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MEMORANDUM REPORT ARBRL-MR-02999

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TESTS OF AN AFT-EJECTION GUN-PROBE SYSTEM AT TONOPAH TEST RANGE, NEVADA

E. D. Boyer

March 1980

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The results of initial vertical firing tests of a 5-inch aft-ejection projectile at Sandia's Tonopah Test Range in October, 1977, are presented. Predicted altitudes were attained when projectiles were intact. The radars experienced tracking problems, with these high velocity projectiles, and fuze performance was erratic. The radars tracking problems were resolved during a second series in March 1978. Fuze and projectile problems were not resolved.		

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I. INTRODUCTION

The BRL of ARRADCOM has used a 5-inch gun-probe system capable of attaining 75 kilometers altitude at a number of sites[1,2,3,4,5,6] in the period 1963-1973. One of the last probes developed was an aft-ejection vehicle with an estimated altitude capability of 50 kilometers. Few projectiles of this type were ever tested. During some 155mm shell tests for the BRL at Sandia's Tonopah Test Range (TTR), Nevada, an interest developed in proving the latter projectile as a possible means of parts recovery after high-g tests and in showing the capacity of the TTR radars (MPS-25 and MPS-36) to track a projectile with a high launch velocity. As a result, a few limited tests of the projectile were made in October 1977 and again in March 1978.

II. GUN AND PROJECTILE SYSTEM

The gun system (Figure 1) used was the 5-inch system which has been tested at other sites. The launch tube consisted of two 120mm T123 tank gun tubes which were joined and smooth-bored to form a launcher 12.5 metres long with a nominal 130 mm bore diameter. The trussing system shown is used to reduce whip and help maintain alignment of the long two-piece tube. The tube was mounted on a 155 mm M2A1 towed field carriage and placed on a 30-degree ramp to allow elevations up to 90 degrees.

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1. *E.D. Boyer, "Five Inch HARP Tests at Wallops Island, September 1963," Ballistic Research Laboratories Memorandum Report 1532, January 1964. AD 430232.*
2. *E.D. Boyer, "Five-Inch HARP Tests at Barbados, West Indies, January-February 1966," Ballistic Research Laboratories Memorandum Report 1771, July 1966. AD 640438.*
3. *E.D. Boyer, "Five-Inch Gun Meteorological Sounding Site, Highwater, Quebec," Ballistic Research Laboratories Memorandum Report 1929, July 1968. AD 673712.*
4. *C.H. Murphy and G.V. Bull, "HARP 5-Inch and 16-Inch Guns at Yuma Proving Ground, Arizona," Ballistic Research Laboratories Memorandum Report 1825, February 1967, AD 654123.*
5. *L.E. Williamson, "Gun-Launched Vertical Probes at White Sands Missile Range," Atmospheric Sciences Office, ECOM-5030, February 1966. AD 482330.*
6. *E.D. Boyer and L.E. Williamson, "Five-Inch HARP System - Initial Test Series - Fort Greeley, Alaska," Ballistic Research Laboratories Technical Note 1657, May 1967. AD 655267.*

The standard propellant charge previously developed for the 5-inch probe system was used in these tests. It consisted of mixing three different web-sized M17 propellants (by weight, 2% of 2.90, 68% of 2.00, and 30% of 1.32 mm).

Two different projectiles (Figure 2), were used in both test series the standard 5-1 projectile, which has been fired many times and proven to be reliable, and a 5-3 projectile with very limited previous flight experience, a total of 15 rounds. The 5-1 projectile is a high performance vehicle with a forward ejection of its payload. The 5-3 projectile ejects its payload out the base and its altitude capabilities are reduced by about 25% (compared to the 5-1 projectile) when operating at peak pressure conditions.

The 5-1 projectile is shown in Figure 3, both assembled with sabot as it is launched and without sabot as it is seen in flight. Figure 4 is a smear picture of round 6, depicting sabot separation at 4.5 metres from muzzle after launch.

Figure 5 is a layout view of the sabot and payload for the 5-3 projectile. The sabot consists of four aluminum sections, which are attached to the model via buttress threads (grooves for the 5-1); four lexan sections, to increase the in-bore riding area; and two polypropylene pieces for obturation. The payload carried on these flights consisted of a 2 metre square (MK33) standard meteorological parachute with a 145 gram lexan weight (to simulate a temperature sensor). The small disc to the rear of the model is the base-closing plug.

The electronic timing and ejection fuze (not shown) is housed in the forward section of the projectile. The position of the "g-switch" and detonator are reversed in fuze assembly for the aft-ejection 5-3 as opposed to that for the 5-1. Both the 5-3 and 5-1 use the same payload and ejection fuze. The sabot separation can be seen for rounds 2 and 5 in Figure 6.

III. TEST

The first test series consisted of firing two 5-1 projectiles and four 5-3 projectiles at an elevation of 89 degrees. The main purposes of the test were:

1. To prove the tracking capabilities of the Tonopah radars with high velocity gun-launched projectiles (1585 m/s).

2. To demonstrate operation of the new electronic 120 second fuze-ejection system.

3. To demonstrate flight characteristics and capabilities of the proven 5-1 projectile used in earlier testing.

4. To demonstrate the capabilities of a rear-ejection payload projectile.

Firing results from the first test series are given in Table "Series I". The radars were unable to acquire the models within a few seconds out of the gun and tracking problems were experienced. This is a problem area that has been noted at other facilities and has improved with operator experience in dealing with the over 1600 m/s launch.

Of the two 5-1 projectiles fired, both appeared to fly properly. Round 1 was seen by radar at 5 seconds in its window but radar was not able to lock on and track. The parachute was picked up at 16 minutes after launch at an altitude of 34 kilometers. This was the proper position and time for the projectile to have had a nominal flight to 75 kilometers and payload ejection at 120 seconds.

Round 6 (the other 5-1 projectile) also was not tracked but sound reports of the projectile impacting the ground indicated that the flight was nominal to 75 km.

Two of the 5-3 projectiles were launched successfully. Round 2 hung up in the gun tube during the loading process and was seated 54 cm short of the standard loading position (168 cm from the rear face of tube). Being unable to move the round any further, it was fired at a reduced charge. The model was not tracked but the parachute was sighted at 50 km after three minutes.

Round 5 was tracked from 20 seconds after launch to impact. It achieved an altitude of 64 km but no chute was sighted. This indicates that either the chute was lost during the launching process or the fuze didn't function.

The other two 5-3 projectiles, rounds 3 and 4, came apart during the launching process. They had breech pressures of 400 and 425 kPa, respectively. Previous firings of this projectile had not exceeded 386 kPa.

Since the 5-3's payload is ejected rearward, the base of the projectile must be sealed, for launching purposes, with a plug that is ejectable at the time of fuze function. This plug can be seen in the still photograph of Figure 5. The plug is held in the projectile with an O-ring on the stud and a pinning arrangement through the body of the projectile into the stud. This plug can be seen in the post-launch photograph, Figure 6. For round 2 it is still flush with the base of the projectile; however, for round 5 the plug has started to move away from the base and the lips seem to be bent.

Figure 7 (round 4) shows three segments of the boom of the projectile. This indicates that gun pressure may have failed the plug during the launching process and blown the projectile apart. The smear pictures for round 3 showed only small parts and it is assumed that the plug also failed and hence, must be redesigned to be strong enough to withstand the higher operating pressures.

SUMMARY OF FIRING DATA
SERIES I

Date Oct. 1977	Round	Local Firing Time (PST)	Projectile Type	Launch Weight (kg)	Charge (kg)	Loading Distance (cm)	Breech Pressure (kPa)	Altitude (km)
18	1	1056	5-1	13.38	15.9	168	407	
20	2	1112	5-3	14.74	10.9	114	260	50
20	3	1210	5-3	14.74	15.9	173	400*	----
21	4	0950	5-3	14.74	15.4	168	425*	----
21	5	1048	5-3	14.74	14.1	168	355	64
21	6	1135	5-1	13.38	14.1	160	350	79

**The 5-3 projectile held up at 386 kPa in previous tests.*

A second series of firings was done in March of 1978. The results of this series are summarized in Table "Series II". The radar's performance on this series was improved so that all rounds were tracked. The track of the first round was somewhat spotty, with the first sighting at 20 seconds and no lock-on. The radar had only an occasional look at the projectile. For all other flights, acquisition was at 7 seconds and lock-on was obtained for the remainder of the flight.

Both the 5-1 and 5-3 projectiles were fired in this second series. The 5-1 was employed to resolve the radar tracking problem encountered in the first series and the 5-3 to evaluate the performance of a rearward payload-ejection projectile. Trajectories are shown in Figure 8.

Four 5-1 projectiles were fired. The first two carried no payloads, but were used only to resolve the radar tracking problem. Radar was able to see the first round at 20 seconds but could not obtain lock-on. The second round was acquired at 7 seconds and tracked to impact. After establishing tracking capabilities, two projectiles were fired with payloads and ejection systems. No ejection was obtained on one round, but the other ejected a payload (Chaff) at 120 seconds.

Once radar tracking capabilities were established, five of the rear-ejection 5-3 projectiles were fired. The first three were launched at normal pressures (315 KPA) to obtain an altitude of 58 KM. Of these three projectiles, one had sabot failure, one fuze functioned at 20 seconds, and the third projectile had a normal flight and a fuze function at 119 seconds. However, the parachute was damaged and had an abnormally high fall rate.

The final two rounds were fired at reduced pressures of 277 KPA. The trajectories were as predicted and they obtained altitudes of 51 KM. The fuzes were erratic with functions at 92 and 140 seconds.

IV. CONCLUSIONS

The performance of the two 5-1 projectiles was as expected from earlier test programs. The rearward-ejecting 5-3 projectile attained predicted altitudes when intact, but broke up at breech pressures above the previously tested level (386 kPa). These failures may be related to an inadequate design of the base plug sealing the payload cavity during launch and up to ejection. The 5-3 projectile launches properly at reduced pressures (277 KPA). At 315 KPA, however, there was a sabot failure.

The TTR radars had difficulty acquiring these high-velocity, gun-launched projectiles during the first series. The best radar performance was acquisition at 20 seconds after launch for one of the lower velocity projectiles. Similar performance on initial attempts has occurred at a number of other sites where the radar operators were mainly experienced in tracking rockets which have slower lift-off velocities. Thus, the second test series showed that the Tonopah radars are capable of tracking high velocity projectiles and the 5-1 projectile flights were as predicted.

The ejection fuze is erratic with times from 20-192 seconds, for a 120 second setting, and a parachute was damaged during deployment.

The base plug for the 5-3 projectile should be strengthened, stronger connections utilized, and the projectiles fired at lower pressures until flight integrity has been established. Once the flight conditions and radar capabilities have been established, attempts should be made to place a parachute payload at altitudes above 50 km with the 5-3 projectile.

SUMMARY OF FIRING DATA

SERIES II

Date March 78	Rnd	Local Firing Time (PST)	Projectile Type	Launch Weight (kg)	Charge (kg)	Loading Distance (cm)	Breech Pressure (kpa)	Altitude (km)	Event Time (sec)	Comments
14	1	1108	5-1	13.38	13.5	160	271	67*	---	Carried no payload
14	2	1130	5-1	13.38	13.5	160	275	67	---	Carried no payload
15	3	0955	5-1	13.38	13.5	160	282	68	None	No Payload Ejection
16	9	1124	5-1	13.38	14.0	160	312	71	122	Good Payload
15	4	1019	5-3	14.74	13.5	168	316	58*	20	Early Ejection-Chute Torn
15	5	1051	5-3	14.74	13.5	168	312	15	None	Projectile Failed
15	6	1113	5-3	14.74	13.5	168	306	58	119	Chute Torn
16	7	1041	5-3	14.74	12.6	168	277	51	140	Late Ejection Good Chute
16	8	1105	5-3	14.74	12.6	168	277	51	92	Early Ejection Chute Torn

*Estimated From Flight Times.

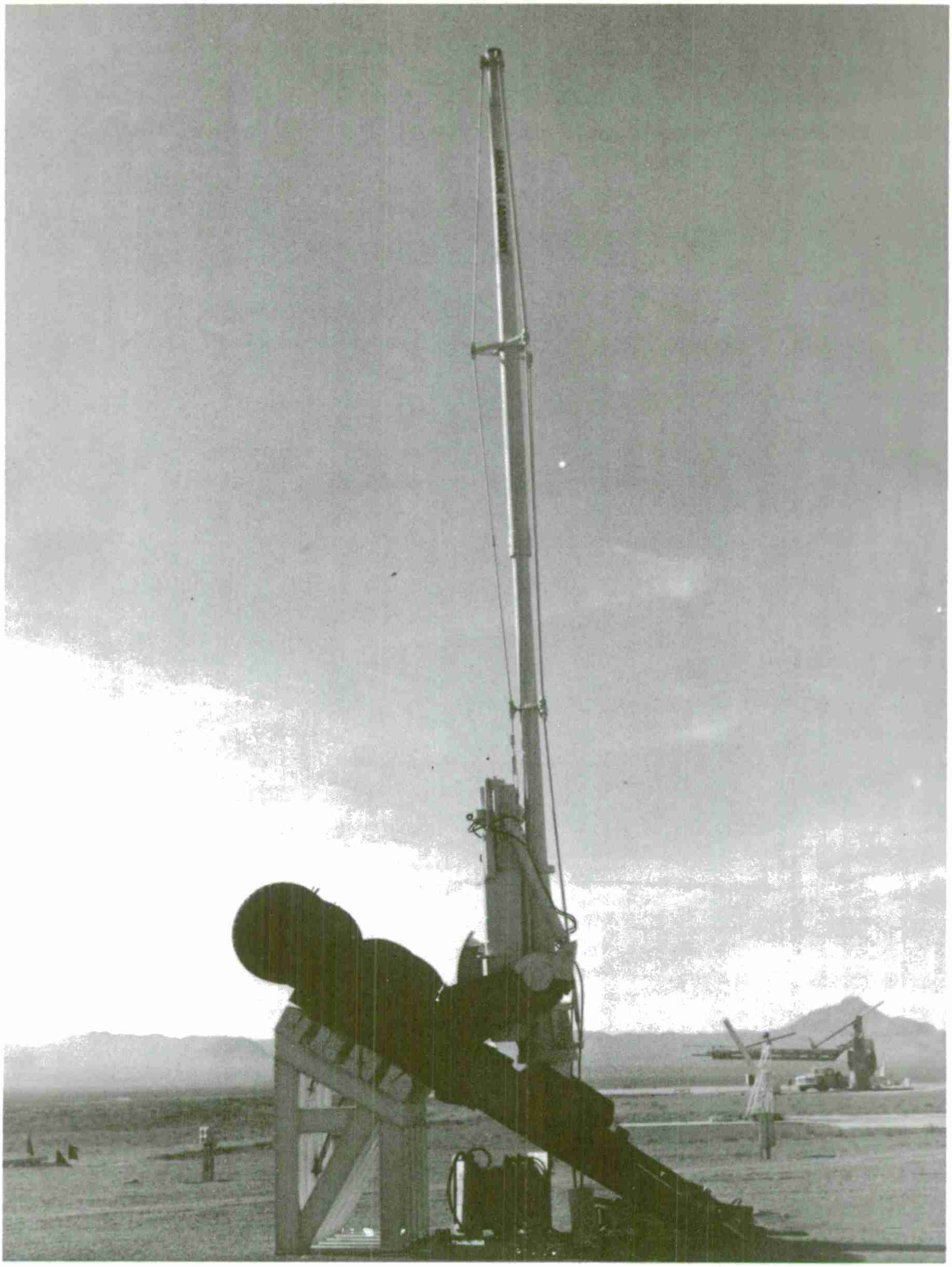

Figure 1. 5-Inch Probe Gun

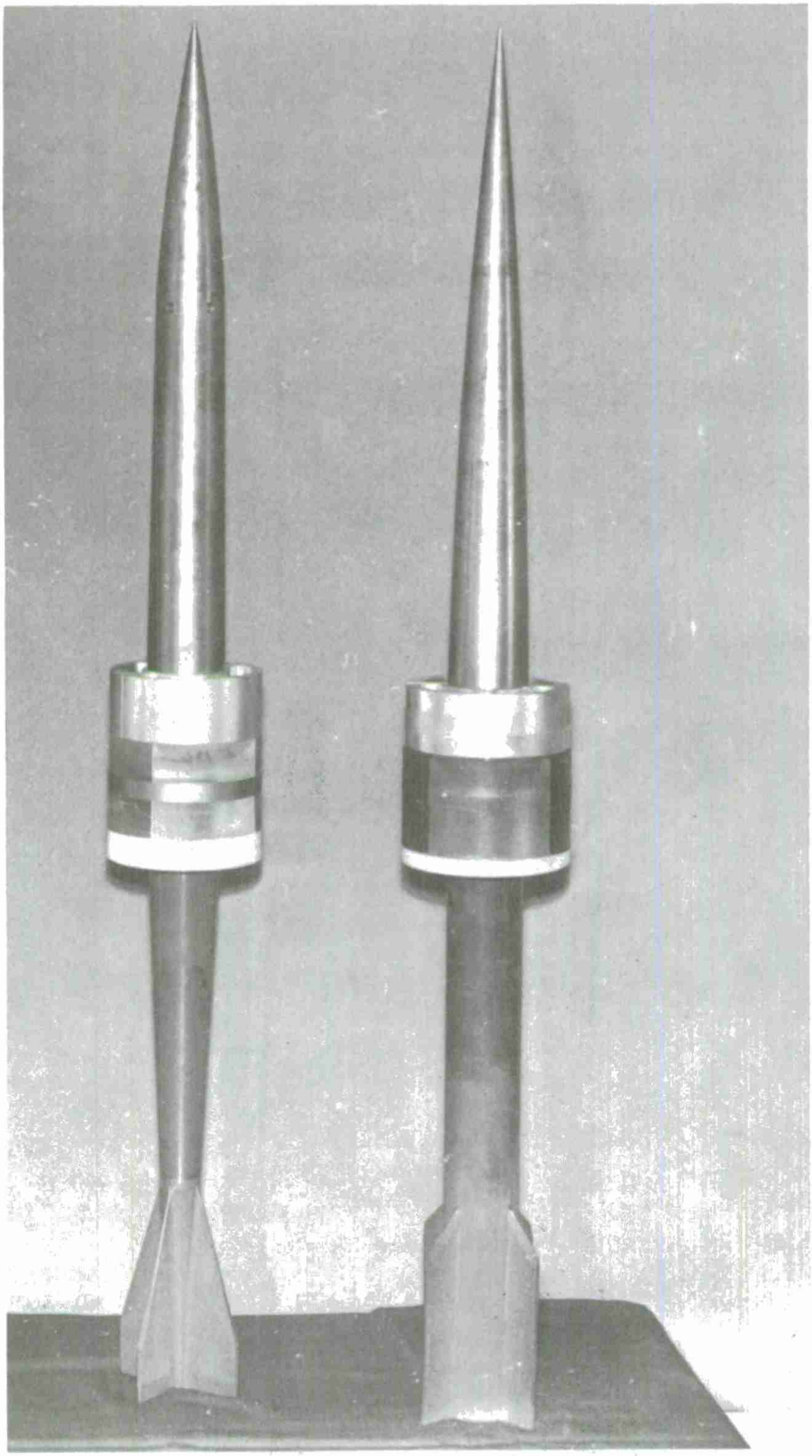

Figure 2. 5-1, 5-3 Projectiles With Sabots

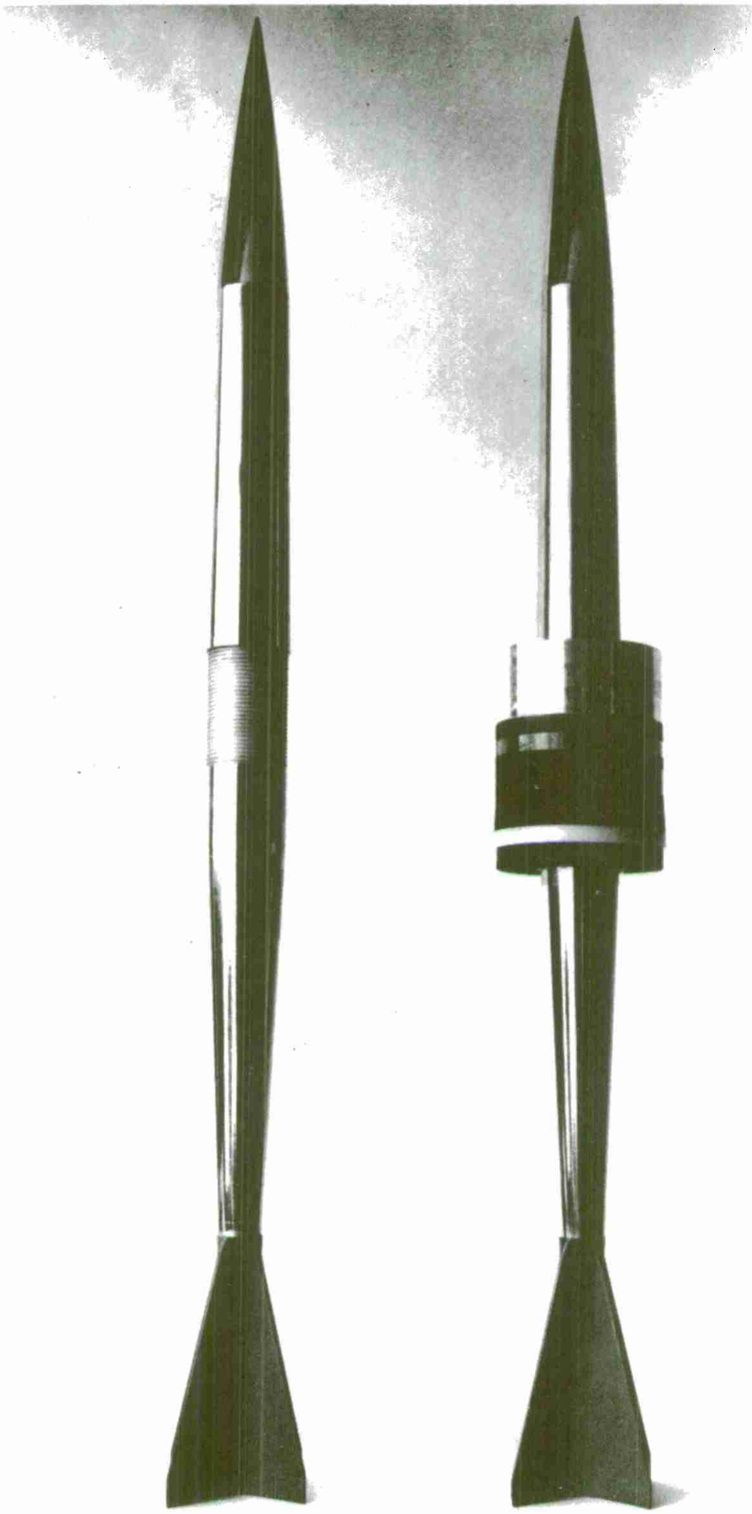

Figure 3. 5-1 Projectiles

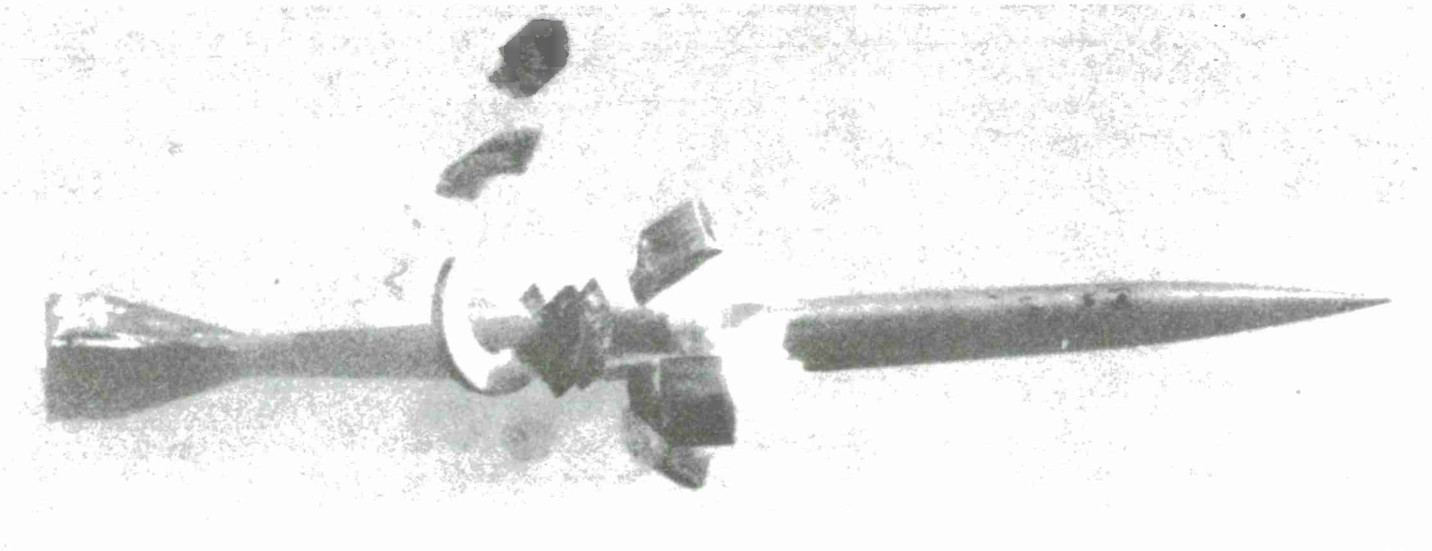

Figure 4. 5-1 Projectile With Sabot Separation, Round 6

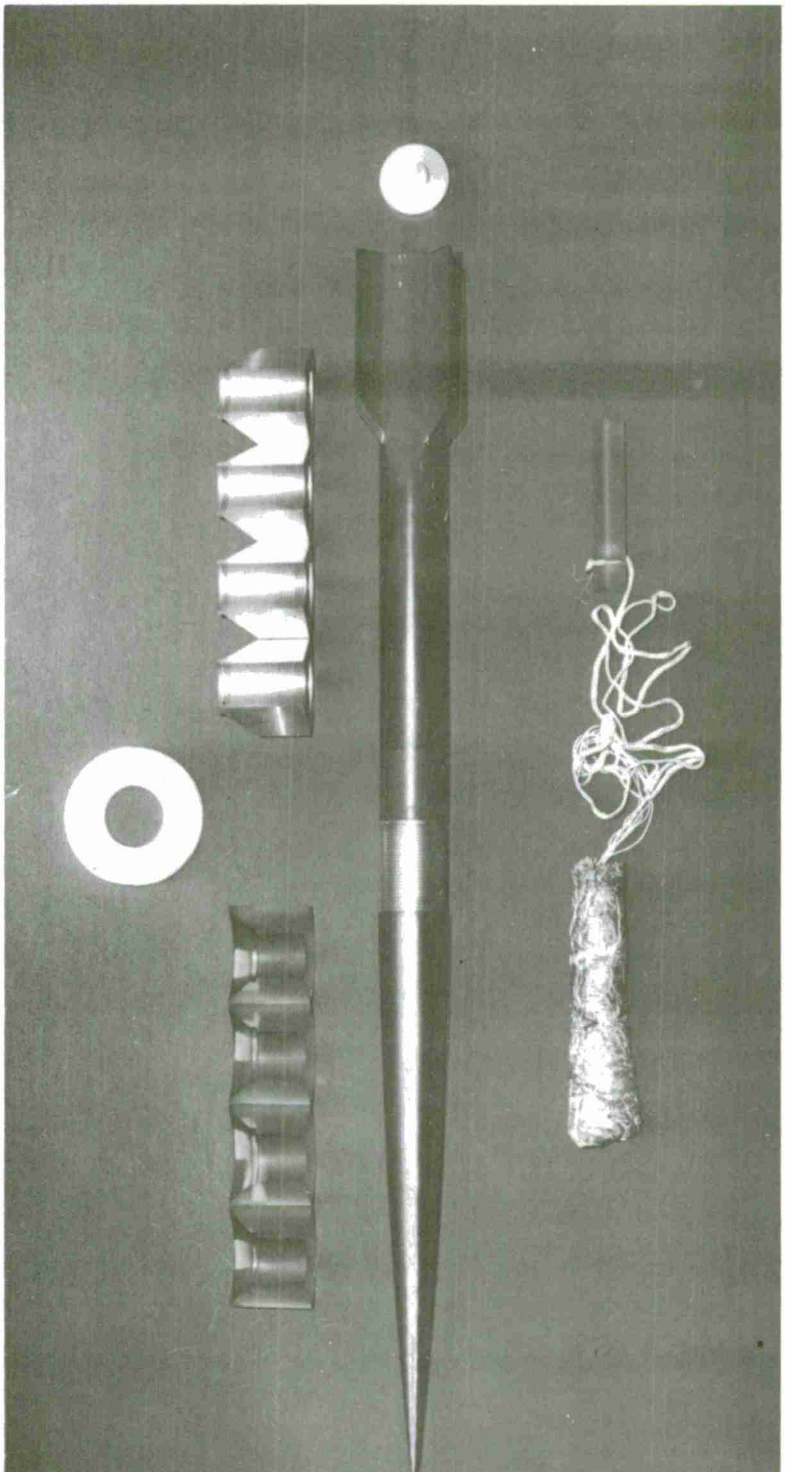

Figure 5. 5-3 Projectile

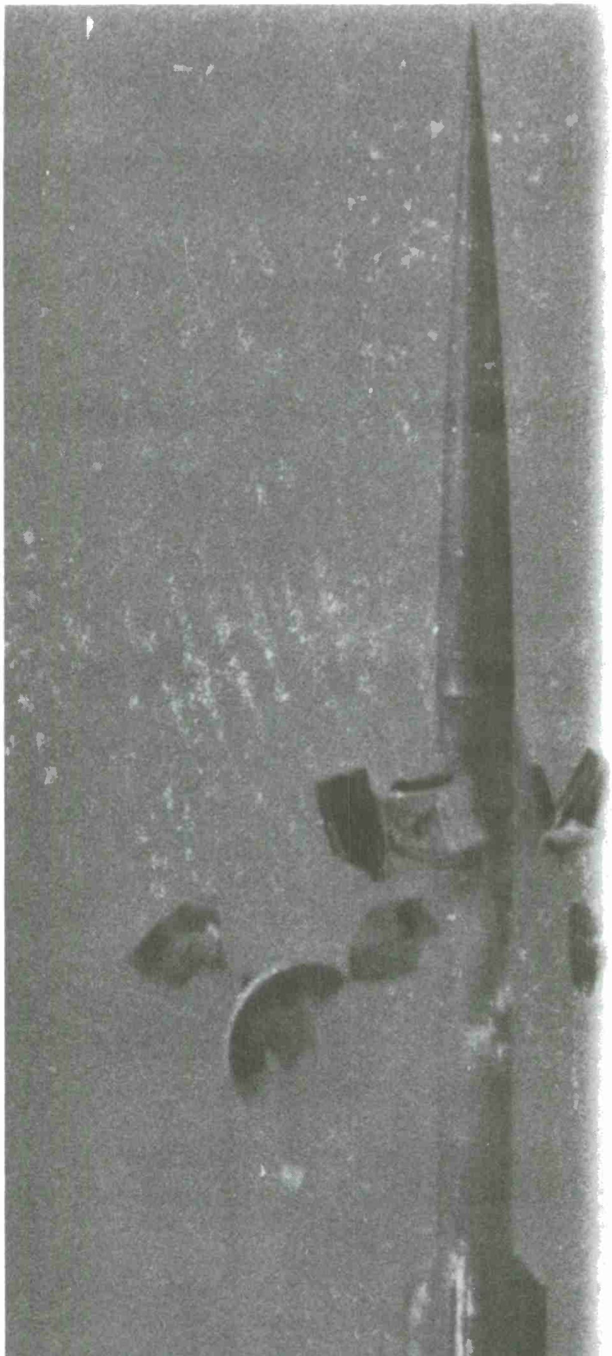

Figure 6a. 5-3 Projectile, Round 2

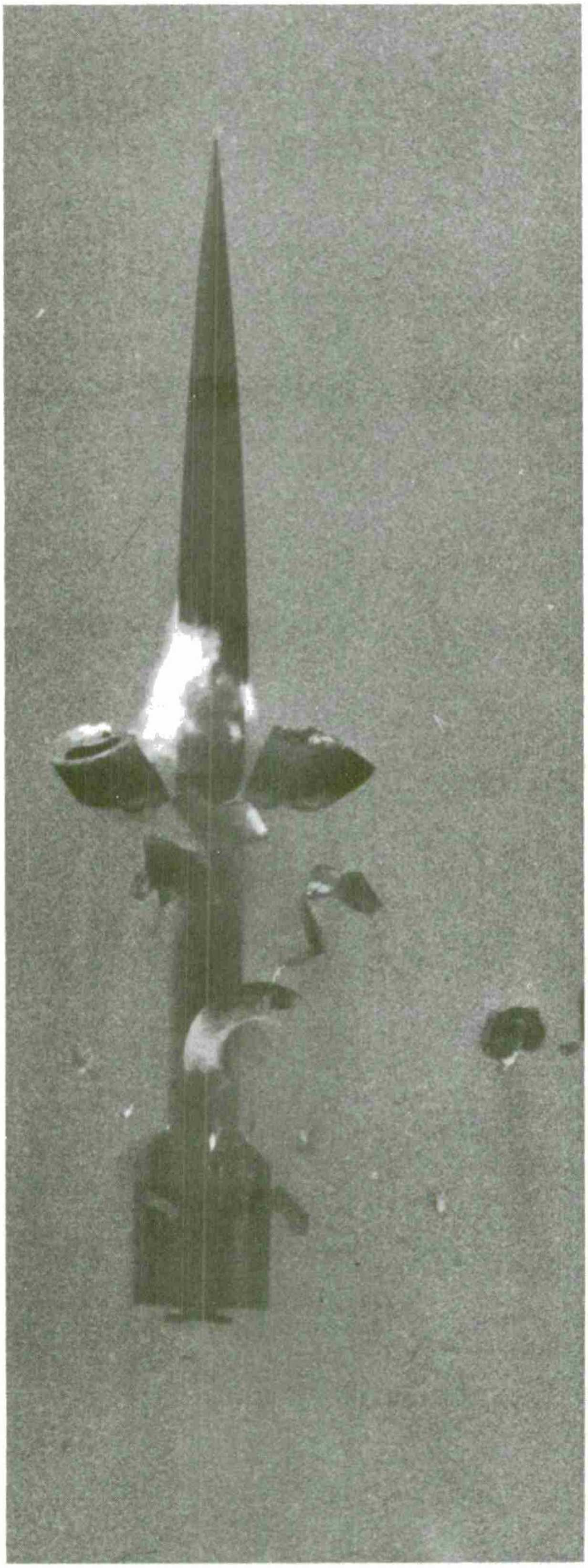

Figure 6b. 5-3 Projectile, Round 5

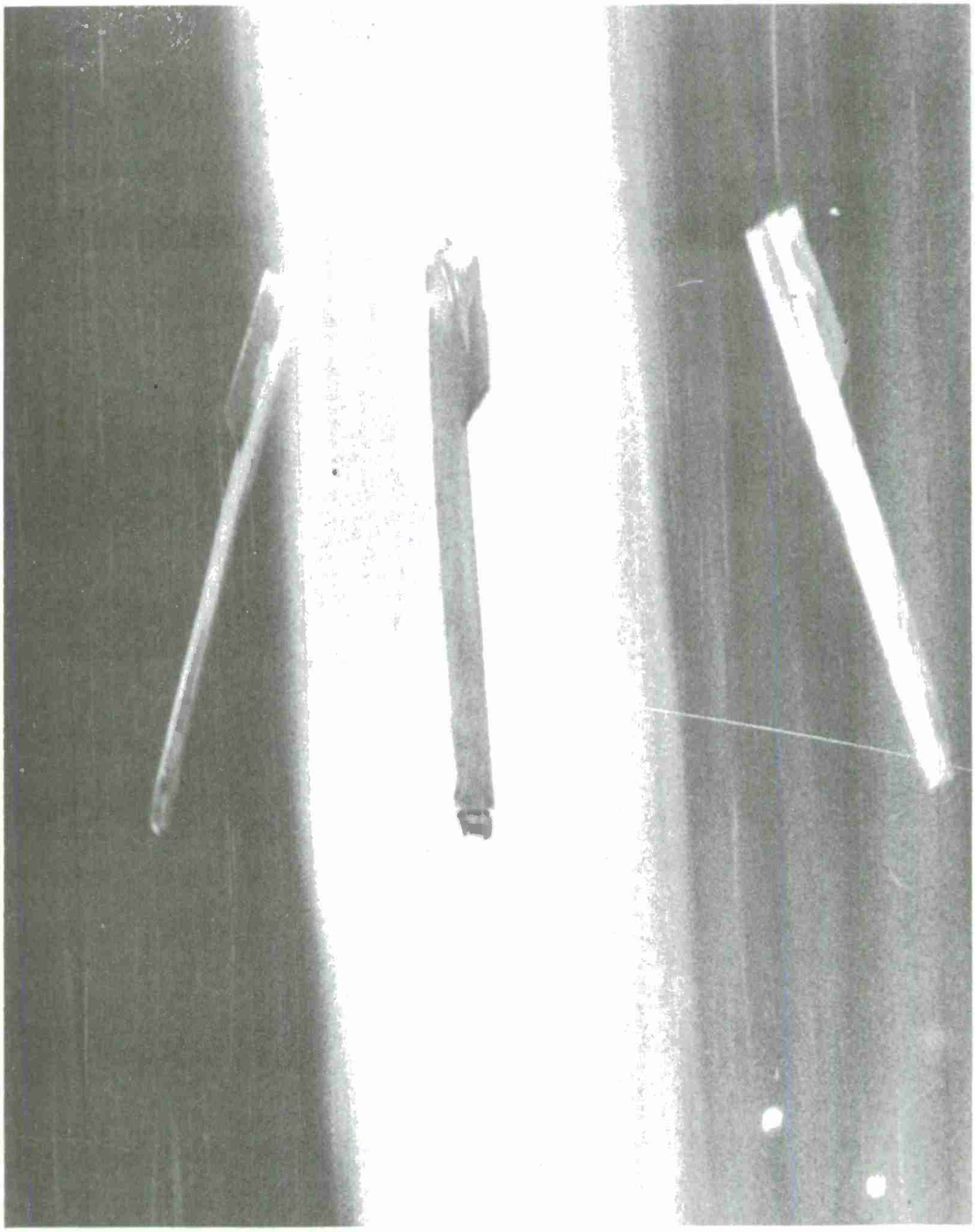

Figure 7. 5-3 Projectile, Round 4

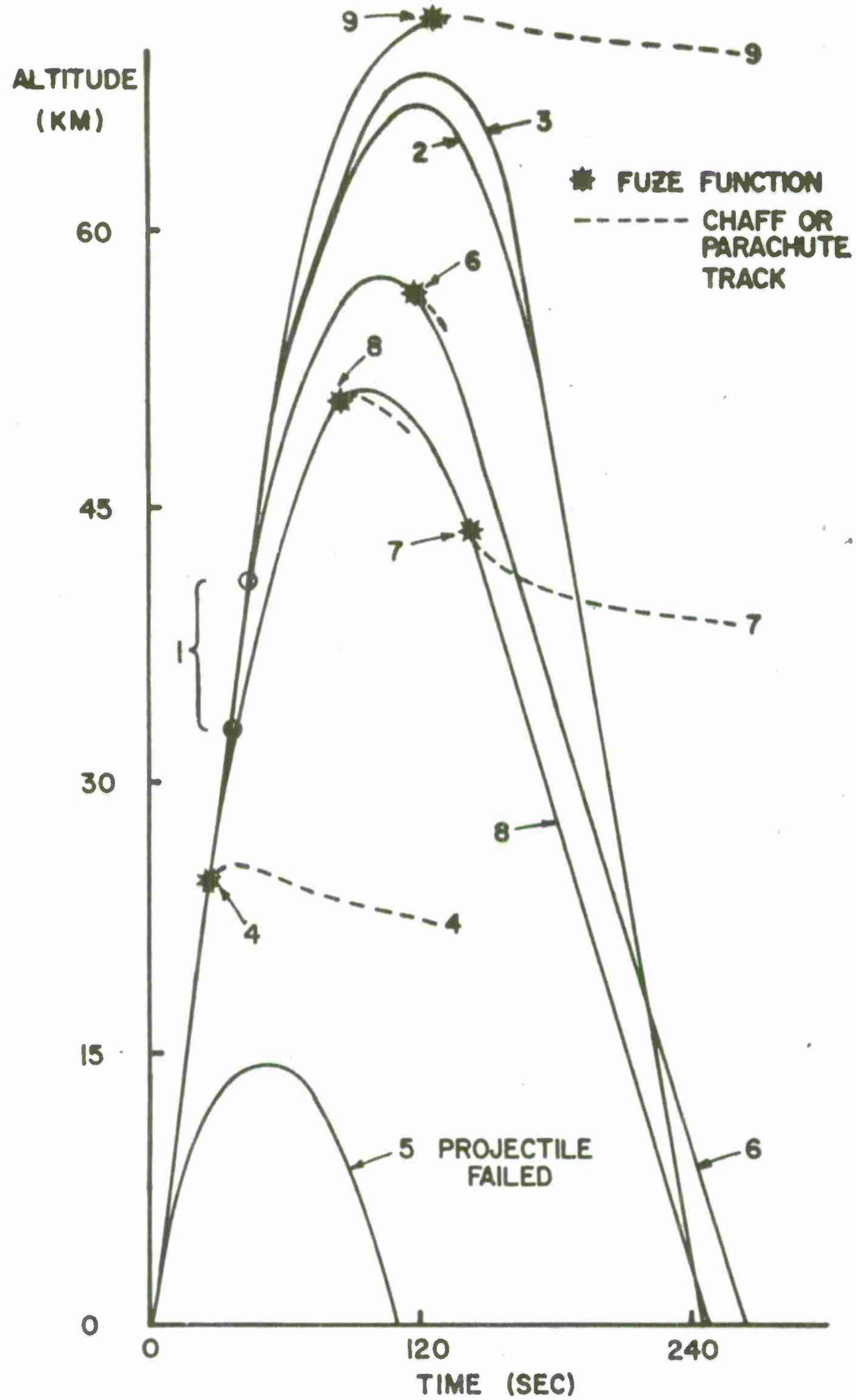

Figure 8. Trajectories Altitude Vs. Time, Series II: Rounds 1, 2, 3, 9 (5-1), Rounds 4, 5, 6, 7, 8 (5-3)

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1. E.D. Boyer, "Five Inch HARP Tests at Wallops Island, September 1963," Ballistic Research Laboratories Memorandum Report 1532, January 1964. AD 430232.

2. E.D. Boyer, "Five-Inch HARP Tests at Barbados, West Indies, January-February 1966," Ballistic Research Laboratories Memorandum Report 1771, July 1966. AD 640438.

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5. L.E. Williamson, "Gun-Launched Vertical Probes at White Sands Missile Range," Atmospheric Sciences Office, ECOM-5030, February 1966. AD 482330.

6. E.D. Boyer and L.E. Williamson, "Five-Inch HARP System - Initial Test Series - Fort Greeley, Alaska," Ballistic Research Laboratories Technical Note 1657, May 1967. AD 655267.

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