TECHNICAL REPORT 4980

INTERGRATED PROJECTILE SYSTEMS SYNTHESIS MODEL (IPSSM)

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AUGUST 1976

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PICATINNY ARSENAL
DOVER, NEW JERSEY
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DISPOSITION

Destroy this report when no longer needed. Do not return to the originator.
A Computer model called IPSSM (Integrated Projectile Systems Synthesis Model) is being developed for use in the preliminary design of large caliber projectiles. Complete capabilities of the interim version of this model are detailed, and instructions are given for users of the program in both the interactive teletype and batch modes. The use of this initial version of IPSSM will determine additional modules to be added as well as refinements in the over-all operation of the system.

**Report Title:** Integrated Projectile Systems Synthesis Model (IPSSM)

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**Performing Organization:** Picatinny Arsenal

**Controlled Office:** Approved for public release; distribution unlimited.
ACKNOWLEDGEMENTS

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OBJECTIVES AND APPROACH

The objective of this program is to develop a complete computer model for use in the preliminary design of large caliber projectiles. This model, called IPSSM (Integrated Projectile Systems Synthesis Model), is a set of computer program modules and subroutines integrated in such a manner as to provide a realistic, interactive, computational tool for engineers and designers engaged in the development of preliminary design information for projectiles. The model described in this report includes the capability of performing extensive calculations necessary to formulate projectile designs. Computations include interior and exterior ballistics, static shell property calculations, aerodynamic properties generation, lethal area effectiveness, 6-D trajectory calculations, recoil mechanism design, and sabot design.

The general approach in the complete development of the model calls for the selection and modification of existing computer programs to accomplish specific calculations as well as the identification of programming tasks required to complete the model. The essential ingredient of IPSSM is its common data base and a well coordinated and integrated set of computer programs which are not only extracting information from previously run programs within the system but are also generating specific data for subsequent use by other programs. These programs will either continue or modify the design process or be used for optimization. They are modular in nature so as to facilitate future improvements or replacements of the design programs. Over-all control of the model is accomplished by the user through the executive program.

The objective of this report is to provide an initial user's manual for the IPSSM System currently available. Additional features, updates, and modifications will be accomplished as use is made of this initial version of IPSSM.

BACKGROUND

In May 1970, DARCOM (AMC) initiated a feasibility study directed toward weapon system computer modeling which would provide preliminary design parameters for tactical missile weapon system concepts. After DARCOM (AMC) had presented the concept and preliminary comments of subordinate commands to the CAD-E Council in October 1970, the IWSSM (Integrated Weapon System Synthesis Model) Ad Hoc Working Group of the Council was established to study the concept in more detail. After a six-month effort, the working group concluded that such a system was both feasible and desirable, but initially it should be limited to the construction of a number of computer models, each
addressing a particular military commodity. It was considered too large an undertaking to develop one model that would handle all commodity designs such as guns, projectiles, missiles, aircraft, vehicles, etc.

The recommendation of the IWSSM Working Group was that each command submit a Program Data Sheet outlining a proposed activity directed toward a specific commodity. The Integrated Projectile System Synthesis Model (IPSSM) Program was established at Picatinny Arsenal to address the preliminary design of large caliber projectiles such as artillery and mortar rounds.

The Picatinny IPSSM program was funded as a CAD-E task on 1 April 1972. A substantial initial effort was directed toward a survey of existing computer programs in use at Picatinny and other government agencies which would be suitable for incorporation into the IPSSM System. Major areas of design interest were identified by system engineers, and computer programs within each area were identified. The programs were examined for (1) adequate documentation and technical adaptability within the design area, and (2) adaptability of input and output data formats that would be consistent with the over-all requirements of the executive program.

Existing computer programs to determine static and aerodynamic shell properties, perform interior and exterior ballistics calculations, compute lethal areas, do 6-D trajectory calculations, and design recoil mechanisms and sabot designs were selected. Source listings were obtained and put into update format, and proper operation was verified with test cases. Each of the nine codes (Weight, Spinner, Aerol, Interior Ballistics, Lethal Area, 6-D Trajectory, Recoil Mechanism, Sabot Design and Heppner-Interior Ballistics) has been made operational under both the interactive teletype (TTY) and batch mode to facilitate entry and exit from the executive program. Major effort was devoted to the design and checkout of the preliminary IPSSM executive program. The system has been used on a trial basis and is now ready for general use to determine its adequacy as a design tool.

Several user sessions have been conducted to acquaint engineers and scientists involved in projectile design and evaluation with the operation of the current IPSSM system. These sessions will continue as more personnel become involved. As a result of these initial meetings, several important modifications were made to improve the operational capabilities of the system. For example, an optional abbreviated input format can now be utilized to quicken system response in the TTY mode. Testing of user responses in the TTY interactive mode has also been incorporated to avoid program abort as a result of
trivial user typing errors. In addition, an independent computer program (IPSDATA) has been written to simplify the establishment of initial data base files. Output from this program provides the basis for accurate checking of input data files.

PRESENT STATUS

The present IPSSM System can execute nine applications programs from either batch or teletype (TTY) mode. These programs perform the following computations: (1) Static Properties Calculations, (2) Generation of Aerodynamic Coefficients, (3) Interior Ballistics, (4) Exterior Ballistics, (5) Lethal Area Computations, (6) 6-D Trajectory Calculations, (7) Recoil Mechanism Design, (8) Sabot Design, and (9) Heppner-Interior Ballistics.

In TTY mode, the executive program contains options for examining and modifying common data base information. In both modes the program allows the user to modify the data base variables, to store the modified data base in a new permanent file if desired, and to run linked cases of selected variables to facilitate the execution of parametric analyses. Special abbreviated output can be generated and stored automatically for later examination at the TTY. Options also exist for directing entire input/output for each set of application runs to the user's batch terminal or to the central site. The system is also capable of generating input data in the format required for running the graphics projectile measurement program (PROMS) (Reference 2). Output from PROMS can then be entered into the common data base for subsequent computations within the IPSSM System. Figure 1 illustrates the executive module operation in the batch or TTY mode. Figure 2 shows the input-output interface scheme utilized within IPSSM. Although this chart shows the technique for the exterior ballistic interface, the same system has been applied for all application programs. Figure 3 shows the latest flow diagram for IPSSM. The small boxes between the applications programs represent the input-output interfaces controlled by the executive program. Data analysis and optimization will be incorporated to a much greater extent as directed by future user requirements.

Options have also been installed to allow either the current data base to be automatically updated with the results of the current program or to have a separate and distinct new data base created with the same generated results.
EXECUTIVE MODULE OPERATION (IPSSM)

**Batch Mode**
- Programs and data storage initially
- Program execution
- Output data stored
- Additional programs & data stored

**Interactive Mode**
- User calls exec from teletype (or graphics) terminal
- User selects program & data for execution
- User calls for selective lines of output
- User modifies input data modules

**Data Bank**
- IPSSM program modules
- Input data for initial runs
- Output data storage
- Data modules for various designs
- Job control cards

*Figure 1*
INPUT - OUTPUT INTERFACE

(EXTerior BALLISTICS)

APPLICATION PROGRAM
- Trajectory History
- Time of Flight
- Height of Burst
- Range
- Terminal Velocity
- Stability

INPUT DATA FORMATTED

INPUT DATA GENERATOR

OUTPUT OPTIONS

EXECUTIVE MODULE (USER)
- Calls Appl Program and Stored Data
- Keys In Modes
- Selects Number of Runs
- Outputs Options

CENTRAL SITE

BATCH

TTY

PERMANENT STORAGE
A. Data Preparation

1. General

In order to execute the IPSSM Program, a data base containing the
generic characteristics of the projectile to be analyzed must be
available. This is established initially through the use of a program
called IPSDATA (Cycle 5). Subsequent to this, data may be added,
deleted, or changed either by rerunning IPSDATA with the modified
data base cards or by using IPSSM's executive program, which is called
IPSM (Cycle 5). The latter option may be accomplished through either
the batch or the teletype (TTY) mode.

2. Data Base Generation Using IPSDATA

The program called IPSDATA was written for easy cataloging and
checking of an entire data base. Use of the following deck of cards
will result in your data base being entered on whichever permanent
file you specify:

(JOBCARD),CM75000.

(COMMENT CARD)
ATTACH,IPSM,IPSD,CY=5,ID=NICHOLS,MR=1

IPSM.

(7/8/9 CARD)

(DATA BASE CARDS)

(6/7/8/9 CARD)

The first data base card contains the title to be associated with
your data base. The second card contains the cycle number followed
by a comma and the permanent file name (up to 10 alpha-numerics) in
which you wish your data base to be stored. These two cards are
followed by the key variable data cards. Each such card is identified
by its three-letter symbol in the first three columns. The fourth
column is blank. The value of the variable is then entered in free
floating point format (cannot be integer) on the card anywhere in the
next ten columns. Following the last key variable data card is a
card with the word "END" punched in the first three columns (see Sample Input for Initial Data Base Generation).

The key variable data are followed by the table entries required to execute the AERO 1 (AR), WEIGHT (WT), and LETHAL AREA (LA) Programs. Format for entering these tables is described in the discussions of programs in "Application Programs and Descriptions".

"Sample Input for Initial Data Base Generation" contains an example of a set of data base cards for the M106 8-inch Projectile which permits execution of the first five programs listed on page 3. Other data sets were generated in a similar manner to execute the remaining programs currently in operation within IPSSM. These sample data can be used to test the operation of each application program within IPSSM. (See "Sample Test Cases and Setup" for typical batch and TTY runs). These files will remain in the system as a permanent file for users to become familiar with the IPSSM System.

When establishing an initial data base, it should be noted that IPSDATA will store the data base in the requested cycle under a permanent file name of the form PFNXX, where PFN is the particular permanent file name you have selected, and XX is the symbol for the particular application program being run (AR, WT, LA, etc.). IPSDATA attaches these last two letters automatically by determining what data are being catalogued in that particular run. For example, if for an initial run of IPSDATA, the user includes data for the AR and LA programs and specifies that he wishes the data base stored in JOHN, cy=5, IPSDATA will automatically create two data bases: JOHNAR, cy=5 will contain the data needed to run the AR program and JOHNLA, cy=5 will contain the data needed to run the LA program. NOTE: This automatic appending of the two-letter program symbol is only done when running through IPSDATA; any subsequent modification of data bases using the executive program IPSH will recatalog the modified data base exactly as specified at the time of modification.

3. Multiple Value Option for Running Parametric Studies

As part of the general data base setup within IPSSM, a provision exists for entering up to six values for each key variable. Such an option can be useful in preparing combinations of runs where key variables take on different values and, in addition, may require the simultaneous change of other key variables. The technique for entering such data is described in subsequent paragraphs. The symbols, P, L, and N will aid in this description. These symbols can be associated with the words "permutation", "link", and "number", respectively.
This system is not unique to IPSSM. It has been used quite successfully in several other programs written at Picatinny Arsenal.

To begin with, each key variable has a P, L and N number (all integers) associated with it. N simply denotes the number of different values currently available for the given key variable. The P and L values are used to set up run combinations. The value of L determines whether or not the given key variable is "linked" with any other key variable. That is, in a combination of runs, if the L value for two or more key variables is the same, each of these variables will change their values simultaneously on each successive run. Finally, the P value determines the variable to be changed on each run and the number of runs to be made. For those variables which are linked through the L value, only one of these variables can have a nonzero P value. This is evident since when one linked variable changes its value, all other variables linked to it will also change. By assigning different L values, it is clear that sets of linked variables can be identified. Since L is currently restricted to the integers 1 through 9, nine sets of linked variables can be defined, if necessary. It should be stressed that only one variable within each set can have a nonzero P value.

As an example, suppose three key variables AXX, BXX, and CXX were to be varied in a combination of runs. Let AXX have two values and be independent of BXX and CXX. Let BXX and CXX have three values each and suppose they are linked. Then, to run all combinations under these assumptions AXX, BXX and CXX would have the following P, L and N numbers:

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>L</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>AXX</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>BXX</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>CXX</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

NOTE: Variable BXX in this case is used as the "permuted" variable.

4. Format and Use of P, L and N Numbers

At this point the meaning of the P, L and N numbers (abbreviated PLN numbers) should be clear. This paragraph describes how data are entered and modified within the data base when PLN numbers are involved. In paragraph 2 preceding, the entering of only single values for each key variable was described. In this case, the IPSDATA
program automatically associates a PLN of 101 to each entry. If a PLN number other than 101 is used, then a comma is entered in column four (rather than a blank) and the PLN number is entered in columns 5, 6 and 7. The N values (up to 6) are then entered in the remaining columns of the card in free floating point format separated by commas. No blanks are permitted following the first data entry.

Modifications of an existing data base to include PLN values other than 101 are described in the instructions for running the executive program in Batch or TTY mode. (See parts B and C of this section)

5. Data Base Modification Using the Executive Program

In order to modify an existing data base using the executive program (IPSH) (as opposed to creating an entirely new data base file using IPSDATA), the initial data base must first be available as a permanent file. The procedure using the teletype is explained in Part B of this Section titled "Instructions for Teletype Mode" under question 10. This question, namely, "MODIFY DATA BASE, YES OR NO =" is answered "YES". This invokes questions 11 and 12 which allow the user to enter data for key variables, even if no values currently exist for that variable. In this way data can be entered for a number of variables. Where limited data entries are required, for example, in executing the Interior Ballistics Program or the Aerodynamic Coefficient Program, this method would be preferable. For entering data via the Batch mode, the user should refer to part C of this section.

B. Instructions for TTY Mode

1. General

The following pages indicate the instructions used to execute the executive program (IPSH) in the TTY mode. This mode is conversational and requires limited response to perform many useful operations. It is required for users who do not have access to a Batch Terminal, and is particularly useful in conjunction with a portable teletype. The system allows the user to access any program within the IPSSM System. Where extensive production runs are required, it is recommended that the Batch Mode be used. However, certain options for some programs are currently available only in the TTY mode.

The first instruction required to enter the INTERCOM System (see Reference 7, page 3-2) from the teletype is "LOGIN". The system
responds with "ENTER USER NAME" to which you type XXXXYYYYZZZ where XXXX is a four letter user code assigned by the MISD.

YYY = Cost Center Code (See Reference 8, page 4-8)

ZZZ = Charge Code (See Reference 8, page 4-5a)

The system responds with "ENTER PASSWORD" to which you respond with the Picatinny Arsenal Code (Consult MISD).

The system then types some accounting information followed by the word "COMMAND:. From this point on, see the following table for specific IPSSM TTY instructions.

2. Explanation of "INPUT/OUTPUT OPTION LIST" (see question 23, page 18).

a. Teletype Options

The first two digits control the teletype function.

Put a "1" in the second place if you wish to come back to the teletype for the results of your run when it has finished. You will be asked to supply a permanent file name on which the results will be stored for eventual teletype display. In most cases, the results stored for teletype retrieval will be an abbreviated version of the complete results.

If, in addition to these abbreviated results, you would like the values of specific variables to be printed out, include a "1" in the first place. You will then be asked to identify these variables (up to 6).

b. Data Base Transfer Option

The third and fourth digits are used to replace particular data base values with new values obtained during your current execution of an application program.

This option can currently be used in two modes: when running the SP program, part of the SP output contains variables that are required in the AR input. Likewise, portions of the WT output are variables that are used as SP input. Thus, either an AR or SP data base can be automatically updated with this option when running either the SP or WT programs, respectively.
<table>
<thead>
<tr>
<th>QUESTION</th>
<th>EXPLANATION</th>
<th>RESPONSE EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Command</td>
<td>Attach the executive program (IPSM)</td>
<td>ATTACH,IPSM,IPSH,CY=5, ID=NICHOLS,R=1</td>
</tr>
<tr>
<td>b. Command</td>
<td>Start Execution</td>
<td>IPSM.</td>
</tr>
<tr>
<td>1. THIS IS IPSSM MODE TTY OR BATCH =</td>
<td></td>
<td>TTY</td>
</tr>
<tr>
<td>2. WILL THIS BE A NEW RUN, YES OR NO =</td>
<td>YES indicates a new run, NO signals the program that you have previously entered a run and are now coming back for the results.</td>
<td>YES</td>
</tr>
<tr>
<td>3. PROGRAM =</td>
<td>Enter the two-letter symbol and one digit corresponding to one of the nine application program names in IPSM's library and the current operational cycle number of that program. Current library symbols are:</td>
<td>AR5</td>
</tr>
<tr>
<td>QUESTION</td>
<td>EXPLANATION</td>
<td>RESPONSE EXAMPLE</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>AR - aeroballistics program</td>
<td>IB5</td>
<td></td>
</tr>
<tr>
<td>IB - interior ballistics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP - spinner (aerodynamic coefficients) etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WT - weight (static properties)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LA - lethal area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TR - six-D trajectory program</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RM - recoil mechanism design program</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD - sabot design program</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IH - Heppner-interior ballistics</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. DATA LOCATION: CY, PFNAME = Enter the cycle number, a comma, and then the name of the permanent file where your data base is stored. 4,XM58

5. GRAPHICS YES OR NO = This question will be asked only if you are running the WT program. If you answer YES, you will be asked to name a permanent file to store data to be used at the graphics terminal  YES
<table>
<thead>
<tr>
<th>QUESTION</th>
<th>EXPLANATION</th>
<th>RESPONSE EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(The title of your data base will be written out)</td>
<td></td>
<td>(no response)</td>
</tr>
<tr>
<td>6. EXAMINE DATA BASE, YES OR NO =</td>
<td>NO - Program will skip to question 10 YES - If you wish to ask the value(s) of specific variables in your data base.</td>
<td>YES</td>
</tr>
<tr>
<td>7. SYM =</td>
<td>Type in one three-letter variable symbol from the application program, or type in the word ALL if you wish to examine all of the key variables for that program.</td>
<td>WGT</td>
</tr>
<tr>
<td>9. SYM =</td>
<td>Type in the next three-letter variable symbol you wish to inspect. When you have finished examining data base values, type END.</td>
<td>END</td>
</tr>
<tr>
<td>QUESTION</td>
<td>EXPLANATION</td>
<td>RESPONSE EXAMPLE</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
<td>------------------</td>
</tr>
<tr>
<td>10. MODIFY DATA BASE, YES OR NO =</td>
<td>No - if you wish to run the data as it is stored program will skip to next appropriate question. YES - if you wish to change one or more values.</td>
<td>YES</td>
</tr>
<tr>
<td>11. SYM, PLN =</td>
<td>See instructions for creating initial data base</td>
<td>WGT,202</td>
</tr>
<tr>
<td>12. VALUES =</td>
<td>The number of values entered must be the same as the last digit entered from previous question. Use a decimal point in each value. Separate the values with commas. (Leave no blanks)</td>
<td>200.,202.5</td>
</tr>
<tr>
<td>13. SYM, PLN =</td>
<td>When you have finished changing the data base for this run, type END.</td>
<td>END</td>
</tr>
<tr>
<td>QUESTION</td>
<td>EXPLANATION</td>
<td>RESPONSE EXAMPLE</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
<td>------------------</td>
</tr>
<tr>
<td>14. DELETE TABLES, YES OR NO =</td>
<td>This question will be asked only if you previously indicated that you are running the AR program. For other programs, it will skip to question #18. The AR program will not run successfully if there are too many tables left in the database for the number of flight phases that are being run in the present case. Accordingly, tables may have to be deleted.</td>
<td>YES</td>
</tr>
<tr>
<td>15. TABLE NO. =</td>
<td>Insert the number of the first table you wish deleted.</td>
<td>12</td>
</tr>
<tr>
<td>16. TABLE NO. =</td>
<td>Insert the number of the next table you wish deleted.</td>
<td>13</td>
</tr>
<tr>
<td>17. TABLE NO.&quot;=</td>
<td>When you have finished deleting tables, type END.</td>
<td>END</td>
</tr>
<tr>
<td>QUESTION</td>
<td>EXPLANATION</td>
<td>RESPONSE EXAMPLE</td>
</tr>
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</tr>
<tr>
<td>18. CHG ITEMS YES OR NO =</td>
<td>This question will be asked if you have indicated that you are running the WT program. A response of NO signals the system to ask question 19. If you type YES a series of additional questions are asked to change, add, or delete shell items. (See pages 26-27 for these procedures).</td>
<td>NO</td>
</tr>
<tr>
<td>19. STORE MOD DATA, YES OR NO =</td>
<td>This question will be asked if you answered yes to either of questions 10 or 14.</td>
<td>YES</td>
</tr>
<tr>
<td>20. NEW TITLE =</td>
<td>Enter a title for your new data base.</td>
<td>M106 TEST CASE</td>
</tr>
<tr>
<td>WHERE DO YOU WISH TO STORE MOD DATA: CY, PFNAME =</td>
<td>Specify cycle number and name of permanent file (10 or less alpha-numerics).</td>
<td>3, TEST</td>
</tr>
<tr>
<td>MOD DATA STORED: CY = 3, PF = TEST</td>
<td></td>
<td>(No Response)</td>
</tr>
<tr>
<td>QUESTION</td>
<td>EXPLANATION</td>
<td>RESPONSE EXAMPLE</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>23. INPUT/OUTPUT OPTION</td>
<td>This question calls for a response of two digits (either 1 or 0 signifying yes or no, respectively) for each of the four input/output option categories: teletype, data base, terminal, central site. (See paragraph 2 for further details.)</td>
<td>11001100</td>
</tr>
<tr>
<td>LIST (Y=1, N=0) TTY, DB, TERM, CS =</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. CORE REQD: CM,T =</td>
<td>Note - CM values must be octal. T is in system seconds (decimal).</td>
<td>177000,180</td>
</tr>
<tr>
<td>25. COST CENTER - CHARGE CODE XXX-XXX =</td>
<td></td>
<td>123-123</td>
</tr>
<tr>
<td>26. STOP 00</td>
<td>First response example will place the run in the input queue of the central site. Second response example will place the run in the input queue of remote terminal XX.</td>
<td>BATCH(JOB,INPUT) OR BATCH(JOB,INPUT,XX)</td>
</tr>
<tr>
<td>27. IPSMXXX.$000 etc.</td>
<td>Job is now in input queue under the name of IPSM.</td>
<td>(No Response)</td>
</tr>
<tr>
<td>QUESTION</td>
<td>EXPLANATION</td>
<td>RESPONSE EXAMPLE</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>28. COMMAND -</td>
<td>If you wish to enter another case, the second response example will recycle the IPSSM program.</td>
<td>LOGOUT OR IPSM.</td>
</tr>
</tbody>
</table>
A "0" in the third position together with a "1" in the fourth position indicates an automatic replacement of old values with current ones in the AR or SP data base specified. If a "1" is entered in both the third and fourth positions, the system will take the current output values and update the old data base specified into a new data base defined by the user, and, in addition, will allow the user to enter a title for his new data base. In this instance, the old AR or SP data base will remain intact with its original values.

A "0" in both the third and fourth positions indicates that no data transfers will be made.

c. **Batch Terminal Option**

The fifth and sixth digits control printing on remote terminals.

A "1" in the sixth position will provide a complete set of results at the remote terminal.

A "1" in the fifth position will cause the input data sets (as modified for the present run) to be printed out at the remote terminal site also. This will facilitate future identification of the computer run with the input data base that generated it.

d. **Central Site Option**

The seventh and eighth digits control the disposition of output to the central site.

A "1" in the eighth position disposes the results at the central site.

A "1" in the seventh position also copies the input data sets to the central site.

3. **IPSSM Short TTY Inputs**

For users who have become familiar with the TTY mode, input can be entered more quickly as shown below:

a. If the run is going to be a new one, questions 1, 2, 3, 4 of paragraph 2 may be answered at once in the following manner:
Question 1. THIS IS IPSSM

MODE: TTY OR BATCH =

TTY, AR5, 5, XM58

If one of the answers is not accepted by the program, an error message will be printed and the program will ask you to correct the information.

b. Questions 22 and 23 may always be answered together in the following manner:

Question 22. TTY, DB, TERM, CS =

11001100, 177000, 180

C. Instructions for Batch Mode Operation

1. General

If the user has access to a card reader at the central site or at a batch terminal, he will probably find it more useful to run IPSSM via card input. Four options are currently available:


b. Delete tables used in the exterior ballistics (AR) program.

c. Prepare data for the graphics (PROM) program.

d. Perform and store error computations for the exterior ballistics (AR) program.

2. Control Cards

In this mode, the executive program generates input data on a local file named TAPE9. The executable (LGO) file of the program selected is copied to a local file named TAPE8. The control cards listed on the following page provide the necessary cards to attach and run the executive program, which, in turn, executes the selected application program. Cards enclosed in brackets are included only if you are making use of the error analysis option. The cycle number

21
which you specify here when cataloging the permanent file ERROR must agree with the number you specify on the ERROR card (paragraph 3).

(JOBNAME),CM145000,T210.

(COMMENTCARD)

ATTACH(IPS,M,IPSH,CY=5,1D=NICHOLS,MR=1)

IPS.

REQUEST,TEMP3,*PF.

REWind,TAPE9.

COPYBF,TAPE9.

REQUEST,TEMP3,TAPE9,TAPE6,TAPE10.

RF,145000.

MAP(0FF)

REWIND,TAPE12.

C0PYBF(TAPE12,TEMP1)

REWIND,TEMP1.

RETURN,TAPE12.

TAPE8(TAPE9).

REWIND,TAPE6.

C0PYBF(TAPE6,OUTPUT)

REWIND,TAPE12.

C0PYBF(TAPE12,TEMP2)

REWIND,TEMP2.

REWIND,TAPE12.
COPYBF(TEMP1,TAPE12)
BKSP(TAPE12,1)
COPYBF(TEMP2,TAPE12)
REWIND,TAPE12.
COPYBF(TAPE12,TEMP3)
RETURN,TAPE12.
REWIND,TEMP3.
CATALOG(TEMP3,ERROR,CY=N,ID=NICHOLS)
(7/8/9CARD)
(BATCHINSTRUCTIONCARDS)
(6/7/8/9CARD)

NOTE: The CM and T values specified on the job card must both agree with the values specified on card (b) of the batch instruction cards (see next paragraph).

3. Batch Instruction Cards

In order to explain the use of batch instruction cards, the following example illustrates all available options:

a. BATCH,AR5,5,M106AR
b. 00011100,145000,210
c. DATA
   VMX,202
   2500.,2700.
   THD
   30.
   END
The explanation is given in terms of the card numbers designated on the left.

CARD a:

The word "BATCH" is entered in the first five columns followed by a comma in column 6. Columns 7 and 8 will have the two-letter symbol corresponding to the program in IPSSM's library that is being run. Column 9 is the number specifying the current operational cycle number of that program (usually 5). Column 10 contains a comma, followed by the cycle number, a comma, and the name of the permanent file where data base is located.

CARD b:

In columns 1-8 are entered the input/output option list values (for explanation-see question 23 and paragraph 3 of Part B), followed by a comma in column 9. The computer core and time required to execute the applications program are entered next, separated by a comma. The core requirement is designated in octal. See note on page 23.

CARD c:

If changes in the data base are to be made, then a card with the word "DATA" entered in columns 1-4 is inserted next. The next card follows with the symbol of the key variable to be changed entered in columns 1-3. The PLN value of 101 will be assumed for that variable unless it is followed by a comma in column 4, in which case the different PLN number is entered in columns 5-7. The next card provides the value(s) for that variable in free floating point format (No blanks; start in column 1.) After all the data changes have been entered, a card with the word "END" punched in columns 1-3 is inserted to terminate this option.
CARD d:

If the AR program is being run and table deletion is desired, then a card with the word "TABLE" entered in columns 1-5 is inserted next. One of the table numbers to be deleted is entered in the first two columns of the next card. Each table number is indicated on a separate card. A card with the word "END" punched in columns 1-3 is inserted last to terminate this option. NOTE: A table card is permissible only if you are running the AR program. Otherwise an error message will be printed and your job will resume execution.

4. Storage Options

If it is desired to store the new data as modified by any run, additional entries can be made on either the DATA or TABLE cards as follows:

A comma is placed after the word "DATA" or "TABLE", followed by the cycle number and the name of the permanent file where the modified data base is to be stored. These entries must also be separated by a comma. A new title card for the new data base is also entered on the card in columns 25-80.

CARD e:

If the WT program is being run and it is desired to have the output made available for later display on the graphics projectile measurement program (PROMS), then a graphics card is included. The word "GRAPHICS" is entered in columns 1-8, followed by a comma. The cycle number in column 10, a comma, and the permanent file name (starting in column 12) where you wish to store the graphics input follow. The title for the graphics display is also entered on the same card in columns 25-80. NOTE: A graphics card is permissible only when running the WT program. Otherwise an error message will be printed and your job will resume execution.

CARD f:

If the AR program is being run and it is desired that an error analysis be performed on the data for future teletype retrieval, then an ERROR card is included. The word "ERROR" is punched in columns 1-5, followed by a comma. Then the cycle number (corresponding to the one specified in the control cards) is punched in column 7, followed by a comma and the ID name, NICHOLS (starting in column 9). Example 11 on page 56 illustrates the method of retrieving on the
teletype the error analysis stored in this way. NOTE: An ERRØR card is permissible only when running the AR program. Otherwise an error message will be printed and your job will resume execution. NOTE: Only the first two cards and the ERRØR card are order-dependent. The DATA, TABLE, and GRAPHICS cards can be inserted in any order or any one or all of them can be left out. If the ERRØR card is included, it must directly precede the 6/7/8/9 card.

APPLICATION PROGRAMS AND DESCRIPTIONS

In order to have this manual somewhat self-contained without making it too cumbersome, a brief description of each application program is provided in this section. References to more complete documentation are given, together with options available through the use of the executive program (IPSH). References are also made to specific appendices which describe key variable input and tables required to each program.

A. Static Properties and Stability Calculations (WT)

The program used in IPSSM for performing static property calculations is a program currently known as WEIGHT. An earlier version of this program was called DAGMAR. Reference 1 contains the latest complete instructions and use of the weight program. The key variables associated with this program through IPSSM are given in Appendix A1. In addition to the key variable input, the description of each shell item, i.e. body, fin, known and ogival is entered following a card with the name WGTTAB punched on it, starting in Column 1. The format for entering this information is identical to that used in the WEIGHT program. For completeness, this format is given in Appendix A2; however, for a complete explanation of reference points, associated diagrams and the equations used, see Reference 1. The variables named NBI, NOF, NFP, NKI and NOI provide the number of body, fin, fin pieces, known and ogival items, respectively. The number of cards following WGTTAB must agree and correspond with the values given for the key variables. Following the shell description cards is the card with ENDWGT punched in columns 1 to 6.

The executive program (IPSH) is capable of changing the shell items in a similar way to that done at the graphics terminal. The procedure is written in conversational mode that starts with the question: "CHG ITEMS, YES OR NO = ". (See question 18 -- TTY Instructions). If the answer is NO, the executive routine continues by asking the question; "STORE MOD DATA YES OR NO = " (question 19).
However, if you answer YES, the program asks the following: “ITEM TYPE - BDY, FIN, KNO, OGV OR END -”. You may then select the appropriate type or end the process with END. Having selected an item type, the next question is; "DEL, ADD, OR CHG -". Typing DEL means you wish to delete one entire item (line) of the type you selected. The program will then ask for the item number: "ITEM NO. =". The item number corresponds to the particular location of the item, i.e., line number within its group (body, fin, or ogive). This can most easily be determined by looking at a previous WT run on which the items are numbered within their group.

**WARNING:** DEL should be the last operation specified, after all ADDs and CHGs are performed, as the lines will be automatically re-numbered after each deletion and any subsequent attempts to add or change item numbers will most likely be inaccurate.

For the same reason all deletions should be specified in the order of the highest item number first to the lowest item number last. ADD requires that you specify additional data for the item type selected. The data are then typed in free floating point format as it is asked for and the new item is automatically entered into the data base for the run being made. These changes are not permanent unless you store the modified data base. The CHG option requires that you specify the item you wish to change and then the field within that item that you wish to modify. Field one represents the first formatted entry on that particular body, fin, or ogive card; field two the second, and so on.

These options allow for limited modifications of the shell configuration via the teletype. Obviously, the graphics system called PROMS (Reference 2) with a visual display is much easier to work with, particularly if you are working with new shell designs. However, for a limited number of straightforward design changes the user may find it more convenient to use the teletype located in his immediate area. The TTY procedure is not recommended for any extensive changes.

In addition to this option, the executive program can also prepare data for use with the PROMS system. After selecting the weight program (WT), the question "GRAPHICS YES OR NO=" will be asked. If your answer is YES, you are then required to specify a cycle number and permanent file name to store the data for a subsequent graphics run.
The graphics output (currently in the form of cards) can then be re-entered into the data base for additional IPSSM runs.

B. Generation of Aerodynamic Coefficients (SP)

The program used in IPSSM for calculating aerodynamic coefficients is a program known as SPINNER. The documentation for this program is given in Reference 3. The program was originally written in Fortran IV for use of the IBM 360/65. Later it was converted to run on the CDC 6500. Computational techniques used to estimate the aerodynamic coefficients of spin-stabilized projectiles are based upon the use of empirical equations and apply for Mach numbers from 0.01 to 3.0. The key variable data required to execute the program are given in Appendix B. The following aerodynamic coefficients are predicted by SPINNER for projectiles of 3.6 to 9.0 calibers in length, with ogival nose lengths of 1.8 to 4.0 calibers and boattail lengths between 0.0 (square base) and 1.0 calibers:

- Zero Yaw Drag Coefficient
- Normal Force Coefficient Derivative
- Pitching Moment Coefficient
- Magnus Force Coefficient Derivative
- Magnus Moment Coefficient Derivative
- Damping in Pitch Coefficient Derivative
- Spin Deceleration Coefficient

The formulas are based upon the use of "standard" projectile length, and center of gravity from the standard.

The SPINNER Program does provide the engineer with a rapid, accurate technique for estimating the aerodynamic coefficients for use in preliminary design studies. However, SPINNER results should be checked against reliable aerodynamic data when available. (The above remarks are excerpts from Reference 3)
C. Interior Ballistics Calculations (IB)

The program used in IPSSM for interior ballistic calculations is a short FORTRAN program called INTERIOR BALLISTICS, and is described in Reference 4. The program uses a series of simple equations to compute muzzle velocity given charge weight, chamber volume, maximum pressure, and other variables shown in Appendix C. The program can also be used to calculate charge weight if the muzzle velocity is known. However, the process used in this case is an iterative scheme which usually converges. Maximum pressure can also be estimated by another iterative process. The codes required for the key variable PKI are 1.0, 2.0, 5.0, 6.0, 8.0, 9.0, 10.0, 15.0, 17.0, 26.0, 30.0, 31.0 which represent the propellants M1, M2, M5, M6, M8, M9, M10, M15, M17, M26, M30, and M31, respectively.

D. Exterior Ballistics Calculations (AR)

The program used in IPSSM for exterior ballistic calculations is a two-stage, point-mass trajectory program called AEROI with drag cancelling and stability calculation options. One of the original versions of the program was known as RKTCAN, which was written in 1962. The most recent documentation for this program can be found in Reference 5. It was written for the IBM 360/65 and did not contain the stability calculations. In 1966 a new version of RKTCAN was written to include stability, and is currently known as AEROI. Documentation for this program is contained in Reference 6. Basically, the program can be used for both one and two-stage missiles or Rocket-Assisted Projectiles (RAP). The trajectory calculations are divided into the following four phases:

- **Phase I** Acceleration of Booster and Main Stage
  - a. Start from Launcher (VMX=0.)
  - b. Start without Launcher (VMX greater than zero)
- **Phase II** Coasting of Main Stage
- **Phase III** Acceleration of Main Stage
- **Phase IV** Free Flight of Main Stage
For calculations involving Rocket-Assisted Projectiles, only Phases III and IV are required. Other combinations can be used, depending on the functions of the missile or projectile. A purely ballistic trajectory may be simulated by either Phase II or Phase IV. A listing of the key variables used in this program is given in Appendix D1, together with an explanation of their meaning, values, and format. The program tables required for the program are given in Appendix D2. For consistency, all tables are described by the same format, which requires six cards. The first three denote values of the independent variable (mach number, altitude, or time); the last three give the values of the dependent variable (drag coefficient, thrust, weight, density, temperature, etc.). Each card is in 10F7.0 format.

All table cards are inserted in the initial IPSDATA data deck behind two table control cards. The first card has the name EXTTAB punched on it starting in column 1. The second card denotes the tables to follow. Each column of the card corresponds to the number of the table to be inserted. A 1 in any given column indicates that the correspondingly numbered table will be included. For example, a 1 punched in column 1 of the card would indicate that six cards for Table 1 would appear next. A blank in any column indicates no corresponding table will be inserted. Thus, the second card indicates the tables that follow (in order) corresponding to the column number containing a 1. Depending on the value of certain key variables listed in Appendix D1, certain tables must be inserted for proper execution of the AEROI Program. However, any table can be stored initially in the data base as long as the appropriate ones are deleted when setting up a run through the executive program (IPSH). The AEROI table cards must be followed by a card with ENDEXT punched in columns 1 to 6. For the TTY mode, tables, by number, can be deleted one at a time (see Instruction for TTY mode, page 10). For the batch mode, tables are deleted by a number following the card labelled "TABLE" (see Instruction for Batch Mode, page 21). All aerodynamic coefficients are "C" coefficients. The conversion of "k" coefficients to "C" coefficients is given in Reference 6.

A fixed flat earth and the 1959 ARDC standard atmosphere are used when no other option is identified. Provision for inserting nonstandard atmospheres is provided by the use of the key variable NAT and Tables 19 and 20.
E. Terminal Effectiveness Calculations (LA)

The effectiveness program used in IPSSM computes the lethal area of fragmentation ammunition. It has many options and computational features that are described in references. The essential input to the program is the fragmentation data as a function of "zones" described with respect to the axis of symmetry of the shell. A zone is the region between two conical surfaces whose axes are at the center of gravity of the round and whose half-angle is measured from the nose end of the round. Fragmentation data within each zone consist of the number of fragments within given weight groups and the initial velocity of the fragments. Each fragment in a weight group has a weight equal to the average fragment weight. All fragments within a given zone are assumed to have the same initial velocity. However, their drag is dependent upon a shape factor, the size and weight of the fragments themselves, and the type of media (air, grass, leaves, etc.) through which the fragment will travel.

The shell is assumed to detonate at some point in space above the target area or at impact with the ground plane. The shell may have a terminal velocity at detonation. Its angle of fall with respect to the ground plane is also required input. The targets for this program are personnel in various postures such as prone, standing, or in foxholes and are also assumed to be in some stage of military readiness. These military situations are described further in the references. Those who use the program will recognize the required key variables given in Appendix E.

The program is also capable of generating probability of kill (PK) matrices in the ground plane. In this case, the target area is divided into rectangular cells that can be specified by the user or generated internally, depending upon the option called for by the input data. The PK is then calculated for each cell. The PK matrices can then be used in other lethality programs to determine the effectiveness of volley fire and multiple round firings. Programs which evaluate multiple round effectiveness could be incorporated into IPSSM at some future date, if desired.

Another significant feature of the program is its ability to account for velocity decay of the fragments as they pass through different layers between planes parallel to the ground plane. The regions between layers can represent various types of media representative of environments such as grass, jungle tangle, or high canopy forests.
It should be emphasized that for purposes of the IPSSM system some of these sophistications need not be used to obtain a preliminary estimate of the shell's lethal potential. However, having this program available does allow for parametric studies to be made in an easy manner by varying the key variable data.

The format of the fragmentation data is identical to that used when running the lethal area program independent of IPSSM. Preceding the fragmentation data is a card labelled FVMTAB in columns 1 to 6, and following the last fragmentation data card is a card labelled ENDFVM. Data describing the fragment drag tables are separated in a similar manner by cards labelled FDXTAB and ENDFDX in columns 1 to 6. This table is required and must contain at least two values for both the dependent and independent variables.

F. 6-D Trajectory Program (TR) (references 9, 13)

The six degree-of-freedom missile trajectory program may be utilized to compute trajectories for one and two-stage rockets and/or ballistic projectiles (fin and spin-stabilized) and consists of the following phases:

- Phase I  Acceleration of Booster and Main Stage
- Phase II  Coasting of Booster and Main Stage
- Phase III Separation of Booster from Main Stage
- Phase IV  Coasting of Main Stage
- Phase V   Acceleration of Main Stage
- Phase VI  Free-flight of Main Stage

Any of these phases may be excluded in the computation. For ballistic trajectory computations, only Phase VI is required.

Thrust values for the acceleration phases (I and V) are obtained in the computation by linear interpolation of a thrust versus time table. Provisions in the program permit altering the table thrust values by using a constant thrust modifier term. Also, the correction of presented thrust data for changes of atmospheric pressure with altitude may be performed, if desired, by the user.
Thrust misalignments may be introduced by establishing the thrust misalignment distances and angles as input data. Also, a constant jet torque may be introduced.

A linear change in mass during acceleration or a change in mass as a function of the thrust and specific impulse of the rocket propellant is another option for phases one and five. If a separation thrust is required in phase three, only a linear mass change is computed.

During all acceleration phases, center of gravity and moments of inertia are varied linearly with time.

Range, cross-range, and vertical winds may be introduced in the program in tables as functions of range and altitude for flat earth profiles. At present, wind equations for a spherical earth have not been included in the computer program because data formats for these wind profiles have not been made available. Constant flat earth winds may also be introduced for the entire trajectory. Inclusion of winds in the computation is an option and not required for all trajectories.

Normal force, yaw damping, drag ballistic coefficients, and normal force center of pressure axial positions are introduced in the program as table functions of mach number and angle of attack. When they are available, magnus, roll moment, and roll damping (or spin deceleration) ballistic coefficients and the magnus force center of pressure positions may also be included as table functions of mach numbers and angle of attack. For entry of tabular data, consult Aeroballistics Branch, FRL, "icatiny Arsenal.

G. Recoil Mechanism Design (RM)

This program was written at Rodman Laboratories, Rock Island. Documentation is not available at this time. It is suggested that Mr. B. Moody at Rodman be contacted for further information.

H. Sabot Design Program (SD)

The program SABOT DESIGN is currently used in IPSSM for the determination of sabot design parameters. Before a weapon system can be designed and tailored to achieve stated objectives, adequate design criteria must be established. In the case of weapon systems employing saboted flechettes, many interdependent variables are present that serve to confound the design process. Reference 10 contains the latest complete instructions for the use of the SABOT DESIGN Program, which can accomplish the coordination of such
variables as sabot geometry, inbore pressure, intersegment spacing, bore friction, sabot density, and flechette weight. These and other key variables associated with this program through IPSSM are listed in Appendix H.

In addition to various numerical analyses, SABOT DESIGN is capable of producing Calcomp and printer plots of inbore loading through the use of the NANCY plotting routine. Examples can be found in Reference 9.

The SABOT DESIGN Program enables a sound engineering approach to sabot design that, in the past, largely relied upon numerous cut and try methods. At Frankford Arsenal, where the program was written, it has already been used to design two functional flechette/sabot assemblies.

I. Heppner Interior Ballistics (IH) (reference 11)

The use of multigranulation propellant charges requires improved ballistic theory for the prediction of interior ballistic phenomena. Accordingly, the Hitchcock equations of interior ballistics were modified and new procedures developed that are more applicable to the high charge-to-projectile weight systems. These modifications, incorporated into the Heppner Interior Ballistics Program, give more reliable predictions of the effects of changes in the weight of the charge, the weight of the projectile, web size, and type of propellant and granulation of ammunition. The program performs all necessary computations for the high-velocity guns for any shape of propellant grain and multigrain charges.

Principal output is proportion of propellant burned, projectile travel and velocity, chamber pressure, pressure on the base of the projectile (all as a function of time), and "variable quickness" (as a function of projectile travel in the tube of the gun). Another feature of the IH program is that if experimental data (velocity and maximum pressure) are available for a particular system (gun, projectile, or propellant), the data can be used as a "basis" for calculations of additional pressure and velocity charge relationships for new systems to be studied. The closer the new system is to the basis system, the more accurate the calculations will be.
SAMPLE INPUT FOR INITIAL DATA BASE GENERATION

Following is a list of the data base cards used to generate the data base titled "PROJECTILE 8-INCH M106", using the IPSDATA program. These cards would be inserted into the deck format shown on page 7, and as a result of this run, five different permanent files (M106AR, M106TR, M106SP, M106WT, and M106LA) are created and catalogued (cy=5), as discussed on page 8. Note that these five different files are created as a result of both 5, M106 being specified on the second data base card and the inclusion of data used by each of the five application programs. Appendix J shows the output of this run.

```plaintext
 PROJECTILE 8-INCH M106
 CY = 5

 card 1
 card 2
 card 3
 card 4
 card 5
 card 6
 card 7
 card 8
 card 9
 card 10
 card 11
 card 12
 card 13
 card 14
 card 15
 card 16
 card 17
 card 18
 card 19
 card 20

card 21
```
| Value  | 0.000 | 2.500 | 7.500 | 12.500 | 17.500 | 22.500 | 27.500 | 32.500 | 37.500 | 42.500 | 47.500 | 52.500 | 57.500 | 62.500 | 67.500 | 72.500 | 77.500 | 82.500 | 87.500 | 92.500 | 97.500 | 102.500 | 107.500 | 112.500 | 117.500 | 122.500 | 127.500 | 132.500 | 137.500 | 142.500 | 147.500 |
|--------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|        | 0.000 | 2.500 | 7.500 | 12.500 | 17.500 | 22.500 | 27.500 | 32.500 | 37.500 | 42.500 | 47.500 | 52.500 | 57.500 | 62.500 | 67.500 | 72.500 | 77.500 | 82.500 | 87.500 | 92.500 | 97.500 | 102.500 | 107.500 | 112.500 | 117.500 | 122.500 | 127.500 | 132.500 | 137.500 | 142.500 | 147.500 |
|---------|--------|--------|--------|--------|--------|--------|
| 157.580 | 162.650 | 160.000 | 2600.000 | 2675.000 | 2650.000 | 12.000 |
| 41.843 | 1.702 | 3.443 | 6.836 | 10.921 | 12.863 | 17.217 |
| 6.166 | 1.166 | 1.166 | 1.166 | 1.166 | 1.166 | 1.166 |
| 162.580 | 167.000 | 165.000 | 2675.000 | 2600.000 | 2700.000 | 16.000 |
| 17.244 | 1.722 | 2.862 | 6.629 | 9.396 | 12.648 | 17.958 |
| 37.144 | 31.649 | 42.799 | 56.676 | 65.167 | 74.139 | 80.532 |
| 147.580 | 172.580 | 170.000 | 2600.000 | 2700.000 | 2500.000 | 23.000 |
| 23.468 | 31.110 | 47.927 | 50.111 | 64.837 | 77.171 | 89.798 |
| 97.091 | 107.667 | 175.012 | 235.382 | 380.841 | 492.492 | 529.529 |
| 1.044 | 3.047 | 3.043 | 1.047 | 1.043 | 1.043 | 1.043 |
| 1.511 | 1.511 | 1.511 | 1.511 | 1.511 | 1.511 | 1.511 |
| 172.580 | 177.580 | 175.000 | 2575.000 | 3116.667 | 2650.000 | 24.000 |
| 5.310 | 1.447 | 3.428 | 5.147 | 6.310 | 12.728 | 17.642 |
| 21.680 | 22.433 | 30.826 | 54.297 | 61.613 | 72.357 | 88.006 |
| 92.969 | 112.580 | 178.714 | 174.331 | 238.964 | 279.361 | 330.334 |
| 401.798 | 615.166 | 1533.671 | 111.672 | 27.702 | 29.611 | 17.684 | 4.708 | 8.264 |
| 5.819 | 10.197 | 6.708 | 2.820 | 2.820 | 1.686 | 1.979 |
| 37.990 | 31.689 | 4.887 | 5.816 | 5.816 | 4.887 | 4.887 |
| 0.700 | 2.940 | 7.776 | 7.776 | 7.776 | 7.776 | 7.776 |
| 177.200 | 178.750 | 3116.667 | 3350.000 | 3350.000 | 21.000 |
| 1.238 | 1.424 | 3.113 | 4.757 | 4.757 | 11.980 | 17.923 |
| 20.244 | 29.012 | 43.673 | 59.861 | 61.920 | 72.733 | 107.443 |
| 128.436 | 175.174 | 231.231 | 414.414 | 800.227 | 1550.000 | 2669.167 |
| 17.400 | 1.272 | 1.247 | 1.392 | 1.392 | 1.392 | 1.392 |
| 0.669 | 1.729 | 2.688 | 1.557 | 1.557 | 1.557 | 1.557 |
| 1.069 | 0.733 | 0.733 | 0.733 | 0.733 | 0.733 | 0.733 |

<table>
<thead>
<tr>
<th>FDFVDF</th>
<th>FXFTAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.40</td>
<td>470.0</td>
</tr>
<tr>
<td>372.0</td>
<td>1148.1</td>
</tr>
<tr>
<td>0.53</td>
<td>0.54</td>
</tr>
<tr>
<td>0.64</td>
<td>0.64</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FDFDFx</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.64</td>
</tr>
</tbody>
</table>
SAMPLE TEST CASES AND SETUP

A. Introduction

This section provides sample cases of both TTY and Batch runs using IPSSM. They are given to illustrate the use of the system as well as to show specific techniques. It is recommended that some or all of these cases be run by new users. The permanent file named M106 (Cycle 5) is available for this use and is used by all the examples. However, other data base files may be generated by the use of IPSDATA (Cycle 5). Care should be taken to specify different permanent file names than those catalogued in these examples to avoid conflict and possible job abort.

B. TTY Examples

1. General Information

The following lines show the initial login and attach procedure that is common to all the teletype examples mentioned in this manual. All subsequent examples will begin with the first statement generated by IPSSM, namely, "THIS IS IPSSM,

```
CONTROL DATA INTERCOM 4.8
DATE 06/28/78
TIME 13.18.49.

PLEASE LOGIN
LOGIN

ENTER USER NAME- LLPHD26TOO

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION
```
MODE: TTY or BATCH=". All information shown underlined is user-supplied. Continuous reference to Table 1 should be made while reviewing the following examples; the batch outputs generated by these runs are shown in Appendix K.

2. Representative TTY Examples

a. Example 1 illustrates the running of the Static Shell Properties Program (WT) using the M106 data without modification.

```
THIS IS EXAMPLE
MODE= TTY OR BATCH = TTY,TTY,TTY,TTY
TITLE=
  PROJECTILE 5 INCH M106
REQUEST:TYPE(118).RRF
REQUEST:TYPE(196).RRF
GRAPHICS, YES OR NO = NO
EXAMINE DATA BASE, YES OR NO = NO
MODIFY DATA, YES OR NO = NO
CNS ITEMS YES OR NO = NO

INPUT/OUTPUT OPTION LIST
(V=1) R=0) TTV,RE,RE,RE,RE = 1101110
CORE REQ= CN,T = 1100000.115
TTV INPUT LIST- SYMBOLS = NO
SPECIFY PNAME FOR TTV RESULTS-
FILENAME, CY, 12=
DAVENT.1.M106
CATALOG CYCLE W=1
CT= 1001 NICHOLS FY=1967 CY= 001 AO=001 USER= A1
COST CENTER=CHARGE CODE=
AO=100 CY= 000 = 100-000
STOP 09
1.540 SECONDS EXECUTION TIME
COMMAND= BATCH,RE,INPUT,RE
```

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

42
Note that the short TTY input (page 21) is used to answer question 1. Also, TTY results (a summary) are asked for and will be saved on a permanent file called SAVEWT (cycle 1), in addition to the more complete batch results that will be sent to the remote terminal site (see Appendix K-1 for entire batch output). Also, the number of shell body items (NBI) has been selected to be included in the TTY results for the user's own reference.

The following TTY run was used to obtain the TTY results stored previously on the file SAVEWT (Cycle 1). Note that, for reference, the number of shell body items (NBI) is also provided.

```
THIS IS IPSM
MODE- TTY OR BATCH = TTY
WILL THIS BE A NEW RUN, YES OR NO = NO
WHERE WERE RESULTS STORED, PFNAME.CV, ID= SAVEWT.1.NIAG
NBI 36.000
PROJECTILE 8 INCH M106
PROPERTIES OF ENTIRE SHELL
WEIGHT = 800.8185 POUNDS
CG TO REF = 22.7413 INCHES
POLAR INERTIA = 1800.5168 POUND INCH SQUARE
TRANSVERSE INERTIA = 1582.7227 POUND INCH SQUARE
OUTER VOLUME = 1230.1008 CUBIC INCHES

END OF TTY RESULTS
STOP .000
.103 CP SECONDS EXECUTION TIME
```

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION
b. Example 2 below also illustrates the running of the Static Shell Properties Program (WT), but, in this case, the density of body item number 3 is changed to 0.300. Ogival item number 4 has also been deleted. The complete remote output is given in Appendix K-2.

```
THIS IS IPSSN
MODE- TTY OR BATCH - TTY,UTC,S,80080
TITLE-
PROJECTILE 8 INCH M106
REQUEST(TAPE,3,SPF)
REQUEST(TAPE,5,SPF)
GRAPHICS, YES OR NO - NO
EXAMINE DATA BASE, YES OR NO - NO
MODIFY DATA, YES OR NO - NO
CHG ITEMS YES OR NO - YES
ITEM TYPE- BDY,FIN,KNO,OGU OR END = BDY
DEL, ADD OR CHG = CHG
ITEM NO. = 03
FIELD NO., VALUE = 4,0.3
ITEM TYPE- BDY,FIN,KNO,OGU OR END = OGU
DEL, ADD OR CHG = DEL
ITEM NO. = 04
ITEM TYPE- BDY,FIN,KNO,OGU OR END = END
STORE ADD DATA, YES OR NO - NO

INPUT/OUTPUT OPTION LIST
(V=1 H=0) TTY,BO,TERM,CS - 00001100
CORE RECD- CR,Y = 120000,115
COST CENTER-CHARGE CODE,
XXX-XXX : 500-7000
STOP 00
517 CP BEGINS EXECUTION TIME
CONTINUE- BATCH,JOB,INPUT,00

COPY AVAILABLE TO DDC, DCC
PERMIT FULLY LEGIBLE REPRODUCTION
```
c. Example 3 illustrates the running of the Aeroballistics Coefficients Program (SP). TTY input is shown below. Batch output for this run is given in Appendix K-3. In this case, the key variable CGS (distance in calibers of the center of gravity from the nose of the projectile) is changed from 3.315 to 3.50. Note also that the two values of WTS (shell weight in pounds) are changed by re-entering only one value. The option to automatically generate a new data base with the permanent file name MOD (Cycle 1) and the title "MOD 8 IN PROJECTILE" is also accomplished. This data base can then be used by the Exterior Ballistics Program (AR) with the drag tables generated and stored by the SP program in the MOD file (Example 4).

```
THIS IS INPUT MODE- TTY OR BATCH - TTY, Sweep, MOD

TITLE-
PROJECTILE 8 INCH M68
REQUEST(TAPE18, SP)
REQUEST(TAPE18, SP)

EXAMINE DATA BASE, YES OR NO - YES
SYN - VTS
P. = 8 L. = 0 H. = 8
VALUES = 500.000 100.000
SYN - CGS
P. = 3 L. = 9 H. = 1
VALUES = 3.315
SYN - WTS

MODIFY DATA, YES OR NO - YES
SYN, PLH - VTS, 101
VALUES = 500.0
SYN, PLH - CGS, 101
VALUES = 3.5
SYN, PLH - WTS

STORE MOD DATA, YES OR NO - NO

INPUT/OUTPUT, OPTION LIST
(Y = YES) TTY, Sweep, MOD

AR DATA BASE TO BE UPDATED-CY, FFM
NEW DATA BASE FILE-CY, FFM
NEW TITLE - ADD 3 IN PROJECTILE
CORE SIZE - CY, T = 128000, 160

GO CENTER-GENERAL CASE: Sweep

STOP IF CROSSING LIMITATION THEN
COMMAND- Batch, Sweep, MOD
```
Example 4 shows the running of the Exterior Ballistics Program (AR) using the MOD drag data generated by the SP program in Example 3. A recently added provision for conducting a partial error analysis in the AR program is utilized here. The data produced by the AR program are analyzed and stored in the permanent file ERRAN (Cycle 1). A second run is necessary to produce the analyzed results after the initial execution is completed. Below is the TTY input yielding the first set of results shown in Appendix K-4.

NOTE: The permanent file, ERRAN,1,NICHOLS is available for recall. It does not have to be recreated by rerunning this example.
The following run was used to analyze the TTY results previously stored on the file ERRAN. The generated table gives the errors in range contributed by the deviations caused by changing drag data, angle of elevation (THD), and initial muzzle velocity (VMX).

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>NOMINAL VALUE</th>
<th>VARIATION</th>
<th>STANDARD DEVIATION</th>
<th>RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>THD</td>
<td>20,000</td>
<td>2,000</td>
<td>100</td>
<td>177,000</td>
</tr>
<tr>
<td>VMX</td>
<td>2200,000</td>
<td>0,000</td>
<td>0</td>
<td>15,000</td>
</tr>
</tbody>
</table>

END OF TTY RESULTS

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION
e. Example 5 shows the running of the Interior Ballistics Program (IB). Two new values of the propellant weight (PCI) are entered via the TTY as a temporary change to examine differences in muzzle velocity. Appendix K-5 shows the batch results. The TTY input necessary to produce this run is shown below.

```
THIS IS IPROM
NOBB-TTY OR BATCH=TTV.138.5.R18818
TITLE=
PROJECTILE 8 INCH FMOS
REQUEST(TAPELEED, TTY) REQUEST(POPGED, TTY)
EXAMINE DATA BASE, YES OR NO= YES
SVR=PCI
VALUES=2.200
SVR=END
MODIFY DATA, YES OR NO= YES
SVR,PLAN=PCI.502
VALUES=5.000
SVR,PLAN=END
STORE FOR DATA, YES OR NO= NO
INPUT/OUTPUT, OPTION LIST
(Y=1 NO=9) TTY,50,REK,08*
CORE RESO=CHT=120000.115
COST CENTER-CLOSE CODE 100-455X*
STOP OF .450 IN BORE EXECUTION TIME
CONTINUE BATCH.938.TTY"6.11.20
```
f. Example 6 shows the running of the Lethal Area Program (LA), where two variables, burst height (PHB) and angle of fall (AOF), are linked by the L parameter discussed on page 9. Even though both variables have two values each, they are changed simultaneously (the permuted variable is PHB). This run also used the option to store the modified data in a permanent file called LAMO/D2 (cycle 2) with the new title, "LA M0/2 8 IN PROJECTILE". The batch output is shown in Appendix K-6. The TTY input is given below. Note that, in this example, the user initially typed the wrong symbol for the burst height. The system allows corrections as shown without aborting.

```
TITLE=

PROJECTILE 8 INCH R186
REQUEST(TAPE12, SPF)
REQUEST(TAPE6, SPF)

EXAMINE DATA BASE, YES OR NO = NO
MODIFY DATA, YES OR NO = YES

SYN,PLM= PHB,212

PHB IS INCORRECT SYMBOL
SYN,PLM= PHB,212
VALUES = 20, 25.
SYN,PLM= AOF,012
VALUES = 47, 42.
SYN,PLM= END

STORE MOD DATA, YES OR NO = YES

NEW TITLE = LA MOD 8 IN PROJECTILE
WHERE DO YOU WISH TO STORE MOD DATA: CY, PFNAME = Mode

MOD DATA STORED: CY = 2 PF = LAMO/D

REQUEST(TAPE10, SPF)
CT IB= NICHOLS PFN=LAMO/D
CT CY= 006 00001478 WORDS.

INPUT/OUTPUT OPTION LIST
(V=1 H=8) TTY, BB, TERR, CS = 00001100
CORE REGS= CR, T = 130000, 400

COST CENTER-CHARGE CODE:

100-100K = BBD-700

STOP 99
1.000 CP SECONDS EXECUTION TIME
COMMAND = BATCH, 300, INPUT, AB

49
```
g. Example 7 illustrates the running of the Interior Ballistics Program (IB). Here the option of examining all values of the data base is utilized by typing the word ALL in answer to the question "EXAMINE DATA, YES OR NO =". TTY input is shown below, and batch output is given in Appendix K-7.

```
THIS IS IPSMR
MODE- TTY OR BATCH = TTY,IBS,IB106IB
TITLE=
PROJECTILE 3 INCH M106
REQUEST(TAPE12,SPF)
REQUEST(TAPE2,SPF)

EXAMINE DATA BASE, YES OR NO = YES
SYN = ALL

SYN PLN VALUES

DII  101  3.643
ASI  101  166.000
SCI  101  50000.000
PCI  101  18.000
RSI  101  8.000

MODIFY DATA, YES OR NO = NO

INPUT/OUTPUT OPTION LIST
(Y=1 N=0) TTY,DS,TERM,CS = 00001100
CORE REQD- OR,T = 150000.11E

COST CENTER-CHARGE CODE, 10XX-XX0 = 880-700

STOP 80
6.83 CP SECONDS EXECUTION TIME
COMMAND- BATCH.JOB,INPUT,AD
FILE NAME-IPSROMC, DISP=INPUT, ID=AD
```

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION
h. Example 8 illustrates the running of the Recoil Mechanism Design Program (RM). In this case, the option to examine results of the run (in summary) on the TTY is selected. Note that the value of the rise-fall time of the rod pull curve (TIR) is selected for initial printout when the results stored in RMD1 (cycle 2) are later retrieved (page 52). The data base for this run is located in TESTRM (cycle 1). Also, the recoil tables in RMTAB (cycle 1) must be specified. TTY input is shown below. Batch output is given in Appendix K-8.

```
THIS IS IPERM
MODE- TTY OR BATCH = TTY,RMD,1,TESTRM
TITLE- 
   RECOIL MECHANISM TEST
REQUEST(TAPE1,2,SPF)
REQUEST(TAPE5,SPF)
EXAMINE DATA BASE, YES OR NO = NO
MODIFY DATA, YES OR NO = NO
INPUT/OUTPUT OPTION LIST
   (V=1 N=8) TTY,DB,TERM,CS = 11001100
CORE REQD- CT,T = 120000,110
TTY INPUT LIST- SYMBOLS = TIR
SPECIFY PFNAME FOR TTY RESULTS-PFNAME,CY,1D= RMD1,2,NICHOLS
CATALOG CYCLE WAS = 2
RECOIL TABLES - PFNAME,CY,1D=
   CT ID- NICHOLS PFN=RMD1
   CT CY- ID: 000 00000128 WORDS=RMTAB,1,NICHOLS
COST CENTER-CHARGE CODE,
   XXX: 880-700
STOP 00
0.267 CP SECONDS EXECUTION TIME
COMMAND- BATCH,JOB,input,AD
```

COPY AVAILABLE TO PDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION
The following run is necessary to retrieve the results stored in RMD1 (cycle 2) on the previous page. Note that the first line printed out contains the value of TIR, as requested when RMD1 was initially created.

```plaintext
THIS IS PROGRAM
NAME: TTY OR BATCH = TTY
WILL THIS BE A NEW RUN, YES OR NO = NO
WHERE WERE RESULTS STORED, FOLDER, CYCLE = RMD1_2
TIR = 0.10

INPUT DATA

<table>
<thead>
<tr>
<th>MON0</th>
<th>MON1</th>
<th>MON2</th>
<th>MON3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1000</td>
<td>0.2000</td>
<td>1.0000</td>
<td>0.3000</td>
</tr>
<tr>
<td>10.3000</td>
<td>0.4000</td>
<td>0.5000</td>
<td>0.6000</td>
</tr>
<tr>
<td>60.0000</td>
<td>60.0000</td>
<td>60.0000</td>
<td>60.0000</td>
</tr>
<tr>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>2.0000</td>
<td>2.0000</td>
<td>2.0000</td>
<td>2.0000</td>
</tr>
<tr>
<td>2.0000</td>
<td>2.0000</td>
<td>2.0000</td>
<td>2.0000</td>
</tr>
<tr>
<td>0.0000</td>
<td>22.0000</td>
<td>22.0000</td>
<td>22.0000</td>
</tr>
</tbody>
</table>

MON1 | MON2 | MON3 | MON4 |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5000.0000</td>
<td>5000.0000</td>
<td>5000.0000</td>
<td>5000.0000</td>
</tr>
<tr>
<td>1161.0000</td>
<td>1161.0000</td>
<td>1161.0000</td>
<td>1161.0000</td>
</tr>
<tr>
<td>119.3000</td>
<td>119.3000</td>
<td>119.3000</td>
<td>119.3000</td>
</tr>
<tr>
<td>10.3000</td>
<td>10.3000</td>
<td>10.3000</td>
<td>10.3000</td>
</tr>
<tr>
<td>119.3000</td>
<td>119.3000</td>
<td>119.3000</td>
<td>119.3000</td>
</tr>
<tr>
<td>119.3000</td>
<td>119.3000</td>
<td>119.3000</td>
<td>119.3000</td>
</tr>
<tr>
<td>119.3000</td>
<td>119.3000</td>
<td>119.3000</td>
<td>119.3000</td>
</tr>
</tbody>
</table>

END OF TTY RESULTS
STOP 800
COMMAND OF RECORD EXECUTION TIME

52
```
Example 9 illustrates the running of the 6-D Trajectory Program (TR). Here the data base is located in TRAJFLTR (cycle 3). Also, a file containing 6-D coefficients (TRDATA, cycle 1) must be specified. Note that the short format for entering CM and T values has been utilized. TTY input is shown below. Batch output is given in Appendix K-9.

```
TITLE =
    XM 483 SPINNER ALL DALE BODY
REQUEST (TAPE12, SPF)
REQUEST (TAPED, SPF)
6D COEFFICIENTS - PFNAME, CY, ID =
    TRDATA, 1, NICHOLS
EXAMINE DATA BASE, YES OR NO =
    NO
MODIFY DATA, YES OR NO =
    NO
INPUT/OUTPUT OPTION LIST
    (V=1 H=0) TTY, DB, TERM, CS =
    00001100, 150000, 000
COST CENTER - CHARGE CODE,
    XXX-XXX =
    520-700
STOP .731 CP SECONDS EXECUTION TIME
COMMAND = BATCH, JOB, INPUT, AD
FILE NAME = IPSMMBU, DISP = INPUT, ID = AD
```

COPY AVAILABLE TO CBO DOES NOT PERMIT FULL SCALE PRODUCTION
j. Example 10 illustrates the running of the Sabot Design Program (SD), whose data base is located in SFRSD (cycle 1). Here the NPR parameter (Appendix 8) is set equal to 3.0, which is the option to obtain printer and Calcomp plots. The modified data are stored in PLOT (cycle 5) so that the graphs may be obtained again at a future date, if so desired (page 55). TTY input is shown below.

Batch output, together with the Calcomp plot obtained, is given in Appendix K-10.

```
THIS IS IPSSM
MODE- TTY OR BATCH = TTY,SDBS,1,SFRSD

TITLE=
   SABOT DESIGN - SFR
REQUEST(TAPE12,SFR)
REQUEST(TAPE8,SFR)
EXAMINE DATA BASE, YES OR NO = NO
MODIFY DATA, YES OR NO = YES
   SV=X,PLN= NPR, 101
   VALUES = 3.0
   SV=X,PLN= END
STORE ROD DATA, YES OR NO = YES
NEW TITLE = PRINTER & CALCOMP PLOTTING
WHERE DO YOU WISH TO STORE ROD DATA- CV,PFNAME = 5,PL

   ROD DATA STORED- CY = 5 PF = PLOT
REQUEST(TAPE10,SFR)
CT ID- NICHOLLS PFN- PLOT
CT CY = 005 00000000 WORDS :.
INPUT/OUTPUT OPTION LIST
   (Y=1 N=0) TTY, DB, PFN,CB = 00001000
CORE REGS= CT,T = 100000, 400

   COST CENTER-CHARGE CODE, 10000000 = 289-700
STOP 00 .37S OF SECONDS EXECUTION TIME
COMMAND= BATCH, JDS, INPUT, 50
FILE NAME-IPKBBS, DISP-INPUT

COPY AVAILABLE TO SDS DOES NOT PERMIT FULLY LEGIBLE PRODUCTION
```
The following TTY run is necessary to obtain extra copies of the plots stored previously (page 54) on PLQT (cycle 5).

```
THIS IS IPSSM
MODE- TTY OR BATCH - TTY,SDS,5,PLOT

TITLE-
PRINTER & CALCOMP PLOTTING
REQUEST(TAPE12,SPF)
REQUEST(TAPE3,SPF)

EXAMINE DATA BASE, YES OR NO = YES
SYN = NBR
  P = 1 L = 0 M = 1
  VALUES = 3,000
SYN = END

MODIFY DATA, YES OR NO = NO

INPUT/OUTPUT OPTION LIST
(V=1 N=0) TTY,SD,TERM,CS

CORE REQD- CR,T 150000,800

COST CENTER-CHARGE CODE, JSX-100X 880-700

STOP 00
.800 CP SECONDS EXECUTION TIME
COMMAND- BATCH,JOB,INPUT,AB
```

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION
Example 11 shows the run necessary to retrieve the error analysis stored in the batch mode in ERROR (page 60).
1. Example 12 illustrates the running of the Heppner Interior Ballistics Program (IH). In this case, the values of peak pressure (PEP) and muzzle velocity (VO) are examined and subsequently modified. The option to store this modified data with a new title is selected here. TTY input is given below. Batch output is shown in Appendix K-11.

```
TITLE

HEPPNER-INTERIOR BALLISTICS

REQUEST (TYPE "II", "PP")
REQUEST (TYPE "II", "PF")

EXAMINE DATA BASE, YES OR NO = YES

SYN = PEP
VALUES = 80000.000

SYN = VO
VALUES = 5000.000

MODIFY DATA, YES OR NO = YES

SYN, PLX = PEP
VALUES = 50000.

SYN, PLX = VO, 101
VALUES = 40000.

STORE OLD DATA, YES OR NO = YES

NEW TITLE = EXPERIMENT IN
WHERE DO YOU WISH TO STORE OLD DATA- CY, PFTMPHE

FILE STORED- CY = 1 PF = THTMPHE

INPUT/OUTPUT OPTION LIST
(YES NO) "IV", "ID", "IN", "GF" - 0000100, 1000000, 000

COPY CENTER-CHANGE CODE.
JCH = JCH

CONTROL CASES WRITTEN
STOP OF

COUPON- BATCH, JCH, INPUT, AB
FILE NAME = IPENCASE, DISP=INPUT, ID=AB

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION
```
C. Batch Examples

1. General Input Information

Section C, page 21 provides general instructions for running IPSSM in the batch mode. The examples below will show only the batch instruction cards necessary to run certain options. The complete set of control cards is given in pages 22, 23.

2. Representative Batch Examples

a. Example 1 is the same run illustrated in Example 3 of the TTY runs. Note that the DATA card is used to change the key variable CGS from 3.315 (value in data base) to 3.50 and also to delete one value of WTS. Batch output shown in Appendix K-12 is identical with Appendix K-3. Batch instruction cards are shown below:

```
BATCH,SP5,5,M106SP
00001100,120000,115
DATA
WTS
200.
CGS
3.5
END
```

b. Example 2 shows the use of the TABLE card. This card is used to delete exterior ballistic tables before running the AR program. In the case below, Table 12 is deleted, since only phase 2 of the trajectory is to be run. Table 12 is used only if phase 1 is to be run. Appendix K-13 shows the output for this run.

```
BATCH,SP5,5,M106SP
00001100,120000,115
TABLE
12
END
```

NOTE: When rerunning examples 2c and 2d care should be taken to specify different permanent file names than 1,M106GRAPH and 2,TEST1 and ERROR,3 to avoid conflict and possible job abort.
c. Example 3 illustrates the use of setting up a data set compatible with the PROMS graphics program. The WT program is called for with the M106 data. The graphics data set is cataloged as M106GRAPH (cycle 1). Appendix K-14 shows the output for this run.

BATCH,WT5,5,M106WT
00001100,120000,115
GRAPHICS,1,M106GRAPH

BATCH,AR5,5,M106AR
01001100,145000,210
DATA,2,TEST1
VMX,202
2500., 2700.
THD 30.
END
TABLE
12
END
ERROR,3,NICHOLS
REFERENCES


5. R. Beck, "RKTCAN - A Two-Dimensional Trajectory Computer Program with Drag - Cancelling Option for One or Two - Stage Missiles Using a Flat Earth Model", Technical Memorandum 1851, Picatinny Arsenal, September 1968.


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APPENDIX A1

STATIC PROPERTIES CALCULATION PROGRAM (WT)

KEY VARIABLE INPUT
### I. Number of Each Shell Item:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBI</td>
<td>F10.4</td>
<td>Number of body items*</td>
</tr>
<tr>
<td>NOF</td>
<td>F10.4</td>
<td>Number of fins</td>
</tr>
<tr>
<td>NFP</td>
<td>F10.4</td>
<td>Number of fin pieces*</td>
</tr>
<tr>
<td>NKI</td>
<td>F10.4</td>
<td>Number of known items*</td>
</tr>
<tr>
<td>NOI</td>
<td>F10.4</td>
<td>Number of ogival items*</td>
</tr>
</tbody>
</table>

*The total number of these items should correspond to the number of cards following the WGTTAB card referred to on page 26.

### II. Control for Program Options:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>WTC</td>
<td>0.0</td>
<td>Do weight calculation</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Do not do weight calculation</td>
</tr>
<tr>
<td>DRS</td>
<td>0.0</td>
<td>Provide shell drawing</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Do not provide shell drawing</td>
</tr>
<tr>
<td>STC</td>
<td>0.0</td>
<td>Do not do stability calculation</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Do stability calculation</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Supply volume of entire shell (VOW)</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>Supply PIW, CGW, TIW</td>
</tr>
<tr>
<td>NAR</td>
<td>F10.4</td>
<td>Number of additional runs</td>
</tr>
<tr>
<td>DDC</td>
<td>1.0</td>
<td>Drawing of each change</td>
</tr>
<tr>
<td>COO</td>
<td>F10.4</td>
<td>Number of copies of output</td>
</tr>
</tbody>
</table>

*The total number of these items should correspond to the number of cards following the WGTTAB card referred to on page 26.
### Additional Cards Required for Stability Calculation:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIW</td>
<td>F10.4</td>
<td>Polar moment of inertia</td>
</tr>
<tr>
<td>CGW</td>
<td>F10.4</td>
<td>Center of gravity</td>
</tr>
<tr>
<td>TIW</td>
<td>F10.4</td>
<td>Transverse moment of inertia</td>
</tr>
<tr>
<td>VOW</td>
<td>F10.4</td>
<td>Volume</td>
</tr>
<tr>
<td>BDW</td>
<td>F10.4</td>
<td>Bore diameter</td>
</tr>
<tr>
<td>BAD</td>
<td>F10.4</td>
<td>Base diameter</td>
</tr>
<tr>
<td>TEW</td>
<td>F10.4</td>
<td>Temperature (degrees F)</td>
</tr>
<tr>
<td>TWW</td>
<td>F10.4</td>
<td>Twist</td>
</tr>
<tr>
<td>PVM</td>
<td>F10.4</td>
<td>Projectile velocity</td>
</tr>
<tr>
<td>COS</td>
<td>F10.4</td>
<td>Copies of stability output</td>
</tr>
</tbody>
</table>
APPENDIX A2

STATIC PROPERTIES CALCULATION PROGRAM (WT)

FORMAT OF SHELL ITEM INPUTS
**Body Item Card:**

Columns 1-10  
D1, diameter on left

Columns 11-20  
D2, diameter on right

Columns 21-30  
H, length

Columns 31-40  
R, density

Columns 41-50  
BARX, distance from D1 surface to reference. If D1 is to the right of the reference, BARX is positive.

Columns 61-71  
Identification

Column 72  
If blank, then this element is not a part of the outer surface of the shell. If "1", then this element is a part of the outer surface of the shell. Column 72 must contain either a blank or a 1.

**Fin Item Card:**

Columns 1-10  
FD1, radius on left

Columns 11-20  
FD2, radius on right

Columns 21-30  
FH, length

Columns 31-40  
FR, density

Columns 41-50  
FBARX, distance from FD1 surface to reference

Columns 51-60  
FD, thickness of fin

Columns 61-71  
Identification

Column 72  
If blank, this element is not a part of outer volume. If "1", this element is part of the outer volume.
Known Item Card:

Columns 1-10: Weight
Columns 11-20: Polar inertia
Columns 21-30: Transverse inertia
Columns 31-40: Distance of CG to reference
Columns 41-50: Volume, if needed for column 72
Columns 61-71: Identification
Column 72: If 0, not outer volume. If "1", outer volume

Ogival Item Card:

Columns 1-10: GA, see Reference 1
Columns 11-20: GB, see Reference 1
Columns 21-30: GS, length of ogive
Columns 31-40: GRH, density
Columns 41-50: GREP, distance to reference
Columns 51-60: GRAD, radius of ogive
Columns 61-71: Identification
Column 72: If blank, no outer volume. If "L" outer volume

The dimension cards are included only for a weight calculation or a plot. If a stability calculation only is required, there will be no dimension cards.
APPENDIX B
AEROBALLISTIC COEFFICIENTS PROGRAM (SP)
KEY VARIABLE INPUT
### I. Program Constants and Parameters

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUE OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLS</td>
<td>F10.4</td>
<td>Projectile length (calibers)</td>
</tr>
<tr>
<td>NLS</td>
<td>F10.4</td>
<td>Nose length (calibers)</td>
</tr>
<tr>
<td>BLS</td>
<td>F10.4</td>
<td>Boattail length (calibers)</td>
</tr>
<tr>
<td>CGS</td>
<td>F10.4</td>
<td>Distance of CG from nose (calibers)</td>
</tr>
<tr>
<td>DIS</td>
<td>F10.4</td>
<td>Diameter of shell (calibers)</td>
</tr>
<tr>
<td>AMS</td>
<td>F10.4</td>
<td>Axial moment of inertia (lb-in&quot;)</td>
</tr>
<tr>
<td>TMS</td>
<td>F10.4</td>
<td>Traverse moment of inertia (lb-in&quot;)</td>
</tr>
<tr>
<td>WTS</td>
<td>F10.4</td>
<td>Weight (lb)</td>
</tr>
<tr>
<td>TST</td>
<td>F10.4</td>
<td>Twist (caliber/turn)</td>
</tr>
<tr>
<td>BOS</td>
<td>F10.4</td>
<td>Boom length (calibers)</td>
</tr>
</tbody>
</table>

### II. Program Options

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUE OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>STS</td>
<td>1.0</td>
<td>Calculate stability</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>Do not calculate stability</td>
</tr>
<tr>
<td>ARS</td>
<td>1.0</td>
<td>Punch AERO I tables</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>Do not punch AERO I tables</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>VALUE OR FORMAT</td>
<td>MEANING</td>
</tr>
<tr>
<td>--------</td>
<td>----------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>SLS</td>
<td>1.0</td>
<td>Punch SAUL 7 tables</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>Do not punch SAUL 7 tables</td>
</tr>
<tr>
<td>N6S</td>
<td>1.0</td>
<td>Punch NOL6D tables</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>Do not punch NOL6D tables</td>
</tr>
<tr>
<td>NGS</td>
<td>1.0</td>
<td>Punch graph output</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>Do not punch graph output</td>
</tr>
</tbody>
</table>
APPENDIX C
INTERIOR BALLISTICS PROGRAM (IB)
KEY VARIABLE INPUT
<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>DII</td>
<td>F10.4</td>
<td>Diameter of gun (inches)</td>
</tr>
<tr>
<td>XLI</td>
<td>F10.4</td>
<td>Length of projectile traveled (inches)</td>
</tr>
<tr>
<td>VOI</td>
<td>F10.4</td>
<td>Chamber volume (cubic inches)</td>
</tr>
<tr>
<td>MPI</td>
<td>F10.4</td>
<td>Maximum pressure (psi)</td>
</tr>
<tr>
<td>PMI</td>
<td>F10.4</td>
<td>Projectile weight (lb)</td>
</tr>
<tr>
<td>PCI</td>
<td>F10.4</td>
<td>Propellant weight (lb)</td>
</tr>
<tr>
<td>PKI</td>
<td>F10.4</td>
<td>Propellant type (code)</td>
</tr>
<tr>
<td>MVI</td>
<td>F10.4</td>
<td>Muzzle velocity (fps)</td>
</tr>
</tbody>
</table>

**NOTE:**

One of the above values must remain zero in order for the interior ballistics to execute properly. The parameter that is set initially to zero is variable to be calculated. Thus, seven of the above eight variables require data input.
APPENDIX D1
EXTERIOR BALLISTICS PROGRAM (AR)
KEY VARIABLE INPUT
I. Phase Options:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>NX1</td>
<td>1.0</td>
<td>Compute Phase I</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>Do not compute Phase I</td>
</tr>
<tr>
<td>NX2</td>
<td>1.0</td>
<td>Compute Phase II</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>Do not compute Phase II</td>
</tr>
<tr>
<td>NX3</td>
<td>1.0</td>
<td>Compute Phase III</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>Do not compute Phase III</td>
</tr>
<tr>
<td>NX4</td>
<td>1.0</td>
<td>Compute Phase IV</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>Do not compute Phase IV</td>
</tr>
</tbody>
</table>

II. Initial Conditions and Constants:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>THD</td>
<td>F10.4</td>
<td>Quadrant elevation (Q.E.) (degrees)</td>
</tr>
<tr>
<td>VMX</td>
<td>F10.4</td>
<td>Initial velocity (ft/sec)</td>
</tr>
<tr>
<td>WGT</td>
<td>F10.4</td>
<td>Missile weight (lb)</td>
</tr>
<tr>
<td>DIA</td>
<td>F10.4</td>
<td>Diameter (inches) of projectile</td>
</tr>
<tr>
<td>XIN</td>
<td>F10.4</td>
<td>Initial range (ft)</td>
</tr>
<tr>
<td>YIN</td>
<td>F10.4</td>
<td>Initial altitude (ft)</td>
</tr>
<tr>
<td>TIN</td>
<td>F10.4</td>
<td>Initial time (sec)</td>
</tr>
<tr>
<td>TWS</td>
<td>F10.4</td>
<td>Effective gun twist (1/25 use 25.0, etc.)</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>VALUES OR FORMAT</td>
<td>MEANING</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------</td>
<td>---------</td>
</tr>
<tr>
<td>YLA</td>
<td>F10.4</td>
<td>Launcher length (ft)</td>
</tr>
<tr>
<td>DEL</td>
<td>F10.4</td>
<td>Integration increment (sec)</td>
</tr>
<tr>
<td>SDT</td>
<td>F10.4</td>
<td>Initial spin rate (rad/sec)</td>
</tr>
<tr>
<td>YFA</td>
<td>F10.4</td>
<td>Terminal altitude (ft) on descent of trajectory</td>
</tr>
<tr>
<td>FFA</td>
<td>F10.4</td>
<td>Factor used for temperature variations</td>
</tr>
<tr>
<td>CKD</td>
<td>F10.4</td>
<td>Constant drag coefficient (Only necessary when KDC=2.0)</td>
</tr>
<tr>
<td>FCT</td>
<td>F10.4</td>
<td>Form factor for all drag tables. This value may be left blank when form factor is unity.</td>
</tr>
<tr>
<td>BIA</td>
<td>F10.4</td>
<td>Sustaining thrust (lb) in addition to that which is necessary to overcome drag. (Use only when CAN=1.0).</td>
</tr>
<tr>
<td>TK1</td>
<td>F10.4</td>
<td>Constant rolling moment (lb-ft) during Phase I.</td>
</tr>
<tr>
<td>TK2</td>
<td>F10.4</td>
<td>Constant rolling moment (lb-ft) during Phase II.</td>
</tr>
<tr>
<td>TK3</td>
<td>F10.4</td>
<td>Constant rolling moment (lb-ft) during Phase III.</td>
</tr>
</tbody>
</table>
### III. Phase I and III Options:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTH</td>
<td>1.0</td>
<td>Use variable thrust</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Use constant thrust</td>
</tr>
<tr>
<td>MXX</td>
<td>1.0</td>
<td>Use variable burning rate</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Use constant burning rate</td>
</tr>
</tbody>
</table>

### IV. Phase I Options:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>THR</td>
<td>F10.4</td>
<td>Constant thrust value (lb) for Phase I (NTH = 2.0)</td>
</tr>
<tr>
<td>DTM</td>
<td>F10.4</td>
<td>Constant burning rate (lb-sec) during Phase I (MXX = 2.0)</td>
</tr>
<tr>
<td>BWT</td>
<td>F10.4</td>
<td>Booster weight (lb): weight of metal parts that are dropped off immediately following burnout in Phase I.</td>
</tr>
</tbody>
</table>
V. Phase III Options:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>TH2</td>
<td>F10.4</td>
<td>Constant thrust value (lb) for Phase III (NTH = 2.0)</td>
</tr>
<tr>
<td>DT2</td>
<td>F10.4</td>
<td>Constant burning rate (lb/sec) during Phase III (MXX = 2.0)</td>
</tr>
</tbody>
</table>

VI. Time Constants for Each Phase:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>TM1</td>
<td>F10.4</td>
<td>Time in seconds at end of completion of Phase I.</td>
</tr>
<tr>
<td>TM2</td>
<td>F10.4</td>
<td>Time in seconds at end of completion of Phase II.</td>
</tr>
<tr>
<td>TM3</td>
<td>F10.4</td>
<td>Time in seconds at end of completion of Phase III.</td>
</tr>
<tr>
<td>TM4</td>
<td>F10.4</td>
<td>Time in seconds at end of completion of Phase IV.</td>
</tr>
<tr>
<td>DL1</td>
<td>F10.4</td>
<td>Integration increment (sec) for Phase I.</td>
</tr>
<tr>
<td>DL2</td>
<td>F10.4</td>
<td>Integration increment (sec) for Phase II.</td>
</tr>
<tr>
<td>DL3</td>
<td>F10.4</td>
<td>Integration increment (sec) for Phase III.</td>
</tr>
<tr>
<td>DL4</td>
<td>F10.4</td>
<td>Integration increment (sec) for Phase IV.</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>DW1</td>
<td>F10.4</td>
<td>Printout interval (sec) for Phase I</td>
</tr>
<tr>
<td>DW2</td>
<td>F10.4</td>
<td>Printout interval (sec) for Phase II</td>
</tr>
<tr>
<td>DW3</td>
<td>F10.4</td>
<td>Printout interval (sec) for Phase III</td>
</tr>
<tr>
<td>DW4</td>
<td>F10.4</td>
<td>Printout interval (sec) for Phase IV</td>
</tr>
</tbody>
</table>

**VII. Program Options:**

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>KOC</td>
<td>1.0</td>
<td>Use variable drag coefficients</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Use constant drag coefficients</td>
</tr>
<tr>
<td>KTH</td>
<td>1.0</td>
<td>Input magnus force and magnus center of pressure coefficients</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Input magnus moment coefficients</td>
</tr>
<tr>
<td>NUN</td>
<td>1.0</td>
<td>Output given in feet</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Output given in meters</td>
</tr>
<tr>
<td>JZN</td>
<td>F5.1</td>
<td>Number of trajectories to be computed</td>
</tr>
<tr>
<td>NJR</td>
<td>F5.1</td>
<td>Number identifying first trajectory run in the set specified by JZN</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>VALUES OR FORMAT</td>
<td>MEANING</td>
</tr>
<tr>
<td>--------</td>
<td>----------------</td>
<td>---------</td>
</tr>
<tr>
<td>ISP</td>
<td>0.0</td>
<td>Compute spin and stability calculation</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Perform only spin calculations</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Omit spin and stability inputs (Tables I thru II)</td>
</tr>
<tr>
<td>IAX</td>
<td>F5.1</td>
<td>Frequency of stability calculations in terms of printout (Example - if it is desired to have stability calculations every third printout, set IAX equal to 3.0)</td>
</tr>
<tr>
<td>NOR</td>
<td>XX.X</td>
<td>Number of time points entered in the &quot;G-Norm&quot; Table</td>
</tr>
<tr>
<td>NAT</td>
<td>F5.1</td>
<td>Number of nonstandard altitudes, temperatures and densities to be entered (NAT is set equal 0.0 if 1959 ARDC standard atmosphere is to be used)</td>
</tr>
<tr>
<td>CAN</td>
<td>1.0</td>
<td>Cancel drag</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Do not cancel drag</td>
</tr>
</tbody>
</table>

VIII. Constant Factors for Table Changes:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>T12</td>
<td>0.0 or 1.0</td>
<td>No change to Table 12</td>
</tr>
<tr>
<td></td>
<td>F10.4</td>
<td>Multiply all dependent variable values by the given constant</td>
</tr>
</tbody>
</table>
### IX. Factors Used in Error Analysis (See Example 4):

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>13P</td>
<td>X.XXX</td>
<td>Nominal variation factor for Drag Table 13</td>
</tr>
<tr>
<td>THP</td>
<td>XX.XXX</td>
<td>Nominal variation factor for the Thrust (THD)</td>
</tr>
<tr>
<td>VMP</td>
<td>XXX.XX</td>
<td>Nominal variation factor for the Initial Velocity (VMX)</td>
</tr>
<tr>
<td>13D</td>
<td>X.XXX</td>
<td>Standard deviation factor for Drag Table 13</td>
</tr>
<tr>
<td>TSD</td>
<td>XX.XXX</td>
<td>Standard deviation factor for the Thrust (THD)</td>
</tr>
<tr>
<td>VSD</td>
<td>XXX.XX</td>
<td>Standard deviation factor for the Initial Velocity (VMX)</td>
</tr>
</tbody>
</table>

NOTE: Symbols T14 through T18 perform the same function for Tables 14 through 18, respectively, as T12 and T13 described above.
X. Constants Used to Plot Trajectory Output:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSY</td>
<td>33.0 =</td>
<td>Code numbers defining symbol to be plotted at data points. For a complete listing, see Reference 6.</td>
</tr>
<tr>
<td></td>
<td>54.0 =</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12.0 =</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16.0 =</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14.0 =</td>
<td></td>
</tr>
<tr>
<td>NPL</td>
<td>1.0</td>
<td>Plot trajectory</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>Do not plot trajectory</td>
</tr>
<tr>
<td>DXG</td>
<td>XX.X</td>
<td>Number of Range Units (feet or meters) per inch on the X-axis of the graph</td>
</tr>
<tr>
<td>DYG</td>
<td>XX.X</td>
<td>Number of Altitude Units on the Y-axis of the graph</td>
</tr>
</tbody>
</table>
APPENDIX D2
EXTERIOR BALLISTICS PROGRAM (AR)
LIST OF TABLES

89
<table>
<thead>
<tr>
<th>TABLE NUMBER</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Roll damping coefficients vs. mach no.</td>
</tr>
<tr>
<td>2</td>
<td>Roll moment coefficients vs. mach no.</td>
</tr>
<tr>
<td>3</td>
<td>Normal force coefficients vs. mach no. (Omit when ISP = 1. or 2.)</td>
</tr>
<tr>
<td>4</td>
<td>Normal centers of pressure (calibers from nose) vs. mach no. (Omit when ISP = 1. or 2.)</td>
</tr>
<tr>
<td>5</td>
<td>Magnus moment coefficients vs. mach no. (Omit when either ISP = 1. or when KTH = 1.)</td>
</tr>
<tr>
<td>6</td>
<td>Magnus force coefficient vs. mach no. (Omit when either ISP = 1. or when KTH = 2.)</td>
</tr>
<tr>
<td>7</td>
<td>Magnus centers of pressure (calibers from nose) vs. mach no. (Omit when either ISP = 1. or when KTH = 2.)</td>
</tr>
<tr>
<td>8</td>
<td>YAW damping moment coefficients vs. mach no. (Omit when ISP = 1.)</td>
</tr>
<tr>
<td>9</td>
<td>Centers of gravity (calibers from nose) vs. time. (Omit when ISP = 1.)</td>
</tr>
<tr>
<td>10</td>
<td>Transverse moment of inertia (lb-ft²) vs. time. (Omit when ISP = 1.)</td>
</tr>
<tr>
<td>11</td>
<td>Axial moment of inertia (lb-ft²) vs. time.</td>
</tr>
<tr>
<td>12</td>
<td>Drag coefficients vs. mach. no. for Phase I. (Omit when either NX1 = 0. or when KDC = 2.)</td>
</tr>
<tr>
<td>13</td>
<td>Drag coefficients vs. mach no. for Phases II and IV. (Omit when either NX2 = 0. and NX4 = 0. or when KDC = 2.)</td>
</tr>
<tr>
<td>TABLE NUMBER</td>
<td>MEANING</td>
</tr>
<tr>
<td>--------------</td>
<td>---------</td>
</tr>
<tr>
<td>14</td>
<td>Drag coefficients vs. mach no. for Phase III. (Omit when either NX3 = 0. or KDC = 2.)</td>
</tr>
<tr>
<td>15</td>
<td>Thrust (lb) vs. time for Phase I. (Omit when either NX1 = 0. or NTH = 2.)</td>
</tr>
<tr>
<td>16</td>
<td>Missile weight (lb) vs. time for Phase I. (Omit when either NX1 = 0. or MXX = 2.)</td>
</tr>
<tr>
<td>17</td>
<td>Thrust (lb) vs. time for Phase III. (Omit when either NX3 = 0. or NTH = 2.)</td>
</tr>
<tr>
<td>18</td>
<td>Missile weight (lb) vs. time for Phase III. (Omit when either NX3 = 0. or MXX = 2.)</td>
</tr>
<tr>
<td>19</td>
<td>Altitude (ft) vs. temperature in degrees Rankine (Omit when NAT = 0.)</td>
</tr>
<tr>
<td>20</td>
<td>Altitude (ft) vs. density (lb-sec²/ft⁴).</td>
</tr>
<tr>
<td>21</td>
<td>Normal acceleration in &quot;g's&quot; vs. time (Omit if NOR = 0.)</td>
</tr>
</tbody>
</table>

**NOTE:** The same increments in altitude must be used in Tables 19 and 20.
APPENDIX E

TERMINAL EFFECTIVENESS PROGRAM (LA)

KEY VARIABLE INPUT
I. Terminal Conditions and Constants:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHB</td>
<td>F10.4</td>
<td>Burst height (feet)</td>
</tr>
<tr>
<td>AOF</td>
<td>F10.4</td>
<td>Angle of fall (degrees)</td>
</tr>
<tr>
<td>TVM</td>
<td>F10.4</td>
<td>Terminal velocity (ft/sec)</td>
</tr>
<tr>
<td>COR</td>
<td>F10.4</td>
<td>Scale factor to correct for total fragment weight (set to 0.0 if no factor is to be used.)</td>
</tr>
<tr>
<td>NOZ</td>
<td>F10.4</td>
<td>Number of fragmentation zones</td>
</tr>
</tbody>
</table>

II. Lethal Area Computation Options:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRP</td>
<td>0.0</td>
<td>Use Simpson's Rule Integration.</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Use Trapezoidal Rule</td>
</tr>
<tr>
<td>NQA</td>
<td>3.0</td>
<td>Compute lethal areas for foxhole and prone targets only.</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Compute lethal areas for standing, foxhole, and prone targets only</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Compute lethal areas for standing, foxhole, prone and the six-point standing target</td>
</tr>
<tr>
<td>SKP</td>
<td>1.0</td>
<td>Lethal areas are computed as defined by NQA stated above</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>If NQA = 1.0, compute standing target lethal area only; if NQA = 2.0, compute six-point standing target lethal area only</td>
</tr>
</tbody>
</table>
### III. Lethal Area Cut-Off Options:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>BET</td>
<td>F10.4</td>
<td>Cutoff angle (degrees)</td>
</tr>
<tr>
<td>COP</td>
<td>1.0</td>
<td>Use constant cutoff velocity (CVL)</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Compute cutoff velocity for each weight group using constant shape factor (CKQ)</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>Compute cutoff velocity for each weight group using constant A/M value (AQM)</td>
</tr>
<tr>
<td>CVL</td>
<td>F10.4</td>
<td>Constant cutoff velocity</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>No cutoff mass used</td>
</tr>
<tr>
<td>RMC</td>
<td>F10.4</td>
<td>Constant mass cutoff (used if nonzero value is entered)</td>
</tr>
</tbody>
</table>

### IV. Fragment Blast Option:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLT</td>
<td>0.0</td>
<td>Blast effects are not included</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Use blast radii</td>
</tr>
<tr>
<td>RB1</td>
<td>F10.4</td>
<td>First blast radius</td>
</tr>
<tr>
<td>RB2</td>
<td>F10.4</td>
<td>Second blast radius (RB2 must be greater than RB1)</td>
</tr>
</tbody>
</table>

### V. Fragment Drag Options:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCK</td>
<td>0.0</td>
<td>Compute shape factor given C12 and AMB</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Use shape factor (CKQ)</td>
</tr>
</tbody>
</table>
CKQ  F10.4  Shape factor
C12  F10.4  Constant to determine shape factor
AMB  F10.4  Average value of A/M
NCD  F10.4  Number of values in drag vs. velocity table (must be equal to or greater than two)

VI. Casualty Criteria Options:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td>0.0</td>
<td>Use casualty index value</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Enter AXC, BXC, CXC values</td>
</tr>
<tr>
<td>NCC</td>
<td>XX.X</td>
<td>Casualty criteria index</td>
</tr>
<tr>
<td>AXC</td>
<td>F10.4</td>
<td>Casualty criteria constant</td>
</tr>
<tr>
<td>BXC</td>
<td>F10.4</td>
<td>Casualty criteria constant</td>
</tr>
<tr>
<td>CXC</td>
<td>F10.4</td>
<td>Casualty criteria constant</td>
</tr>
</tbody>
</table>

VII. Print and Punch Options:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>IOU</td>
<td>0.0</td>
<td>Do not print zone data output</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Print zone data output</td>
</tr>
<tr>
<td>NDL</td>
<td>1.0</td>
<td>Print PK arcs vs. range (If matrix is to be generated CLS must also be equal to 1.0)</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Do not print</td>
</tr>
<tr>
<td>CLS</td>
<td>0.0</td>
<td>Do not print</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Print PK arcs vs. range if matrix is to be generated</td>
</tr>
</tbody>
</table>
NT7  
1.0  Print and Punch avg PK vs. range  
2.0  Do not print or punch  
3.0  Print avg PK vs. range  

VIII. Matrix Options:  

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAT</td>
<td>0.0</td>
<td>Do not compute matrix</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Compute matrix</td>
</tr>
<tr>
<td>NDG</td>
<td>F10.4</td>
<td>Number of cells in deflection</td>
</tr>
<tr>
<td>NRG</td>
<td>F10.4</td>
<td>Number of cells in range</td>
</tr>
<tr>
<td>RAD</td>
<td>1.0</td>
<td>Use cell size in range and deflection and matrix center (RAM, DAM and CNT)</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Compute cell size based on maximum effective range</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>Use cell size in range and deflection directions. RAX, DAY, DAX number of cells based upon maximum range.</td>
</tr>
<tr>
<td>DAM</td>
<td>F10.4</td>
<td>Cell size in deflection</td>
</tr>
<tr>
<td></td>
<td>Used with RAD = 1.0</td>
<td></td>
</tr>
<tr>
<td>RAM</td>
<td>F10.4</td>
<td>Cell size in range</td>
</tr>
<tr>
<td></td>
<td>Used when RAD = 1.0</td>
<td></td>
</tr>
<tr>
<td>CNT</td>
<td>F10.4</td>
<td>Center of matrix</td>
</tr>
<tr>
<td></td>
<td>Used when RAD = 1.0</td>
<td></td>
</tr>
<tr>
<td>DAY</td>
<td>F10.4</td>
<td>Cell size in deflection</td>
</tr>
<tr>
<td></td>
<td>Used when RAD = 3.0</td>
<td></td>
</tr>
<tr>
<td>RAX</td>
<td>F10.4</td>
<td>Cell size in range</td>
</tr>
<tr>
<td></td>
<td>Used when RAD = 3.0</td>
<td></td>
</tr>
</tbody>
</table>
MCT 0.0  Insures at least two arcs cutting each cell of probability of kill matrix

F10.4 Specifies given number of cuts in each cell of matrix

OSK 0.0  Do not punch matrix cards
1.0  Punch matrix cards

IX. Target Posture for Matrix:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN2</td>
<td>0.0</td>
<td>Do not compute matrix for ORO foxhole</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Compute matrix for ORO foxhole</td>
</tr>
<tr>
<td>IN4</td>
<td>0.0</td>
<td>Do not compute matrix for BRL prone</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Compute matrix for BRL prone</td>
</tr>
<tr>
<td>IN7</td>
<td>0.0</td>
<td>Do not compute matrix for one-point standing target</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Compute matrix for one-point standing target</td>
</tr>
<tr>
<td>IN8</td>
<td>0.0</td>
<td>Do not compute matrix for six-point standing target</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Compute matrix for six-point standing target</td>
</tr>
</tbody>
</table>

NOTE: Only one of the above postures may be selected for any given computer run.
APPENDIX F
6-D TRAJECTORY PROGRAM (TR)
KEY VARIABLE INPUT
## I. Control Parameters:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>NER</td>
<td>1.0</td>
<td>Flat earth.</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Spherical earth.</td>
</tr>
<tr>
<td>ROT</td>
<td>1.0</td>
<td>Rotating earth.</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>No earth rotation.</td>
</tr>
<tr>
<td>NWD</td>
<td>1.0</td>
<td>Include wind tables.</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Do not include wind tables.</td>
</tr>
<tr>
<td>NKC</td>
<td>1.0</td>
<td>Use &quot;k&quot; coefficients.</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Use &quot;c&quot; coefficients.</td>
</tr>
<tr>
<td>NIR</td>
<td>1.0</td>
<td>Include atmosphere table.</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Use standard atmosphere.</td>
</tr>
<tr>
<td>MAL</td>
<td>1.0</td>
<td>Use cutoff at max. alt.</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Use no cutoff at max. alt.</td>
</tr>
<tr>
<td>NKS</td>
<td>1.0</td>
<td>Print coefficient tables.</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Do not print coefficient tables.</td>
</tr>
<tr>
<td>KFC</td>
<td>1.0</td>
<td>Include magnus (force) coefficients as input.</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Do not include magnus coefficients as input.</td>
</tr>
<tr>
<td>KPC</td>
<td>1.0</td>
<td>Include roll moment coefficients.</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Do not include roll moment coefficients.</td>
</tr>
<tr>
<td>KZC</td>
<td>1.0</td>
<td>Include (yaw) roll damping coefficients.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td>KCM</td>
<td>2.0</td>
<td>Do not include (yaw) roll damping coefficients.</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Include magnus force C.P.</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Do not include magnus force C.P.</td>
</tr>
<tr>
<td>NTV</td>
<td>0.0</td>
<td>Use table of thrust vs. time</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Use table of thrust vs. altitude.</td>
</tr>
<tr>
<td>KTP</td>
<td>1.0</td>
<td>Punch card output for PMTASS input.</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>Do not punch card output.</td>
</tr>
<tr>
<td>KON</td>
<td>0.0</td>
<td>Assume KFC input to be based on $\frac{\pi}{16}$.</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Assume KFC input to be based on $\frac{\pi}{8}$.</td>
</tr>
<tr>
<td>KMR</td>
<td>0.0</td>
<td>Print output in feet.</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Print output in meters.</td>
</tr>
<tr>
<td>KSP</td>
<td>1.0</td>
<td>For three-way table lookup of KFC and CPF. KFC and CPF will now be a function of mach no., angle of attack, and spin.</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>For two-way table lookup of KFC and CPF.</td>
</tr>
<tr>
<td>NTA</td>
<td>24.0</td>
<td>Number of entries in atmosphere table. Default value is 24.0.</td>
</tr>
<tr>
<td>NIW</td>
<td>40.0</td>
<td>Number of entries in wind table. Default value is 40.0.</td>
</tr>
<tr>
<td>NAX</td>
<td>F10.4</td>
<td>Max. number of angle of attack arguments in coefficients.</td>
</tr>
<tr>
<td>NMX</td>
<td>F10.4</td>
<td>Max. number of mach number arguments.</td>
</tr>
</tbody>
</table>
NUR  F10.4  Number of trajectories to be computed using same control parameters, atmosphere, thrust, wind, and ballistic coefficients.

NRU  F10.4  Starting number of trajectories indicated by NUR above.

NNW  F10.4  Number of range values in wind tables (max. 40). NOTE: 40 altitudes must be given for each range value.

NSP  F10.4  Max. number of spin variables to be supplied when KSP=1.0.

DMA  F10.4  Max. time interval (DLT max.).
          0.0  Set DLT min. = 0.00005.

DMI  F10.4  Min. time interval (DLT min.).
          0.0  Set DLT min. = 0.5.

II. Phase Options:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1X</td>
<td>0.0</td>
<td>Do not compute Phase I.</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Compute Phase I.</td>
</tr>
<tr>
<td>N2X</td>
<td>0.0</td>
<td>Do not compute Phase II.</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Compute Phase II.</td>
</tr>
<tr>
<td>N3X</td>
<td>0.0</td>
<td>Do not compute Phase III.</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Compute Phase III.</td>
</tr>
<tr>
<td>N4X</td>
<td>0.0</td>
<td>Do not compute Phase IV.</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Compute Phase IV.</td>
</tr>
<tr>
<td>N5X</td>
<td>0.0</td>
<td>Do not compute Phase V.</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Compute Phase V.</td>
</tr>
</tbody>
</table>
N6X  0.0  Do not compute Phase VI.
      1.0  Compute Phase VI.

N7X  0.0  Do not compute Phase VII.
      1.0  Compute Phase VII.

### III. Initial Conditions:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANA</td>
<td>F10.4</td>
<td>Longitude (degrees).</td>
</tr>
<tr>
<td>ANB</td>
<td>F10.4</td>
<td>Latitude (degrees).</td>
</tr>
<tr>
<td>AZI</td>
<td>F10.4</td>
<td>Azimuthal heading (degrees).</td>
</tr>
<tr>
<td>QEL</td>
<td>F10.4</td>
<td>Angle of elevation (degrees).</td>
</tr>
<tr>
<td>XOT</td>
<td>F10.4</td>
<td>Initial displacement (feet or meters).</td>
</tr>
<tr>
<td>YOT</td>
<td>F10.4</td>
<td>Initial altitude (feet or meters).</td>
</tr>
<tr>
<td>TAS</td>
<td>F10.4</td>
<td>Time at start (seconds).</td>
</tr>
<tr>
<td>AKN</td>
<td>F10.4</td>
<td>Multiplies air densities by this factor (0.0 is read as 1.0).</td>
</tr>
<tr>
<td>DTR</td>
<td>F10.4</td>
<td>Diameter (inches).</td>
</tr>
<tr>
<td>WTR</td>
<td>F10.4</td>
<td>Weight (pounds).</td>
</tr>
<tr>
<td>VXP</td>
<td>F10.4</td>
<td>$V_x$ feet per second.</td>
</tr>
<tr>
<td>VYP</td>
<td>F10.4</td>
<td>$V_y$ feet per second.</td>
</tr>
<tr>
<td>VZP</td>
<td>F10.4</td>
<td>$V_z$ feet per second.</td>
</tr>
<tr>
<td>SPT</td>
<td>F10.4</td>
<td>Missile spin rate (rad/sec).</td>
</tr>
<tr>
<td>WYP</td>
<td>F10.4</td>
<td>Pitch rate (rad/sec).</td>
</tr>
<tr>
<td>WZP</td>
<td>F10.4</td>
<td>Yaw rate (rad/sec).</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
<td>Units</td>
</tr>
<tr>
<td>------</td>
<td>----------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>CIX</td>
<td>Booster initial $I_X$ (axial moment, lb-sq in).</td>
<td></td>
</tr>
<tr>
<td>CIY</td>
<td>Booster initial $I_Y$ (transverse moment, lb-sq in).</td>
<td></td>
</tr>
<tr>
<td>XCG</td>
<td>Booster initial center of gravity from nose (inches).</td>
<td></td>
</tr>
<tr>
<td>PUB</td>
<td>Booster specific impulse (lb-sec/lb fuel).</td>
<td></td>
</tr>
<tr>
<td>WDT</td>
<td>Booster burning rate (lb-fuel/sec).</td>
<td></td>
</tr>
<tr>
<td>CX2</td>
<td>Booster final $I_X$ (axial moment lb-sq in).</td>
<td></td>
</tr>
<tr>
<td>CY2</td>
<td>Booster final $I_Y$ (transverse moment, lb-sq in).</td>
<td></td>
</tr>
<tr>
<td>CG2</td>
<td>Booster final center of gravity (inches).</td>
<td></td>
</tr>
<tr>
<td>ANO</td>
<td>Booster nozzle diameter (inches).</td>
<td></td>
</tr>
<tr>
<td>AMA</td>
<td>Booster mal. angle, $A$ (degrees).</td>
<td></td>
</tr>
<tr>
<td>TMA</td>
<td>Booster mal. angle, $T$ (degrees).</td>
<td></td>
</tr>
<tr>
<td>RXT</td>
<td>Booster mal. distance, $R_X$ (inches).</td>
<td></td>
</tr>
<tr>
<td>RYT</td>
<td>Booster mal. distance, $R_Y$ (inches).</td>
<td></td>
</tr>
<tr>
<td>RZT</td>
<td>Booster mal. distance, $R_Z$ (inches).</td>
<td></td>
</tr>
<tr>
<td>TKA</td>
<td>Booster jet torque moment (inches).</td>
<td></td>
</tr>
<tr>
<td>TMD</td>
<td>Booster thrust modifier.</td>
<td></td>
</tr>
<tr>
<td>CXS</td>
<td>Main stage initial $I_X$ (lb-sq in).</td>
<td></td>
</tr>
<tr>
<td>CYS</td>
<td>Main stage initial $I_Y$ (lb-sq in).</td>
<td></td>
</tr>
<tr>
<td>CGM</td>
<td>Main stage initial center of gravity (inches).</td>
<td></td>
</tr>
<tr>
<td>Code</td>
<td>Type</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>PUS</td>
<td>F10.4</td>
<td>Main stage specific impulse (lb-sec/lb).</td>
</tr>
<tr>
<td>WRS</td>
<td>F10.4</td>
<td>Main stage burning rate (lb/sec).</td>
</tr>
<tr>
<td>CX6</td>
<td>F10.4</td>
<td>Main stage final $I_X$ (lb-sq in).</td>
</tr>
<tr>
<td>CY6</td>
<td>F10.4</td>
<td>Main stage final $I_Y$ (lb-sq in).</td>
</tr>
<tr>
<td>CG6</td>
<td>F10.4</td>
<td>Main stage final center of gravity (inches).</td>
</tr>
<tr>
<td>D05</td>
<td>F10.4</td>
<td>Main stage nozzle diameter (inches).</td>
</tr>
<tr>
<td>AL5</td>
<td>F10.4</td>
<td>Main stage mal. angle, $A$ (degrees).</td>
</tr>
<tr>
<td>TL5</td>
<td>F10.4</td>
<td>Main stage mal. angle, $\tau$ (degrees).</td>
</tr>
<tr>
<td>RX5</td>
<td>F10.4</td>
<td>Main stage mal. distance, $R_X$ (degrees).</td>
</tr>
<tr>
<td>RY5</td>
<td>F10.4</td>
<td>Main stage mal. distance, $R_Y$ (inches).</td>
</tr>
<tr>
<td>RZ5</td>
<td>F10.4</td>
<td>Main stage mal. distance, $R_Z$ (inches).</td>
</tr>
<tr>
<td>TK5</td>
<td>F10.4</td>
<td>Main stage jet torque arm (inches).</td>
</tr>
<tr>
<td>TM5</td>
<td>F10.4</td>
<td>Main stage thrust modifier.</td>
</tr>
<tr>
<td>TI1</td>
<td>F10.4</td>
<td>Time at end of Phase I (seconds).</td>
</tr>
<tr>
<td>TI2</td>
<td>F10.4</td>
<td>Time at end of Phase II (seconds).</td>
</tr>
<tr>
<td>TI3</td>
<td>F10.4</td>
<td>Time at end of Phase III (seconds).</td>
</tr>
<tr>
<td>TI4</td>
<td>F10.4</td>
<td>Time at end of Phase IV (seconds).</td>
</tr>
<tr>
<td>TI5</td>
<td>F10.4</td>
<td>Time at end of Phase V (seconds).</td>
</tr>
<tr>
<td>TI6</td>
<td>F10.4</td>
<td>Time at end of Phase VI (seconds).</td>
</tr>
<tr>
<td>WT5</td>
<td>F10.4</td>
<td>Initial main stage weight (pounds).</td>
</tr>
</tbody>
</table>
BRB F10.4 Burning rate at separation (lb/sec).
FF1 F10.4 Phase I form factor drag.
FF2 F10.4 Phase II form factor drag.
FF3 F10.4 Phase III form factor drag.
FF4 F10.4 Phase IV form factor drag.
FF5 F10.4 Phase V form factor drag.
FF6 F10.4 Phase VI form factor drag.
FF7 F10.4 Phase VII form factor drag.
ST5 F10.4 Separation thrust (pounds).

IV. Integration and Print Options:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>DI1</td>
<td>F10.4</td>
<td>Phase I integration step size (seconds).</td>
</tr>
<tr>
<td>DI2</td>
<td>F10.4</td>
<td>Phase II integration step size (seconds).</td>
</tr>
<tr>
<td>DI3</td>
<td>F10.4</td>
<td>Phase III integration step size (seconds).</td>
</tr>
<tr>
<td>DI4</td>
<td>F10.4</td>
<td>Phase IV integration step size (seconds).</td>
</tr>
<tr>
<td>DI5</td>
<td>F10.4</td>
<td>Phase V integration step size (seconds).</td>
</tr>
<tr>
<td>DI6</td>
<td>F10.4</td>
<td>Phase VI integration step size (seconds).</td>
</tr>
<tr>
<td>DI7</td>
<td>F10.4</td>
<td>Phase VII integration step size (seconds).</td>
</tr>
</tbody>
</table>
DAZ F10.4 Diameter (in.) of second stage. If left blank will be assumed = DTR

DS1 F10.4 Phase I output spacing (seconds).

DS2 F10.4 Phase II output spacing (seconds).

DS3 F10.4 Phase III output spacing (seconds).

DS4 F10.4 Phase IV output spacing (seconds).

DS5 F10.4 Phase V output spacing (seconds).

DS6 F10.4 Phase VI output spacing (seconds).

DS7 F10.4 Phase VII output spacing (seconds).

SPZ F10.4 Spin rate of second stage. If left blank, SPT will be assumed to be that which existed at end of last phase.

V. Constants and Parameters:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRS F10.4</td>
<td>Static test atmospheric pressure (lb/sq in).</td>
<td></td>
</tr>
<tr>
<td>VWX F10.4</td>
<td>Constant range wind (feet/sec).</td>
<td></td>
</tr>
<tr>
<td>VWY F10.4</td>
<td>Constant cross-range wind (feet/sec).</td>
<td></td>
</tr>
<tr>
<td>VWZ F10.4</td>
<td>Constant vertical wind (feet/sec).</td>
<td></td>
</tr>
<tr>
<td>IYO F10.4</td>
<td>Initial deflection (feet).</td>
<td></td>
</tr>
<tr>
<td>TZF F10.4</td>
<td>Terminal altitude (feet).</td>
<td></td>
</tr>
<tr>
<td>COD F10.4</td>
<td>CODE (three numeric characters to identify job - are printed out).</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX G

RECOIL MECHANISM DESIGN PROGRAM (RM)

KEY VARIABLE INPUT
### I. Program Options:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>XND</td>
<td>0.0</td>
<td>Run next set of input data</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Do not run next set of input data</td>
</tr>
<tr>
<td>PRT</td>
<td>0.0</td>
<td>Print auxiliary output data</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Do not print auxiliary output data</td>
</tr>
<tr>
<td>ISW</td>
<td>0.0</td>
<td>Switch to bypass namelist</td>
</tr>
</tbody>
</table>

### II. Constants and Parameters:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIR</td>
<td>F10.4</td>
<td>Rise-fall time of rod pull curve (sec)</td>
</tr>
<tr>
<td>RH1</td>
<td>F10.4</td>
<td>Density of primary material-steel (lb/in.²)</td>
</tr>
<tr>
<td>SIG</td>
<td>F10.4</td>
<td>Allowable stress in primary material (lb/in.²)</td>
</tr>
<tr>
<td>RH2</td>
<td>F10.4</td>
<td>Density of secondary material-bronze (lb/in.³)</td>
</tr>
<tr>
<td>XMR</td>
<td>F10.4</td>
<td>Mass of recoiling parts-initially the mass of gun tube and components (in-slug)</td>
</tr>
<tr>
<td>XMP</td>
<td>F10.4</td>
<td>Mass of projectile (in-slug)</td>
</tr>
<tr>
<td>XMC</td>
<td>F10.4</td>
<td>Mass of propelling charge (in-slug)</td>
</tr>
<tr>
<td>RSR</td>
<td>F10.4</td>
<td>Design recoil length-short (in.)</td>
</tr>
<tr>
<td>RLR</td>
<td>F10.4</td>
<td>Design recoil length-long (in.)</td>
</tr>
<tr>
<td>XIR</td>
<td>F10.4</td>
<td>Net impulse imparted (lb-sec)</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>VALUES OR FORMAT</td>
<td>MEANING</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------</td>
<td>---------</td>
</tr>
<tr>
<td>VOR</td>
<td>F10.4</td>
<td>Projectile muzzle velocity (in./sec)</td>
</tr>
<tr>
<td>ALP</td>
<td>F10.4</td>
<td>Time to centroid of breech force (sec)</td>
</tr>
<tr>
<td>PMX</td>
<td>F10.4</td>
<td>Design fluid pressure-recoil (lb/in.²)</td>
</tr>
<tr>
<td>DGT</td>
<td>F10.4</td>
<td>Diameter of gun tube at breech (in.)</td>
</tr>
<tr>
<td>DR1</td>
<td>F10.4</td>
<td>Allowable expansion (recoil)</td>
</tr>
<tr>
<td>DR2</td>
<td>F10.4</td>
<td>Allowable expansion (C ≤ recoil inner)</td>
</tr>
<tr>
<td>DR3</td>
<td>F10.4</td>
<td>Allowable expansion (C ≤ recoil outer)</td>
</tr>
<tr>
<td>DLM</td>
<td>F10.4</td>
<td>Allowable deflection (breech ring)</td>
</tr>
<tr>
<td>XNR</td>
<td>F10.4</td>
<td>Number of recoil cylinders</td>
</tr>
<tr>
<td>CDR</td>
<td>F10.4</td>
<td>Discharge coefficient for recoil</td>
</tr>
<tr>
<td>SC1</td>
<td>F10.4</td>
<td>Stress concentration for threaded members</td>
</tr>
<tr>
<td>SC2</td>
<td>F10.4</td>
<td>Stress concentration for grooves and thread reliefs</td>
</tr>
<tr>
<td>OVS</td>
<td>F10.4</td>
<td>Allowable difference in size between recoil and C ≤ recoil</td>
</tr>
<tr>
<td>DLP</td>
<td>F10.4</td>
<td>Increment of design fluid pressure (lb/in.²)</td>
</tr>
<tr>
<td>CLR</td>
<td>F10.4</td>
<td>Clearance between gun tubes and cylinders (in.)</td>
</tr>
<tr>
<td>TRU</td>
<td>F10.4</td>
<td>Height from floor to trunnions (in.)</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>VALUES OR FORMAT</td>
<td>MEANING</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------</td>
<td>---------</td>
</tr>
<tr>
<td>BAL</td>
<td>F10.4</td>
<td>Thickness of rotor for ballistic protection (in.)</td>
</tr>
<tr>
<td>CMT</td>
<td>F10.4</td>
<td>Distance from front (muzzle end) of breech to gun tube center of gravity (in.)</td>
</tr>
<tr>
<td>ROF</td>
<td>F10.4</td>
<td>Distance from floor to roof in cab (in.)</td>
</tr>
<tr>
<td>PGS</td>
<td>F10.4</td>
<td>Starting value of maximum gas pressure (lb/in.$^2$)</td>
</tr>
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APPENDIX H
SABOT DESIGN PROGRAM (SD)
KEY VARIABLE INPUT
I. Program Options:

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOC</td>
<td>0.0</td>
<td>Segments of sabot are open</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Segments of sabot are closed</td>
</tr>
<tr>
<td>GFC</td>
<td>0.0</td>
<td>Rear geometry is cylinder</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Rear geometry is frustrum</td>
</tr>
<tr>
<td>NPR</td>
<td>1.0</td>
<td>Printer plotting</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>CALCOMP plotting</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>Printer and CALCOMP plotting</td>
</tr>
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</table>

II. Constants and Parameters

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>PKP</td>
<td>F10.4</td>
<td>Peak pressure (PSI)</td>
</tr>
<tr>
<td>PFW</td>
<td>F10.4</td>
<td>Projectile-flechette weight (lb)</td>
</tr>
<tr>
<td>KK1</td>
<td>F10.4</td>
<td>Percentage head friction</td>
</tr>
<tr>
<td>CCF</td>
<td>F10.4</td>
<td>Percentage rear strut friction</td>
</tr>
<tr>
<td>NNS</td>
<td>F10.4</td>
<td>Number of sabot segments</td>
</tr>
<tr>
<td>WOB</td>
<td>F10.4</td>
<td>Weight of obturator (lb)</td>
</tr>
<tr>
<td>FRB</td>
<td>F10.4</td>
<td>Major frustrum radius (in.)</td>
</tr>
<tr>
<td>FRL</td>
<td>F10.4</td>
<td>Minor frustrum radius (in.)</td>
</tr>
<tr>
<td>LFR</td>
<td>F10.4</td>
<td>Length of frustrum (in.)</td>
</tr>
<tr>
<td>RVB</td>
<td>F10.4</td>
<td>Volume of rear section - 0.0 is meaningless (in.³)</td>
</tr>
<tr>
<td>FVH</td>
<td>F10.4</td>
<td>Volume of sabot head (in.³)</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td>SPS</td>
<td>F10.4</td>
<td>Sabot material density (lb/in³)</td>
</tr>
<tr>
<td>THK</td>
<td>F10.4</td>
<td>Thickness of rear strut (in.)</td>
</tr>
<tr>
<td>PFD</td>
<td>F10.4</td>
<td>Diameter of projectile (in.)</td>
</tr>
<tr>
<td>MBD</td>
<td>F10.4</td>
<td>Mean diameter between lands and grooves of bore (in.)</td>
</tr>
</tbody>
</table>
APPENDIX I

HEPPNER-INTERIOR BALLISTICS (IH)

KEY INPUT VARIABLES
### I. Program Options:

<table>
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<tr>
<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICK</td>
<td>F10.4</td>
<td>Plotting parameter for subroutine SYMBOL (angle at which text is to be printed - see Reference 11).</td>
</tr>
<tr>
<td>IPL</td>
<td>1.0</td>
<td>Printout only</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>Plot only</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>Printout and plot</td>
</tr>
<tr>
<td>RNS</td>
<td>F10.4</td>
<td>Number of runs</td>
</tr>
<tr>
<td>ZLI</td>
<td>F10.4</td>
<td>Number of lines between typeout.</td>
</tr>
</tbody>
</table>

### II. Constants and Parameters:

<table>
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<th>SYMBOL</th>
<th>VALUES OR FORMAT</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEP</td>
<td>F10.1</td>
<td>Peak pressure (PSI)</td>
</tr>
<tr>
<td>VOM</td>
<td>F10.1</td>
<td>Muzzle velocity (ft/in²)</td>
</tr>
<tr>
<td>CHV</td>
<td>F8.3</td>
<td>Chamber volume (in³)</td>
</tr>
<tr>
<td>CSA</td>
<td>F8.3</td>
<td>Cross-section of bore (in²)</td>
</tr>
<tr>
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PROJECTILE 1 INCH WIDE

PROPERTIES OF ENTIRE SHELL

WEIGHT: 209,8195 BOUND

CG TO BOUND: 22.3417 INCHES

POLAR INERTIA: 1399.41 INCH SQUARE

TRANSVERSE INERTIA: 1386.7727 ROUND INCH SQUARE

INTER VOLUME: 1770.1896 CUBIC INCHES
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End of today's data.
INTERIOR BALLISTICS
PROJECTILE 8 INCH WIDE

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\begin{align*}
    O &= 3.5423 \\
    X &= 792.0000 \\
    VG &= 998.0000 \\
    H &= 5388.00 \\
    Z &= 17.65 \\
    \gamma &= 1.5 \\
    \alpha &= 0.08
\end{align*}
\]

FOR PRACTICAL HIT:

\[
\begin{align*}
    F &= -0080480071.7967 \\
    \text{TRAVEL AT Muzzle} &= 10.665 \\
    \text{TRAVEL AT BOREOUT} &= 4217
\end{align*}
\]

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\text{VELOCITY AT Muzzle Equiv.} = 3073.07 \text{ FT/SEC}
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INTERIOR BALLISTICS
PROJECTILE 9 INCH HIGH

| T | 1.5673 |
| L | 105.0000 |
| V0 | 198.0000 |
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| SN | 82.09 |
| C | 8.79 |
| k | 17 |
| v | 0.90 |

GCB IS GREATER THAN 0.8271. HENCE PROPELLANT MAY NOT BURN SMOOTHLY
FOR PROPELLANT WITH

F = 0.67060 + 0.470
TRAVEL AT MUSCLE = 11.141
TRAVEL AT MUDGOUT = 5.330

VELOCITY AT MUSCLE EQUALS 4013.26 FT./SEC
Section K-8
MISSILE INPUT DATA FOR 2 DOF FREEDOM TRAJECTORY

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ROCKET DATA

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Range, Altitude and Reflection are in Meters.
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**Range in Meters**: 3000, 12

**Maximum Altitude in Meters**: 106, 20
Section K-11
**INTERIOR BULLETICS**

**EXPERIMENT IN**

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**COMPLETED DATA**

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**TOTAL COMBUSTION DEPTH FOR ALL CHARGES**

- 230
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End of Table No. 243
### TWO-DIMENSIONAL TWO-STATE JACKET TRANSITION

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- M: 3.000, 2.000, 1.000, 0.000, 0.000, 0.000, 0.000, 0.000
- Tt: 4.000, 3.000, 2.000, 1.000, 0.000, 0.000, 0.000, 0.000
- V: 1.000, 2.000, 3.000, 4.000, 5.000, 6.000, 7.000, 8.000
- W: 9.000, 10.000, 11.000, 12.000, 13.000, 14.000, 15.000, 16.000
- Time: 1.000, 2.000, 3.000, 4.000, 5.000, 6.000, 7.000, 8.000
- Fact: 1.000, 2.000, 3.000, 4.000, 5.000, 6.000, 7.000, 8.000
- Y: 9.000, 10.000, 11.000, 12.000, 13.000, 14.000, 15.000, 16.000
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END OF TRAJECTORY NO. 1
APPENDIX L

UNABBREVIATED OUTPUT AT THE TELETYPING
Unabbreviated Output at the Teletype

Normal usage of IPSSM at the teletype involves batching the job to a central computer site, where the full output can later be retrieved, and/or asking for an abbreviated set of results to be recallable at the same teletype terminal. At Picatinny Arsenal a routine DISPLAYOUTPUT is available to allow the full unabbreviated output of an IPSSM run to be examined at the teletype. Specific instructions follow.

Before typing IPSM at the start of the teletype run, enter:

\texttt{ATTACH,DISPLAY,FULLOUTPUT,CY=1,ID=MISDSEAD.}

Then proceed normally, but when ready to batch your program, enter:

\texttt{BATCH,JOB,INPUT,HERE.}

A name will then be assigned to your job; wait until the job has executed and is in the output queue, then enter:

\texttt{BATCH,(JOBNAME),LOCAL}

\texttt{DISPLAY,(JOBNAME)}

The system response will be

\texttt{PAGE NUMBER = 1 TOTAL PAGES OF OUTPUT = N}

\texttt{PAGE NUMBER = --- (RIGHT JUSTIFIED)}

The page number to be examined is now entered in right-justified format (i.e., the third page would be designated as 003).

Upon completion of examination at the teletype terminal, \texttt{PAGE 999} is entered to terminate this routine. You may then logout or use the \texttt{DISPOSE} facility to send a permanent record of the unabbreviated results to batch terminal. To dispose your output to a specific terminal, enter the following statement:

\texttt{DISPOSE,OUTPUT,(TERMINAL CODE)}
DISTRIBUTION LIST

Commander
Frankford Arsenal
ATTN: Mr Sylvan Eisman
Philadelphia, PA 19137

Commander
Rock Island Arsenal
ATTN: SARRI-LR Mr W. McGarvey
Mr. Burnett Moody
Rock Island, IL 61201

Commander
Redstone Arsenal
ATTN: Mr Richard Eppes
Redstone, AL 35809

Headquarters
Department of the Army
Washington, DC 20310

Commander
US Army Armament Command
ATTN: DRSAR-RDM, Dr. N. Coleman
Rock Island, IL 61201

Commander
Picatinny Arsenal
ATTN: SARPA-CO, Mr. H.W. Painter
Mr. R.C. Lundquist
SARPA-FR-S, Mr. J.W. Gregorits
Mr. A.A. Loeb
Mr. G. Demitrack
Mr. G. Friedman
SARPA-AD, Mr. V. Lindner
SARPA-AD-C, Mr. S. Einbinder
Mr. E. Leibowitz
SARPA-AD-D, Mr. E.H. Buchanan
Mr. R. Reisman
Mr. T. Stevens
SARPA-AD-E, Mr. D. Katz
Mr. S. Bernstein
SARPA-AD-F, Mr. F. Saxe
SARPA-ND, Mr. A.M. Moss

279
SARPA-ND-C, Mr. C.I. Jackman 23
  Mr. P. Angelotti 24
  Mr. D. Miller 25
  Dr. L.F. Nichols 26 - 55
  Mr. F. Scerbo 56
SARPA-ND-D, Mr. H. Grundler 57
  Mr. M. Rosenberg 58
SARPA-MI, Mr. D. Grobsttein 59
SARPA-MI-E, Mr. R.I. Isakower 60
SARPA-MI-M, Mr. B.D. Barnett 61
SARPA-MI-T, Mr. I.E. Rucker 62
  Mr. F. McMains 63
  Mr. J. Bevelock 64
SARPA-TS-X, Mr. L. Glass 65
  Mr. R. Drake 66
SARPA-QA-X, Mr. E. Loniewski 67
Dover, NJ 07801

Commander
US Army MICOM
ATTN: AMSMI-RHS-AHELD/Bldg 0971 Mr Arthur Werkheiser 68
Redstone Arsenal, AL 35809

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Cameron Station 69 - 80
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