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EARTH PENETRATOR WEAPON SYSTEM DESIGN (U)

W. J. PATTERSON AND N. A. LAPETINA; SANDIA NATIONAL LABORATORIES

PRESENTED AT THE

AIAA BMO FUTURE SYSTEMS
AND
MISSILE SYSTEMS TECHNOLOGY
WORKSHOP

MARCH 22 - 25, 1988

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Title Surv., Penetrator Weapon Development Division Date 3/21/88

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INTRODUCTION

Design rationale for the mechanical design (shapes, mass properties, and materials) of the Earth Penetrator Weapon (EPW) is discussed. The major subsystems are defined; the major factors affecting the mechanical design of the EPW system, such as target and delivery system considerations, terradynamic stability, and structural survivability, are examined. Two EPW designs are presented. An overview of the EPW field test program is provided. Finally, EPW weight reduction, including lighter weight materials, is also discussed.

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EARTH PENETRATOR WEAPON SYSTEM DESIGN

W. J. PATTERSON AND N. A. LAPETINA; SANDIA NATIONAL LABORATORIES

INTRODUCTION

MAJOR EPW SUBSYSTEMS

EPW SYSTEM DESIGN RATIONALE

TEST PROGRAM

WEIGHT REDUCTION

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[redacted]

MAJOR EPW SUBSYSTEMS

The EPW design consists of three major subsystems: (1) nuclear package, (2) weapon electrical system (WES), and (3) EPW case. The nuclear laboratories (Los Alamos National Laboratory and Lawrence Livermore National Laboratory) are responsible for the design of the nuclear package and Sandia National Laboratories are responsible for the design of the WES and EPW case.

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EARTH PENETRATOR WEAPON SYSTEM DESIGN

MAJOR EPW SUBSYSTEMS

EPW CASE

NUCLEAR SYSTEM

WARHEAD ELECTRICAL SYSTEM

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FIGURE OF GENERIC EPW SYSTEM DESIGN

This figure illustrates a typical EPW system design where the nuclear and WES assemblies are packaged in the EPW case. The WES is typically located in the aft section to simplify assembly. The physical properties of an EPW are typically characterized by its overall length, average diameter, weight, and center of gravity (CG) location.

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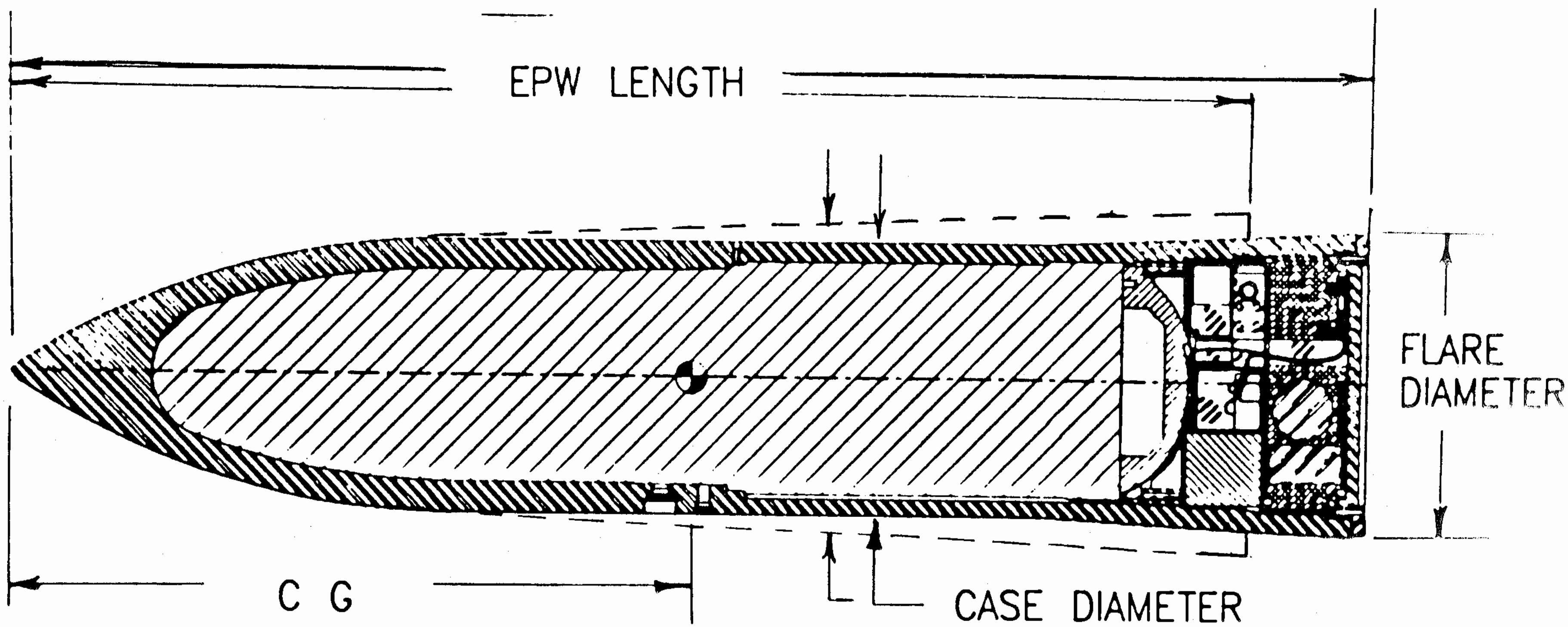
EARTH PENETRATOR WEAPON SYSTEM DESIGN



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EPW SYSTEM DESIGN RATIONALE

The EPW design was based on an evolutionary process which consisted of:

(1) a concept study to generate a preliminary EPW design including size and shape estimates of the nuclear and WES assemblies,

(2) a design of an EPW case based on these estimates and present earth penetration/terradynamic technology,

(3) an evaluation of the EPW case design through a coupled experimental/analytical program utilizing most recent understanding of target characteristics,

Note: A "bona fide" EPW case must be designed prior to the development and test evaluation of the nuclear and WES assemblies.

(4) an assessment of nuclear system packaging/interface requirements, and

(5) a WES design to meet the necessary requirements.

EARTH PENETRATOR WEAPON SYSTEM DESIGN

EPW SYSTEM DESIGN RATIONALE

REQUIRED INFORMATION FOR FIRST DESIGN ITERATION

EPW CASE DESIGN

- TERRADYNAMIC CONSIDERATIONS
- TARGET CHARACTERISTICS THAT IMPACT EPW SURVIVABILITY

NUCLEAR SYSTEM LOCATIONS

WARHEAD ELECTRICAL SYSTEM CONCERNS

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REQUIRED INFORMATION FOR FIRST DESIGN ITERATION

Information required for the first design iteration includes a definition of the targets, type of delivery systems available, and estimate of nuclear yield required to destroy the targets. The target definition must describe the underground structures (for nuclear yield study) and surrounding geologies (for nuclear yield and penetrator survivability studies). The delivery systems presently under consideration are ICBMs (with MaRV to tailor the impact conditions to EPW survivability limits), cruise missiles, and gravity bombs. This information is then used, by system analysts, to determine the nuclear yield required to destroy the targets of interest. Once the required yield range is established, the design begins by integrating the EPW case and WES with the nuclear package.

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EARTH PENETRATOR WEAPON SYSTEM DESIGN

REQUIRED INFORMATION FOR FIRST DESIGN ITERATION

- TARGET SET DEFINITION
  - LOCATION, DEPTH, SIZE AND HARDNESS OF STRUCTURES
  - SITE GEOLOGY, SOIL AND ROCK MATERIAL PROPERTIES, TOPOLOGY,
- POTENTIAL DELIVERY SYSTEMS
  - ICBM, CRUISE MISSILE, OR GRAVITY BOMB
- ESTIMATE OF NUCLEAR YIELD REQUIRED TO DESTROY TARGETS

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EPW CASE DESIGN CONSIDERATIONS

The EPW case design consists of defining the internal and external contours and selecting the appropriate case material. The internal definition is driven by the dimensions and load bearing requirements of the nuclear and WES assemblies. The external definition, though somewhat reflective of the inner contour, is driven by minimizing the length, diameter, and weight while considering its terradynamic stability and structural survivability. Candidate EPW case materials must have high strength combined with high fracture toughness such

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EARTH PENETRATOR WEAPON SYSTEM DESIGN

EPW CASE DESIGN CONSIDERATIONS

INTERNAL CASE SIZING

DIMENSIONS DEPENDENT ON NUCLEAR SYSTEM AND WARHEAD ELECTRICAL SYSTEM (WES) DESIGNS

EXTERNAL CASE SIZING

DIMENSIONS OPTIMIZED FOR MINIMUM LENGTH, DIAMETER AND WEIGHT BUT MUST CONSIDER:

- TERRADYNAMIC STABILITY
- WORST CASE STRUCTURAL LOADING
- DELIVERY SYSTEM ACHIEVABLE IMPACT CONDITIONS

CASE MATERIAL

HIGH STRENGTH STEEL WITH HIGH FRACTURE TOUGHNESS

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TERRADYNAMIC CONSIDERATIONS

The EPW design must consider two primary terradynamic issues which affect survivability of the WES and nuclear system: stability and structural loading. The EPW stability is strongly influenced by its nose shape, CG location, and length-to-diameter ratio (L/D). The EPW structural loading (i.e., deceleration loads) is strongly dependent also on its nose shape and on its weight-to-cross sectional area ratio (W/A).

Factors, other than those associated directly with the EPW design, which also influence stability and structural loading include target properties, surface features, and impact conditions.

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EARTH PENETRATOR WEAPON SYSTEM DESIGN

TERRADYNAMIC CONSIDERATIONS

EPW STABILITY STRONGLY INFLUENCED BY:

EPW STRUCTURAL LOADING PRIMARILY INFLUENCED BY:

- NOSE SHAPE (SHARPER NOSED EPW RESULTS IN LOWER LOADS)
- WEIGHT TO CROSS SECTIONAL RATIO, W/A

STABILITY AND STRUCTURAL LOADING ALSO STRONGLY DEPENDENT ON:

- TARGET PROPERTIES
- SURFACE FEATURES
- IMPACT CONDITIONS

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TARGET CHARACTERISTICS THAT IMPACT EPW SURVIVABILITY

The principal properties of a homogeneous target which greatly affect the structural loading (i.e., penetration g-loads) of an EPW are the confined shear strength (pressure dependent curve, which is dependent on moisture content), volumetric compressibility, and density. Nonhomogeneous targets and irregular target surface features (such as buildings, rubble, boulders, etc.) can cause unavoidable oblique impact conditions that induce large lateral loads. Trees are also a concern since they may cause an angle of attack on the EPW prior to ground impact.

EARTH PENETRATOR WEAPON SYSTEM DESIGN

TARGET CHARACTERISTICS THAT IMPACT EPW SURVIVABILITY

HARDNESS

- CONFINED SHEAR STRENGTH (PRESSURE DEPENDENT)
- VOLUMETRIC COMPRESSIBILITY
- DENSITY
- MOISTURE CONTENT

IRREGULARITIES (INDUCE LARGE LATERAL LOADS)

- BUILDINGS
- RUBBLE
- BOULDERS
- TREES
- TARGET NON HOMOGENEITY

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WES DRIVERS

The primary function of the WES is to provide arming, fuzing, and firing functions with high reliability and a very high degree of nuclear safety. The WES design must also consider compatibility with the delivery system (DOD interface), and the fuzing options (including airburst, contact, and time-delay). However, there are two unique issues that could make designing and packaging a WES for EPW applications extremely difficult.

EARTH PENETRATOR WEAPON SYSTEM DESIGN

WARHEAD ELECTRICAL SYSTEM DRIVERS

NUCLEAR SAFETY

DELIVERY SYSTEM INTERFACE

RUGGED, RELIABLE, FLEXIBLE PACKAGING

MULTIPLE FUZING OPTIONS

AIRBURST, CONTACT, AFTER PENETRATION, SYNCHRONOUS

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FIGURE OF EPW WES EXAMPLE DESIGN

Packaging WES components to survive EPW loads has proven to be a difficult task. Past experience, along with recent field tests, offers guidelines for survivable WES packaging designs which include rigid support structures to minimize displacement between subassemblies, elimination of all unnecessary air voids, preloading major subassemblies, and encapsulating subassemblies with rigid potting material such as GMB epoxy.

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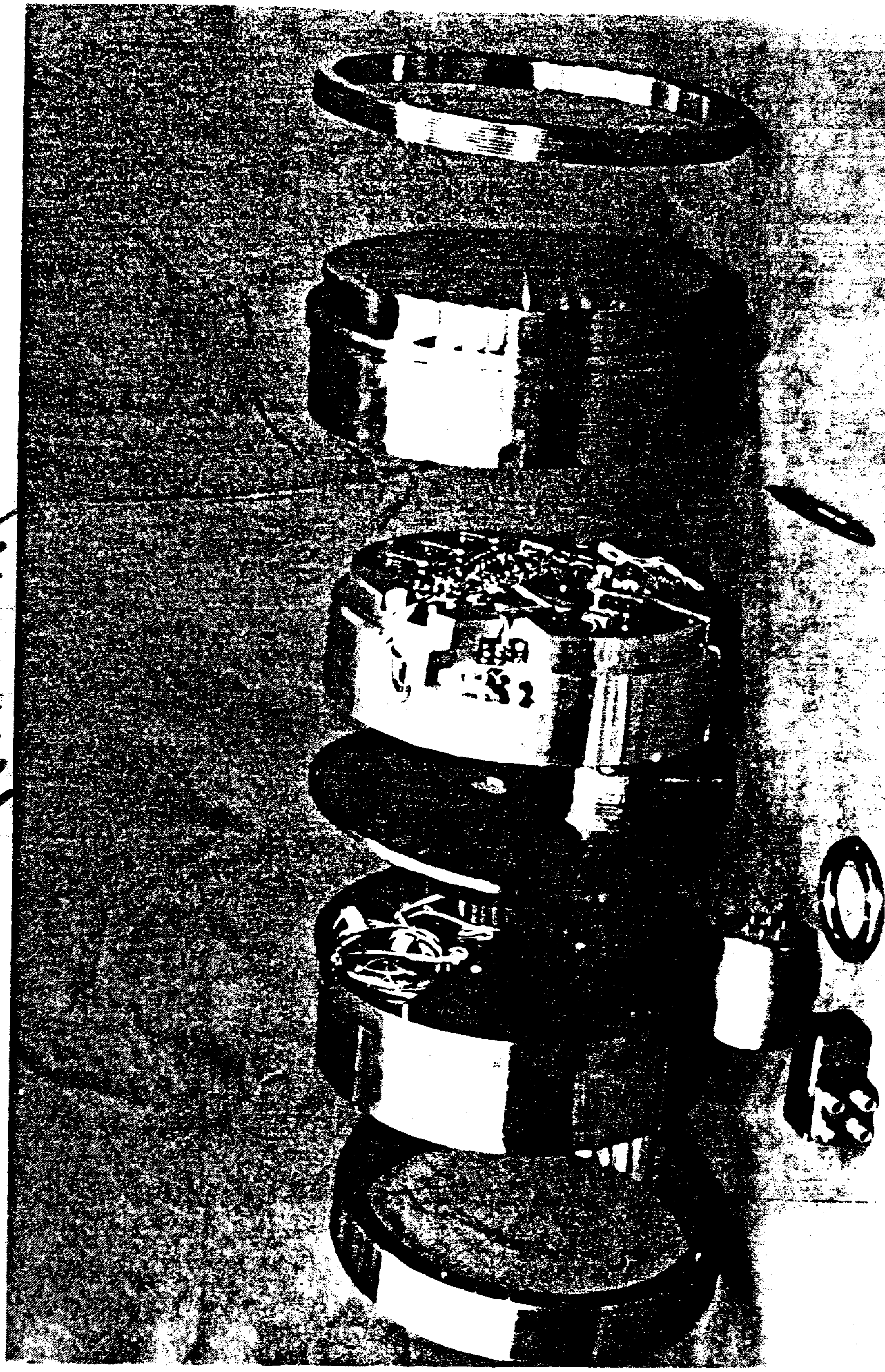

TAPERED AFTERBODY EPW DESIGN

DOE b(3)

Factors that may necessitate changes to the baseline design (e.g., physical properties, nuclear yield) include a redefinition or refinement of targets, delivery conditions, and fuzing options. In addition, improved analytical modeling capabilities for design optimization may also warrant a change to the present design.

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TAPERED AFTERBODY EPW DESIGN

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CYLINDRICAL AFTERBODY/AFT FLARE EPW DESIGN

This figure shows the general configuration of the SEPW and gives the major dimensions, weight, and yield class.

In order to obtain maximum structural capability from the EP case, no joints are allowed. All components are inserted through the rear of the case. The forward cross-hatched section represents the nuclear system and ballast. The warhead electrical system is in the aft section.

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EARTH PENETRATOR WEAPON SYSTEM DESIGN

DOD b(1) b(3)

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TEST PROGRAM

Since current computational tools for modeling EPW phenomena are quite limited, an extensive test program has been underway to assist in the development of the EPW. These tests--which have provided information on penetrator stability, penetration environment, and component survival--utilize launch devices (Davis or gas gun, rocket system, rocket sled track) which are capable of launching test vehicles into various targets with various impact conditions (velocity, angle of incidence, angle of attack). Onboard digital data recording packages were utilized for tests requiring strain and/or acceleration time history data.

EARTH PENETRATOR WEAPON SYSTEM DESIGN

TEST PROGRAM

TEST PROGRAM OBJECTIVES

- DEMONSTRATE STRUCTURAL INTEGRITY
- DEMONSTRATE STABILITY OF PENETRATOR DESIGN
- PROVIDE STRAIN AND ACCELERATION DATA FOR CODE VERIFICATION
- EVALUATE EFFECTIVENESS OF COUNTERMEASURES
- EVALUATE NEW EPW CASE MATERIALS
- DEMONSTRATE FUNCTIONAL CAPABILITY OF WES COMPONENTS

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EARTH PENETRATOR TEST DEVICE

This figure illustrates a typical EPW test device containing an on-board data package. Scaled models were fabricated to represent the physical properties of the baseline design. Typically, the nuclear system was replaced by ballast and WES components were added to test their structural integrity. Some tests included portions of the nuclear package. All EPW test devices launched from the Davis or gas guns included either an integrated or detachable pusher plate at the aft end which was designed to withstand the high base pressure during launch. Onboard data packages were utilized either to record strain and/or acceleration data for code verification, measuring penetration environment, or for evaluating the response of nuclear or WES components.

86TH5000.08

EARTH PENETRATOR TEST DEVICE

PROPERTIES

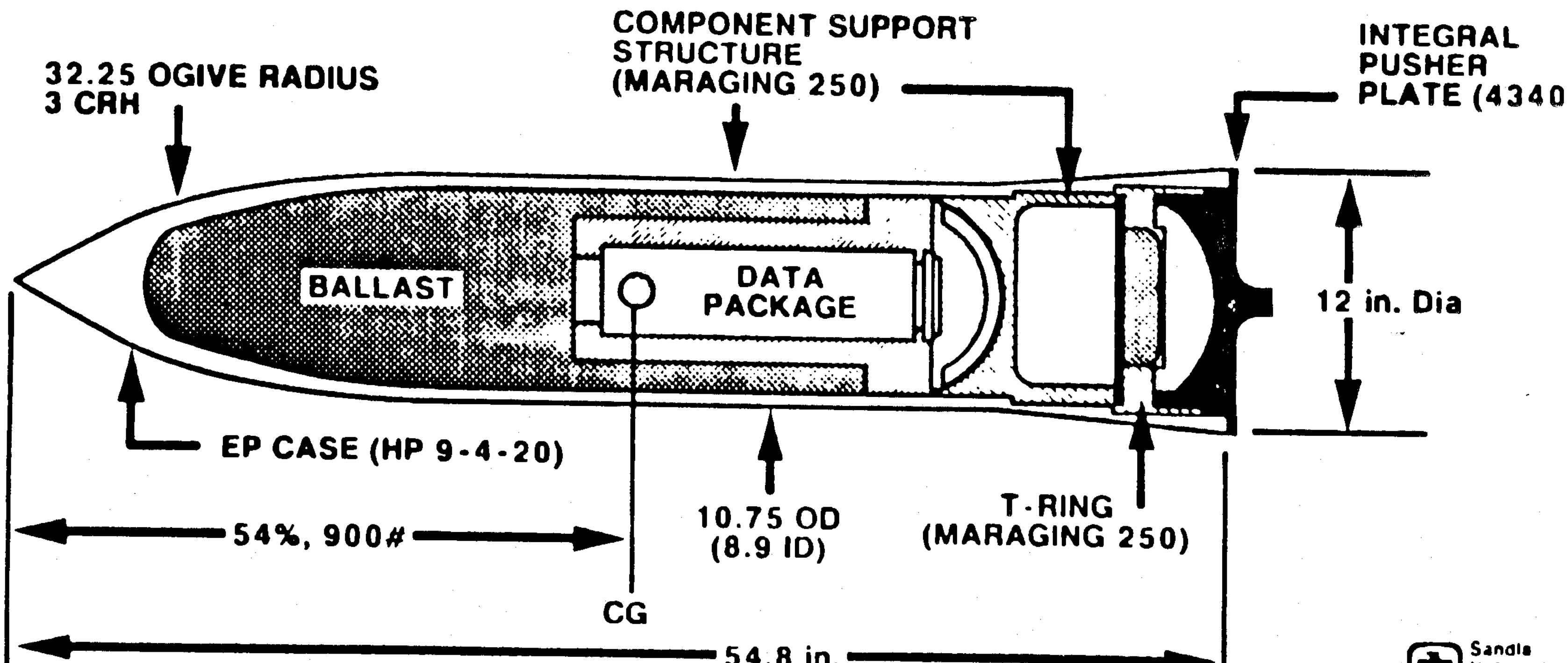
L/D = 5.1

W/A = 9.9

Wt = 900 lb

CG = 29.6 in.

PITCH = 2.1×10^5 lb-in.^{2}



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SYSTEMS USED IN EPW STRUCTURAL TESTING

9-MAR-88

EARTH PENETRATOR WEAPON SYSTEM DESIGN

SYSTEMS USED IN EPW STRUCTURAL TESTING

12 INCH DAVIS GUN

16 INCH DAVIS GUN (EXPECTED TO BE OPERATIONAL EARLY FY 89)

6 INCH GAS GUN (EXPECTED TO BE OPERATIONAL EARLY FY 89)

4 INCH GAS GUN

2-STAGE ROCKET SYSTEM, FIREUP - FIRE DOWN

ROCKET SLED TRACK

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Summary of EPW Davis Gun Tests

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EARTH PENETRATOR WEAPON SYSTEM DESIGN

SEPW TEST SUMMARY

NUMBER OF TESTS	OBJECTIVES	RESULTS

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SEPW PARAMETRIC STUDY

This figure illustrates that four criteria are used to evaluate an EPW design for a given set of impact conditions. Three criteria are used for examining the maximum velocity a system can survive.

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For the impact conditions shown, the EPW survivability is bounded above by the lateral acceleration limit and below by the minimum velocity curve. Curves such as these are used to generate velocity-gamma maps.

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DOE
b(3)

EPW CASE WEIGHT REDUCTION/RATIONALE AND PENALTIES

Several DOD-related issues may warrant the need of a lighter-weight EPW (compared with the baseline weight of approximately . Possible benefits of a light-weight EPW are (1) extending delivery vehicle range, (2) minimizing degree of modifications to current delivery vehicles, and (3) maximizing the total number of EPWs that can be installed on a given delivery vehicle. However, there are several disadvantages of a lighter-weight EPW. Based on terradynamics, this will reduce the depth of penetration and increase the penetration loads. Other penalties include a possible reduction of the EPW structural capability and a possible increase in EPW material and fabrication costs.

EARTH PENETRATOR WEAPON SYSTEM DESIGN

EPW WEIGHT REDUCTION

RATIONALE

- OPTIMIZE DELIVERY SYSTEM RANGE
- MINIMIZE DELIVERY SYSTEM INTERFACE MODIFICATIONS
- MAXIMIZE TOTAL NUMBER OF MaRVs FOR A GIVEN DELIVERY VEHICLE

PENALTIES

- DECREASES DEPTH OF PENETRATION AND INCREASES LOADS
- COULD DECREASE STRUCTURAL CAPABILITY
- COULD INCREASE MATERIAL AND FABRICATION COSTS

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EPW CASE WEIGHT REDUCTION/METHODS

Decreasing the weight of the baseline EPW design will only be achieved by modifying the EPW case design. The nuclear and WES assemblies do not offer much potential for weight reduction. The [redacted] greater strength-to-weight ratio) such as titanium, composites, or bi-metallics.

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EARTH PENETRATOR WEAPON SYSTEM DESIGN

EPW CASE WEIGHT REDUCTION METHODS

REDUCE WEIGHT OF BASELINE STEEL CASE BY RESTRICTING:

- DELIVERY CONDITIONS
- TARGET TYPES

USE LIGHTER WEIGHT MATERIALS

- TITANIUM
- HYBRID COMPOSITE (e.g. METAL PLUS GRAPHITE/RESIN)
- BI–METALIC (e.g. STEEL + TITANIUM)

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EPW CASE-WEIGHT LIMIT CURVES

These curves illustrate the point that weight savings can be achieved hv restricting the impact conditions.

Similarly, case weight reduction could be achieved if the EPW survivability was restricted to "softer" targets.

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Organization Sandia National Laboratories [redacted]

Signature

Date 4/11/88

HB-III Helicopter Air Drop

Axial Strain

(0 degrees + 180 degrees) / 2

Analog LPF: 4800 Hz
Digital LPF: none

Test Date
02-12-88

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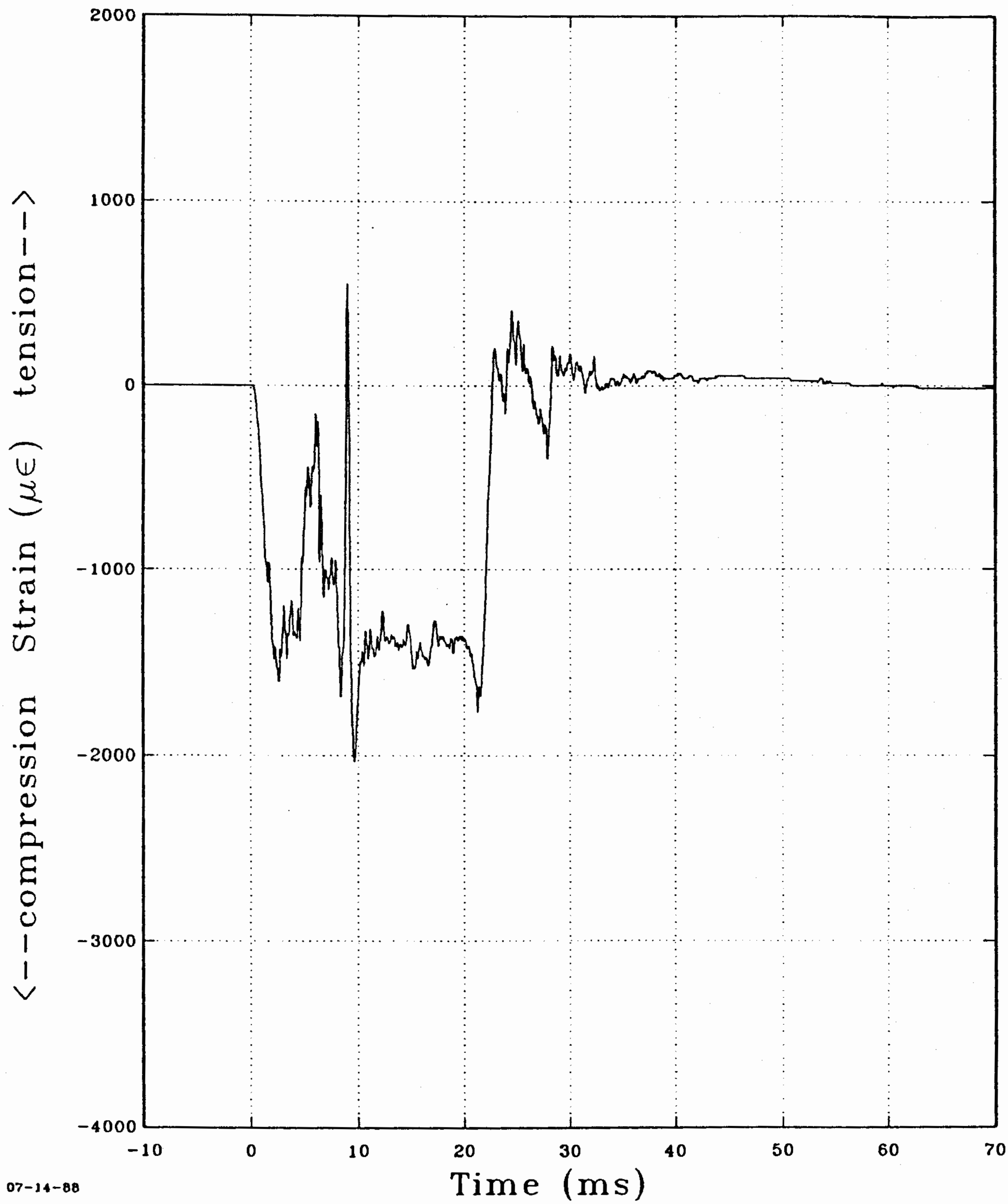

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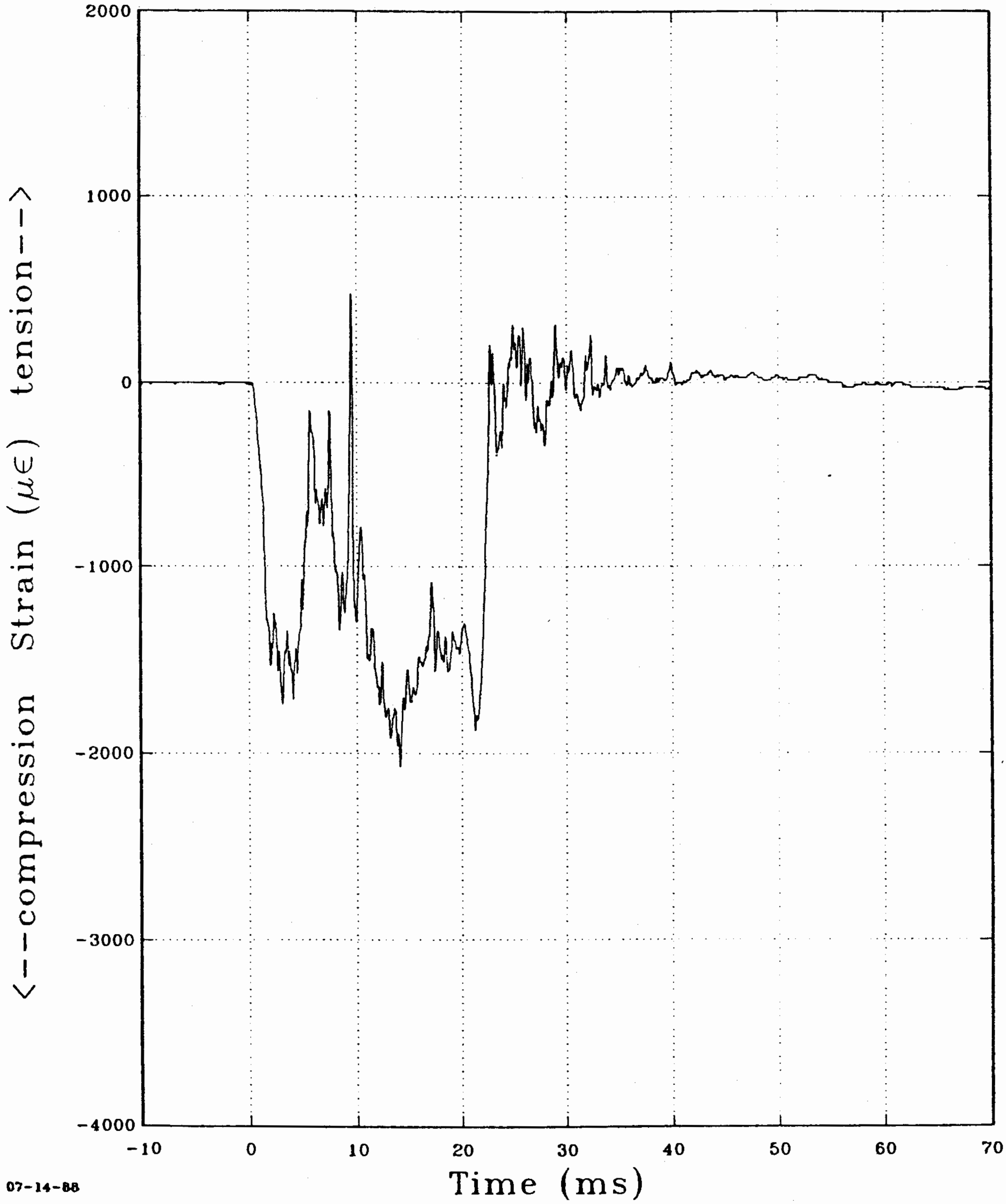
HB-III Helicopter Air Drop

Axial Strain

(90 degrees + 270 degrees) / 2

Analog LPF: 4800 Hz | Test Date | W61-3
Digital LPF: none | 02-12-88 | SSP-85



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HB-III Helicopter Air Drop

Bending Strain

(0 degrees - 180 degrees) / 2

Analog LPF: 4800 Hz
Digital LPF: none

Test Date
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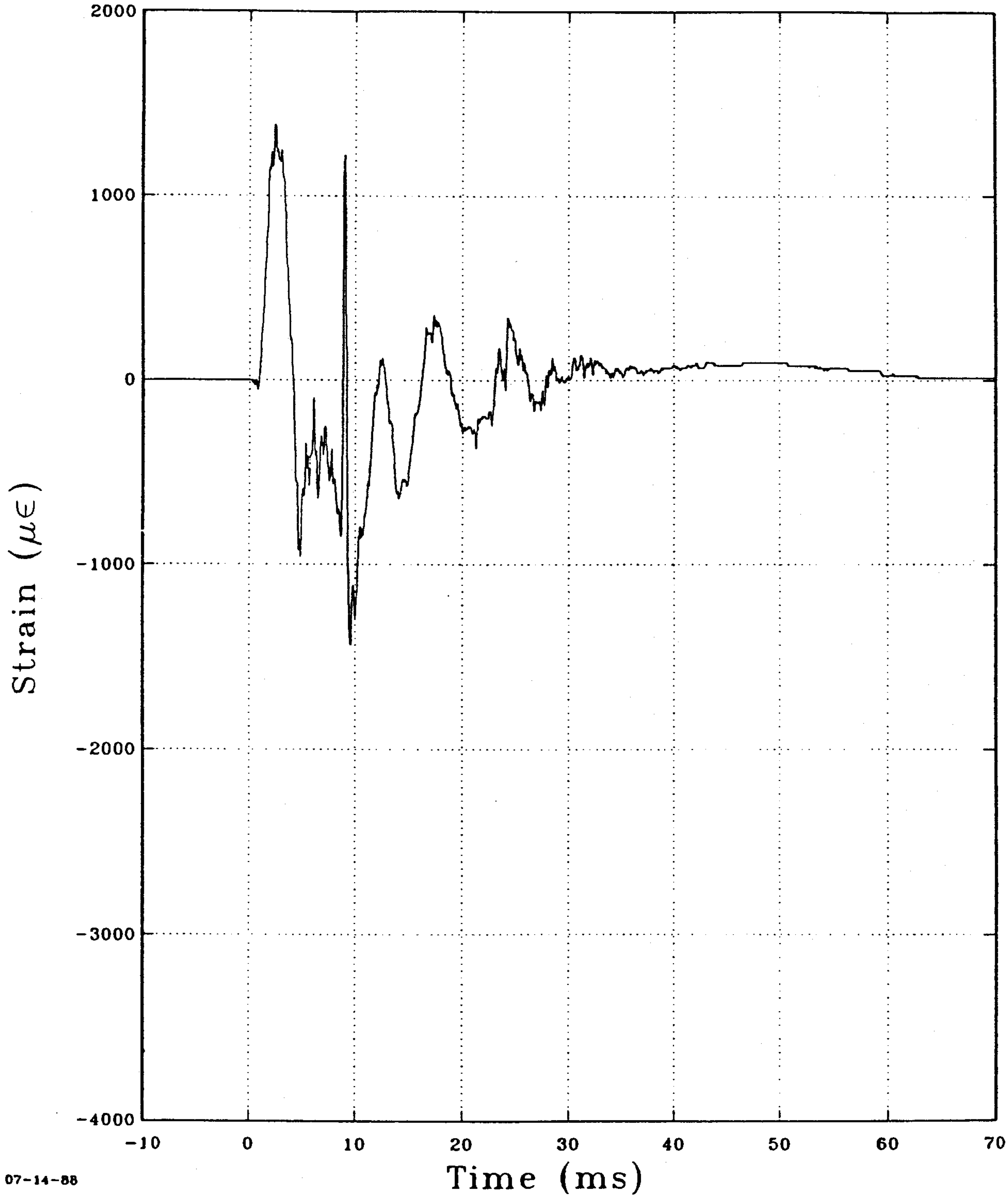

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HB-III Helicopter Air Drop
Bending Strain
(90 degrees - 270 degrees) / 2

Analog LPF: 4800 Hz
Digital LPF: none

Test Date
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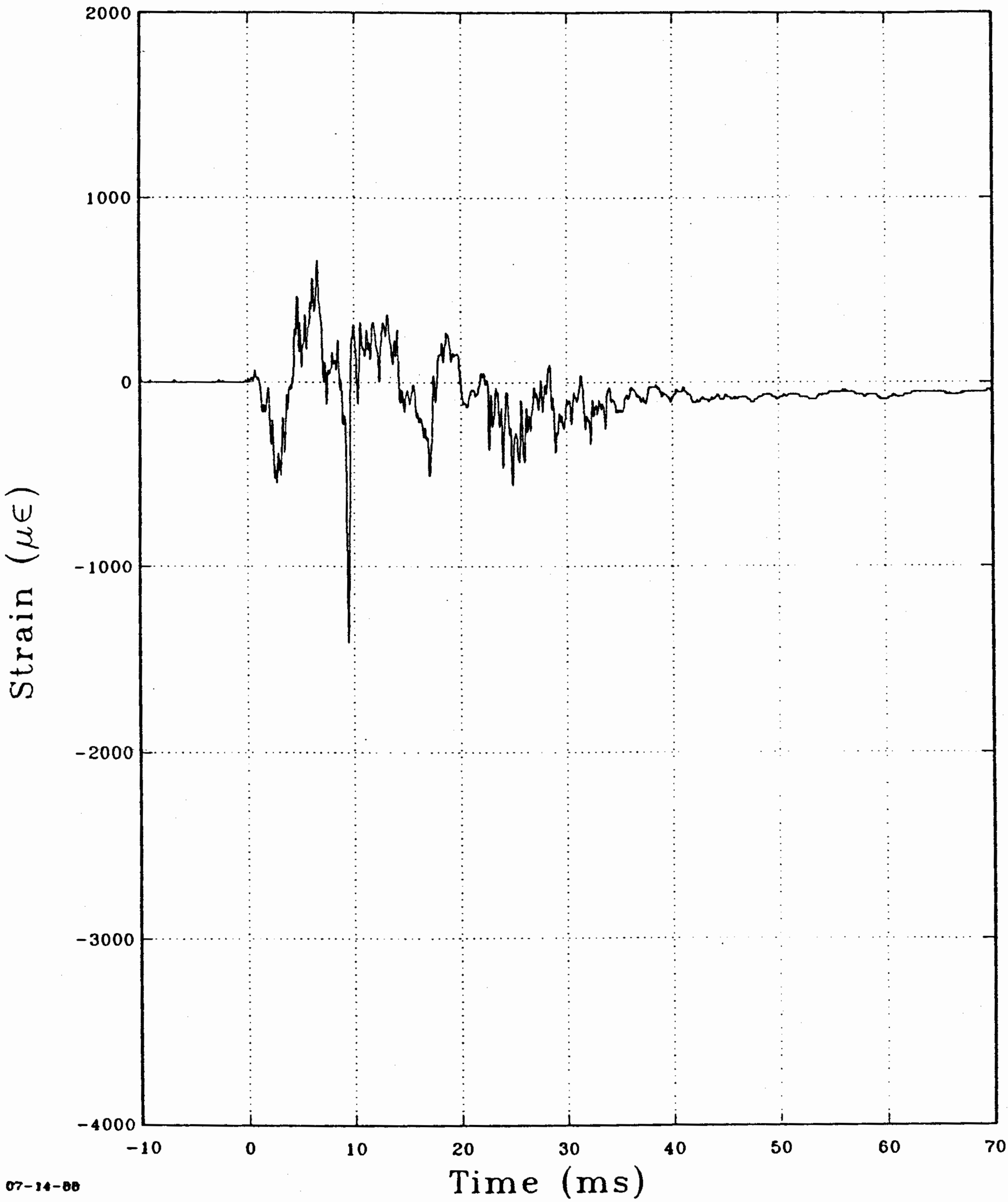
W61-3
SSP-85



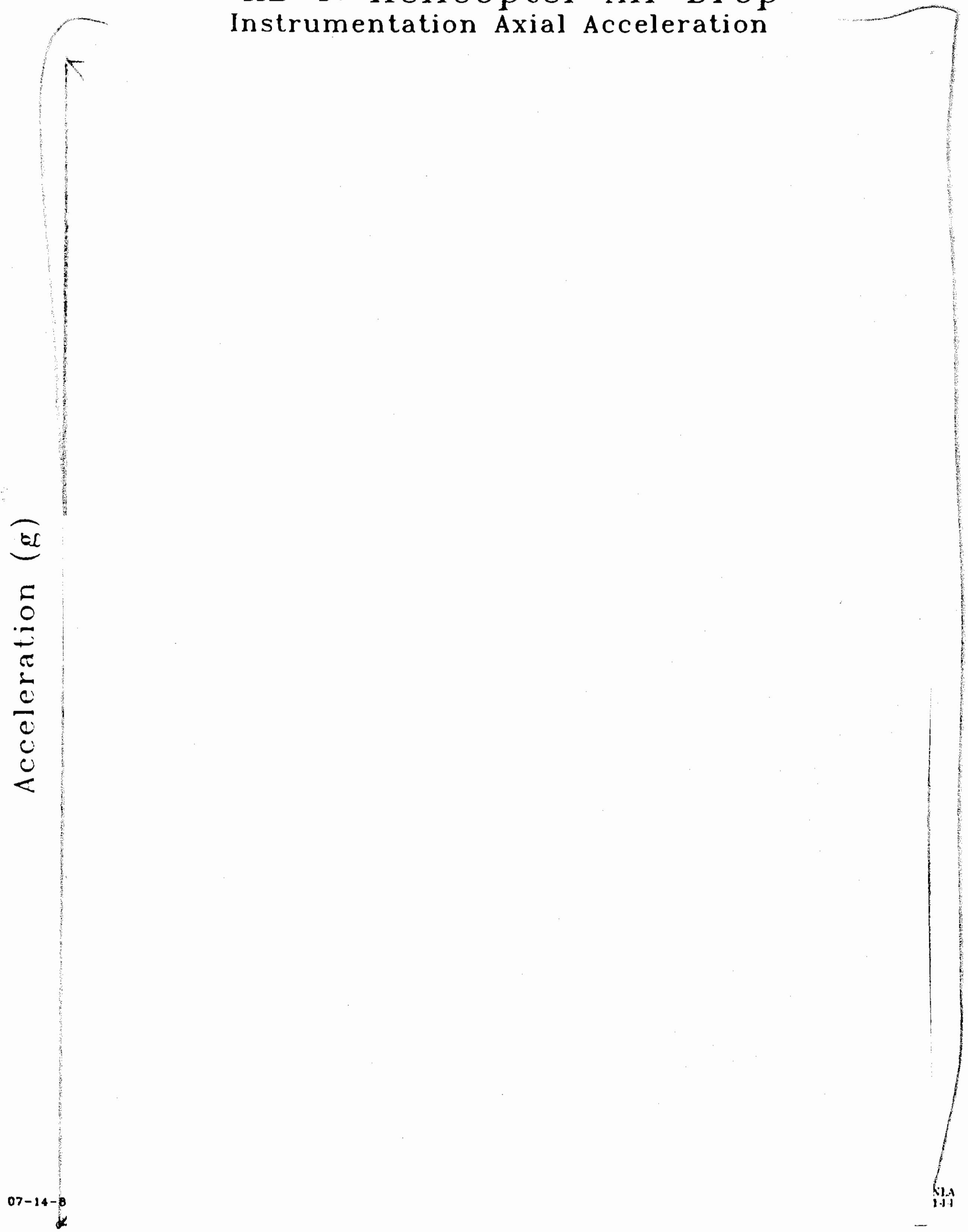
07-14-88

SNLA 5144

[redacted] UNCLASSIFIED

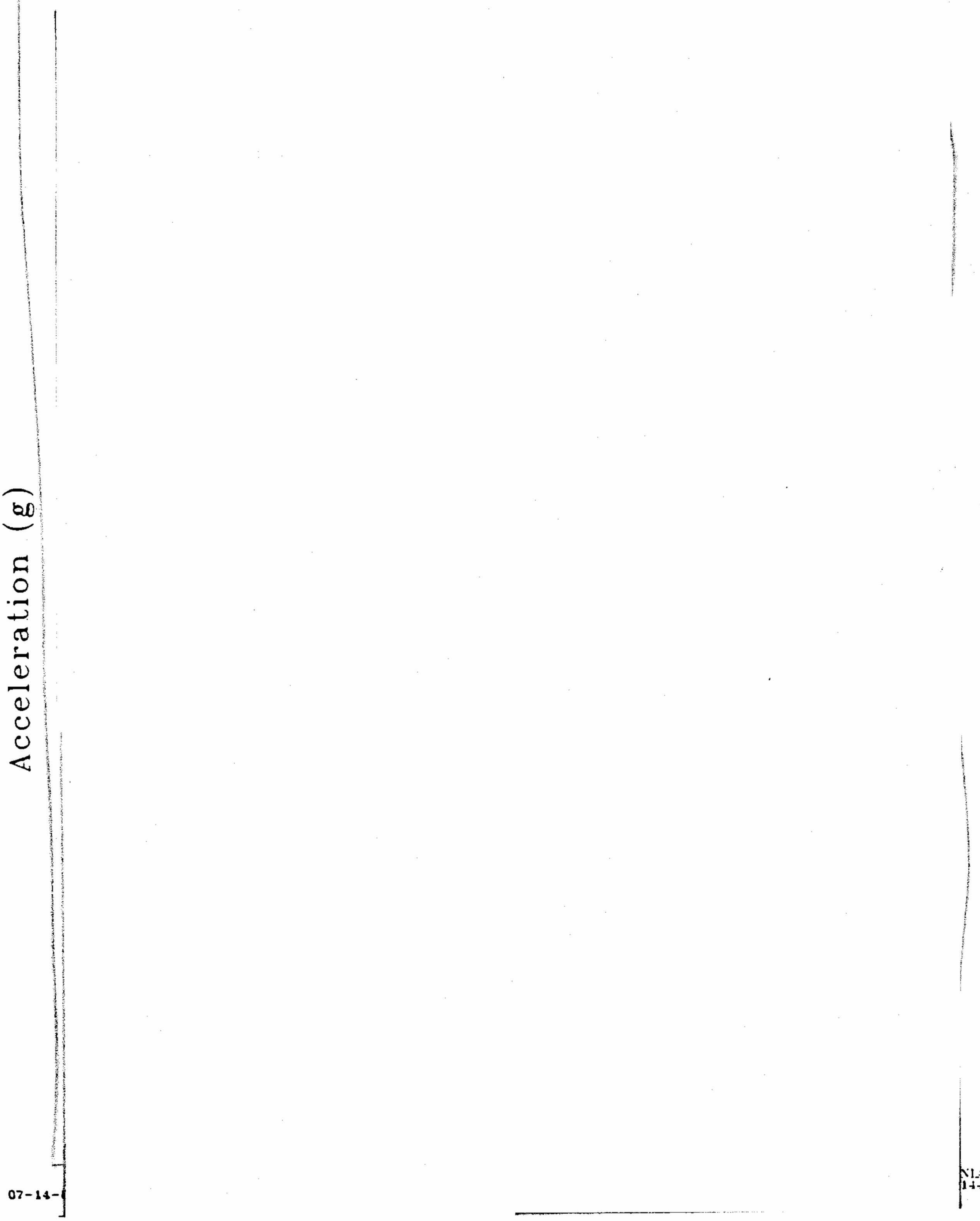
HB-IV Helicopter Air Drop
Instrumentation Axial Acceleration

DOE b(3)



UNCLASSIFIED

HB–IV Helicopter Air Drop
Instrumentation Axial Acceleration

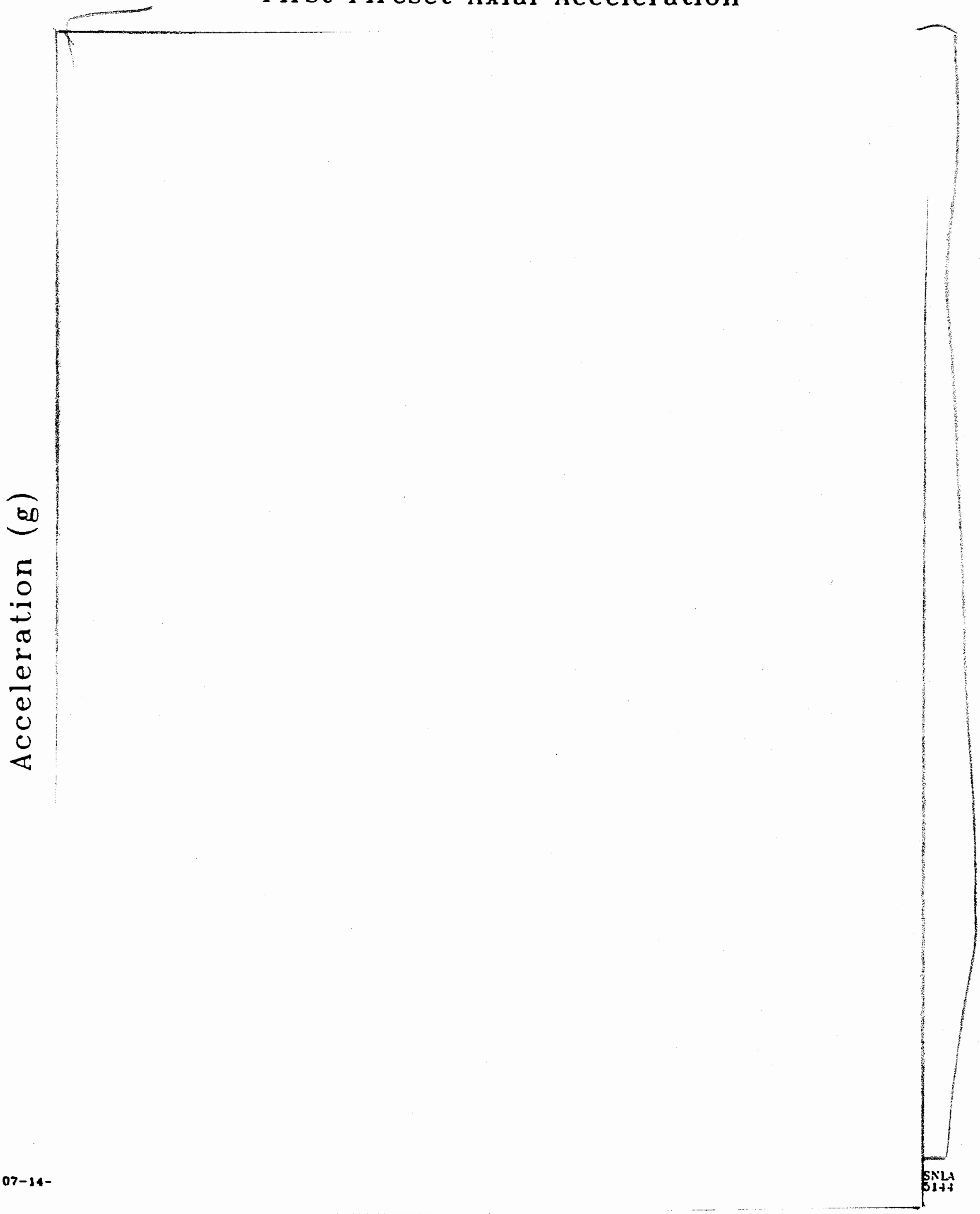


DOE b(3)

UNCLASSIFIED

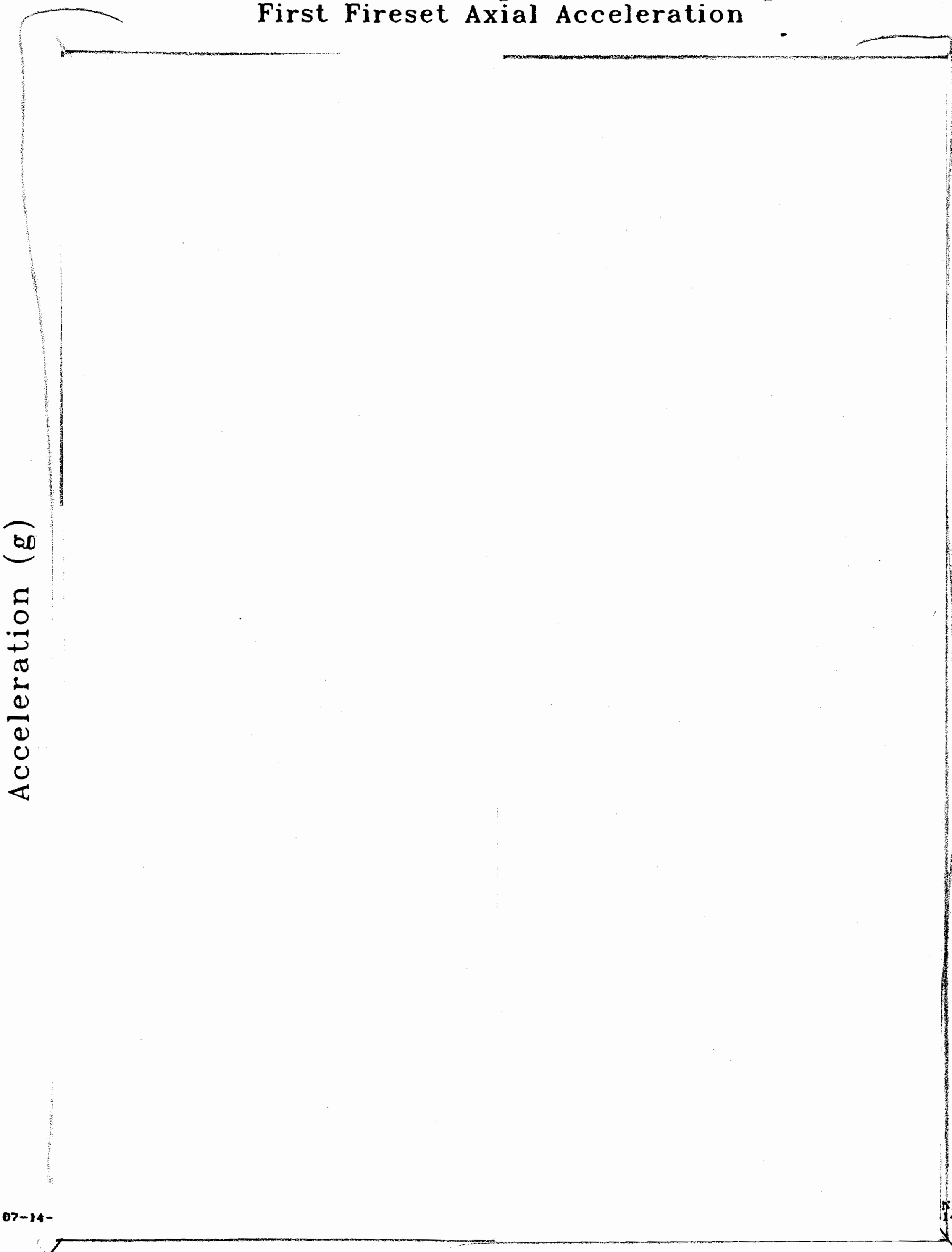
HB-IV Helicopter Air Drop
First Fireset Axial Acceleration

DOE
b(3)



HB–IV Helicopter Air Drop

First Fireset Axial Acceleration

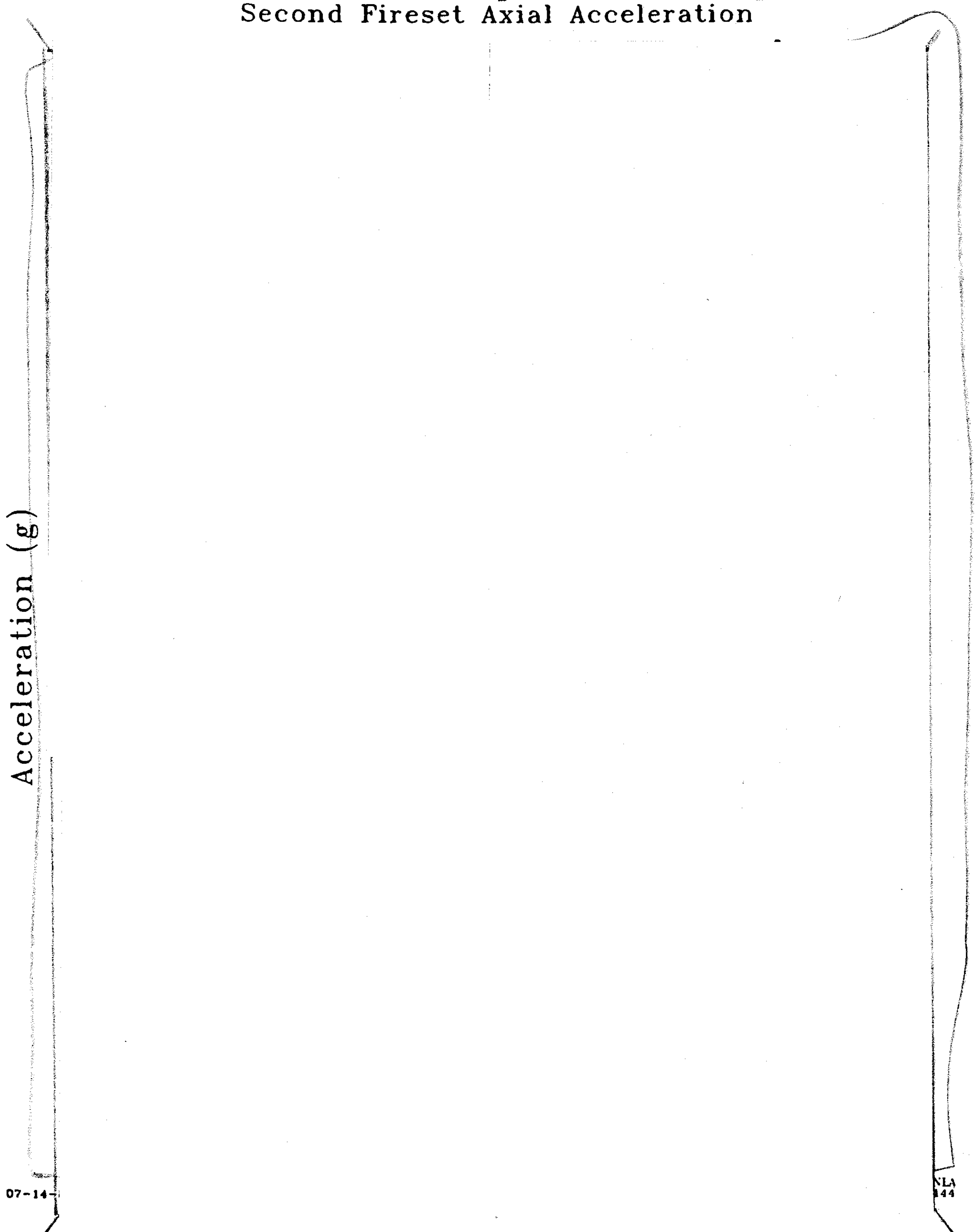


DOE
b(3)

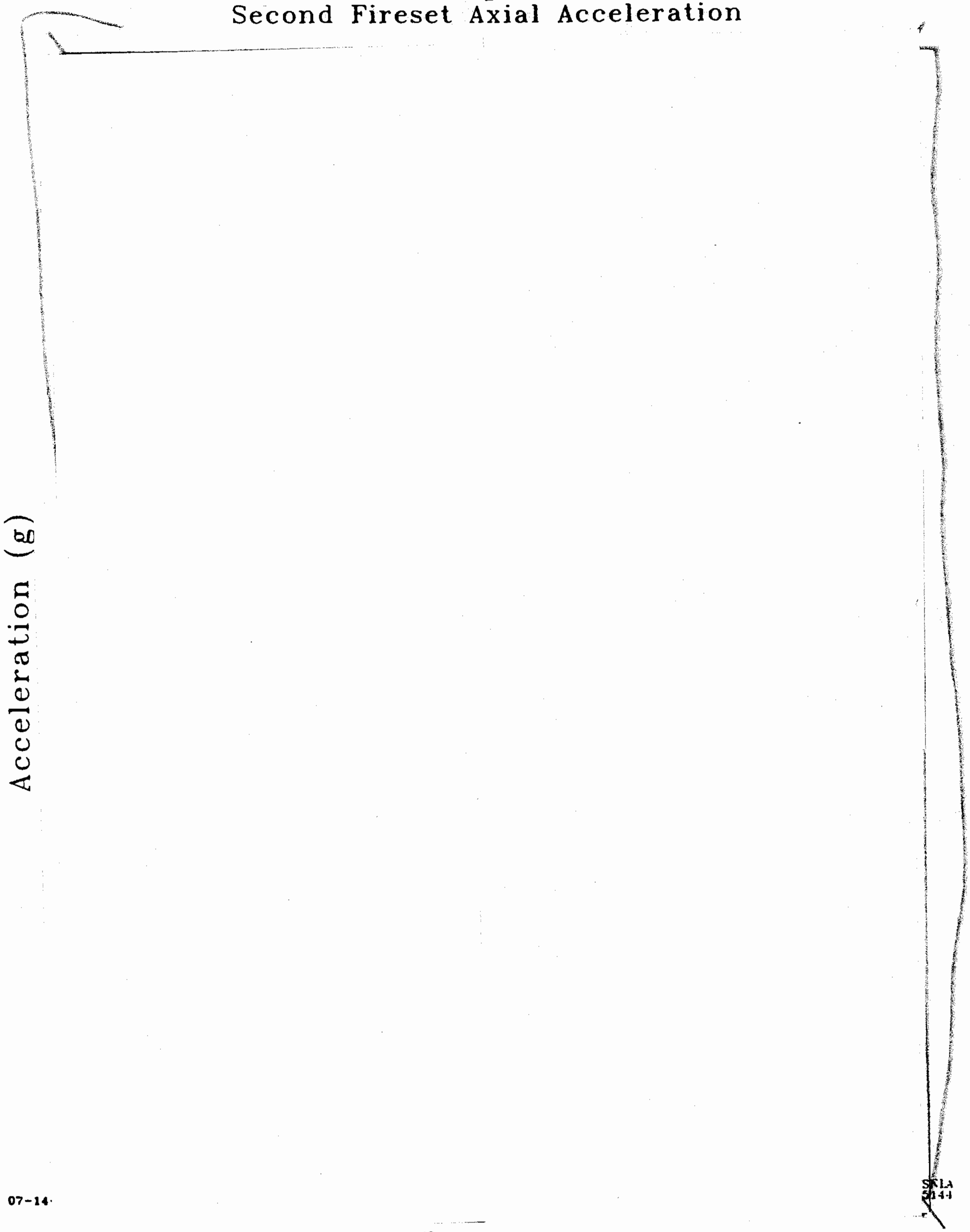
HB-IV Helicopter Air Drop

Second Fireset Axial Acceleration

DOE
b(3)



HB-IV Helicopter Air Drop
Second Fireset Axial Acceleration



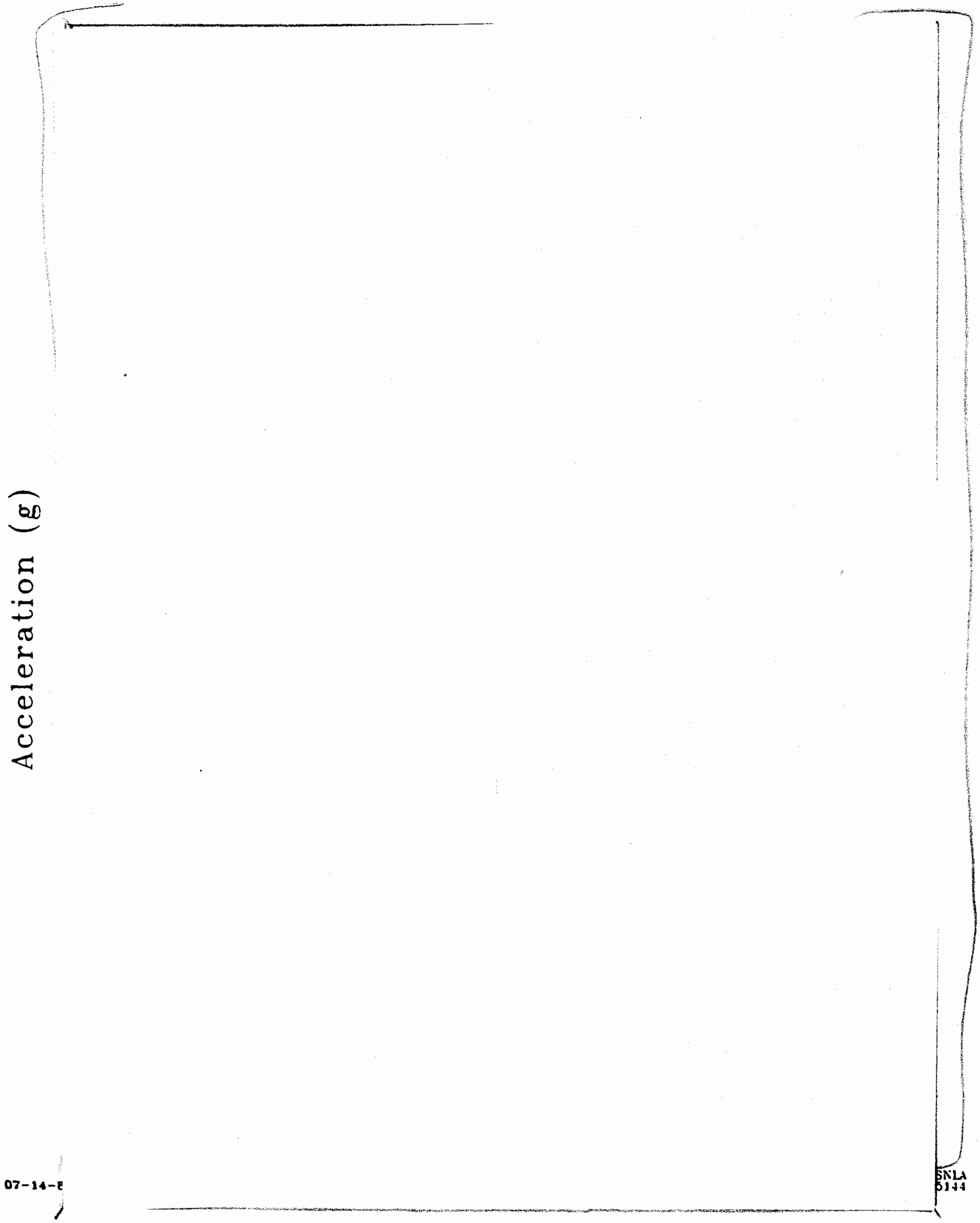
DOE
b(3)

07-14

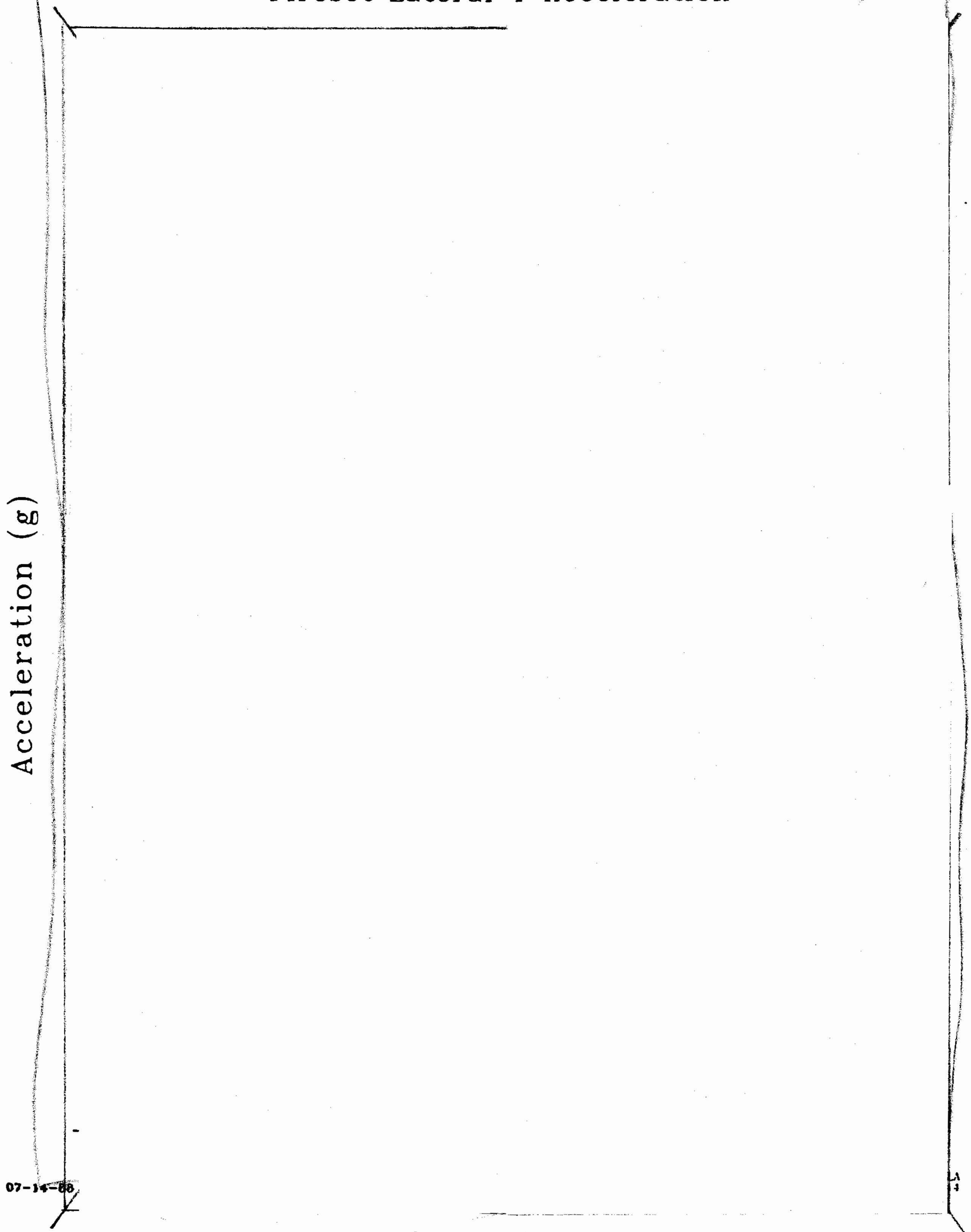
HB–IV Helicopter Air Drop

Fireset Lateral Y Acceleration

DOE b(3)



HB–IV Helicopter Air Drop
Fireset Lateral Y Acceleration

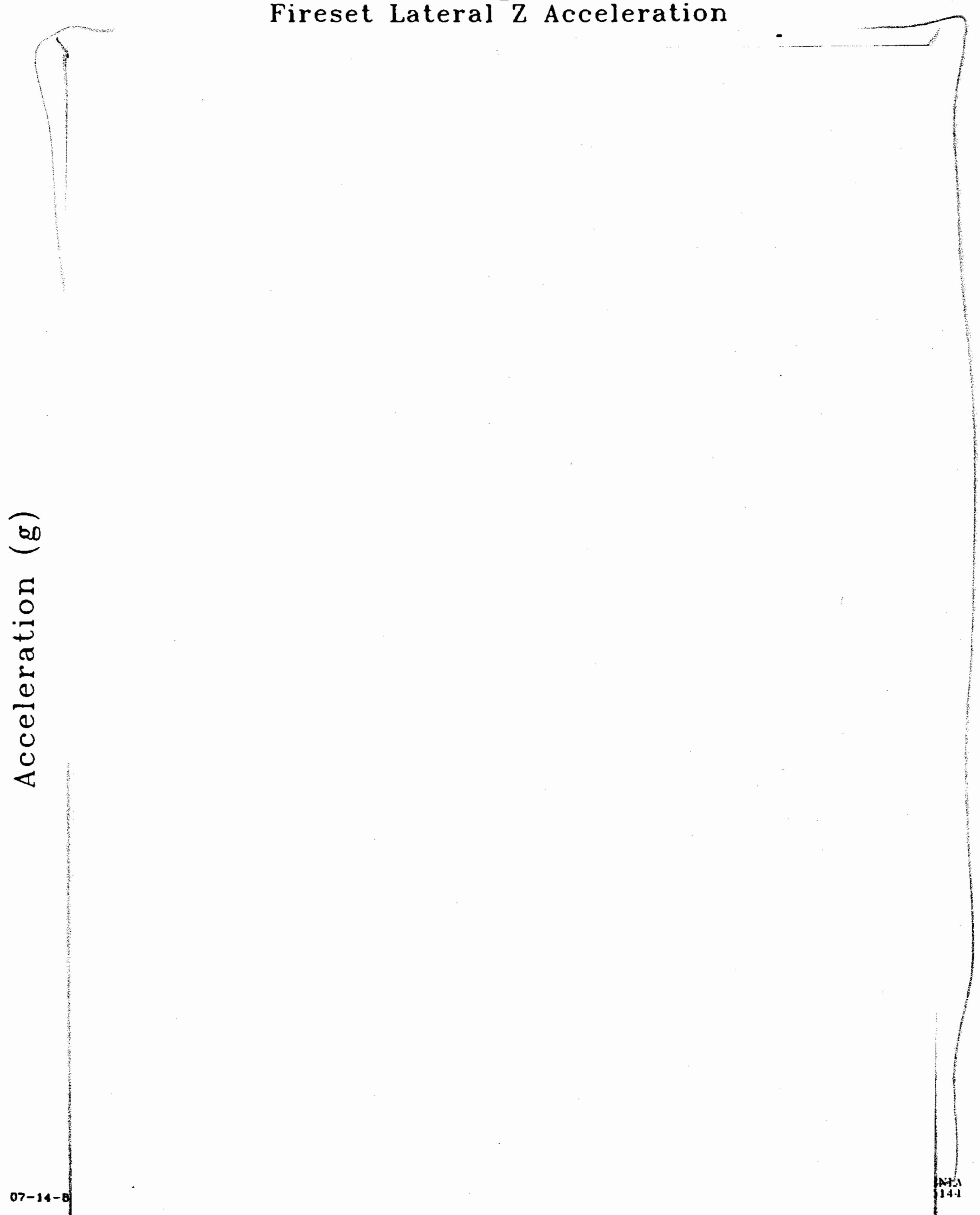


DOE
b(3)

[redacted] UNCLASSIFIED

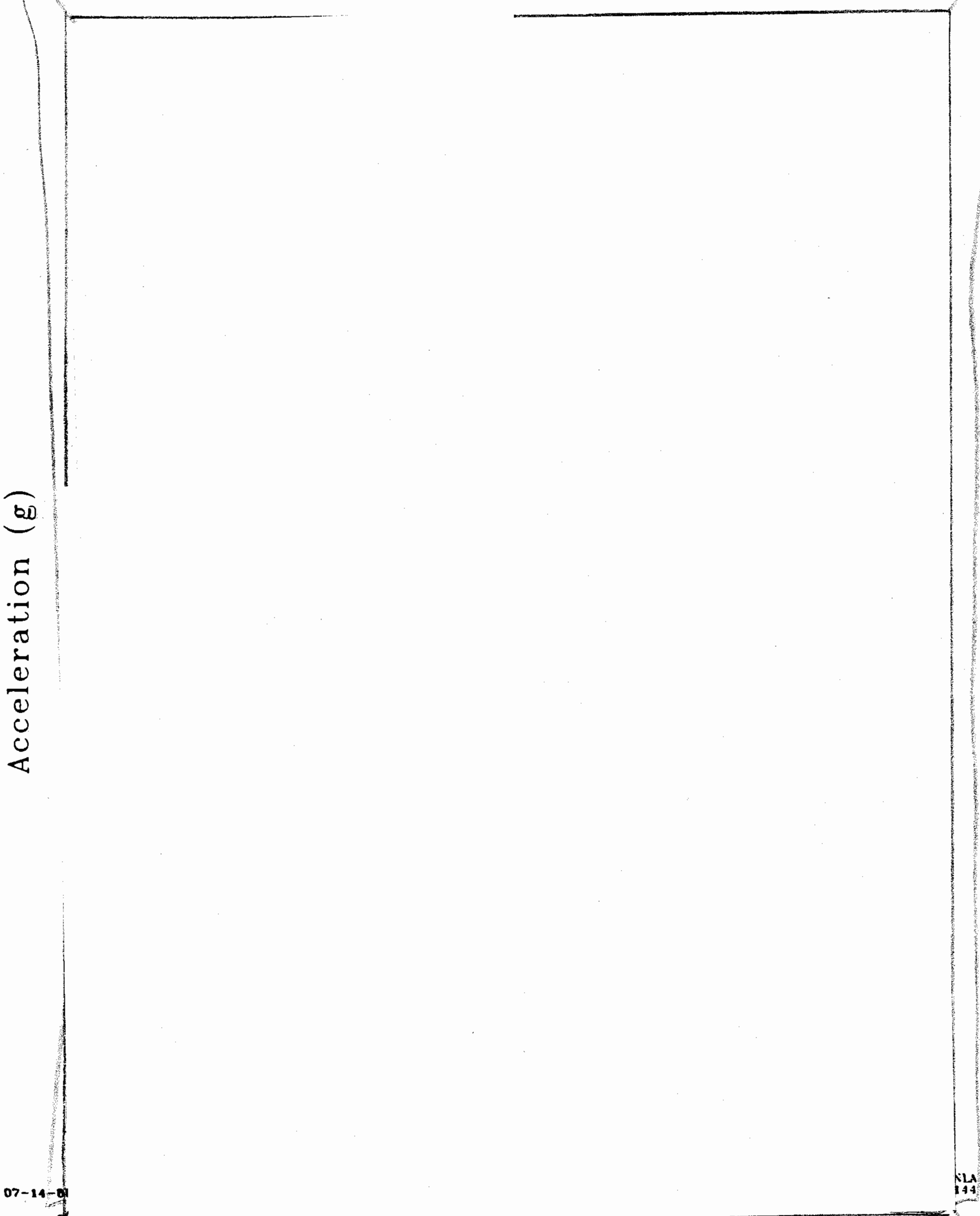
HB-IV Helicopter Air Drop
Fireset Lateral Z Acceleration

DOE b(3)



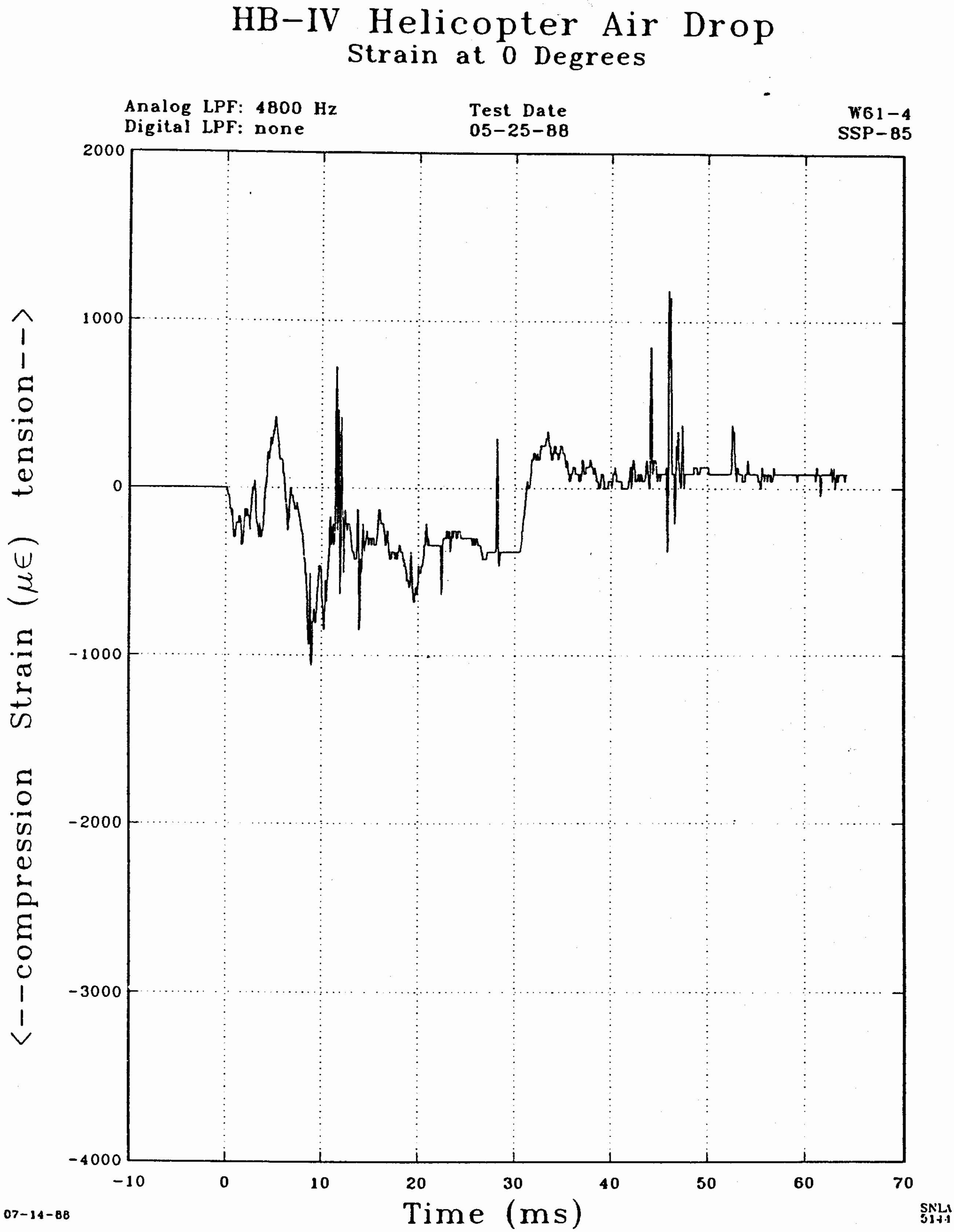
[redacted] UNCLASSIFIED

HB–IV Helicopter Air Drop
Fireset Lateral Z Acceleration



DOE b(3)

SECRET UNCLASSIFIED



SECRET UNCLASSIFIED

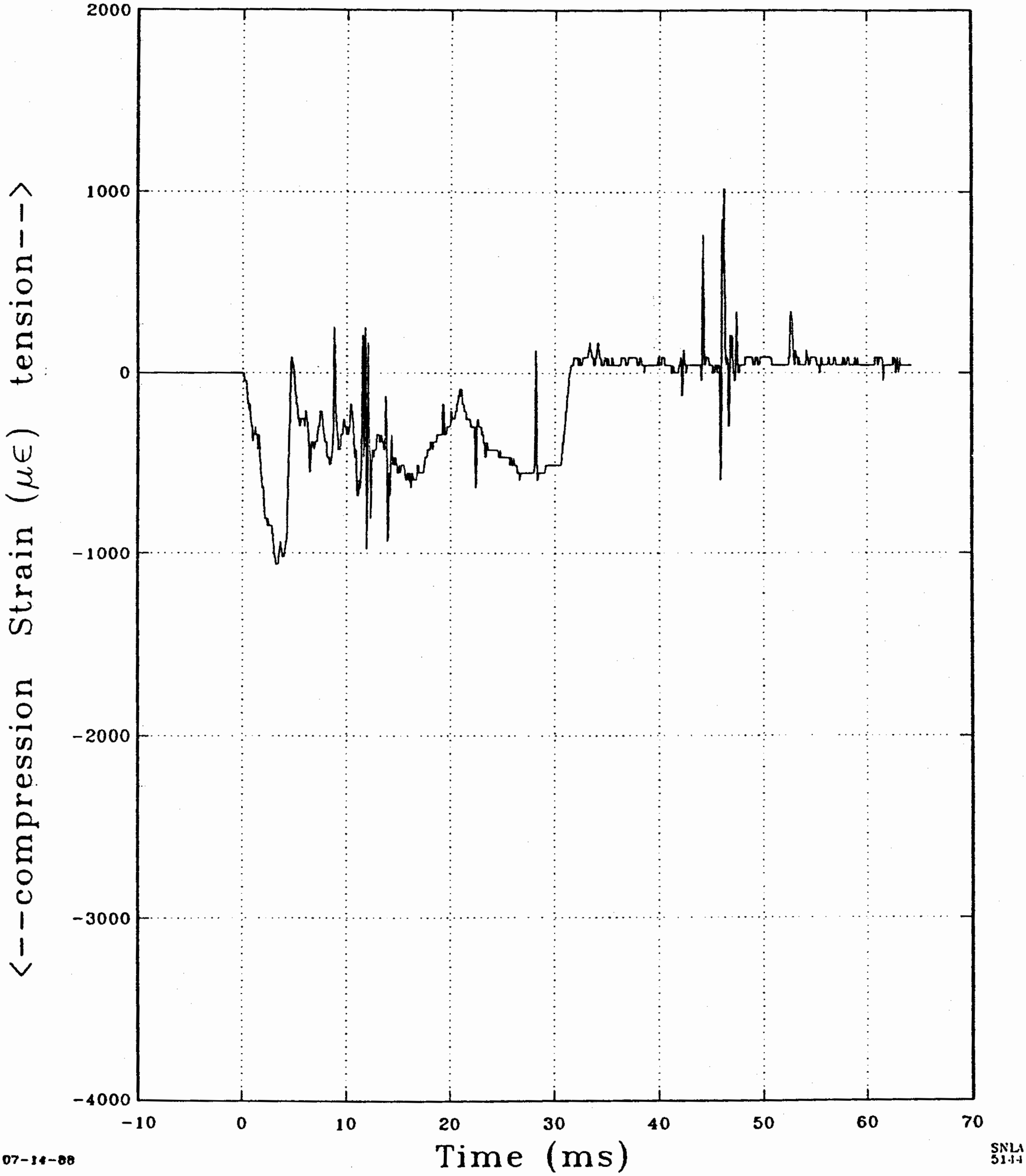
[redacted] UNCLASSIFIED

HB-IV Helicopter Air Drop
Strain at 120 Degrees

Analog LPF: 4800 Hz
Digital LPF: none

Test Date
05-25-88

W61-4
SSP-85



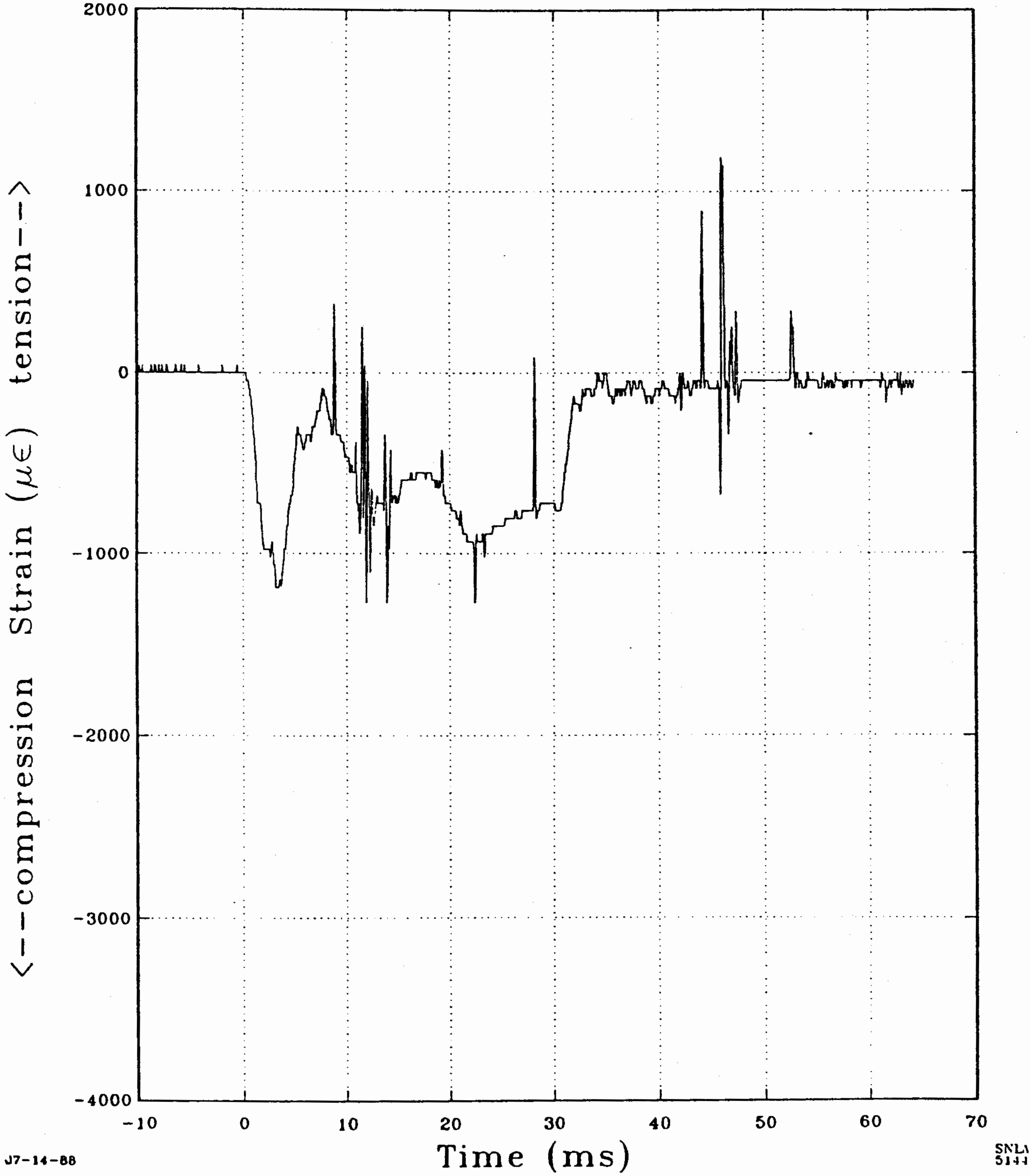
07-14-88

SNLA 5144

[redacted] UNCLASSIFIED

HB-IV Helicopter Air Drop
Strain at 240 Degrees

Analog LPF: 4800 Hz	Test Date	W61-4
Digital LPF: none	05-25-88	SSP-85



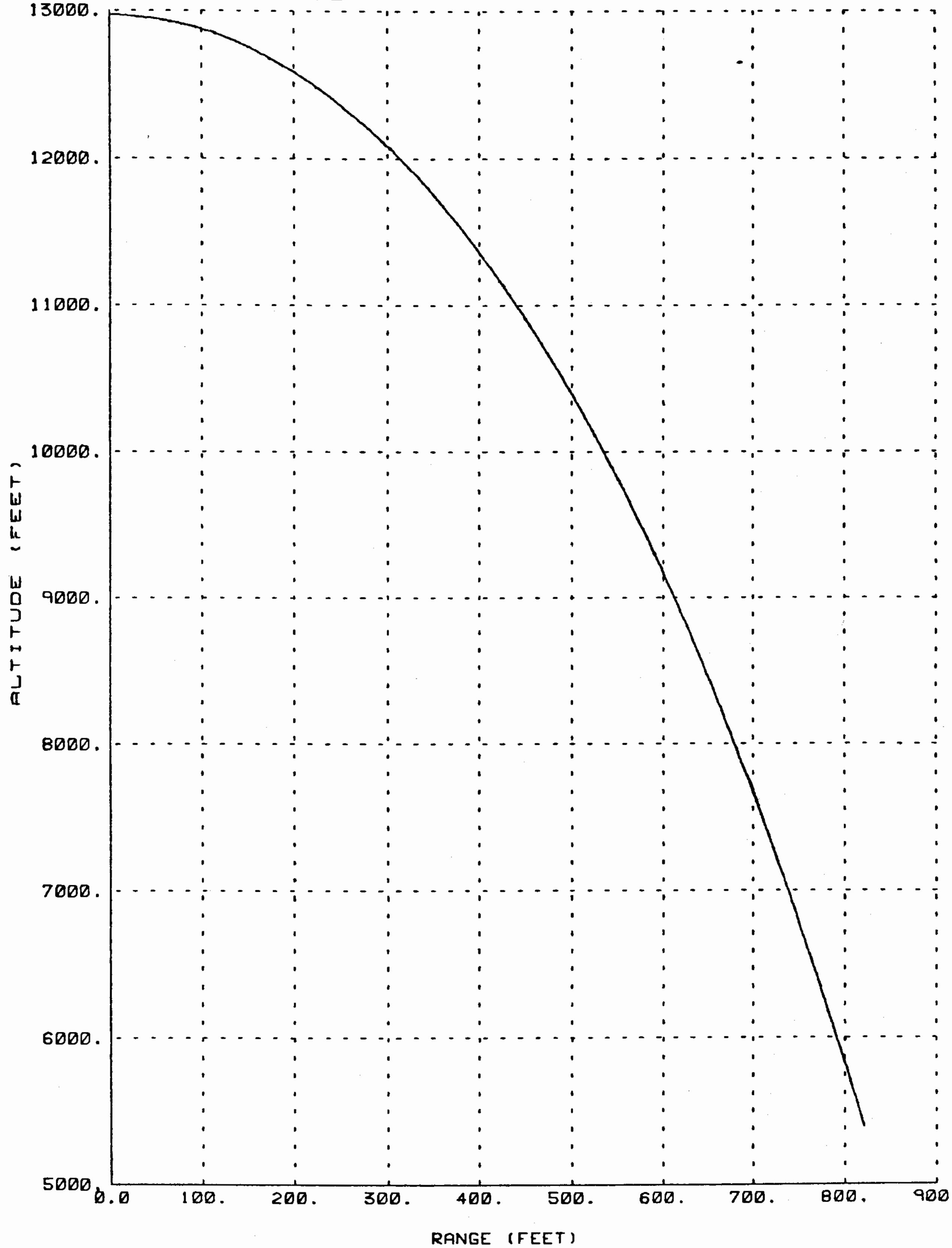
APPENDIX D

Photo-Optical Data

DOE
b(3)

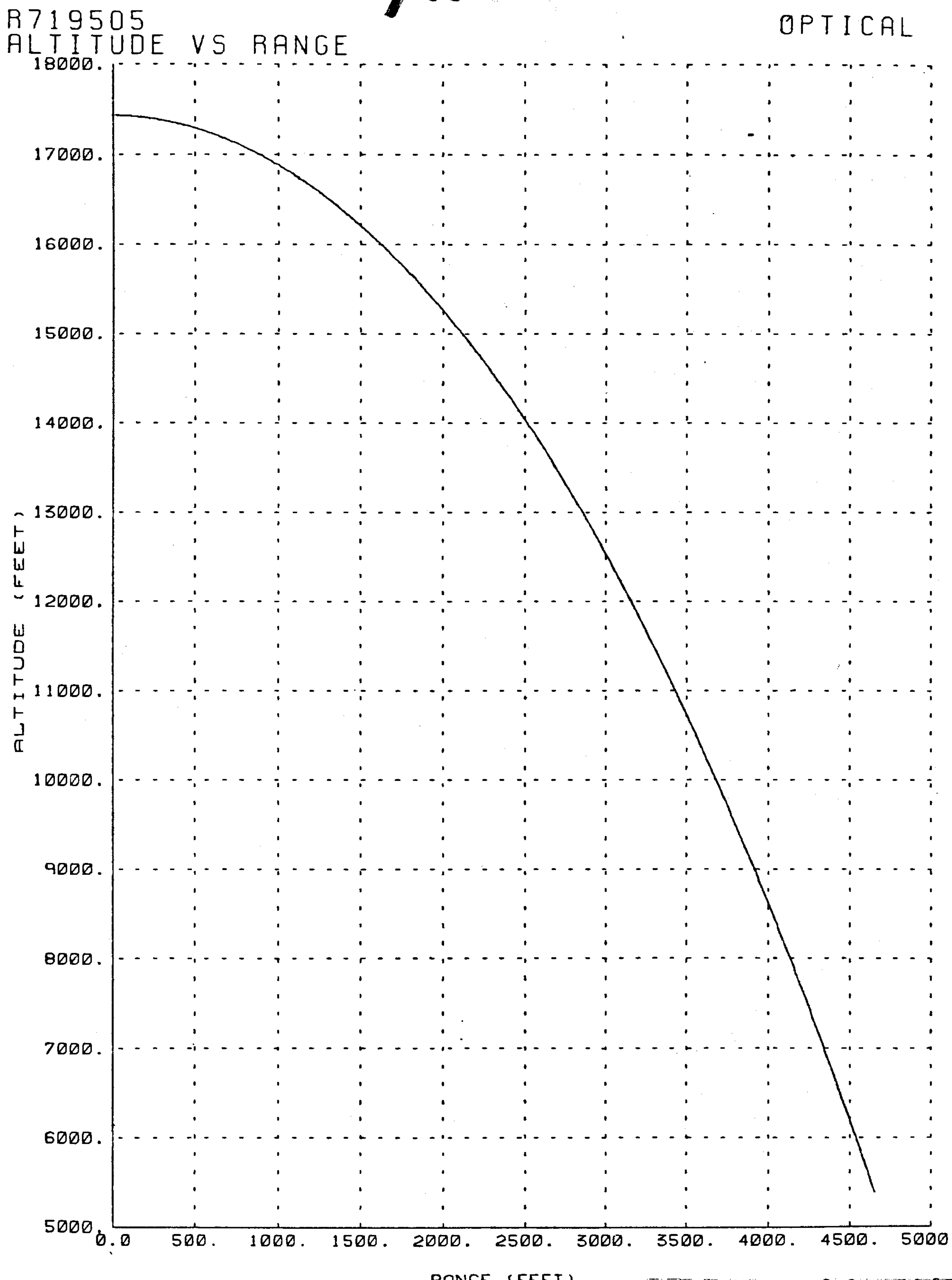
OPTICAL

R719500
ALTITUDE VS RANGE



DOE
b(3)

UNCLASSIFIED



UNCLASSIFIED

UNCLASSIFIED

[redacted]

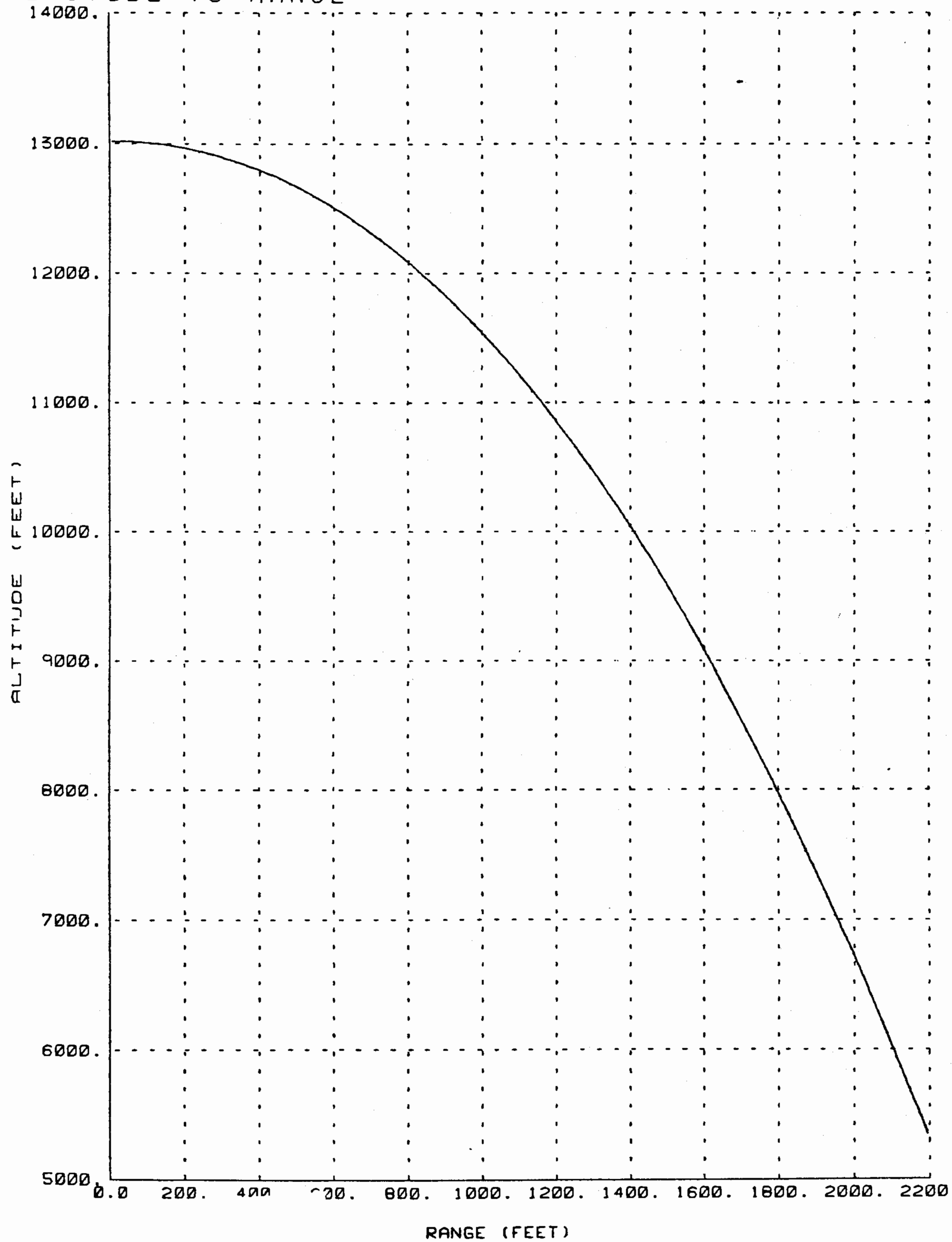
DOE b(3)

[redacted]

UNCLASSIFIED

R719506
ALTITUDE VS RANGE

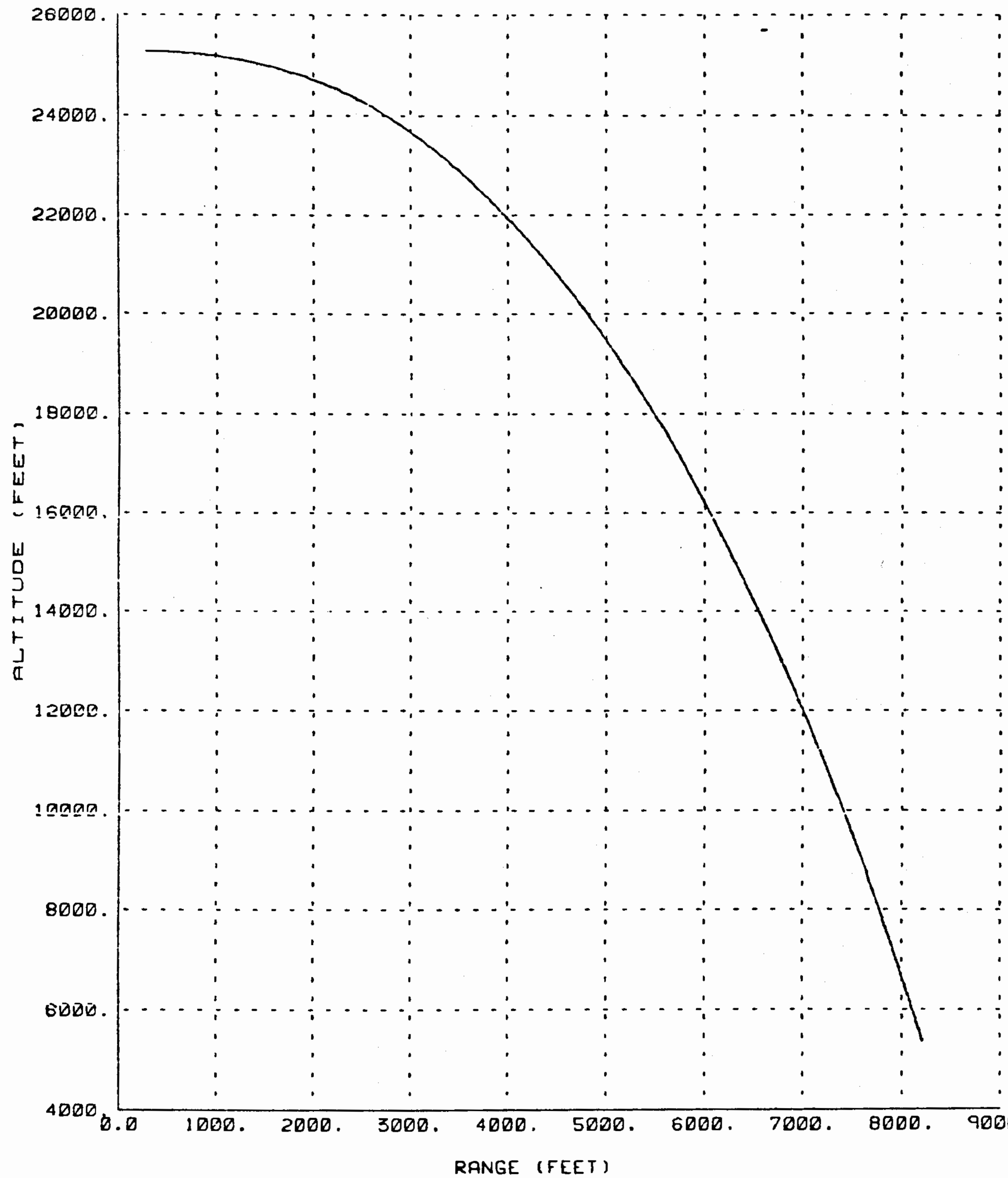
OPTICAL



DOE
b(3)

R719507 OPTICAL

ALTITUDE VS RANGE

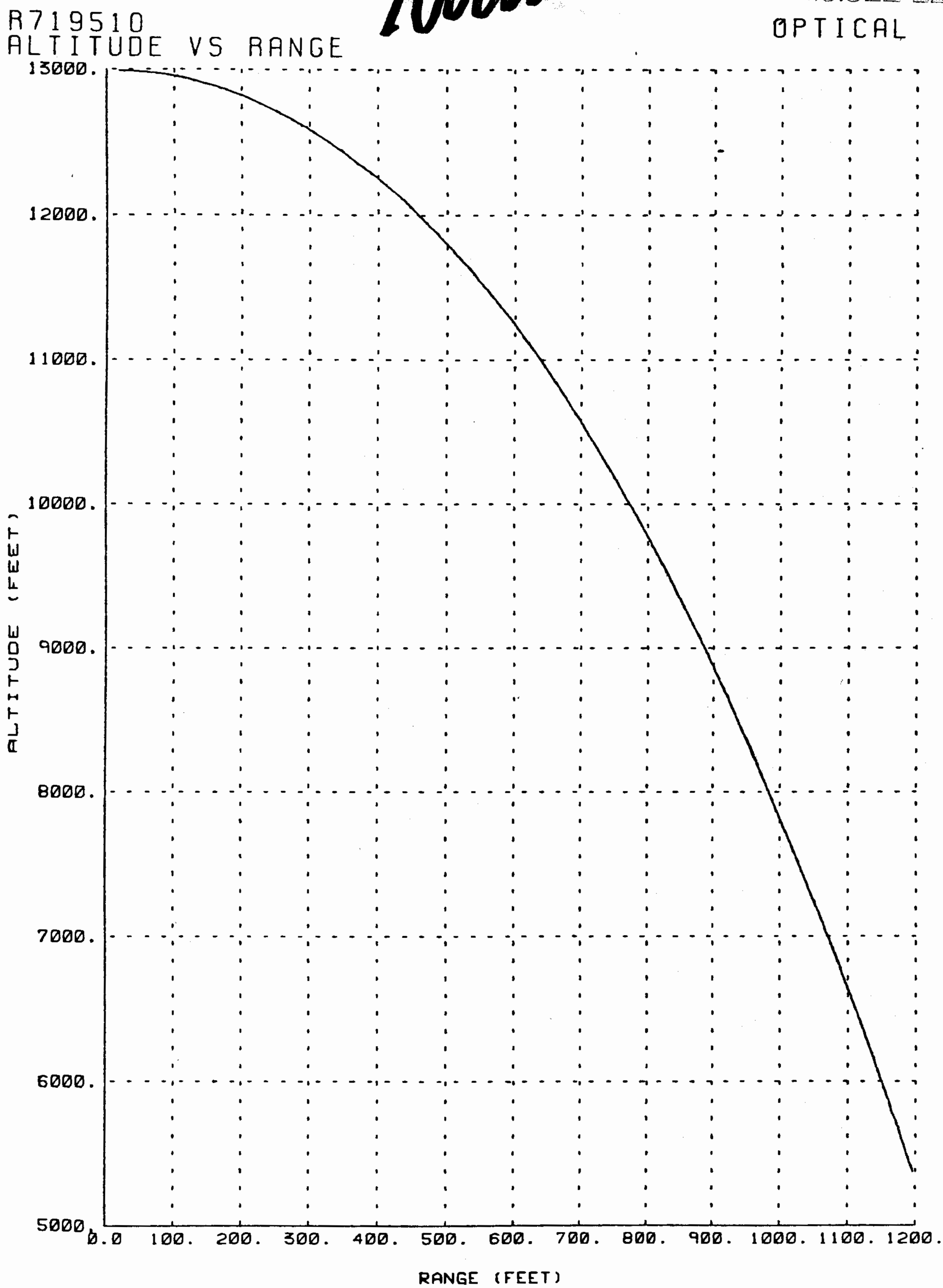


DOE
b(3)

SECRET

UNCLASSIFIED

OPTICAL



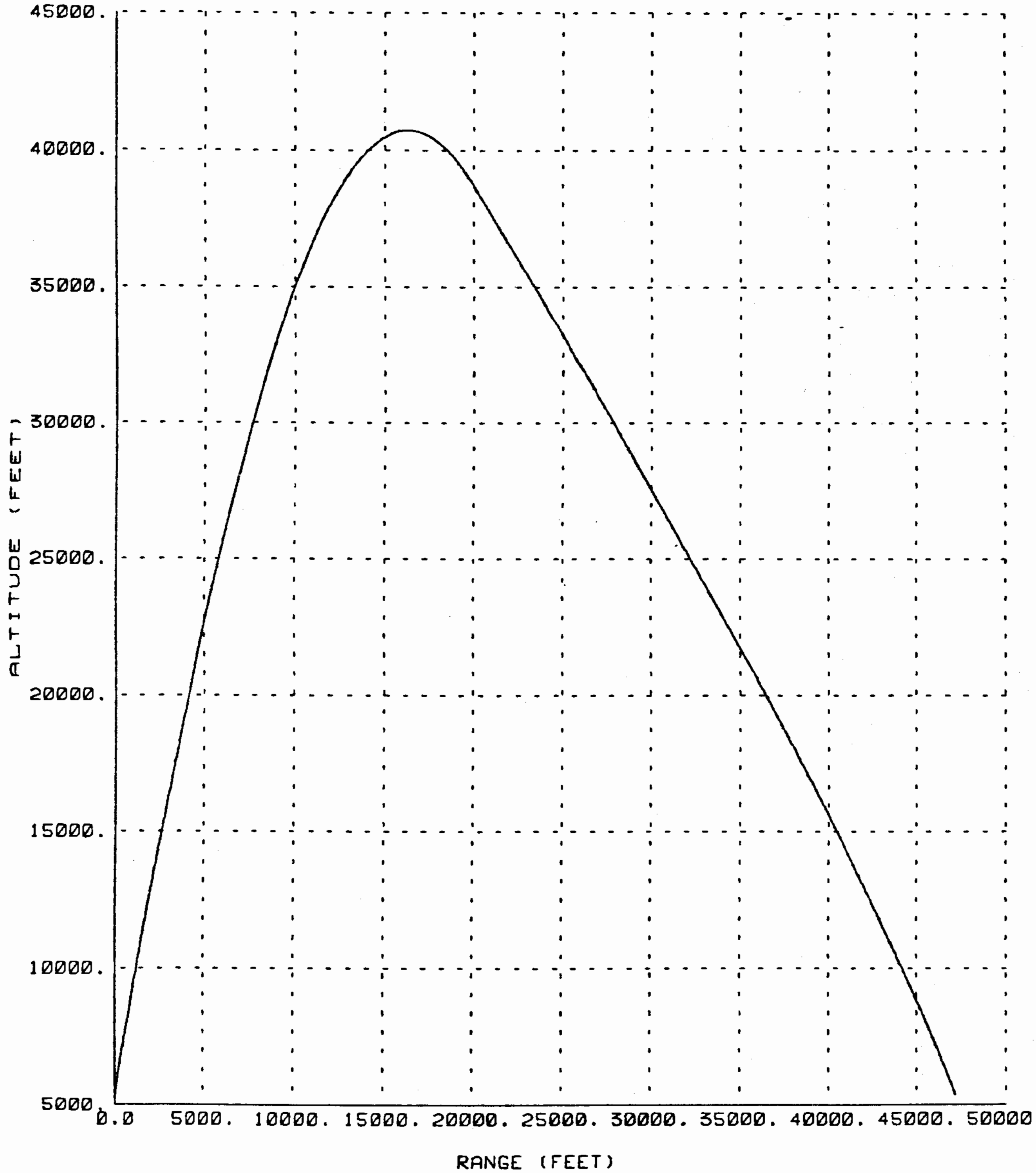
SECRET

UNCLASSIFIED

DOE b(3)

R719511 OPTICAL

ALTITUDE VS RANGE



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APPENDIX E

JTA Readouts

Data Processor Data List
End Event Data

T	=	Td (SA3167)
1	=	TR1
2	=	TR2
5	=	Neutrons in Window A
6	=	Neutrons in Window B
7	=	A Occurred (SA3167)
8	=	B Occurred (SA3167)
78	=	A Before B (SA3167)
87	=	B Before A (SA3167)
3D	=	DT [TR1 to Neutron Current Pulse (I1)]
3A	=	Fault Current (I1)
3B	=	PW [Neutron Current Pulse (I1)]
3C	=	Number of Crossings (I1)
4D	=	DT [TR2 to Neutron Current Pulse (I2)]
4A	=	Fault Current (I2)
4B	=	PW [Neutron Current Pulse (I2)]
4C	=	Number of Crossings (I2)
5I	=	Integral of ND1 (Total Neutrons)
6I	=	Integral of ND2 (Total Neutrons)

1T to 16I Decoded Same as Above
Self-Check Data

HELLBENDER I
1-27-87

MC 3801 S/N BBN-X009-B85
MC 3802 S/N BBN-X010-A85

Self-Check Data

T	=	000
1	=	1
2	=	1
5	=	1
5	=	1
6	=	1
8	=	1
78	=	0
87	=	0
3D	=	064
3A	=	0
3B	=	007
3C	=	1
4D	=	064
4A	=	0
4B	=	007
4C	=	1
5I	=	181
6I	=	208
1T	=	117
11	=	1
12	=	1
15	=	1
16	=	1
17	=	1
18	=	1
178	=	0
187	=	1
13D	=	065.5
13A	=	0
13B	=	007.5
13C	=	1
14D	=	060.5
14A	=	0
14B	=	005.5
14C	=	2
15I	=	064
16I	=	052

DOE
b(3)

HELLBENDER II
6-29-87

MC	3801	S/N	BBN-X009-B85
MC	3802	S/N	BBN-X010-A85

DOE
b(3)

Self-Check Data

T = 001
1 = 1
2 = 1
5 = 1
6 = 1
7 = 1
8 = 1
78 = 1
87 = 0
3D = 064
3A = 0
3B = 007
3C = 1
4D = 064
4A = 0
4B = 007
4C = 1
5I = 182
6I = 217
1T = 118
11 = 1
12 = 1
15 = 1
16 = 1
17 = 1
18 = 1
178 = 1
187 = 1
13D = 065.5
13A = 0
13B = 007.5
13C = 1
14D = 060.5
14A = 0
14B = 005.5
14C = 2
15I = 064
16I = 054

HELLBENDER III
3-3-88

MC 3801 S/N BBN-X009-B85
MC 3802 S/N BBN-X010-A85

DOE
b(3)

Self-Check Data

T =	000
1 =	1
2 =	1
5 =	1
6 =	1
7 =	0
8 =	0
78 =	0
87 =	0
3D =	064
3A =	0
3B =	007.5
3C =	1
4D =	064
4A =	0
4B =	007
4C =	1
5I =	208
6I =	130
1T =	117
11 =	1
12 =	1
15 =	1
16 =	0
17 =	1
18 =	1
178 =	0
187 =	1
13D =	065.5
13A =	0
13B =	007.5
13C =	1
14D =	060.5
14A =	0
14B =	005.5
14C =	2
15I =	060
16I =	036

HELLBENDER IV
6-14-88

MC 3801 S/N BBN-X1012-A87
MC 3802 S/N BBN-X1014-C88

[redacted]

DOE b(3)

Self-Check Data

T =	000
1 =	1
2 =	1
5 =	1
6 =	1
7 =	0
8 =	0
78 =	0
87 =	0
3D =	063
3A =	0
3B =	007.5
3C =	1
4D =	063.5
4A =	0
4B =	007
4C =	1
5I =	195
6I =	228
1T =	118
11 =	1
12 =	1
15 =	1
16 =	1
17 =	1
18 =	1
178 =	0
187 =	1
13D =	065.5
13A =	0
13B =	007.5
13C =	1
14D =	060.5
14A =	0
14B =	005.5
15I =	057
16I =	052

MK-11/I
1-12-88

MC	3801	S/N	BBN-X008-B85
MC	3802	S/N	L-85

DOE
b(3)

Self-Check Data

T = 000
1 = 1
2 = 1
5 = 1
6 = 1
7 = 0
8 = 0
78 = 0
87 = 0
3D = 064
3A = 0
3B = 006.5
3C = 1
4D = 064
4A = 0
4B = 006.5
4C = 1
5I = 160
6I = 205
1T = 118
11 = 1
12 = 1
15 = 1
16 = 1
17 = 1
18 = 1
178 = 0
187 = 1
13D = 065.5
13A = 0
13B = 007.5
13C = 1
14D = 060.5
14A = 0
14B = 005.5
14C = 2
15I = 051
16I = 045

~~SECRET~~ UNCLASSIFIED

MARK 11/II
4-26-88

MC	3801	S/N	BBN-X008-B85
MC	3802	S/N	L-85

DOE
b(3)

Self-Check Data

T = 000
1 = 1
2 = 1
5 = 1
6 = 1
7 = 0
8 = 0
78 = 0
87 = 0
3D = 064
3A = 0
3B = 006.5
3C = 1
4D = 064
4A = 0
4B = 006.5
4C = 1
5I = 220
6I = 165
1T = 118
11 = 1
12 = 1
15 = 1
16 = 1
17 = 1
18 = 1
178 = 0
187 = 1
13D = 065.5
13A = 0
13B = 007.5
13C = 1
14D = 060.5
14A = 0
14B = 005.5
14C = 2
15I = 047
16I = 045

UNCLASSIFIED

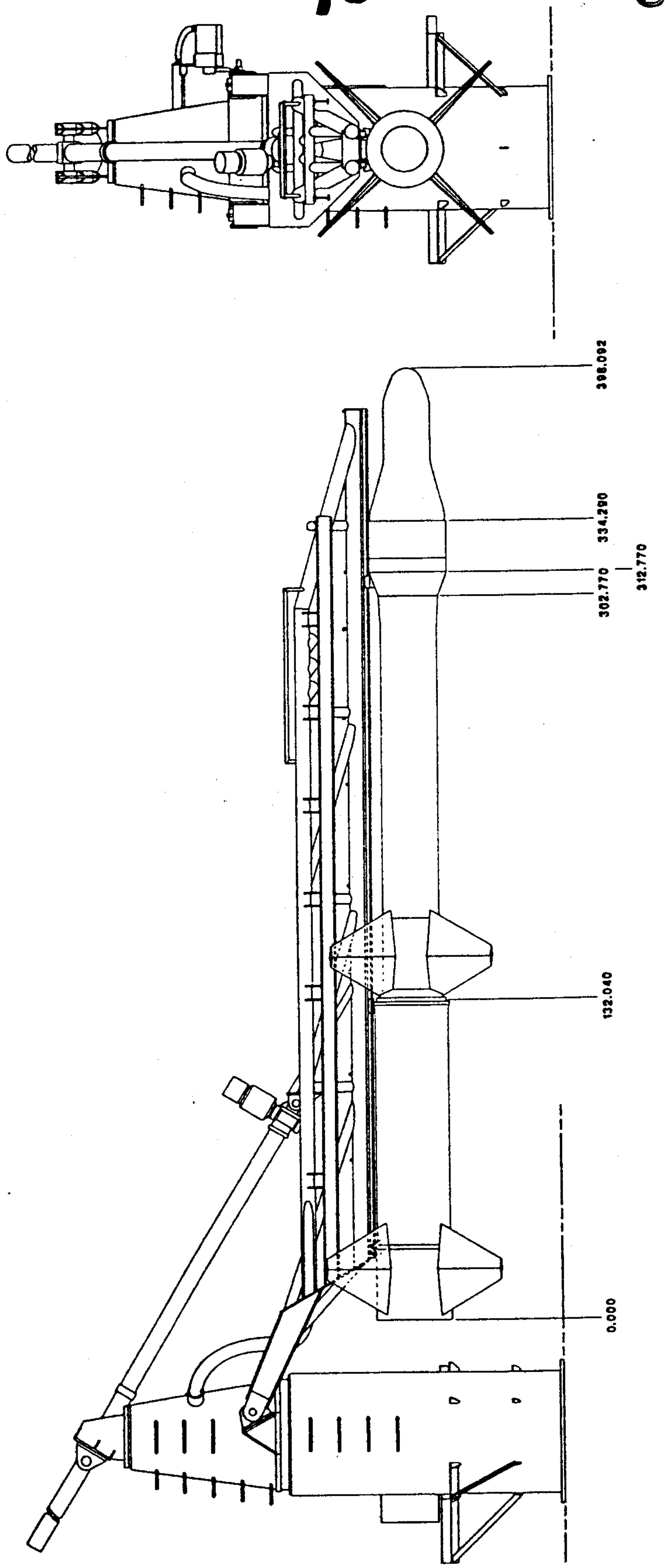
 ~~SECRET~~

APPENDIX F

Mk-11 Rocket Test Specifications

[redacted]

UNCLASSIFIED



TALOS / HONEST JOHN / MK11 APPLICATION

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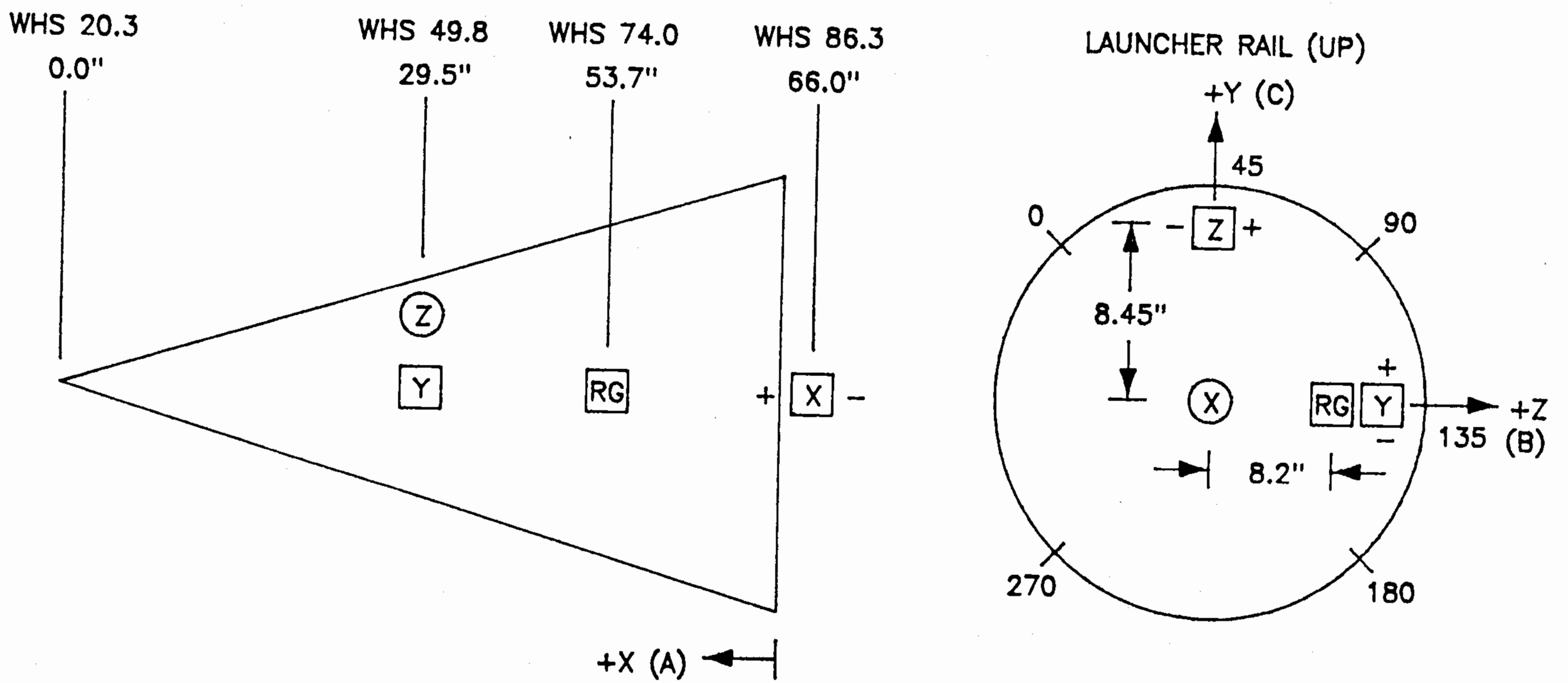
[redacted]

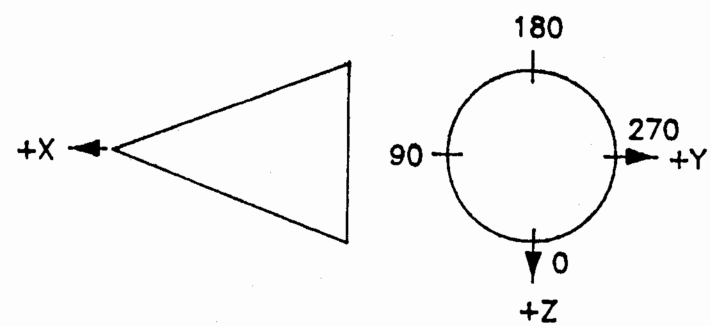
TRANSDUCER LOCATIONS AND SIGN CONVENTIONS



NOTE: ALL ROTATIONS (A,B,C) ARE POSITIVE IN THE CLOCKWISE DIRECTION LOOKING IN THE POSITIVE (X,Y,Z) AXIS

MASS PROPERTIES

WT: 1314.2 LBS	IXX: 38575 IN-LB2
XBAR: 30.37 IN (WHS 50.67)	IYY: 466847 LB-IN2
YBAR: .0008 IN	IZZ: 468524 LB-IN2
ZBAR: .0025 IN	IXY: 802.7 LB-IN2
RBAR: .0026 IN	IXZ: 546.5 LB-IN2
PAT: .130 DEG	IYZ: -721.9 LB-IN2



MK11 ROCKET TEST SPECIFICATIONS

	FIRST STAGE	SECOND STAGE
MOTOR TYPE	TALOS	IMPROVED HONEST JOHN
LENGTH (IN)	133	164.5
DIAMETER (IN)	31	24.5
WEIGHT (LBS) FULL	4278	2890
EMPTY	1475	1227
SPEC IMPULSE (LBF-SEC/LBM)	213	215
BURN TIME (SEC)	5.75	3.4
AVERAGE THRUST (LBF)	109800	100000

TOTAL SYSTEM WEIGHT AT LAUNCH: 9353.5 LBS (MEASURED)

TOTAL SYSTEM LENGTH AT LAUNCH: 398 IN = 33.2 FT

DISTRIBUTION:

1A	M0647	AFWL/NTSW Attn: D. Fisher Kirtland AFB, NM 87117-6008
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3-8A	M0737B	Los Alamos National Laboratory Attn: E. D. Aragon, WX-1, MS-C936 J. R. Conn, WT/WP, MS-F631 G. G. Hill, WXBO, MS-P945 J. Holt, WT/WP, MS-F631 T. O. Seitz, ADWT, MS-A105 L. E. Witt, WX-1, MS-C936 PO Box 1667 Los Alamos, NM 87545-5000
9A	M1163B	USDOE DASMA/DP-242.1 Attn: LtC P. Neeley PO Box A Germantown, MD 20874
10-11A	M0800	E. E. Ives, 8100 J. A. Wackerly, 8524
12A	1522	J. T. Black
13A	2300	J. L. Wirth
14A	2500	R. L. Schwoebel
15A	5100	H. W. Schmitt
16A	5110	C. C. Burks
17A	5111	D. L. McCoy
18-19A	5111	P. R. Hooper
20A	5140	C. M. Tapp
21A	5141	C. A. Harris
22A	5143	R. D. Robinett
23A	5144	D. E. Ryerson
24A	5160	G. R. Otey
25A	5161	K. D. Nokes
26A	5165	G. R. Otey, Actg
27A	5165	K. R. Eklund
28A	5165	W. J. Patterson
29A	7200	C. H. Mauney
30A	9122	R. H. Braasch
31-35A	3141	S. A. Landenberger
36A	3151	W. I. Klein For DOE/OSTI (NWD Index)

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