AD-763 331

HNS/TEFLON EXPLOSVIE CHARGES FOR THE APOLLO 17 SEISMIC EXPERIMENT, LSPE

E. Eugene Kilmer

Naval Ordnance Laboratory
White Oak, Maryland

10 May 1973

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Naval Ordnance Laboratory White Oak, Silver Spring, Maryland 20910	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE
HNS/TEFLON Explosive Charges for the APOLLO 17 Seismic Experiment, LSPE

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(First name, middle initial, last name)*
E. Eugene Kilmer

6. REPORT DATE 10 May 1973	7a. TOTAL NO. OF PAGES ~~111 + 15~~ 21	7b. NO. OF REFS 8
8a. CONTRACT OR GRANT NO. b. PROJECT NO. NOL 998/NASA c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) NOLTR 73-44 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*	

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY NASA Lyndon B. Johnson Space Center Houston, Texas 77058

13. ABSTRACT

ABSTRACT: A new plastic bonded explosive composed of HNS and Teflon was used in seismic charges on the recent APOLLO 17 space mission. Eight of the explosive charges were transported to the lunar surface aboard the LM vehicle and were subsequently detonated from earth. This report is concerned with the physical and detonation properties of dry blended HNS/TEFLON explosive charges and how such charges responded to environmental conditioning. Thermal cracking of the charges occurred, but this cracking did not affect charge performance.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Plastic Bonded Explosives						
New Explosives						
Thermally Stable Explosives						
Explosive Properties						
Hexanitrostilbene (HNS)						
PBX Explosive, HNS/TEFLON						
LSPE						
Seismic Explosive Charges						
APOLLO 17 Explosives						

DD FORM 1 NOV 65 1473 (BACK)
(PAGE 2)

HNS/TEFLON EXPLOSIVE CHARGES FOR THE APOLLO 17 SEISMIC EXPERIMENT, LSPE

Prepared by:
E. Eugene Kilmer

ABSTRACT: A new plastic bonded explosive composed of HNS and Teflon was used in seismic charges on the recent APOLLO 17 space mission. Eight of the explosive charges were transported to the lunar surface aboard the LM vehicle and were subsequently detonated from earth. This report is concerned with the physical and detonation properties of dry blended HNS/TEFLON explosive charges and how such charges responded to environmental conditioning. Thermal cracking of the charges occurred, but this cracking did not affect charge performance.

EXPLOSION DYNAMICS DIVISION
EXPLOSIONS RESEARCH DEPARTMENT
NAVAL ORDNANCE LABORATORY
WHITE OAK, SILVER SPRING, MARYLAND

NOLTR 73-44 10 May 1973

HNS/TEFLON Explosive Charges for the APOLLO 17 Seismic Experiment, LSPE

This is a report on part of the work done on developing the "Explosive for the Lunar Seismic Profiling Experiment (LSPE) (U)". The work was conducted for NASA, Lyndon B. Johnson Space Center Houston, Texas under Task NOL 998/NASA (T-558).

The Naval Ordnance Laboratory (NOL) developed explosive charges were transported to the moon and test fired there as part of the active seismic experiment conducted during the APOLLO 17 space flight.

This report discusses in particular the results of the environmental conditioning tests conducted on the explosive charges and the effects of the cracks caused by environmental conditioning on explosive performance.

The author wishes to acknowledge the streak camera studies by N. Coleburn and L. Roslund of the Naval Ordnance Laboratory and the environmental testing accomplished by A. English and N. Schlemm of the Naval Weapons Laboratory. The identification of the commercial materials implies no criticisms or endorsement of them by NOL.

ROBERT WILLIAMSON II
Captain, USN
Commander

C. J. ARONSON
By direction

CONTENTS

TABLES

ILLUSTRATIONS

1.0 INTRODUCTION

1.1 Many different kinds and types of explosives have been used by astronauts to perform various functions during space flight and lunar missions. Of these many applications, one recently was in a seismic refraction system[1]. During the APOLLO 17 mission a Lunar Seismic Profiling Experiment (LSPE) was set up. This experiment utilized artificially induced seismic energy to obtain data on the physical properties of the lunar surface. The seismic energy was produced by detonating explosives on predetermined deployment sites. The explosive selected for this experiment was a blend of HNS (2,2', 4,4', 6,6', Hexanitrostilbene)[2] 90% with a 10% binder of powdered TEFLON-7C*. The Naval Ordnance Laboratory (NOL) developed this plastic bonded explosive (PBX) for the NASA Lyndon B. Johnson Space Center The expected use of this material in the lunar environment led to a study of the reaction of an HNS charge detonated in a vacuum as discussed in reference 3. Explosive charges of HNS/TEFLON have been prepared for other APOLLO missions[4] (ALSEP) but in small quantities and from a different type of TEFLON material. The purpose of this paper is to present some of the detonation properties of the explosive material used in the APOLLO 17 lunar mission and to show that the detonation properties of the charges were unaffected by the adverse environmental treatment to which they were subjected.

2.0 DETONATION PROPERTIES

2.1 The sizes of the explosive charges required to provide the induced seismic shock waves varied with the predetermined distances of deployment from the main geophone array. The smallest charge weighed 1/8 pound and was deployed at a distance of about 175 meters. The charge weights were 1/8, 1/4, 1/2, 1, 3, and 6 pounds. (See Figure 1). Some of the thermal properties of HNS/TEFLON are shown in Table 1.

2.2 As a part of determining the explosive properties of the HNS/TEFLON-7C, the detonation velocity was measured. To view the shock arrival along the edge and base of the charge, a streak camera arrangement was used. The edge was observed directly, while a mirror reflected the image indirectly from the bottom of the charge. The arrangement is shown in Figure 2A.

---

*TEFLON is a registered trade mark of the E. I. duPont de Nemours Co.

Scribe marks were placed on the side and base of the explosive charge to increase the intensity of the light as the shock wave moved toward and across the base of the charge.

2.3 To minimize time and cost, it was decided to test first the 1-pound charges. The charge height was 2.750", the diameter 2.750", and the density approximately 1.6 g/cc. The charge was initiated by an explosive lead acting over an air gap. The streak camera record is shown in Figure 2B. Shock arrivals, denoted by the increased intensity of light viewed through the camera slit, were plotted graphically as time vs distance from a single initiation point. It was difficult to determine accurately the location of the initiation point because of the large surface area exposed to the hot fragments and gases from the explosive lead. Assuming the detonation started at a point projected along the centerline of the lead as it interfaced with the surface of the main charge, the calculated detonation velocity from the side arrival measurement was 6650-6700 m/sec. from the end measurement 6850-6950 m/sec. The shock arrival values towards the base of the charge appear to be of a constant velocity with no apparent "fading" of the detonation. Thus, the 1-pound explosive charge of HNS/TEFLON-7C will support detonation in the specified configuration. The intended engineering configuration (Figure 3) of the hardware was such that the point of initiation would be along the center axis of the 1/8-pound charge and would be displaced as the charge size increased. The arrangement of the associated electronics package above the charge determined the location of the initiation point.

2.3 The second streak camera shot was made on a special 5-pound charge. The height was 4.185", the diameter 5.007", and the density 1.68 g/cc. The detonation velocity from side arrival of the shock was 6800-6950 m/sec; that from the end arrival 7000-7100 m/sec. These values are slightly higher than for the 1-pound shot, but it should be pointed out that the density of the charge is also higher. On the basis of the results of these tests, it was concluded that the HNS/TEFLON-7C should perform properly.

3.0 ENVIRONMENTAL TESTING OF THE EXPLOSIVE PACKAGE

3.1 The environmental testing was accomplished in various phases with the explosive section of the experimental package tested separately from the electronics section. Mass simulators were used to replace actual electronics and timing mechanisms. A typical test vehicle is shown prior to assembly in Figure 4A. Note the foam fill used to reduce the air volume when the various size explosive charges are used. The assembly is shown in Figure 4B.

3.2 Since the explosive packages were transported to the lunar surface attached to a transport frame, the environmental tests were conducted with the explosives attached to the transport frame for proper simulation. A typical set of 8 charges is shown attached to the frames in Figure 5. The program for sequentially testing the prototype hardware is described below.

3.2.1 Thermal Cycling (Design Limit). The packages were exposed to the following time/temperature profile:

Reduce temperature from ambient to -100°F (0-3 hrs)
Raise temperature to -40°F (3-6.5 hrs)
Raise temperature to 250°F (6.5-11.5 hrs)
Reduce temperature to 190°F (11.5-16 hrs)
Reduce temperature to -100°F (16-18 hrs)
Raise temperature to Ambient 75°F (18-24 hrs)

The packages were X-rayed before and after the thermal shock. It was apparent from the radiographs following the tests that cracking occurred in the larger charges. Further investigation revealed that the charges above the 1/4-pound size, i.e., 1/2, 1, 3, and 6 pounds showed various degrees of cracking brought about by the thermal cycling. A radiograph of typical cracking in the cubical geometry (6 pounds) and the cylindrical geometry (3 pounds) is shown in Figure 6. In the cubical geometry the cracks were both vertical and cross/axis to the charge. The cylindrical charges all exhibited the same cross/axis cracking.

At this point several questions arose: whether a charge could be fabricated to withstand this thermal cycling without cracking, and whether the cracked charges were safe or reliable. A literature search revealed little on the safety in handling or the reliability of performance of an explosive charge containing fissures. The consensus was to continue testing.

3.2.2 Acceptance Vibration. The specification for this test was to vibrate from 5-12-100 hz at 0.15" double amplitude or 1.0-G peak. The transport frames were vibrated on three (3) orthogonal axes with the maximum running time of 1.4 minutes for each axis.

A review of radiographs following this vibration test revealed no additional cracking or powdering of the explosive.

3.2.3 Vibration Tests (Design Limit). The units were then subjected to the following vibration test:

a. Vibrate 5-100-5 hz at 0.2" double amplitude with a crossover at 1.4 G and continue to sweep at 1.4 G. Subject to one complete cycle only up and down. The approximate running time was 2.9 minutes. The units were tested on three (3) orthogonal axes using the above values.

b. Vibrate at 6 hz, 1.5 G for 10 seconds on each axis.

c. All units were vibrated, for random noise, to the following specification:

20-40 hz	12 db/octave increase
40-85 hz	0.03 G^2/hz
85-110 hz	6 db/octave increase
110-400 hz	0.05 G^2/hz
400-460 hz	6 db/octave
450-1100 hz	0.04 G^2/hz
1100-2000 hz	12 db/octave

The total time for each axis was one minute.

3.2.4 Shock Testing (Design Limit). Each unit was subjected to shock on each axis at 15-G peak sawtooth with each having a 10-millisecond rise to peak and 1-millisecond fall for a total duration of 11 milliseconds.

The X-rays following these tests revealed no additional fissures over the original ones caused by the thermal cycling.

4.0 DISCUSSION OF EXPLOSIVE CHARGE CRACKS

4.1 Considerable effort went into the fabrication of the explosive charges at NOL. Included were studies to determine the compressive strength and the thermal properties of the HNS/TEFLON-30 and the HNS/TEFLON-7C. The cracking phenomenon in explosive charges, both castings and pressed charges, is not new but has been covered by few publications. A discussion of the effect of crack-like voids in high explosive charges on their performance is given in reference 5. It was there pointed out that, depending on the length and width of the cracks and the weight of the explosive, the formation of high pressure jets could be produced by explosion of a cracked charge. However, there was no indication that the explosion would not propagate across the crack. Detrimental effects, if any, would depend on the performance required of the explosive, i.e., whether it is a simple explosion, a wave shaping explosive device, or perhaps a shaped charge used for penetrating or cutting of targets. Since for the LSPE experiment the energy from the explosion is to be used to simulate a seismic shock wave, any minor jetting from the cracks would not appear to detract from the explosive's effectiveness. Also, based on the environmental task, there appeared to be no safety problem associated with transportation of the charges from earth to the moon and throughout the lunar deployment.

4.2 On the question of reliability of the explosive train functioning, one charge of each explosive weight (including the 1/8- and 1/4-pound uncracked charges) was tested before a streak camera to determine if the detonation wave was degraded or thought to be unreliable because of either the cracking or the exposure to the various environments. There was no indication from the results of any fading or decay in the shock velocity associated with any of the charges subjected to the environmental testing. The data indicated a detonation velocity of 6900 m/sec, which is comparable to that obtained from units not subjected to the testing.

4.3 The complete unit as shown in Figure 7 was assembled in the field and tested. The explosive packages were deployed and successfully fired according to a test plan which simulated expected distances of travel on the lunar surface for the LSPE. During the APOLLO 17 mission, the LSPE was transported to the lunar surface aboard the LM in the Quad IV Section. The explosive packages were removed from the LM and deployed by the astronauts in a pattern typical of the one shown in Figure 8. They were successfully fired from earth on 17 December 1972.

5.0 CONCLUSIONS

5.1 HNS/TEFLON-7C blend has been successfully used to fabricate a high density, machinable explosive charge which was found to be safe and reliable in the LSPE explosive package.[6,7]

5.2 The detonation velocity measurements with the streak camera indicated a stable detonation in the HNS/TEFLON-7C explosive charges. Cracking in the large explosive charges following thermal cycling did not affect their performance.

5.3 It has been determined from the results of thermal cycling, acceptance vibration, and design shock that the cracked explosive charges fabricated from the HNS/TEFLON blend were safe to handle.[8]

5.4 Eight explosive packages were deployed on the lunar surface in the Taurus-Littrow area and all were detonated successfully from earth during the APOLLO 17 mission. Since HNS has proven to be an excellent explosive throughout all of the APOLLO missions it should be a candidate for future space explorations.

TABLE I PROPERTIES OF HNS/TEFLON COMPARED WITH HNS-II

	HNS-II	HNS/TEFLON 90/10
MELTING POINT (°C)	318	318
THEORETICAL MAXIMUM DENSITY (G/CC)	1.74	1.78
VACUUM THERMAL STABILITY 260°C (CC/GM/HR)	0.23	250° 0.52
VACUUM THERMAL STABILITY 230°C (CC/GM/HR)	NOT TESTED	0.15
ELECTROSTATIC SPARK SENSITIVITY	FIRES ABOVE 0.0001 MFD @ 1[illegible] KV	NOT TESTED
DETONATION VELOCITY (M/SEC @ DENSITY) (G/CC)	7000 1.70	6900 1.68
50% INIT PRESS (KBar) @ DENSITY (G/CC)	18.74 1.64	21.87 1.70
STEEL DENT OUTPUT (MILS)	54	43
AVAILABILITY	PROD	PILOT PROD
SPECIFICATION	WS5003	NOLS 1015

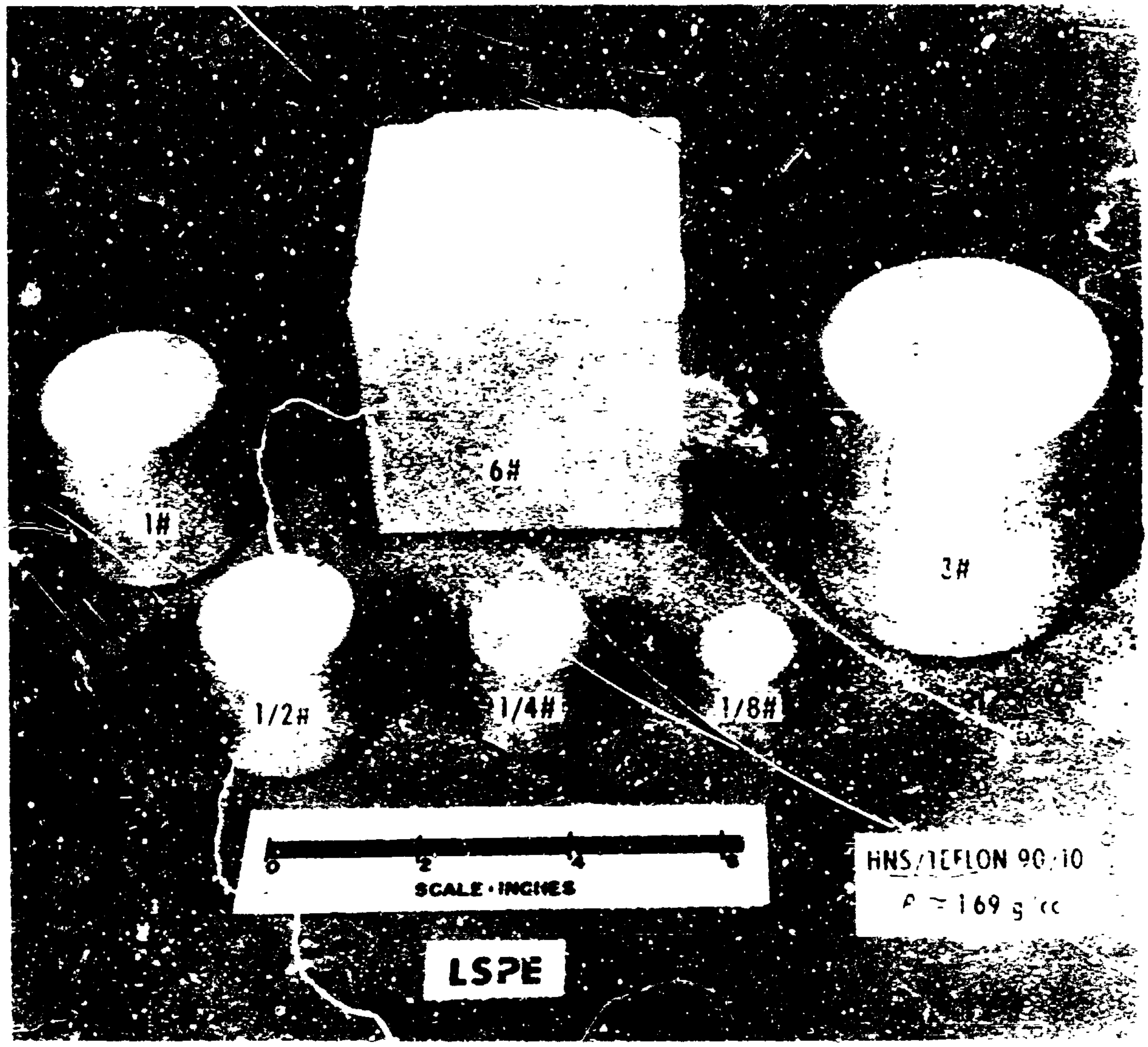

FIG. : LSPE EXPLOSIVE CHARGES

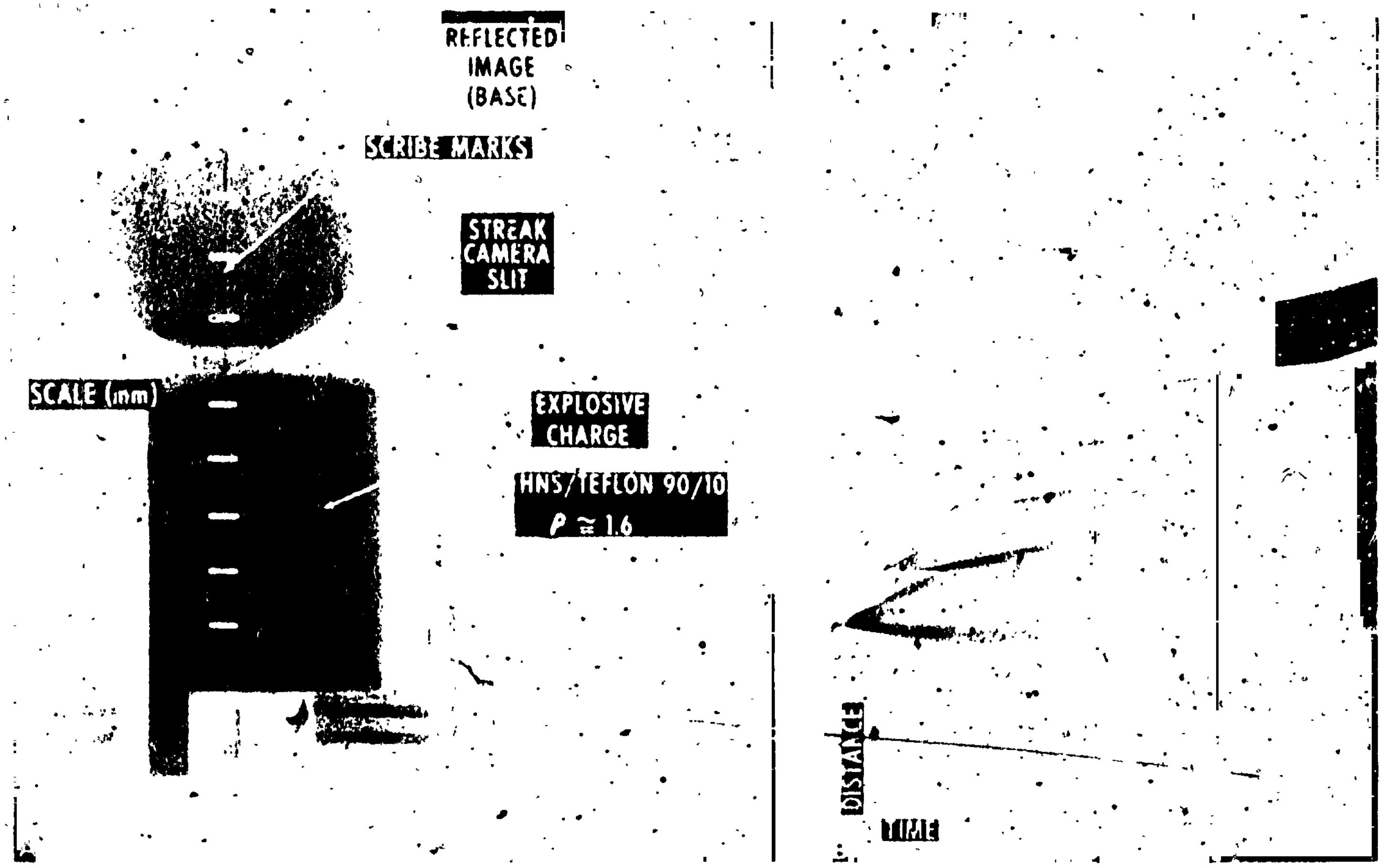

FIG. 2 DETONATION VELOCITY MEASUREMENT BY STREAK CAMERA METHOD

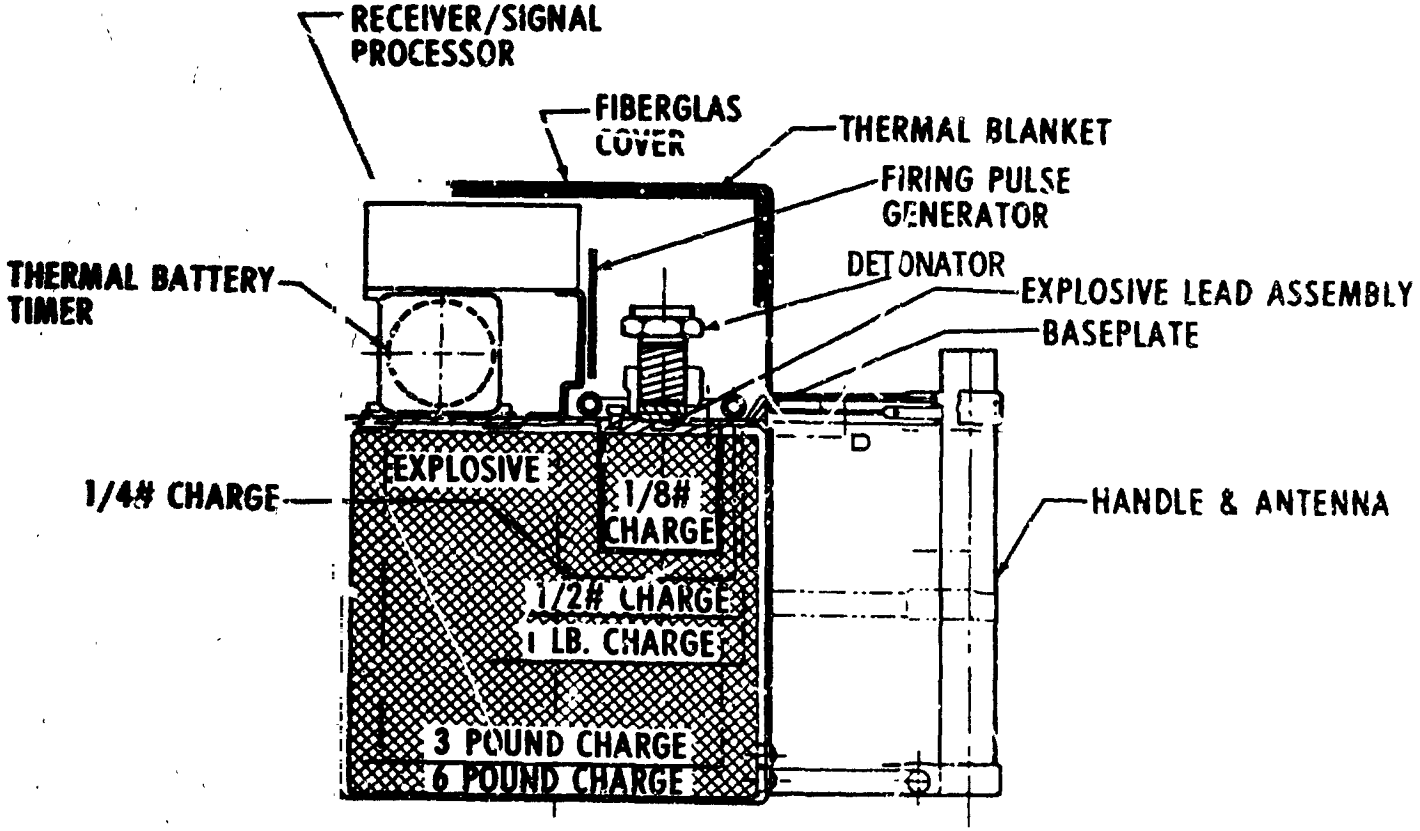

FIG. 3 EXPLOSIVE PACKAGE ASSEMBLY CROSS-SECTION (AS PER BENDIX AEROSPACE)

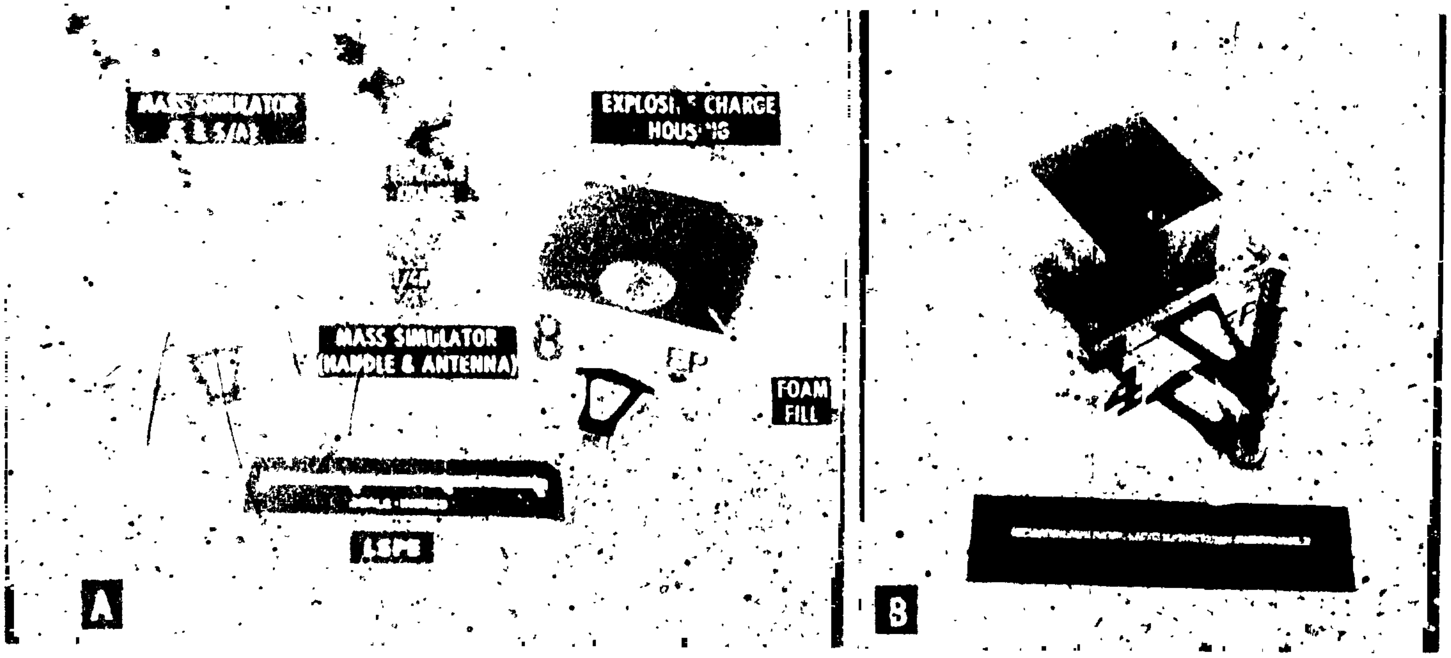

FIG. 4 COMPONENTS OF EXPLOSIVE PACKAGE SUBMITTED TO ENVIRONMENTAL TESTING

FIG. 5 EXPLOSIVE TRANSPORT FRAME MODULES

FIG. 6 RADIOGRAPHS OF TYPICAL 6-LB AND 3-LB EXPLOSIVE CHARGES AFTER THERMAL CYCLING

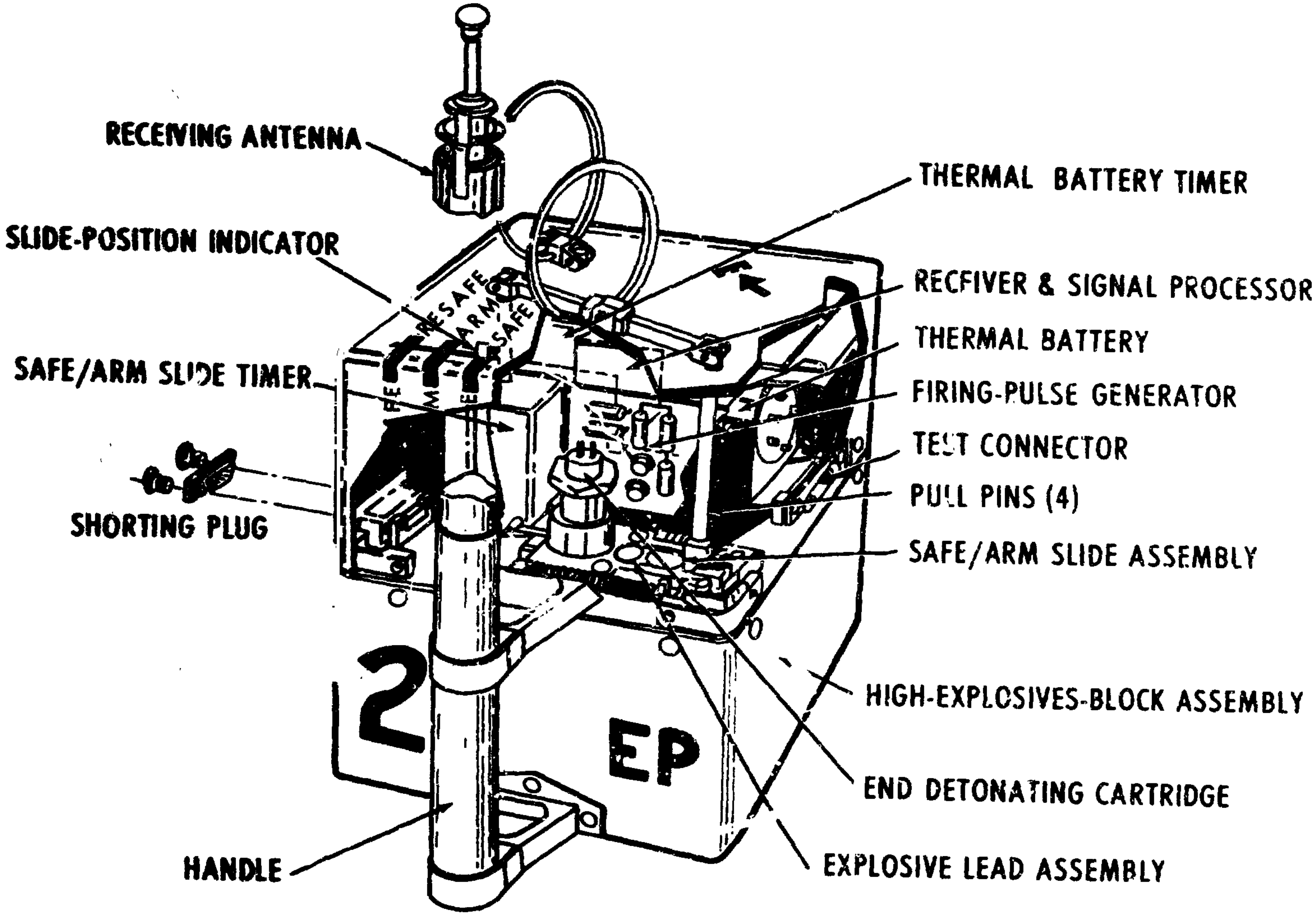

FIG. 7 LSPE EXPLOSIVE PACKAGE ASSEMBLY (BENDIX AEROSPACE)

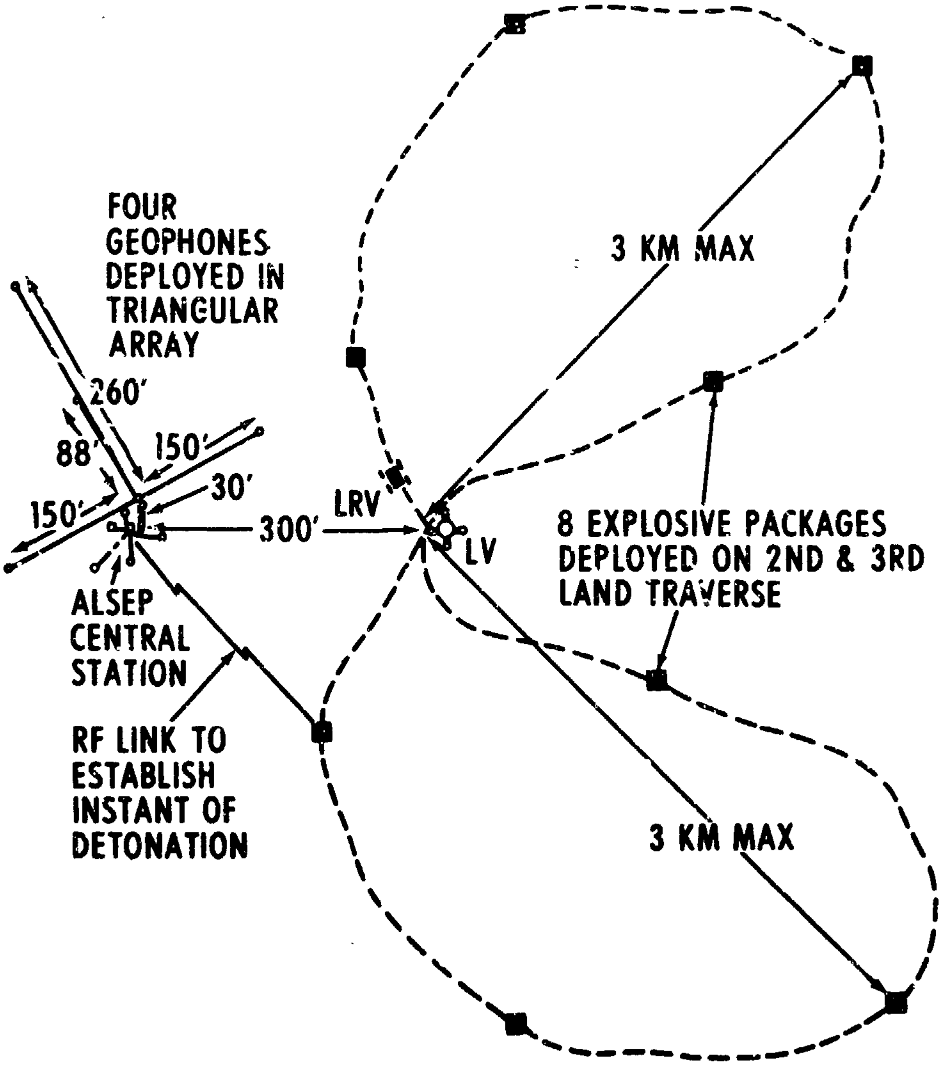

FIG. 8 LSPE DEPLOYED LAYOUT (BENDIX AEROSPACE)

6.0 REFERENCES

1. B. D. McAllister, J. Kerr, J. Zimmer, R. L. Kovach, and J. Watkins, "A Seismic Refraction System for Lunar Use", Trans. IEEE, GE-7, 164 (1969)
2. K. G. Shipp and L. A. Kaplan, "Reactions of a Substituted Polynitrotoluene II. The Generation and Reactions of 2,4,6-trinitrobenzylanion", J. Org. Chem. 31, [illegible] 857 (1966)
3. T. J. Ahrens, C. F. Allen, and R. L. Kovach, "Explosive Gas Blast: The Expansion of Detonation Products in Vacuum", Appl. Phy. J., 42, 2, 815 (1971)
4. E. E. Kilmer, "Heat-Resistant Explosives for Space Applications", J. Space. Roc., 5, 10, 1216 (1968)
5. NAVORD Rpt 5699, V. Milani, L. E. Starr, and G. W. Reynolds, "The Effect of Crack-Like Voids in High Explosive on Damage of Steel Targets in Close Proximity to the Charge", 7 Jun 1957 (U)
6. NOLTR 72-294, L. J. Montesi, "The Safety and Reliability of the Safe/Arm Mechanism Designed for the NASA/LSPE Program", 23 Jan 1973 (U)
7. NOLTR 72-45, C. C. Misener, "Explosives for Lunar Seismic Profiling Experiment", 15 May 1972 (U)
8. NWLTR 2888, A. L. English, "Environmental Test Report for Explosive Charge Assemblies for a Lunar Seismic Experiment", 4 Jan 1973 (U)