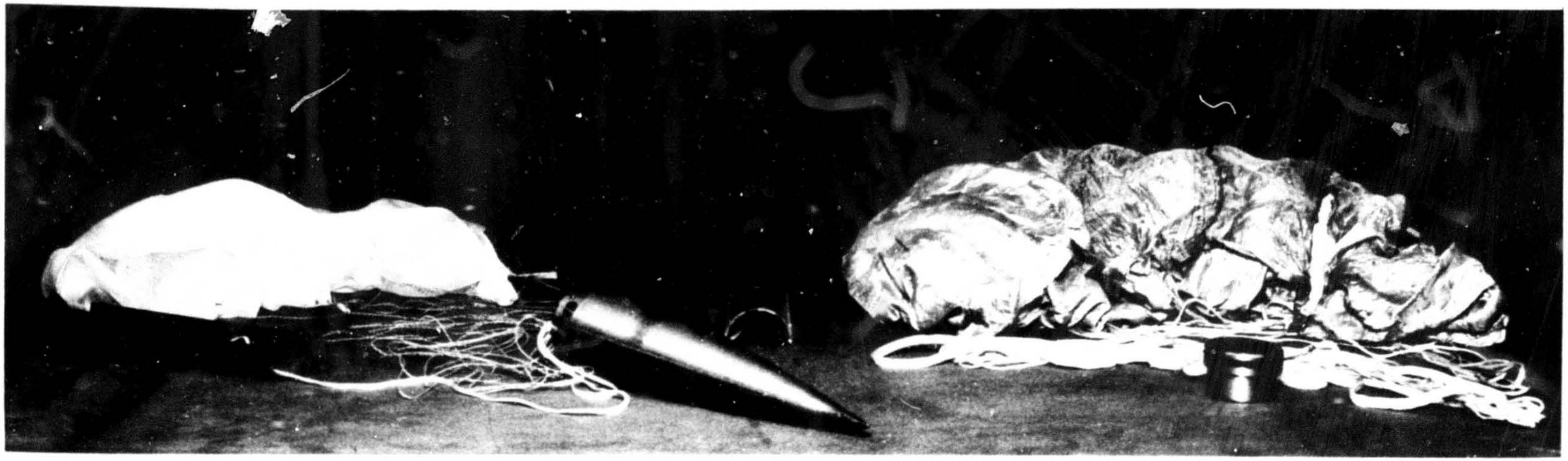

Figure 9. Parachutes

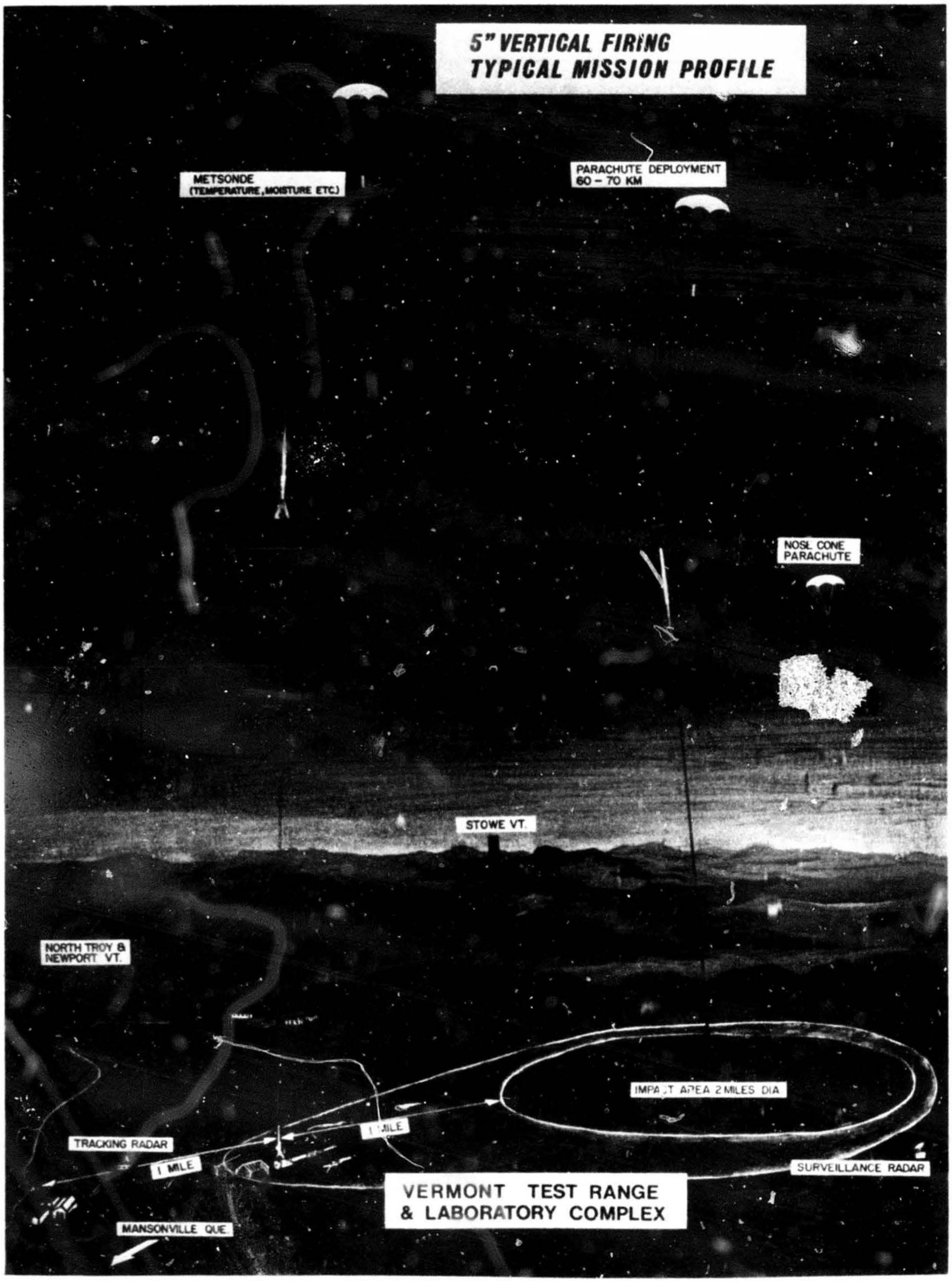
5" VERTICAL FIRING
TYPICAL MISSION PROFILE
METSONDE
(TEMPERATURE, MOISTURE ETC.)
PARACHUTE DEPLOYMENT
60 – 70 KM
NOSL CONE
PARACHUTE
STOWE VT.
NORTH TROY &
NEWPORT VT.
IMPACT AREA 2 MILES DIA
TRACKING RADAR
I MILE
I MILE
SURVEILLANCE RADAR
VERMONT TEST RANGE
& LABORATORY COMPLEX
MANSONVILLE QUE.

Figure 10

Date 1967	Local Firing Time	Air Temp. (deg F)	Charge (lb)	Pressure x 10^{-3}	Alt. (k/ft)	Q.E. (mils)	A_z (mils)	Sound Impacts from Aiming Poin (ft)	(ft)
Feb									
10	1400[1]	40	34	49.9	248	1586.0	5.5L	1860W	1980
11	1100[1]	40	33	52.2	245	1583.5	5.0L	740E	1740
11	1400[1]	32	32	44.9	210	1583.0	3.3L	2600W	1980
Mar									
7	1500	31	32	48.6	222	1584.5	6.8L	2730E	1120
8	1500	26	32	44.0	216	1584.7	4.6L	1120W	870
10	1500	54	32	41.0	208	1584.5	2.8L	2360E	990
13	1600	38	32	51.1	235	1584.0	3.4L	2850E	1120
14	1500[2]	42	31.5	41.7	203	1584.0	3.4L	7200E	3970
15	1500	36	31.5	42.2	204	1584.6	2.3L	3970E	250
17	1100	14	31.5	41.3	208	1587.8	1.3L	3100E	2480
20	1200[3]	34	31.5	42.0	206	1589.3	.6R	620E	870
22	1200	30	31.5	40.4	204	1590.4	6.1L	5080E	3600
29	1200	50	31.5	42.0	205	1581.7	4.5L	120E	2110
Apr									
18	1207	40	31.5	43.9	213	1586.8	4.6L	740W	1120
May									
17	1200	58	31.0	41.4	204	1585.7	1.9L	1860E	120
19	1200	52	30.5	35.8	181	1585.4	2.6L	250W	620
24	1200	63	31	37.6	187	1589.4	4.5L	4970E	500
26	1200[4]	50	32	39.5	200	1593.8	2.2R	620E	1240
29	1200[5]	64	32	40.7	200	1585.0	2.5R	2230E	2730
June									
28	1200[5]	88	31.5	43	200	1592.4	3.5L	4710E	1610

Launch wt. = 26 lb Flight wt. = 20.5 lb M30 propellant (charge temp. = 70°F).
B1 - Granular mix 078 web (85 percent), 053 web (15 percent).

[1] Proof shots without parachutes.
[2] Using 24 hour old wind data.
[3] No payload ejection.
[4] Radar problems, no wind data.
[5] Parachute did not function.

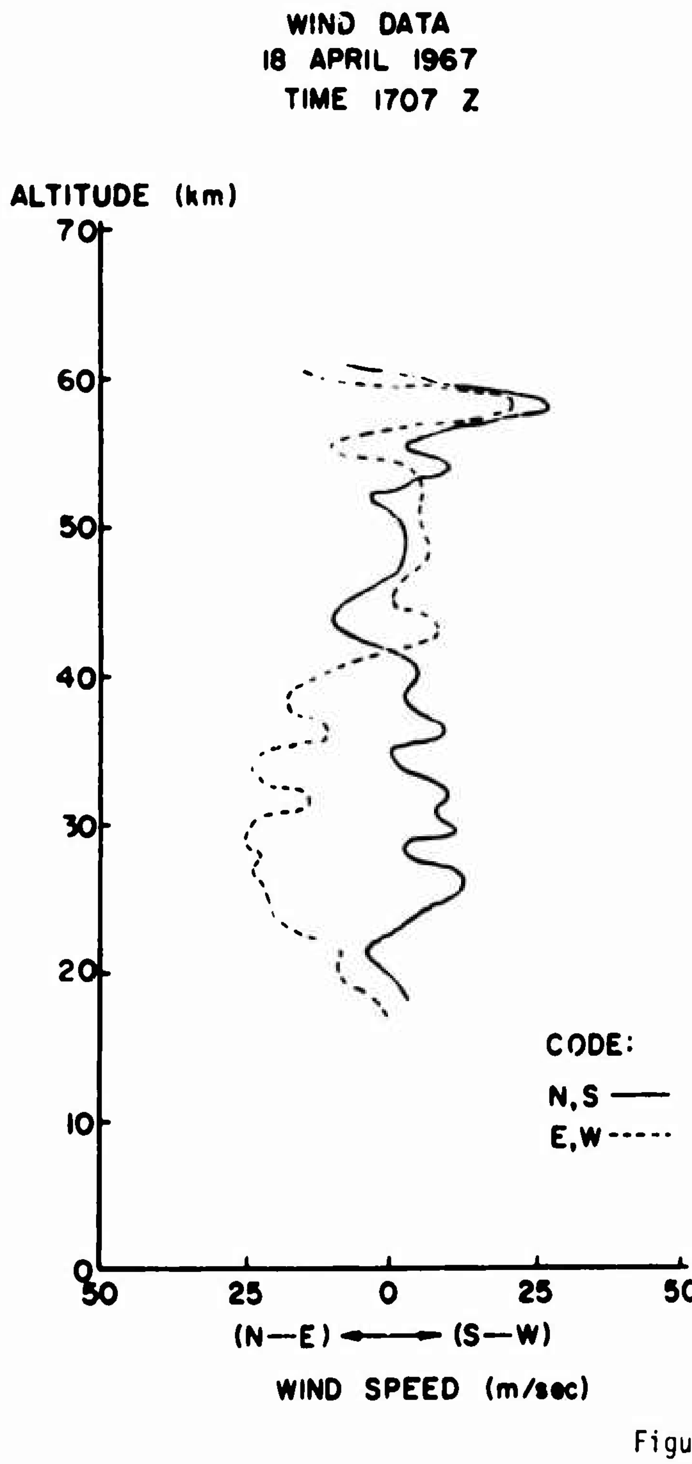
WIND DATA
18 APRIL 1967
TIME 1707 Z
ALTITUDE (km)
70
60
50
40
30
20
10
0
CODE:
N,S
E,W
50
25
0
25
50
(N—E) (S—W)
WIND SPEED (m/sec)

Figure 11

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13. ABSTRACT

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