1 of 1

Users Manual for CATNIP: A Computer Analysis Tool for Normal Impact Penetration

Brad S. Altman

Advanced Munitions Department, 9723

Sandia National Laboratories

Albuqueraue, New Mexico 87185

Abstract

This software is used to predict depth of penetration and time histories of depth, velocity, and acceleration of ogive-nose projectiles into various target materials. The predictions use projectile and target properties as inputs to the program. The program is based on analytical penetration models developed by Forrestal and co-workers using spherical cavity expansion approximations. The program has a graphical user interface which requires minimal time to learn and allows for simplicity while entering data.

Acknowledgement

Table of Contents

List of Figures

Introduction

This program was developed to provide a computer based framework for analytical models developed by Forrestal and co-workers [1-2] to predict depth of penetration and temporal quantities for rigid, non-deforming ogive-nose projectiles penetrating into a wide variety of targets. CATNIP provides results for penetration into semi-infinite targets, but does not provide for perforation events. The program has a graphical user interface to facilitate operation so that people unfamiliar with the analytical models can use the code with a minimum of training. CATNIP runs on Apple Macintosh computers using the Hypercard program. The Hypercard program is included with the system software on all Macintosh computers. A familiarity with the Macintosh use of pointing and clicking with the mouse is assumed for the use of this program.

Executing the CATNIP software

First install the Hypercard program onto the Macintosh's hard drive according to the instructions supplied with the software. Next install the CATNIP program onto the hard drive by dragging the CATNIP program icon from the floppy disk to the hard disk. The CATNIP program can be started in two ways: first, by double-clicking on the CATNIP icon on the hard disk; or second, start the Hypercard program by double-clicking on the Hypercard icon, choose Open from the File menu, click on the CATNIP name in the scroll box, and finally clicking the open button.

Capabilities and use of CATNIP

CATNIP uses a 'graphical penetration equation' shown in Figure 1. This equation states that the projectile parameters plus the target properties combine to give the necessary quantities for deep Penetration Response. Once the projectile and target parameters are input, the operator of CATNIP moves to the Penetration Response part of the program that calculates the depth and time of penetration as a function of striking velocity. Each of the three parts of the CATNIP penetration equation is a button. Clicking each specific button allows you to access each specific part of CATNIP.

PROJECTILE PARAMETERS.

Clicking the PROJECTILE PARAMETERS button moves you to the PROJECTILE PARAMETERS screen (Figure 2). The input parameters for the projectile are: nose shape or caliber-radius-head (CRH), mass (kg), and shank diameter (m).

> **nose shape**: Figure 2 shows a schematic diagram of four different nose shapes or caliber-radius heads of the projectile. The caliber-radius-head ψ is defined by $\psi = R/d$ where R is the ogive radius and d is the shank diameter. A nose shape is selected by placing the pointer over the desired icon and clicking the button. The nose shape is highlighted during this procedure to show that it has been selected. An option for variable caliber-radius-head is used by clicking on the [**UARIABLE CRH**] button. Type the desired caliber-radius-head. NOTE: this type of input box only requires that the desired number be input (no units), but hitting the return key is not required -- this convention will be followed throughout the CATNIP software program.

> **mass:** The mass of the projectile is input by placing the cursor over the [**mass**] button and clicking once. Type the mass in kilograms (kg) in the box with the flashing vertical bar cursor.

> **diameter:** The shank diameter of the projectile is input by placing the cursor over the [**diameter**] button and clicking once. Type the diameter in meters (m) in the box with the flashing vertical bar.

> **verify:** Clicking the [**verify**] button displays the inputs and verifies that they are correct before continuation of the program. In addition to seeing the inputs, the nose shape coefficient $N(\psi) = 24 \psi^2/(8\psi - 1)$ is evaluated and displayed.

When the inputs on this screen are completed and the [**verify**] button has been clicked, click on the ⊔⊿ button to move back to the main CATNIP penetration equation screen.

TARGET MATERIALS .

Clicking the TARGET button moves you to the TARGET MATERIALS screen (Figure 3). This screen shows a list of the current target materials available. Placing the pointer on the desired target material title and clicking will take you to that materials parameter input screen. Currently

there are three target materials available. One for concrete and two for soil. The soils are divided into two locking solid models, one for Tresca [1] and the other for Mohr-Coulomb [1] yield criteria.

CONCRETE.

The concrete material model used here is given by [2]. The model is based upon an empirical fit of concrete penetration data covering a wide variety of projectile masses and target strengths. The parameters for this model are: unconfined compressive strength f'_c, empirical parameter S, and density ρ. The Concrete target screen is shown in Figure 4.

> **unconfined compressive strength f'_c**: The unconfined compressive strength of the concrete is input by placing the cursor over the ⌐f'c⌐ button and clicking once. Type the appropriate unconfined compressive strength in Pascals (Pa) in the box with the flashing vertical bar.

> **S parameter**: The empirical parameter S (no units) is input by placing the cursor over the ⌐S Parameter⌐ button and clicking once. This button responds differently than the other buttons. When you click the button, CATNIP automatically calculates S according to the empirical model and puts it in the correct place. The calcualted S paramter can be input manually by double-clicking in the S parameter value box and then typing the desired value for S.

> **density** : The density ρ of the concrete is input by placing the cursor over the ⌐density⌐ button and clicking once. Type the density in kilograms per cubic meter (kg/m^3) in the box with the flashing vertical bar.

> **model reference**: Clicking the Model Reference button gives a reference for more detailed explanation the material model.

When the inputs on this screen are completed, click on the ↩ button to move back to the main CATNIP penetration equation screen.

SOIL: Tresca yield criterion.

The soil material models used here are given by [1]. The soil target screen that uses the Tresca yield criterion is shown in Figure 5. The parameters for this model are: 'locked' value of volumetric strain η^*, shear strength τ_0, Young's modulus E, and density ρ.

> **volumetric strain η^***: The locked volumetric strain value for the soil is input by placing the cursor over the icon of η^* on the p- η graph and clicking once. Type the locked value of volumetric strain (no units) in the box with the flashing vertical bar.

> **shear strength**: The shear strength τ_0 of the soil is input by placing the cursor over the icon of τ_0 on the τ_0- p graph and clicking once. Type the shear strength in Pascals (Pa) in the box with the flashing vertical bar.

> **Young's modulus**: The Young's modulus E of the soil is input by placing the cursor over the ⌈ Young's modulus ⌋ button and clicking once. Type the Young's modulus in Pascals (Pa) in the box with the flashing vertical bar.

> **density**: The density ρ of the soil is input by placing the cursor over the ⌈ density ⌋ button and clicking once. Type the density in kilograms per cubic meter (kg/m^3) in the box with the flashing vertical bar.

> **model reference**: Clicking the Model Reference button gives a reference for more detailed explanation the material model.

When the inputs on this screen are completed, click on the ☞ button to move back to the main CATNIP penetration equation screen.

SOIL: Mohr-Coulomb yield criterion.

The soil target screen that uses the Mohr-Coulomb yield criterion is shown in Figure 6. The parameters for this model are: 'locked' value of volumetric strain η^*, pressure dependent shear strength defined by τ_0 and λ, Young's modulus E, and density ρ. The additional parameter λ describes the slope of the τ-p curve. All of the inputs act identically to those described in the Soil: Tresca yield criterion section and the input of the pressure dependent parameter λ is described below.

pressure dependent parameter: The pressure dependent parameter λ of the soil is input by placing the cursor over the icon λ on the τ-p graph and clicking once. Type the locked value of volumetric strain (no units) in the box with the flashing vertical bar.

When the inputs on this screen are completed, click on the ☞ button to move back to the main CATNIP penetration equation screen.

PENETRATION RESPONSE.

Clicking the PENETRATION RESPONSE button moves you to the penetration response screen (Figure 7). This is the section of the program where predictions of penetration depth as a function of striking velocity and coefficient of sliding friction are made This screen has two inputs: striking velocity and coefficient of sliding friction. The outputs or results are the time and depth of penetration. In addition there are a buttons to generate history plots of the temporal quantities.

striking velocity: The striking velocity is input by placing the cursor over the [STRIKING VELOCITY] button and clicking once. Type the striking velocity in meters per second (m/s) in the box with the flashing vertical bar.

friction: The coefficient of sliding friction is input by placing the cursor over the FRICTION button and clicking once. Type the coefficient of sliding friction (no units) in the box with the flashing vertical bar.

penetration response: Clicking the [PENETRATION RESPONSE] button gives the results of the CATNIP program for the specific penetration event. The results are total time of penetration in ms (the time elapsed from striking the target until the projectile comes to rest), the depth of penetration in m (the depth from striking the target surface to the nose of the projectile), and the maximum deceleration in g's and the time at maximum deceleration .

deceleration history plot: Clicking the [DECELERATION HISTORY PLOT] button moves to the deceleration plot screen (Figure 8). A deceleration-time plot for the current penetration event is displayed A button labeled PRINT GRAPH is included on this card. Clicking this button will print the graph on the current printer. Click on the ☞ button to move back to the **PENETRATION RESPONSE** screen.

velocity history plot: Clicking the [VELOCITY HISTORY PLOT] button moves to the velocity plot screen (Figure 9). A velocity-time plot for the current penetration event is displayed. A button labeled PRINT GRAPH is included on this card. Clicking this button will print the graph on the current printer. Click on the ⬛↖ button to move back to the **PENETRATION RESPONSE** screen.

displacement history plot: Clicking the [DISPLACEMENT HISTORY PLOT] button moves to the displacement plot screen (Figure 10). A displacement-time plot for the current penetration event is displayed. A button labeled PRINT GRAPH is included on this card. Clicking this button will print the graph on the current printer. Click on the ⬛↖ button to move back to the **PENETRATION RESPONSE** screen.

When finished with this screen, click on the ⬛↖ button to move back to the main CATNIP penetration equation screen. Note that at any time it is possible to return to any screen, change parameters, and return to the **PENETRATION RESPONSE** screen for further penetration response calculations.

Summary

This document comprises a users manual for CATNIP: A Computer Analysis tool for Normal Impact Penetration. The features of the program are documented, but the reader is referred to the cited references for in-depth investigation of the penetration and material models.

References

[1] M. J. Forrestal and V. K. Luk, "Penetration Into Soil Targets", International Journal of Impact Engineering, V 12, No. 3, pp427-444, 1992.

[2] M. J. Forrestal, B. S. Altman, J. D. Cargile, and S. J. Hanchak, "An Empirical Equation for Penetration Depth of Ogive-nose Projectiles into Concrete Targets", to appear in the International Journal of Impact Engineering, 1993.
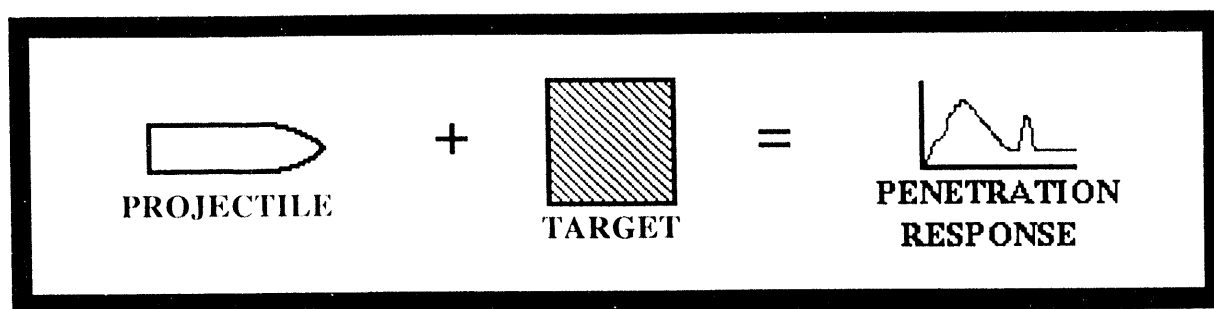
Figure 1. Control screen of CATNIP showing the 'graphical penetration equation'.

Figure 2. Projectile parameters input screen.

Choose the Target Material

```
CONCRETE : NEW EMPIRICAL EQUATION                              ⬆
SOIL : ELASTIC TRESCA PLASTIC with CRATER PHASE
SOIL : ELASTIC MOHR-COULOMB PLASTIC with CRATER PHASE
4
5
6
7
                                                              ⬇
```

☞

Figure 3. Target materials screen.

CONCRETE TARGET

f'c

Type in the value of   36.2*10^6
f'c in Pa.

S Parameter

Type in the value of S   12

density

Type in the density of   2370
the target in kg/m^3

Model Reference

Figure 4. Concrete target material parameters input screen.

SOIL TARGET:

• Locking Solid

• Tresca Criterion
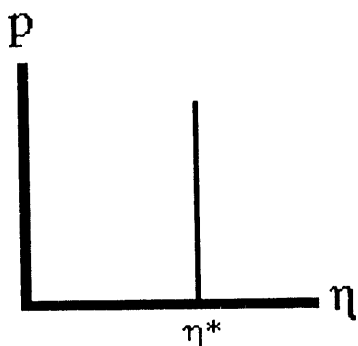
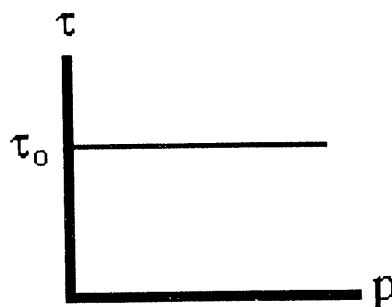Model Reference

Type in the value $\eta*$ | .13 |

Type in the value of τ_0 in Pa. | 10*10^6 |

Young's modulus

Type in the value of E in Pa. | 160*10^6 |

density

Type in the density of the target in kg/m^3 | 1860 |

Figure 5. Soil target input screen using the Tresca yield criterion.

SOIL TARGET:
- **Locking Solid** p ... η, η^*
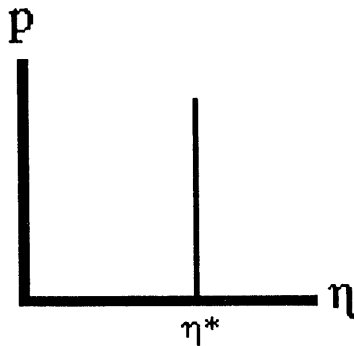
  Type in the value η^* [.1]

  Young's modulus
  Type in the value of E [100000] in Pa.

  density
  Type in the density of [1750] the target in kg/m^3

- **Mohr-Coulomb Criterion** Model Explanation

  τ, τ_o, λ, p
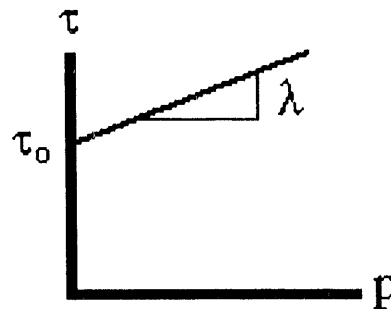
  Type in the value of τ_o in Pa. [5000]

  Type in the value of λ [500]

Figure 6. Soil target input screen using the Mohr-Coulomb yield criterion.

12

PENETRATION RESPONSE

INPUTS:

(STRIKING VELOCITY) Type in the striking |600 |
                       velocity in m/s

(FRICTION) Type in the coefficient |0 |
              of sliding friction

OUTPUTS:

(PENETRATION RESPONSE)

Total time of penetration = 2.056 ms.
Total penetration depth = 0.6032 m
Maximum deceleration = -35865.769 g at time = 0.090 ms.

(DECELERATION HISTORY PLOT)

(VELOCITY HISTORY PLOT)

(DISPLACEMENT HISTORY PLOT)

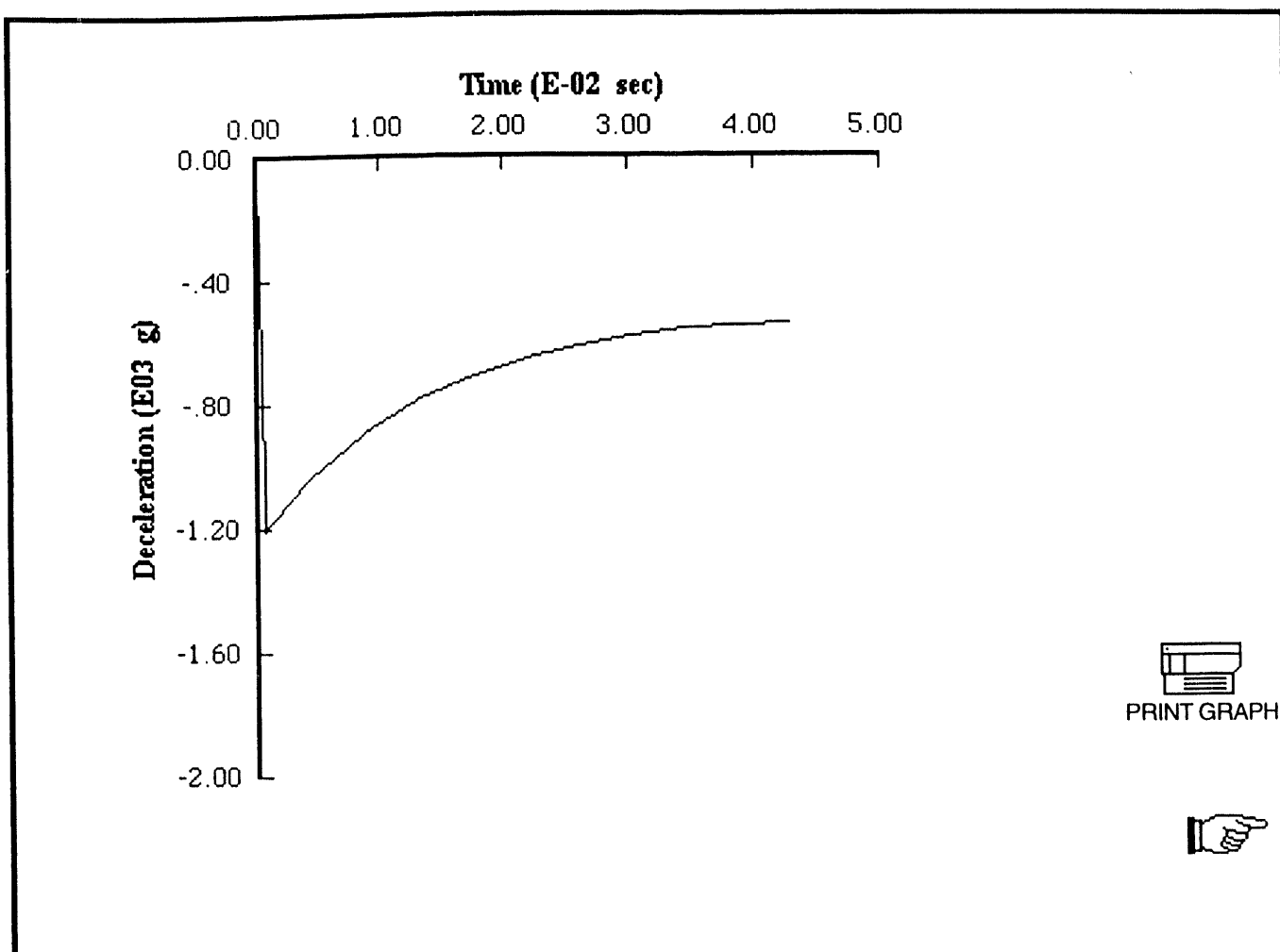Figure 7. Penetration response screen.

13

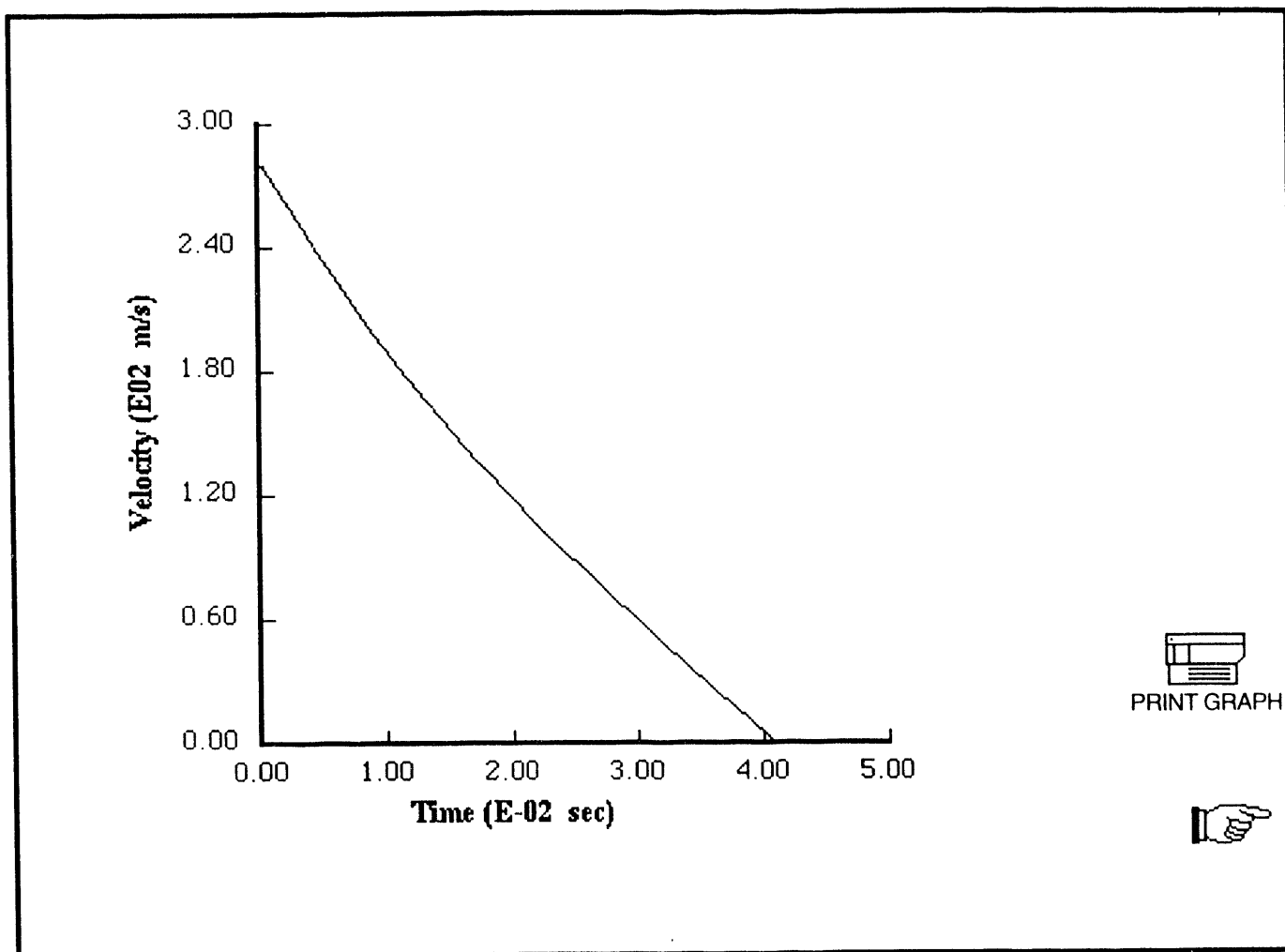Figure 8. Deceleration history plot screen.
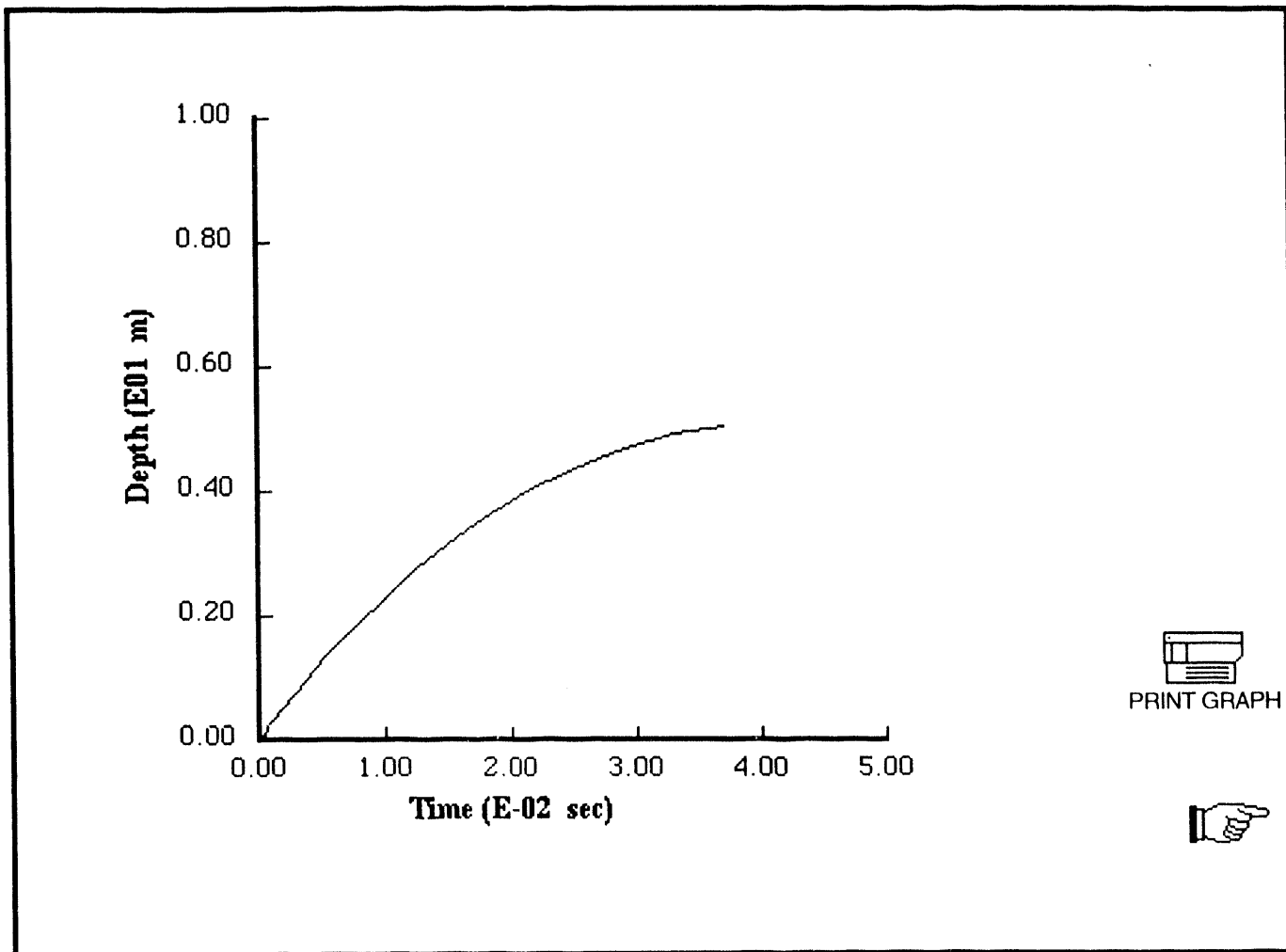
Figure 9. Velocity history plot screen.

Figure 10. Displacement history plot screen.

Distribution List

Alliant Techsystems Inc.
Attn: Dr. Gordon Johnson
MN 11-2925
600 2nd St NE
Hopkins, MN 55343

California Research and Technology
Attn: Y. M. Ito
20943 Devonshire St.
Chatsworth, CA 91311

Logicon/RDA
Attn: Ed Humphreys
6940 S. Kings Hwy, Ste 210
Alexandria, VA 22310

FC/DNA
Attn: Doug Seemann
FCTP
Kirtland AFB, NM 87115-5000

Naval Surface Warfare Center
Dahlgren Division
Attn: Walter Hoye, Code G22 (2 copies)
Dahlgren, VA 22448-5000

Waterways Experiement Station
Attn: CEWES-SD-R/Dr. Bob Rohani (4 copies)
P.O. Box 631
Vicksburg, MS 39180

Armament Directorate
Attn: John Collins (3 copies)
WL/MNMW
101 W. Eglin Blvd, Ste 337
Eglin AFB, FL 32542-6810

Defense Nuclear Agency
Attn: Joseph Renick
FCDNA/FCTP
Kirtland AFB, NM 87117

Director
Defense Nuclear Agency
Attn: SPSD/ Mr. Mike Giltrude
6801 Telegraph Road
Alexandria, VA 22310-3398

Armament Directorate
Attn: Dick Mabry (3 copies)
WL/MNMW
101 W. Eglin Blvd, Ste 219
Eglin AFB, FL 32542-6810

UDRI
Attn: S. N. Brar
Impact Physics Laboratory
Dayton, OH 45469

Calif. Inst. of Tech.
Attn: Tom Ahrens
Graduate Aeronautical Laboratories
Pasadena, CA 91125

University of Denver Research Institute
Attn: James Kellar
2050 East Iliff Ave
BW-228
Denver, CO 80208

Applied Research Associates
Attn: Frank Maestas
4300 San Mateo Blvd.
Suite A-220
Albuquerque, NM 87110

Sandia National Labs
Attn: Mike Ferrario
P.O. Box 969, Dept 5375
Livermore, CA 94550

1432	S. A. Silling
1433	D. E. Grady
1434	D. B. Longcope
1562	R. K. Thomas
1562	E. P. Chen
1562	E. D. Reedy
2664	D. E. Ryerson
5165	N. R. Hansen
6117	W. A. Olsson
6411	B. S. Altman (10 copies)
7141	Technical Library (5 copies)
7151	Technical Publications
7613-2	Document Processing for DOE/OSTI (10 copies)
8523-2	Central Technical Files
9701	J. P. Hickerson (2 copies)
9702	W. K. Tucker
9723	J. Holovka
9723	M. J. Forrestal (5 copies)
9723	R. G. Lundgren
9723	V. K. Luk
9727	B. J. Gomez

END

DATE FILMED

1 / 7 / 94