NASA Contractor Report 165832

ELLIPPTICAL ORBIT PERFORMANCE COMPUTER PROGRAM

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SUMMARY

This report describes and presents a FORTRAN coded computer program which generates and plots elliptical orbit performance capability of space boosters for presentation purposes. The program requires input data from a trajectory simulation which defines the booster's velocity capability as a function of insertion altitude and payload weight. The Elliptical Orbit Performance computer program manipulates the velocity-altitude-payload weight data to obtain apogee altitude-perigee altitude-payload weight data and generates a computer plot. Included in this report are program theory, user instructions, output definitions, subroutine descriptions and detailed FORTRAN coding information.
1.0 INTRODUCTION

A common method of presentation of orbital performance capability of space boosters is to show apogee and perigee altitude as a function of payload weight. Typically, apogee and perigee altitude data are calculated from parametric data of altitude and velocity at orbit insertion. The booster's velocity capability as a function of altitude and payload weight at orbit insertion are commonly calculated by a computer program which simulates the booster flight. Thus, based upon the parametric results of a trajectory program which simulates a specific space booster, the orbit insertion data can be manipulated to produce parametric data of apogee and perigee altitude as a function of payload weight. The mechanization of this manipulating process resulted in computer program Elliptical Orbit Performance (acronym ELOPE) and is described herein.
2.0 DEFINITIONS

Flowchart conventions used in this report are as follows:

- **Process**
- **Input/Output**
- **Subroutine**
- **Decision**
- **Subroutine Call**
3.0 PROGRAM DESCRIPTION

This section describes program theory, input instructions and output definitions.

3.1 Program Theory

The purpose of computer program ELOPE is to calculate parametric data in apogee altitude, perigee altitude and payload weight and generate a computer plot. The technique used in ELOPE to obtain this plot includes interpolation of data and the solution of a two body energy equation.

Parametric data in altitude, velocity and payload weight at orbit insertion must be input to ELOPE. These data can be obtained by use of a trajectory program, such as NEMAR of Reference (1), which simulates booster flight. By calculating trajectories with various values of payload weight and vehicle pitchover rate, the data map depicted below can be obtained.

\[ h_a = \frac{2}{r_p} \left( \frac{2}{r_p^2} \frac{V_p^2}{GM} \right) - r_p - r_e \]

where \( r_p = \) perigee radius = \( h_p + r_e \)
\( V_p = \) perigee velocity
\( r_e = \) Earth radius
\( GM = \) Earth's gravitational constant
\( GM = 1.4076576 \times 10^{18} \text{ft}^3/\text{sec}^2 \)

The above information is interpolated at the perigee altitudes of interest for each payload weight. Perigee is assumed to be at the point of insertion since insertion at perigee results in maximum vehicle performance and since orbiting vehicles commonly insert at perigee. The interpolated velocity(payload weight at each specific perigee is itself interpolated for the range of payloads weights defined by input. The resulting values of perigee velocities are converted to apogee altitudes by the following relationship:

\[ h_a = \frac{2}{r_p} \left( \frac{2}{r_p^2} \frac{V_p^2}{GM} \right) - r_p - r_e \]
The parametric orbital performance plot is defined by repeating the above described process for the range of perigee altitudes defined by input.

Following the payload weight calculation cycle for a specific perigee altitude, payload weights are calculated which correspond to circular and Earth escape orbits. Circular orbit velocity is obtained from:

\[ V_c = \sqrt{\frac{GM}{r_p}} \]

Earth escape velocity is obtained from:

\[ V_e = \sqrt{\frac{2GM}{r_p}} \]

The previously defined velocity-payload weight data are interpolated at the above two velocities to define the circular and escape payload weights.

When the payload weight is desired for a specific orbit, in lieu of parametric performance, the velocity-payload weight data is calculated for the perigee altitude of interest as previously described. The velocity required for the specific orbit is then calculated from:

\[ V_p^2 = GM \left( \frac{2}{r_p} - \frac{1}{a} \right) \]

where \( a = \text{semi-major axis} = \frac{r_a + r_p}{2} \)

\[ r_a = \text{apogee radius} = h_a + r_e \]

This perigee velocity is used to interpolate the velocity-payload weight data for the payload weight corresponding to the specific orbit.

3.2 User Instructions

ELOPE uses a modified FORTRAN NAMELIST for inputting data which provides the user with readability and simplicity of use.

The following rules apply to NAMELIST used by ELOPE:

1. First card of a data group or case is \$INPUTD beginning in column 2. Blanks are not allowed.

2. Last card of a data group or case is \$END beginning in column 2. Blanks are not allowed.
3. Blanks may not be used within names but may be used elsewhere.

4. Variable names are followed by an equal sign which is followed by a value which is followed by a comma, e.g., WEIGHT = 323.07,

5. Only columns 2-72, inclusive, are used.

6. Titling information may be input by the appropriate title names, e.g., TITLE1= ELLIPTICAL ORBIT PERFORMANCE - VAFB LAUNCH. TITLE1 must begin in column 2.

7. Any number of names and values may be on a single card or line.

8. Complete data arrays are input in the following form:
   name = value, value, value, ...
   Data values may be continued on the next line, but the last character on every line must be a comma, excluding title cards.

9. Repeated data values may be input by using a repetition factor and an asterisk, e.g., V1 = 38050, 36525, 2*31510, 28450,

10. One or more specific elements of an array may be input, e.g., WEIGHT(3) = 200, 300,

Subsequent data cases are allowed by providing additional sets of NAMELIST data. All input data is retained for subsequent cases but can be changed by inputting new values.

A sample data case is included as Appendix A to exemplify data case setup.

Execution of ELOPE requires that the CalComp pen plotting facility be available to the computer job at the time of program load. This facility consists of the CalComp 763 pen plotter hardware and the CalComp Basic Software Package, Reference (2). ELOPE generates three plots per case if selected by input. A non-zero value of IPLOT results in plotting on graph paper which has a perforation size of 11 x 17 inches, a grid size of 9 7/8 x 15 inches and grid type of 10 divisions per centimeter. At the Vought installation, this paper is identified as CAL32. A non-zero value of LPLOT results in plotting on 4 cycle semi-log graph paper which has a perforation size of 11 x 8 1/2, a grid size of 10 x 7 and grid type of 2 1/2 inches per cycle and 10 divisions per inch. At the Vought installation, this paper is identified as CAL44. Additionally, this same data is plotted on no-grid paper and may be scaled down in size for use in vugraphs. This plot is placed on paper identified as CAL36 at the Vought installation.

Definitions of specific NAMELIST inputs to ELOPE are shown below. Default values are shown when they are set by the program prior to reading input data.

- 6 -
NAMELIST Input Definitions

ALTMX
Maximum perigee altitude used for parametric output. Units according to IOPT. Use when IOPT = 1 or 2.

ALTMN
Minimum perigee altitude used for parametric output. Units according to IOPT. Use when IOPT = 1 or 2.

APOGEE
Apogee altitude of single orbit case. Units according to IOPT. Use when IOPT = 3 or 4.

DELALT
Increment in perigee altitude for parametric output. Units according to IOPT. Use when IOPT = 1 or 2. Maximum number of altitude points is 50.

DELWT
Increment in payload weight for parametric output. Units according to IOPT. Use when IOPT = 1 or 2.

FACT
Ratio of plot size to normal plot size. When greater than zero but less than or equal to one, the semi-log graph is plotted on no-grid paper. This plot resides on local file name PLT3. (0. built-in)

IOPT
Output data option
= 1 Input ALTMN, ALTMX, DELALT, WTMIN, WTMAX, DELWT and output parametric data in n.mi. and lbs. (1 built-in)
= 2 Input ALTMN, ALTMX, DELALT, WTMIN, WTMAX, DELWT and output parametric data in km and kg.
= 3 Input APOGEE, PERIGE and output single orbit only in n.mi. and lbs.
= 4 Input APOGEE, PERIGE and output single orbit only in km and kg.

IPLOT
Non-zero value produces a CalComp plot of altitude as a function of velocity. Local file name of plot is PLT2. (0 built-in)

IPRNT
Output frequency control. Parametric data is calculated at DELWT intervals from WTMIN and printed at the IPRNT frequency. (1 built-in)

IRAD
Input data option
= 1 Input R1 - R15 as radius in feet. (1 built-in)
= 2 Input R1 - R15 as radius in n.mi.
= 3 Input R1 - R15 as altitude in n.mi.

KASE
Case number.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPLOT</td>
<td>Non-zero value produces a CalComp semi-log plot of apogee altitude as a function of perigee altitude and payload weight. Local file name of plot is PLOT. (0 built-in)</td>
</tr>
<tr>
<td>PERIGE</td>
<td>Perigee altitude of single orbit case. Units according to IOPT. Use when IOPT = 3 or 4.</td>
</tr>
<tr>
<td>PLABEL1 - PLABEL9</td>
<td>Labels placed on upper right side of apogee-perigee plot. Maximum of 30 characters each.</td>
</tr>
<tr>
<td>PTITLE1 - PTITLE4</td>
<td>Titles placed at top center of apogee-perigee plot. Maximum of 40 characters each.</td>
</tr>
<tr>
<td>REARTH</td>
<td>Earth radius used to calculate altitudes, ft. (20925741. built-in)</td>
</tr>
<tr>
<td>Rl - R15</td>
<td>Tables of radius or altitude (according to IRAD) for each WEIGHT. Input in increasing order. Minimum of 4 and maximum of 10 values per table. Enter 0. after last value of each table if less than 10 values are input. Minimum of 4 tables.</td>
</tr>
<tr>
<td>TITLE1</td>
<td>Title printed at top of each page. Maximum of 72 characters.</td>
</tr>
<tr>
<td>TITLE2</td>
<td>Title printed at top of each page. Maximum of 72 characters.</td>
</tr>
<tr>
<td>Vl - V15</td>
<td>Tables of inertial velocity in fps for each Rl - R15. Maximum of 10 values per table.</td>
</tr>
<tr>
<td>WEIGHT</td>
<td>Table of payload weights in lbs. Corresponding tables of radius and velocity must be input for each WEIGHT. Maximum of 15 values.</td>
</tr>
<tr>
<td>WTMAX</td>
<td>Maximum payload weight used for parametric output. Units according to IOPT. Input when IOPT = 1 or 2.</td>
</tr>
<tr>
<td>WTMIN</td>
<td>Minimum payload weight used for parametric output. Units according to IOPT. Input when IOPT = 1 or 2.</td>
</tr>
<tr>
<td>XINC</td>
<td>Increment value of x axis major divisions of apogee-perigee plot. Units according to IOPT. There are 7 major divisions on the x axis. (100. built-in)</td>
</tr>
</tbody>
</table>
3.3 Output Description

The NAMELIST input data is listed verbatim as read. This list provides a quick check of the input data for format correctness and validity. Additionally, the parametric data of weight, altitude and velocity are output in a different format than input for inspection purposes.

Subsequent pages provide parametric data of perigee altitude, apogee altitude and payload weight. For each perigee altitude, as defined by the input, apogee altitude is calculated at each payload weight increment from the minimum value to the maximum value. The resulting values, in both English and metric units, are output according to the value of the input IPRNT. Following the parametric data of each perigee, the payload weight corresponding to a circular orbit and to escape velocity are shown. A sample data case is included as Appendix A. The plots resulting from this data case are also included in Appendix A.

For single orbit cases, data for the specific orbit are shown in lieu of the payload-apogee altitude parametric data.
4.0 SUBROUTINE DESCRIPTIONS

This section provides a brief explanation of each subroutine of ELOPE.

4.1 ELOPE (Main Program)

The main program initializes the input data defaults; converts input data to internal units; calculates parametric data of apogee altitude, perigee altitude and payload weight; calculates payload weight at circular and escape velocities; writes parametric data on disk units 1 and 2 for subsequent plotting; calculates single orbit payload weights; and outputs the results.

4.2 INPUT

Subroutine INPUT reads input data in a modified NAMELIST format. Titling information on title cards are placed in appropriate arrays for use by the main program. Non-title cards are written on disk unit 8 for a FORTRAN NAMELIST read from the main program.

4.3 INTER

Subroutine INTER is a second-order interpolator of two variables. It selects the four closest data points to the desired value of the independent variable and interpolates or extrapolates for the value of the dependent variable.

4.4 PLOTLG

Subroutine PLOTLG produces a CalComp semi-log plot of apogee altitude as a function of perigee altitude and payload weight. The ordinate is fixed at a four cycle logarithm scale from 100 to 1,000,000 n.m. or kilometers. The abscissa scale is determined by input data but is limited to seven major divisions in length. Plotted data is taken from disk units 1 and 2, which are written by the main program. The data plotted is scaled according to an input multiplier in order to decrease the physical size of the plot. This multiplier is one when plotting on grid paper.
Subroutine PLOTLR produces a CalComp plot of insertion (perigee) altitude as a function of insertion velocity. These data are input values and are plotted for inspection purposes only. The ordinate is a fixed scale from 0 to 1200 nautical miles. The abscissa is a fixed scale from 18000 to 37000 feet per second. Also plotted on this graph are the circular and escape velocity lines.
5.0 PROGRAM CODING

This section presents details about the program coding. Included are flowcharts of each subroutine, FORTRAN listings of each subroutine and definitions of the FORTRAN variables. The information presented in this section is intended to be helpful in developing a thorough understanding of ELOPE and in making modifications to the program.

5.1 Subroutine Flowcharts

Flowcharts are presented in Figures 5.1 through 5.5. Flowchart conventions used in these figures are defined in Section 2.0 of this report.

5.2 FORTRAN Listings

ELOPE is coded in FORTRAN IV, Reference (3), on the CDC CYBER 175 computer with the NOS/BE 1.4 operating system. Listings of the FORTRAN coding are presented in Appendix B.

5.3 FORTRAN Variable Definition

Definitions of the FORTRAN variables are shown below. This information is usually used only when making modifications to the program.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Semi-major axis, n.mi.</td>
</tr>
<tr>
<td>ALTMAX</td>
<td>Input value</td>
</tr>
<tr>
<td>ALTMIN</td>
<td>Input value</td>
</tr>
<tr>
<td>APOGEE</td>
<td>Input value</td>
</tr>
<tr>
<td>DELALT</td>
<td>Input value</td>
</tr>
<tr>
<td>DELWT</td>
<td>Input value</td>
</tr>
<tr>
<td>DH</td>
<td>Perigee altitude increment, n.mi.</td>
</tr>
<tr>
<td>DW</td>
<td>Payload weight increment, lb.</td>
</tr>
<tr>
<td>FACT</td>
<td>Input value</td>
</tr>
<tr>
<td>Variable</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------</td>
<td>------------</td>
</tr>
<tr>
<td>FTNM</td>
<td>Feet per n.mi., 6076.11549</td>
</tr>
<tr>
<td>GM</td>
<td>Earth's gravitational constant, $1.4076576 \times 10^{16}$ ft$^3$/sec$^2$</td>
</tr>
<tr>
<td>H</td>
<td>Table of altitudes from R1 - R15, n.mi.</td>
</tr>
<tr>
<td>HA</td>
<td>Apogee altitude of single orbit case, n.mi.</td>
</tr>
<tr>
<td>HAMAX</td>
<td>Maximum apogee altitude plotted - 1,000,000 - n.mi. or km</td>
</tr>
<tr>
<td>HAMET</td>
<td>Apogee altitude, km</td>
</tr>
<tr>
<td>HF</td>
<td>Perigee altitude, n.mi.</td>
</tr>
<tr>
<td>HH</td>
<td>Table of perigee altitudes of parametric output, n.mi.</td>
</tr>
<tr>
<td>HHMET</td>
<td>Current perigee altitude, km</td>
</tr>
<tr>
<td>HMAX</td>
<td>Maximum perigee altitude of parametric output, n.mi.</td>
</tr>
<tr>
<td>HMIN</td>
<td>Minimum perigee altitude of parametric output, n.mi.</td>
</tr>
<tr>
<td>HNEW</td>
<td>Current perigee altitude, n.mi.</td>
</tr>
<tr>
<td>HP</td>
<td>Perigee altitude of single orbit case, n.mi.</td>
</tr>
<tr>
<td>HPMET</td>
<td>Perigee altitude, km</td>
</tr>
<tr>
<td>IOPT</td>
<td>Input value</td>
</tr>
<tr>
<td>IPAGE</td>
<td>Page number</td>
</tr>
<tr>
<td>IPILOT</td>
<td>Input value</td>
</tr>
<tr>
<td>IPRNT</td>
<td>Input value</td>
</tr>
<tr>
<td>IRAD</td>
<td>Input value</td>
</tr>
<tr>
<td>KASE</td>
<td>Case number</td>
</tr>
<tr>
<td>LABEL</td>
<td>Character data of information input via LABEL1 - LABEL9</td>
</tr>
<tr>
<td>LPLOT</td>
<td>Input value</td>
</tr>
<tr>
<td><strong>Variable</strong></td>
<td><strong>Definition</strong></td>
</tr>
<tr>
<td>--------------</td>
<td>---------------</td>
</tr>
<tr>
<td>NC</td>
<td>Tables of number of non-zero values in the R1 - R15 tables</td>
</tr>
<tr>
<td>NDIM</td>
<td>Number of permissable values in R1 - R15 and V1 - V15 tables, set to 10</td>
</tr>
<tr>
<td>NH</td>
<td>Number of perigee altitudes of parametric output</td>
</tr>
<tr>
<td>NNW</td>
<td>Number of payload weights of parametric output</td>
</tr>
<tr>
<td>NREC</td>
<td>Number of records of data written on disk unit 1</td>
</tr>
<tr>
<td>NWT</td>
<td>Number of non-zero values of the WEIGHT table</td>
</tr>
<tr>
<td>PERIGE</td>
<td>Input value</td>
</tr>
<tr>
<td>PL</td>
<td>Current payload weight, lb</td>
</tr>
<tr>
<td>PLM</td>
<td>Current payload weight, kg</td>
</tr>
<tr>
<td>R</td>
<td>Array of R1 - R15, input units</td>
</tr>
<tr>
<td>RBAR</td>
<td>Circular orbit radius, ft</td>
</tr>
<tr>
<td>RE</td>
<td>Earth radius, n.mi.</td>
</tr>
<tr>
<td>REARTH</td>
<td>Input value</td>
</tr>
<tr>
<td>RF</td>
<td>Perigee radius, ft</td>
</tr>
<tr>
<td>R1 - R15</td>
<td>Input values</td>
</tr>
<tr>
<td>TITLE</td>
<td>Character data of information input via PTITLE1 - PTITLE4</td>
</tr>
<tr>
<td>TITLE1</td>
<td>Input value</td>
</tr>
<tr>
<td>TITLE2</td>
<td>Input value</td>
</tr>
<tr>
<td>V</td>
<td>Array of V1 - V15, ft/sec</td>
</tr>
<tr>
<td>VEL</td>
<td>Current velocity, ft/sec</td>
</tr>
<tr>
<td>VELC</td>
<td>Circular orbit velocity, ft/sec</td>
</tr>
<tr>
<td>VELE</td>
<td>Escape orbit velocity, ft/sec</td>
</tr>
<tr>
<td>Variable</td>
<td>Definition</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
</tr>
<tr>
<td>VI</td>
<td>Table of velocities at the current perigee altitude, ft/sec</td>
</tr>
<tr>
<td>VMAX</td>
<td>Velocity corresponding to an apogee of 1,000,000 ft/sec</td>
</tr>
<tr>
<td>VV</td>
<td>Tables of velocities for each perigee altitude of parametric output, ft/sec</td>
</tr>
<tr>
<td>V1 - V10</td>
<td>Input values</td>
</tr>
<tr>
<td>WEIGHT</td>
<td>Input value</td>
</tr>
<tr>
<td>WI</td>
<td>Table of payload weights at the current perigee altitude, lb</td>
</tr>
<tr>
<td>WMAX</td>
<td>Maximum payload weight of parametric output, lb</td>
</tr>
<tr>
<td>WMIN</td>
<td>Minimum payload weight of parametric output, lb</td>
</tr>
<tr>
<td>WNEW</td>
<td>Current payload weight of parametric output, lb</td>
</tr>
<tr>
<td>WTC</td>
<td>Circular orbit payload weight, lb</td>
</tr>
<tr>
<td>WTCMET</td>
<td>Circular orbit payload weight, kg</td>
</tr>
<tr>
<td>WTE</td>
<td>Escape orbit payload weight, lb</td>
</tr>
<tr>
<td>WTEMET</td>
<td>Escape orbit payload weight, kg</td>
</tr>
<tr>
<td>WTI</td>
<td>Input value</td>
</tr>
<tr>
<td>WTMIN</td>
<td>Input value</td>
</tr>
<tr>
<td>WW</td>
<td>Tables of payload weights for each perigee altitude of parametric output, lb</td>
</tr>
<tr>
<td>XINC</td>
<td>Input value</td>
</tr>
<tr>
<td>XKG</td>
<td>Kilograms per lb, 0.45359</td>
</tr>
<tr>
<td>XKM</td>
<td>Kilometers per n.mi., 1.852</td>
</tr>
</tbody>
</table>
Figure 5.1
FLOWCHART OF MAIN PROGRAM ELOPE

START
- Initialize input data defaults

INPUT
- Read NAMELIST input data

Set internal parameters according to input values
- Convert input radius or altitude to altitude in n.m.

IF I L O T > 0
- Write altitudes and velocities on unit 3 for plotting

PLOTLR
- YES
- Plot altitude as a function of velocity. Read data from unit 3.
- IF I O P T ≥ 3
  - Set perigee altitude
  - Calculate apogee altitude
  - Loop for all perigee altitudes
  - Repeat for all payload weights

YES
- Print results. Write altitude and payload weight on unit 1

END LOOP
- Loop
- Create circular and escape payload at perigee altitude

END LOOP
- Create semi-log plot of apogee altitude as a function of perigee and payload weight. Read data from units 1 and 2.

IF I PLOT > 0
- YES

YES
- Print results on unit 1

PRINT NUMBER OF RECORDS ON UNIT 1
- NO

IF I PLOT > 0
- PLOTLG

NO

IF I O P T ≥ 3
- Set payload weight

PRINT ALTITUDE AND PAYLOAD WEIGHT ON UNIT 1

NO

IF I O P T ≥ 3
- Repeat for all payload weights

PRINT RESULTS.
- Write altitude and payload weight on unit 1

NO

Calculate single orbit payload weight

PRINT RESULTS

NO

Set internal parameters according to input values

Convert input radius or altitude to altitude in n.m.

Set payload weight

Calculate apogee altitude

Print results. Write altitude and payload weight on unit 1

Plot altitude as a function of velocity. Read data from unit 3.

Create semi-log plot of apogee altitude as a function of perigee and payload weight. Read data from units 1 and 2.
Figure 5.3
FLOWCHART OF SUBROUTINE INTER

Enter INTER

If number of elements =4

YES
Set index to 1

NO

If number of elements in data array <4

YES
Write diagnostic

NO

Select interpolator index to the 4 closest values to the desired independent variable

NO

Interpolate for dependent variable according to index selected

Return
Figure 5.4

FLOWCHART OF SUBROUTINE PLOTLG

- Enter PLOTLG
- Draw and label X and Y axes and print titles
- Read record number from unit 2
- If End-Of-File read:
  - Yes: Write additional labels on plot
  - No: Read payload weights and apogees from unit 1
- Define scale factors
- Draw curve
- Return
Figure 5.5

FLOWCHART OF SUBROUTINE PLOTLR

Enter PLOTLR

Draw and label X and Y axes and print titles

Calculate circular and escape velocity and plot data

Read data from unit 3. Store in plot arrays

If End-Of-File read

YES

Define scale factors. Plot data

NO

Return
REFERENCES


APPENDIX A

Sample Data Case

---

DATE IS 04/12/71
TIME IS 14:45:25

- A1 -
| WEIGHT (LBS.) | 49.0 |
| VELLOCITY (FPS) | 7.0 | 7.0 | 7.0 | 7.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |

| WEIGHT (LBS.) | 72.0 |
| ALTITUDE (N. M. I.) | 340.0 |
| VELLOCITY (FPS) | 7.0 | 7.0 | 7.0 | 7.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |

| WEIGHT (LBS.) | 105.0 |
| ALTITUDE (N. M. I.) | 420.0 |
| VELLOCITY (FPS) | 7.0 | 7.0 | 7.0 | 7.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |

| WEIGHT (LBS.) | 138.0 |
| ALTITUDE (N. M. I.) | 500.0 |
| VELLOCITY (FPS) | 7.0 | 7.0 | 7.0 | 7.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |

- A2 -
<table>
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<tr>
<th>TIME (msec)</th>
<th>VEL. (mph)</th>
<th>ALT. (ft)</th>
<th>VEL. (fps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1532.740</td>
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<td>544.624</td>
<td>744.340</td>
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<tr>
<td></td>
<td>246.397</td>
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<td>26257.30</td>
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<table>
<thead>
<tr>
<th>TIME (msec)</th>
<th>VEL. (mph)</th>
<th>ALT. (ft)</th>
<th>VEL. (fps)</th>
</tr>
</thead>
<tbody>
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<tr>
<td></td>
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<td>0.0</td>
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- A3 -
The image contains a table with data from a payload injection test. The table is labeled as follows:

**Interpolation Data (Check for Accuracy)**

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<th>PAYLOAD</th>
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<td>M.T. LAS</td>
</tr>
<tr>
<td>VEL., FPS</td>
</tr>
<tr>
<td>200.0</td>
</tr>
<tr>
<td>250.0</td>
</tr>
<tr>
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<tr>
<td>400.0</td>
</tr>
<tr>
<td>450.0</td>
</tr>
<tr>
<td>500.0</td>
</tr>
</tbody>
</table>

The table includes columns for PAYLOAD, M.T. LAS, VEL., FPS, and other metrics such as PAYLOAD WT., LBS, APPOGEE ALT., N.MI., PAYLOAD ALT., N.MI., PAYLOAD VEL., FPS, PAYLOAD WT., KG, and APPOGEE ALT., KM.

The page also includes a note indicating the payload weight and velocity for circular and escape cases.
### PAYLOAD INJECTION VEL. FPS

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<th>Injection Vel. (fps)</th>
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</thead>
<tbody>
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<tr>
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<td>31165.9</td>
</tr>
</tbody>
</table>

### PERIGEE ALT. N. M. I. PAYLOAD W. LBS APOGEE ALT. N. M. I. PERIGEE VEL. FPS PAYLOAD W. KG APOGEE ALT. KM

<table>
<thead>
<tr>
<th>Alt. (mi)</th>
<th>Payload (lbs)</th>
<th>Injection Vel. (fps)</th>
<th>Payload (kg)</th>
<th>Injection Vel. (m/s)</th>
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</thead>
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</table>

**Circular Payload = 544.9 lbs = 250.2 km**

**Circular Vel. = 25214.5 fps**

**Escape Payload = 92.6 lbs = 42.6 km**

**Escape Vel. = 35552.7 fps**
<table>
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<th>PAYLOAD WT., LBS</th>
<th>APOGEE ALT., N.MI.</th>
<th>APOGEE VEL., FPS</th>
<th>PAYLOAD ALT., N.MI.</th>
<th>PAYLOAD WT., KG</th>
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CIRCULAR PAYLOAD = 510.5 LBS = 221.5 KG  CIRCULAR VEL. = 24775.5 FPS
ESCAPE PAYLOAD = 24.8 LBS = 39.4 KG  ESCAPE VEL. = 35179.2 FPS
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<th>PAYLOAD ALT.</th>
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## Elliptical Orbit Performance (English Units)

### Inclination Data (Check for accuracy)

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**Circular Payload** = 415.4 Lbs = 192.4 Kg

**Circular Vel.** = 24234.5 Fps

**Escape Payload** = 72.2 Lbs = 32.7 Kg

**Escape Vel.** = 24775.4 Fps
PERIGEE ALT. = 600 N.MI. = 1011.2 KM

INTERPOLATION DATA (CHECK FOR ACCURACY)

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PERIGEE PAYLOAD APOGEE
ALT., N.MI. WT., LBS ALT., N.MI. VEL., FPS

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| 400.0 | 160.0 | 28136.5 | 31870.1 |
| 600.0 | 120.0 | 15998.6 | 30928.1 |
| 600.0 | 140.0 | 11323.6 | 30097.1 |
| 600.0 | 150.0 | 8782.3 | 29342.6 |
| 600.0 | 180.0 | 6763.0 | 28646.8 |
| 600.0 | 200.0 | 5343.2 | 28011.8 |
| 600.0 | 220.0 | 4288.7 | 27428.5 |
| 600.0 | 240.0 | 3454.6 | 26878.3 |
| 600.0 | 260.0 | 2789.7 | 26361.7 |
| 600.0 | 280.0 | 2246.9 | 25840.6 |
| 600.0 | 300.0 | 1794.9 | 25429.9 |
| 600.0 | 320.0 | 1455.5 | 24905.4 |
| 600.0 | 340.0 | 1170.0 | 24534.6 |
| 600.0 | 360.0 | 843.3 | 24164.9 |

CIRCULAR PAYLOAD = 374.0 LBS = 169.7 KG  CIRCULAR VEL. = 23935.0 FPS
ESCAPE PAYLOAD = 54.9 LBS = 29.4 KG  ESCAPE VEL. = 33849.2 FPS
**SCOUT LAUNCH VEHICLE**

**ECCENTRIC ORBIT PERFORMANCE**

**ENGLISH UNITS**

**VAUGHN CORPORATION**

**PROGRAM ELOPE**

**CASE 1 PAGE 7**

**PERIGEE ALT. = 760 C. N. M. = 1294.4 K.M.**

**INTERPOLATION DATA (CHECK FOR ACCURACY)**

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**CIRCULAR PAYLOAD = 336.2 LBS= 152.5 K.C**

**CIRCULAR VEL. = 23644.4 FPS**

**ESCAPE PAYLOAD = 57.7 LBS= 26.2 KG**

**ESCAPE VEL. = 33438.3 FPS**

---

**A10**
**SCOUT LAUNCH VEHICLE**  
**ELLIPOTICAL ORBIT PERFORMANCE**  
**ENGLISH UNITS**  

**VOUGHT CORP.**  
**ORIENTATION**  
**CASE I**  
**PAGE 4**

---

**PERIGEE ALT. =**  
**500.0 N.MI. = 1481.6 KM**

---

**INTERPOLATION DATA (CHECK FOR ACCURACY)**

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**PERIGEE ALT.**  
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**PAYLOAD WT. KG**  
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**CIRCULAR PAYLOAD = 351.2 LBS = 159.0 KG**  
**CIRCULAR VEL. = 2334.2 FPS**  
**ESCAPE PAYLOAD = 50.6 LBS = 23.0 KG**  
**ESCAPE VEL. = 32042.0 FPS**
PERIGEE ALT. = 900.0 N.MI. = 1536.9 KM

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CIRCULAR PAYLOAD = 259.5 LBS = 121.3 KG

ESCAPE PAYLOAD = 43.5 LBS = 19.7 KG

CIRCULAR VEL. = 23042.7 FPS

ESCAPE VEL. = 32659.5 FPS
PERIGEE ALT. 1000.0 N.MI. 12,520.0 KM

INTERPOLATION DATA (CHECK FOR ACCURACY)

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PERIGEE PAYLOAD = 237.7 LBS = 107.8 KG  CIRCULAR PAYLOAD = 36.5 LBS = 16.6 KG

CIRCULAR PAYLOAD = 237.7 LBS = 107.8 KG  CIRCULAR VEL. = 22822.4 FPS

ESCAPE PAYLOAD = 36.5 LBS = 16.6 KG  ESCAPE VEL. = 32289.7 FPS
APPENDIX B
FORTRAN CODE LISTINGS

PROGRAM ELOPE(INPUT, OUTPUT, TAPE5=INPUT, TAPE6=OUTPUT, 
    TAPE1, TAPE2, TAPE3, TAPE8)

    PROGRAM ELOPE CONVERTS PERIGEE ALTITUDE-VELOCITY-PAYLOAD DATA
    TO PERIGEE ALTITUDE-APOGEE ALTITUDE-PAYLOAD DATA PARAMETRICALLY.

    ************************** INPUT DATA **************************

    ALTMAX = MAXIMUM PERIGEE ALTITUDE USED FOR PARAMETRIC
              OUTPUT. UNITS ACCORDING TO IOPT.

    ALTMIN = MINIMUM PERIGEE ALTITUDE USED FOR PARAMETRIC
              OUTPUT. UNITS ACCORDING TO IOPT.

    APOGEE = APOGEE ALTITUDE OF SINGLE ORBIT. UNITS ACCORDING
              TO IOPT. INPUT WHEN IOPT=3 OR 4.

    DELALT = INCREMENTAL PERIGEE ALTITUDE USED FOR PARAMETRIC
              OUTPUT. UNITS ACCORDING TO IOPT. MAXIMUM NUMBER
              OF ALTITUDE POINTS IS 50.

    DELWT = INCREMENTAL PAYLOAD USED FOR PARAMETRIC OUTPUT.
              UNITS ACCORDING TO IOPT.

    FACT = FACTOR TO INCREASE OR DECREASE SIZE OF LOG PLOT.

    IOPT  = DATA OPTION
            =1 INPUT ALTMAX, ALTMIN, DELALT, DELWT, WTMAX, AND
              WTMN IN N. MI., LBS., AND COMPUTE PARAMETRIC
              DATA IN N. MI. AND LBS. (1 BUILT-IN)
            =2 INPUT ALTMAX, ALTMIN, DELALT, DELWT, WTMAX, AND
              WTMN IN KM AND KG AND COMPUTE PARAMETRIC DATA
              IN KM AND KG.
            =3 INPUT APOGEE AND PERIGEE IN N. MI. AND COMPUTE
              SINGLE ORBIT ONLY.
            =4 INPUT APOGEE AND PERIGEE IN KM AND COMPUTE
              SINGLE ORBIT ONLY.

    I_PLOT = A NON ZERO VALUE PRODUCES A PLOT OF ALTITUDE VS
             VELOCITY. LOCAL PLOT FILE NAME IS PLT2. (O BUILT-IN)

    IPRNT = FREQUENCY OF OUTPUT CONTROL. DATA IS COMPUTED AT
            DELWT INTERVALS FROM WTMN AND PRINTED EVERY IPRNT
            DATA POINTS CALCULATED. (1 BUILT-IN)

    IRAD  = DATA OPTION
            =1 INPUT R1-R15 AS RADIUS IN FEET (1 BUILT-IN)
            =2 INPUT R1-R15 AS RADIUS IN N. MI.
            =3 INPUT R1-R15 AS ALTITUDE IN N. MI.

    KASE  = CASE NUMBER

    L_PLOT = NON-ZERO VALUE PRODUCES A SEMI-LOG PLOT OF APOGEE
             AND PERIGEE ALTITUDE AS A FUNCTION OF PAYLOAD WEIGHT.
             LOCAL PLOT FILE NAME IS PLOT. (O BUILT-IN)

    PERIGE = PERIGEE ALTITUDE OF SINGLE ORBIT. UNITS ACCORDING
              TO IOPT. INPUT WHEN IOPT=3 OR 4.

    PLABEL1 = LABELS PLACED ON UPPER RIGHT SIDE OF APOGEE-PERIGEE

    PLABEL9 = PLOT. 30 TITLE CHARACTERS EACH.

    TITLE9 = TITLES PLACED AT TOP OF SEMI-LOG PLOTS.

    PTITLE4 = 40 TITLE CHARACTERS EACH.

    R1-P15 = EARTH RADIUS USED TO COMPUTE ALTITUDES, FEET.
             (29925741, BUILT-IN)

    R1-P15 = TABLE OF RADIUS OR ALTITUDE (ACCORDING TO IRAD) FOR
             EACH WEIGHT. INPUT IN INCREASING ORDER. MINIMUM OF
             4 AND MAXIMUM OF 10 VALUES PER TABLE. ENTER 0 AFTER
             LAST VALUE IF LESS THAN 10 VALUES ARE INPUT.
             MINIMUM OF 4 TABLES.
IMPLICIT REAL(A-H,O-Z)
COMMON /BLK1/TITLE1(8),TITLE2(8),TITLE(16),LABEL(36)
DIMENSION NC(15),WW(15,50),WEIGHT(15)
DIMENSION R(10,15),R1(10),R2(10),R3(10),R4(10),R5(10),
  R6(10),R7(10),R8(10),R9(10),R10(10),R11(10),
  R12(10),R13(10),R14(10),R15(10),V1(10),W1(10),
  V(10,15),V1(10),V2(10),V3(10),V4(10),V5(10),
  V6(10),V7(10),V8(10),V9(10),V10(10),V11(10),
  V12(10),V13(10),V14(10),V15(10),
  H(10,15),HH(50),VV(15,50)
EQUIVALENCE ( R1(1),R(1, 1)),( R2(1),R(1, 2)),( R3(1),R(1, 3)),
  ( R4(1),R(1, 4)),( R5(1),R(1, 5)),( R6(1),R(1, 6)),
  ( R7(1),R(1, 7)),( R8(1),R(1, 8)),( R9(1),R(1, 9)),
  ( R10(1),R(1,10)),( R11(1),R(1,11)),( R12(1),R(1,12)),
  ( R13(1),R(1,13)),( R14(1),R(1,14)),( R15(1),R(1,15)),
  ( V1(1),V(1, 1)),( V2(1),V(1, 2)),( V3(1),V(1, 3)),
  ( V4(1),V(1, 4)),( V5(1),V(1, 5)),( V6(1),V(1, 6)),
  ( V7(1),V(1, 7)),( V8(1),V(1, 8)),( V9(1),V(1, 9)),
  ( V10(1),V(1,10)),( V11(1),V(1,11)),( V12(1),V(1,12)),
  ( V13(1),V(1,13)),( V14(1),V(1,14)),( V15(1),V(1,15))
DATA TITLE1,TITLE2/16*10H /
DATA TITLE,LABEL/52*10H /
DATA FTN4/6C76.11549/*GM/1.4076576E16/*XKG/.45359/*XKM/1.852/
DATA NOIM/10/
NAMELIST /INPUTO/IRAD,IOPT,WEIGHT,ALTMIN,ALTMAX,DELALT,
  WTMN,WTMAX,DELWT,REARTH,APOGEE,PERIGE,R1,R2,
  R3,R4,R5,R6,R7,R8,R9,R10,R11,R12,R13,R14,R15,
  V1,V2,V3,V4,V5,V6,V7,V8,V9,V10,V11,V12,V13,
  V14,V15,LPLOT,IPRNT,IPLOT,XINC,KASE,FACT

INITIALIZE DEFAULTS
APOGEE=0.
FACT=1.
IOPT=1
IPLOT=0
IPRNT=1
IRAD=1
KASE=1
LPLT=0
PEPTGE=0.
* EARTH=26925741.
XINC=10C.

C

READ INPUT DATA
10 CONTINUE
CALL INPUT
READ( 9,INPUTD)
C  UNIT 1 USED FOR SEMI-LOG PLOT
C  UNIT 2 USED FOR SEMI-LOG PLOT
C  UNIT 3 USED FOR LINEAR PLOT
REWIND 1
REWIND 2
REWIND 3
C

Determine number of payload weights
DO 20 I=1,15
IF (WEIGHT(I).EQ.0.) GOTO 30
NWT=I
20 CONTINUE
30 CONTINUE
C

Determine number of data points per payload
DO 60 I=1,NWT
DO 40 J=1,NOIM
IF (R(J,I).EQ.0.) GOTO 50
40 CONTINUE
NC(I)=J
GOTO 60
50 NC(I)=J-1
60 CONTINUE
IPAGE=1
C

Convert appropriate input to English if metric
GOTO (70,80,90,100), IOPT
70 CONTINUE
HMIn=ALTMIN
HMAX=ALTMAX
DH=DEALT
WMIn=WTMIN
WMAX=WTMAX
DW=DELWT
HMAX=1.E6
GOTO 110
80 CONTINUE
HMIn=ALTMIN/XKm
HMAX=ALTMAX/XKm
DH=DEALT/XKm
WMIn=WTMIN/XKg
WMAX=WTMAX/XKg
DW=DELWT/XKg
HMAX=1.E6/XKm
GOTO 110
90 CONTINUE

- 83 -
HA=APOGEE
HP=PERIGE
GOTO 110

110 CONTINUE
HA=APOGEE/XKM
HP=PERIGE/XKM
GOTO 110

CONVERT INPUT ALTITUDES OR RADIiS TO ALTITUDE, NM
GOTO (120,150,180), IRAD

120 CONTINUE
DO 140 I=1,NWT
   DO 130 J=1,NDIM
      H(J,I)=R(J,I)/FTNM-RE
      IF (R(J,I).EQ.R) H(J,I)=0.
   130 CONTINUE
140 CONTINUE
GOTO 210

150 CONTINUE
DO 170 I=1,NWT
   DO 160 J=1,NDIM
      H(J,I)=R(J,I)-RE
      IF (R(J,I).EQ.R) H(J,I)=0.
   160 CONTINUE
170 CONTINUE
GOTO 210

180 CONTINUE
DO 200 I=1,NWT
   DO 190 J=1,NDIM
      H(J,I)=R(J,I)
   190 CONTINUE
200 CONTINUE

210 CONTINUE
DO 230 I=1,NWT
   IF (I.EQ.1 .OR. I.EQ.7 .OR. I.EQ.13) WRITE (6,400)
      WRITE (6,420) WEIGHT(i)
      WRITE (6,410) (H(J,I),J=1,NDIM)
      WRITE (6,430)
      WRITE (6,440) (V(J,I),J=1,NDIM)
   DO 220 J=1,NDIM
      WRITE (3) H(J,I),V(J,I)
   220 CONTINUE
230 CONTINUE
   IF (IPLTNE.O) CALL PLOTLR(TITLE1,TITLE2,REARTH)
   IF (IOPT.GE.3) GOTO 370

C
CALCULATE NUMBER OF PERIGEE ALTITUDES
NH=INT((HMAX-HMIN)/DH+1.5)
NH=MIN(NH,50)

C
CALCULATE VELOCITY FOR EACH PERIGEE AND PAYLOAD LINE
HNEW=HMIN
DO 250 K=1,NH
   HH(K)=HNEW
   DO 240 I=1,NWT
CALL INTER(HNEW,VEL,NC(I),V(I),H(I))
VV(I,K)=VEL
WW(I,K)=WEIGHT(I)

CONTINUE
HNEW=HNEW+DW

CONTINUE

C CALCULATE ORBIT DATA AT EACH PERIGEE
DO 330 K=1,NH
NREC=C
HMET=HH(K)*XKM
WRITE (6,450) TITLE1,TITLE2,KASE,IPAGE
WRITE (6,460) H(H(K),HMET
WRITE (6,470)
WRITE (6,480) (WW(I,K),VV(I,K),I=1,NWT)
WRITE (6,490)
HF=HH(K)
RF=(HF+RE)*FTNM

C REVERSE ORDER OF VELOCITY AND WEIGHT ARRAYS
J=NWT
DO 260 I=1,NWT
VI(I)=VV(J,K)
WI(I)=WW(J,K)
J=J-1

CONTINUE

C CALCULATE PAYLOAD AT 1E6 APOGEE ALTITUDE
A=((HAMAX+RE)*FTNM+RF)/2.
VMAX=SORT(GM*(2./RF-1./A))
CALL INTER(VMAX,PL,NWT,VI,VI)
IF (PL.LT.WMIN) GOTO 270
NREC=NREC+1
WRITE (1) PL,HAMAX
CONTINUE

C CALCULATE NUMBER OF PAYLOAD WEIGHTS
NW=INT((WMAX-WMIN)/DW+1.5)

C CALCULATE ORBIT DATA AT PAYLOAD INCREMENT
WNEW=WMIN
DO 300 I=1,NNW
CALL INTER(WNEW,VEL,NWT,VV(I,K),WW(I,K))
IF (VEL.GT.VMAX) GOTO 290
HA=(2./(2./RF-VEL**2/GM)-RF)/FTNM-RE
IF (HA.LT.HF) GOTO 310
IF (MOD(I-1,IPRNT).NE.0) GOTO 280
PLM=WNEW*XKG
HAMET=HA*XKM
WRITE (6,500) HF,WNEW,HA,VEL,PLM,HAMET
CONTINUE
IF (LPLOT.EQ.0) GOTO 290
IF (HA.GT.HAMAX) GOTO 290
WRITE (1) WNEW,HA
NREC=NREC+1

CONTINUE
WNEW=WNEW+DW

- 85 -
CONTINUE

CALCULATE CIRCULAR AND ESCAPE PAYLOAD AT PERIGEE ALTITUDE
VELC=SQRT(GM/RF)
CALL INTER(VELC,WTC,NWT,VI,VI)
WTC=WTET=WTC*TKG
VEL=SQRT(2.*VELC)
CALL INTER(VEL,WTE,NWT,VI,VI)
WTE=WTET=WTE*TKG
WRITE (6,510) WTC,WTCET,VELC,WTE,WTEET,VEL
IPAGF=IPAGE+1
IF (LPLT.EQ.0) GOTO 390
IF (WTC.GT.WMAX) GOTO 320
WRITE (1) WTC,HF
NREC=NREC+1
CONTINUE

WRITE (2) NREC
CONTINUE
IF (LPLT.EQ.0) GOTO 390

CALCULATE CIRCULAR ORBIT LINE
HP=HMIN
HA=HMIN
NREC=0
CONTINUE
J=NWT
DO 350 I=1,NWT
CALL INTER(HP,VEL,NC(I),V(1,I),H(1,I))
VI(J)=VEL
WI(J)=WEIGHT(I)
J=J+1
CONTINUE
RBAR=(HP+RE)*FTNM
A=(2.*RE+HP+HA)/2.*FTNM
VEL=SQRT(GM*(2.*RBAR-1./A))
CALL INTER(VEL,PL,NWT,VI,VI)
IF (PL.LE.WMIN .OR. PL.GT.WMAX) GOTO 360
NREC=NREC+1
WRITE (1) PL,HA
CONTINUE
HA=HA+DH/10.
HP=HA
IF (HP.LE.HMAX) GOTO 340
WRITE (2) NREC
CALL PLOTLG (ILOPT,XINC,ALTMIN,DELALT,NH,1,44,4HPLOT)
CALL PLOTLG (ILOPT,XINC,ALTMIN,DELALT,NH,FACT,36,4HPLT3)
GOTO 390

CALCULATE SINGLE ORBIT
CONTINUE
J=NWT
DO 350 I=1,NWT
CALL INTER(HP,VEL,NC(I),V(1,I),H(1,I))
VI(J)=VEL
WI(J)=WEIGHT(I)
J = J - 1
380 CONTINUE
R = R*(HP + RE)*FNM
A = (2.0*RE + HP + HA)/2.*FNM
VEL = SQRT((2./PBAR - 1./A))
CALL INTER(VEL, PL, NWT, WI, VI)
HPMET = HP*XKM
HAMET = HA*XKM
PLM = PL*XKG
WRITE (6, 450) TITLE1, TITLE2, KASE, IPAGE
WRITE (6, 460) HP, HPMET
WRITE (6, 490)
WRITE (6, 500) HP, PL, HA, VEL, PLM, HAMET

C 390 CONTINUE
KASE = KASE + 1
GOTO 10

C 400 FORMAT (1H1)
410 FORMAT ((15X,5(F10.3)))
420 FORMAT (/,,15X,WEIGHT(LBS.)=*,F8.1/15X,ALTITUDE(N.MI.)*)
430 FORMAT (15X,VELOCITY(FPS*))
440 FORMAT ((15X,5(F10.1)))
450 FORMAT (*1*, 8X,8A10, T68,*VOUGHT CORPORATION*/,
       ^ 9X,8A10, T73,**PROGRAM ELOPE*/,
       ^ T68,*CASE **,I2,
       ^ T79, *PAGE **,I2//)
460 FORMAT (25X,*PERIGEE ALT.==*,F6.1,* N.MI. ==*,F6.1,* KM/**)
470 FORMAT (15X,*INTERPOLATION DATA (CHECK FOR ACCURACY)*/,
       ^ 13X,*PAYLOAD*,6X,*INJECTION*/,
       ^ 13X,*WT.,LBS*,7X,*VEL.,FPS*/)
480 FORMAT (5X,2F15.1)
490 FORMAT (/,,13X,*PERIGEE*,9X,*PAYLOAD*,8X,*APOGEE*,8X,*PERIGEE*,
       ^ 3X,*PAYLOAD*,4X,*APOGEE*/,
       ^ 13X,*ALT.*N.MI.*,6X,*WT.*LBS*,6X,*ALT.*N.MI.*,,
       ^ 5X,*VEL.*FPS*,4X,*WT.*KG*,3X,*ALT.*KM/**)
500 FORMAT (5X,4F15.1,2F10.1)
510 FORMAT (/,,13X,*CIRCULAR PAYLOAD==*,F6.1,* LBS==*,F6.1,* KG*,
       ^ 5X,*CIRCULAR VEL.*==*,F8.1,* FPS*/
       ^ 13X,*ESCAPE PAYLOAD ==*,F6.1,* LBS==*,F6.1,* KG*,
       ^ 5X,*ESCAPE VEL.* ==*,F8.1,* FPS*))
END
SUBROUTINE INPUT

THIS SUBROUTINE READS MODIFIED NAMELIST FORMATTED DATA.
IT READS A CARD ON UNIT 5, WRITES THE CARD ON UNIT 6,
WRITES THE CARD ON UNIT 3 (FIRST 72 CHARACTERS ONLY).
THE TITLE CARDS AS DEFINED IN THE DATA STATEMENT BELOW
ARE NOT WRITTEN ON UNIT 6 BUT THE DATA IS PLACED IN
THE APPROPRIATE ARRAYS FOR TRANSFER BACK TO THE CALLING
PROGRAM. THE TITLE CARDS MUST BEGIN IN COLUMN 2 WITH
NO SPACES. THE CALLING PROGRAM MUST BLANK THE TITLE
ARRAYS, CALL INPUT AND READ(8, INPUTD). NAMELIST DATA
MUST BEGIN WITH $INPUTD AND END WITH $END, BOTH
BEGINNING IN COLUMN 2.

IMPLICIT INTEGER (A-Z)
COMMON /9L1/ TITLE(6P)
DIMENSION CARD(8), LINE(15)
DATA LINE/1OH TITLE1 ,10H TITLE2 ,10H TITLE1 ,10H PTITLE 2
^,10H PTITLE3 ,10H PTITLE4 ,10H PLABEL 1 ,10H PLABEL2
^,10H PLABEL3 ,10H PLABEL4 ,10H PLABEL5 ,10H PLABEL6
^,10H PLABEL7 ,10H PLABEL8 ,10H PLABEL9 /
DATA BLANK/1OH /

REWIND 8
WRITE (6,70)
10 CONTINUE
READ (5,11C) CARD
IF (EOF(5).NE.0) STOP
WRITE (6,9C) CARD
BLANK COLUMNS 9 AND 10
ENCODE (10,8G,WORD) CARD(1), BLANK
DO 30 I=1,15
IF (WORD.NE.LINE(I)) GOTO 30
CARD READ IS A TITLE CARD
IF (I.EQ.1) J=1
IF (I.EQ.2) J=9
IF (I.GE.3) GOTO 20
ENCODE(72,60,TITLE(J))CARD
GOTO 10
20 CONTINUE
J=17+4*(I-3)
ENCODE(30,50,TITLE(J)) CARD(1), CARD(2), CARD(3), CARD(4)
GOTO 10
30 CONTINUE
BLANK COLUMNS 73-80 OF DATA CARD
ENCODE (1G,1CJ,CARD(8)) CARD(8), BLANK
WRITE (8,110) CARD
IF (CARD(1).NE.10H $END ) GOTO 10
REWIND 8
CALL DATE(DAT)
CALL TIME(TIM)
WRITE (6,40) DAT,TIM
RETURN
C
42 FORMAT ('///', 'DATE IS *A9/ ', 'TIME IS *A9')
50 FORMAT ('R1', 'A10', 'A10', 'A9')
61 FORMAT ('32', '7A15')
71 FORMAT ('1H_')
80 FORMAT ('AP', 'A2')
90 FORMAT ('10X', '8A10')
100 FORMAT ('A2', 'A8')
110 FORMAT ('8A1C')
END
SUBROUTINE INTER (X, Y, NUM, B, A)
C
SECOND ORDER INTERPOLATOR
C
SELECT FOUR DATA POINTS CLOSEST TO X TO INTERPOLATE FOR Y.
C
X=INDEPENDENT VARIABLE VALUE
C
Y=RESULTING DEPENDENT VARIABLE VALUE
C
LMT=NO. OF ELEMENTS IN A AND B
C
B=ARRAY OF DEPENDENT VARIABLES
C
A=ARRAY OF INDEPENDENT VARIABLES
C
DIMENSION A(15), B(15)
C
I=1
IF (NUM.EQ.4) GOTO 30
IF (NUM.LT.4) WRITE (6, 40) NUM
IF (NUM.LT.4) STOP
C
IF (X.LT.A(3)) I=1
IF (X.GT.A(NUM-2)) I=NUM-3
IF (X.LT.A(3) .OR. X.GT.A(NUM-2)) GOTO 30
C
LMT=NUM-2
DO 10 K=4, LMT
     IF (X.LT.A(K)) GOTO 20
10 CONTINUE
20 CONTINUE
I=K-2
C
30 CONTINUE
X0=A(I)
X1=A(I+1)
X2=A(I+2)
X3=A(I+3)
Y11=((X1-X)*B(I)-(X0-X)*B(I+1))/(X1-X0)
Y21=((X2-X)*B(I)-(X3-X)*B(I+2))/(X2-X0)
Y31=((X3-X)*B(I)-(X0-X)*B(I+3))/(X3-X0)
Y22=((X2-X)*Y11-(X1-X)*Y21)/(X2-X1)
Y32=((X3-X)*Y11-(X1-X)*Y31)/(X3-X1)
Y=((X3-X)*Y22-(X2-X)*Y32)/(X3-X2)
RETURN
C
40 FORMAT (/1CX, *SUBROUTINE INTER - VALUES IN INTERPOLATION TABLE =*
^     I3* MUST BE .GE. 4*)
END
SUBROUTINE PLOTLC (IOPT, XINC, WMIN, DH, NUMH, FACT, ICAL, PFILE)

THIS SUBROUTINE GENERATES A SEMI-LOG PLOT OF APOGEE
ALTITUDE AS A FUNCTION OF PERIGEE ALTITUDE AND
PAYLOAD WEIGHT.

******************** INPUT DATA *****************************

DH = PERIGEE ALTITUDE INCREMENT
FACT = FACTOR FOR RELATIVE SIZE OF PLOT PRODUCED.
WMIN = MINIMUM PERIGEE ALTITUDE
ICAL = TWO DIGIT CALCODE.
IC = 1 IF ENGLISH UNITS
     = 2 IF METRIC UNITS
NUMH = NUMBER OF PERIGEE ALTITUDES
PFILE = LOCAL FILE NAME OF PLOT FILE.
XINC = ABSCISSA MAJOR DIVISION INCREMENT

IMPLICIT REAL(A-H,O-S,U-Z),
INTEGER(I-N,T)
COMMON /BLK/I,TITLE1(8),TITLE2(8),TITLE(16),LABEL(36)
DIMENSION X(100), Y(100)
DIMENSION A(5), LABELY(20)
DATA LABELY/10H100, 10H200, 10H400, 10H800, 10H1600,
      10H3200, 10H6400, 10H12800, 10H256000,
      10H512000, 10H1024000, 10H2048000,
      10H4096000, 10H8192000, 10H16384000,
      10H32768000, 10H65536000,
      10H131072000, 10H262144000, 10H524288000,
      10H1048576000, 10H2097152000,
      10H4194304000, 10H8388608000,
      10H16777216000, 10H33554432000,
      10H67108864000, 10H134217728000,
      10H268435456000, 10H536870912000/}

DATA XKG/0.45359/,XKM/1.852/}

ICAL=5
CALL PLOTS (ICAL, O, PFILE)
CALL FACTOR(FACT)
REIND 1
REIND 2
NCYCLE=4
A(1)=0.
A(2)=-ALOG10(2.)
A(3)=-ALOG10(4.)
A(4)=-ALOG10(6.)
XINT=0.

OPAW TICK MARKS ON Y AXIS AND ANNATE
DO 20 J=1,NCYCLE
  DO 10 I=1,5
    Y1=(FLOAT(J-1)+A(I))*2.5
    CALL PLOT (G., Y1, 3)
    CALL PLOT (-.05, Y1, 2)
    X1=-.1*(3.*FLOAT(J))
    Y1=Y1-.05
    IBCD=LABELY(5*J-5+I)
    NCHAR=2+J
    CALL SYMBOL (X1, Y1, 1, IBCD, G., NCHAR)
10  CONTINUE


CONTINUE
Y1=FLOAT(NCYCLE)+A(1))*2.5
CALL PLOT (C*,Y1,3)
CALL PLOT (-.05,Y1,2)
Y1=-1*(3.+FLOAT(NCYCLE+1))
Y1=Y1-.05
CALL SYMBOL (X1,Y1,.1,7H100GCC,0.,+7)

DRAW TICK MARKS ON X AXIS AND ANNOTATE
DO 3 J=1,N
X1=FLOAT(J-1)
CALL PLOT (X1,C*,3)
CALL PLOT (X1,-.15,2)
X1=X1-.15
FPN=XINT+(J-1)*XNC
CALL NUMBER(X1,-.2,.1,FPN,0.,-1)

CONTINUE

LABEL X AND Y AXIS
IF (IOPT.EQ.1)
  CALL SYMBOL(-.64,2.45,.1,21HAPOGEE ALTITUDE-N.MI.,90.,+23)
IF (IOPT.EQ.1)
  CALL SYMBOL(2.3,-.35,1,21HPAYLOAD WEIGHT-POUNDS,0.,+23)
IF (IOPT.EQ.2)
  CALL SYMBOL(-.64,2.45,.1,18HAPOGEE ALTITUDE-KM,90.,+20)
IF (IOPT.EQ.2)
  CALL SYMBOL(2.3,-.35,1,24HPAYLOAD WEIGHT-KILOGRAMS,0.,+23)

WRITE 4 LINES OF TITLE AND 9 LINES OF LABEL
K=1
X1=7.*/2.-8.*.14
Y1=10.-*1.14
DO 40 I=1,4
  CALL SYMBOL (X1,Y1,.14,TITLE(K),0.,30)
  Y1=Y1-.14-.035
  K=K+4

CONTINUE

K=1
Y1=7.-.10*30.5
Y1=8.5
DO 50 I=1,9
  CALL SYMBOL (X1,Y1,.10,LABEL(K),0.,30)
  Y1=Y1-.10-.035
  K=K+4

CONTINUE

FILL ARRAYS FOR PLOTTING
CONTINUE
READ(2) NREC
IF (EOF(2).NE.O) GOTO 80
DO 70 I=1,NREC
  READ(1) WT,HA
  IF (IOPT.EQ.1) X(I)=WT
  IF (IOPT.EQ.1) Y(I)=ALOG10(HA)-2.
  IF (IOPT.EQ.2) X(I)=WT*XKG
  IF (IOPT.EQ.2) Y(I)=ALOG10(4A*XKM)-2.
CONTINUE
DEFINE SCALE FACTORS
X(NREC+1)=XINT
X(NREC+2)=XINC
Y(NREC+1)=6.
Y(NREC+2)=1./2.5

DRAW CURVE
CALL LINE (X,Y,NREC,1,0,0)
GOTO 60

80 CONTINUE

WRITE ADDITIONAL LABELS IN RIGHT BORDER OF PLOT
X1=F.
Y1=6.
HGT=5.35
IF (IOPT.EQ.1)
  CALL SYMBOL (X1,Y1,HGT,24HPERIGEE ALTITUDE - NM,0.,0.,+24)
IF (IPT.EQ.2)
  CALL SYMBOL (X1,Y1,HGT,21HPERIGEE ALTITUDE - KM,0.,+21)
DO 90 I=1,NUMH
  Y1=Y1-HGT-.35
  FPN=HMIN+DH*(I-1)
  CALL NUMBER(X1,Y1,HGT,FPN,0.,-1)
90 CONTINUE
Y1=Y1-.2
CALL SYMBOL (X1,Y1,HGT,15HCIRCULAR ORBITS,0.,+15)
CALL PLOT (12.,0.,999)
RETURN
END
SUBROUTINE PLOTLP(TITLE1,TITLE2,REARTH)
C THIS SUBROUTINE GENERATES A LINEAR PLOT OF PERIGEE ALTITUDE
C AS A FUNCTION OF VELOCITY AND PAYLOAD WEIGHT.
C IMPLICIT REAL(A-H,O-S,V-Z),
C INTEGER(I-N,T)
C DIMENSION TITLE1(8), TITLE2(8)
C DIMENSION X(152), Y(152), Z(150)
C DATA CM/2.54/, CM/1.4076576E16/
C CALL PLOTS(E=CAL32,0,4HPLT2)
C REWIND 3
C ANNOTATE X-AXIS
C NCHAR=5
NO 1 J=1,20
X1=FLOAT(J-1)*2./CM
CALL PLOT(X1,0.,3)
CALL PLOT(X1,-.05,2)
X1=X1+.1*NCHAR/2.
FPN=180.0C.+160C.*(J-1)
CALL NUMBER(X1,-.2,.1,FPN,0.,-1)
10 CONTINUE
CALL SYMBOL(.5,.35,.1,23HINJECTION VELOCITY, FPS,0.,23)
C ANNOTATE Y-AXIS
C NCHAR=4
DO 20 J=1,13
Y1=FLOAT(J-1)*2./CM
CALL PLOT(0.,Y1,3)
CALL PLOT(-.05,Y1,2)
Y1=Y1-.05
X1=-.05-.1*NCHAR
FPN=3.*160C.*(J-1)
CALL NUMBER(X1,Y1,.1,FPN,0.,-1)
20 CONTINUE
CALL SYMBOL(-.6,2.5,.1,22HINJECTION ALTITUDE, NM,90.,22)
C WRITE TITLES
X1=8.,14*46.
Y1=10.,.07
CALL SYMBOL(X1,Y1,.14, TITLE1,G.,80)
Y1=Y1-.21
CALL SYMBOL(X1,Y1,.14, TITLE2,0.,80)
C DRAW CIRCULAR AND ESCAPE VELOCITY LINES
H=100.
I=1
30 CONTINUE
X(I)=H
Y(I)=SORT(GM/(X(I)*6.076.11549+REARTH))
Z(I)=SQRT(Y(I))
IF (H.EQ.120C.) GOTO 40
I=I+1
H=H+.20.
GOTO 30

40 CONTINUE
  Y(I+1)=0.
  X(I+2)=150./2.*CM
  Y(I+1)=1800G.
  Y(I+2)=1600G./2.*CM
  Z(I+1)=1800G.
  Z(I+2)=163G./2.*CM
  CALL LINE(Y,X,I,1,0,0)
  CALL LINE(Z,X,I,1,0,0)
  RETURN

C PLOT DATA
I=1
50 CONTINUE
  READ(3) Y(I),X(I)
  IF (ENDF(3),NE.,0.0) GOTO 60
  IF (Y(I) .LT. 0.0 .OR. Y(I) .GT. 1200.0 .OR.
   X(I) .LT. 1800.0 .OR. X(I) .GT. 3760.0) GOTO 50
  CONTINUE
  I=I+1
  GOTO 50
60 CONTINUE
I=I-1
  Y(I+1)=0.
  X(I+2)=100./2.*CM
  X(I+1)=18000.
  X(I+2)=1600G./2.*CM
  CALL LINE(X,Y,I,1,-1,1)
  CALL PLOT(17.,0.,999)
  RETURN
END
APPENDIX C

SCIENTIFIC DATA PROCESSING ROUTINE
SUMMARY DOCUMENTATION

IDENTIFICATION

Title  Elliptical Orbit Performance

Routine No. 7031 Date Filed March 72 Security Class: U

Responsible Engineer T. R. Myler

Date Completed March 1972 Source FORTRAN Other

Language: IV

Key Words Orbit parameters, interpolation, CalComp plot

RESOURCE REQUIREMENTS

Typical CPU 5 sec Machine(s) CDC CYBER 175 No. Source Cards 710

Core 60k (octal) Tape none Plot yes Graphics none

DESCRIPTION

Purpose: To calculate elliptical orbit altitudes as a function of payload weight and generate a CalComp plot.

Input: Parametric data of insertion velocity as a function of insertion altitude and payload weight. Also selectors on desired plot.

Output: A table of apogee altitude and payload weight for each perigee altitude selected. Also the payload weight at the circular and escape condition. All data output in both English and metric units. CalComp plot.

Functional Description: Uses a 2-body orbit equation for orbit determination and a second order curve fit to interpolate for velocity and payload weight.

DOCUMENTATION

This report describes and presents a FORTRAN coded computer program which generates and plots elliptical orbit performance capability of space boosters for presentation purposes.

Orbital performance capability of space boosters is typically presented as payload weight as a function of perigee and apogee altitudes.

The parameters are derived from a parametric computer simulation of the booster flight which yields the payload weight as a function of velocity and altitude at insertion (i.e., flight path angle = 0 deg.). The process of converting from velocity and altitude to apogee and perigee altitude and plotting the results as a function of payload weight has been mechanized with the ELOPE program. Included in this report are the program theory, user instruction, input/output definitions, subroutine descriptions and detailed FORTRAN coding information.

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