AD 779 528

TECHNICAL REPORT
74-9-AD (II)

DEVELOPMENT OF A TOTAL TRAJECTORY SIMULATION FOR SINGLE RECOVERY PARACHUTE SYSTEMS

Volume II: Calculation Procedures and Computer Program

by

Robert A. Noreen

and

David P. Saari

University of Minnesota

Minneapolis, Minnesota USA

Project reference: 1F162203AA33

Approved for public release; distribution unlimited.

December 1973

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

U.S. ARMY TROOP SUPPORT COMMAND

Airdrop Engineering Laboratory

Distribution of this
document is unlimited

AD________________

TECHNICAL REPORT

74-9-AD (II)

DEVELOPMENT OF A TOTAL TRAJECTORY SIMULATION FOR SINGLE RECOVERY PARACHUTE SYSTEMS

VOLUME II: Calculation Procedures and Computer Program

by

Robert A. Noreen
David P. Saari

University of Minnesota
Minneapolis, Minnesota USA

Contract No. DAAG17-72-C-0030

Project reference:
1F162203AA33

December 1973

Airdrop Engineering Laboratory
U. S. Army Natick Laboratories
Natick, Massachusetts 01760

ERRATA

Technical Report 74-9-AD

Development of a Total Trajectory Simulation for Single Recovery Parachute Systems, Volume II: Calculation Procedures and Computer Program by Robert A. Noreen and David P. Saari, December 1973.

(1) On page 22, Equation (4)

$$\Delta V = \frac{\rho V^2 C_D S_T}{2 m_{rs}} \Delta t \quad \text{should be} \quad \Delta V = -\frac{\rho V^2 C_D S_T}{2 m_{rs}} \Delta t$$

(2) On page 35, in Euqation 47

$$+\frac{V}{m_T} (\Delta m_i + \Delta m_a)$$ term should be

$$-\frac{V}{m_T} (\Delta m_i + \Delta m_a)$$

FOREWORD

This work was performed under US Army Natick Laboratories Contract No. DAAG17-72-C-0030 during the period 15 November 1971 and 30 June 1973. The project number was 1F162203AA33 and the task number was 04 entitled "Study of Dynamic Stability Characteristics of Parachute-Load System". Mr. Edward J. Giebutowski served as Project Officer.

The objective of the effort was to produce a computerized trajectory simulation which would describe the motion of a single parachute and its cargo from the time of release from the aircraft to the time of impact.

This report is intended to serve as a user manual for the computer program developed in Volume I. It includes flow charts for the major routines, a listing of computer mnemonics and a program listing. Sample output for some trial cases is also included.

CONTENTS

Page

ILLUSTRATIONS

TABLES

TABLES (CONT.)

SYMBOLS

$\underline{a}$	acceleration
a_{ij}	component of the matrix $\underline{\underline{A}}$, i^{th} row, j^{th} column, Eqns (149) through (157)
A	inverse of effective spring constant of suspension system, Eqn (10)
$\underline{\underline{A}}$	direction cosine matrix
B	Eqn (11)
c	effective porosity
C	Eqn (12)
C_{D_o}	drag coefficient of parachute based on nominal area
C_{D_p}	drag coefficient of parachute based on projected area
C_DS	drag area
C_{N_o}	aerodynamic normal force coefficient of parachute
C_{M_o}	aerodynamic moment coefficient of parachute
C_{T_o}	aerodynamic tangent force coefficient of parachute
d	canopy inlet diameter
D	aerodynamic drag
D_o	nominal diameter of parachute
D_p	instantaneous projected diameter of parachute
D_{Pmax}	projected diameter of fully inflated parachute
$\underline{F}$	Force
$\underline{F}_a$	force due to included and apparent mass
F_A	aerodynamic force (during snatch)
E_p	allowable relative error in integration

F_{max}	opening shock
$\underline{F}_N$	aerodynamic normal force
F_{ϕ}	instantaneous opening force
g	gravitational acceleration
h	altitude; D_p/D_o
$\underline{\underline{I}}$	inertia tensor of parachute-load system about its mass center
k	spring constant of suspension system
ℓ	distance between load and secondary body or load and aircraft during deployment
ℓ_1	distance from parachute-load system center of mass to load
ℓ_2	distance from parachute-load system center of mass to parachute center of volume
ℓ_3	distance from parachute-load system center of mass to parachute moment center
ℓ_R	reefing line length
L	distance load travels in aircraft; X-component of $\underline{M}$, body fixed
L_{Br}	length of load bridle in Z-direction
L_E	length of riser extension
L_R	length of suspension lines
L_S	length of suspension lines
L_{static}	length of static line
m	mass
m_a	apparent mass of parachute
m_{Br}	mass of load bridle
m_E	mass of riser extensions

m_i — mass of included air in parachute canopy

m_{L_s} — mass of suspension lines

m_{pb} — mass of pilot or extraction parachute and main parachute deployment bag

m_{rs} — total mass of load and packed recovery system

m_R — mass of risers

m_{ss} — mass of suspension lines, risers, extensions, bridle and links

m_T — total mass = $m_\ell + m_{ss} + m_p + m_i + m_a$

m_I — mass of primary body during deployment of the suspension system = $m_\ell + \frac{1}{2} m_{ss}$

$\underline{M}$ — moment acting on parachute-load system

M — Y-component of $\underline{M}$, body fixed

$\underline{M}_A$ — aerodynamic moment due to parachute

M_I — mass of primary body at snatch = $m_\ell + m_{ss}$

M_{II} — mass of secondary body during deployment of the suspension system = $m_p + \frac{1}{2} m_{ss} + m_{pb}$

N — Z-component of $\underline{M}$, body fixed

P — X-component of $\underline{\omega}$, body fixed

P_{max} — maximum snatch force

Q — Y-component of $\underline{\omega}$, body fixed; mass ratio, Eqn (15)

$\underline{r}$ — position vector

R — reefing ratio; Z-component of $\underline{\omega}$, body fixed

$\overline{s}$ — reference distance from canopy skirt to parachute-load system center of mass in fully inflated configuration

s_1 — reference distance from canopy skirt to suspension line center of mass in fully inflated configuration

s_2	reference distance from canopy skirt to riser center of mass in fully inflated configuration
s_3	reference distance from canopy skirt to riser extension center of mass in fully inflated configuration
s_4	reference distance from canopy skirt to load bridle center of mass in fully inflated configuration
s_5	reference distance from canopy skirt to load center of mass in fully inflated configuration
s_c	reference distance from canopy skirt to parachute center of volume in fully inflated configuration
S_o	nominal area
t	time
t_{CD}	reefing cutter delay time
t_D	time at which extraction or pilot parachute is released or main parachute is disreefed to initiate inflation
t_{ff}	final filling time; measured from end of bag strip to first attainment of hemispherical canopy volume
t_{f_R}	filling time for reefed inflation period
T	dimensionless time scale; aerodynamic tangent force of parachute
t_{RCA}	time at which reefing cutters are armed
T_R	dimensionless time scale for reefed inflation periods
U	X-component of $\underline{v}$, body fixed
$\underline{v}$	general velocity; velocity of parachute-load system mass center
v	general velocity; magnitude of velocity of parachute-load system center of mass
v_s	snatch velocity, Eqn (16)
V	volume; Y-component of $\underline{v}$, body fixed
W	Z-component of $\underline{v}$, body fixed; weight

x — space-fixed coordinate direction; position of parachute-load system center of mass

X — body-fixed coordinate

y — space-fixed coordinate direction; position of parachute-load system center of mass

Y — body-fixed coordinate

z — space-fixed coordinate direction; position of parachute-load system center of mass

Z — body-fixed coordinate

α — angle of attack in XZ-plane

α_t — trajectory angle

β — angle of attack in YZ-plane

γ — angle between velocity and XZ-plane

δ — angle between velocity and YZ-plane

η — allowable absolute error in integration

θ — Euler angle, system angle for problems constrained to three degrees of freedom

θ_p — angle between parachute velocity and systems axis

ν — integrand in Eqn (30)

ρ — air density

ρ_o — sea level air density

σ — air density ratio = ρ/ρ_o

$\underline{\omega}$ — angular velocity of parachute-load system

φ — Euler angle

ψ — Euler angle

Subscripts

a	apparent
B	main parachute deployment bag
ex	extraction parachute(s)
i	included
ℓ	load
o	nominal, initial
p	parachute
R	referring to inflation of the main parachute with reefing
T	value required for instantaneous trajectory calculation
x	component in space-fixed x coordinate direction
X	component in body-fixed X coordinate direction
y	component in space-fixed y coordinate direction
Y	component in body-fixed Y coordinate direction
z	component in space-fixed z coordinate direction
Z	component in body-fixed Z coordinate direction
1	referring to end of reefed inflation stage
I	primary body
II	secondary body
—	indicates vector quantity
=	indicates matrix or tensor quantity

ABSTRACT

A method of total trajectory simulation was established which is based on the governing equations of the various phases of an airdrop or recovery system. In view of these equations, a computer program capable of predicting the performance characteristics of a parachute-load system from the instant of initiation to the moment of landing was established. Calculations were performed for a number of different aerial delivery systems. The calculated results fall well within the broad ranges of expected performance, based upon a familiarity with field test results.

In Volume I simulation methods and numerical calculation results are presented; in Volume II details of the calculation procedures and computer program are presented. The system is ready to be used for overall prediction of parachute performance characteristics and an intensive comparison of calculated and recorded field test results is highly desirable for validation and improvement of the technique of total trajectory simulation.

I. INTRODUCTION

In this study mechanical and mathematical models have been selected to provide a total trajectory simulation for four parachute separation-deployment systems. In Volume I of this report these simulation methods are presented, and in this volume, Volume II, the calculation procedures for obtaining numerical results are shown.

The calculations were made using a Fortran IV computer program and a Control Data Corporation 6600 computer. Thus this volume presents the software documentation required for duplication and use of the computer program, beginning with a general description of the program and progressing to more detailed information. However, the various Sections cannot be considered independent; referring to later sections of the report may add to the understanding of the early sections.

The compile time with the standard Fortran compiler is approximately 5.6 seconds for the three degree of freedom solution and 7.1 seconds for the solution allowing six degrees of freedom for the free descent phase. The running time for the various trajectory calculations averaged about 7 to 8 seconds, ranging from 3 to 4 seconds for low altitude simulations to about 13 seconds for high altitude simulations.

II. GENERAL DESCRIPTION

The computer program for the total trajectory simulation can be considered to consist of three calculation phases organized to model four parachute separation-deployment systems. The three calculation phases correspond to the physical processes of an airdrop, and are: 1) separation and deployment, 2) inflation of the main parachute, and 3) free descent with consideration of dynamic characteristics. The first two phases have been limited to two dimensions; for free descent, the user can select two or three dimensional calculations. The program was organized with major subroutines directly related to physical processes so that calculation methods could be easily changed or improved by merely replacing a subroutine.

The user must select inputs that specify the physical characteristics of his parachute-load system and which of the four separation-deployment systems he is modeling. The separation-deployment systems are 1) static line, 2) static line deployed pilot chute, 3) extraction parachute, and 4) reefed main parachute extraction. The user also can have a range of outputs, from a nearly continuous print of trajectory data to only a few results at significant occurrences during the simulation.

A. Basic Program Organization

MAIN PRØGRAM is the first entry to the program; its basic functions are to read most of the input data, print some parameters of interest, sequence the calls to the major subroutines, and then either start the next simulation or terminate the run. Very few calculations are done in MAIN PRØGRAM itself, its major purposes are organization and sequencing.

The first functional call by MAIN PRØGRAM is to Subroutine EXTRACT, which is the first major subroutine that directs calculations for the separation-deployment process. EXTRACT calculates the process of separation from the aircraft for all systems and informs MAIN PRØGRAM whether or not a call to subroutine SNATCH is required. SNATCH is the second major subroutine of the separation-deployment phase, and calls subroutine BØDIES for calculating the separation between primary and secondary bodies of the parachute-load system.

After separation-deployment, MAIN PRØGRAM directs the simulation to the inflation of the main parachute, subroutine ØPENING. ØPENING is primarily an organizational subroutine and calls FILLTIM for a calculation of filling time and CALC for trajectory calculations during inflation.

The last phase is free descent, and since this can be two- or three-dimensional, the appropriate integer inputs as well as the desired subroutine decks must be selected by the user. Since the required aerodynamic force coefficients for three-dimensional calculations have not yet been measured, the majority of calculations will probably be two-dimensional, and thus there is no need to compile the three-dimensional subroutines for every calculation. In both cases subroutine MØTIØN is the major subroutine, and is basically organizational. MØTIØN calls subroutine INTGRAT for integration of the equations of motion. INTGRAT requires subroutine FØRMULA for the integration and subroutine EMØTIØN for numerical evaluation of the equations of motion. EMØTIØN calls subroutine DYNAMIC to evaluate terms in the equations of motion, and subroutine CØEFFTS supplies values of the aerodynamic coefficients to EMØTIØN. Subroutines INTGRAT, FØRMULA, and DYNAMIC are identical for two or three dimensional calculations; the others have the same names in both cases but are different. Subroutine CØSINES is added to evaluate the terms of the direction cosine matrix in three-dimensional calculations.

The subroutines DENSITY and TRAJEQN are called by many of the other subroutines. DENSITY calculates atmospheric density as a function of altitude and TRAJEQN evaluates the two-dimensional, point mass trajectory equations for use until the parachute is fully inflated.

B. Computer Program Outputs

The output from the computer program in all subroutines which include output statements can be divided into three categories: (1) all input data, (2) trajectory variables and other calculated information at points of interest throughout the program, and (3) continuous output of variables describing the calculated trajectory.

The first and second of these groups are always printed. All inputs are immediately printed in the main program or in the particular subroutine in which they are read. The trajectory variables at the following points during the trajectory simulation are printed immediately before exit from the following subroutines:

Subroutine EXTRACT--static line stretch and main parachute canopy unfolded or initiation of main parachute deployment; or load leaves aircraft and initiation of main parachute deployment or inflation,

Subroutine SNATCH--snatch force occurrence,

Subroutine ØPENING--inflation of the main parachute to any reefed stage or to full inflation,

Subroutine MØTIØN--the first three instances when the parachute-load system is vertical or near vertical.

In addition, snatch force, snatch velocity, and primary and secondary body velocities at snatch are printed before exit from SNATCH. The projected diameter corresponding to the prescribed final reefing ratio, time of disreef (if applicable), filling time, and opening shock for each inflation are printed before exit from ØPENING.

The continuous output can be controlled by the program user. The variable NINT may be read into the program as a negative number, which then eliminates all continuous output. If NINT is positive, it represents the number of calculations which are to be made between successive printings of the trajectory variables in subroutines EXTRACT and SNATCH, and to some degree in ØPENING and MØTIØN. During the inflation periods in ØPENING, and if the automatically selected time increment in MØTIØN becomes too large, NINT does not affect the output of trajectory variables if it is greater than zero. The trajectory variables are time, altitude, system angle, position components, total velocity and velocity components, and total acceleration. These variables refer to the mass center of the parachute-load system until the main parachute is fully inflated, and to the load during the free descent phase in MØTIØN.

C. Separation-Deployment Systems

The values of the integer variables ISTATIC and IEXTRAC, and the variable $D_{O_{Pilot}}$ control the selection of one of the four separation-deployment systems as shown in Fig 1. These variables are examined upon entry to EXTRACT, which then directs the simulation to the appropriate calculations. For the static line deployed pilot chute or extraction parachute systems a snatch force calculation is required and EXTRACT sets ISNATCH to -1 which then directs the MAIN PRØGRAM

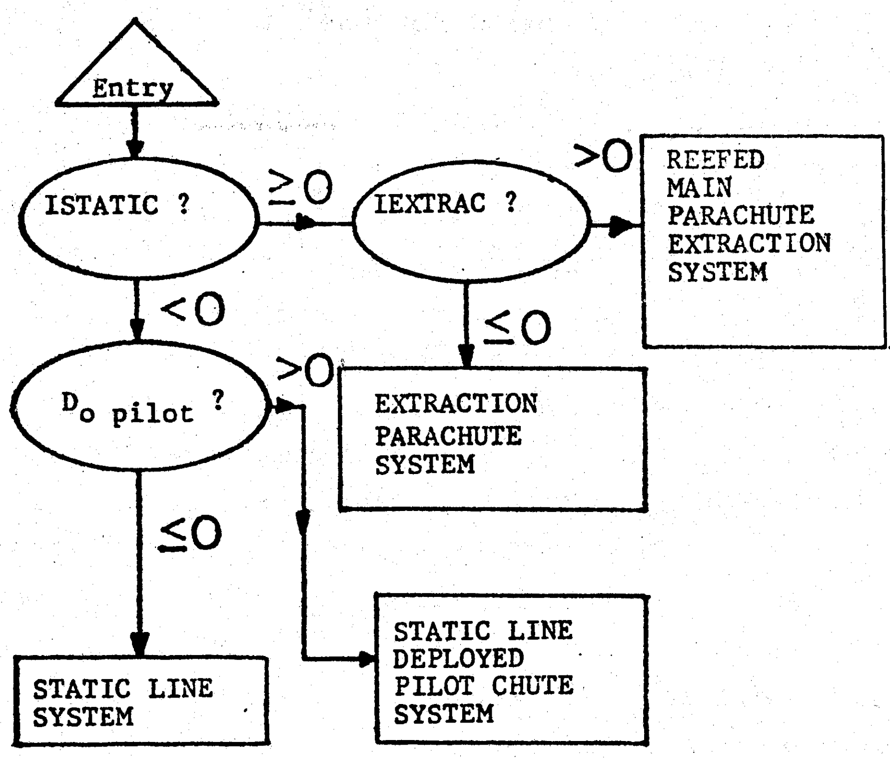

FIG 1 Determination of the Separation-Deployment System in Subroutine EXTRACT

sequence to SNATCH. For the static line and reefed main parachute extraction systems no snatch force calculation is required and EXTRACT sets ISNATCH to +1 which directs the MAIN PRØGRAM sequence directly to ØPENING.

The following Items include figures which show the separation-deployment process and the sequencing of the simulation through MAIN PRØGRAM, the values of the pertinent variables for selecting the separation-deployment system, and a list of the physical processes involved in separation and deployment with the name of the subroutine that models the process.

1. Static Line System

Figures 2 and 3
ISTATIC = -1
DPILØT = 0
ISNATCH = +1

Separation from aircraft	EXTRACT
Main Canopy Unfolding	EXTRACT

2. Static Line Deployed Pilot Chute System

Figures 4 and 5
ISTATIC = -1
DPILØT = $D_{o_{pilot}}$
ISNATCH = -1

Separation from aircraft	EXTRACT
Suspension system deployment	BØDIES
Snatch force	SNATCH
Main parachute unfolding	BØDIES

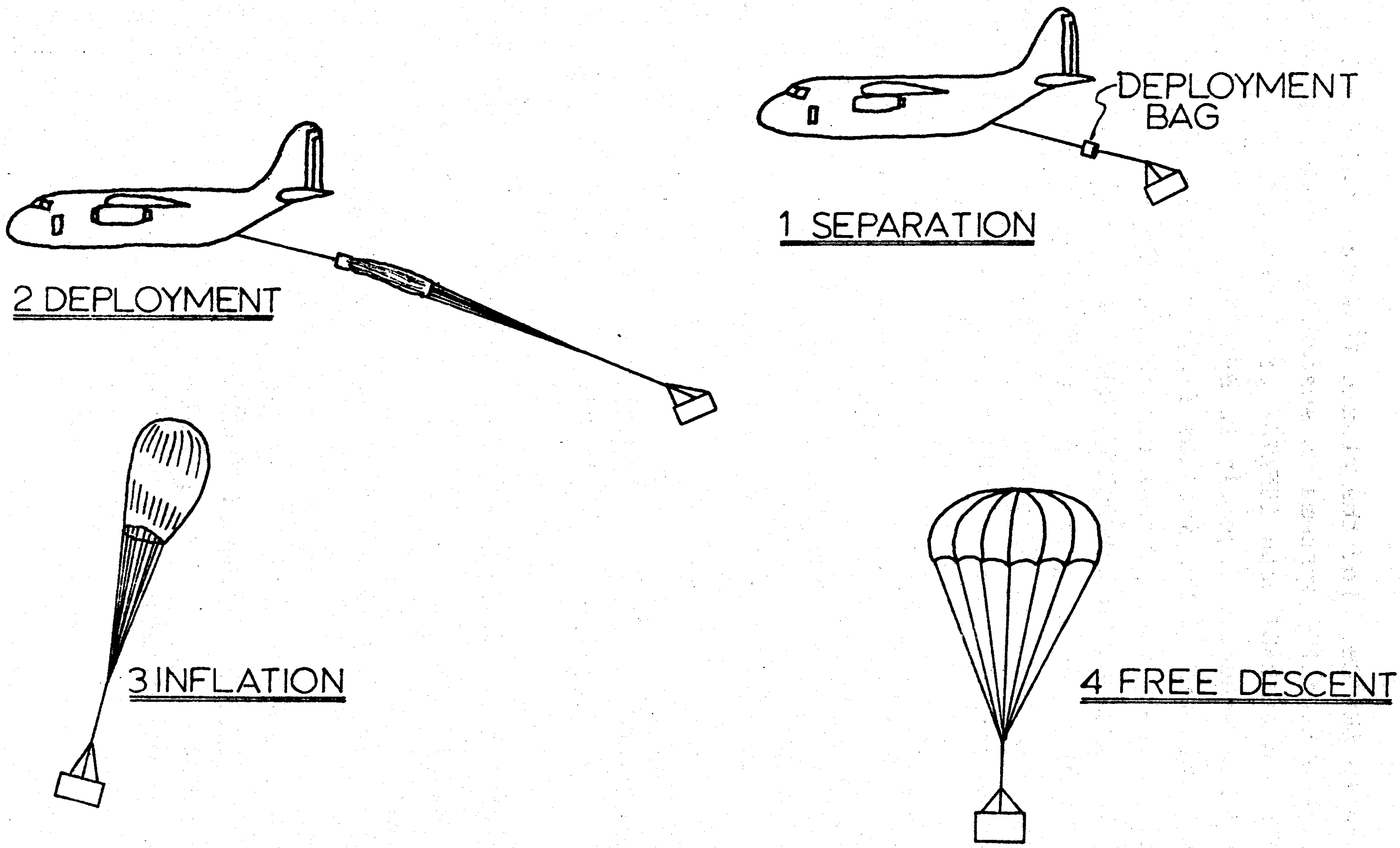

Fig 2 Static Line System

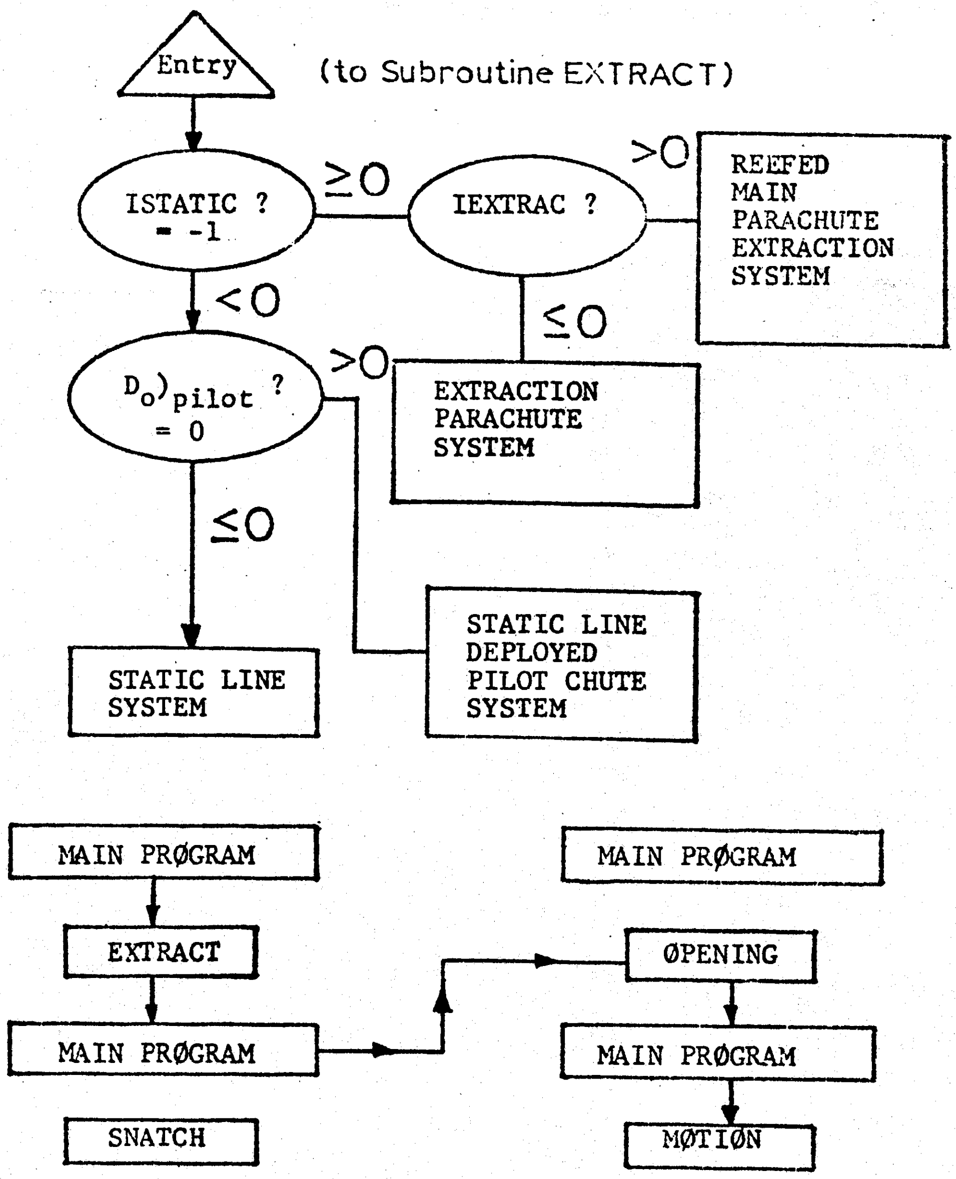

FIG 3 Sequence of Computer Solution for Static Line System

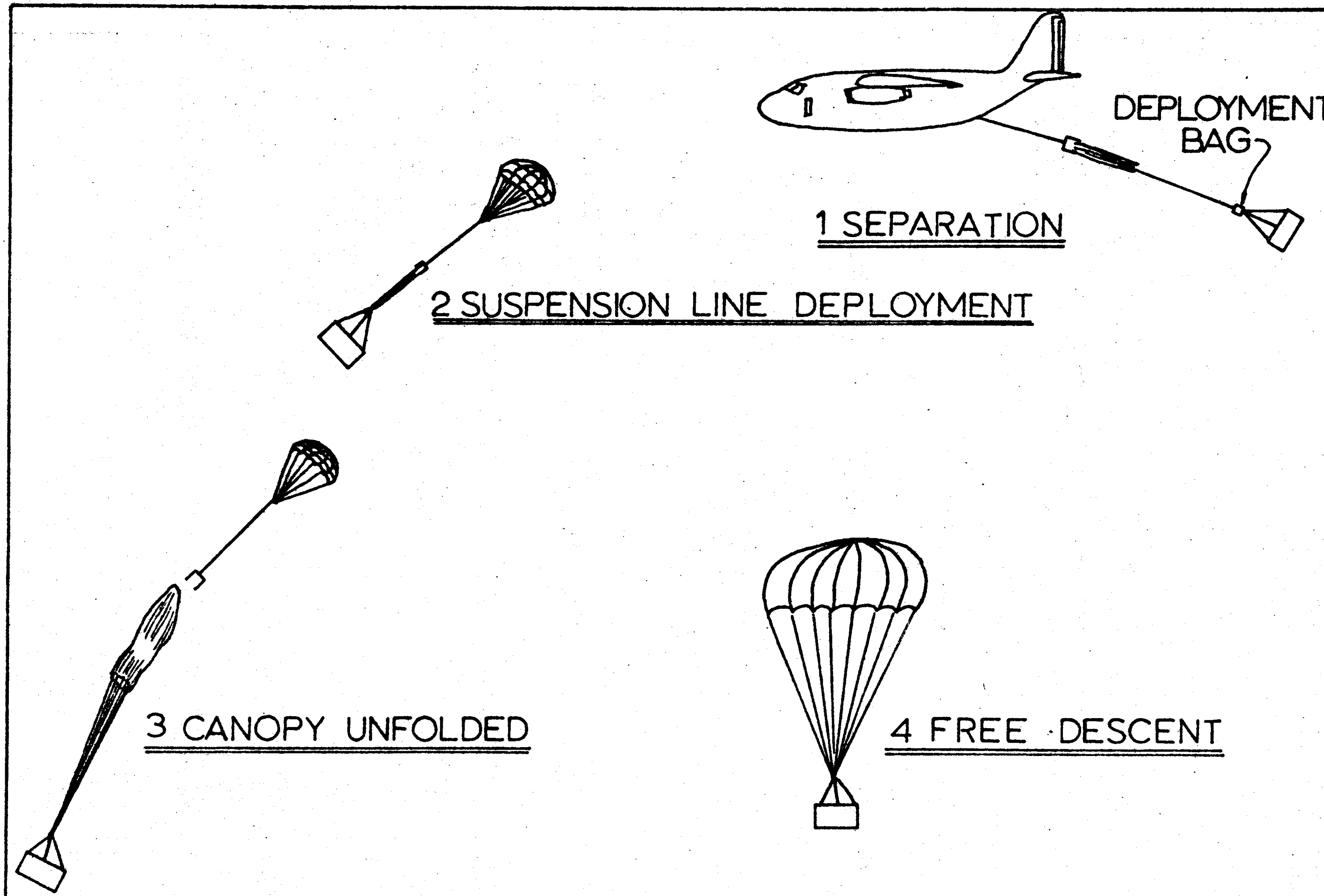

Fig 4 Static Line Deployed Pilot Chute System

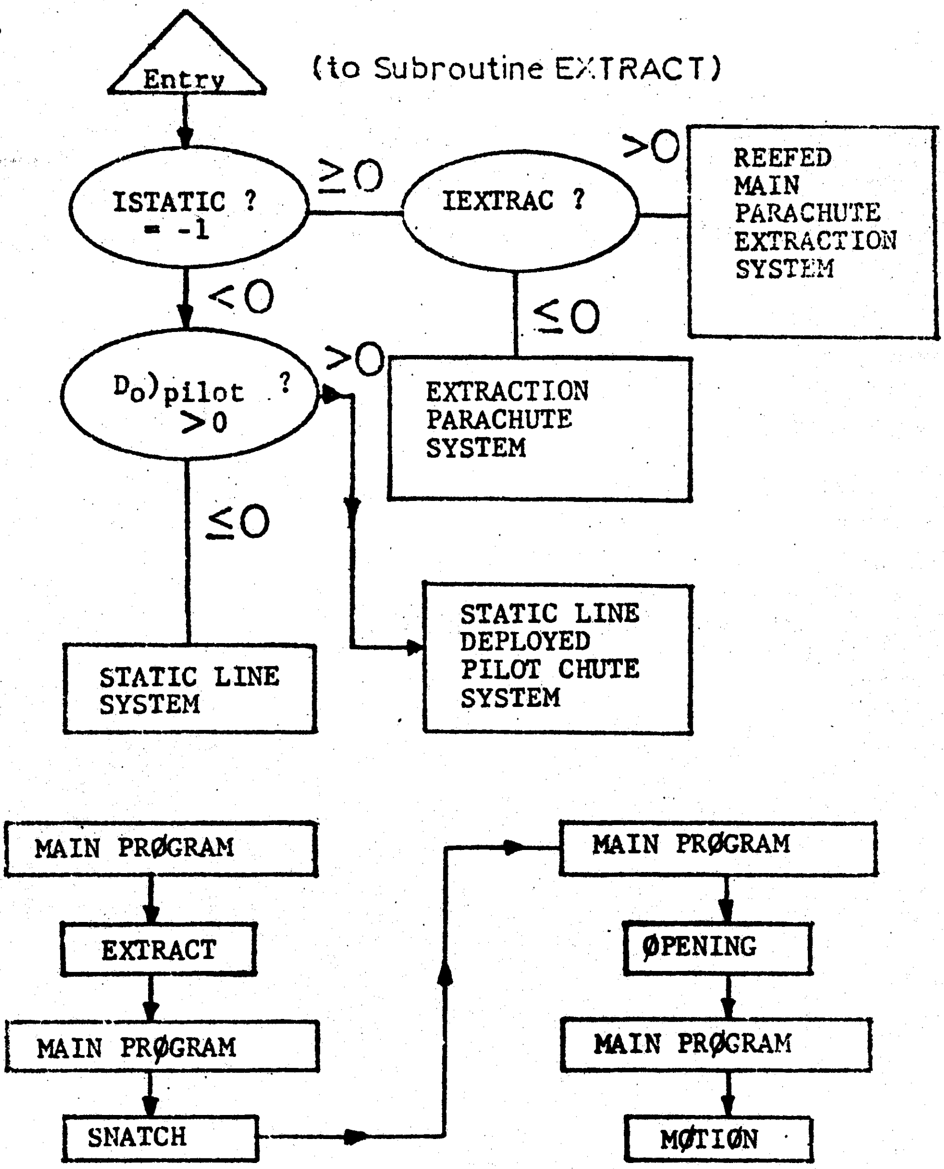

FIG 5 Sequence of Computer Solution for Static Line Deployed Pilot Chute System

3. Extraction Parachute System

Figures 6 and 7

ISTATIC = +1

IEXTRAC = 0

ISNATCH = -1

Separation from aircraft	EXTRACT
Suspension system deployment	BØDIES
Snatch force	SNATCH
Main parachute unfolding	BØDIES

4. Reefed Main Parachute Extraction System

Figures 8 and 9

ISTATIC = +1

IEXTRAC = +1

ISNATCH = +1

Separation from aircraft	EXTRACT

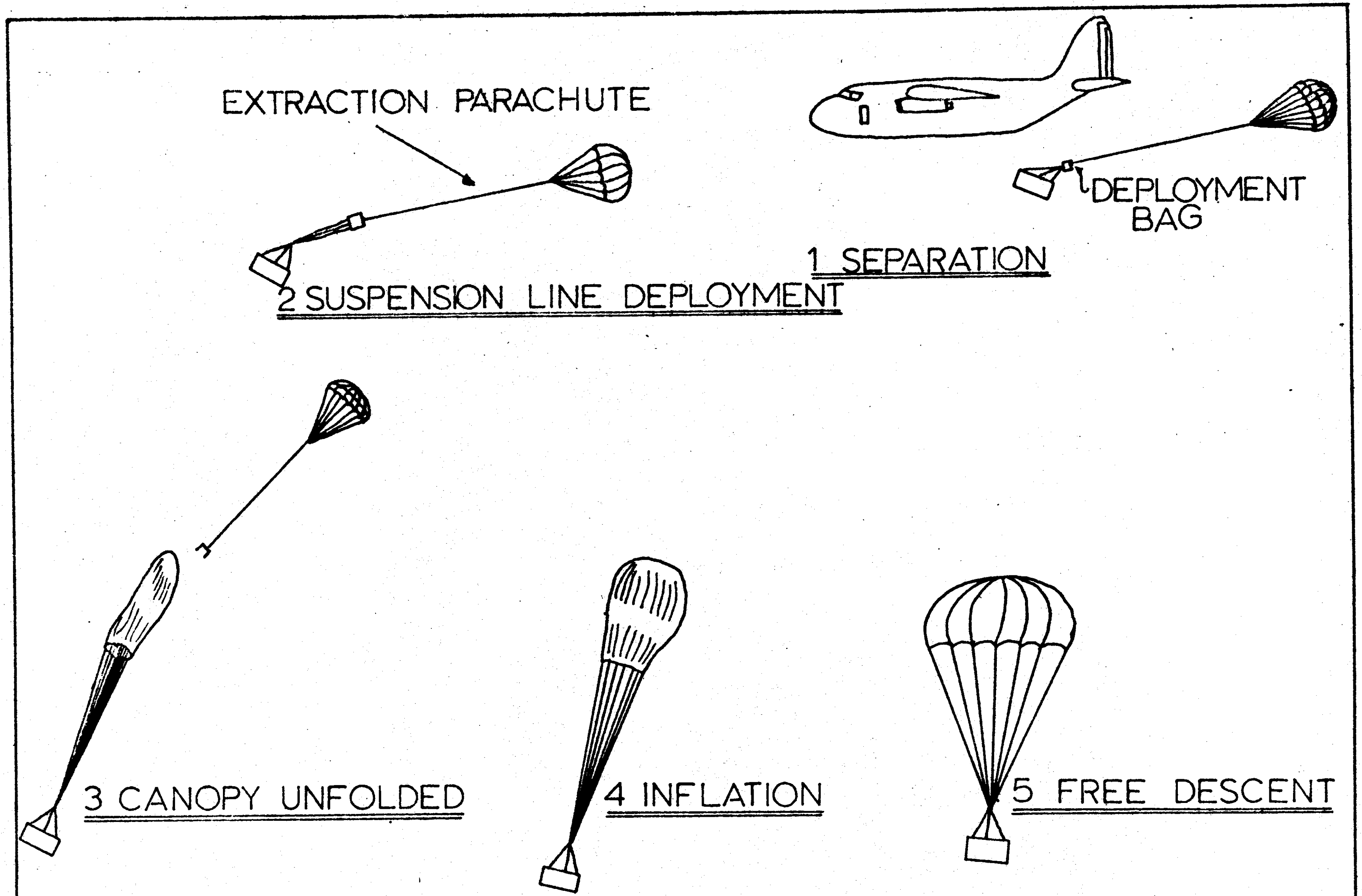

Fig 6 Extraction Parachute System

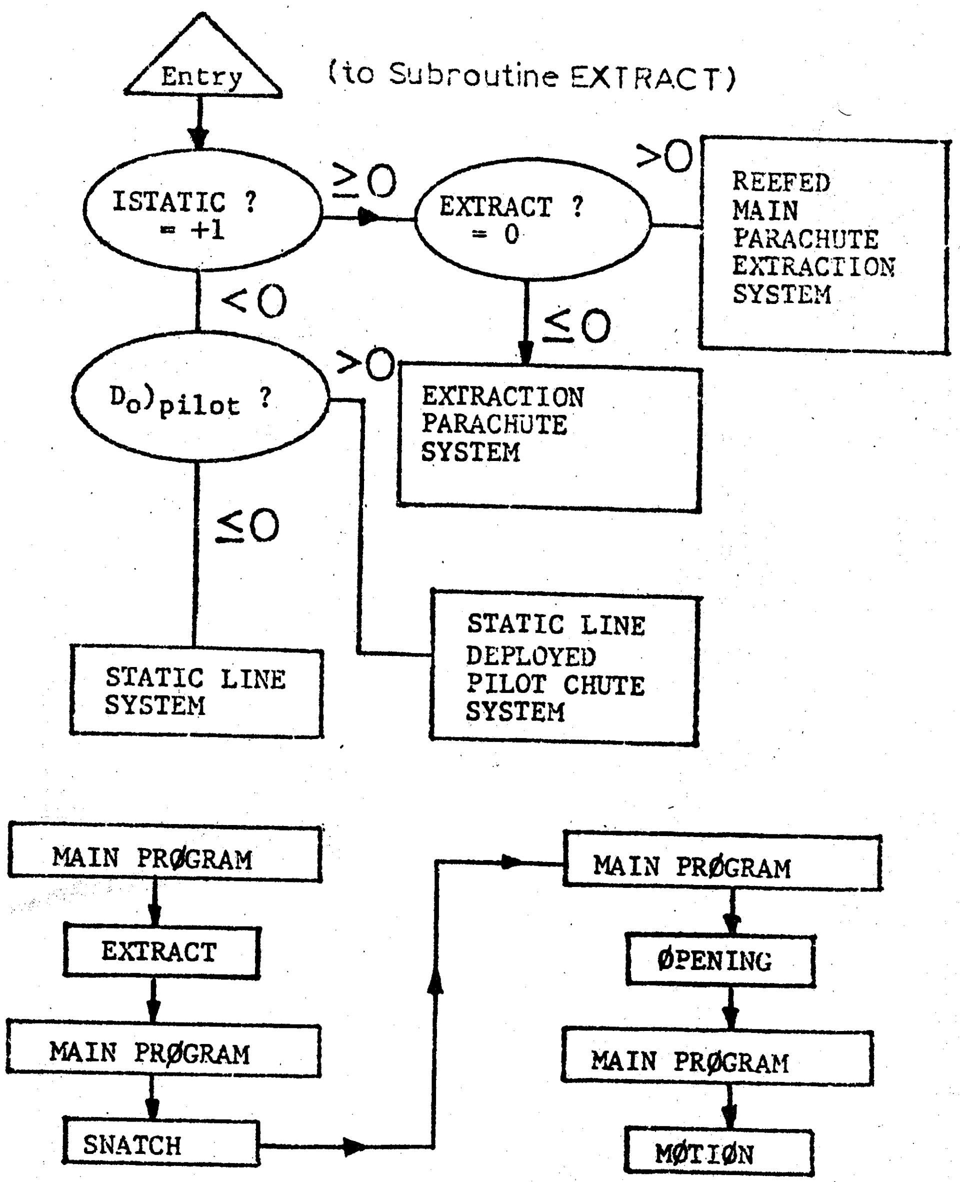

FIG 7 Sequence of Computer Solution for Extraction Parachute System

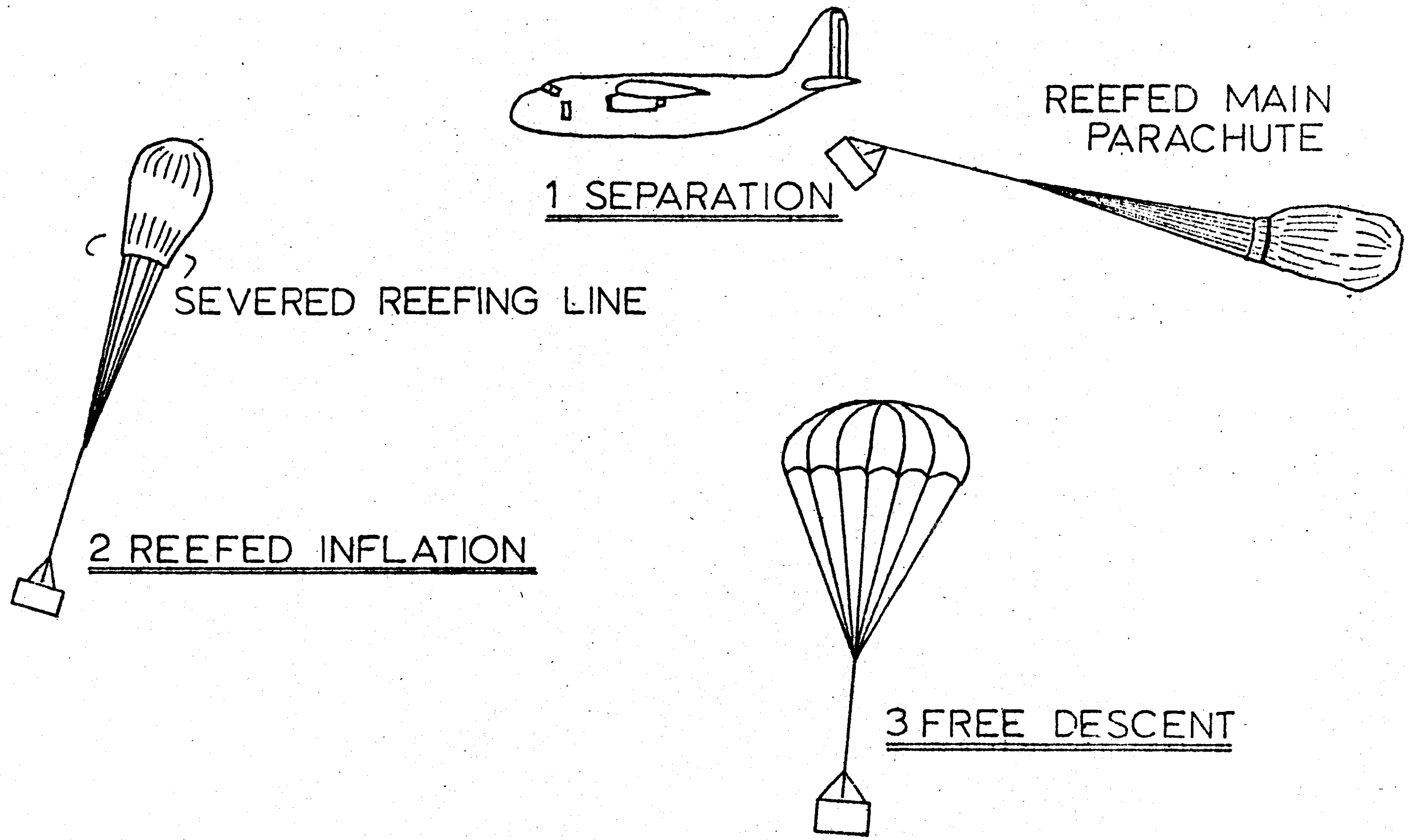

Fig 8 Reefed Main Parachute Extraction System

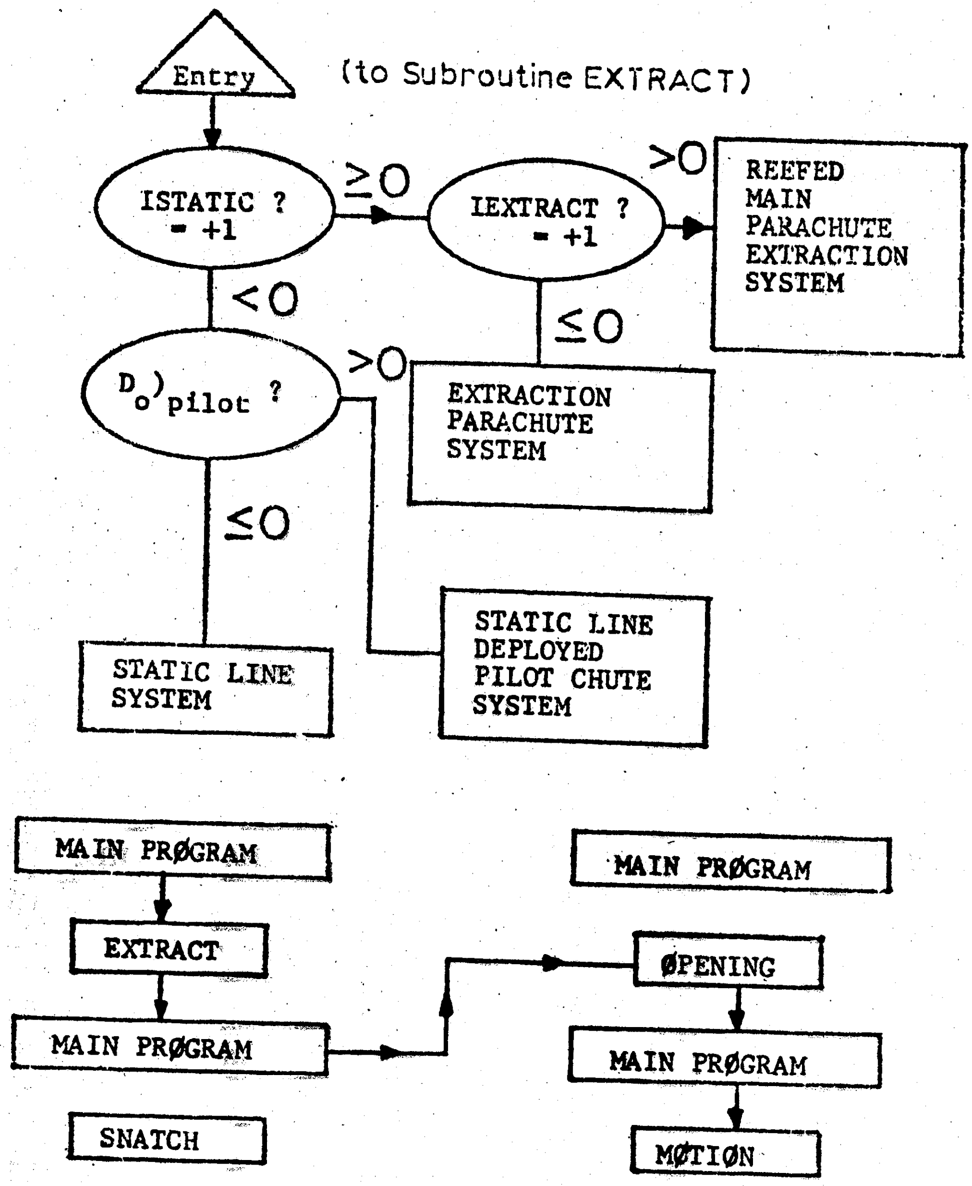

FIG 9 Sequence of Computer Solution for Reefed Main Parachute Extraction System

III. DESCRIPTION OF COMPUTER PROGRAM

This section describes the computer program used for the total trajectory simulations. The format used in the following is to include, for each program or subprogram, the following information: 1) list of inputs, 2) list of outputs, 3) list of formal parameters, 4) list of common blocks, and 5) an explanation of the calculation methods. Computer mnemonics are used in the lists of inputs, outputs, parameters, and common blocks to aid later cross references with the program listing, Section VII. These and all other non-standard mnemonics are defined in Section VI. The formal parameters and common blocks appear as they are shown in the listing of the particular subroutine. For assistance in following the calculation methods, the calling parameters of all calls to each subroutine are shown in Section IV.

A. <u>MAIN PRØGRAM</u>

The mnemonic symbol MAIN PRØGRAM is used in the text to describe PRØGRAM TRAJSIM, the name given by the authors to the main program for the total trajectory simulation. The name of the main program can be changed to any suitable form by the program user without affecting the functioning of the computer program. The standard files INPUT and ØUTPUT are required for the MAIN PRØGRAM.

1. Input

NSIM, C1, C2, C3, C4, C5, ALT, VO, MST, MP, MLS, MR, MRX, MBR, ML, X1, X2, X3, X4, X5, IZ, IAZO, DNØT, LSS, CDP, CDSL, Q1, Q2, VØLUME, N, NNN, DT1, DT2, DT3, NINT, ETA, PCTERR

2. Output

C1, C2, C3, C4, C5, ALT, VO, MST, ML, MP, MLS, MR, MRX, MBR, A8, B8, ALT, A9, B9, ALT, X1, X2, X3, X4, X5, A4, B4, ALT, A5, B5, ALT, A6, B6, ALT, A7, B7, ALT, DNØT, LSS, A1, B1, ALT, A2, B2, ALT, A3, B3, ALT, Q1, Q2, VØLUME, CDP, CDSL, N

3. Common Blocks

/CØNST/: ALT, PI, G, DNØT, CDSL, LSS, ML, MP, MSS, MST, NINT
/VARIABL/: RHØ, T, V, THETA, X, Z, ALPHAL, ALPHAP, L1
/DYNAM/: DYDNØT, X1, X2, X3, X4, X5, MBR, DYML, MLS, DYMP, MR, MRX, IAZO, IZ, Q1, Q2, VØLUME, XNUM, XDENØM

4. Methods

MAIN PRØGRAM oversees the operation of the total trajectory simulation, providing for a specified number, NSIM, of trajectory simulations to be accomplished in one run of the computer program. For each total trajectory simulation, the operation of MAIN PRØGRAM is as follows. The title and most parachute-load system data are read and printed. The parameters

$$\text{XNUM} = m_{L_s} s_1 + m_R s_2 + m_E s_3 + m_{Br} s_4 + m_\ell s_5 - m_p s_c$$

$$\text{XDENØM} = m_{L_s} + m_R + m_E + m_{Br} + m_\ell + m_p$$

are established for use in subroutine DYNAMIC. Note that common block DYNAM must have different names for its variables, even though some represent the same variables as are in CØNST. To bracket the variable parachute-load system dynamic characteristics to be encountered, subroutine DYNAMIC is called for mean sea level density and for release altitude density and the results of these two calls are printed. The necessary information for calculation is transmitted via the calling parameter list and the common block DYNAM.

The first call of the actual trajectory simulation is to EXTRACT, following which MAIN PRØGRAM directs the calculations by calling SNATCH, ØPENING, and MØTIØN as detailed in Subsections IIA and IIC for the particular separation-deployment system. When control is returned to MAIN PROGRAM after the call to MØTIØN, the next trajectory simulation begins or the program is terminated if the run is complete.

B. Separation-Deployment Phase

Three subroutines perform the calculations for the physical processes in the separation-deployment phase. The major subroutine is EXTRACT, which calculates the separation from the aircraft for all systems and contains all of the remaining deployment calculations for systems that do not have a snatch force. If a snatch force is required, EXTRACT directs MAIN PRØGRAM to subroutines SNATCH and BØDIES, the other two subroutines for this phase, SNATCH calculates maximum snatch force and calls BØDIES for calculating the separation between the primary and secondary bodies of the parachute load system.

1. Subroutine EXTRACT

a. Input

All Systems:

ISTATIC, IEXTRAC

Static Line System:

LSTATIC, CDSBAG, CDSP, DPILØT, LSPILØT, TD, LRXBR (CDSP = 0,

DPILØT = 0, LSPILØT = 0, TD = 0)

Static Line Deployed Pilot Chute System:

LSTATIC, CDSBAG, CDSP, DPILØT, LSPILØT, TD, LRXBR.

Extraction Parachute System:

LENGTH, CDSBAG, CDSEX, TD.

Reefed Main Parachute Extraction System:

R, LENGTH, TD

b. Output

Static Line System:

ALL NINT: LSTATIC, CDSBAG, T1, TRAJ1, X1, Z1, V1, T, TRAJANG, X, Z, V.

NINT > 0: T, ALT-Z, TRAJANG, TRAJANG, X, Z, V, VX, VZ.

Static Line Deployed Pilot Chute System:

ALL NINT: LSTATIC, CDSBAG, CDSP, DPILØT, LSPILØT, TD, T1, TRAJ1, X1, Z1, V1, T, TRAJANG, X, Z, V.

NINT > 0: T, ALT-Z, TRAJANG, TRAJANG, X, Z, V, VX, VZ.

Extraction Parachute System:

ALL NINT: LENGTH, CDSBAG, CDSEX, TD, T1, X1, V1, T, TRAJANG, X, Z, V.

NINT > 0: T, ALT-Z, TRAJANG, TRAJANG, X, Z, V, V.

Reefed Main Parachute Extraction System:

ALL NINT: LENGTH, R, H*DNØT, TD, T1, X1, V1, T, TRAJANG, X, Z, V.

NINT > 0: T, ALT-Z, TRAJANG, TRAJANG, X, Z, V, V.

c. Formal Parameters

ISNATCH, IEXTRAC, VO, DT, TRCA

d. Common Blocks

/CØNST/: ALT, PI, G, CDP, DNØT, CDSL, LSS, ML, MP, MSS, MST, NINT.

/VARIABL/: RHØ, T, V, THETA, X, Z, UNUSED, UNUSED2, UNUSED3.

e. Methods

i) Static Line System

The governing equations for the parachute-load system during the periods of separation and deployment of the main parachute by static line are the two-dimensional, point mass, trajectory equations, incorporated in subroutine TRAJEQN. Thus the procedure in subroutine EXTRACT is to call subroutine TRAJEQN with calling parameters representing the appropriate mass and drag area with time increments Δt between successive calls. The duration of the first calculation phase is determined by the distance between the release point in the aircraft and the recovery system mass center, given by

$$\ell = \sqrt{(V_o t - x)^2 + z^2} \tag{1}$$

The main parachute is deployed, and control is returned to the main program, when

$$\ell \geq L_{static} + L_S + L_R + D_o/2 + L_E + L_{Br} \tag{2}$$

The parameter ISNATCH is assigned the value +1 before control is returned to the main program. The value of the time at this point is the value given to the return parameter t_{RCA}, which is required if reefing will be required in the inflation phase.

ii) Static Line Deployed Pilot Chute System

The procedure for this case is the same as for static line deployment, except that the pilot parachute is being deployed rather than the main parachute. The pilot parachute is deployed when

$$\ell \geq L_{static} + L_{s\,pilot} + \frac{1}{2} D_{o\,pilot} \qquad (3)$$

At this point, the calling parameter for subroutine TRAJEQN representing the drag area must be increased by the drag area of the pilot parachute. The parameter ISNATCH is assigned the value -1. Successive calls to subroutine TRAJEQN are made until the time exceeds the value t_D.

iii) Extraction Parachute System

ISNATCH is set equal to -1. The governing equation while the load is in the aircraft is

$$\Delta v = \frac{-\rho v^2 C_D S_T}{2 m_{rs}} \Delta t \qquad (4)$$

where $C_D S_T$ is the drag area of the extraction parachute(s). The condition which indicates that the load has left the aircraft is

$$V_o t - x \geq L \qquad (5)$$

At this point, the value of $C_D S_T$ is increased by the drag area of the load and the packed main parachute, $C_D S_\ell + C_D S_B$, and the trajectory is simulated by successive calls to subroutine TRAJEQN with time increment Δt. Control is returned to the main program when the time exceeds t_D.

iv) Reefed Main Parachute Extraction System

ISNATCH is set to +1. The drag area of the reefed main parachute is given by

$$C_D S_T = C_{Dp} \frac{\pi h^2 D_o^2}{4} \qquad (6)$$

where

$$h = \frac{4(L_s + L_R)R + 2RD_o}{4(L_s + L_R) + \pi R D_o} \qquad (7)$$

The calculation procedure is the same as for standard extraction parachutes, with the value of $C_D S_T$ from Eqn (6) used in Eqn (4). After the criterion (5) is satisfied, the value of $C_D S_T$ is increased by the drag area of the load, $C_D S_\ell$, and successive calls are made until t exceeds t_D. The value of t_{RCA} is set to zero.

2. Subroutine SNATCH

a. Input

MPBAG, CDS2, K, LRXBR

b. Output

ALL NINT: MPBAG, CDS2, K, LRXBR, TL, TRAJL, XL, ZL, V1L, V2L, PMAX, VF

NINT > 0: T, ALT-Z, TRAJANG, TRAJANG, X, Z, V1, V1X, V1Z

c. Formal Parameters

TRCA, DT

d. Common Blocks

/CØNST/: ALT, PI, G, CDP, DNØT, CDSL, LSS, ML, MP, MSS, MST, NINT

/VARIABL/: RHØ, T, V, THETA, X, Z, UNUSED1, UNUSED2, UNUSED3

e. Methods

The trajectories of the primary and secondary bodies and the separation ℓ are calculated by calls to subroutine BØDIES for the periods before and after snatch. Subroutine BØDIES is called successively until

$$\ell = L_S + L_R + L_E + L_{Br} \tag{8}$$

when snatch occurs. The snatch force equations are

$$P_{max} = -B + \sqrt{B^2 - C/A} \tag{9}$$

$$A = 1/k \tag{10}$$

$$B = F_{AI}\left[1 + Q + \frac{2v_{II}Q}{v_s - v_{II}}\right] + F_{AII}\left[Q + \frac{2v_{II}Q}{v_s - v_{II}}\right] \tag{11}$$

$$C = M_I \frac{Q-1}{Q}\left[\frac{Q+1}{Q}(v_s - v_{II})^2 + 2v_{II}(v_s - v_{II})\right] + m_p\left[(v_s - v_{II})^2 + 2v_{II}(v_s - v_{II})\right] \tag{12}$$

$$F_{AI} = \frac{\rho C_D S_I}{4}(v_I^2 + v_s^2) \tag{13}$$

$$F_{AII} = \frac{\rho C_D S_{II}}{4}(v_{II}^2 + v_s^2) \tag{14}$$

$$Q = \frac{M_I}{M_I + m_p} \tag{15}$$

$$v_s = \frac{M_I v_I + m_p v_{II}}{M_I + m_p} \tag{16}$$

The time t_{RCA} is set to the time value at snatch. Subroutine BØDIES is then again called successively, after adjusting primary and secondary velocities to the value v_s, and changing the masses to $(m_p + m + m_{ss})$ for the primary body, and to m_{p_b} for the secondary body. This continues until

$$\ell = L_s + L_R + L_{III} + L_{Br} + D_o/2 \tag{17}$$

at which time control is returned to MAIN PRØGRAM.

3. Subroutine BØDIES

a. Input

None

b. Output

None

c. Formal Parameters

M1, CDS1, M2, CDS2, V1, V2, L, DT

d. Common Blocks

/CØNST/: ALT, PI, G, CDP, DNØT, CDSL, LSS, ML, MP, MSS, MST, NØUSE.

/VARIABL/: RHØ, T, V, THETA, X, Z, UNUSED, UNUSED2, UNUSED 3.

e. Methods

This subroutine merely evaluates the equations

$$\Delta \theta = - \frac{g \sin \theta}{V_I} \Delta t \tag{18}$$

$$\Delta V_I = \left(g \cos \theta - \frac{\rho C_D S_I V_I^2}{2 m_I} \right) \Delta t \tag{19}$$

$$\Delta V_{II} = \left(g \cos \theta - \frac{\rho C_D S_{II} V_{II}^2}{2 m_{II}} \right) \Delta t \tag{20}$$

$$\Delta x = V_I \sin \theta \, \Delta t \tag{21}$$

$$\Delta z = V_I \cos \theta \, \Delta t \tag{22}$$

$$\Delta \ell = V_I \Delta t - V_{II} \Delta t \tag{23}$$

C. Inflation of the Main Parachute

The second calculation phase is represented by subroutines ØPENING, FILLTIM, and CALC. This calculation phase is required for all of the separation-deployment systems, and is initiated by a call from MAIN PRØGRAM to ØPENING, which then calls FILLTIM and CALC. This phase represents inflation of the main parachute with provision for any number of reefed stages. The extent of the calculation phase is from the point when the main parachute is deployed in a stretched-out manner, or at the time $t = t_D$ for extraction by the reefed main parachute, until the main parachute is fully inflated.

1. Subroutine ØPENING

a. Input

No Reefing: NREEF
Reefing: NREEF, RO, R1, TCD

b. Ouput

No Reefing:
ALL NINT: T, TRAJANG, X, Z, V, FO, TF
NINT > 0: ALT-Z, TRAJANG, TRAJANG, X, Z, V, VX, VZ, -FRCE/ML
Reefing:
ALL NINT: R1, H1*DNØT, TCD, TDR; T, TRAJANG, X, Z, V, FO, TF, at end of each reefing stage.
NINT > 0: T, ALT-Z, TRAJANG, TRAJANG, X, Z, V, VX, VZ, -FRCE/ML

c. Formal Parameters

DQ, TRCA, N, F, VOLUMG, IEXTRAC, DTT

d. Common Blocks

/CØNST/: ALT, PI, G, CDP, DNØT, CDSL, LSS, ML, MP, MSS, MST, NINT
/VARIABL/: RHØ, T, V, THETA, X, Z, UNUSED, UNUSED2, UNUSED3

e. Methods

The first input to subroutine ØPENING is the value NREEF, representing the number of reefing lines employed during the inflation. If the value of NREEF is zero, i.e. if the inflation is without reefing, no further inputs are made. If reefing is employed, the reefing ratios at the beginning and end of each reefed inflation and the reefing cutter delays must be read. Thus for the first reefed inflation stage, the initial value of the reefing ratio is zero and the final value is the reefing ratio corresponding to the first reefing line. For the last reefed inflation stage, the initial reefing ratio value corresponds to the final reefing line, and the final value is equal to the assumed projected diameter ratio for the fully inflated parachute, $2/\pi$.

The procedure for calculation of the simulated trajectory by subroutine ØPENING is as follows. For inflation of the main parachute without reefing, the volume increase of the parachute during inflation is given by the fully inflated volume V. The values for the initial and final projected diameter ratios are set by ØPENING to

$$h_o = (D_p/D_o)_{T=0} = 0 \tag{24}$$

$$h_1 = (D_p/D_o)_{T=1} = \frac{2}{\pi} \tag{25}$$

The values of V, h_o, and h_1 are used for determination of the final filling time t_{ff} by calling subroutine FILLTIM. The trajectory is then calculated by successive calls to subroutine CALC, and control is returned to the main program when T = 1. The opening force during the inflation is found from

$$F_0 = m_\ell \left(g\cos\theta - \frac{\Delta v}{t_{ff}\Delta T} \right) \qquad (26)$$

the opening shock being the largest value of F_0.

For inflation from one reefed stage to another, the increase in volume is given by

$$V_R = \frac{\pi}{12} \left\{ D_o^3 (h_1^3 - h_o^3) + D_o^2 \left[h_1^2 \sqrt{\left(L_s + L_R + D_o/2 - \frac{\pi h_1 D_o}{4}\right)^2 - \frac{h_1^2 D_o^2}{4}} - h_o^2 \sqrt{\left[L_s + L_R + D_o/2 - \frac{\pi h_o D_o}{4}\right]^2 - \frac{h_o^2 D_o^2}{4}} \right] - D_o^2 \left[R_1^2 \sqrt{(L_s + L_R)^2 - \frac{R_1^2 D_o^2}{4}} - R_o^2 \sqrt{(L_s + L_R)^2 - \frac{R_o^2 D_o^2}{4}} \right] \right\} \qquad (27)$$

The values of the projected diameter ratios are found from the reefing ratios R_o and R_1 by

$$h_o = \frac{4(L_s + L_R) R_o + 2 R_o D_o}{4(L_s + L_R) + \pi R_o D_o} \qquad (28)$$

$$h_1 = \frac{4(L_s + L_R) R_1 + 2 R_1 D_o}{4(L_s + L_R) + \pi R_1 D_o} \qquad (29)$$

The filling time t_{fR} is then calculated by calling FILLTIM with the values of V_R, h_o, and h_1 from Eqns (27) through (29). The trajectory during a reefed inflation is calculated by successive calls to subroutine CALC until $T_R = 1$. The opening force is found from (26) with $t_{fR}\Delta T_R$ replacing $t_{ff}\Delta T$. If the parachute is not fully inflated, i.e. if another inflation stage is required, there is in general a coasting phase before the next inflation begins. The length of this phase is determined by the input of the reefing cutter delay, t_{CD}. The trajectory during the coasting phase is determined by successive calls to TRAJEQN, with the values of the parachute-load system mass and the drag area of the system in its partially inflated configuration, and time increments Δt, until the time exceeds $t_{RCA} + t_{CD}$. At this point, the values of R_o, R_1, and t_{CD} for the next inflation stage are read. If the time already exceeds $t_{RCA} + t_{CD}$ when $T_R = 1$, no coasting phase is included and these values are read immediately. If, at the point $T_R = 1$, the parachute is fully inflated, i.e. at the end of the last inflation stage, control is returned to MAIN PRØGRAM.

When the main parachute is inflated to a reefed configuration at the entry to the subroutine, i.e when the reefed main parachute extraction system is used, the number of inflation stages is equal to the number of reefing lines, NREEF. In the general case, the number of inflation stages is equal to NREEF + 1. Thus, to distinguish between the two possibilities, the process described above is performed NREEF + 1 - IEXTRAC times, the value of IEXTRAC being 1 for extraction by the reefed main parachute and 0 otherwise. The number NREEF can assume any integer value up to 9 in the present arrangement of the computer solution, the restriction being due merely to the input format for NREEF and the dimension of the array REEF.

2. Subroutine FILLTIM

a. Input

None

b. Output

None

c. Formal Parameters

VO, XO, ZO, THETAO, MS, HO, H1, N, VOLDØT, TF

d. Common Blocks

/CØNST/: ALT, PI, G, CDP, DNØT, CDSL, LSS, ML, MP, MSS, MST, NØUSE

/VARIABL/: RHØ, T, V, THETA, X, Z, UNUSED, UNUSED2, UNUSED3

e. Methods

The filling time is given by the equation

$$V\O LUME = \pi t_{fR} \int_0^1 \left[v\left(1 + 2.2cT - T\right)\frac{d^2}{4} - \frac{1.1cD_p^2}{2}\right] dT_R \quad (30)$$

for the general reefed case. This formula applies for the unreefed case by replacing the subscript R by f. The function of subroutine FILLTIM is to evaluate the filling time by an iterative scheme as follows.

An initial estimate for the filling time is made by FILLTIM from the formula

$$t_{fR_1} = \frac{2h_1 D_0}{V_0} \quad (31)$$

The estimate is based on the concept of a constant filling distance, adjusted for the projected diameter at the end of the inflation. An approximation to Eqn (30) is found by Simpson's rule with N increments, i.e. Eqn (30) is evaluated for N values of T_R. The required information is found from calls to CALC, for the values of T_R, ΔT_R, T, and ΔT, where

$$T = \frac{\pi^2}{4}\left[h_1^2 T_R + h_0^2 (1 - T_R)\right] \tag{32}$$

$$\Delta T = \frac{\pi^2}{4}(h_1^2 - h_0^2)\,\Delta T_R \tag{33}$$

Again, in the unreefed case the values T_R and T are equal as well as the increments ΔT_R and ΔT since $h_o = 0$ and $h_1 = 2\pi$. The effective porosity c is found from (Ref 1)

$$c = c_0\,\sigma^{1/7} \tag{34}$$

where c_o is assigned the constant value 0.05. This value was selected as representative of the parachute cloths encountered in this study, MIL-C-7020, Types I and II, MIL-C-7350, Type I, and MIL-C-4279, Type II, based on Ref 1. If ν represents the quantity under the integral sign in (30), the volume increase corresponding to a given value of the filling time t_{fR_n} is approximately, by Simpson's rule,

$$V\emptyset L = \pi t_{fR_n} \frac{\Delta T_R}{3}\left(\nu_0 + 4\nu_1 + 2\nu_2 + \cdots + \nu_N\right) \tag{35}$$

The value of VØL from Eqn (35) is compared with the parameter VØLUME, and a new filling time approximation is given by

$$t_{fR_{n+1}} = t_{fR_n}\left(\frac{V\emptyset LUME}{V\emptyset L}\right) \tag{36}$$

The above process is repeated until the value of t_{fR} is such that VØL from Eqn (35) satisfies the condition

$$\frac{|V\emptyset L - V\emptyset LUME|}{V\emptyset LUME} \le 10^{-5} \tag{37}$$

The number t_{fR} is then returned to subroutine ØPENING as the approximation to the filling time.

3. Subroutine CALC

a. Input

None

b. Output

None

c. Formal Parameters

CAPT, TF, DCAPT, DCAPTR, M, DV, DP, D

d. Common Blocks

/CØNST/: ALT, PI, G, CDP, DNØT, CDSL, LSS, ML, MP, MSS, MST, NØUSE

/VARIABL/: RHØ, T, V, THETA, X, Z, UNUSED, UNUSED2, UNUSED3

e. Method

The function of subroutine CALC is to evaluate the following equations.

$$D_p = \frac{2D_0}{\pi} T^{1/2} \tag{38}$$

$$D_{p_{max}} = \frac{2D_0}{\pi} \tag{39}$$

$$\frac{d(D_p)}{dT} = \frac{D_o}{\pi T^{1/2}} \tag{40}$$

$$d = \frac{4(L_s+L_R)\,D_p}{4(L_s+L_R)+2D_o-\pi D_p} \tag{41}$$

$$\frac{d(d)}{dT} = \frac{\left[4(L_s+L_R)+2D_o-\pi D_p\right]4(L_s+L_R)\,\frac{d(D_p)}{dT}}{\left[4(L_s+L_R)+2D_o-\pi D_p\right]^2} + \frac{4(L_s+L_R)\,\pi\,D_p\;d(D_p)/dT}{\left[4(L_s+L_R)+2D_o-\pi D_p\right]^2} \tag{42}$$

$$m_a = \frac{\pi\rho}{32}\,\frac{D_p^5}{(D_{p\,max})^2} \tag{43}$$

$$\Delta m_a = \frac{5\pi\rho D_p^4}{32\,(D_{p\,max})^2}\,\frac{d(D_p)}{dT}\,\Delta T \tag{44}$$

$$m_i = \frac{\pi\rho}{12}\left\{D_p^3 + D_p^2\sqrt{\left(L_s+L_R+\frac{D_o}{2}-\frac{\pi}{4}D_p\right)^2 - \frac{D_p^2}{4}} - d^2\sqrt{(L_s+L_R)^2-\frac{d^2}{4}}\right\} \tag{45}$$

$$\Delta m_i = \frac{\pi \rho}{12} \left\{ 3 D_p^2 \frac{d(D_p)}{dT} - D_p^2 \left[\frac{\left[2(L_s+L_R) + D_o - \frac{\pi}{2} D_p\right] \frac{\pi}{4} \frac{d(D_p)}{dT}}{2\left[(L_s+L_R+D_o/2 - \pi D_p/4)^2 - D_p^2/4\right]^{1/2}} + \frac{\frac{D_p}{2} \frac{d(D_p)}{dT}}{2\left[(L_s+L_R+\frac{D_o}{2}-\frac{\pi}{4}D_p)^2 - \frac{D_p^2}{4}\right]^{1/2}} \right] + 2 D_p \frac{d(D_p)}{dT} \sqrt{(L_s+L_R+\frac{D_o}{2}-\frac{\pi}{4}D_p)^2 - \frac{D_p^2}{4}} \right. \tag{46}$$

$$\left. + \frac{d^3}{4\left[(L_s+L_R)^2 - d^2/4\right]^{1/2}} - 2d \frac{d(d)}{dT} \sqrt{(L_s+L_R)^2 - \frac{d^2}{4}} \right\} \Delta T$$

$$\Delta v = \left[\left(\frac{m_\ell + m_{ss} + m_p}{m_T} \right) g \cos\theta - \frac{\rho v^2 \left(C_D S_\lambda + C_{D_p} \frac{\pi D_p^2}{4}\right)}{2 m_T} \right] \cdot t_{fR} \Delta T_R \approx \frac{v}{m_T} (\Delta m_i + \Delta m_a) \tag{47}$$

$$\Delta\theta = -\left(\frac{m_\ell + m_{ss} + m_p}{m_T} \right) \frac{g \sin\theta}{v} t_{fR} \Delta T_R \tag{48}$$

$$\Delta x = v \sin\theta \, t_{fR} \Delta T_R \tag{49}$$

$$\Delta z = v \cos\theta \, t_{fR} \Delta T_R \tag{50}$$

D. Free Descent; Three Degrees of Freedom

The final calculation phase, the free descent phase, is required for all of the separation-deployment systems. Due to the degree of complexity involved in the general case which has six degrees of freedom, the computer solution was programmed separately for the restricted problem of three degrees of freedom. The trajectory simulation is readily applicable to either three or six degrees of freedom merely by inserting the proper subroutines in the computer program and using the correct input value for allowable degrees of freedom in the main program.

When the simulation is restricted to three degrees of freedom, the subroutines required by the computer program for the free descent calculation phase are MØTIØN, INTGRAT, FØRMULA, EMØTIØN, DYNAMIC, and CØEFFTS. The function of this calculation phase is to calculate the trajectory of the parachute-load system during the period from full inflation to a specified time thereafter or until a specified altitude is reached, as defined by the program user.

1. Subroutine MØTIØN

a. Input

TSTØP, ZSTØP

b. Output

ALL NINT: T, ALT-RZ, RX, RZ, V, VX, VZ, A at the first three instances the parachute-load system is vertical or near vertical

NINT > 0: T, ALT-RZ, SYSANGL, TRAJANG, RX, RZ, V, VX, VZ, A

c. Formal Parameters

DQ, PCTERR, ETA, DT

d. Common Blocks

/CØNST/: ALT, PI, G, CDP, DNØT, CDSL, LSS, ML, MP, MSS, MST, NINT

/VARIABL/: RHØ, T, V, THETA, X, Z, ALPHAL, ALPHAP, L1

e. Method

The problem during the free descent calculation phase is to solve the six differential equations of motion for U, W, Q, θ, x, and z simultaneously. These quantities are represented in the computer solution by the six-dimensional array Y. The initial conditions for the free descent calculation phase are determined by the conditions which exist at the instant of full inflation. Thus MØTIØN first assigns the following values to Y:

$$Y(1) = U = 0 \tag{51}$$

$$Y(2) = W = v \tag{52}$$

$$Y(3) = Q = -\frac{g \sin\theta}{v} \tag{53}$$

$$Y(4) = \theta \tag{54}$$

$$Y(5) = x \tag{55}$$

$$Y(6) = z \tag{56}$$

where v, θ, x, and z are the values of velocity, system angle, and position of the mass center determined by ØPENING at the time of full inflation of the main parachute. The array YDØT represents the time derivatives $\dot{U}$, $\dot{W}$, $\dot{Q}$, $\dot{\theta}$, $\dot{x}$, and $\dot{z}$. An initial condition is assigned for $\dot{Q}$ such that

$$YD\O T(3) = \dot{Q} = \frac{g^2 \cos\theta \sin\theta}{V^2} + \frac{g \sin\theta}{V}\frac{dv}{dt} \qquad (57)$$

the value of dv/dt being given by the formal parameter DQ.

Once the initial conditions have been established, the actual solution of the equations of motion is accomplished by means of subroutine INTGRAT. For the first call to INTGRAT, the calling parameter ID is set equal to +1, and for subsequent calls ID equals -1. The calls to INTGRAT are made as part of a DØ loop which has a variable terminator, NUMB. Output of the trajectory parameters is executed after the operations of the DØ loop have been completed; the loop is then executed again. This process continues until the free descent calculation phase is terminated. The original value of the DØ loop terminator, |NINT|, is set by the program user via the main program. Since the integration routine INTGRAT automatically selects time increments for the solution of the equations of motion, output could come at infrequent intervals of time as the time increment is increased during phases which approach steady state conditions if the loop terminator were not allowed to vary. Thus, if at any time the product of NUMB with the time increment DX (assigned by INTGRAT) is larger than one second, the value of NUMB is adjusted so that trajectory parameters will be printed at roughly one second intervals.

The parameters of the call to INTGRAT are T, Y, TF, G, PCTERR, ETA, X1, X2, X3, W, YDØT, B, ID, DX, TI, and K. The parameter G indicates the number of equations to be solved by

INTGRAT; X1, X2, X3, W, and B are arrays established for use in INTGRAT and FØRMULA; and DX is the time increment set by INTGRAT. T1 is a temporary variable for the time values, and K is a signal which is positive if the solution of the equations blow up due to the parachute angle of attack exceeding 85°. The results of the call to INTGRAT are the values of the arrays Y and YDØT evaluated at the time TF, which is defined before each call to INTGRAT as TF = T + DX or, before the first call, as TF = T + DT.

After calling INTGRAT, the next step taken by MØTIØN is to evaluate the position, velocity, and acceleration components of the load, following the relations

$$r_{\ell x} = x + \ell_1 \sin\theta \tag{58}$$

$$r_{\ell z} = z + \ell_1 \cos\theta \tag{59}$$

$$v_{\ell x} = (U + Q\ell_1)\cos\theta + W\sin\theta \tag{60}$$

$$v_{\ell z} = -(U + Q\ell_1)\sin\theta + W\cos\theta \tag{61}$$

$$a_{\ell x} = (\dot{U} + QW + \dot{Q}\ell_1)\cos\theta + (\dot{W} - QU - Q^2\ell_1)\sin\theta \tag{62}$$

$$a_{\ell z} = -(\dot{U} + QW + \dot{Q}\ell_1)\sin\theta + (\dot{W} - QU - Q^2\ell_1)\cos\theta \tag{63}$$

The value $r_{\ell z}$ is first stored as a variable R2 for consideration of interpolation at the end of MØTIØN.

The load trajectory angle is given by

$$\alpha_{t_\ell} = \theta - \alpha_\ell \tag{64}$$

where α_ℓ is available from the Common block /VARIABL/, having been calculated in EMØTIØN.

In order to calculate the trajectory parameters at the first three instances when the system is vertical or near vertical, it is necessary to define the oscillatory behavior of the system in a quantitative sense. A counter, NMARK, is defined, initially equal to zero, such that it is increased by one each time that the sign of the system angle changes or the system angle reaches an extreme position. Then the parachute-load system will be vertical, or near vertical, when NMARK equals one, three, and five, and the corresponding values of t, $h_o - r_{\ell_z}$, r_{ℓ_x}, r_{ℓ_z}, v, v_{ℓ_x}, v_{ℓ_z}, and a_ℓ, which have been stored in the array VERTPAR, approximate the required trajectory parameters at the first three vertical positions.

The final calculations performed by MØTIØN occur when the time exceeds TSTØP or the altitude loss exceeds ZSTØP. The trajectory parameters at the point t = TSTØP or z = ZSTØP are then found by linear interpolation, using a correction given by

$$CØRR = \frac{ZSTØP - r_{\ell_z}}{R2 - r_{\ell_z}} \tag{65}$$

or

$$CØRR = \frac{TSTØP - t}{T1 - t} \tag{66}$$

The final values of the parameters are then printed, and control is returned to the main program.

2. Subroutine INTGRAT

a. Input

None

b. Output

None

c. Formal Parameters

T, Y, TF, NN, PCTERR, ETA, TRY1, TRY2, TRY3, W, YDØT, Z, ID, DX, T1, ISIGNAL

d. Common Blocks

None

e. Method

This subroutine is arranged in the form of a general solution method for a given number of simultaneous first order differential equations. The numerical technique employed is the Runge-Kutta method, (Ref 2) and INTGRAT is based strongly on the University Computer Center library subroutine RK. The advantage of structuring the subroutine in the manner of a general differential equation solving method is that the same subroutine can be used without modifications to solve both the three and six degree of freedom cases. Furthermore, with slight modifications, the subroutine can be used to solve a system of differential equations which may arise at a future time if substitute methods are to be used for any of the trajectory calculation phases rather than those for which the trajectory simulation computer program was originally written.

The formal parameter T represents the initial time, TF is the time at which the values of the arrays Y and YDØT are desired, and T1 is the running value of the time used by INTGRAT. When returned to MØTIØN, T1 and TF are equal. NN gives the dimension of the arrays Y, YDØT, TRY1, TRY2, TRY3, ETA, W, and Z, and physically represents the number of equations to be solved. For the free descent calculation phase, NN is twice the allowable number of degrees of freedom. PCTERR and ETA are the relative and absolute error parameters input to the main program. Values of these parameters are discussed in Section IX. ID and ISIGNAL are signals; ID signals to INTGRAT whether or not the call from MØTIØN is the first call and ISIGNAL indicates to MØTIØN whether $|\alpha_p| > 85^o$ (the variable K in MØTIØN is equal to ISIGNAL).

The basic functioning of INTGRAT is as follows. The variable IMDØNE indicates whether or not the integration has proceeded successfully to a solution at the time TF. Initially IMDØNE is set equal to -1. If the call to INTGRAT is the first, indicated by a positive value of ID, the time increment for a first approximation to the integration with the Runge-Kutta formula is taken as TF-T. On subsequent calls, the time increment is taken as DX, which was a suitable time increment at the end of the previous call.

The solution of the equations of motion is approximated by calls to subroutine FØRMULA, which evaluates the Runge-Kutta formula. For a given time increment, the equations are numerically integrated by FØRMULA, over the entire corresponding time interval and the results stored in the array TRY1. To evaluate the acceptability of these results, the equations are then integrated over half the time interval, the integrated quantities being stored in TRY2, and then over the other half of the time interval, yielding results in the array TRY3. The two separate integrations, yielding values of the variables represented by Y at the initial time plus the time increment, are then compared. If any of the quantities in TRY3 and TRY1 differ in absolute value by more than the prescribed relative or absolute errors (PCTERR and ETA), the solution is considered unacceptable. The time increment is then halved and the process repeated until satisfactory results are obtained for Y_i at the time TF.

In this way, the actual time increment used in FØRMULA may become quite small. If, however, five consecutive calls to FØRMULA are made without halving the time increment, the increment is doubled. The number of successful consecutive calls to FØRMULA is stored by the variable M, which continuously counts the calls to FØRMULA disregarding the fact that control may revert to MØTIØN. Thus, the solution method for the free descent phase uses only as small a time increment as is required to meet the prescribed allowable error. If the time increment must be halved twenty times before a successful integration is made, as indicated by MM, control is returned with a signal that the equations cannot be integrated.

The last function of INTGRAT is to call subroutine EMØTIØN to evaluate the derivatives $YDØT_i$ which correspond to the time TF. The third calling parameter of the call to EMØTIØN is 1, indicating that the call comes from INTGRAT rather than FØRMULA. Control is then returned to subroutine MØTIØN.

3. Subroutine FØRMULA

a. Input

None

b. Output

None

c. Formal Parameters

Y, H, YI, NN, W, YDØT, Z, ISIGNAL

d. Common Blocks

None

e. Method

The only function of this subroutine is to evaluate the Runge-Kutta formula for each of the equations being solved. Thus FØRMULA provides an approximation to the integration of the equations of motion by

$$Y_{i,n+1} = Y_{i,n} + \frac{1}{6}(k_0 + 2k_1 + 2k_2 + k_3) \qquad i = 1, 2, \ldots, NN \tag{67}$$

where

$$k_0 = \Delta t \; \dot{Y}_i \, (Y_{i,n})$$
$$k_1 = \Delta t \; \dot{Y}_i \, (Y_{i,n} + \tfrac{1}{2} k_0)$$
$$k_2 = \Delta t \; \dot{Y}_i \, (Y_{i,n} + \tfrac{1}{2} k_1)$$
$$k_3 = \Delta t \; \dot{Y}_i \, (Y_{i,n} + k_0)$$

to yield k_0, k_1, k_2, and k_3 in successive steps of the program.

The evaluation of Eqn (67) is accomplished by means of nested DØ loops. Initially the contents of Z are set equal to the contents of YDØT, and the contents of W and of YI are set equal to Y. A DØ loop is then utilized to call EMØTIØN with W and Z as parameters four times. W is updated after each call by the relation

$$W_i = Y_i + A_K Z_i \quad ; \quad K=1,2,3,4 \tag{68}$$

where

$$A_1 = A_2 = A_5 = \frac{1}{2}\Delta t$$

$$A_3 = A_4 = \Delta t$$

and YI is updated by the relation

$$YI_i = YI_i + \frac{1}{3} A_{K+1} Z_i \quad ; \quad K=1,2,3,4 \tag{69}$$

Relations (68) and (69) are carried out by a DØ loop such that i runs from one to NN. All calls to EMØTIØN have the third calling parameter 2 to indicate that the call comes from FØRMULA rather than INTGRAT. If ISIGNAL indicates that the solution blows up, control is returned to INTGRAT where the time increment is adjusted. After the equation (67) has been successfully evaluated, control is returned to INTGRAT.

4. Subroutine EMØTIØN

a. Input

None

b. Output

None

c. Formal Parameters

Y, YDØT, ISTØP, ISIGNAL

d. Common Blocks

/CØNST/: ALT, PI, G, CDP, DNØT, CDSL, LSS, ML, MP, MSS, MST, NØUSE

/VARIABL/: RHØ, T, V, THETA, X, Z, ALPHAL, ALPHAP, L1

e. Method

The function of EMØTIØN is to evaluate the new array of derivatives YDØT from the given array of values Y and YDØT. The derivatives of U, W, Q, θ, x, and z are not explicit functions of time, and thus the only required information is the values of U, W, Q, θ, x, z, and $\dot{Q}$.

The calculations made by EMØTIØN are as follows. First, calls are made to DENSITY and DYNAMIC to determine the proper values of ℓ_1, ℓ_2, ℓ_3, I_{XX}, I_{YY}, I_{ZZ}, I_{XZ}, m_i and m_a. I_{XX}, I_{ZZ}, and I_{XZ} are not required in the three degrees of freedom solution. The following equations are then evaluated in sequence.

$$V^2 = U^2 + W^2 \tag{70}$$

$$\alpha = \tan^{-1}\left(-\frac{U}{W}\right) \tag{71}$$

$$V_p^2 = V^2 + Q^2 \ell_2^2 + 2UQ\ell_2 \tag{72}$$

$$\alpha_p = \tan^{-1}\left(-\frac{U + Q\ell_2}{W}\right) \tag{73}$$

$$V_\ell^2 = V^2 + Q^2\ell_1^2 + 2UQ\ell_1 \tag{74}$$

$$\alpha_\ell = \tan^{-1}\left(-\frac{U + Q\ell_1}{W}\right) \tag{75}$$

Subroutine CØEFFTS is then called to give the values of C_{T_O}, C_{N_O}, and C_{M_O} corresponding to α_p. Calling parameter ISTØP indicates to CØEFFTS whether the call to EMØTIØN was from INTGRAT or FØRMULA, and ISIGNAL indicates whether $|\alpha_p| < 85^\circ$. If $|\alpha_p|$ is too large, control is returned to the calling program. The equations of motion are then evaluated if $|\alpha_p| < 85^\circ$, i.e.

$$\dot{U} = -\left(\frac{m_i + m_a}{m_T}\right)\dot{Q}\ell_2 - \left(\frac{m_\ell + m_{ss} + m_p}{m_T}\right) g \sin\theta + \frac{F_N}{m_T} + \frac{D}{m_T}\sin\alpha_\ell - QW \tag{76}$$

$$\dot{W} = \left(\frac{m_i + m_a}{m_T}\right) Q^2\ell_2 + \left(\frac{m_\ell + m_{ss} + m_p}{m_T}\right) g \sin\theta - \frac{T}{m_T} - \frac{D}{m_T}\cos\alpha_\ell + QU \tag{77}$$

$$\dot{Q} = \frac{F_N \ell_3}{I_{YY}} + \frac{D\ell_1 \sin\alpha_\ell}{I_{YY}} + \frac{M_A}{I_{YY}} - \frac{(m_\ell \ell_1 + m_p \ell_2)\, g\sin\theta}{I_{YY}} \tag{78}$$

$$\dot{\theta} = Q \tag{79}$$

$$\dot{x} = U\cos\theta + W\sin\theta \tag{80}$$

$$\dot{z} = -U\sin\theta + W\cos\theta \tag{81}$$

The relation between the quantities as expressed above and the arrays Y and YDØT is

$$Y(1) = U \;, \quad YD\emptyset T(1) = \dot{U}$$

$$Y(2) = W \;, \quad YD\emptyset T(2) = \dot{W}$$

$$Y(3) = Q \;, \quad YD\emptyset T(3) = \dot{Q}$$

$$Y(4) = \theta \;, \quad YD\emptyset T(4) = \dot{\theta}$$

$$Y(5) = x \;, \quad YD\emptyset T(5) = \dot{x}$$

$$Y(6) = z \;, \quad YD\emptyset T(6) = \dot{z}$$

Control is then returned to the calling program, either INTGRAT or FØRMULA.

5. Subroutine DYNAMIC

a. Input

None

b. Output

None

c. Formal Parameters

RHØ, L1, L2, L3, IXX, IYY, IZZ, IXZ, MI.

d. Common Blocks

/DYNAM/: DNØT, X1, X2, X3, X4, X5, MBR, ML, MLS, MP, MR, MRX, IAZO, IZ

e. Method

The equations programmed in DYNAMIC are:

$$m_i = \rho V \tag{82}$$

$$\bar{S} = \frac{XNUM - m_i S_c}{XDEN\emptyset M + m_i} \tag{83}$$

$$\ell_1 = S_5 - \bar{S} \tag{84}$$

$$\ell_2 = -\bar{S} - S_c \tag{85}$$

$$\ell_3 = D_o - \bar{S} \tag{86}$$

$$I_a = (0.13195)\, \rho\, D_p^3\, \ell_2^2 \tag{87}$$

$$I_Y = m_p \ell_2^2 + m_{Ls}(\bar{s}-s_1)^2 + m_R(s_2-\bar{s})^2 + m_E(s_2-\bar{s})^2 + m_{Br}(s_4-\bar{s})^2 + m_\ell \ell_1^2 \tag{88}$$

$$I_{YY} = I_Y + I_a \tag{89}$$

$$I_{XX} = I_{YY} \tag{90}$$

$$I_{ZZ} = I_Z + I_{a_Z})_o \left[\frac{\rho}{(.002378)}\right] \tag{91}$$

$$I_{XZ} = 0 \tag{92}$$

Thus the present arrangement of the computer solution is for parachutes which are rotationally symmetric. For a parachute without rotational symmetry, subroutine DYNAMIC must be modified for the appropriate components of the inertia tensor. After evaluation of the above equations, control is returned to the calling program.

6. Subroutine CØEFFTS

a. Input

None

b. Output

None

c. Formal Parameters

ALPHAP, CT, CN, CM, IPRINT, ISIGNAL

d. Common Blocks

None

e. Method

The function of this subroutine is to evaluate the aerodynamic coefficients corresponding to the parachute angle of attack. If α_p is larger in absolute value than 85^o, the parameter ISIGNAL is set equal to +1 and control returned immediately. If IPRINT is 1 a message indicating this occurrence is printed, and the successive travel of parameter ISIGNAL will cause the particular run to terminate. Otherwise, the only result will be to decrease the time increment in subroutine INTGRAT, after control is returned by means of EMØTIØN and FØRMULA.

If α_p is within the acceptable range, the following results are calculated for solid flat circular or T-10 parachutes:

Solid Flat Circular:

for $|\alpha_p| < 30^o$

$$C_{T_o} = 0.647 - (1.2 \times 10^{-5}) |\alpha_p| + (9.15 \times 10^{-4}) |\alpha_p|^2 - (7.13 \times 10^{-5}) |\alpha_p|^3 + (1.33 \times 10^{-6}) |\alpha_p|^4 \quad (93)$$

$$C_{N_o} = -(6.74 \times 10^{-3}) \alpha_p + (5.57 \times 10^{-4}) \alpha_p^2 - (1.53 \times 10^{-5}) \alpha_p^3 + (1.9 \times 10^{-7}) \alpha_p^4 \quad (94)$$

$$(\alpha_p > 0)$$

$$C_{M_o} = (4.844 \times 10^{-3})\,\alpha_p - (3.94 \times 10^{-4})\,\alpha_p^2 + (1.043 \times 10^{-5})\,\alpha_p^3 - (1.32 \times 10^{-7})\,\alpha_p^4 \quad (\alpha_p > 0) \tag{95}$$

for $|\alpha_p| \geq 30^{\circ}$

$$C_{T_o} = 0.62 \tag{96}$$

$$C_{N_o} = (.0056)(\alpha_p - 30^{\circ}) + .04 \qquad (\alpha_p > 0) \tag{97}$$

$$C_{M_o} = -(.0044)(\alpha_p - 30^{\circ}) - .034 \qquad (\alpha_p > 0) \tag{98}$$

T-10:
for $|\alpha_p| < 30^{\circ}$

$$C_{T_o} = 0.570 - (2.48 \times 10^{-3})\,|\alpha_p| + (1.219 \times 10^{-3})\,|\alpha_p|^2 - (7.687 \times 10^{-5})\,|\alpha_p|^3 + (1.2797 \times 10^{-6})\,|\alpha_p|^4 \tag{99}$$

$$C_{N_o} = -(2.058 \times 10^{-2})\,\alpha_p + (1.95 \times 10^{-3})\,\alpha_p^2 + (6.022 \times 10^{-5})\,\alpha_p^3 - (6.827 \times 10^{-7})\,\alpha_p^4 \quad (\alpha_p > 0) \tag{100}$$

$$C_{M_o} = (1.845 \times 10^{-2})\,\alpha_p - (1.929 \times 10^{-3})\,\alpha_p^2 + (6.78 \times 10^{-5})\,\alpha_p^3 - (8.709 \times 10^{-7})\,\alpha_p^4 \quad (\alpha_p > 0) \tag{101}$$

for $\alpha_p \geq 30^o$

$$C_{T_o} = -(.0032)(|\alpha_p| - 30^o) + .553 \tag{102}$$

$$C_{N_o} = (.0072)(\alpha_p - 30^o) + .064 \quad (\alpha_p > 0) \tag{103}$$

$$C_{M_o} = -(.0060)(\alpha_p - 30^o) - .056 \quad (\alpha_p > 0) \tag{104}$$

The proper subroutine must be inserted for computer trajectory simulations with a given parachute type so that the corresponding aerodynamic coefficients are used. Any parachute type other than the solid flat circular or T-10 may be used by properly providing the aerodynamic coefficients by means of subroutine CØEFFTS in the manner outlined here for solid flat circular and T-10 parachutes.

E. Free Descent; Six Degrees of Freedom

The free descent calculation phase follows the same organization when six degrees of freedom are allowed as when the trajectory simulation is restricted to three degrees of freedom. The names of the subroutines are the same for the six degree of freedom solution as for the solution allowing only three degrees of freedom, with the exception of the addition of subroutine CØSINES for the six degree of freedom case. The subroutines INTGRAT, FØRMULA, and DYNAMIC are identical for both cases. Subroutines MØTIØN, EMØTIØN, and CØEFFTS are not the same when six degrees of freedom are allowed. In the following, only subroutines MØTIØN, EMØTIØN, CØEFFTS, and CØSINES are discussed.

1. Subroutine MØTIØN

a. Input

TSTØP, ZSTØP

b. Output

ALL NINT: T, ALT-RZ, RX, RY, RZ, V, VX, VY, VZ, AT, at the first three instances the parachute-load system is vertical or near vertical

NINT > 0: T, ALT-RZ, SYSANGL, TRAJANG, RX, RY, RZ, V, VX, VY, VZ, AT

c. Formal Parameters

DQ, PCTERR, ETA, DT

d. Common Blocks

/CØNST/: ALT, PI, G, CDP, DNØT, CDSL, LSS, ML, MP, MSS, MST, NINT

/VARIABL/: RHØ, T, V, THETA, X, Z, ALPHAL, ALPHAP, L1

e. Method

The basic aspects of subroutine MØTIØN are the same for the three and six degree of freedom cases. All input and output is the same, except that position and velocity components in the y-direction are included when all six degrees of freedom are allowed. The procedures for output and for calling the solution routine INTGRAT with variable time increments are exactly the same. After each call to INTGRAT, the position, velocity, and acceleration components of the load are evaluated by

$$r_{\ell_x} = x + \ell_1 a_{13} \tag{105}$$

$$r_{\ell_y} = y + \ell_1 a_{23} \tag{106}$$

$$r_{\ell_z} = z + \ell_1 a_{33} \tag{107}$$

$$v_{\ell_x} = (U + Q\ell_1)\, a_{11} + (V - P\ell_1)\, a_{12} + W\, a_{13} \tag{108}$$

$$v_{\ell_y} = (U + Q\ell_1)\, a_{21} + (V - P\ell_1)\, a_{22} + W\, a_{23} \tag{109}$$

$$v_{\ell_z} = (U + Q\ell_1)\, a_{31} + (V - P\ell_1)\, a_{32} + W\, a_{33} \tag{110}$$

$$c_3 = \dot{U} + QW - RV + \dot{Q}\ell_1 + PR\ell_1 \tag{111}$$

$$c_4 = \dot{V} + RU - PW - \dot{P}\ell_1 + QR\ell_1 \tag{112}$$

$$c_5 = \dot{W} - PV - QU - (P^2 + Q^2)\ell_1 \tag{113}$$

$$a_{\ell_x} = c_3 a_{11} + c_4 a_{12} + c_5 a_{13} \tag{114}$$

$$a_{\ell_y} = c_3 a_{21} + c_4 a_{22} + c_5 a_{23} \tag{115}$$

$$a_{\ell_z} = c_3 a_{31} + c_4 a_{32} + c_5 a_{33} \tag{116}$$

For the six degree of freedom case, the system angle and load trajectory angle are defined by

$$\alpha_s = \cos^{-1}(a_{33}) \tag{117}$$

$$\alpha_{t\ell} = \cos^{-1}\left\{ \frac{V_{\ell_z}}{\left[V_{\ell_x}^2 + V_{\ell_y}^2 + V_{\ell_z}^2\right]^{1/2}} \right\} \tag{118}$$

The values of the trajectory parameters corresponding to the first three vertical positions are stored in the array VERTPAR and are determined in the same manner as for the three degrees of freedom. When the termination condition TSTØP or ZSTØP is exceeded, the trajectory parameters at the given condition are approximated by linear interpolation and control is returned to the main program.

2. Subroutine EMØTIØN

a. Input

None

b. Output

None

c. Formal Parameters

Y, YDØT, ISTØP, ISIGNAL

d. Common Blocks

/CØNST/: ALT, PI, G, CDP, DNØT, CDSL, LSS, ML, MP, MSS, MST, NØUSE

/VARIABL/: RHØ, T, V, THETA, X, Z, ALPHAL, ALPHAP, L1

e. Method

The purpose of EMØTIØN is to evaluate the equations of motion, providing the array YDØT containing the time derivatives of the twelve variables given the previously existing values of Y and YDØT. The calculation procedure for subroutine EMØTIØN is as follows. The values of ℓ_1, ℓ_2, ℓ_3, I_{XX}, I_{YY}, I_{ZZ}, I_{XZ}, m_i, and m_a are determined by means of calls to DENSITY and DYNAMIC. EMØTIØN then finds the following quantities:

$$U_\ell = U + Q\ell_1 \tag{119}$$

$$V_\ell = V - P\ell_1 \tag{120}$$

$$U_p = U + Q\ell_2 \tag{121}$$

$$V_p = V - P\ell_2 \tag{122}$$

$$v_\ell^2 = U_\ell^2 + V_\ell^2 + W^2 \tag{123}$$

$$v_p^2 = U_p^2 + V_p^2 + W^2 \tag{124}$$

$$\alpha_\ell = \tan^{-1}\left(-\frac{U_\ell}{W}\right) \tag{125}$$

$$\beta_\ell = \tan^{-1}\left(\frac{V_\ell}{W}\right) \tag{126}$$

$$\gamma_\ell = \tan^{-1}\left\{\frac{V_\ell}{(U_\ell^2 + W^2)^{1/2}}\right\} \tag{127}$$

$$\delta_\ell = \tan^{-1}\left\{\frac{U_\ell}{(V_\ell^2 + W^2)^{1/2}}\right\} \tag{128}$$

$$\alpha_p = \tan^{-1}\left(-\frac{U_p}{W}\right) \tag{129}$$

$$\beta_p = \tan^{-1}\left(\frac{V_p}{W}\right) \tag{130}$$

$$\theta_p = \cos^{-1}\left\{\frac{W}{(U_p^2 + V_p^2 + W^2)^{1/2}}\right\} \tag{131}$$

θ_p represents the angle between the systems axis and the parachute velocity in the plane formed by the systems axis and the parachute velocity. The aerodynamic coefficients are then found by calling CØEFFTS; α_p, β_p, and θ_p are supplied and C_{T_o}, C_{X_o}, C_{Y_o}, C_{MX_o}, and C_{MY_o} are returned from CØEFFTS. The signals ISTØP and ISIGNAL in the call to CØEFFTS represent the same signals as in the three degree of freedom case. The aerodynamic forces and moments are given by

$$F_{NX} = \frac{1}{2} \rho V_p^2 C_{NX_o} S_o \tag{132}$$

$$F_{NY} = \frac{1}{2} \rho V_p^2 C_{NY_o} S_o \tag{133}$$

$$T = \frac{1}{2} \rho V_p^2 C_{T_o} S_o \tag{134}$$

$$M_{AX} = \frac{1}{2} \rho V_p^2 C_{MX_o} S_o D_o \tag{135}$$

$$M_{AY} = \frac{1}{2} \rho V_p^2 C_{MY_o} S_o D_o \tag{136}$$

The direction cosines are evaluated by a call to CØSINES, and the equations of motion are then evaluated:

$$\dot{U} = \left(\frac{m_\ell + m_{ss} + m_p}{m_T}\right) g\, a_{31} + \frac{D_\ell}{m_T} \cos\gamma_\ell \sin\alpha_\ell + \frac{F_{NX}}{m_T} - \left(\frac{m_i + m_a}{m_T}\right) \ell_2 (\dot{Q} + PR) - QW + RV \tag{137}$$

$$\dot{V} = \left(\frac{m_\ell + m_{ss} + m_p}{m_T}\right) g a_{32} - \frac{D_\ell}{m_T} \cos \delta_\ell \sin \beta_\ell$$
$$+ \frac{F_{NY}}{m_T} + \left(\frac{m_i + m_a}{m_T}\right) \ell_2 (\dot{P} - QR) + PW - RU \tag{138}$$

$$\dot{W} = \left(\frac{m_\ell + m_{ss} + m_p}{m_T}\right) g a_{33} - \frac{D_\ell}{m_T} \cos \gamma_\ell \cos \alpha_\ell$$
$$- \frac{T}{m_T} + \left(\frac{m_i + m_a}{m_T}\right) \ell_2 (P^2 + Q^2) - PV + QU \tag{139}$$

$$\dot{P} = -\frac{F_{NY} \ell_3}{I_{XX}} + \frac{M_{AX}}{I_{XX}} + \frac{D_\ell}{I_{XX}} \cos \delta_\ell \sin \beta_\ell \, \ell_1$$
$$- \frac{g a_{32}}{I_{XX}} (m_\ell \ell_1 + m_p \ell_2) + \dot{R} \frac{I_{XZ}}{I_{XX}} - QR\left(\frac{I_{ZZ} - I_{YY}}{I_{XX}}\right) + PQ \frac{I_{XZ}}{I_{XX}} \tag{140}$$

$$\dot{Q} = \frac{F_{NX} \ell_3}{I_{YY}} + \frac{M_{AY}}{I_{YY}} + \frac{D_\ell}{I_{YY}} \cos \gamma_\ell \sin \alpha_\ell \, \ell_1$$
$$+ \frac{g a_{31}}{I_{YY}} (m_\ell \ell_1 + m_p \ell_2) - PR\left(\frac{I_{XX} - I_{ZZ}}{I_{YY}}\right) - (P^2 - R^2) \frac{I_{XZ}}{I_{YY}} \tag{141}$$

$$\dot{R} = \dot{Q} \frac{I_{XZ}}{I_{ZZ}} - PQ \frac{(I_{YY} - I_{XX})}{I_{ZZ}} - QR \frac{I_{XZ}}{I_{ZZ}} \tag{142}$$

$$\dot{\theta} = Q \cos\varphi - R \sin\varphi \tag{143}$$

$$\dot{\varphi} = P + Q \sin\varphi \tan\theta + R \cos\varphi \tan\theta \tag{144}$$

$$\dot{\psi} = (Q \sin\varphi + R \cos\varphi) \sec\theta \tag{145}$$

$$\dot{x} = U a_{11} + V a_{12} + W a_{13} \tag{146}$$

$$\dot{y} = U a_{21} + V a_{22} + W a_{23} \tag{147}$$

$$\dot{z} = U a_{31} + V a_{32} + W a_{33} \tag{148}$$

Control is then returned to the main program.

3. Subroutine CØSINES

a. Input

None

b. Output

None

c. Formal Parameters

A, Y

d. Common Blocks

None

e. Method

The formal parameters of CØSINES are A and Y. A is a 3 x 3 array representing the direction cosine matrix, whose components are functions of the Euler angles. The subroutine merely evaluates the following relationships:

$$a_{11} = \cos\theta \cos\psi \tag{149}$$

$$a_{12} = \sin\varphi \sin\theta \cos\psi - \cos\varphi \sin\psi \tag{150}$$

$$a_{13} = \cos\varphi \sin\theta \cos\psi + \sin\varphi \sin\psi \tag{151}$$

$$a_{21} = \cos\theta \sin\psi \tag{152}$$

$$a_{22} = \sin\varphi \sin\theta \sin\psi - \cos\varphi \cos\psi \tag{153}$$

$$a_{23} = \cos\varphi \sin\theta \sin\psi - \sin\varphi \cos\psi \tag{154}$$

$$a_{31} = -\sin\theta \tag{155}$$

$$a_{32} = \sin\varphi \cos\theta \tag{156}$$

$$a_{33} = \cos\varphi \cos\theta \tag{157}$$

Control is then returned to the calling program.

4. Subroutine COEFFTS

a. Input

None

b. Output

None

c. Formal Parameters

ALPHAP, BETAP, PØLANG, CT, CX, CY, CMX, CMY, IPRINT, ISIGNAL

d. Common Blocks

None

e. Method

This subroutine supplies the aerodynamic coefficients as functions of the parachute angles α_p, β_p, and θ_p. At present, measurements of the functional relationships which are required are not avilable. As an example of a possible arrangement for this subroutine, the following relationships are based on two-dimensional measurements for a solid flat circular parachute (Ref 3):

$$C_{T_o} = 0.647 - (1.2\times10^{-5})\,|\theta_p| + (9.15\times10^{-4})\,|\theta_p|^2 - (7.13\times10^{-5})\,|\theta_p|^3 + (1.33\times10^{-6})\,|\theta_p|^4, \quad |\theta_p| < 30^\circ \tag{158}$$

$$C_{N\mathrm{X}_o} = -(6.74 \times 10^{-3})\,\alpha_p + (5.57 \times 10^{-4})\,\alpha_p^2 - (7.13 \times 10^{-5})\,\alpha_p^3 + (1.9 \times 10^{-7})\,\alpha_p^4 \,, \qquad 0 \le \alpha_p < 30^\circ \tag{159}$$

$$C_{N\mathrm{Y}_o} = -(6.74 \times 10^{-3})\,\beta_p + (5.57 \times 10^{-4})\,\beta_p^2 - (7.13 \times 10^{-5})\,\beta_p^3 + (1.9 \times 10^{-7})\,\beta_p^4 \,, \qquad 0 \le \beta_p < 30^\circ \tag{160}$$

$$C_{M\mathrm{Y}_o} = (4.844 \times 10^{-3})\,\alpha_p - (3.94 \times 10^{-4})\,\alpha_p^2 + (1.043 \times 10^{-5})\,\alpha_p^3 - (1.32 \times 10^{-7})\,\alpha_p^4 \,, \qquad 0 \le \alpha_p < 30^\circ \tag{161}$$

$$C_{M\mathrm{X}_o} = (4.844 \times 10^{-3})\,\beta_p - (3.94 \times 10^{-4})\,\beta_p^2 + (1.043 \times 10^{-5})\,\beta_p^3 - (1.32 \times 10^{-7})\,\beta_p^4 \,, \qquad 0 \le \beta_p < 30^\circ \tag{162}$$

$$C_{T_o} = 0.62 \,, \qquad |\theta_p| \ge 30^\circ \tag{163}$$

$$C_{N\mathrm{X}_o} = (.0056)(\alpha_p - 30^\circ) + .04 \qquad \alpha_p \ge 30^\circ \tag{164}$$

$$C_{NY_0} = (.0056)(\beta_p - 30^\circ) + .04 \qquad (165)$$
$$\beta_p \geq 30^\circ$$

$$C_{MY_0} = -(.0044)(\alpha_p - 30^\circ) - .034 \qquad (166)$$
$$\alpha_p \geq 30^\circ$$

$$C_{MX_0} = -(.0044)(\beta_p - 30^\circ) - .034 \qquad (167)$$
$$\beta_p \geq 30^\circ$$

Limits must be set on the allowable magnitude of the angles to prevent the solution from blowing up. When any of the angles are larger in absolute value than, for example, 85°, the parameter ISIGNAL so indicates. After the coefficients are determined, or the angles exceed the limit, control is returned to the calling program.

F. DENSITY and TRAJEQN

1. Subroutine DENSITY

a. Input

None

b. Output

None

c. Formal Parameters

RHØ, H

d. Common Blocks

None

e. Method

This subroutine provides the value of the air density at altitude h, as follows:

$$\rho = (0.002378)\, e^{-h/32{,}916}, \quad 0 \le h \le 15{,}000 \text{ ft}$$

(168)

$$\rho = (0.002378)(1.07133)\, e^{-h/28{,}953}, \quad 15{,}000 \text{ ft} \le h \le 35{,}000 \text{ ft}$$

2. Subroutine TRAJEQN

a. Input

None

b. Output

None

c. Formal Parameters

T, V, THETA, X, Z, RHØ, CDS, M, DT, G, ALT, DV

d. Common Blocks

None

e. Method

This subroutine evaluates the following two-dimensional point mass trajectory equations:

$$\Delta v = \left[g \cos \theta - \frac{\rho v^2 C_D S}{2m} \right] \Delta t \tag{169}$$

$$\Delta \theta = - \frac{g \sin \theta}{v} \Delta t \tag{170}$$

$$\Delta x = v \sin \theta \, \Delta t \tag{171}$$

$$\Delta z = v \cos \theta \, \Delta t \tag{172}$$

and then adds these finite increments to v, θ, x, z, and t.

IV. CALLING PARAMETERS

The calling parameters for each call by the various calling programs to each subroutine are listed in the following. The formal parameter list of the particular subroutine is shown first for a reference, followed by the call statements in the indicated subroutine.

A. EXTRACT (ISNATCH, IEXTRAC, VO, DT, TRCA)

MAIN PRØGRAM:

CALL EXTRACT (ISNATCH, IEXTRAC, VO, DT1, TRCA)

B. SNATCH (TRCA, DT)

MAIN PRØGRAM:

CALL SNATCH (TRCA, DT1)

C. BØDIES (M1, CDS1, M2, CDS2, V1, V2, L, DT)

SNATCH:

CALL BØDIES (M1, CDS1, CAPM2, CDS2, V1, V2, L, DT)
CALL BØDIES (M1, CDS1, MPBAG, CDS2, V1, V2, L, DT)

```
D.   ØPENING   (DQ, TRCA,   N,      F, VØLUMG, IEXTRAC, DTT)

MAIN PRØGRAM:

CALL ØPENING   (DQ, TRCA, NNN, SPACE, VØLUME, IEXTRAC , DT3)


E.   FILLTIM   (VØLUME, VO, XO, ZO, THETAO, MS, HO,H1,
                N, VØLDØT, TF)

ØPENING:

CALL FILLTIM   (VØLUME, VO, XO, ZO, THETAO, MS, HO, H1,
                N,       F, TF)
CALL FILLTIM   (VØLUME, VO, XO, ZO, THETAO, MS, HO, H1,
                N,       F, TF)


F.   CALC      (CAPT, TF, DCAPT, DCAPTR,  M, DV, DP, D)

ØPENING:

CALL CALC      (CAPT, TF, DCAPT, DCAPTR, MS, DV, DP, D)
CALL CALC      (CAPT, TF, DCAPT, DCAPTR, MS, DV, DP, D)

FILLTIM:

CALL CALC      (CAPT, TF, DCAPT, DCAPTR, MS, DV, DP, D)


G.   MØTIØN    (DQ, PCTERR, ETA,  DT)

MAIN PRØGRAM:

CALL MØTIØN    (DQ, PCTERR, ETA, DT3)
```

```
H.    INTGRAT   (T, Y, TF, NN, PCTERR, ETA, TRY1, TRY2,
                  TRY3, W, YDØT, Z, ID, DX, T1, ISIGNAL)
```

MØTIØN (Three Degrees of Freedom):

```
CALL INTGRAT   (T, Y, TF, 6, PCTERR, ETA,     X1,    X2,
                   X3, W, YDØT, B, ID, DX, T1,        K)
```

MØTIØN (Six Degrees of Freedom):

```
CALL INTGRAT   (T, Y, TF, 12, PCTERR, ETA,    X1,    X2,
                   X3, W, YDØT, B, ID, DX, T1,        K)
```

```
I.    EMØTIØN   (Y, YDØT, ISTØP, ISIGNAL)
```

FØRMULA:

```
CALL EMØTIØN   (W,    Z,      2, ISIGNAL)
```

INTGRAT:

```
CALL EMØTIØN   (Y, YDØT,      1, ISIGNAL)
```

```
J.    DYNAMIC   (      RHØ, L1, L2, L3, IXX, IYY, IZZ, IXZ, MI)
```

MAIN PRØGRAM:

```
CALL DYNAMIC   (0.002378, A1, A2, A3,  A4,  A5,  A6,  A7, A8)
CALL DYNAMIC   (     RHØ, B1, B2, B3,  B4,  B5,  B6,  B7, B8)
```

EMØTIØN:

```
CALL DYNAMIC   (     RHØ, L1, L2, L3, IXX, IYY, IZZ, IXZ, MI)
```

K. CØEFFTS (ALPHAP, CT, CN, CM, IPRINT, ISIGNAL)

EMØTIØN (Three Degrees of Freedom):

CALL COEFFTS (ALPHAP, CT, CN, CM, ISTØP, ISIGNAL)

L. CØEFFTS (ALPHAP,BETAP, PØLANG, CT, CX, CY, CMX, CMY, IPRINT, ISIGNAL)

EMØTIØN (Six Degrees of Freedom):

CALL CØEFFTS (ALPHAP, BETAP, PØLANG, CT, CX, CY, CMX, CMY, ISTØP, ISIGNAL)

M. CØSINES (A, Y)

MØTIØN (Six Degrees of Freedom):

CALL CØSINES (A, Y)

EMØTIØN (Six Degrees of Freedom):

CALL CØSINES (A, Y)

N. DENSITY (RHØ, H)

MAIN PROGRAM:

CALL DENSITY (RHØ, ALT)

BØDIES, TRAJEQN, CALC:

CALL DENSITY (RHØ, ALT-Z)

EMØTIØN (Three Degrees of Freedom):

CALL DENSITY (RHØ, ALT-Y(6))

EMØTIØN (Six Degrees of Freedom):

CALL DENSITY (RHØ, ALT-Y(12))

O. TRAJEQN (T, V, THETA, X, Z, RHØ, CDS, M, DT, G, ALT, DV)

EXTRACT:

CALL TRAJEQN (T, V, THETA, X, Z, RHØ, CDST, MT, DT, G, ALT, DV)

CALL TRAJEQN (T, V, THETA, X, Z, RHØ, CDST, MT, DT, G, ALT, DV)

ØPENING:

CALL TRAJEQN (T, V, THETA, X, Z, RHØ, CDST, MS, DTT, G, ALT, DV)

V. FLOW CHARTS

This section includes flow charts for the main program and for all of the computer program subroutines. The order of presentation corresponds to the order in which they are discussed in Section III. All details of the input and output in the various subroutines are not indicated. Input and/or output are treated in detail only where required for a basic understanding of the computer program.

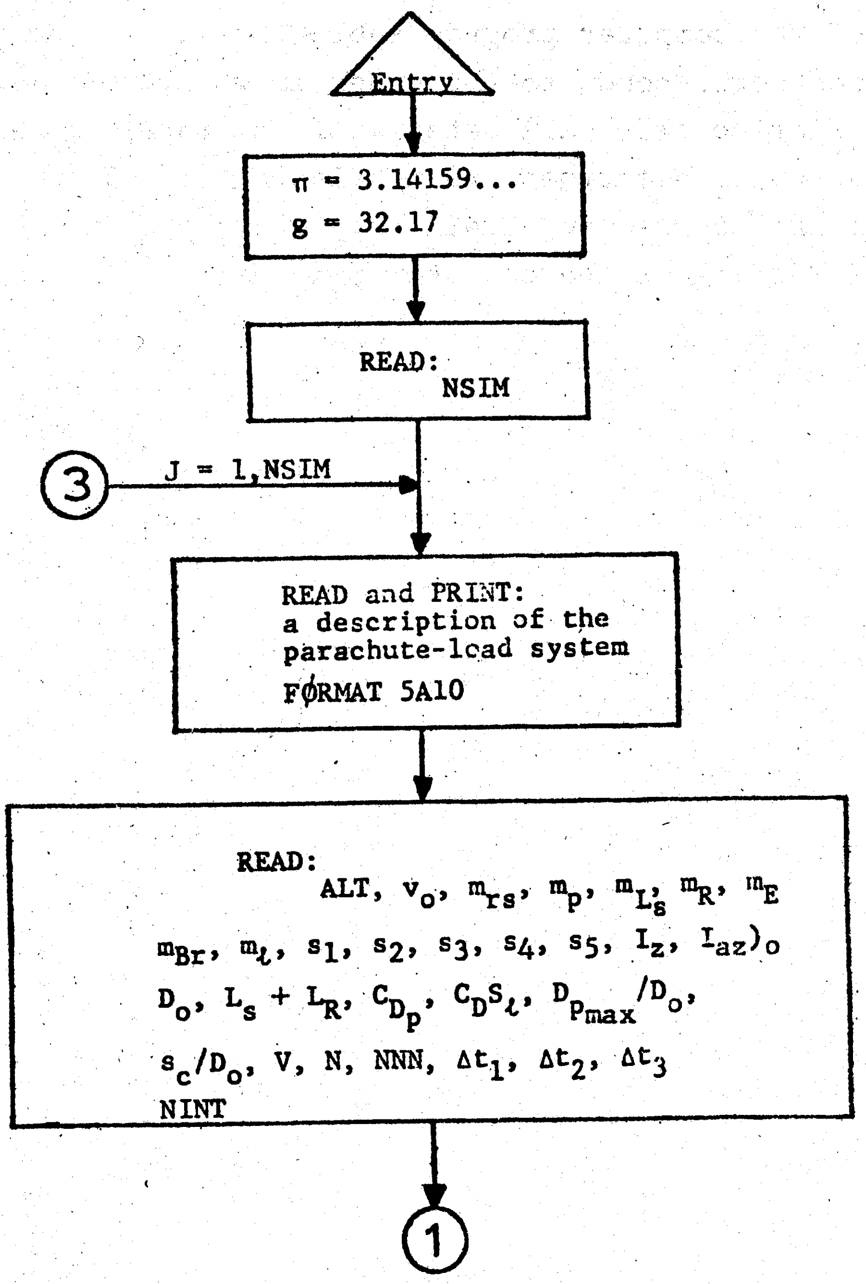

FIG 10 MAIN PRØGRAM

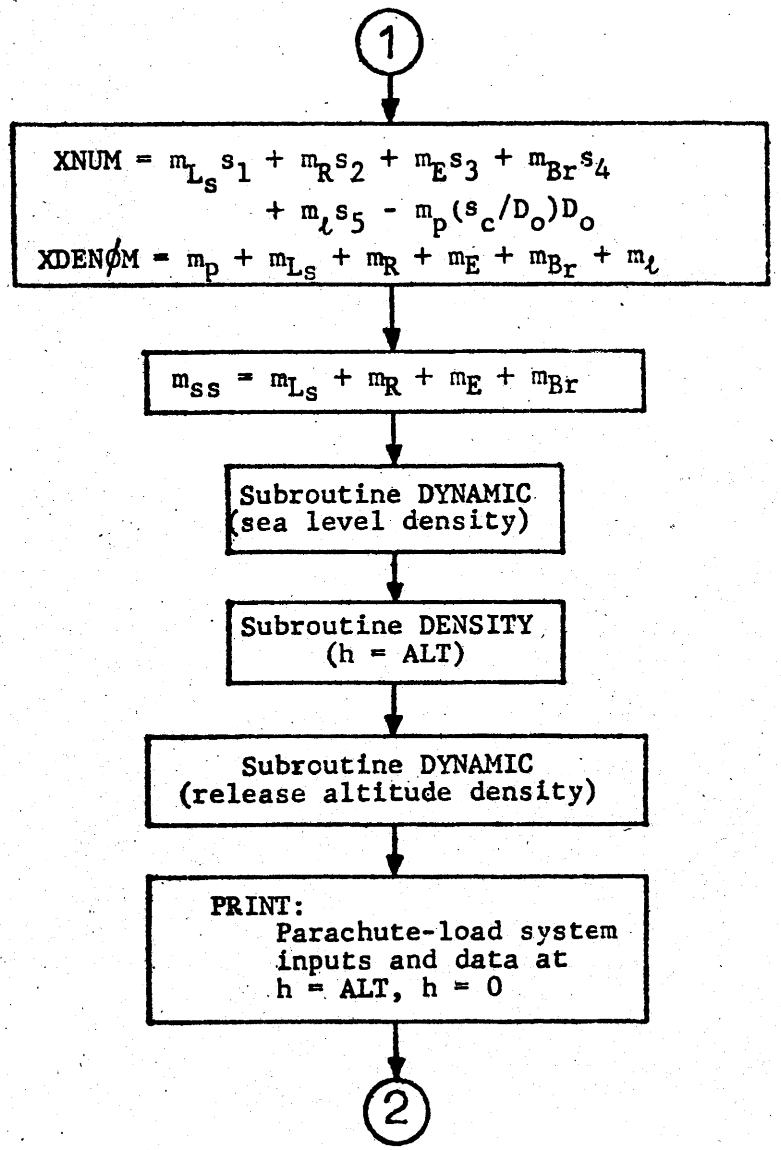

FIG 10 MAIN PRØGRAM (Continued)

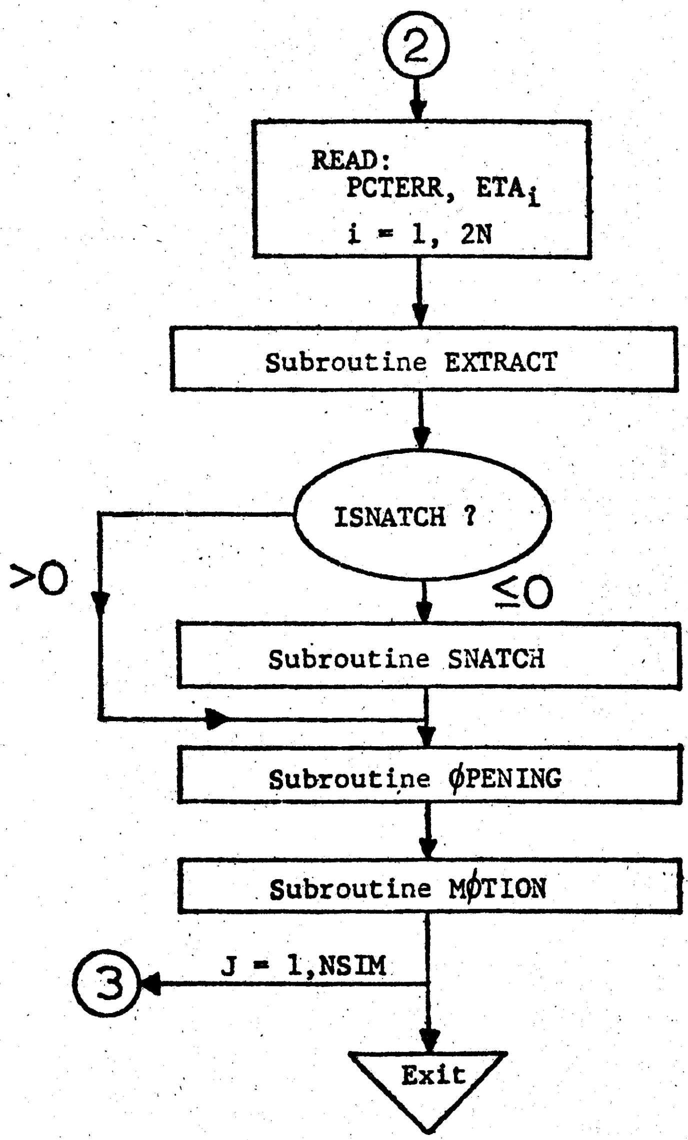

FIG 10 MAIN PRØGRAM (Concluded)

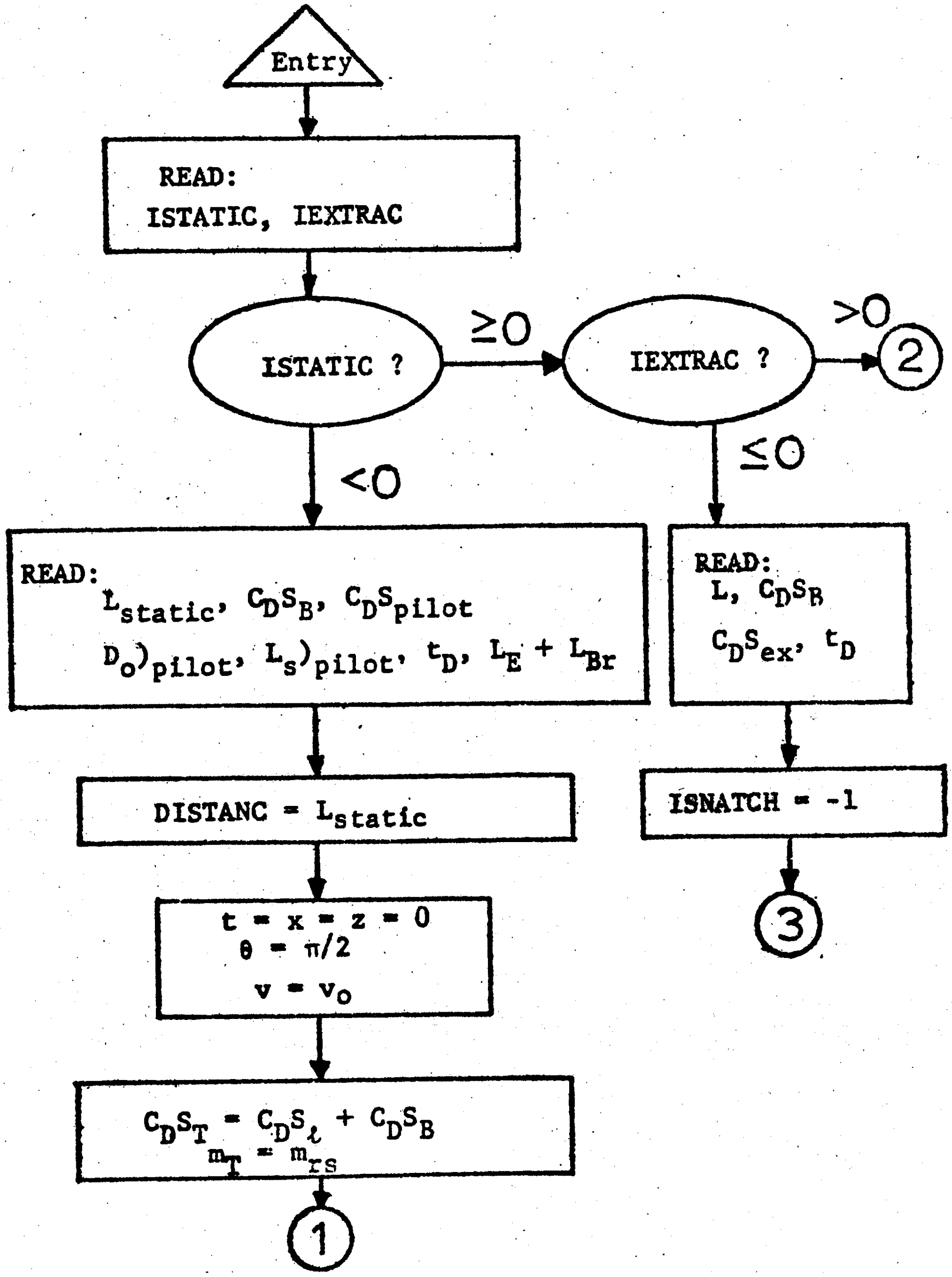

FIG 11 Subroutine EXTRACT

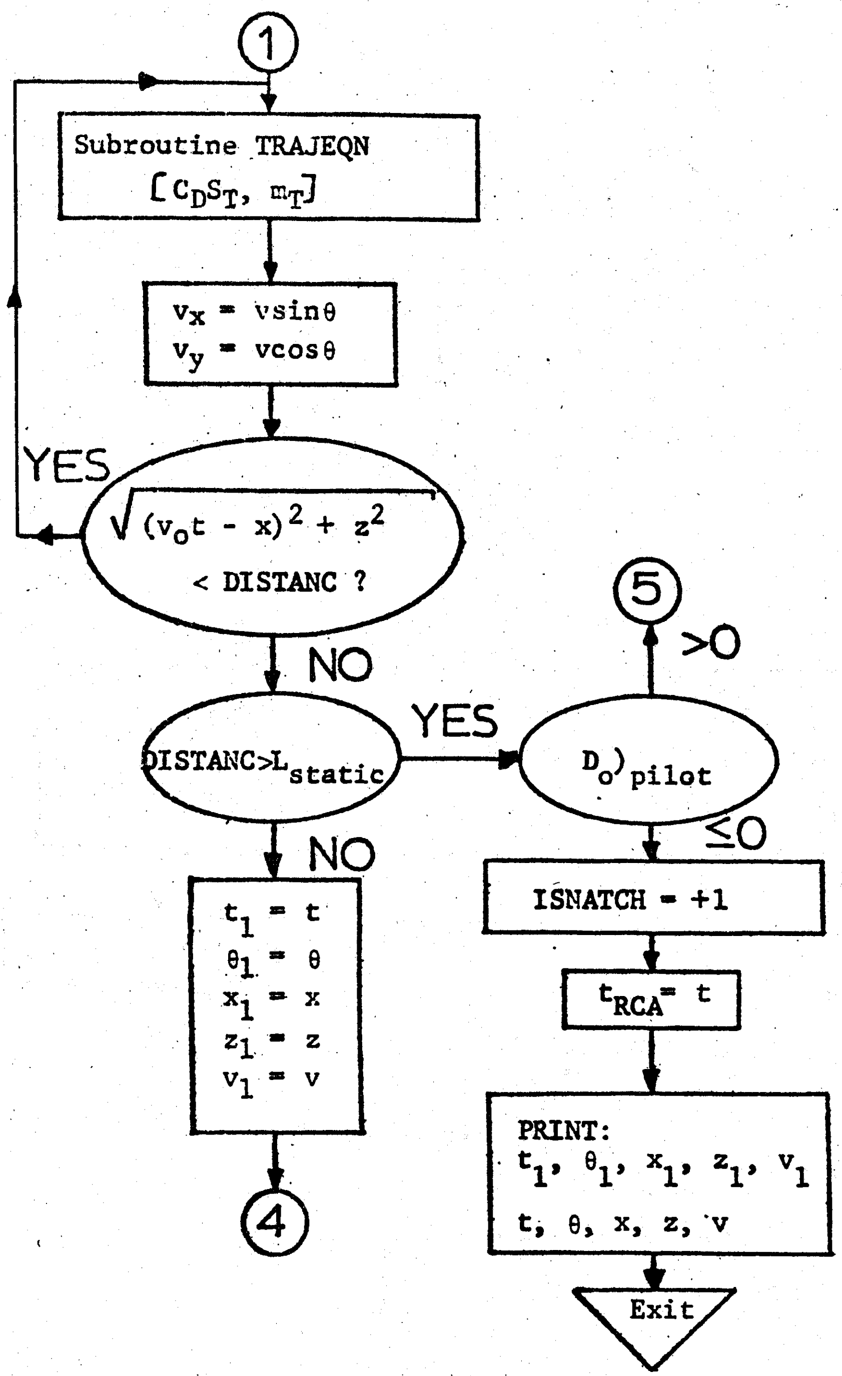

FIG 11 Subroutine EXTRACT (Continued)

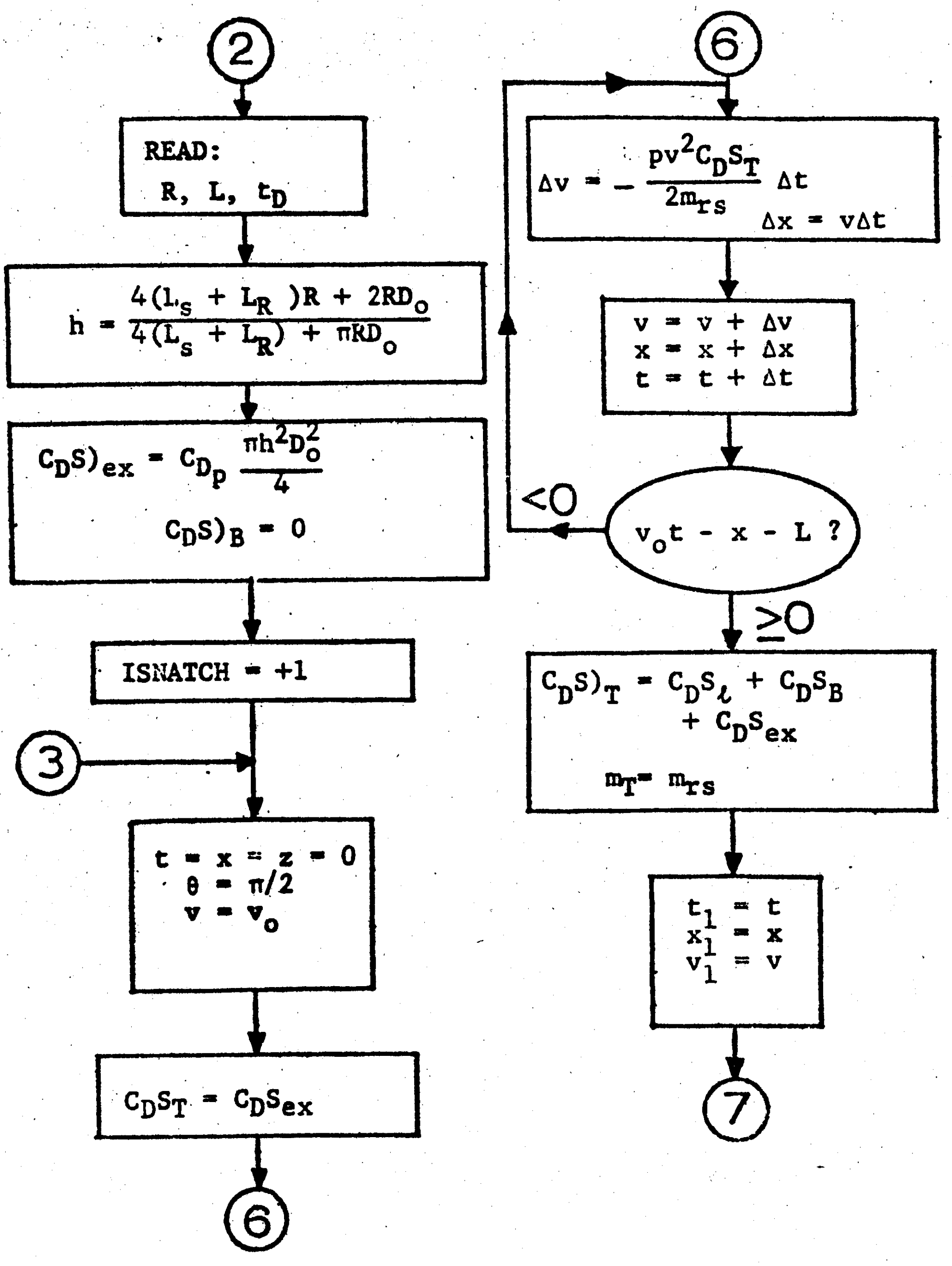

FIG 11 Subroutine EXTRACT (Continued)

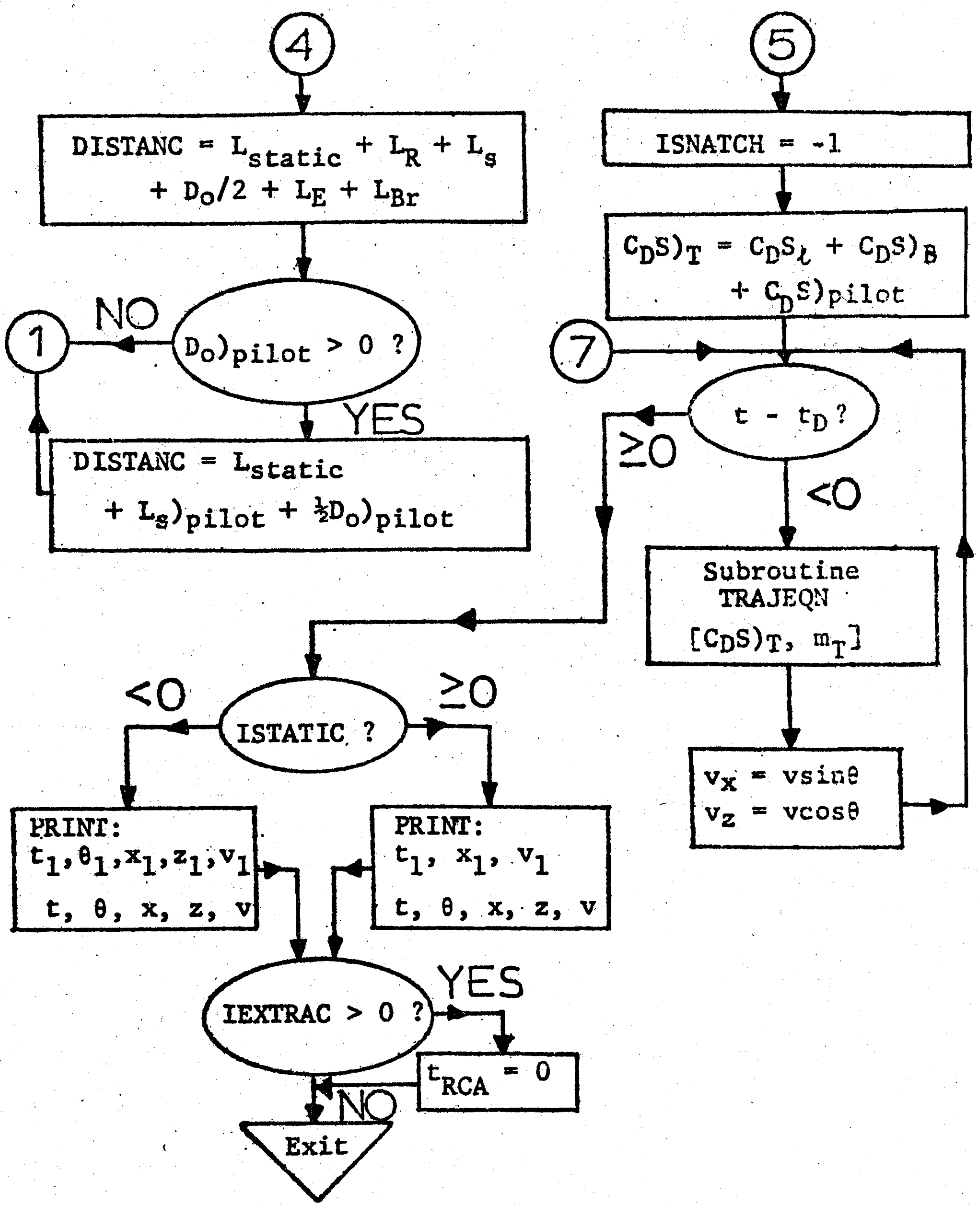

FIG 11 Subroutine EXTRACT (Concluded)

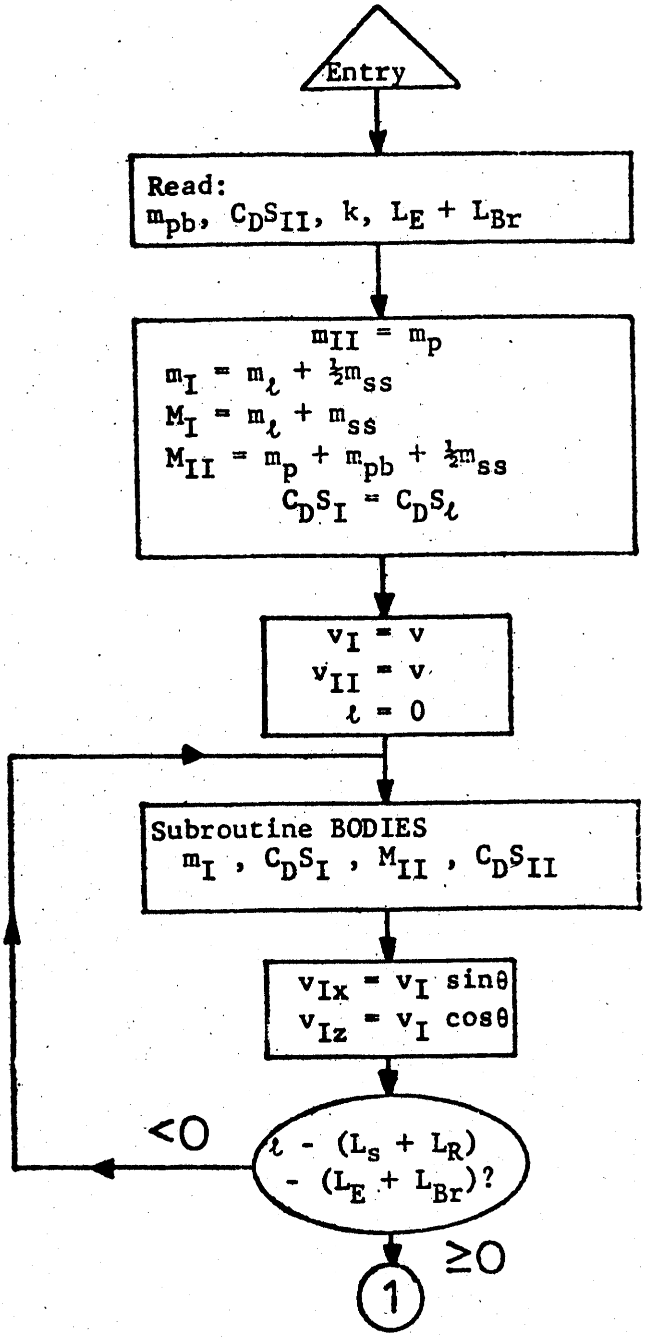

FIG 12 Subroutine SNATCH

(1)

$$t_\ell = t$$
$$\theta_\ell = \theta$$
$$x_\ell = x$$
$$z_\ell = z$$
$$v_{I\ell} = v_I$$
$$v_{II\ell} = v_{II}$$

$$Q = \frac{M_I}{M_I + m_{II}}$$

$$v_s = \frac{M_I v_I + m_{II} v_{II}}{M_I + m_{II}}$$

$$\Delta v = v_s - v_{II}$$

$F_{AI}(\rho, C_D S_I, v_I, v_s)$, Eqn (13)

$F_{AII}(\rho, C_D S_{II}, v_{II}, v_s)$, Eqn (14)

$A = 1/k$; B, Eqn (11); C, Eqn (12)

$$P_{max} = -B + \sqrt{B^2 - C/A}$$

$$t_{RCA} = t$$
$$v_I = v_{II} = v_s$$

$$m_I = m_\ell + m_p + m_{ss}$$
$$C_D S_I = C_D S_\ell + (0.015) C_{D_p} \frac{\pi D_o^2}{4}$$

(2)

FIG 12 Subroutine SNATCH (Continued)

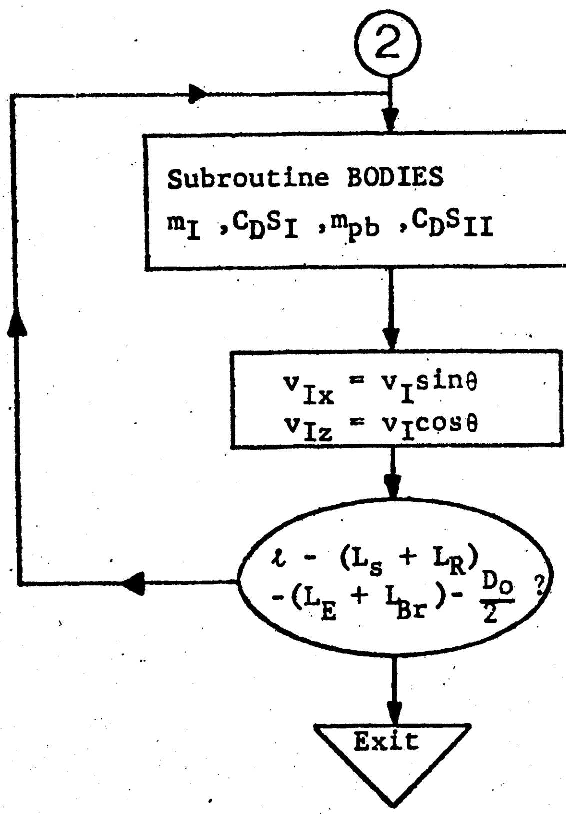

FIG 12 Subroutine SNATCH (Concluded)

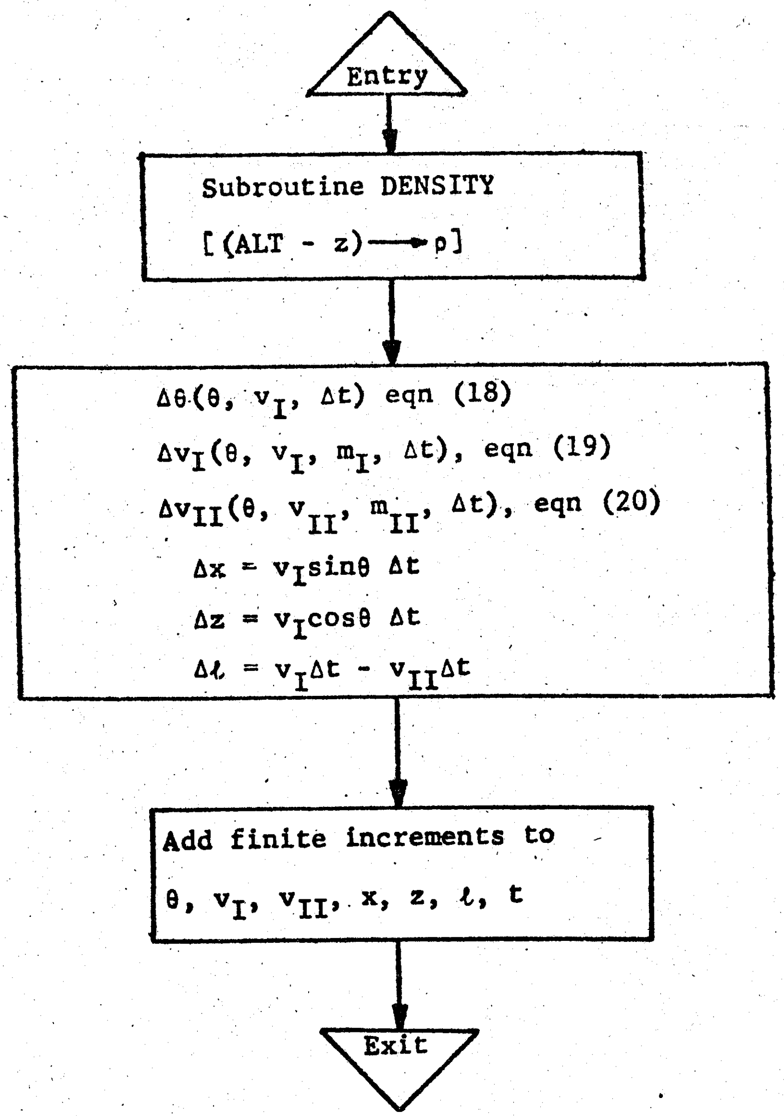

FIG 13 Subroutine BØDIES

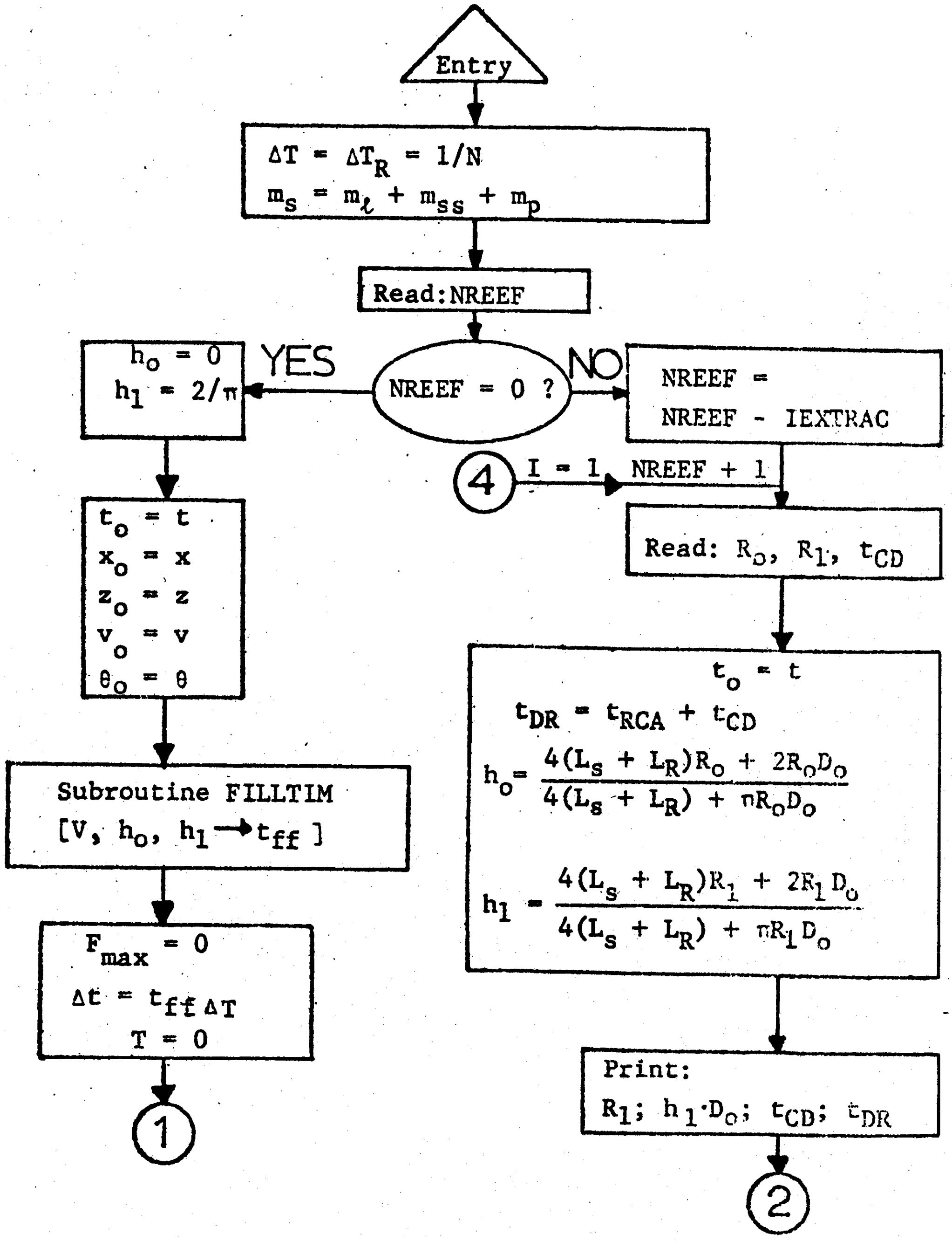

FIG 14 Subroutine ØPENING

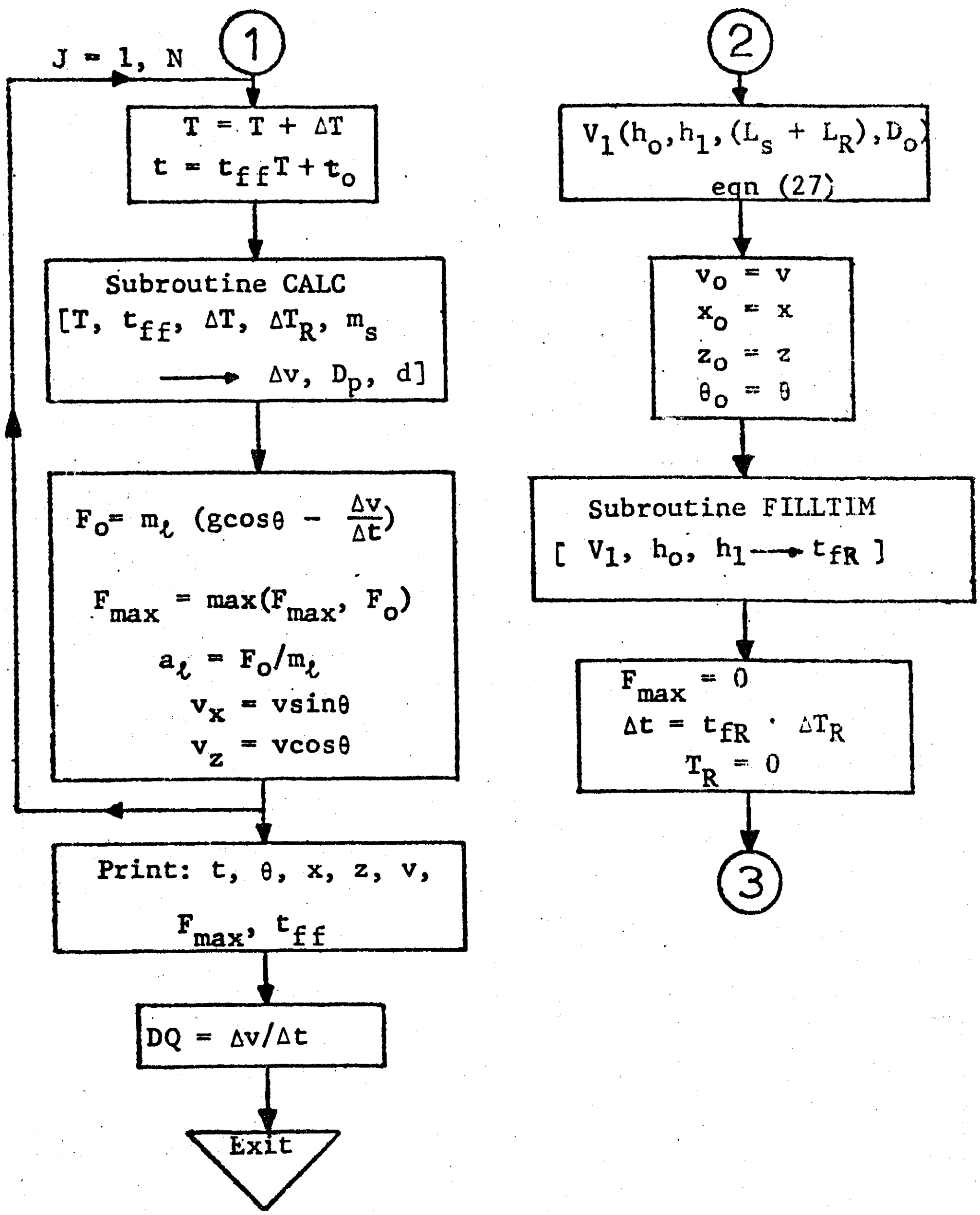

FIG 14 Subroutine ØPENING (Continued)

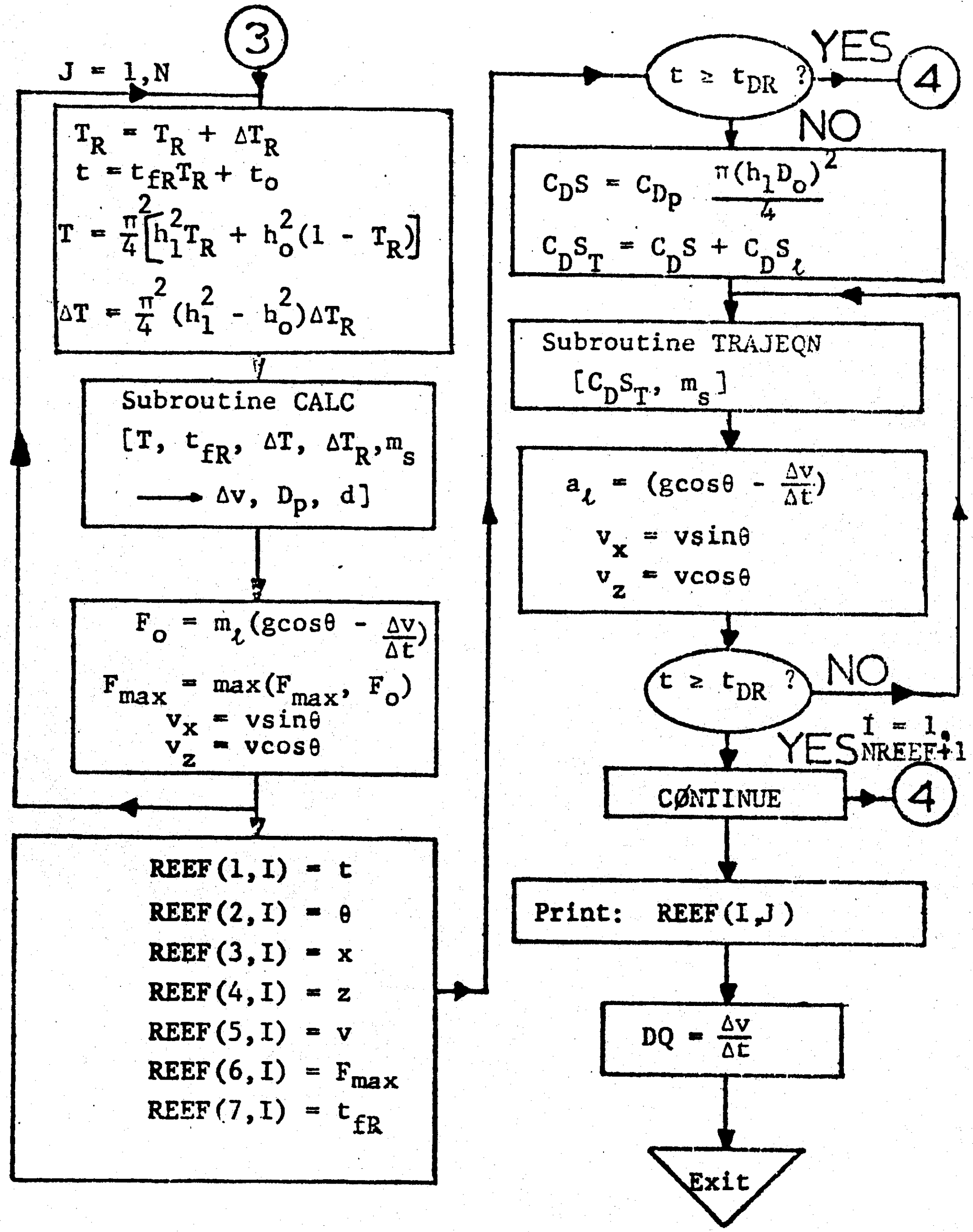

FIG 14 Subroutine ØPENING (Concluded)

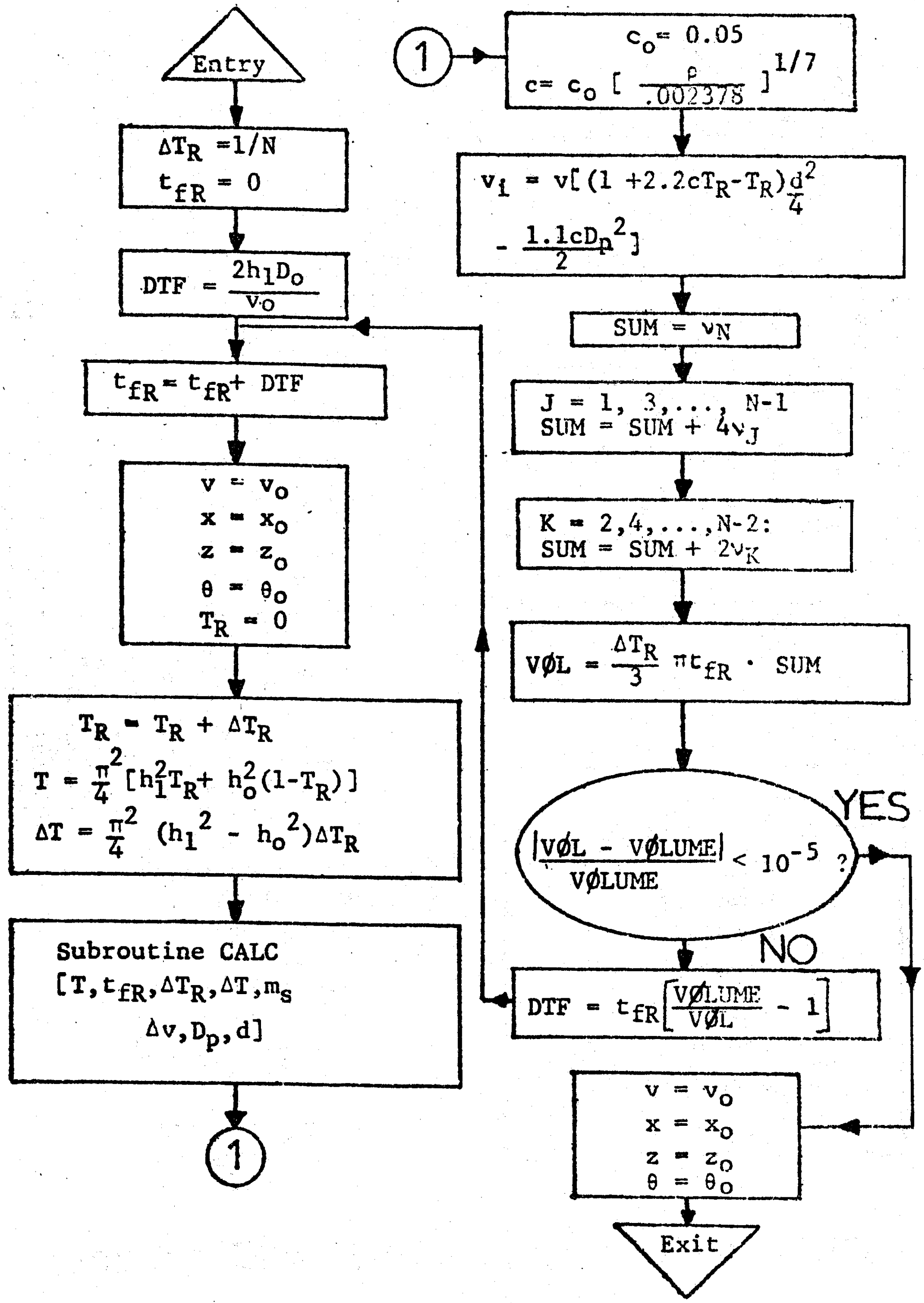

FIG 15 Subroutine FILLTIM

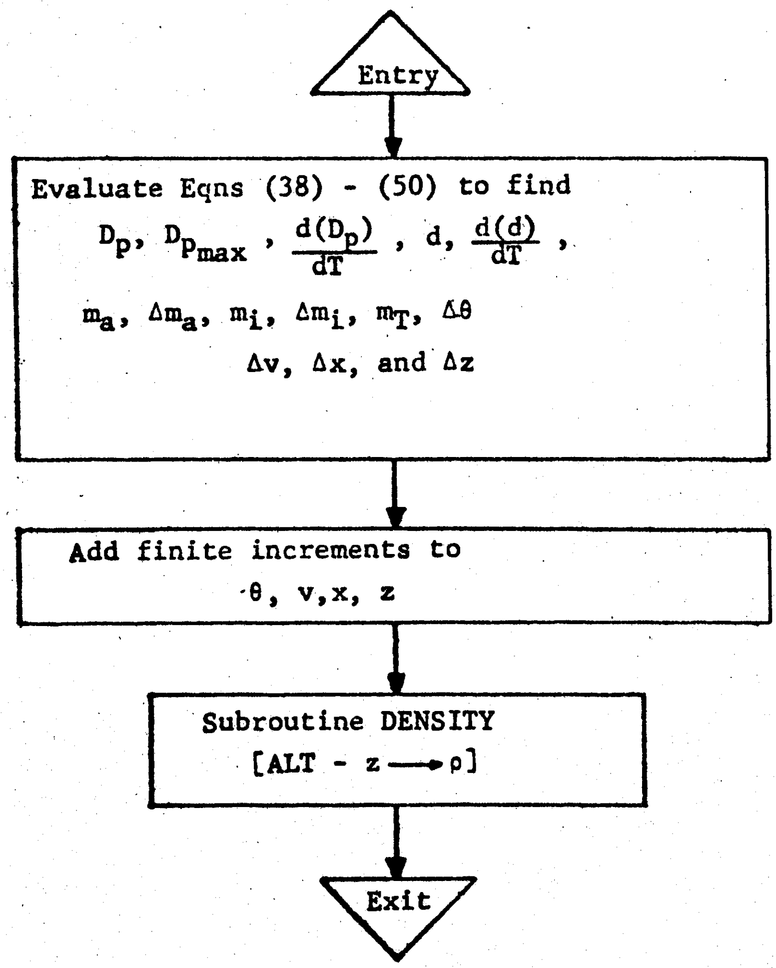

FIG 16 Subroutine CALC

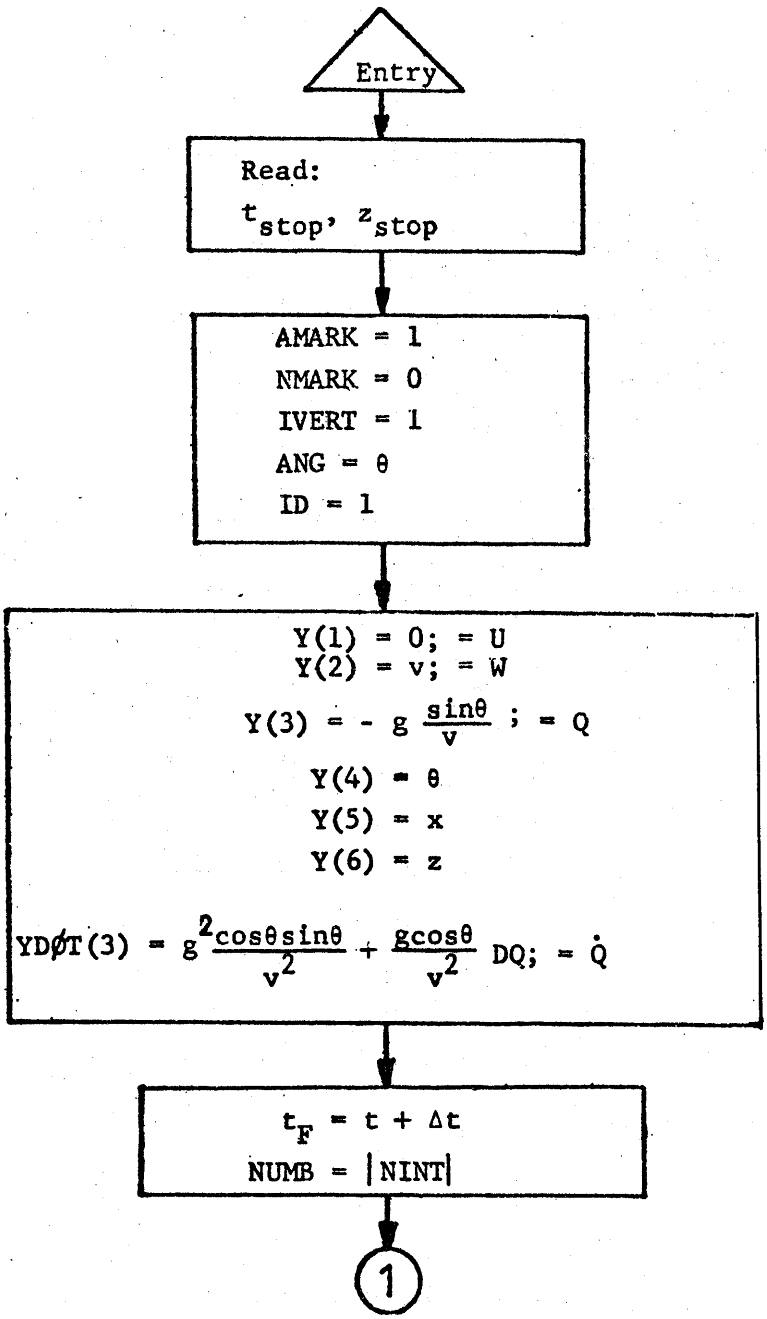

FIG 17 Subroutine MØTIØN (Three Degrees of Freedom)

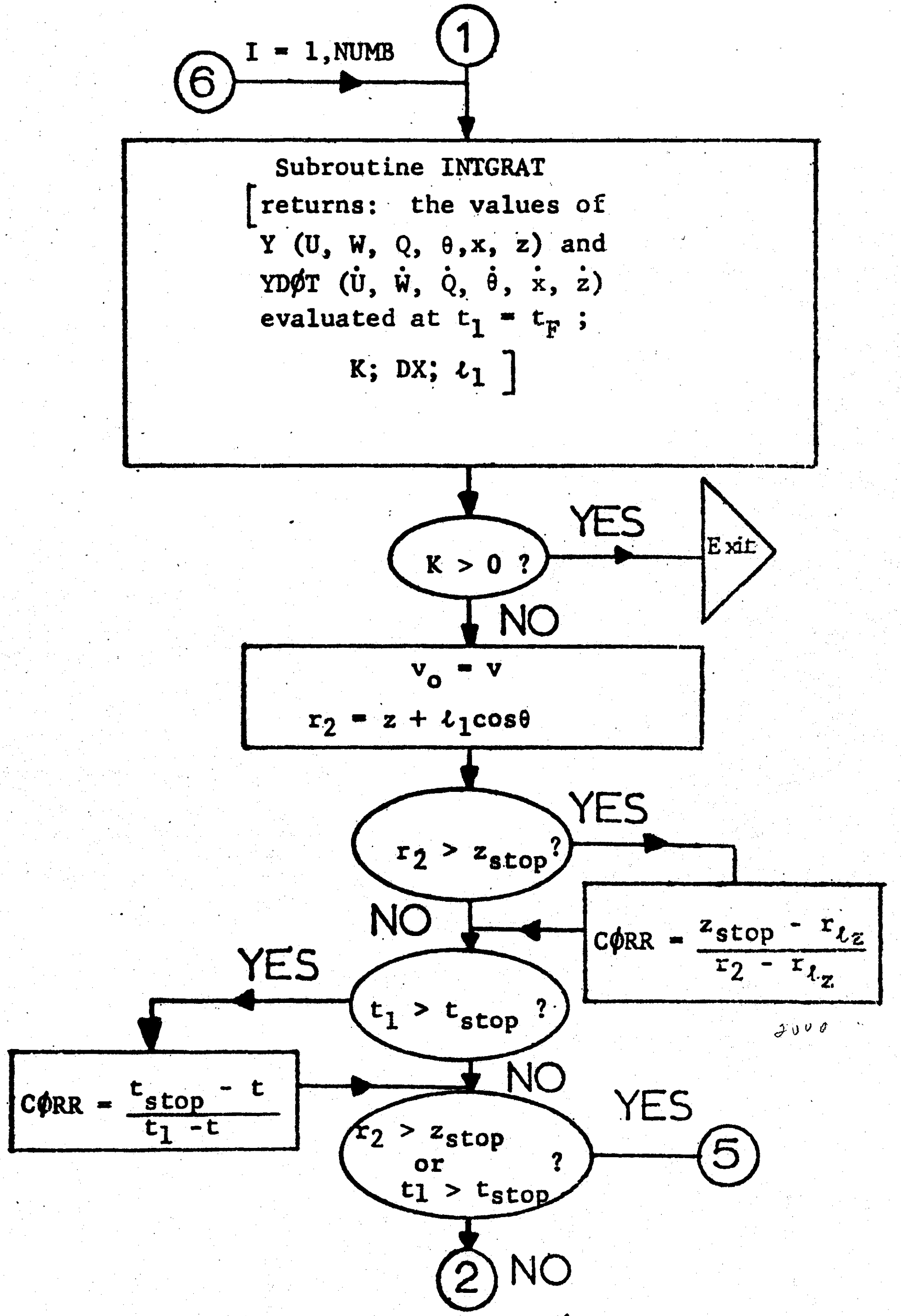

FIG 17 Subroutine MØTIØN (Three Degrees of Freedom) (Continued)

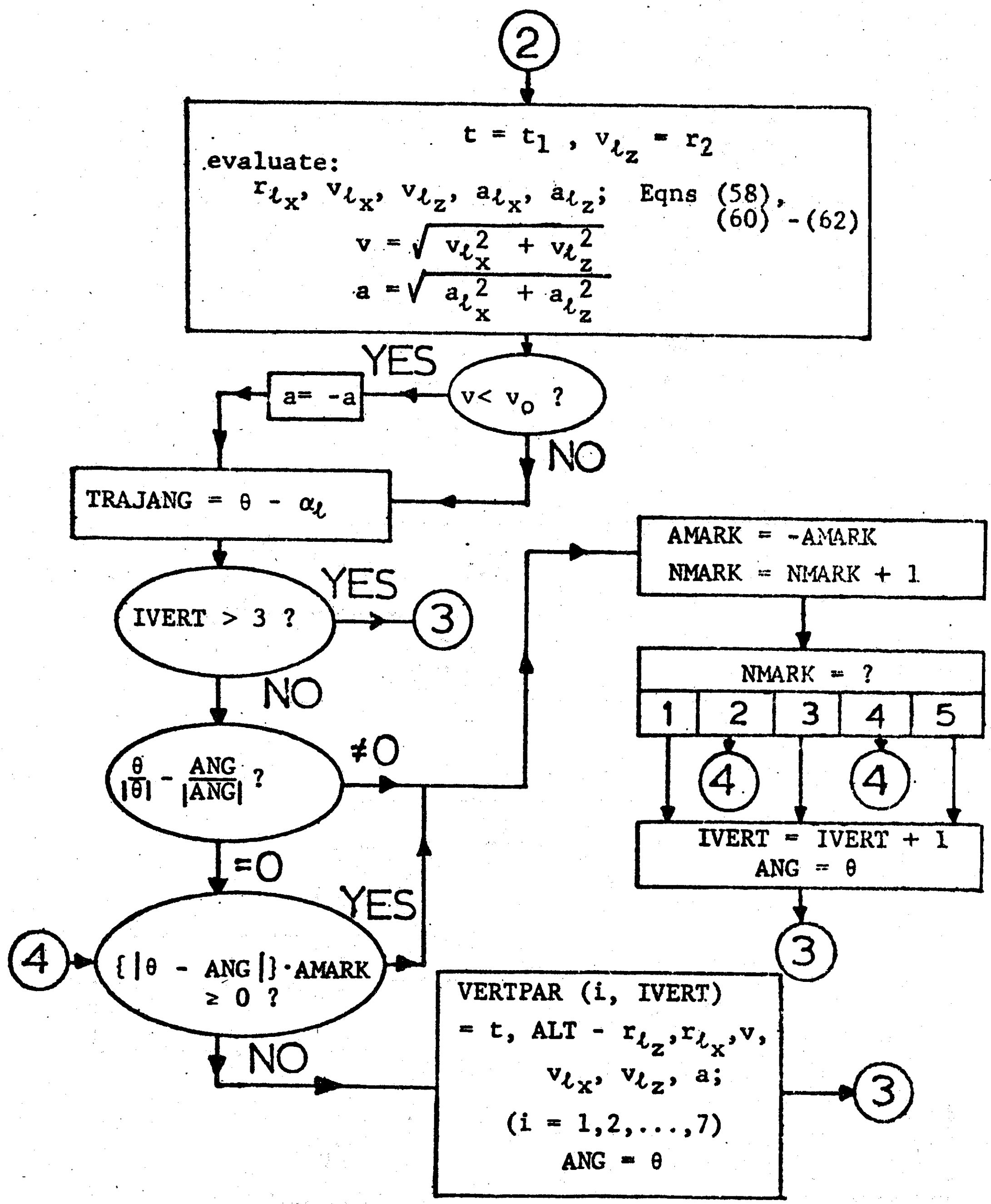

FIG 17 Subroutine MØTIØN (Three Degrees of Freedom) (Continued)

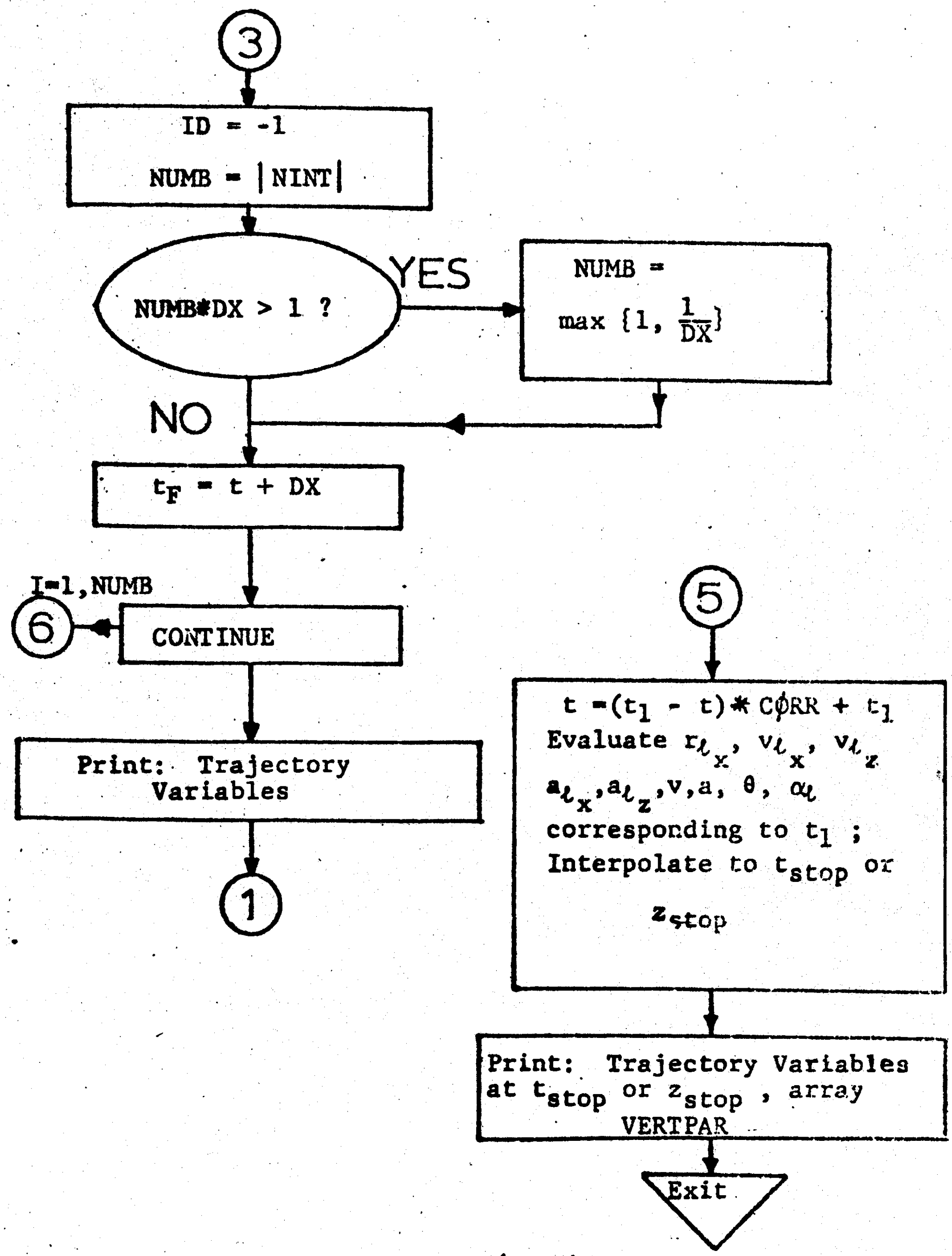

FIG 17 Subroutine MØTIØN (Three Degrees of Freedom) (Concluded)

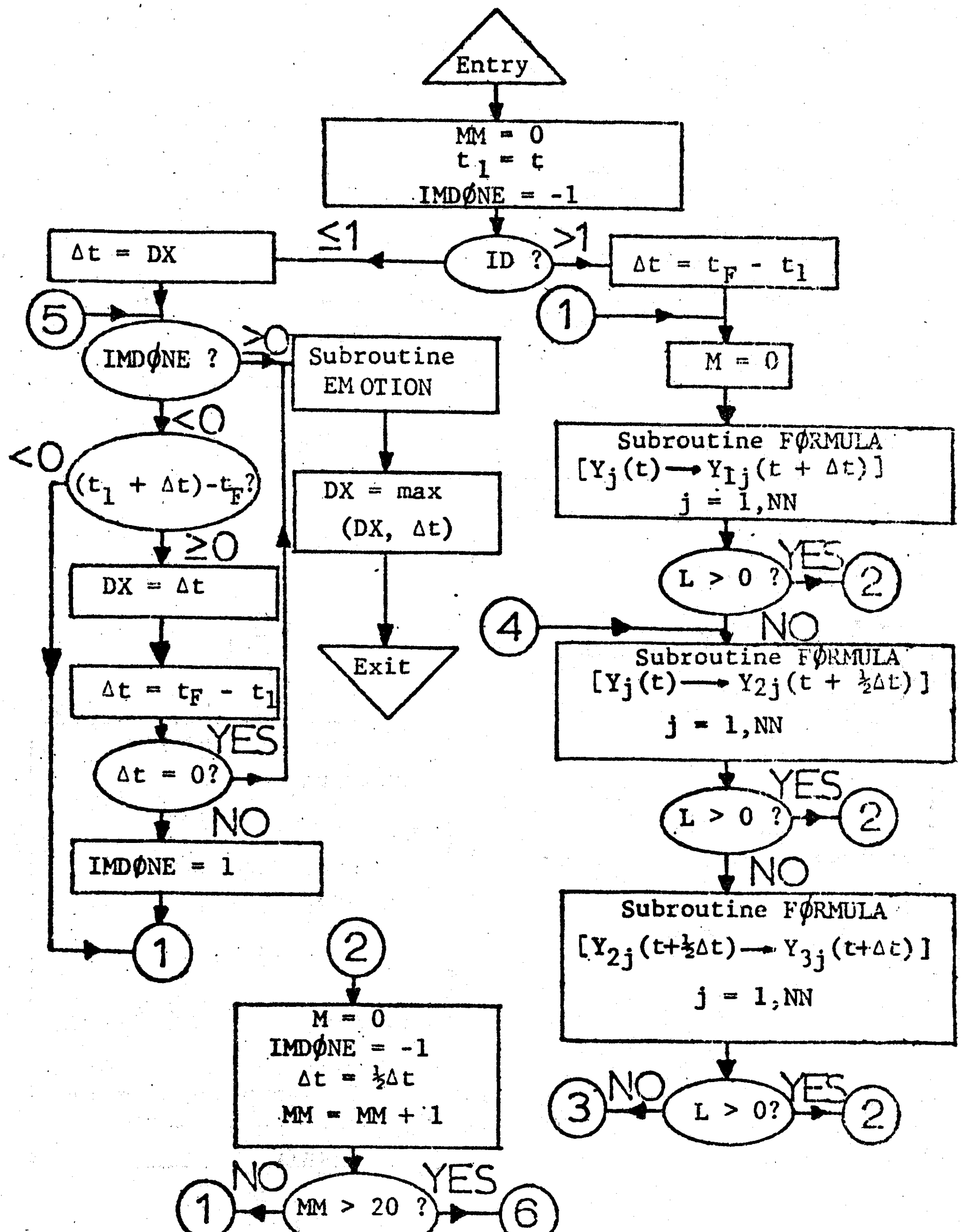

FIG 18 Subroutine INTGRAT

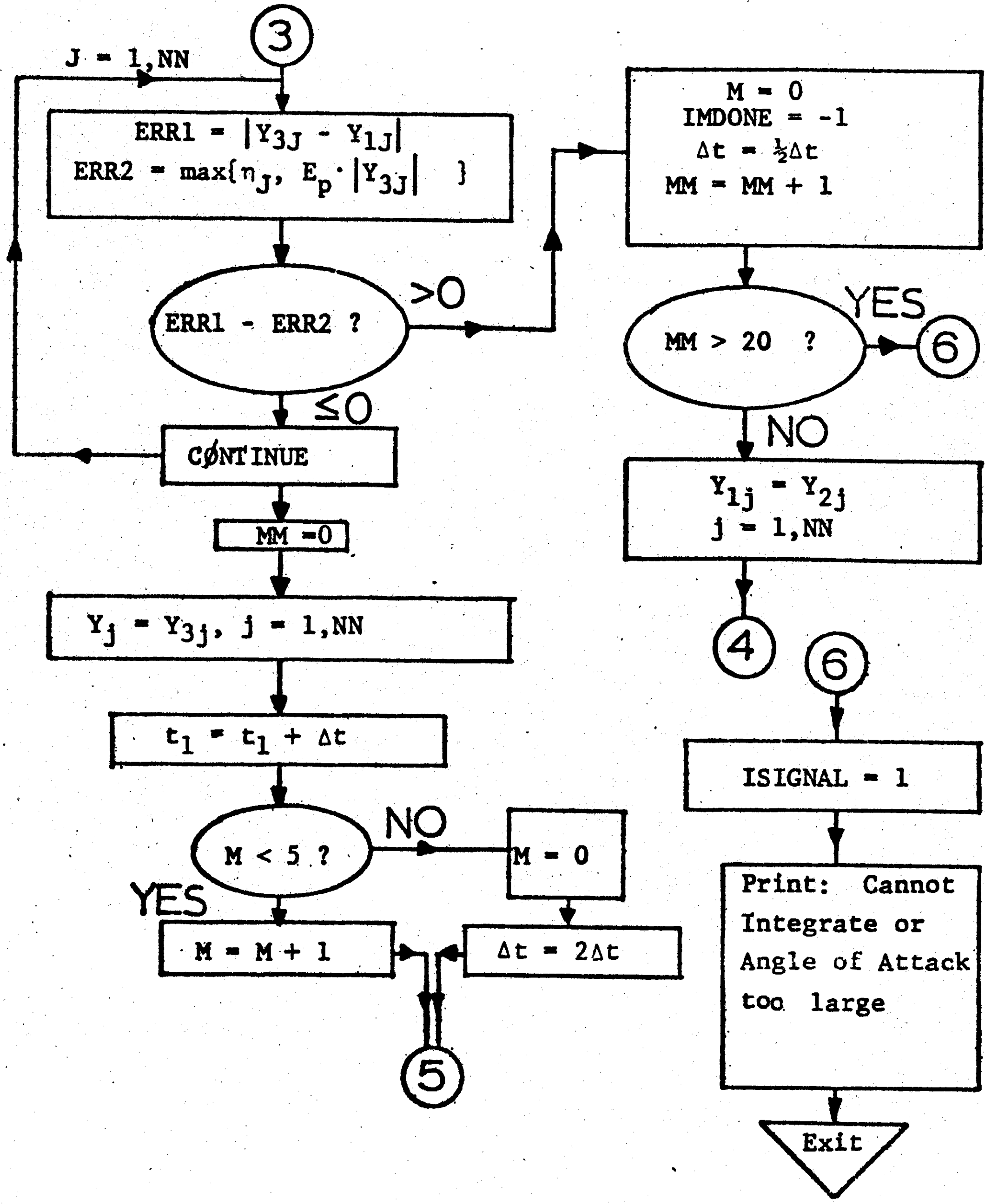

FIG 18 Subroutine INTGRAT (Concluded)

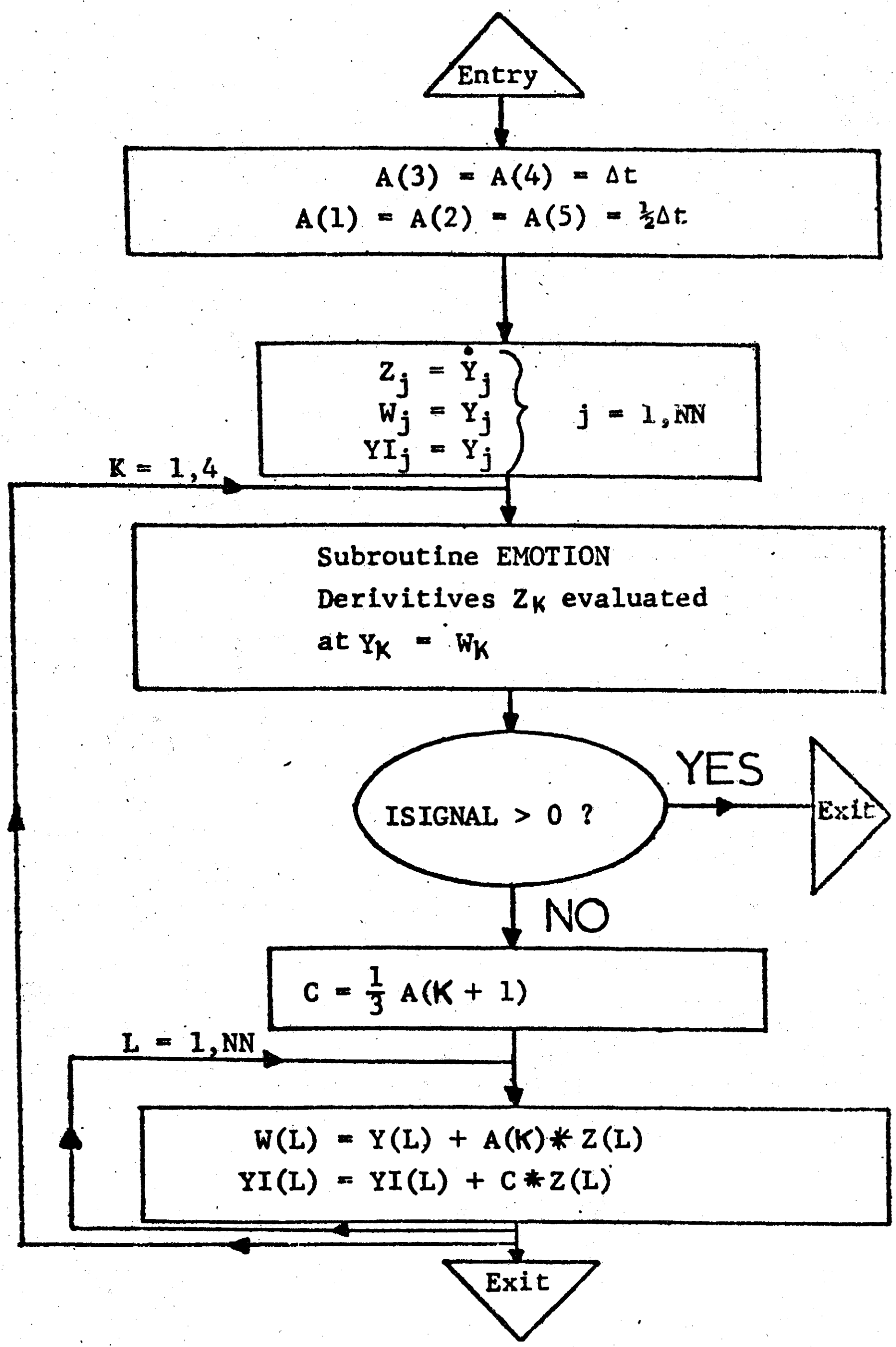

FIG 19 Subroutine FØRMULA

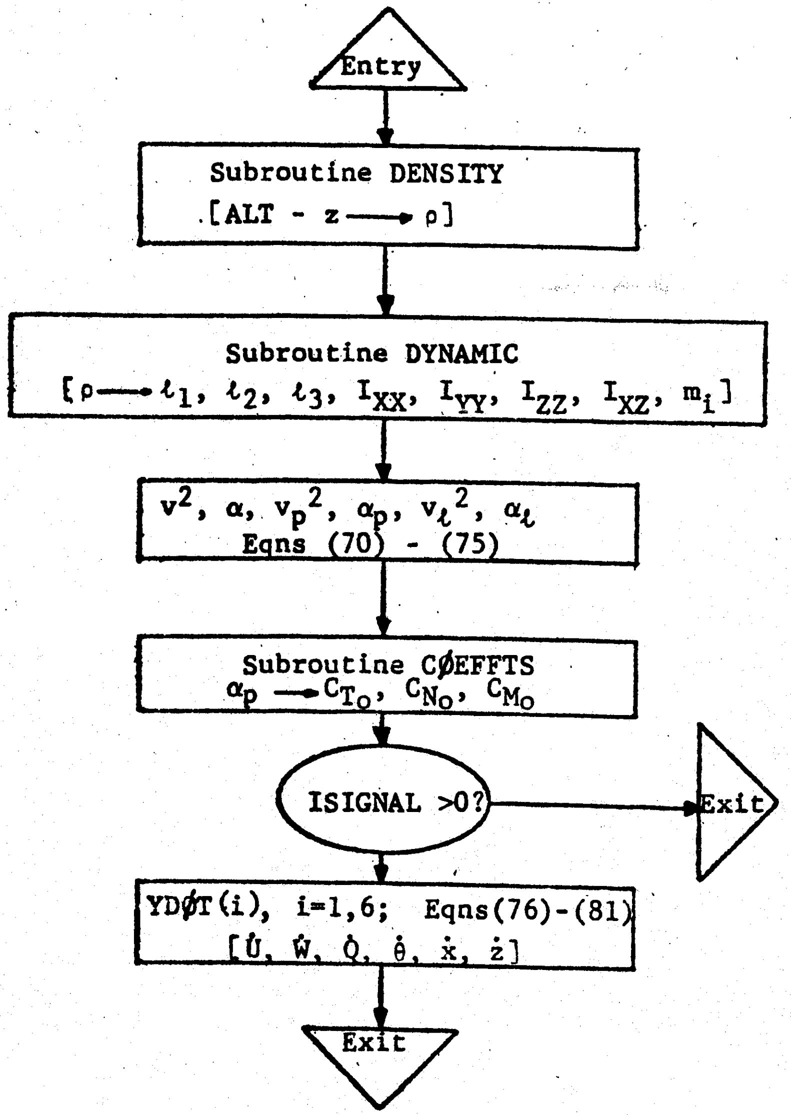

FIG 20 Subroutine EMØTIØN (Three Degrees of Freedom)

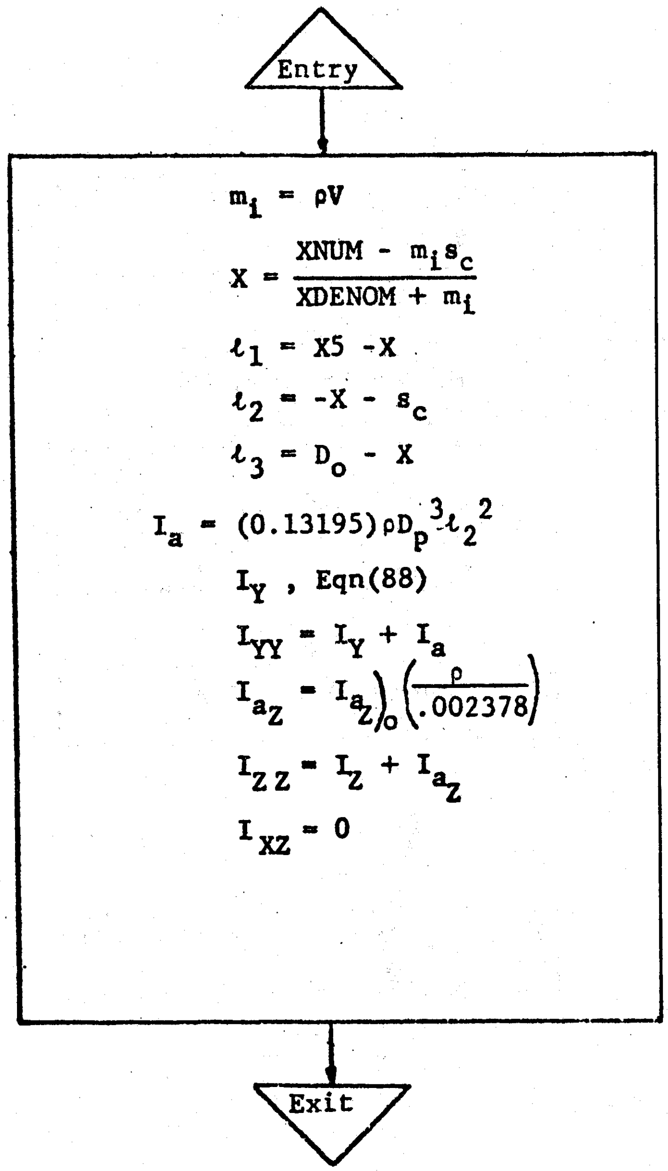

FIG 21 Subroutine DYNAMIC

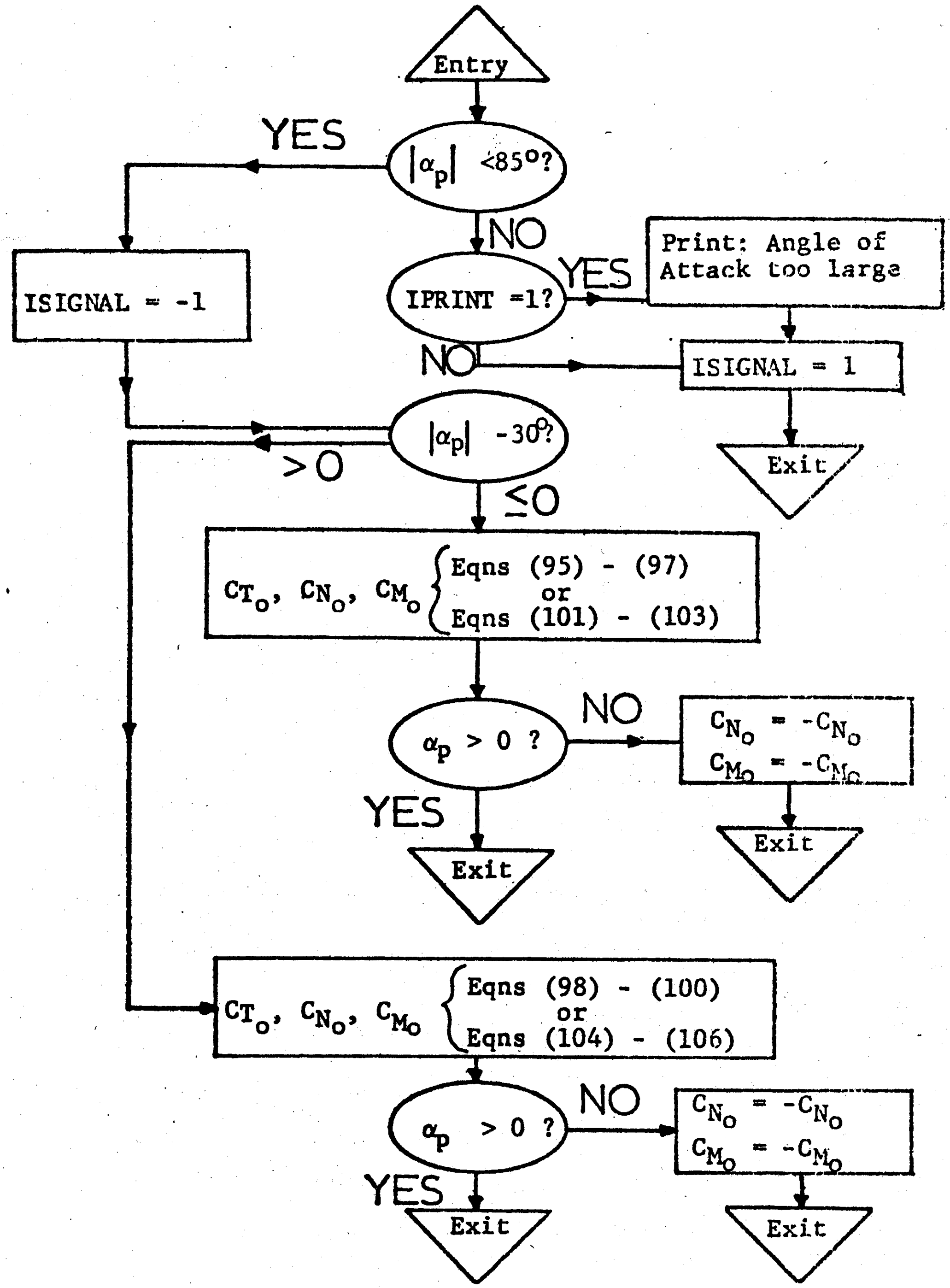

FIG 22 Subroutine CØEFFTS (Three Degrees of Freedom)

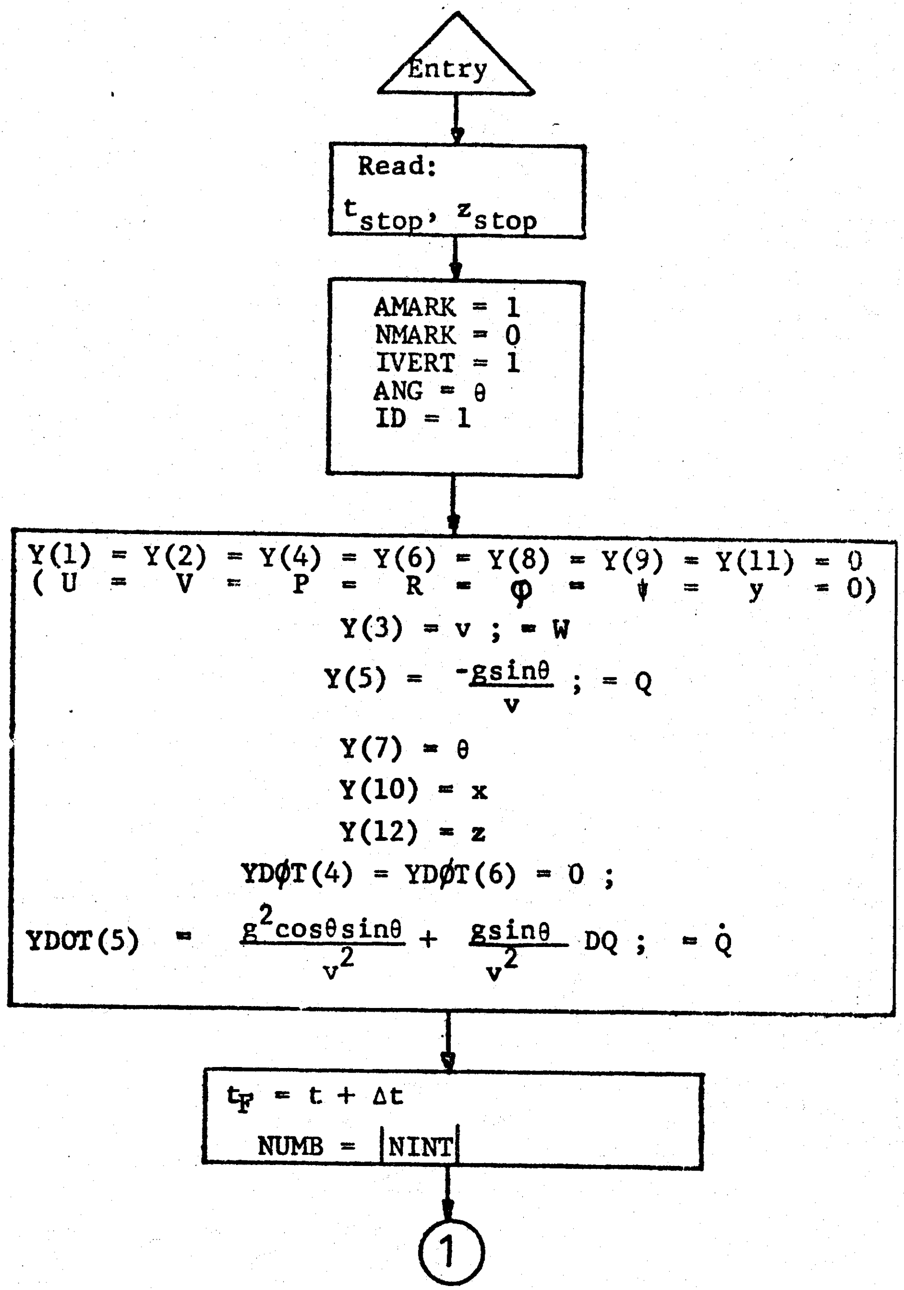

FIG 23 Subroutine MØTIØN (Six Degrees of Freedom)

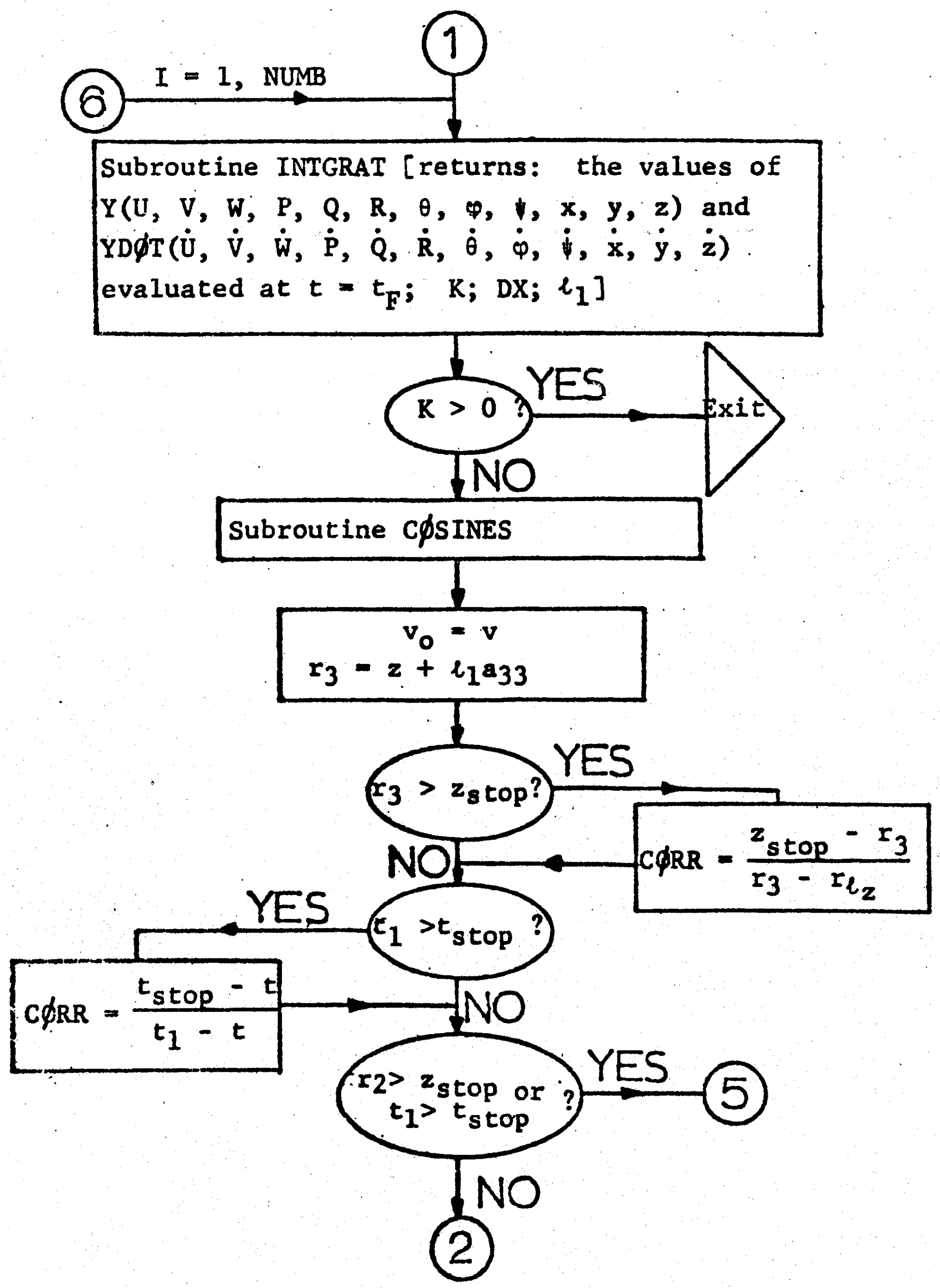

FIG 23 Subroutine MØTIØN (Six Degrees of Freedom) (Continued)

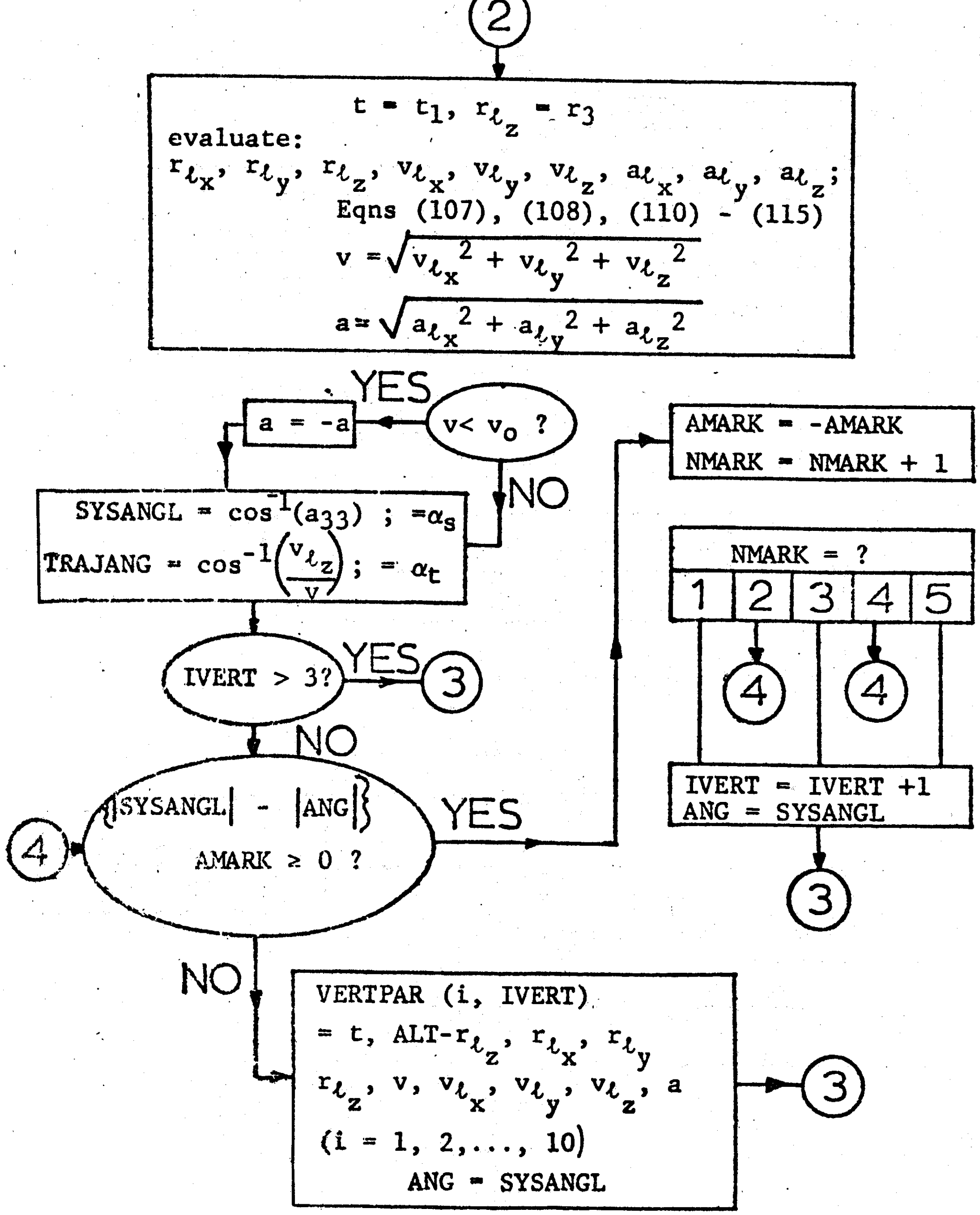

FIG 23 Subroutine MØTIØN (Six Degrees of Freedom) (Continued)

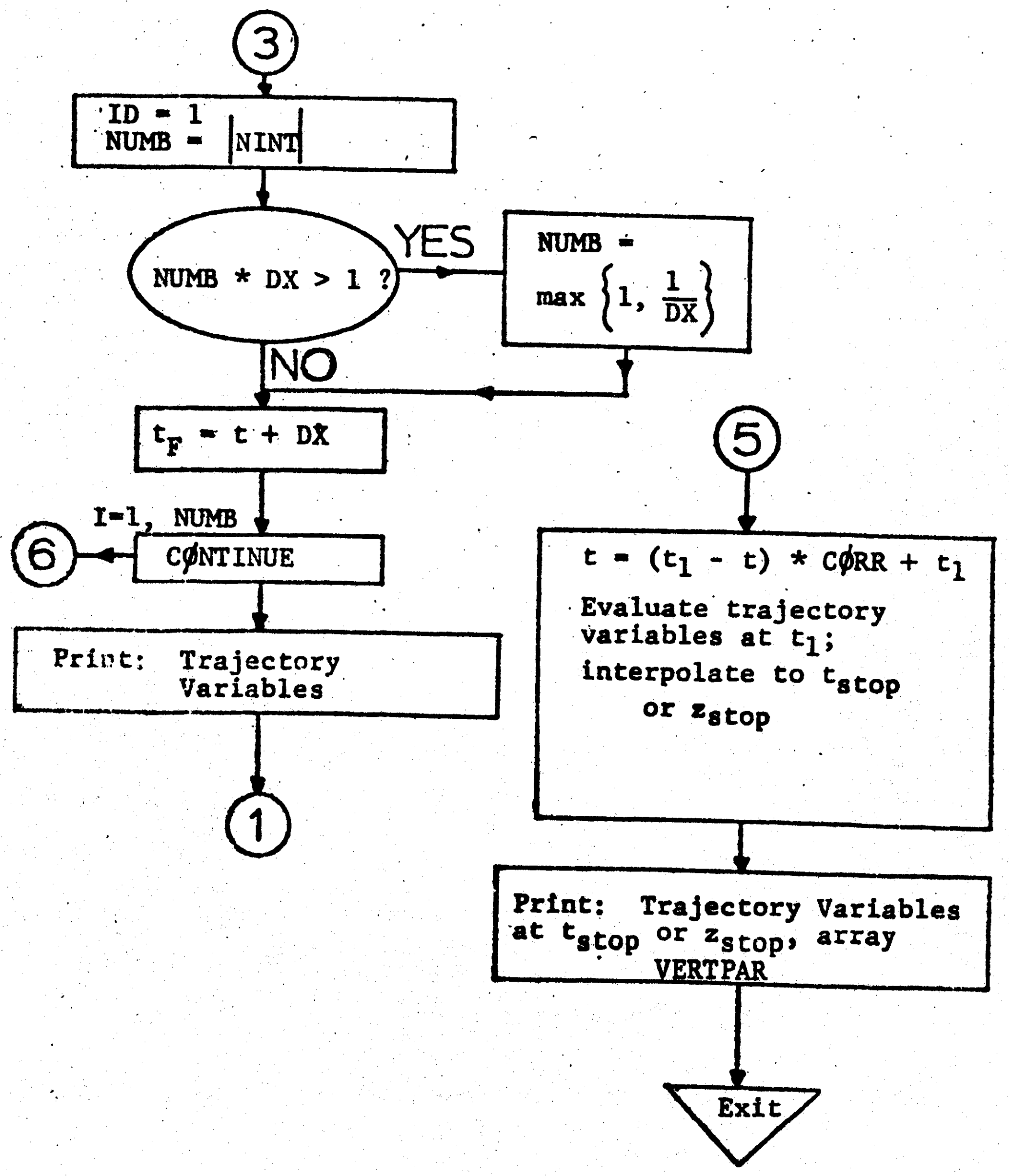

FIG 23 Subroutine MØTIØN (Six Degrees of Freedom) (Concluded)

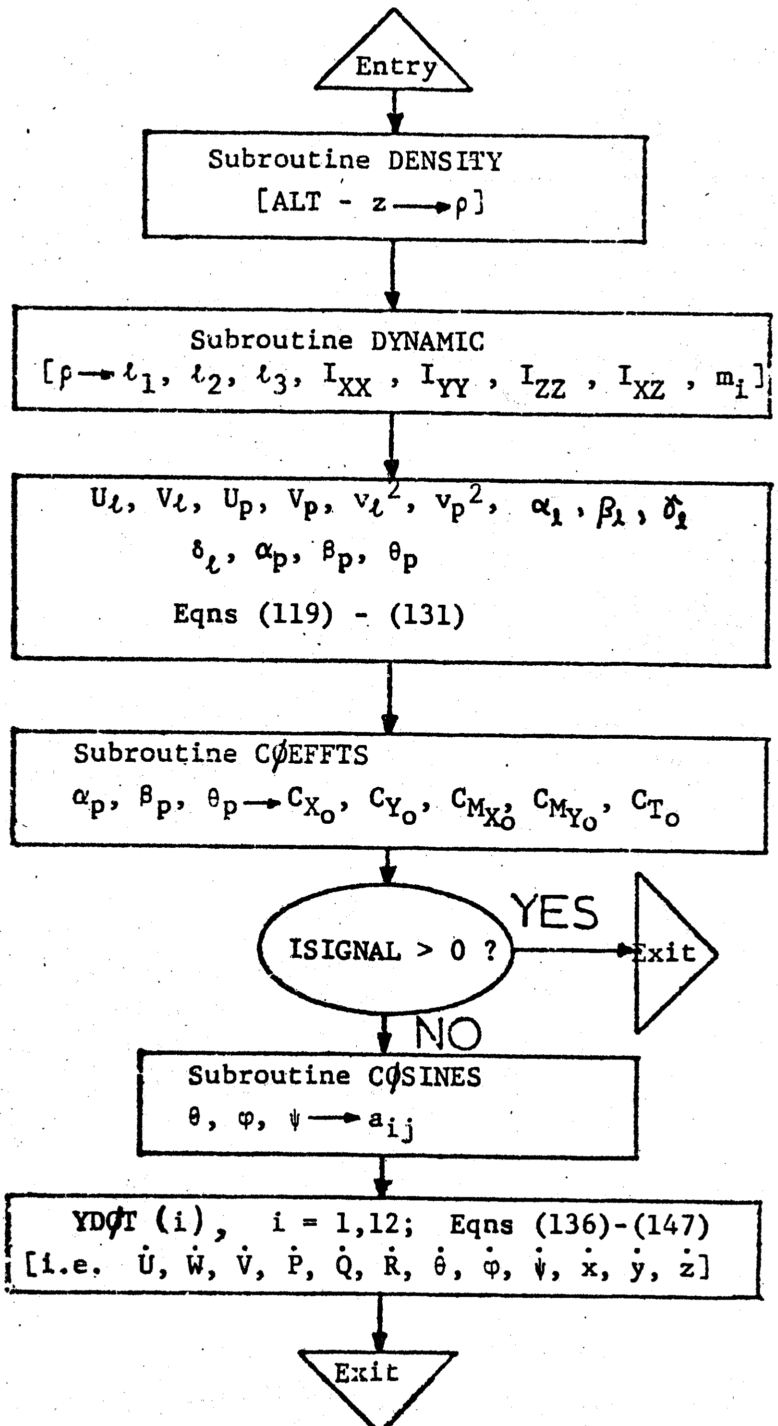

FIG 24 Subroutine EMØTIØN (Six Degrees of Freedom)

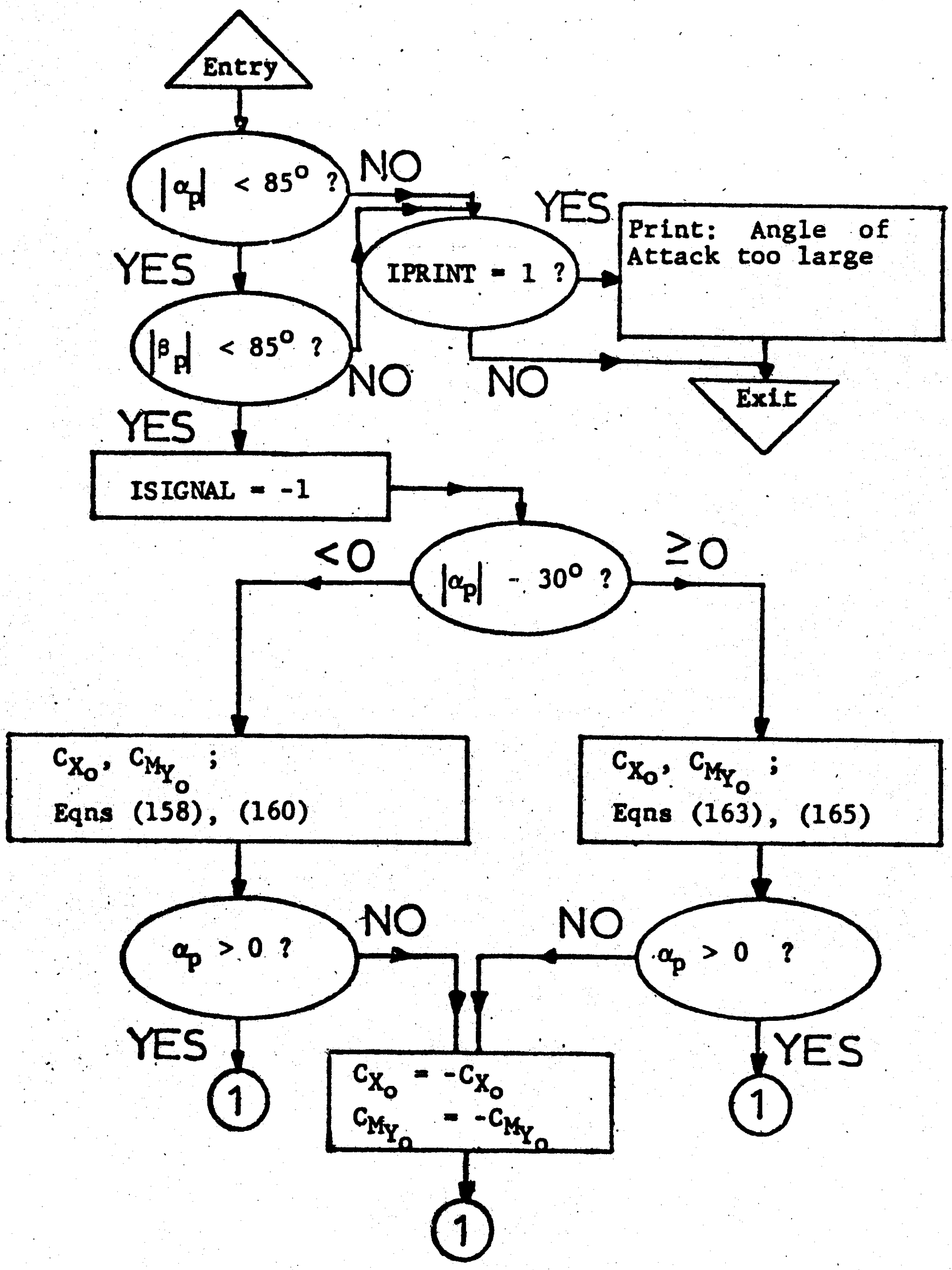

FIG 25 Subroutine CØEFFTS (Six Degrees of Freedom)

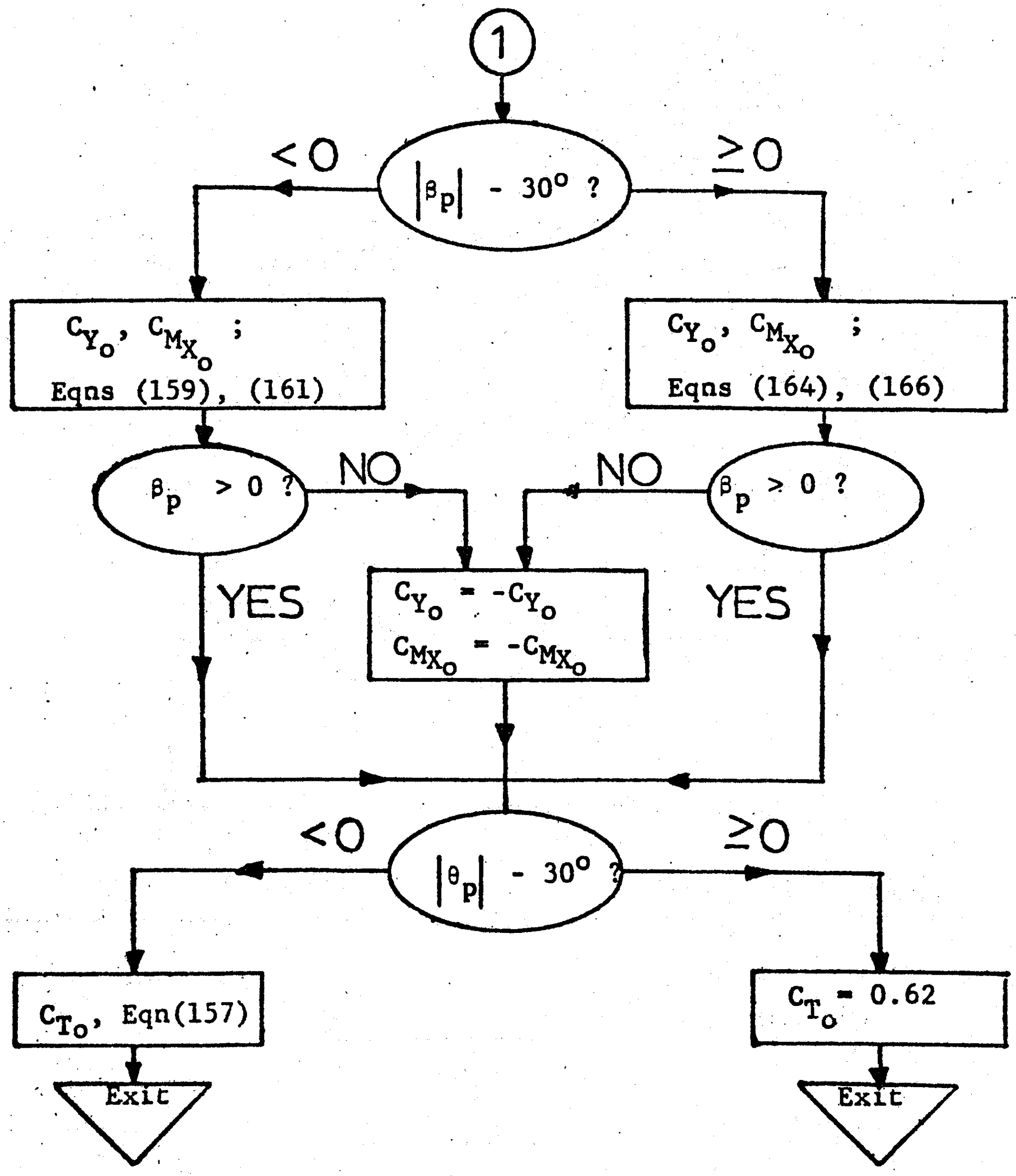

FIG 25 Subroutine CØEFFTS (Six Degrees of Freedom) (Concluded)

Entry

$$a_{11} = \cos\theta\cos\psi$$

$$a_{12} = \sin\varphi\sin\theta\cos\psi - \cos\varphi\sin\psi$$

$$a_{13} = \cos\varphi\sin\theta\cos\psi + \sin\varphi\sin\psi$$

$$a_{21} = \cos\theta\sin\psi$$

$$a_{22} = \sin\varphi\sin\theta\cos\psi + \cos\varphi\cos\psi$$

$$a_{23} = \cos\varphi\sin\theta\sin\psi - \sin\varphi\cos\psi$$

$$a_{31} = -\sin\theta$$

$$a_{32} = \sin\varphi\cos\theta$$

$$a_{33} = \cos\varphi\cos\theta$$

$$[Y(7) = \theta,\ Y(8) = \varphi,\ Y(9) = \psi]$$

Exit

FIG 26 Subroutine CØSINES

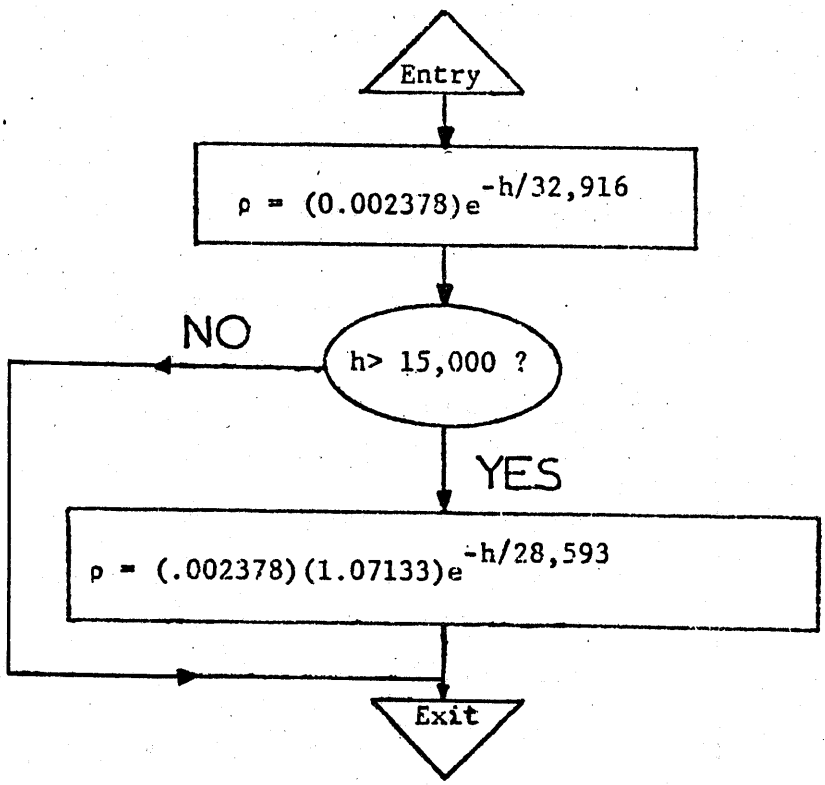

FIG 27 Subroutine DENSITY

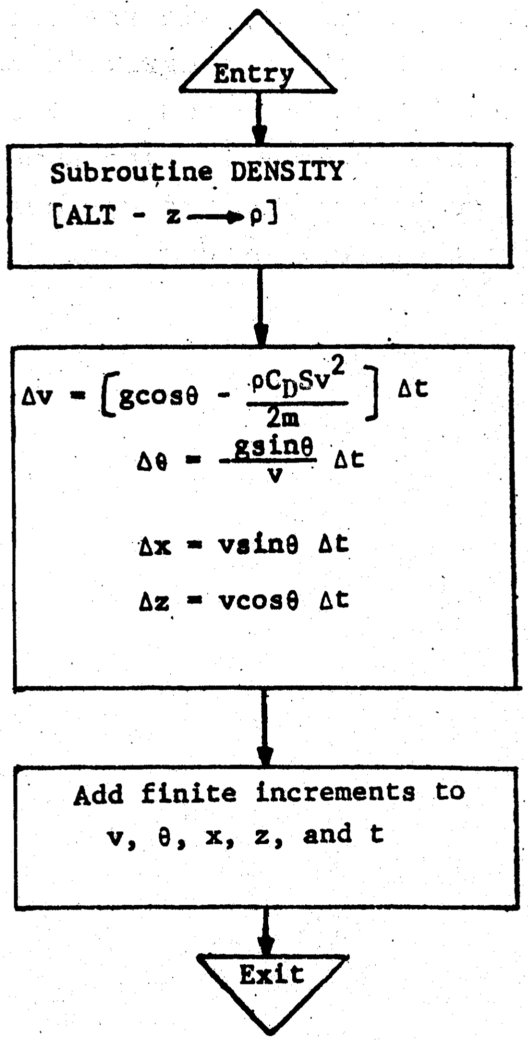

FIG 28 Subroutine TRAJEQN

VI. COMPUTER PROGRAM SYMBOLS

Tables I through XIX explain the various mnemonic symbols used in the computer program in terms of symbols used in the text of Volumes I and II of this report, where applicable, and brief comments. The symbols are arranged in tables which correspond to the various subroutines and are presented in the order of discussion in Section III.

TABLE I

Computer Symbols for MAIN PRØGRAM

Mnemonic Variation	Symbol	Comment
ALT	h_o	release altitude
A1	ℓ_1	ℓ_1 at mean sea level
A2	ℓ_2	ℓ_2 at mean sea level
A3	ℓ_3	ℓ_3 at mean sea level
A4	I_{XX}	I_{XX} at mean sea level
A5	I_{YY}	I_{YY} at mean sea level
A6	I_{ZZ}	I_{ZZ} at mean sea level
A7	I_{XZ}	I_{XZ} at mean sea level
A8	m_i	m_i at mean sea level
A9	m_a	m_a at mean sea level
B1	ℓ_1	ℓ_1 at h_o
B2	ℓ_2	ℓ_2 at h_o
B3	ℓ_3	ℓ_3 at h_o
B4	I_{XX}	I_{XX} at h_o
B5	I_{YY}	I_{YY} at h_o
B6	I_{ZZ}	I_{ZZ} at h_o
B7	I_{XZ}	I_{XZ} at h_o
B8	m_i	m_i at h_o
B9	m_a	m_a at h_o
CDP	C_{D_p}	drag coefficient of parachute based on projected area
CDSL	$C_D S_\ell$	drag area of load

TABLE I (Cont'd.)

Computer Symbols for MAIN PRØGRAM

Mnemonic Variation	Symbol	Comment
C1-C5		A block of alphanumeric characters which form the title for a particular simulation
DNØT	D_o	nominal diameter
DQ	$\frac{dv}{dt}$	acceleration at the moment of full inflation
DT1	Δt	Δt in EXTRACT
DT2	Δt	Δt in SNATCH
DT3	Δt	Δt in ØPENING, MØTIØN
DYDNØT	D_o	nominal diameter
DYML	m_ℓ	mass of load
DYMP	m_p	mass of parachute
ETA	η	absolute errors allowed in INTGRAT - N dimensional array
G	g	acceleration of gravity
I		implied DØ loop index for reading ETA
IAZO	$I_{a_{Z)}o}$	Apparent moment of inertia about Z-axis at mean sea level
IEXTRAC		Integer Variable; if ISTATIC ≥ 0: IEXTRAC > 0, Reefed main parachute extraction system, IEXTRAC ≤ 0, Extraction parachute system
ISNATCH		Integer variable; if ISNATCH > 0, no snatch force calculation

TABLE I (Cont'd.)
Computer Symbols for MAIN PRØGRAM

Mnemonic Variation	Symbol	Comment
IZ	I_Z	moment of inertia about Z-axis due to physical masses of load, parachute, and suspension system
J		DØ loop index for NSIM
LSS	$L_S + L_R$	suspension line + riser length
MBR	m_{Br}	mass of load bridle
ML	m_ℓ	mass of load
MLS	m_{L_S}	mass of suspension lines
MP	m_p	mass of parachute
MR	m_R	mass of risers
MRX	m_E	mass of riser extensions
MSS	m_{ss}	$m_{L_S} + m_R + m_E + m_{Br}$
MST	~~m_T~~ M_{rs}	total mass
N		number of degrees of freedom allowed in MØTIØN
NINT		number of calculations between successive prints in EXTRACT, SNATCH, ØPENING and MØTIØN
NN		2·N
NNN	n	number of steps used to approximate inflation in ØPENING

TABLE I (Cont'd.)

Computer Symbols for MAIN PRØGRAM

Mnemonic Variation	Symbol	Comment
NSIM		number of total trajectory simulations in 1 computer run
PCTERR		Percentage error allowed in INTGRAT
PI	π	3.141592653589793
Q1	s_c/D_o	ratio of reference distance from canopy skirt to parachute center of volume in fully inflated condition to D_o
Q2	$D_{P_{max}}/D_o$	projected diameter ratio in fully inflated configuration
RHØ	ρ	air density
TRCA	t_{RCA}	time at which reefing cutters are armed
VØLUME	V	fully inflated volume
VO	v_o	initial velocity
XDENØM		$m_p + m_{Ls} + m_R + m_E + m_{Br} + m_\ell$
XNUM		$m_{L_s} s_1 + m_R s_2 + m_E s_3 + m_{Br} s_4 + m_\ell s_5 - m_p s_c$
X1	s_1	reference distance from canopy skirt to suspension line center of mass in fully inflated configuration
X2	s_2	reference distance from canopy skirt to riser center of mass in fully inflated configuration
X3	s_3	reference distance from canopy skirt to riser extension center of mass in fully inflated configuation

TABLE I (Cont'd.)

Computer Symbols for MAIN PRØGRAM

Mnemonic Variation	Symbol	Comment
X4	s_4	reference distance from canopy skirt to load bridle center of mass in fully inflated configuration
X5	s_5	reference distance from canopy skirt to load center of mass in fully inflated configuration

TABLE II

Computer Symbols for Subroutine EXTRACT

Mnemonic Variation	Symbol	Comment
ALT	h_o	release altitude
CDP	C_{D_p}	drag coefficient based on projected area
CDSBAG	C_DS_B	drag area of main parachute deployment bag
CDSEX	C_DS_{ex}	drag area of extraction parachute
CDSL	C_DS_{ℓ}	drag area of load
CDSP	C_DS_{pilot}	drag area of pilot chute
CDST	C_DS_T	drag area for calls to EXTRACT or for Eqn (4)
DISTANC		distinct values of ℓ where modeled physical process is changed
DNØT	D_o	nominal diameter
DPILØT	D_{Pilot}	flat diameter of pilot chute
DT	Δt	time increment
DV	Δv	velocity increment
DX	Δx	x increment, $v\Delta t$
G	g	acceleration of gravity
H	$(D_p/D_o)_{ex}$	D_p/D_o of reefed main extraction parachute
ICØUNT		index for number of calculations made without print
IEXTRAC		IntegerVariable; If ISTATIC $\geq$ 0, IEXTRAC > 0, Reefed main parachute extraction system; IEXTRAC $\leq$ 0, Extraction parachute system
ISNATCH		Integer variable; ISNATCH > 0, no snatch force calculation
ISTATIC		Integer variable; ISTATIC < 0, static line used

TABLE II (Cont'd.)

Computer Symbols for Subroutine EXTRACT

Mnemonic Variation	Symbol	Comment
LENGTH	L	distance load travels in aircraft
LSPILØT	$L_{S_{Pilot}}$	length of pilot chute suspension lines
LSS		$L_s + L_R$
LSTATIC	L_{Static}	Static line length
MST	m_{rs}	mass of entire recovery system
MR	m_T	mass used for calls to TRAJEQN or for Eqn (4)
NINT		number of calculations to be made between successive prints; if NINT < 0, continuous output is suppressed
PI	π	3.14159...
R	R_{ex}	$\frac{(\ell_R/\pi)\ ex}{D_o}$
RHØ	ρ	air density
T	t	time
TD	t_D	coasting time at constant drag area
THETA	θ	system angle, radians
TRAJANG	θ	system angle, degrees
TRAJ1	θ_1	θ at static line stretch
TRCA	t_{RCA}	time at which reefing cutters are armed
T1	t_1	t at static line stretch or when load leaves aircraft
V	v	velocity
VX	v_x	x component of v
VZ	v_z	z component of v
VO	v_o	initial velocity

TABLE II (Cont'd.)
Computer Symbols for Subroutine EXTRACT

Mnemonic Variation	Symbol	Comment
V1	v_1	v at static line stretch or when load leaves airvraft
X	x	x position
X1	x_1	x at static line stretch or when load leaves aircraft
Z	z	z position
Z1	z_1	z at static line stretch

TABLE III

Computer Symbols for Subroutine SNATCH

Mnemonic Variation	Symbol	Comment
A	A	inverse of spring constant, k
ALT	h_o	release altitude
B	B	Equation (11)
C	C	Equation (12)
CAPM1	M_I	$m_\ell + m_{ss}$
CAPM2	M_{II}	$m_p + \frac{1}{2}m_{ss} + m_{Pb}$
CDP	C_{D_p}	drag coefficient based on projected area of parachute
CDSL	C_DS_ℓ	drag area of load
CDS1	C_DS_I	drag area of primary body
CDS2	C_DS_{II}	drag area of secondary body
DELTAV	$v_s - v_{II}$	difference between velocity of parachute immediately before snatch and snatch velocity
DNØT	D_o	nominal diameter
DT	Δt	time increment
FA1	F_{A_I}	Equation (13)
FA2	$F_{A_{II}}$	Equation (14)
ICØUNT		index for number of calculations made without print
K	k	suspension system spring constant

TABLE III (Cont'd.)

Computer Symbols for Subroutine SNATCH

Mnemonic Variation	Symbol	Comment
L	ℓ	distance between load and secondary body during deployment
LRXBR		$L_E + L_{BR}$
LSS		$L_S + L_R$
ML	m_ℓ	mass of load
MP	m_p	mass of parachute
MPBAG	m_{pb}	mass of pilot or extraction parachute and main parachute deployment bag
MSS	m_{ss}	$m_{L_s} + m_R + m_E + m_{Br}$
M1	m_I	$m_\ell + \frac{1}{2}m_{ss}$
M2	m_p	m_p
NINT		number of calculations to be made between successive prints; if NINT < 0 continuous output is suppressed
PI	π	3.14159...
PMAX	P_{max}	maximum snatch force
Q	Q	mass ratio, Equation (15)
RHØ	ρ	air density
T	t	time
THETA	θ	systems angle, radians

TABLE III (Cont'd.)

Computer Symbols for Subroutine SNATCH

Mnemonic Variation	Symbol	Comment
TL		t at snatch
TRAJANG	θ	system angle, degrees
TRAJL		θ at snatch
TRCA	t_{RCA}	time at which reefing cutters are armed
V	v	velocity
VF	v_s	velocity just after snatch
V1	v_I	velocity of primary body
V1L		velocity of primary body at snatch
V1X	v_{I_x}	x - component of v_I
V1Z	v_{I_z}	z - component of v_I
V2	v_{II}	velocity of secondary body
V2L		velocity of secondary body at snatch
X	x	x position
XL		x at snatch
Z	z	z position
ZL		z at snatch

TABLE IV

Computer Symbols for Subroutine BØDIES

Mnemonic Variation	Symbol	Comment
ALT	h_o	release altitude
CDS1	C_DS_I	drag area of primary body
CDS2	C_DS_{II}	drag area of secondary
DL	$\Delta\ell$	increment in distance between bodies
DT	Δt	time increment
DTHETA	$\Delta\theta$	system angle increment
DV1	Δv_I	primary body velocity increment
DV2	Δv_{II}	secondary body velocity increment
DX	Δx	x increment
DZ	Δz	z increment
G	g	acceleration of gravity
L	ℓ	separation distance between bodies
M1	m_I	$m_\ell + \frac{1}{2}m_{ss}$
M2	m_p	m_p
RHØ	ρ	air density
T	t	time
THETA	θ	system angle, degrees
V1	v_I	velocity of primary body
V2	v_{II}	velocity of secondary body

TABLE IV (Cont'd.)

Computer Symbols for Subroutine BØDIES

Mnemonic Variation	Symbol	Comment
X	x	x position
Z	z	z position

TABLE V

Computet Symbols for Subroutine ØPENING

Mnemonic Variation	Symbol	Comment
AL		acceleration
ALT	h_o	release altitude
CAPT	T	dimensionless time
CAPTR	T_R	dimensionless time for reefed inflation
CDP	C_{D_p}	drag coefficient of parachute based on projected area
CDS	$(C_DS)_p$	drag area of parachute
CDSL	C_DS_ℓ	drag area of load
CDST		$(C_DS)_p + C_DS_\ell$; for call to TRAJEQN
D	d	canopy inlet diameter
DCAPT	ΔT	increment in T
DCAPTR	ΔT_R	increment in T_R
DNØT	D_o	nominal diameter
DP	D_p	projected diameter
DQ	$\Delta v/\Delta t$	acceleration at full inflation
DT		time increment during inflation
DTT	Δt	time increment for coasting stages
DV	Δv	velocity increment
F		array established for ν_i in subroutine FILLTIM

TABLE V (Cont'd.)

Computer Symbols for Subroutine ØPENING

Mnemonic Variation	Symbol	Comment
FØ	F_{max}	maximum opening force
FRCE	F_O	instantaneous opening force
G	g	acceleration of gravity
HO	h_o	initial reefed D_p/D_o
H1	h_1	final reefed D_p/D_o
I		DØ loop index for loop encompassing the complete inflation with reefed stages
ICØUNT		number of calculations made without print during coasting stages
IEXTRAC		integer variable, see MAIN PRØGRAM
J		DØ loop index for inflation periods; implied DØ loop index for printing array REEF
LSS		$L_s + L_R$
ML	m_ℓ	mass of load
MP	m_p	mass of parachute
MS		$m_\ell + m_{ss} + m_p$
MSS	m_{ss}	mass of suspension system
N		number of steps used to approximate inflation periods

TABLE V (Cont'd.)

Computer Symbols for Subroutine ØPENING

Mnemonic Variation	Symbol	Comment
NINT		number of calculations to be made between successive prints during coasting stages; if NINT < 0, continuous output is suppressed
NREEF		integer variable, number of reefing lines used
PI	π	3.14159...
REEF		array which contains trajectory variables, opening shock, and filling time at end of each reefed inflation period
RHØ	ρ	air density
RO	R_o	initial reefing ratio = $\frac{\ell_R/\pi}{D_o}$
R1	R_1	final reefing ratio = $\frac{\ell_R/\pi}{D_o}$
T	t	time
TCD	t_{CD}	reefing cutter delay time
TDR	t_{DR}	rime of disreef, $t_{DR} = t_{RCA} + t_{CD}$
TF	t_{ff} or t_{fR}	filling time
THETA	θ	system angle, radians
THETAO	θ_o	θ initial, at entry to FILLTIM
TNØT	t_o	t initial, at beginning of each inflation stage
TRAJANG	θ	system angle, degrees

TABLE V (Cont'd.)

Computer Symbols for Subroutine ØPENING

Mnemonic Variation	Symbol	Comment
TRCA	t_{RCA}	time at which reefing cutters are armed
V	v	velocity
V1 - V5		terms in Eqn (27)
VØLUME	V or V_R	volume, V or V_R, for call to FILLTIM
VØLUMG	V	volume of fully inflated parachute
VX	v_x	x component of velocity
VZ	v_z	z component of velocity
VO		initial velocity, at entry to FILLTIM
X	x	x position
XO		initial x, at entry to FILLTIM
Z	z	z position
ZO		initial z, at entry to FILLTIM

TABLE VI

Computer Symbols for Subroutine FILLTIM

Mnemonic Variation	Symbol	Comment
C	c	effective porosity
CAPT	T	dimensionless time
CAPTR	T_R	dimensionless time for reefed inflation periods
CO	c_o	effective porosity at mean sea level
D	d	canopy inlet diameter
DCAPT	ΔT	increment of T
DCAPTR	ΔT_R	increment of T_R
DNØT	D_o	nominal diameter
DP	D_p	projected diameter
DTF		filling time increment, $\left(\frac{\text{VØLUME}}{\text{VØL}} - 1\right) t_{fR}$
DV	Δv	velocity increment
HO	h_o	initial reefed D_p/D_o
H1	h_1	final reefed D_p/D_o
I		DØ loop index for evaluation of continuity equation
J, K		DØ loop indices for evaluation of Simpson's rule formula
MS		$m_\ell + m_{ss} + m_p$

TABLE VI (Cont'd.)

Computer Symbols for Subroutine FILLTIM

Mnemonic Variation	Symbol	Comment
N		number of steps used for integration of continuity equation by Simpson's rule
PI	π	3.14159...
RHØ	ρ	air density
SUM		approximation to $\int v \left[(1+2.2cT-T) \frac{d^2}{4} - \frac{1.1c}{2} D_p^2 \right] dT$
TF	t_{ff} or t_{fR}	filling time
THETA	θ	system angle, radians
THETAO	θ_o	initial θ, at entry to FILLTIM
V	v	velocity
VØL	V	volume from integration of continuity equation
VØLDØT		array which contains integrand of Eqn (30)
VØLUME	V or V_R	volume increase for the particular inflation
VO		initial velocity, at entry to FILLTIM
X	x	x position
XO		initial x, at entry to FILLTIM
Z	z	z position
ZO		initial z, at entry to FILLTIM

TABLE VII

Computer Symbols for Subroutine CALC

Mnemonic Variation	Symbol	Comment
ALT	h_o	release altitude
CAPT	T	dimensionless filling time
CDP	C_{D_p}	drag coefficient of parachute based on projected area
CDS		$(C_DS)_p + C_DS_\ell$
CDSL	C_DS_ℓ	drag area of load
D	d	inlet diameter
DCAPT	ΔT	increment in T
DCAPTR	ΔT_R	increment in T_R
DDØT	$\frac{d(d)}{dT}$	dimensionless time derivative of d
DMA	Δm_a	increment of m_a
DMI	Δm_i	increment of m_i
DNØT	D_o	nominal diameter
DP	D_p	projected diameter
DPDØT	$d(D_p)/dT$	dimensionless time derivative of D_p
DPMAX	$D_{p_{max}}$	projected diameter of fully inflated parachute
DTHETA	$\Delta\theta$	increment in θ
DV	Δv	increment in v

TABLE VII (Cont'd.)

Computer Symbols for Subroutine CALC

Mnemonic Variation	Symbol	Comment
DX	Δx	increment in x
DZ	Δz	increment in z
G	g	acceleration of gravity
LSS		$L_s + L_R$
M		$m_\ell + m_{ss} + m_p$
MA	m_a	apparent mass
MI	m_i	included mass
MT	m_T	$m_\ell + m_{ss} + m_p + m_a + m_i$
PI	π	3.14159...
RHØ	ρ	air density
SQ		term used in Eqn (46)
SQ1		term used in Eqn (46)
TF	t_{ff} or t_{fR}	filling time
THETA	θ	system angle, radians
V	v	velocity
X	x	x position
Z	z	z position

TABLE VIII

Computer Symbols for Subroutine MØTIØN
(Three Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
A	a_ℓ	acceleration of the load
ALPHAL	α_ℓ	load angle of attack, radians
ALPHA1	α_ℓ	load angle of attack, degrees
ALT	h_o	release altitude
AMARK		$\pm$ 1
ANG	θ	previous value of system angle
AX	a_{ℓ_x}	x-component of a_ℓ
AZ	a_{ℓ_z}	z-component of a_ℓ
A1	a_{ℓ_x}	a_{ℓ_x} if t_1 > TSTØP or R2 > ZSTØP
A2	a_{ℓ_z}	a_{ℓ_z} if t_1 > TSTØP or R2 > ZSTØP
B		dummy array established for use in call to INTGRAT
CØRR		correction for linear interpolation
DQ	$\frac{dv}{dt}$	acceleration at the moment of full inflation
DT	Δt	time increment set by MAIN PRØGRAM
DX	Δt	time increment set by INTGRAT
ETA	η_i	array containing allowable absolute errors in the integration
G	g	acceleration of gravity
I		DØ loop index; implied DØ loop index for printing array VERTPAR
ID		if ID > 0 indicates INTGRAT has not been called previously

TABLE VIII (Cont'd.)

Computer Symbols for Subroutine MØTIØN
(Three Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
IVERT		1, 2, or 3-- the number of times the system has been vertical or near vertical
J		DØ loop index
K		if K > 0 indicates the integration cannot be completed
L1	ℓ_1	distance from patachute-load system mass center to load
NINT		the number of calculations made between prints if the time increment is small enough; if NINT < 0 continuous output is suppressed
NMARK		1, 2, 3, 4 or 5--NMARK = 1, 3, or 5 indicates the system is vertical or near vertical
NUMB		DØ loop index for calculations without print
PCTERR	E_p	allowable relative error in integration
PI	π	3.14159...
RX	r_{ℓ_x}	x position of load
RZ	r_{ℓ_z}	z position of load
R1	r_{ℓ_x}	r_{ℓ_x} if t_1 > TSTØP or R2 > ZSTØP
R2	r_{ℓ_z}	r_{ℓ_z}; used to determine if r_{ℓ_z} > ZSTØP
SYSANGL	θ	system angle, degrees
T	t	time
TF	t_F	time at which integrated values are desired from INTGRAT

TABLE VIII (Cont'd.)

Computer Symbols for Subroutine MØTIØN
(Three Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
THETA	θ	system angle, radians
TRAJANG	$\theta-\alpha_\ell$	trajectory angle of load
TSTØP		time at which simulation terminates; initially number of seconds after full inflation
T1	t_1	time
V	v, v_ℓ	velocity of load or mass center
VERTPAR		array containing information at the first three instances when the system is vertical or near vertical
VX	v_{ℓ_x}	x - component of load velocity
VZ	v_{ℓ_z}	z - component of load velocity
VO	v_ℓ	velocity of the load
V1	v_{ℓ_x}	v_{ℓ_x} if t_1 > TSTØP or R2 > ZSTØP
V2	v_{ℓ_z}	v_{ℓ_z} if t_1 > TSTØP or R2 > ZSTØP
W		array established for call to INTGRAT
X	x	position of mass center at entry to MØTIØN
X1		array established for call to INTGRAT
X2		array established for call to INTGRAT
X3		array established for call to INTGRAT
Y		array of U, W, Q, θ, x, and z

TABLE VIII (Cont'd.)

Computer Symbols for Subroutine MØTIØN
(Three Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
YDØT		array of $\dot{U}$, $\dot{W}$, $\dot{Q}$, $\dot{\theta}$, $\dot{x}$, and $\dot{z}$
Z		array established for call to INTGRAT
ZSTØP		altitude mass at which simulation terminates

TABLE IX

Computer Symbols for Subroutine INTGRAT

Mnemonic Variation	Symbol	Comment
DT	Δt	time increment
DX	Δt	time increment; represents the last successful time increment used by INTGRAT on previous call
ERR1		$\left\| Y_{3_j} - Y_{1_j} \right\|$ j = 1, NN
ERR2		$\max \left\{ \eta_j, E_p \cdot \left\| Y_{3_j} \right\| \right\}$ j = 1,NN
ETA	η_j	array containing sbsooute errors allowed in integration
I		DØ loop index
ID		if ID ≤ 0, INTGRAT has been called previously
IMDØNE		IMDØNE ≥ 0 indicates integration has been completed
ISIGNAL		ISIGNAL > 0 indicates solution cannot be accomplished
J		DØ loop index
K		DØ loop index
L		parameter of calls to FØRMULA; L > 0 indicates time increment must be halved
M		number of successful integrations without halving time increment
MM		number of times time increment is halved without successful integration
NN		number of equations being solved
PCTERR	E_p	relative error allowed in integration
T		time at entry to INTGRAT
TF	t_F	time to which integration is desired

TABLE IX (Cont'd.)

Computer Symbols for Subroutine INTGRAT

Mnemonic Variation	Symbol	Comment
TRY1	Y_{1_J}	array containing values of Y after integration from t_1 to $t_1 + \Delta t$ in one step
TRY2	Y_{2_J}	array containing values of Y after integration from t_1 to $t_1 + \frac{1}{2}\Delta t$
TRY3	Y_{3_J}	array containing values of Y after integration from $t_1 + \frac{1}{2}\Delta t$ to $t_1 + \Delta t$
T1	t	time
W		array used in FØRMULA
Y		array containing variable values for which solution is required
YDØT		array containing derivatives of Y
Z		array used in FORMULA

TABLE X

Computer Symbols for Subroutine FØRMULA

Mnemonic Variation	Symbol	Comment
A		array containing constants for the Runge-Kutta formula
C		1/3 A(K + 1)
H	Δt	time increment
ISIGNAL		ISIGNAL > 0 indicates the call to EMØTIØN could not be successfully completed
J		DØ loop index
K		DØ loop index
L		DØ loop index
NN		number of equations being solved
W		array containing values of Y for calls to EMØTIØN
Y		array, see INTGRAT
YDØT		array, see INTGRAT
YI		final values of Y at t = t + H
Z		array containing the values of YDØT returned by calls to EMØTIØN

TABLE XI

Computer Symbols for Subroutine EMØTIØN
(Three Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
A		$\frac{m_i + m_a}{(m_\ell + m_{ss} + m_p + m_i + m_a)}$
AERØM	M_A	aerodynamic moment of parachute
ALPHA		$\tan^{-1}(-\frac{U}{W})$
ALPHAL	α_ℓ	angle of attack of load
ALPHAP	α_p	angle of attack of parachute
ALT	h_o	release altitude
B		$\frac{(m_\ell + m_{ss} + m_p)\,g}{(m_\ell + m_{ss} + m_p + m_i + m_a)}$
C		$\frac{\rho}{8}\,\pi\,D_o^2$
CDNØT		$(\frac{\rho}{8}\,\pi\,D_o^2)\cdot D_o$
CDSL	C_DS_ℓ	drag area of load
CM	C_{M_o}	aerodynamic moment coefficient
CN	C_{N_o}	aerodynamic normal force coefficient
CT	C_{T_o}	aerodynamic tangent force co-efficient
D	D_ℓ	drag of load
DNØT	D_o	nominal diameter
E		$\frac{1}{2}\,\rho\,C_DS_\ell$
G	g	acceleration of gravity
ISIGNAL		if ISIGNAL > 0, call to CØEFFTS showed $\lvert\alpha_p\rvert$ too large

TABLE XI (Cont'd.)

Computer Symbols for Subroutine EMØTIØN
(Three Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
ISTØP		1 or 2; parameter indicating whether the call to EMØTIØN comes from FØRMULA or INTGRAT
IXX	I_{XX}	moment of inertia about X-axis
IXZ	I_{XZ}	product of inertia
IYY	I_{YY}	moment of inertia about Y-axis
IZZ	I_{ZZ}	moment of inertia about Z-axis
L1	ℓ_1	distance from parachute-load system mass center to load
L2	ℓ_2	distance from parachute-load system mass center to parachute center of volume
L3	ℓ_3	distance from parachute-load system mass center to moment center
M		$m_\ell + m_{ss} + m_p + m_i + m_a$
MA		$m_i + m_a$
MI	m_i	included mass
ML	m_ℓ	mass of load
MP	m_p	mass of parachute
MSS	m_{ss}	mass of suspension system
N	F_N	aerodynamic normal force
PI	π	3.14159...
RHØ	ρ	air density
TT	T	aerodynamic tangent force
VL2		v_ℓ^2

TABLE XI (Cont'd.)

Computer Symbols for Subroutine EMØTIØN
(Three Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
VP2		v_p^2
V2		$U^2 + W^2$
Y		array containing U, W, Q, θ, x, z
YDØT		array containing $\dot{U}$, $\dot{W}$, $\dot{Q}$, $\dot{\theta}$, $\dot{x}$, $\dot{z}$

TABLE XII

Computer Symbols for Subroutine DYNAMIC

Mnemonic Variation	Symbol	Comment
DNØT	D_o	nominal diameter
IA	I_a	apparent moment of inertia about X or Y-axis
IAZ	I_{a_Z}	apparent moment of inertia about Z-axis
IAZO	$I_{a_Z})_o$	I_{a_Z} at mean sea level
IXX	I_{XX}	moment of inertia about X-axis
IXZ	I_{XZ}	product of inertia
IY	I_Y	moment of inertia about Y-axis due to physical masses, Eqn (88)
IYY	I_{YY}	moment of inertia about Y-axis
IZ	I_Z	moment of inertia about Z-axis due to physical masses
IZZ	I_{ZZ}	moment of inertia about Z-axis
L1	ℓ_1	distance from parachute-load system mass center to load
L2	ℓ_2	distance from parachute-load system mass center to parachute center of volume
L3	ℓ_3	distance from parachute-load system mass center to moment center
MBR	m_{Br}	mass of load bridle
MI	m_i	included mass
MLS	m_{L_s}	mass of suspension lines
MP	m_p	mass of parachute
MR	m_R	mass of risers

TABLE XII (Cont'd.)

Computer Symbols for Subroutine DYNAMIC

Mnemonic Variation	Symbol	Comment
MRX	m_E	mass of riser extension
Q_1	s_c/D_o	ratio of reference distance from canopy skirt to parachute center of volume in fully inflated configuration to D_o
Q_2	$D_{p_{max}}/D_o$	projected diameter ratio
RHØ	ρ	air density
VØLUME	V	volume of fully inflated parachute
X	$\overline{s}$	distance of parachute-load system mass center from canopy skirt
XDENØM		$m_p + m_{L_s} + m_R + m_E + m_{Br} + m_\ell$
XNUM		$m_{L_s} \cdot s_1 + m_R \cdot s_2 + m_E \cdot s_3$ $+ m_{Br} \cdot s_4 + m_\ell \cdot s_5 - m_p \cdot s_c$
X1	s_1	reference distance from canopy skirt to suspension line center of mass in fully inflated configuration
X2	s_2	reference distance from canopy skirt to riser center of mass in fully inflated configuration
X3	s_3	reference distance from canopy skirt to riser extension center of mass im fully inflated configuration
X4	s_4	reference distance from canopy skirt to load bridle center of mass in fully inflated configuration
X5	s_5	reference distance from canopy skirt to load center of mass in fully inflated configuration

TABLE XIII

Computer Symbols for Subroutine CØEFFTS
(Three Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
A		$\lvert \alpha_p \rvert$
ALPHAP	α_p	parachute angle of attack, radians
ALPHAPD	α_p	parachute angle of attack, degrees
CM	C_{M_o}	aerodynamic moment coefficient
CN	C_{N_o}	aerodynamic normal force coefficient
CT	C_{T_o}	aerodynamic tangent force coefficient
IPRINT		1 or 2; indicates whether or not to print message concerning parachute angle of attack
ISIGNAL		if ISIGNAL > 1, indicates $\lvert \alpha_p \rvert > 85^o$

TABLE XIV

Computer Symbols for Subroutine MØTIØN (Six Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
A	$\underline{\underline{A}}$	3 x 3 array containing direction cosines
ALT	h_o	release altitude
AMARK		see MØTIØN (3DOF)
ANG		previous value of the system angle
AT	a_ℓ	total acceleration of load
AX	a_{ℓ_x}	x-component of load acceleration
AY	a_{ℓ_y}	y-component of load acceleration
AZ	a_{ℓ_z}	z-component of load acceleration
A1	a_{ℓ_x}	a_{ℓ_x} if t_1 > TSTØP or R3 > ZSTØP
A2	a_{ℓ_y}	a_{ℓ_y} if t_1 > TSTØP or R3 > ZSTØP
A3	a_{ℓ_z}	a_{ℓ_z} if t_1 > TSTØP or R3 > ZSTØP
CØRR		see MØTIØN (3DOF)
C1		$U + Q\ell_1$
C2		$V - R\ell_1$
C3		$\dot{U} + PW - RV + \dot{Q}\ell_1 + PR\ell_1$
C4		$\dot{V} + RU - QW - \dot{P}\ell_1 + QR\ell_1$
C5		$\dot{W} + QV - PU - (P^2 + Q^2)\ell_1$
DQ	$\frac{dv}{dt}$	see MØTIØN (3DOF)

TABLE XIV (Cont'd.)

Computer Symbols for Subroutine MØTIØN
(Six Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
DT	Δt	see MØTIØN (3DOF)
DX	Δt	see MØTIØN (3DOF)
ETA	η	see MØTIØN (3DOF)
G	g	acceleration of gravity
I		see MØTIØN (3DOF)
ID		see MØTIØN (3DOF)
IVERT		see MØTIØN (3DOF)
J		see MØTIØN (3DOF)
K		see MØTIØN (3DOF)
L1	ℓ_1	distance from parachute-load system mass center to load
NINT		see MØTIØN (3DOF)
NMARK		see MØTIØN (3DOF)
NUMB		see MØTIØN (3DOF)
PCTERR	E_p	see MØTIØN (3DOF)
PI	π	3.14159...
RX	r_{ℓ_x}	x-component of load position
RY	r_{ℓ_y}	y-component of load position
RZ	r_{ℓ_z}	z-component of load position
R1	r_{ℓ_x}	r_{ℓ_x} if t_1 > TSTØP or R3 > ZSTØP
R2	r_{ℓ_y}	r_{ℓ_y} if t_1 > TSTØP or R3 > ZSTØP
R3	r_{ℓ_z}	r_{ℓ_z} ; used to determine if r_{ℓ_z} > ZSTØP
SYSANGL		system angle

TABLE XIV (Cont'd.)

Computer Symbols for Subroutine MØTIØN
(Six Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
T	t	time
TF	t_F	see MØTIØN (3DOF)
THETA	θ	system angle at entry to MØTIØN
TRAJANG		trajectory angle of load
TSTØP		see MØTIØN (3DOF)
T1	t	time
VERTPAR		see MØTIØN (3DOF)
VX	v_{ℓ_x}	x-component of velocity
VY	v_{ℓ_y}	y-component of velocity
VZ	v_{ℓ_z}	z-component of velocity
VO	v_{ℓ}	velocity of load
V1	v_{ℓ_x}	v_{ℓ_x} if t_1 > TSTØP or R3 > ZSTØP
V2	v_{ℓ_y}	v_{ℓ_y} if t_1 > TSTØP or R3 > ZSTØP
V3	v_{ℓ_z}	v_{ℓ_z} if t_1 > TSTØP or R3 > ZSTØP
W		see MØTIØN (3DOF)
X		see MØTIØN (3DOF)
X1		see MØTIØN (3DOF)
X2		see MØTIØN (3DOF)
X3		see MØTIØN (3DOF)
Y		array containing U, V, W, P, Q, R, θ, φ, ψ, x, y, z
YDØT		array containing $\dot{U}$, $\dot{V}$, $\dot{W}$, $\dot{P}$, $\dot{Q}$, $\dot{R}$, $\dot{\theta}$, $\dot{\varphi}$, $\dot{\psi}$, $\dot{x}$, $\dot{y}$, $\dot{z}$
Z		see MØTIØN (3DOF)

TABLE XIV (Cont'd.)

Computer Symbols for Subroutine MØTIØN (Six Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
ZSTØP		see MØTIØN (3DOF)

TABLE XV

Computer Symbols for Subroutine EMØTIØN
(Six Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
A	$\underline{\underline{A}}$	3 x 3 array containing direction cosines
AERØMX	M	X-component of aerodynamic moment
AERØMY	M	Y-component of aerodynamic moment
ALPHAL	α_ℓ	angle of attack of load in XZ-plane
ALPHAP	α_p	angle of attack of load in XZ-plane
ALT	h_o	release altitude
B		$\frac{(m_\ell + m_{ss} + m_p)\, g}{(m_\ell + m_{ss} + m_p + m_i + m_a)}$
BETAL	β_ℓ	angle of attack of load in YZ-plane
BETAP	β_p	angle of attack of parachute in YZ-plane
C		$\frac{\rho}{8} \pi D_o{}^2$
CDNØT		$(\frac{\rho}{8} \pi D_o{}^2)\ D_o$
CDSL	$C_D S_\ell$	drag area of load
CMX	$C_{M_{X_o}}$	coefficient of aerodynamic moment about X axis
CMY	$C_{M_{Y_o}}$	coefficient of aerodynamic moment about Y axis
CT	C_{T_o}	aerodynamic tangent force coefficient
CX	$C_{N_{X_o}}$	coefficient of aerodynamic normal force in X-direction

TABLE XV (Cont'd.)

Computer Symbols for Subroutine EMØTIØN
(Six Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
CY	$C_{N_{Y_o}}$	coefficient of aerodynamic normal force in Y-direction
D	D_ℓ	drag of load
DELTAL	δ_ℓ	angle between load velocity and YZ-plane
DNØT	D_o	nominal diameter
E		$\frac{1}{2}\rho C_D S_\ell$
FX	F_{NX}	normal force in X-direction
FY	F_{NY}	normal force in Y-direction
G	g	acceleration of gravity
GAMMAL	γ_ℓ	angle between load velocity and XZ-plane
H1		$(I_{ZZ} - I_{YY})/I_{XX}$
H2		$(I_{XX} - I_{ZZ})/I_{YY}$
H3		$(I_{YY} - I_{XX})/I_{ZZ}$
H4		I_{XZ}/I_{XX}
H5		I_{XZ}/I_{YY}
H6		I_{XZ}/I_{ZZ}
ISIGNAL		see EMØTIØN (3DOF)
ISTØP		see EMØTIØN (3DOF)
IXX	I_{XX}	moment of inertia about X-axis
IXZ	I_{XZ}	product of inertia
IYY	I_{YY}	moment of inertia about Y-axis

TABLE XV (Cont'd.)

Computer Symbols for Subroutine EMØTIØN
(Six Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
IZZ	I_{ZZ}	moment of inertia about Z-axis
L1	ℓ_1	distance from parachute-load system mass center to load
L2	ℓ_2	distance from parachute-load system mass center to parachute center of volume
L3	ℓ_3	distance from parachute-load system mass center to moment center
M		$m_\ell + m_{ss} + m_p + m_i + m_a$
MA		$m_i + m_a$
MI	m_i	included mass
ML	m_ℓ	mass of load
MP	m_p	mass of parachute
MSS	m_{ss}	mass of suspension system
PI	π	3.14159...
PØLANG	θ_p	polar angle of parachute velocity
R		$\dfrac{m_i + m_a}{m_\ell + m_{ss} + m_p + m_i + m_a}$
RHØ	ρ	air density
TT	T	aerodynamic tangent force
UL		$U + Q\ell_1$
UP		$U + Q\ell_2$
VL		$V - P\ell_1$

TABLE XV (Cont'd.)

Computer Symbols for Subroutine EMØTIØN
(Six Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
VL2		v_{ℓ}^{2}
VP		$V - P\ell_{2}$
VP2		v_{p}^{2}
Y		array containing U, V, W, P, Q, R, θ, φ, ψ, x, y, z
YDØT		array containing $\dot{U}$, $\dot{V}$, $\dot{W}$, $\dot{P}$, $\dot{Q}$, $\dot{R}$, $\dot{\theta}$, $\dot{\varphi}$, $\dot{\psi}$, $\dot{x}$, $\dot{y}$, $\dot{z}$

TABLE XVI

Computer Symbols for Subroutine CØEFFTS
(Six Degrees of Freedom)

Mnemonic Variation	Symbol	Comment
A		$\|\alpha_p\|$
ALPHAP	α_p	angle of attack of parachute in XZ-plane, radians
ALPHAPD	α_p	angle of attack of parachute in XZ-plane, radians
B		$\|\beta_p\|$
BETAP	β_p	angle of attack of parachute in YZ-plane, radians
BETAPD	β_p	angle of attack of parachute in YZ-plane, degrees
CMX	$C_{M_{X_o}}$	coefficient of aerodynamic moment about X-axis
CMY	$C_{M_{Y_o}}$	coefficient of aerodynamic moment about Y-axis
CT	C_{T_o}	aerodynamic tangent force coefficient
CX	$C_{N_{X_o}}$	coefficient of aerodynamic normal force in X-direction
CY	$C_{N_{Y_o}}$	coefficient of aerodynamic normal force in Y-direction
P		$\|\theta_p\|$
PØLANG	θ_p	polar angle of parachute

TABLE XVII

Computer Symbols for Subroutine CØSINES

Mnemonic Variation	Symbol	Comment
A	$\underline{\underline{A}}$	3 x 3 array containing direction cosines
Y(7)	θ	Euler Angle
Y(8)	φ	Euler Angle
Y(9)	ψ	Euler Angle

TABLE XVIII

Computer Symbols for Subroutine DENSITY

Mnemonic Variation	Symbol	Comment
H	h	altitude
RHØ	ρ	air density

TABLE XIX

Computer Symbols for Subroutine TRAJEQN

Mnemonic Variation	Symbol	Comment
ALT	h_o	release altitude
CDS	C_DS	drag area
DT	Δt	time increment
DTHETA	$\Delta\theta$	system angle increment
DV	Δv	velocity increment
DX	Δx	x increment
DZ	Δz	z increment
G	g	acceleration of gravity
M	m	mass
RHØ	ρ	air density
T	t	time
THETA	θ	system angle
V	v	velocity
X	x	x position
Z	z	z position

VII. COMPUTER PROGRAM SOURCE LIST

The computer program is arranged in the form which will probably be the most useful at the present time, i.e., including the complete solution allowing three degrees of freedom, with aerodynamic coefficients for a solid flat circular parachute, and listed in Fig 29. In addition, the solution allowing six degrees of freedom for the free descent phase is listed in Fig 30. The only difference between the two solutions lies in the arrangement of the subroutines following subroutine DYNAMIC. The appropriate data cards are inserted immediately after subroutine CØEFFTS. All subroutine calls are indicated by arrows in the left margins of Figs 29 and 30 for aid when referring to these source lists.

```
      PROGRAM TRAJSIM(INPUT,OUTPUT)
C           THIS IS THE MAIN PROGRAM
      DIMENSION ETA(12),SPACE(1000)
      REAL IXX,IYY,IZZ,IXZ,IAZ0,IZ,LSS,L1,L2,L3,MA,MBR,ML,MLS,MP,MR,MRX,
     1MSS,MST
      COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NINT
      COMMON /VARIABL/ RHO,T,V,THETA,X,Z,ALPHAL,ALPHAP,L1
      COMMON /DYNAM/ DYDNOT,X1,X2,X3,X4,X5,MBR,DYML,MLS,DYMP,MR,MRX,IAZ0
     1,IZ,Q1,Q2,VOLUME,XNUM,XDENOM
      PI=3.141592653589793
      G=32.17
      READ 10,NSIM
      DO 11 J=1,NSIM
      READ 9,C1,C2,C3,C4,C5
      PRINT 12,C1,C2,C3,C4,C5
      READ 6,ALT,V0,MST,MP,MLS,MR,MRX,MBR,ML,X1,X2,X3,X4,X5,IZ,IAZ0,
     1DNOT,LSS,CDP,CDSL,Q1,Q2,VOLUME,N,NNN,DT1,DT2,DT3,NINT
      DYDNOT=DNOT
      DYML=ML
      DYMP=MP
      XNUM=MLS*X1+MR*X2+MRX*X3+MBR*X4+ML*X5-MP*Q1*DNOT
      XDENOM=MP+MLS+MR+MRX+MBR+ML
      MSS=MLS+MR+MRX+MBR
      CALL DYNAMIC(0.002378,A1,A2,A3,A4,A5,A6,A7,A8)
      A9=0.375*A8
      CALL DENSITY(RHO,ALT)
      CALL DYNAMIC(RHO,B1,B2,B3,B4,B5,B6,B7,B8)
      B9=0.375*B8
      PRINT 8,ALT,V0,MST,ML,MP, MLS,MR,MRX,MBR,A8,B8,ALT,A9,B9,ALT,X1,
     1X2,X3,X4,X5,A4,B4,ALT,A5,B5,ALT,A6,B6,ALT,A7,B7,ALT,DNOT,LSS,A1,B1
     2,ALT,A2,B2,ALT,A3,B3,ALT,Q1,Q2,VOLUME,CDP
      PRINT 81,CDSL,N
      NN=2*N
      READ 7,(ETA(I),I=1,NN),PCTERR
      CALL EXTRACT(ISNATCH,IEXTRAC,V0,DT1,TRCA)
      IF(ISNATCH) 4,4,5
    4 CALL SNATCH(TRCA,DT2)
    5 CALL OPENING(DQ,TRCA,NNN,SPACE,VOLUME,IEXTRAC,DT3)
      CALL MOTION(DQ,PCTERR,ETA,DT3)
   11 CONTINUE
      STOP
    6 FORMAT(2F10.0/7F10.0/7F10.0/7F10.0/I1,I9,3F10.0,I5)
    7 FORMAT(6F10.0/6F10.0/F10.0)
    8 FORMAT(3/,5X,*TRAJECTORY SIMULATION--T=0,Z=0 IS RELEASE POINT*,3/,
     15X,*RELEASE CONDITIONS*,/,10X,*ALTITUDE=*,F10.0,* FT*,/,10X,*VELOC
     2ITY=*,F10.2,* FT/SEC*,///,5X,*MASSES--SLUGS*,/10X,*TOTAL SYSTEM= *
     3,F10.3,/,10X,*LOAD= *,F10.3,/,10X,*PARACHUTE= *,F10.3,/,10X,*SUSP.
     4 LINES= *,F10.3,/,10X,*RISERS= *,F10.3,/,10X,*RISER EXTENSIONS= *,
     5F10.3,/,10X,*LOAD BRIDLE= *,F10.3,/,10X,*INCLUDED= *,F10.3,*(SEA L
     6EVEL)*,F10.3,*(*,F7.0,*  FT)*,/,10X,*APPARENT= *,F10.3,*(SEA LEVEL
     7)*,F10.3,*(*,F7.0,*  FT)*,///,5X,*REFERENCE DISTANCES FROM SKIRT--
     8 FT*,/,10X,*X1= *,F10.3,/,10X,*X2= *,F10.3,/,10X,*X3= *,F10.3,/,
     910X,*X4= *,F10.3/10X,*X5= *,F10.3///,5X,*MOM./PROD. INERTIA--SLUG
     1FT*,3H**2,/,10X,*IXX= *,F15.3,*(SEA LEVEL)*,F15.3,*(*,F7.0,*  FT)*
     2,/,10X,*IYY= *,F15.3,*(SEA LEVEL)*,F15.3,*(*,F7.0,*  FT)*,/,10X,
     3 *IZZ= *,F15.3,*(SEA LEVEL)*,F15.3,*(*,F7.0,*  FT)*,/,10X,*IXZ= *,
     4F15.3,*(SEA LEVEL)*,F15.3,*(*,F7.0,*  FT)*,///,5X,*DIMENSIONS-- FT
     5*,/,10X,*DNOT= *,F10.3,/,10X,*SUSP. SYSTEM= *,F10.3,/,10X,*L1= *,F
     610.3,*(SEA LEVEL)*,F10.3,*(*,F7.0,*  FT)*,/,10X,*L2= *,F10.3,*(SEA
     7 LEVEL)*,F10.3,*(*,F7.0,*  FT)*,/,10X,*L3= *,F10.3,*(SEA LEVEL)*,F
     810.3,*(*,F7.0,*  FT)*,///,5X,*YC/DNOT= *,F10.3,/,5X,*DP/DNOT= *,F1
     90.3,/,5X,*VOLUME= *,F10.3,6H FT**3,/,5X,*PARACHUTE CDP= *,F10.3)
   81 FORMAT(5X,*LOAD DRAG AREA= *,F10.3,6H FT**2,/,5X,*DEGREES OF FREE
     1DOM= *,I10,5/)
```

FIG 29 Computer Program for Three Degrees of Freedom

```
 9  FORMAT(5A10)
10  FORMAT(I3)
12  FORMAT(1H1,/,5X,*PARACHUTE-LOAD SYSTEM(DEPLOYMENT)--*,5A10)
    END
```

```
      SUBROUTINE EXTRACT(ISNATCH,IEXTRAC,V0,DT,TRCA)
      COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NINT
      COMMON /VARIABL/ RHO,T,V,THETA,X,Z,UNUSED,UNUSED2,UNUSED3
      REAL LENGTH,LSPILOT,LSS,LSTATIC,MST,MT,LRXBR
      ICOUNT=0
      READ 15,ISTATIC,IEXTRAC
      IF(ISTATIC) 1,8,8
    1 READ 16,LSTATIC,CDSBAG,CDSP,DPILOT,LSPILOT,TD,LRXBR
      DISTANC=LSTATIC
      PRINT 22,LSTATIC,CDSBAG
      IF(DPILOT.GT.0.0) PRINT 23,CDSP,DPILOT,LSPILOT,TD
      IF(NINT.GT.0) PRINT 26
      T=X=Z=0.0
      THETA=0.5*PI
      V=V0
      CDST=CDSL+CDSBAG
      MT=MST
  →2  CALL TRAJEQN(T,V,THETA,X,Z,RHO,CDST,MT,DT,G,ALT,DV)
      VX=V*SIN(THETA)
      TRAJANG=THETA*180./PI
      VZ=V*COS(THETA)
      ICOUNT=ICOUNT+1
      ALTMZ=ALT-Z
      IF(ICOUNT.EQ.NINT) PRINT 19,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V,VX,VZ
      IF(ICOUNT.EQ.NINT) ICOUNT=0
      IF(SQRT((V0*T-X)*(V0*T-X)+Z*Z).LT.DISTANC) GO TO 2
      IF(DISTANC.GT.LSTATIC) GO TO 3
      T1=T
      TRAJ1=TRAJANG
      X1=X
      Z1=Z
      V1=V
      DISTANC=LSTATIC+LSS+0.5*DNOT+LRXBR
      IF(DPILOT.GT.0.0) DISTANC=LSTATIC+LSPILOT+0.5*DPILOT
      GO TO 2
    3 IF(DPILOT) 7,7,4
    4 ISNATCH=-1
      CDST=CDSL+CDSBAG+CDSP
    5 IF(T-TD) 6,14,14
  →6  CALL TRAJEQN(T,V,THETA,X,Z,RHO,CDST,MT,DT,G,ALT,DV)
      TRAJANG=THETA*180./PI
      VX=V*SIN(THETA)
      VZ=V*COS(THETA)
      ICOUNT=ICOUNT+1
      ALTMZ=ALT-Z
      IF(ICOUNT.EQ.NINT) PRINT 19,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V,VX,VZ
      IF(ICOUNT.EQ.NINT) ICOUNT=0
      GO TO 5
    7 ISNATCH=1
      TRCA=T
      PRINT 20,T1,TRAJ1,X1,Z1,V1,T,TRAJANG,X,Z,V
      RETURN
    8 IF(IEXTRAC) 9,9,13
    9 READ 17,LENGTH,CDSBAG,CDSEX,TD
      PRINT 24,LENGTH,CDSBAG,CDSEX,TD
      IF(NINT.GT.0) PRINT 26
```

FIG 29 Computer Program for Three Degrees of Freedom (Continued)

```
      ISNATCH=-1
   10 T=X=Z=0.0
      THETA=0.5*PI
      TRAJANG=90.
      CDST=CDSEX
      V=V0
   11 DV=-RHO*CDST*V*V*DT/(2.*MST)
      DX=V*DT
      V=V+DV
      X=X+DX
      T=T+DT
      ICOUNT=ICOUNT+1
      ALTMZ=ALT-Z
      IF(ICOUNT.EQ.NINT) PRINT 19,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V,V
      IF(ICOUNT.EQ.NINT) ICOUNT=0
      IF(V0*T-X-LENGTH) 11,12,12
   12 CDST=CDSL+CDSBAG+CDSEX
      MT=MST
      T1=T
      X1=X
      V1=V
      GO TO 5
   13 READ 18,R,LENGTH,TD
      H=(4.*LSS*R+2.*R*DNOT)/(4.*LSS+PI*R*DNOT)
      HTDNOT=H*DNOT
      PRINT 25,LENGTH,R,HTDNOT,TD
      IF(NINT.GT.0) PRINT 26
      CDSEX=CDP*PI*H*H*DNOT*DNOT/4.
      CDSBAG=0.0
      ISNATCH=1
      GO TO 10
   14 IF(ISTATIC.LT.0) PRINT 20,T1,TRAJ1,X1,Z1,V1,T,TRAJANG,X,Z,V
      IF(ISTATIC.GE.0) PRINT 21,T1,X1,V1,T,TRAJANG,X,Z,V
      IF(IEXTRAC.GT.0) TRCA=0.0
      RETURN
   15 FORMAT(2I2)
   16 FORMAT(7F10.0)
   17 FORMAT(8F10.0)
   18 FORMAT(3F10.0)
   19 FORMAT(1X,F8.2,4F11.2,11X,3F11.2,11X,F11.2)
   20 FORMAT(//,60X,*TIME(SEC)  ANGLE(DEG)    X(FT)       Z(FT)  VELOCITY(FT
     1/SEC)*,/,20X,*STATIC LINE STRETCH*,16X,5F11.2/20X,*PARACHUTE/PILOT
     2 CHUTE DEPLOYMENT*,3X,5F11.2)
   21 FORMAT(//,60X,*TIME(SEC)  ANGLE(DEG)    X(FT)       Z(FT)  VELOCITY(FT
     1/SEC)*,/,20X,*LOAD OUT OF AIRCRAFT*,15X,F11.2,11X,F11.2,11X,F11.2/
     220X,*PILOT CHUTE/EXTRACTION CHUTE RELEASE OR*,/,20X,*MAIN PARACHUT
     3E DISREEF*,13X,5F11.2)
   22 FORMAT(////,20X,*STATIC LINE= *,F10.3,* FT*,/,20X,*PARACHUTE PACK
     1DRAG AREA= *,F10.3,1X,5HFT**2)
   23 FORMAT(20X,*PILOT CHUTE*,/,25X,*DRAG AREA=*,F10.3,1X,5HFT**2,/,25X
     1,*DIAMETER= *,F10.3,* FT*,/,25X,*SUSP. LINES= *,F10.3,* FT*,/,20X,
     2*TIME OF PILOT CHUTE RELEASE= *,F10.2,* SEC*,////)
   24 FORMAT(////,20X,*RELEASE DISTANCE IN AIRCRAFT= *,F10.3,* FT*,/,20X
     1*PARACHUTE PACK DRAG AREA= *,F10.3,1X,5HFT**2,/,20X,*EXTRACTION CH
     2UTE DRAG AREA= *,F10.3,1X,5HFT**2,/,20X,*TIME OF EXTRACTION CHUTE
     3RELEASE= *,F10.2,* SEC*,////)
   25 FORMAT(////,20X,*RELEASE DISTANCE IN AIRCRAFT= *,F10.3,* FT*,/,20X
     1*REEFING RATIO= *,F10.3,/,20X,*REEFED PROJ. DIAMETER= *,F10.3,* FT
     2*,/,20X,*TIME OF PARACHUTE DISREEF= *,F10.2,* SEC*,////)
   26 FORMAT(5/ ,4X,*TIME*,5X,*ALTITUDE*,4X,*SYSTEM*,3X,*C.M. TRAJ.*,10X
     1,*C.M. POSITION*,26X,*C.M. VELOCITY*,18X,*C.M.*,/,26X,*ANGLE*,6X,
     2    *ANGLE*   ,80X,*ACCELERATION*,/4X,*(SEC)*,6X,*(FT)*,7X,*(DEG)*
     3,6X,*(DEG)*,18X,*(FT)*,32X,*(FT/SEC)*,17X,*(FT/SEC/SEC)*,/,50X,*X*
     4,10X,*Y*,10X,*Z*,8X,*TOTAL*,8X,*X*,10X,*Y*,10X,*Z*,8X,*TOTAL*5/)
      END
```

FIG 29 Computer Program for Three Degrees of Freedom (Continued)

```
      SUBROUTINE SNATCH(TRCA,DT)
      COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NINT
      COMMON /VARIABL/ RHO,T,V,THETA,X,Z,UNUSED,UNUSED2,UNUSED3
      REAL K,L,LSS,ML,MP,MPBAG,M1,M2,MSS,LRXBR
      ICOUNT=0
      READ 5,MPBAG,CDS2,K,LRXBR
      PRINT 7,MPBAG,CDS2,K,LRXBR
      IF(NINT.GT.0) PRINT 9
      M2=MP
      M1=ML+0.5*MSS
      CAPM2=MP+MPBAG+0.5*MSS
      CAPM1=ML+MSS
      CDS1=CDSL
      V1=V
      V2=V
      L=0.0
    1 CALL BODIES(M1,CDS1,CAPM2,CDS2,V1,V2,L,DT)
      TRAJANG=THETA*180./PI
      V1X=V1*SIN(THETA)
      V1Z=V1*COS(THETA)
      ICOUNT=ICOUNT+1
      ALTMZ=ALT-Z
      IF(ICOUNT.EQ.NINT) PRINT 6,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V1,V1X,V1Z
      IF(ICOUNT.EQ.NINT) ICOUNT=0
      IF(L-LSS-LRXBR) 1,2,2
    2 TL=T
      TRAJL=TRAJANG
      XL=X
      ZL=Z
      V1L=V1
      V2L=V2
      Q=CAPM1/(CAPM1+M2)
      VF=(CAPM1*V1+M2*V2)/(CAPM1+M2)
      DELTAV=VF-V2
      FA1=RHO*CDS1*(V1*V1+VF*VF)/4.
      FA2=RHO*CDS2*(V2*V2+VF*VF)/4.
      A=1./K
      B=FA1*(1.+Q+2.*V2*Q/DELTAV)+FA2*(Q +2.*V2*Q/DELTAV)
      C=CAPM1*(Q-1.)/Q*((Q+1.)/Q*DELTAV*DELTAV+2.*V2*DELTAV) +M2*(DELTAV
     1*DELTAV+2.*V2*DELTAV)
      PMAX=-B+SQRT(B*B-C/A)
      TRCA=T
      V1=V2=VF
      M1=MP+ML+MSS
      CDS1=CDSL+0.015*CDP*DNOT*DNOT*PI/4.
    3 CALL BODIES(M1,CDS1,MPBAG,CDS2,V1,V2,L,DT)
      TRAJANG=THETA*180./PI
      V1X=V1*SIN(THETA)
      V1Z=V1*COS(THETA)
      ICOUNT=ICOUNT+1
      ALTMZ=ALT-Z
      IF(ICOUNT.EQ.NINT) PRINT 6,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V1,V1X,V1Z
      IF(ICOUNT.EQ.NINT) ICOUNT=0
      IF(L-LSS-LRXBR-DNOT/2.) 3,4,4
    4 V=V1
      PRINT 8,TL,TRAJL,XL,ZL,V1L,V2L,PMAX,VF
      RETURN
    5 FORMAT(4F10.0)
    6 FORMAT(1X,F8.2,4F11.2,11X,3F11.2,11X,F11.2)
    7 FORMAT(////,20X,*PARACHUTE PACK MASS= *,F10.3,* SLUG*,/,20X,*PARAC
     1HUTE PACK AND PILOT/EXTRACTION CHUTE DRAG AREA= *,F10.3,1X,5HFT**2
     2/20X,*SPRING CONSTANT= *,F10.3,* LB/FT*,/,20X,*LENGTH OF RISERS, E
     3XTENSIONS AND LOAD BRIDLE= *,F10.3,* FT*,////)
    8 FORMAT(//,50X,*TIME(SEC) ANGLE(DEG)   X(FT)      Z(FT)    VELOCITY1
     1(FT/SEC) VELOCITY2(FT/SEC)*,/,20X,*SNATCH*,20X,4F11.2,2F15.2,//,
```

FIG 29 Computer Program for Three Degrees of Freedom (Continued)

```
220X,*SNATCH FORCE= *,F10.0,* LB*,/,20X,*SNATCH VELOCITY= *,F10.3,
3* FT/SEC*)
9  FORMAT(5/ ,4X,*TIME*,5X,*ALTITUDE*,4X,*SYSTEM*,3X,*C.M. TRAJ.*,10X
1,*C.M. POSITION*,26X,*C.M. VELOCITY*,18X,*C.M.*,/,26X,*ANGLE*,6X,
2     *ANGLE*    ,80X,*ACCELERATION*,/4X,*(SEC)*,6X,*(FT)*,7X,*(DEG)*
3,6X,*(DEG)*,18X,*(FT)*,32X,*(FT/SEC)*,17X,*(FT/SEC/SEC)*,/,50X,*X*
4,10X,*Y*,10X,*Z*,8X,*TOTAL*,8X,*X*,10X,*Y*,10X,*Z*,8X,*TOTAL*5/)
   END
```

```
   SUBROUTINE BODIES(M1,CDS1,M2,CDS2,V1,V2,L,DT)
   COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NOUSE
   COMMON /VARIABL/ RHO,T,V,THETA,X,Z,UNUSED,UNUSED2,UNUSED3
   REAL M1,M2,L
-> CALL DENSITY(RHO,ALT-Z)
   DTHETA=-G*SIN(THETA)*DT/V1
   DV1=(G*COS(THETA)-RHO*CDS1*V1*V1/(2.*M1))*DT
   DV2=(G*COS(THETA)-RHO*CDS2*V2*V2/(2.*M2))*DT
   DX=V1*SIN(THETA)*DT
   DZ=V1*COS(THETA)*DT
   DL=V1*DT-V2*DT
   THETA=THETA+DTHETA
   V1=V1+DV1
   V2=V2+DV2
   X=X+DX
   Z=Z+DZ
   L=L+DL
   T=T+DT
   RETURN
   END
```

```
   SUBROUTINE OPENING(DQ,TRCA,N,F,VOLUMG,IEXTRAC,DTT)
   DIMENSION F(N),REEF(7,10)
   COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NINT
   COMMON /VARIABL/ RHO,T,V,THETA,X,Z,UNUSED,UNUSED2,UNUSED3
   REAL LSS,ML,MP,MS,MSS
   ICOUNT=0
   DCAPT=DCAPTR=1./N
   MS=ML+MSS+MP
   READ 6,NREEF
   IF(NREEF.EQ.0) GO TO 4
   NREEF=NREEF-IEXTRAC
   NREEF1=NREEF+1
   DO 3  I=1,NREEF1
   READ 7,R0,R1,TCD
   TNOT=T
   TDR=TRCA+TCD
   H0=(4.*LSS*R0+2.*R0*DNOT)/(4.*LSS+PI*R0*DNOT)
   H1=(4.*LSS*R1+2.*R1*DNOT)/(4.*LSS+PI*R1*DNOT)
   HTDNOT=H1*DNOT
   PRINT 11,R1, HTDNOT,TCD,TDR
   IF(NINT.GT.0) PRINT 12
   V1=(H1*H1*H1-H0*H0*H0)*DNOT*DNOT*DNOT
   V2=H1*H1*SQRT((LSS+DNOT/2.-PI/4.*H1*DNOT)**2-H1*H1*DNOT*DNOT/4.)
   V3=H0*H0*SQRT((LSS+DNOT/2.-PI/4.*H0*DNOT)**2-H0*H0*DNOT*DNOT/4.)
```

FIG 29 Computer Program for Three Degrees of Freedom (Continued)

```
      V4=R1*R1*SQRT(LSS*LSS-R1*R1*DNOT*DNOT/4.)
      V5=R0*R0*SQRT(LSS*LSS-R0*R0*DNOT*DNOT/4.)
      VOLUME=(V1+DNOT*DNOT*(V2-V3-V4+V5))*PI/12.
      V0=V
      X0=X
      Z0=Z
      THETA0=THETA
      CALL FILLTIM(VOLUME,V0,X0,Z0,THETA0,MS,H0,H1,N,F,TF)
      F0=0.0
      DT=DCAPTR*TF
      CAPTR=0.0
      DO 1  J=1,N
      ICOUNT=ICOUNT+1
      CAPTR=CAPTR+DCAPTR
      T=TF*CAPTR+TNOT
      CAPT=PI*PI/4.*(H1*H1*CAPTR+H0*H0*(1.-CAPTR))
      DCAPT=PI*PI/4.*(H1*H1-H0*H0)*DCAPTR
      CALL CALC(CAPT,TF,DCAPT,DCAPTR,MS,DV,DP,D)
      FRCE=ML*(G*COS(THETA)-DV/DT)
      F0=AMAX1(FRCE,F0)
      TRAJANG=THETA*180./PI
      VX=V*SIN(THETA)
      VZ=V*COS(THETA)
      IF(NINT.LT.0) GO TO 1
      IF(ICOUNT.LT.N/20) GO TO 1
      ICOUNT=0
      ALTMZ=ALT-Z
      ACC=-(G*COS(THETA)-DV/DT)
      PRINT 8,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V,VX,VZ,ACC
    1 CONTINUE
      REEF(1,I)=T
      REEF(2,I)=TRAJANG
      REEF(3,I)=X
      REEF(4,I)=Z
      REEF(5,I)=V
      REEF(6,I)=F0
      REEF(7,I)=TF
      IF(NREEF+1-I) 3,3,2
    2 IF(T.GE.TDR)  GO TO 3
      CDS=CDP*PI*DNOT*DNOT*H1*H1/4.
      CDST=CDS+CDSL
      CALL TRAJEQN(T,V,THETA,X,Z,RHO,CDST,MS,DTT,G,ALT,DV)
      AL=-G*COS(THETA)+DV/DTT
      TRAJANG=THETA*180./PI
      VX=V*SIN(THETA)
      VZ=V*COS(THETA)
      ICOUNT=ICOUNT+1
      ALTMZ=ALT-Z
      IF(ICOUNT.EQ.NINT) PRINT 8,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V,VX,VZ,AL
      IF(ICOUNT.EQ.NINT) ICOUNT=0
      IF(T-TDR) 2,3,3
    3 CONTINUE
      PRINT 9, (REEF(J,1),J=1,7)
      IF (NREEF.GT.0)PRINT 10,((REEF(J,I),J=1,7),I=2,NREEF1)
      DQ=DV/DT
      RETURN
    4 VOLUME=VOLUMG
      H0=0.0
      H1=2./PI
      IF(NINT.GT.0) PRINT 12
      TNOT=T
      V0=V
      X0=X
      Z0=Z
      THETA0=THETA
      CALL FILLTIM(VOLUME,V0,X0,Z0,THETA0,MS,H0,H1,N,F,TF)
```

FIG 29 Computer Program for Three Degrees of Freedom (Continued)

```
      FO=0.0
      DT=DCAPT*TF
      CAPT=0.0
      DO 5  J=1,N
      ICOUNT=ICOUNT+1
      CAPT=CAPT+DCAPT
      T=TF*CAPT+TNOT
 ---> CALL CALC(CAPT,TF,DCAPT,DCAPTR,MS,DV,DP,D)
      FRCE=ML*(G*COS(THETA)-DV/DT)
      FO=AMAX1(FRCE,FO)
      TRAJANG=THETA*180./PI
      VX=V*SIN(THETA)
      VZ=V*COS(THETA)
      IF(NINT.LT.0) GO TO 5
      IF(ICOUNT.LT.N/20) GO TO 5
      ICOUNT=0
      ALTMZ=ALT-Z
      ACC=-(G*COS(THETA)-DV/DT)
      PRINT 8,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V,VX,VZ,ACC
    5 CONTINUE
      PRINT 9,T,TRAJANG,X,Z,V,FO,TF
      DQ=DV/DT
      RETURN
    6 FORMAT(I1)
    7 FORMAT(3F10.0)
    8 FORMAT(1X,F8.2,4F11.2,11X,3F11.2,11X,2F11.2)
    9 FORMAT(//,61X,*TIME(SEC) ANGLE(DEG) X(FT)      Z(FT)   V(FT/SEC)  F
     1MAX(LB)   TF(SEC)   *,/,20X,*FULL OR REEFED INFLATION  *,12X,F10.2,
     2F 9.2,3F10.2,F10.0,F10.2)
   10 FORMAT(9(58X,F10.2,F 9.2,3F10.2,F10.0,F10.2,/))
   11 FORMAT(////,20X,*REEFED INFLATION*,/,25X,*REEFING RATIO= *,F10.3,/
     1,25X,*REEFED PROJ. DIAM.= *,F10.3,* FT*,/,25X,*CUTTER DELAY= *,F10
     2.3,* SEC *,/,25X,*TIME OF DISREEF= *,F10.3,* SEC*,////)
   12 FORMAT(5/ ,4X,*TIME*,5X,*ALTITUDE*,4X,*SYSTEM*,3X,*C.M. TRAJ.*,10X
     1,*C.M. POSITION*,26X,*C.M. VELOCITY*,18X,*C.M.*,/,26X,*ANGLE*,6X,
     2    *ANGLE*    ,80X,*ACCELERATION*,/4X,*(SEC)*,6X,*(FT)*,7X,*(DEG)*
     3,6X,*(DEG)*,18X,*(FT)*,32X,*(FT/SEC)*,17X,*(FT/SEC/SEC)*,/,50X,*X*
     4,10X,*Y*,10X,*Z*,8X,*TOTAL*,8X,*X*,10X,*Y*,10X,*Z*,8X,*TOTAL*5/)
      END
```

```
      SUBROUTINE FILLTIM(VOLUME,V0,X0,Z0,THETA0,MS,H0,H1,N,VOLDOT,TF)
      COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NOUSE
      COMMON /VARIABL/ RHO,T,V,THETA,X,Z,UNUSED,UNUSED2,UNUSED3
      REAL LSS,MS
      DIMENSION VOLDOT(N)
      DCAPTR=1./N
      TF=0.
      DTF=2.0*H1*DNOT/V0
    1 TF=TF+DTF
      V=V0
      X=X0
      Z=Z0
      THETA=THETA0
      CAPTR=0.0
    2 DO 3 I=1,N
      CAPTR=CAPTR+DCAPTR
      CAPT=PI*PI/4.*(H1*H1*CAPTR+H0*H0*(1.-CAPTR))
      DCAPT=PI*PI/4.*(H1*H1-H0*H0)*DCAPTR
 ---> CALL CALC(CAPT,TF,DCAPT,DCAPTR,MS,DV,DP,D)
      C0=0.05
```

FIG 29 Computer Program for Three Degrees of Freedom (Continued)

```
      C=C0*(RHO/0.002378)**.142857
    3 VOLDOT(I)=V*((1.+2.2*C*CAPT-CAPT)*D*D/4.-1.1*C*DP*DP/2.)
      SUM=VOLDOT(N)
      NM1=N-1
      DO 4 J=1,NM1,2
    4 SUM=SUM+4.*VOLDOT(J)
      NM2=N-2
      DO 5 K=2,NM2,2
    5 SUM=SUM+2.*VOLDOT(K)
      VOL=DCAPTR/3.*SUM*PI*TF
      IF(ABS(VOL-VOLUME)/VOLUME-0.00001) 7,7,6
    6 DTF=TF*(VOLUME/VOL-1.)
      GO TO 1
    7 V=V0
      X=X0
      Z=Z0
      THETA=THETA0
      RETURN
      END
```

```
      SUBROUTINE CALC(CAPT,TF,DCAPT,DCAPTR,M,DV,DP,D)
      COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST ,NOUSE
      COMMON /VARIABL/ RHO,T,V,THETA,X,Z,UNUSED,UNUSED2,UNUSED3
      REAL LSS,M,MA,MI,MT
      DP=2.*DNOT/PI*SQRT(CAPT)
      DPMAX=2.*DNOT/PI
      DPDOT=DNOT/(PI*SQRT(CAPT))
      D=(4.*LSS*DP)/(4.*LSS+2.*DNOT-PI*DP)
      DDOT=((4.*LSS+2.*DNOT-PI*DP)*4.*LSS*DPDOT+4.*LSS*DP*PI*DPDOT)/(4.*
     1LSS+2.*DNOT-PI*DP)**2
      MA=PI*RHO*DP*DP*DP*DP*DP/(32.*DPMAX*DPMAX)
      DMA=5.*PI*RHO/(32.*DPMAX*DPMAX)*DP*DP*DP*DP*DPDOT*DCAPT
      SQ=SQRT((LSS+DNOT/2.-PI*DP/4.)**2-DP*DP/4.)
      SQ1=SQRT(LSS*LSS-D*D/4.)
      MI=PI*RHO/12.*(DP*DP*DP+DP*DP*SQ-D*D*SQ1)
      DMI=PI*RHO/12.*(3.*DP*DP*DPDOT-DP*DP*((2.*LSS+DNOT-PI*DP/2.)*PI*DP
     1DOT/4.+DP*DPDOT/2.)/(2.*SQ)+2.*DP*DPDOT*SQ+D*D*D*DDOT/(4.*SQ1)-2.*
     2D*DDOT*SQ1)*DCAPT
      MT=M+MA+MI
      DTHETA=-G*SIN(THETA)*M*DCAPTR*TF/(V*MT)
      CDS=CDP*PI*DP*DP/4.+CDSL
      DV=(M*G*COS(THETA)/MT-RHO*V*V*CDS/(2.*MT))*DCAPTR*TF-V*(DMI+DMA)
     1/MT
      DX=V*SIN(THETA)*DCAPTR*TF
      DZ=V*COS(THETA)*DCAPTR*TF
      THETA=THETA+DTHETA
      V=V+DV
      X=X+DX
      Z=Z+DZ
--->  CALL DENSITY(RHO,ALT-Z)
      RETURN
      END
```

FIG 29 Computer Program for Three Degrees of Freedom (Continued)

```
      SUBROUTINE INTGRAT(T,Y,TF,NN,PCTERR,ETA,TRY1,TRY2,TRY3,W,YDOT,Z,ID
     1,DX,T1,ISIGNAL)
      DIMENSION Y(NN),YDOT(NN),TRY1(NN),TRY2(NN),TRY3(NN),ETA(NN),W(NN),
     1Z(NN)
      MM=0
      T1=T
      IMDONE=-1
      IF(ID) 1,1,2
    1 DT=DX
      GO TO 12
    2 DT=TF-T1
      M=0
--> 3 CALL FORMULA(Y,DT,TRY1,NN,W,YDOT,Z,L)
      IF(L.GT.0) GO TO 15
--> 4 CALL FORMULA(Y,0.5*DT,TRY2,NN,W,YDOT,Z,L)
      IF(L.GT.0) GO TO 15
-->   CALL FORMULA(TRY2,0.5*DT,TRY3,NN,W,YDOT,Z,L)
      IF(L.GT.0) GO TO 15
      DO 5 J=1,NN
      ERR1=ABS(TRY3(J)-TRY1(J))
      ERR2=AMAX1(ETA(J),PCTERR*ABS(TRY3(J)))
      IF(ERR1-ERR2) 5,5,10
    5 CONTINUE
      MM=0
      DO 6 K=1,NN
    6 Y(K)=TRY3(K)
      T1=T1+DT
      IF(M.LT.5) 8,9
    8 M=M+1
      GO TO 12
    9 M=0
      DT=2.0*DT
      GO TO 12
   10 M=0
      MM=MM+1
      IF(MM.GT.20) GO TO 16
      IMDONE = -1
      DT=DT*0.5
      DO 11 I=1,NN
   11 TRY1(I)=TRY2(I)
      GO TO 4
    7 IF(T1-TF+DT) 3,13,13
   12 IF(IMDONE) 7,14,14
   13 DX=DT
      DT=TF-T1
      IF(DT.EQ.0.) GO TO 14
      IMDONE=1
      GO TO 3
-->14 CALL EMOTION(Y,YDOT,1,ISIGNAL)
      DX=AMAX1(DX,DT)
      RETURN
   15 M=0
      MM=MM+1
      IF(MM.GT.20) GO TO 16
      IMDONE=-1
      DT=DT*0.5
      GO TO 3
   16 ISIGNAL=1
      PRINT 17
      RETURN
   17 FORMAT(5/,5X,5H*****CANNOT INTEGRATE OR ANGLE OF ATTACK LARGE*)
      END
```

FIG 29 Computer Program for Three Degrees of Freedom (Continued)

```
      SUBROUTINE FORMULA(Y,H,YI,NN,W,YDOT,Z,ISIGNAL)
      DIMENSIONY(NN),YDOT(NN),YI(NN),W(NN),Z(NN),A(5)
      A(3)=A(4)=H
      A(1)=A(2)=A(5)=0.5*H
      DO 1 J=1,NN
      Z(J)=YDOT(J)
      W(J)=Y(J)
    1 YI(J)=Y(J)
      DO 2 K=1,4
      CALL EMOTION(W,Z,2,ISIGNAL)
      IF(ISIGNAL.GT.0) RETURN
      C=A(K+1)*0.333333333333333
      DO 2 L=1,NN
      W(L)=Y(L)+A(K)*Z(L)
    2 YI(L)=YI(L)+C*Z(L)
      RETURN
      END
```

```
      SUBROUTINE TRAJEQN(T,V,THETA,X,Z,RHO,CDS,M,DT,G,ALT,DV)
      REAL M
      CALL DENSITY(RHO,ALT-Z)
      DV=(G*COS(THETA)-RHO*CDS*V*V/(2.*M))*DT
      DTHETA=-G*SIN(THETA)*DT/V
      DX=V*SIN(THETA)*DT
      DZ=V*COS(THETA)*DT
      V=V+DV
      THETA=THETA+DTHETA
      X=X+DX
      Z=Z+DZ
      T=T+DT
      RETURN
      END
```

```
      SUBROUTINE DENSITY(RHO,H)
      RHO=0.002378*EXP(-H/32916.)
      IF(H.GT.15000.)  RHO=0.002378*1.07133*EXP(-H/28593.)
      RETURN
      END
```

```
      SUBROUTINE DYNAMIC(RHO,L1,L2,L3,IXX,IYY,IZZ,IXZ,MI)
      REAL IA,IAZ,IAZ0,IY,IYY,IXX,IXZ,IZ,IZZ,L1,L2,L3,MBR,ML,MLS,MR,MRX,
     1MP,MI
      COMMON /DYNAM/ DNOT,X1,X2,X3,X4,X5,MBR,ML,MLS,MP,MR,MRX,IAZ0,IZ,
     1Q1,Q2,VOLUME,XNUM,XDENOM
      MI=RHO*VOLUME
      X=(XNUM-MI*Q1*DNOT)/(XDENOM+MI)
      L1=X5-X
      L2=-X-Q1*DNOT
      L3=DNOT-X
      IA=0.13195*RHO*Q2*Q2*Q2*DNOT*DNOT*DNOT*L2*L2
      IY=MP*L2*L2+MLS*(X-X1)*(X-X1)+MR*(X2-X)*(X2-X)+MRX*(X3-X)*(X3-X)+
     1MBR*(X4-X)*(X4-X)+ML*L1*L1
      IYY=IY+IA
      IXX=IYY
      IAZ=IAZ0*RHO/0.002378
      IZZ=IZ+IAZ
      IXZ=0.0
      RETURN
      END
```

FIG 29 Computer Program for Three Degrees of Freedom (Continued)

```
      SUBROUTINE MOTION(DQ,PCTERR,ETA,DT)
      DIMENSION Y(6),YDOT(6),ETA(6),X1(6),X2(6),X3(6),W(6),B(6),VERTPAR(
     18,3)
      REAL L1
      COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NINT
      COMMON /VARIABL/ RHO,T,V,THETA,X,Z,ALPHAL,ALPHAP,L1
      PRINT 8
      READ 7,TSTOP,ZSTOP
      TSTOP=TSTOP+T
      IF(NINT.GT.0) PRINT 6
      AMARK=1.0
      NMARK=0
      IVERT=1
      ANG=THETA*180./PI
      ID=1
      Y(1)=0.
      Y(2)=V
      Y(3)=-G*SIN(THETA)/V
      Y(4)=THETA
      Y(5)=X
      Y(6)=Z
      YDOT(3)=G*G*COS(THETA)*SIN(THETA)/(V*V)+G*SIN(THETA)/(V*V)*DQ
      TF=T+DT
      NUMB=IABS(NINT)
    1 DO 2 I=1,NUMB
 ---> CALL INTGRAT(T,Y,TF,6,PCTERR ,ETA,X1,X2,X3,W,YDOT,B,ID,DX,T1,K)
      IF(K.GT.0) RETURN
      V0=V
      R2=Y(6)+L1*COS(Y(4))
      IF(R2.GT.ZSTOP) CORR=(ZSTOP-RZ)/(R2-RZ)
      IF(T1.GT.TSTOP)  CORR=(TSTOP-T)/(T1-T)
      IF(R2.GT.ZSTOP.OR.T1.GT.TSTOP) GO TO 3
      T=T1
      RX=Y(5)+L1*SIN(Y(4))
      RZ=R2
      VX=(Y(1)+Y(3)*L1)*COS(Y(4))+Y(2)*SIN(Y(4))
      VZ=-(Y(1)+Y(3)*L1)*SIN(Y(4))+Y(2)*COS(Y(4))
      AX=(YDOT(1)+Y(2)*Y(3)+YDOT(3)*L1)*COS(Y(4))+(YDOT(2)-Y(1)*Y(3)-
     1Y(3)*Y(3)*L1)*SIN(Y(4))
      AZ=-(YDOT(1)+Y(2)*Y(3)+YDOT(3)*L1)*SIN(Y(4))+(YDOT(2)-Y(1)*Y(3)
     1-Y(3)*Y(3)*L1)*COS(Y(4))
      V=SQRT(VX*VX+VZ*VZ)
      A=SQRT(AX*AX+AZ*AZ)
      IF(V.LT.V0) A=-A
      SYSANGL=Y(4)*180./PI
      ALPHA1=ALPHAL*180./PI
      TRAJANG=SYSANGL-ALPHA1
      IF(IVERT.GT.3) GO TO 15
      IF(SYSANGL/ABS(SYSANGL)-ANG/ABS(ANG)) 13,12,13
   12 IF((ABS(SYSANGL)-ABS(ANG))*AMARK.GE.0.0) GO TO 13
      VERTPAR(1,IVERT)=T
      VERTPAR(2,IVERT)=ALT-RZ
      VERTPAR(3,IVERT)=RX
      VERTPAR(4,IVERT)=RZ
      VERTPAR(5,IVERT)=V
      VERTPAR(6,IVERT)=VX
      VERTPAR(7,IVERT)=VZ
      VERTPAR(8,IVERT)=A
      ANG=SYSANGL
      GO TO 15
   13 AMARK=-AMARK
      NMARK=NMARK+1
      GO TO(14,12,14,12,14) NMARK
   14 IVERT=IVERT+1
      ANG=SYSANGL
```

FIG 29 Computer Program for Three Degrees of Freedom (Continued)

```
15 ID=-1
   NUMB=IABS(NINT)
   IF(NUMB*DX.GT.1.0) NUMB=MAX1(1.,1./DX)
   TF=T+DX
 2 CONTINUE
   ALTMRZ=ALT-RZ
   IF(NINT.GT.0) PRINT 4,T,ALTMRZ,SYSANGL,TRAJANG,RX,RZ,V,VX,VZ,A
   GO TO 1
 3 T=(T1-T)*CORR+T
   R1=Y(5)+L1*SIN(Y(4))
   V1=(Y(1)+Y(3)*L1)*COS(Y(4))+Y(2)*SIN(Y(4))
   V2=-(Y(1)+Y(3)*L1)*SIN(Y(4))+Y(2)*COS(Y(4))
   A1=(YDOT(1)+Y(2)*Y(3)+YDOT(3)*L1)*COS(Y(4))+(YDOT(2)-Y(1)*Y(3)-
  1Y(3)*Y(3)*L1)*SIN(Y(4))
   A2=-(YDOT(1)+Y(2)*Y(3)+YDOT(3)*L1)*SIN(Y(4))+(YDOT(2)-Y(1)*Y(3)
  1-Y(3)*Y(3)*L1)*COS(Y(4))
   RX=(R1-RX)*CORR+RX
   RZ=(R2-RZ)*CORR+RZ
   VX=(V1-VX)*CORR+VX
   VZ=(V2-VZ)*CORR+VZ
   AX=(A1-AX)*CORR+AX
   AZ=(A2-AZ)*CORR+AZ
   V=SQRT(VX*VX+VZ*VZ)
   A=SQRT(AX*AX+AZ*AZ)
   IF(V.LT.V0) A=-A
   SYSANGL=(Y(4)*180./PI-SYSANGL)*CORR+SYSANGL
   ALPHA1=(ALPHAL*180./PI-ALPHA1)*CORR+ALPHA1
   TRAJANG=SYSANGL-ALPHA1
   ALTMRZ=ALT-RZ
   IF(NINT.GT.0) PRINT 4,T,ALTMRZ,SYSANGL,TRAJANG,RX,RZ,V,VX,VZ,A
   PRINT 51
   IVERT1=IVERT-1
   DO 31 J=1,IVERT1
31 PRINT 5,  J ,(VERTPAR(I,J),I=1,8)
   RETURN
 4 FORMAT(1X,F8.2,4F11.2,11X,3F11.2,11X,2F11.2)
 5 FORMAT(20X,I1,* VERTICAL/MINIMUM*,F9.2,F12.2,F11.2,3F10.2,2F12.2)
51 FORMAT(//,40X,*TIME(SEC) ALTITUDE(FT)    X(FT)      Z(FT)   V(FT/SEC)
  1 VX(FT/SEC)   VZ(FT/SEC)  A(FT/SEC/SEC)*)
 6 FORMAT(5/ ,4X,*TIME*,5X,*ALTITUDE*,4X,*SYSTEM*,3X,*LOAD TRAJ.*,10X
  1,*LOAD POSITION*,26X,*LOAD VELOCITY*,18X,*LOAD*,/,26X,*ANGLE*,6X,
  2    *ANGLE*   ,80X,*ACCELERATION*,/4X,*(SEC)*,6X,*(FT)*,7X,*(DEG)*
  3,6X,*(DEG)*,18X,*(FT)*,32X,*(FT/SEC)*,17X,*(FT/SEC/SEC)*,/,50X,*X*
  4,10X,*Y*,10X,*Z*,8X,*TOTAL*,8X,*X*,10X,*Y*,10X,*Z*,8X,*TOTAL*5/)
 7 FORMAT(2F10.0)
 8 FORMAT(5/,5X,*NOTE-- POSITIONS,VELOCITIES,ACCELERATIONS,TRAJ. ANGL
  1ES REFER TO LOAD, PREVIOUS RESULTS ARE FOR MASS CENTER*)
   END
```

```
   SUBROUTINE EMOTION(Y,YDOT,ISTOP,ISIGNAL)
   DIMENSION Y(6),YDOT(6)
   REAL M,MA,MI,ML,MP,MSS,IXX,IYY,IZZ,IXZ,L1,L2,L3,N
   COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NOUSE
   COMMON /VARIABL/ RHO,T,V,THETA,X,Z,ALPHAL,ALPHAP,L1
   CALL DENSITY(RHO,ALT-Y(6))
   CALL DYNAMIC(RHO,L1,L2,L3,IXX,IYY,IZZ,IXZ,MI)
   MA=1.375*MI
   M=ML+MP+MSS+MA
   A=MA/M
   B=(ML+MP+MSS)*G/M
```

FIG 29 Computer Program for Three Degrees of Freedom (Continued)

```
      C=RHO*PI*DNOT*DNOT/8.
      CDNOT=C*DNOT
      E=0.5*RHO*CDSL
      V2=Y(1)*Y(1)+Y(2)*Y(2)
      ALPHA=ATAN(-Y(1)/Y(2))
      VP2=V2+Y(3)*Y(3)*L2*L2+2.*Y(1)*Y(3)*L2
      ALPHAP=ATAN((-Y(1)-Y(3)*L2)/Y(2))
      VL2=V2+Y(3)*Y(3)*L1*L1+2.*Y(1)*Y(3)*L1
      ALPHAL=ATAN((-Y(1)-Y(3)*L1)/Y(2))
  --> CALL COEFFTS(ALPHAP,CT,CN,CM,ISTOP,ISIGNAL)
      IF(ISIGNAL.GT.0) RETURN
      N=C*CN*VP2
      TT=C*CT*VP2
      AEROM=CDNOT*CM*VP2
      D=E*VL2
      YDOT(1)=-A*YDOT(3)*L2-B*SIN(Y(4))+N/M+D*SIN(ALPHAL)/M-Y(2)*Y(3)
      YDOT(2)= A*Y(3)*Y(3)*L2+B*COS(Y(4))-TT/M-D*COS(ALPHAL)/M+Y(1)*Y(3)
      YDOT(3)= N*L3/IYY+D*L1*SIN(ALPHAL)/IYY+AEROM/IYY-ML*G*SIN(Y(4))*L1
     1/IYY-MP*G*SIN(Y(4))*L2/IYY
      YDOT(4)=Y(3)
      YDOT(5)=Y(1)*COS(Y(4))+Y(2)*SIN(Y(4))
      YDOT(6)=-Y(1)*SIN(Y(4))+Y(2)*COS(Y(4))
      RETURN
      END
```

```
      SUBROUTINE COEFFTS(ALPHAP,CT,CN,CM,IPRINT,ISIGNAL)
      ALPHAPD=ALPHAP*57.295779515
      IF(ABS(ALPHAPD).LT.85.)  GO TO 2
      IF(IPRINT.EQ.1) PRINT 1,ALPHAPD
      ISIGNAL=1
      RETURN
    1 FORMAT(5X,*ANGLE OF ATTACK= *,F9.3,*  , TOO LARGE*)
    2 ISIGNAL=-1
      A=ABS(ALPHAPD)
      IF(A-30.0) 3,4,4
    3 CT=.647-1.2E-05*A+9.15E-04*A*A-7.13E-05*A*A*A+1.33E-06*A*A*A*A
      CN=-6.74E-03*A+5.57E-04*A*A-1.53E-05*A*A*A+1.9E-07*A*A*A*A
      CM=4.844E-03*A-3.94E-04*A*A+1.043E-05*A*A*A-1.32E-07*A*A*A*A
      IF(ALPHAPD.GT.0.) RETURN
      CN=-CN
      CM=-CM
      RETURN
    4 CT=0.62
      CN=.0056*(A-30.0)+.04
      CM=-.0044*(A-30.0)-.034
      IF(ALPHAPD.GT.0.) RETURN
      CN=-CN
      CM=-CM
      RETURN
      END
```

FIG 29 Computer Program for Three Degrees of Freedom (Concluded)

```
      PROGRAM TRAJSIM(INPUT,OUTPUT)
C           THIS IS THE MAIN PROGRAM
      DIMENSION ETA(12),SPACE(1000)
      REAL IXX,IYY,IZZ,IXZ,IAZ0,IZ,LSS,L1,L2,L3,MA,MBR,ML,MLS,MP,MR,MRX,
     1MSS,MST
      COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NINT
      COMMON /VARIABL/ RHO,T,V,THETA,X,Z,ALPHAL,ALPHAP,L1
      COMMON /DYNAM/ DYDNOT,X1,X2,X3,X4,X5,MBR,DYML,MLS,DYMP,MR,MRX,IAZ0
     1,IZ,Q1,Q2,VOLUME,XNUM,XDENOM
      PI=3.141592653589793
      G=32.17
      READ 10,NSIM
      DO 11 J=1,NSIM
      READ 9,C1,C2,C3,C4,C5
      PRINT 12,C1,C2,C3,C4,C5
      READ 6,ALT,V0,MST,MP,MLS,MR,MRX,MBR,ML,X1,X2,X3,X4,X5,IZ,IAZ0,
     1DNOT,LSS,CDP,CDSL,Q1,Q2,VOLUME,N,NNN,DT1,DT2,DT3,NINT
      DYDNOT=DNOT
      DYML=ML
      DYMP=MP
      XNUM=MLS*X1+MR*X2+MRX*X3+MBR*X4+ML*X5-MP*Q1*DNOT
      XDENOM=MP+MLS+MR+MRX+MBR+ML
      MSS=MLS+MR+MRX+MBR
      CALL DYNAMIC(0.002378,A1,A2,A3,A4,A5,A6,A7,A8)
      A9=0.375*A8
      CALL DENSITY(RHO,ALT)
      CALL DYNAMIC(RHO,B1,B2,B3,B4,B5,B6,B7,B8)
      B9=0.375*B8
      PRINT 8,ALT,V0,MST,ML,MP, MLS,MR,MRX,MBR,A8,B8,ALT,A9,B9,ALT,X1,
     1X2,X3,X4,X5,A4,B4,ALT,A5,B5,ALT,A6,B6,ALT,A7,B7,ALT,DNOT,LSS,A1,B1
     2,ALT,A2,B2,ALT,A3,B3,ALT,Q1,Q2,VOLUME,CDP
      PRINT 81,CDSL,N
      NN=2*N
      READ 7,(ETA(I),I=1,NN),PCTERR
      CALL EXTRACT(ISNATCH,IEXTRAC,V0,DT1,TRCA)
      IF(ISNATCH) 4,4,5
    4 CALL SNATCH(TRCA,DT2)
    5 CALL OPENING(DQ,TRCA,NNN,SPACE,VOLUME,IEXTRAC,DT3)
      CALL MOTION(DQ,PCTERR,ETA,DT3)
   11 CONTINUE
      STOP
    6 FORMAT(2F10.0/7F10.0/7F10.0/7F10.0/I1,I9,3F10.0,I5)
    7 FORMAT(6F10.0/6F10.0/F10.0)
    8 FORMAT(3/,5X,*TRAJECTORY SIMULATION--T=0,Z=0 IS RELEASE POINT*,3/,
     15X,*RELEASE CONDITIONS*,/,10X,*ALTITUDE=*,F10.0,* FT*,/,10X,*VELOC
     2ITY=*,F10.2,* FT/SEC*,///,5X,*MASSES--SLUGS*,/10X,*TOTAL SYSTEM= *
     3,F10.3,/,10X,*LOAD= *,F10.3,/,10X,*PARACHUTE= *,F10.3,/,10X,*SUSP.
     4 LINES= *,F10.3,/,10X,*RISERS= *,F10.3,/,10X,*RISER EXTENSIONS= *,
     5F10.3,/,10X,*LOAD BRIDLE= *,F10.3,/,10X,*INCLUDED= *,F10.3,*(SEA L
     6EVEL)*,F10.3,*(*,F7.0,*  FT)*,/,10X,*APPARENT= *,F10.3,*(SEA LEVEL
     7)*,F10.3,*(*,F7.0,*  FT)*,///,5X,*REFERENCE DISTANCES FROM SKIRT--
     8 FT*,/,10X,*X1= *,F10.3,/,10X,*X2= *,F10.3,/,10X,*X3= *,F10.3,/,
     910X,*X4= *,F10.3/10X,*X5= *,F10.3///,5X,*MOM./PROD. INERTIA--SLUG
     1FT*,3H**2,/,10X,*IXX= *,F15.3,*(SEA LEVEL)*,F15.3,*(*,F7.0,*  FT)*
     2,/,10X,*IYY= *,F15.3,*(SEA LEVEL)*,F15.3,*(*,F7.0,*  FT)*,/,10X,
     3 *IZZ= *,F15.3,*(SEA LEVEL)*,F15.3,*(*,F7.0,*  FT)*,/,10X,*IXZ= *,
     4F15.3,*(SEA LEVEL)*,F15.3,*(*,F7.0,*  FT)*,///,5X,*DIMENSIONS-- FT
     5*,/,10X,*DNOT= *,F10.3,/,10X,*SUSP. SYSTEM= *,F10.3,/,10X,*L1= *,F
     610.3,*(SEA LEVEL)*,F10.3,*(*,F7.0,*  FT)*,/,10X,*L2= *,F10.3,*(SEA
     7 LEVEL)*,F10.3,*(*,F7.0,*  FT)*,/,10X,*L3= *,F10.3,*(SEA LEVEL)*,F
     810.3,*(*,F7.0,*  FT)*,///,5X,*YC/DNOT= *,F10.3,/,5X,*DP/DNOT= *,F1
     90.3,/,5X,*VOLUME= *,F10.3,6H FT**3,/,5X,*PARACHUTE CDP= *,F10.3)
   81 FORMAT(5X,*LOAD DRAG AREA= *,F10.3,6H FT**2,/,5X,*DEGREES OF FREE
     1DOM= *,I10,5/)
```

FIG 30 Computer Program Allowing Six Degrees of Freedom for Free Descent Phase

```
 9  FORMAT(5A10)
10  FORMAT(I3)
12  FORMAT(1H1,/,5X,*PARACHUTE-LOAD SYSTEM(DEPLOYMENT)--*,5A10)
    END
```

```
      SUBROUTINE EXTRACT(ISNATCH,IEXTRAC,V0,DT,TRCA)
      COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NINT
      COMMON /VARIABL/ RHO,T,V,THETA,X,Z,UNUSED,UNUSED2,UNUSED3
      REAL LENGTH,LSPILOT,LSS,LSTATIC,MST,MT,LRXBR
      ICOUNT=0
      READ 15,ISTATIC,IEXTRAC
      IF(ISTATIC) 1,8,8
    1 READ 16,LSTATIC,CDSBAG,CDSP,DPILOT,LSPILOT,TD,LRXBR
      DISTANC=LSTATIC
      PRINT 22,LSTATIC,CDSBAG
      IF(DPILOT.GT.0.0) PRINT 23,CDSP,DPILOT,LSPILOT,TD
      IF(NINT.GT.0) PRINT 26
      T=X=Z=0.0
      THETA=0.5*PI
      V=V0
      CDST=CDSL+CDSBAG
      MT=MST
--> 2 CALL TRAJEQN(T,V,THETA,X,Z,RHO,CDST,MT,DT,G,ALT,DV)
      VX=V*SIN(THETA)
      TRAJANG=THETA*180./PI
      VZ=V*COS(THETA)
      ICOUNT=ICOUNT+1
      ALTMZ=ALT-Z
      IF(ICOUNT.EQ.NINT) PRINT 19,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V,VX,VZ
      IF(ICOUNT.EQ.NINT) ICOUNT=0
      IF(SQRT((V0*T-X)*(V0*T-X)+Z*Z).LT.DISTANC) GO TO 2
      IF(DISTANC.GT.LSTATIC) GO TO 3
      T1=T
      TRAJ1=TRAJANG
      X1=X
      Z1=Z
      V1=V
      DISTANC=LSTATIC+LSS+0.5*DNOT+LRXBR
      IF(DPILOT.GT.0.0) DISTANC=LSTATIC+LSPILOT+0.5*DPILOT
      GO TO 2
    3 IF(DPILOT) 7,7,4
    4 ISNATCH=-1
      CDST=CDSL+CDSBAG+CDSP
    5 IF(T-TD) 6,14,14
--> 6 CALL TRAJEQN(T,V,THETA,X,Z,RHO,CDST,MT,DT,G,ALT,DV)
      TRAJANG=THETA*180./PI
      VX=V*SIN(THETA)
      VZ=V*COS(THETA)
      ICOUNT=ICOUNT+1
      ALTMZ=ALT-Z
      IF(ICOUNT.EQ.NINT) PRINT 19,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V,VX,VZ
      IF(ICOUNT.EQ.NINT) ICOUNT=0
      GO TO 5
    7 ISNATCH=1
      TRCA=T
      PRINT 20,T1,TRAJ1,X1,Z1,V1,T,TRAJANG,X,Z,V
      RETURN
    8 IF(IEXTRAC) 9,9,13
    9 READ 17,LENGTH,CDSBAG,CDSEX,TD
      PRINT 24,LENGTH,CDSBAG,CDSEX,TD
      IF(NINT.GT.0) PRINT 26
```

FIG 30 Computer Program Allowing Six Degrees of Freedom for Free Descent Phase (Continued)

```
      ISNATCH=-1
   10 T=X=Z=0.0
      THETA=0.5*PI
      TRAJANG=90.
      CDST=CDSEX
      V=V0
   11 DV=-RHO*CDST*V*V*DT/(2.*MST)
      DX=V*DT
      V=V+DV
      X=X+DX
      T=T+DT
      ICOUNT=ICOUNT+1
      ALTMZ=ALT-Z
      IF(ICOUNT.EQ.NINT) PRINT 19,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V,V
      IF(ICOUNT.EQ.NINT) ICOUNT=0
      IF(V0*T-X-LENGTH) 11,12,12
   12 CDST=CDSL+CDSBAG+CDSEX
      MT=MST
      T1=T
      X1=X
      V1=V
      GO TO 5
   13 READ 18,R,LENGTH,TD
      H=(4.*LSS*R+2.*R*DNOT)/(4.*LSS+PI*R*DNOT)
      HTDNOT=H*DNOT
      PRINT 25,LENGTH,R,HTDNOT,TD
      IF(NINT.GT.0) PRINT 26
      CDSEX=CDP*PI*H*H*DNOT*DNOT/4.
      CDSBAG=0.0
      ISNATCH=1
      GO TO 10
   14 IF(ISTATIC.LT.0) PRINT 20,T1,TRAJ1,X1,Z1,V1,T,TRAJANG,X,Z,V
      IF(ISTATIC.GE.0) PRINT 21,T1,X1,V1,T,TRAJANG,X,Z,V
      IF(IEXTRAC.GT.0) TRCA=0.0
      RETURN
   15 FORMAT(2I2)
   16 FORMAT(7F10.0)
   17 FORMAT(8F10.0)
   18 FORMAT(3F10.0)
   19 FORMAT(1X,F8.2,4F11.2,11X,3F11.2,11X,F11.2)
   20 FORMAT(//,60X,*TIME(SEC) ANGLE(DEG)    X(FT)        Z(FT) VELOCITY(FT
     1/SEC)*,/,20X,*STATIC LINE STRETCH*,16X,5F11.2/20X,*PARACHUTE/PILOT
     2 CHUTE DEPLOYMENT*,3X,5F11.2)
   21 FORMAT(//,60X,*TIME(SEC) ANGLE(DEG)    X(FT)        Z(FT)  VELOCITY(FT
     1/SEC)*,/,20X,*LOAD OUT OF AIRCRAFT*,15X,F11.2,11X,F11.2,11X,F11.2/
     220X,*PILOT CHUTE/EXTRACTION CHUTE RELEASE OR*,/,20X,*MAIN PARACHUT
     3E DISREEF*,13X,5F11.2)
   22 FORMAT(////,20X,*STATIC LINE= *,F10.3,* FT*,/,20X,*PARACHUTE PACK
     1DRAG AREA= *,F10.3,1X,5HFT**2)
   23 FORMAT(20X,*PILOT CHUTE*,/,25X,*DRAG AREA=*,F10.3,1X,5HFT**2,/,25X
     1,*DIAMETER= *,F10.3,* FT*,/,25X,*SUSP. LINES= *,F10.3,* FT*,/,20X,
     2*TIME OF PILOT CHUTE RELEASE= *,F10.2,* SEC*,////)
   24 FORMAT(////,20X,*RELEASE DISTANCE IN AIRCRAFT= *,F10.3,* FT*,/,20X
     1*PARACHUTE PACK DRAG AREA= *,F10.3,1X,5HFT**2,/,20X,*EXTRACTION CH
     2UTE DRAG AREA= *,F10.3,1X,5HFT**2,/,20X,*TIME OF EXTRACTION CHUTE
     3RELEASE= *,F10.2,* SEC*,////)
   25 FORMAT(////,20X,*RELEASE DISTANCE IN AIRCRAFT= *,F10.3,* FT*,/,20X
     1*REEFING RATIO= *,F10.3,/,20X,*REEFED PROJ. DIAMETER= *,F10.3,* FT
     2*,/,20X,*TIME OF PARACHUTE DISREEF= *,F10.2,* SEC*,////)
   26 FORMAT(5/ ,4X,*TIME*,5X,*ALTITUDE*,4X,*SYSTEM*,3X,*C.M. TRAJ.*,10X
     1,*C.M. POSITION*,26X,*C.M. VELOCITY*,18X,*C.M.*,/,26X,*ANGLE*,6X,
     2    *ANGLE*    ,80X,*ACCELERATION*,/4X,*(SEC)*,6X,*(FT)*,7X,*(DEG)*
     3,6X,*(DEG)*,18X,*(FT)*,32X,*(FT/SEC)*,17X,*(FT/SEC/SEC)*,/,50X,*X*
     4,10X,*Y*,10X,*Z*,8X,*TOTAL*,8X,*X*,10X,*Y*,10X,*Z*,8X,*TOTAL*5/)
      END
```

FIG 30 Computer Program Allowing Six Degrees of Freedom for Free Descent Phase (Continued)

```
      SUBROUTINE SNATCH(TRCA,DT)
      COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NINT
      COMMON /VARIABL/ RHO,T,V,THETA,X,Z,UNUSED,UNUSED2,UNUSED3
      REAL K,L,LSS,ML,MP,MPBAG,M1,M2,MSS,LRXBR
      ICOUNT=0
      READ 5,MPBAG,CDS2,K,LRXBR
      PRINT 7,MPBAG,CDS2,K,LRXBR
      IF(NINT.GT.0) PRINT 9
      M2=MP
      M1=ML+0.5*MSS
      CAPM2=MP+MPBAG+0.5*MSS
      CAPM1=ML+MSS
      CDS1=CDSL
      V1=V
      V2=V
      L=0.0
    1 CALL BODIES(M1,CDS1,CAPM2,CDS2,V1,V2,L,DT)
      TRAJANG=THETA*180./PI
      V1X=V1*SIN(THETA)
      V1Z=V1*COS(THETA)
      ICOUNT=ICOUNT+1
      ALTMZ=ALT-Z
      IF(ICOUNT.EQ.NINT) PRINT 6,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V1,V1X,V1Z
      IF(ICOUNT.EQ.NINT) ICOUNT=0
      IF(L-LSS-LRXBR) 1,2,2
    2 TL=T
      TRAJL=TRAJANG
      XL=X
      ZL=Z
      V1L=V1
      V2L=V2
      Q=CAPM1/(CAPM1+M2)
      VF=(CAPM1*V1+M2*V2)/(CAPM1+M2)
      DELTAV=VF-V2
      FA1=RHO*CDS1*(V1*V1+VF*VF)/4.
      FA2=RHO*CDS2*(V2*V2+VF*VF)/4.
      A=1./K
      B=FA1*(1.+Q+2.*V2*Q/DELTAV)+FA2*(Q +2.*V2*Q/DELTAV)
      C=CAPM1*(Q-1.)/Q*((Q+1.)/Q*DELTAV*DELTAV+2.*V2*DELTAV) +M2*(DELTAV
     1*DELTAV+2.*V2*DELTAV)
      PMAX=-B+SQRT(B*B-C/A)
      TRCA=T
      V1=V2=VF
      M1=MP+ML+MSS
      CDS1=CDSL+0.015*CDP*DNOT*DNOT*PI/4.
    3 CALL BODIES(M1,CDS1,MPBAG,CDS2,V1,V2,L,DT)
      TRAJANG=THETA*180./PI
      V1X=V1*SIN(THETA)
      V1Z=V1*COS(THETA)
      ICOUNT=ICOUNT+1
      ALTMZ=ALT-Z
      IF(ICOUNT.EQ.NINT) PRINT 6,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V1,V1X,V1Z
      IF(ICOUNT.EQ.NINT) ICOUNT=0
      IF(L-LSS-LRXBR-DNOT/2.) 3,4,4
    4 V=V1
      PRINT 8,TL,TRAJL,XL,ZL,V1L,V2L,PMAX,VF
      RETURN
    5 FORMAT(4F10.0)
    6 FORMAT(1X,F8.2,4F11.2,11X,3F11.2,11X,F11.2)
    7 FORMAT(////,20X,*PARACHUTE PACK MASS= *,F10.3,* SLUG*,/,20X,*PARAC
     1HUTE PACK AND PILOT/EXTRACTION CHUTE DRAG AREA= *,F10.3,1X,5HFT**2
     2/20X,*SPRING CONSTANT= *,F10.3,* LB/FT*,/,20X,*LENGTH OF RISERS, E
     3XTENSIONS AND LOAD BRIDLE= *,F10.3,* FT*,////)
    8 FORMAT(//,50X,*TIME(SEC) ANGLE(DEG)    X(FT)      Z(FT)    VELOCITY1
     1(FT/SEC) VELOCITY2(FT/SEC)*,/,20X,*SNATCH*,20X,4F11.2,2F15.2,//,
```

FIG 30 Computer Program Allowing Six Degrees of Freedom for Free Descent Phase (Continued)

```
220X,*SNATCH FORCE= *,F10.0,* LB*,/,20X,*SNATCH VELOCITY= *,F10.3,
3* FT/SEC*)
9 FORMAT(5/ ,4X,*TIME*,5X,*ALTITUDE*,4X,*SYSTEM*,3X,*C.M. TRAJ.*,10X
1,*C.M. POSITION*,26X,*C.M. VELOCITY*,18X,*C.M.*,/,26X,*ANGLE*,6X,
2    *ANGLE*   ,80X,*ACCELERATION*,/4X,*(SEC)*,6X,*(FT)*,7X,*(DEG)*
3,6X,*(DEG)*,18X,*(FT)*,32X,*(FT/SEC)*,17X,*(FT/SEC/SEC)*,/,50X,*X*
4,10X,*Y*,10X,*Z*,8X,*TOTAL*,8X,*X*,10X,*Y*,10X,*Z*,8X,*TOTAL*5/)
  END
```

```
SUBROUTINE BODIES(M1,CDS1,M2,CDS2,V1,V2,L,DT)
COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NOUSE
COMMON /VARIABL/ RHO,T,V,THETA,X,Z,UNUSED,UNUSED2,UNUSED3
REAL M1,M2,L
CALL DENSITY(RHO,ALT-Z)        <---
DTHETA=-G*SIN(THETA)*DT/V1
DV1=(G*COS(THETA)-RHO*CDS1*V1*V1/(2.*M1))*DT
DV2=(G*COS(THETA)-RHO*CDS2*V2*V2/(2.*M2))*DT
DX=V1*SIN(THETA)*DT
DZ=V1*COS(THETA)*DT
DL=V1*DT-V2*DT
THETA=THETA+DTHETA
V1=V1+DV1
V2=V2+DV2
X=X+DX
Z=Z+DZ
L=L+DL
T=T+DT
RETURN
END
```

```
SUBROUTINE OPENING(DQ,TRCA,N,F,VOLUMG,IEXTRAC,DTT)
DIMENSION F(N),REEF(7,10)
COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NINT
COMMON /VARIABL/ RHO,T,V,THETA,X,Z,UNUSED,UNUSED2,UNUSED3
REAL LSS,ML,MP,MS,MSS
ICOUNT=0
DCAPT=DCAPTR=1./N
MS=ML+MSS+MP
READ 6,NREEF
IF(NREEF.EQ.0) GO TO 4
NREEF=NREEF-IEXTRAC
NREEF1=NREEF+1
DO 3  I=1,NREEF1
READ 7,R0,R1,TCD
TNOT=T
TDR=TRCA+TCD
H0=(4.*LSS*R0+2.*R0*DNOT)/(4.*LSS+PI*R0*DNOT)
H1=(4.*LSS*R1+2.*R1*DNOT)/(4.*LSS+PI*R1*DNOT)
HTDNOT=H1*DNOT
PRINT 11,R1, HTDNOT,TCD,TDR
IF(NINT.GT.0) PRINT 12
V1=(H1*H1*H1-H0*H0*H0)*DNOT*DNOT*DNOT
V2=H1*H1*SQRT((LSS+DNOT/2.-PI/4.*H1*DNOT)**2-H1*H1*DNOT*DNOT/4.)
V3=H0*H0*SQRT((LSS+DNOT/2.-PI/4.*H0*DNOT)**2-H0*H0*DNOT*DNOT/4.)
```

FIG 30 Computer Program Allowing Six Degrees of Freedom for Free Descent Phase (Continued)

```
      V4=R1*R1*SQRT(LSS*LSS-R1*R1*DNOT*DNOT/4.)
      V5=R0*R0*SQRT(LSS*LSS-R0*R0*DNOT*DNOT/4.)
      VOLUME=(V1+DNOT*DNOT*(V2-V3-V4+V5))*PI/12.
      V0=V
      X0=X
      Z0=Z
      THETA0=THETA
--->  CALL FILLTIM(VOLUME,V0,X0,Z0,THETA0,MS,H0,H1,N,F,TF)
      F0=0.0
      DT=DCAPTR*TF
      CAPTR=0.0
      DO 1  J=1,N
      ICOUNT=ICOUNT+1
      CAPTR=CAPTR+DCAPTR
      T=TF*CAPTR+TNOT
      CAPT=PI*PI/4.*(H1*H1*CAPTR+H0*H0*(1.-CAPTR))
      DCAPT=PI*PI/4.*(H1*H1-H0*H0)*DCAPTR
--->  CALL CALC(CAPT,TF,DCAPT,DCAPTR,MS,DV,DP,D)
      FRCE=ML*(G*COS(THETA)-DV/DT)
      FO=AMAX1(FRCE,FO)
      TRAJANG=THETA*180./PI
      VX=V*SIN(THETA)
      VZ=V*COS(THETA)
      IF(NINT.LT.0) GO TO 1
      IF(ICOUNT.LT.N/20) GO TO 1
      ICOUNT=0
      ALTMZ=ALT-Z
      ACC=-(G*COS(THETA)-DV/DT)
      PRINT 8,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V,VX,VZ,ACC
    1 CONTINUE
      REEF(1,I)=T
      REEF(2,I)=TRAJANG
      REEF(3,I)=X
      REEF(4,I)=Z
      REEF(5,I)=V
      REEF(6,I)=FO
      REEF(7,I)=TF
      IF(NREEF+1-I) 3,3,2
    2 IF(T.GE.TDR)  GO TO 3
      CDS=CDP*PI*DNOT*DNOT*H1*H1/4.
      CDST=CDS+CDSL
--->  CALL TRAJEQN(T,V,THETA,X,Z,RHO,CDST,MS,DTT,G,ALT,DV)
      AL=-G*COS(THETA)+DV/DTT
      TRAJANG=THETA*180./PI
      VX=V*SIN(THETA)
      VZ=V*COS(THETA)
      ICOUNT=ICOUNT+1
      ALTMZ=ALT-Z
      IF(ICOUNT.EQ.NINT) PRINT 8,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V,VX,VZ,AL
      IF(ICOUNT.EQ.NINT) ICOUNT=0
      IF(T-TDR) 2,3,3
    3 CONTINUE
      PRINT 9, (REEF(J,1),J=1,7)
      IF (NREEF.GT.0)PRINT 10,((REEF(J,I),J=1,7),I=2,NREEF1)
      DQ=DV/DT
      RETURN
    4 VOLUME=VOLUMG
      H0=0.0
      H1=2./PI
      IF(NINT.GT.0) PRINT 12
      TNOT=T
      V0=V
      X0=X
      Z0=Z
      THETA0=THETA
--->  CALL FILLTIM(VOLUME,V0,X0,Z0,THETA0,MS,H0,H1,N,F,TF)
```

FIG 30 Computer Program Allowing Six Degrees of Freedom for Free Descent Phase (Continued)

```
      F0=0.0
      DT=DCAPT*TF
      CAPT=0.0
      DO 5  J=1,N
      ICOUNT=ICOUNT+1
      CAPT=CAPT+DCAPT
      T=TF*CAPT+TNOT
→     CALL CALC(CAPT,TF,DCAPT,DCAPTR,MS,DV,DP,D)
      FRCE=ML*(G*COS(THETA)-DV/DT)
      F0=AMAX1(FRCE,F0)
      TRAJANG=THETA*180./PI
      VX=V*SIN(THETA)
      VZ=V*COS(THETA)
      IF(NINT.LT.0) GO TO 5
      IF(ICOUNT.LT.N/20) GO TO 5
      ICOUNT=0
      ALTMZ=ALT-Z
      ACC=-(G*COS(THETA)-DV/DT)
      PRINT 8,T,ALTMZ,TRAJANG,TRAJANG,X,Z,V,VX,VZ,ACC
    5 CONTINUE
      PRINT 9,T,TRAJANG,X,Z,V,F0,TF
      DQ=DV/DT
      RETURN
    6 FORMAT(I1)
    7 FORMAT(3F10.0)
    8 FORMAT(1X,F8.2,4F11.2,11X,3F11.2,11X,2F11.2)
    9 FORMAT(//,61X,*TIME(SEC) ANGLE(DEG) X(FT)      Z(FT)    V(FT/SEC)  F
     1MAX(LB)   TF(SEC)   *,/,20X,*FULL OR REEFED INFLATION  *,12X,F10.2,
     2F 9.2,3F10.2,F10.0,F10.2)
   10 FORMAT(9(58X,F10.2,F 9.2,3F10.2,F10.0,F10.2,/))
   11 FORMAT(////,20X,*REEFED INFLATION*,/,25X,*REEFING RATIO= *,F10.3,/
     1,25X,*REEFED PROJ. DIAM.= *,F10.3,* FT*,/,25X,*CUTTER DELAY= *,F10
     2.3,* SEC *,/,25X,*TIME OF DISREEF= *,F10.3,* SEC*,////)
   12 FORMAT(5/ ,4X,*TIME*,5X,*ALTITUDE*,4X,*SYSTEM*,3X,*C.M. TRAJ.*,10X
     1,*C.M. POSITION*,26X,*C.M. VELOCITY*,18X,*C.M.*,/,26X,*ANGLE*,6X,
     2    *ANGLE*    ,80X,*ACCELERATION*,/4X,*(SEC)*,6X,*(FT)*,7X,*(DEG)*
     3,6X,*(DEG)*,18X,*(FT)*,32X,*(FT/SEC)*,17X,*(FT/SEC/SEC)*,/,50X,*X*
     4,10X,*Y*,10X,*Z*,8X,*TOTAL*,8X,*X*,10X,*Y*,10X,*Z*,8X,*TOTAL*5/)
      END
```

```
      SUBROUTINE FILLTIM(VOLUME,V0,X0,Z0,THETA0,MS,H0,H1,N,VOLDOT,TF)
      COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NOUSE
      COMMON /VARIABL/ RHO,T,V,THETA,X,Z,UNUSED,UNUSED2,UNUSED3
      REAL LSS,MS
      DIMENSION VOLDOT(N)
      DCAPTR=1./N
      TF=0.
      DTF=2.0*H1*DNOT/V0
    1 TF=TF+DTF
      V=V0
      X=X0
      Z=Z0
      THETA=THETA0
      CAPTR=0.0
    2 DO 3 I=1,N
      CAPTR=CAPTR+DCAPTR
      CAPT=PI*PI/4.*(H1*H1*CAPTR+H0*H0*(1.-CAPTR))
      DCAPT=PI*PI/4.*(H1*H1-H0*H0)*DCAPTR
→     CALL CALC(CAPT,TF,DCAPT,DCAPTR,MS,DV,DP,D)
      C0=0.05
```

FIG 30 Computer Program Allowing Six Degrees of Freedom for Free Descent Phase (Continued)

```
      C=C0*(RHO/0.002378)**.142857
    3 VOLDOT(I)=V*((1.+2.2*C*CAPT-CAPT)*D*D/4.-1.1*C*DP*DP/2.)
      SUM=VOLDOT(N)
      NM1=N-1
      DO 4 J=1,NM1,2
    4 SUM=SUM+4.*VOLDOT(J)
      NM2=N-2
      DO 5 K=2,NM2,2
    5 SUM=SUM+2.*VOLDOT(K)
      VOL=DCAPTR/3.*SUM*PI*TF
      IF(ABS(VOL-VOLUME)/VOLUME-0.00001) 7,7,6
    6 DTF=TF*(VOLUME/VOL-1.)
      GO TO 1
    7 V=V0
      X=X0
      Z=Z0
      THETA=THETA0
      RETURN
      END
```

```
      SUBROUTINE CALC(CAPT,TF,DCAPT,DCAPTR,M,DV,DP,D)
      COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST ,NOUSE
      COMMON /VARIABL/ RHO,T,V,THETA,X,Z,UNUSED,UNUSED2,UNUSED3
      REAL LSS,M,MA,MI,MT
      DP=2.*DNOT/PI*SQRT(CAPT)
      DPMAX=2.*DNOT/PI
      DPDOT=DNOT/(PI*SQRT(CAPT))
      D=(4.*LSS*DP)/(4.*LSS+2.*DNOT-PI*DP)
      DDOT=((4.*LSS+2.*DNOT-PI*DP)*4.*LSS*DPDOT+4.*LSS*DP*PI*DPDOT)/(4.*
     1LSS+2.*DNOT-PI*DP)**2
      MA=PI*RHO*DP*DP*DP*DP*DP/(32.*DPMAX*DPMAX)
      DMA=5.*PI*RHO/(32.*DPMAX*DPMAX)*DP*DP*DP*DP*DPDOT*DCAPT
      SQ=SQRT((LSS+DNOT/2.-PI*DP/4.)**2-DP*DP/4.)
      SQ1=SQRT(LSS*LSS-D*D/4.)
      MI=PI*RHO/12.*(DP*DP*DP+DP*DP*SQ-D*D*SQ1)
      DMI=PI*RHO/12.*(3.*DP*DP*DPDOT-DP*DP*((2.*LSS+DNOT-PI*DP/2.)*PI*DP
     1DOT/4.+DP*DPDOT/2.)/(2.*SQ)+2.*DP*DPDOT*SQ+D*D*D*DDOT/(4.*SQ1)-2.*
     2D*DDOT*SQ1)*DCAPT
      MT=M+MA+MI
      DTHETA=-G*SIN(THETA)*M*DCAPTR*TF/(V*MT)
      CDS=CDP*PI*DP*DP/4.+CDSL
      DV=(M*G*COS(THETA)/MT-RHO*V*V*CDS/(2.*MT))*DCAPTR*TF-V*(DMI+DMA)
     1/MT
      DX=V*SIN(THETA)*DCAPTR*TF
      DZ=V*COS(THETA)*DCAPTR*TF
      THETA=THETA+DTHETA
      V=V+DV
      X=X+DX
      Z=Z+DZ
 -->  CALL DENSITY(RHO,ALT-Z)
      RETURN
      END
```

FIG 30 Computer Program Allowing Six Degrees of Freedom for Free Descent Phase (Continued)

```
      SUBROUTINE INTGRAT(T,Y,TF,NN,PCTERR,ETA,TRY1,TRY2,TRY3,W,YDOT,Z,ID
     1,DX,T1,ISIGNAL)
      DIMENSION Y(NN),YDOT(NN),TRY1(NN),TRY2(NN),TRY3(NN),ETA(NN),W(NN),
     1Z(NN)
      MM=0
      T1=T
      IMDONE=-1
      IF(ID) 1,1,2
    1 DT=DX
      GO TO 12
    2 DT=TF-T1
      M=0
--> 3 CALL FORMULA(Y,DT,TRY1,NN,W,YDOT,Z,L)
      IF(L.GT.0) GO TO 15
--> 4 CALL FORMULA(Y,0.5*DT,TRY2,NN,W,YDOT,Z,L)
      IF(L.GT.0) GO TO 15
-->   CALL FORMULA(TRY2,0.5*DT,TRY3,NN,W,YDOT,Z,L)
      IF(L.GT.0) GO TO 15
      DO 5 J=1,NN
      ERR1=ABS(TRY3(J)-TRY1(J))
      ERR2=AMAX1(ETA(J),PCTERR*ABS(TRY3(J)))
      IF(ERR1-ERR2) 5,5,10
    5 CONTINUE
      MM=0
      DO 6 K=1,NN
    6 Y(K)=TRY3(K)
      T1=T1+DT
      IF(M.LT.5) 8,9
    8 M=M+1
      GO TO 12
    9 M=0
      DT=2.0*DT
      GO TO 12
   10 M=0
      MM=MM+1
      IF(MM.GT.20) GO TO 16
      IMDONE = -1
      DT=DT*0.5
      DO 11 I=1,NN
   11 TRY1(I)=TRY2(I)
      GO TO 4
    7 IF(T1-TF+DT) 3,13,13
   12 IF(IMDONE) 7,14,14
   13 DX=DT
      DT=TF-T1
      IF(DT.EQ.0.) GO TO 14
      IMDONE=1
      GO TO 3
-->14 CALL EMOTION(Y,YDOT,1,ISIGNAL)
      DX=AMAX1(DX,DT)
      RETURN
   15 M=0
      MM=MM+1
      IF(MM.GT.20) GO TO 16
      IMDONE=-1
      DT=DT*0.5
      GO TO 3
   16 ISIGNAL=1
      PRINT 17
      RETURN
   17 FORMAT(5/,5X,5H******CANNOT INTEGRATE OR ANGLE OF ATTACK LARGE*)
      END
```

FIG 30 Computer Program Allowing Six Degrees of Freedom for Free Descent Phase (Continued)

```
      SUBROUTINE FORMULA(Y,H,YI,NN,W,YDOT,Z,ISIGNAL)
      DIMENSIONY(NN),YDOT(NN),YI(NN),W(NN),Z(NN),A(5)
      A(3)=A(4)=H
      A(1)=A(2)=A(5)=0.5*H
      DO 1 J=1,NN
      Z(J)=YDOT(J)
      W(J)=Y(J)
    1 YI(J)=Y(J)
      DO 2 K=1,4
 ---> CALL EMOTION(W,Z,2,ISIGNAL)
      IF(ISIGNAL.GT.0) RETURN
      C=A(K+1)*0.333333333333333
      DO 2 L=1,NN
      W(L)=Y(L)+A(K)*Z(L)
    2 YI(L)=YI(L)+C*Z(L)
      RETURN
      END


      SUBROUTINE TRAJEQN(T,V,THETA,X,Z,RHO,CDS,M,DT,G,ALT,DV)
      REAL M
 ---> CALL DENSITY(RHO,ALT-Z)
      DV=(G*COS(THETA)-RHO*CDS*V*V/(2.*M))*DT
      DTHETA=-G*SIN(THETA)*DT/V
      DX=V*SIN(THETA)*DT
      DZ=V*COS(THETA)*DT
      V=V+DV
      THETA=THETA+DTHETA
      X=X+DX
      Z=Z+DZ
      T=T+DT
      RETURN
      END


      SUBROUTINE DENSITY(RHO,H)
      RHO=0.002378*EXP(-H/32916.)
      IF(H.GT.15000.)  RHO=0.002378*1.07133*EXP(-H/28593.)
      RETURN
      END


      SUBROUTINE DYNAMIC(RHO,L1,L2,L3,IXX,IYY,IZZ,IXZ,MI)
      REAL IA,IAZ,IAZ0,IY,IYY,IXX,IXZ,IZ,IZZ,L1,L2,L3,MBR,ML,MLS,MR,MRX,
     1MP,MI
      COMMON /DYNAM/ DNOT,X1,X2,X3,X4,X5,MBR,ML,MLS,MP,MR,MRX,IAZ0,IZ,
     1Q1,Q2,VOLUME,XNUM,XDENOM
      MI=RHO*VOLUME
      X=(XNUM-MI*Q1*DNOT)/(XDENOM+MI)
      L1=X5-X
      L2=-X-Q1*DNOT
      L3=DNOT-X
      IA=0.13195*RHO*Q2*Q2*Q2*DNOT*DNOT*DNOT*L2*L2
      IY=MP*L2*L2+MLS*(X-X1)*(X-X1)+MR*(X2-X)*(X2-X)+MRX*(X3-X)*(X3-X)+
     1MBR*(X4-X)*(X4-X)+ML*L1*L1
      IYY=IY+IA
      IXX=IYY
      IAZ=IAZ0*RHO/0.002378
      IZZ=IZ+IAZ
      IXZ=0.0
      RETURN
      END
```

FIG 30 Computer Program Allowing Six Degrees of Freedom for Free Descent Phase (Continued)

```
      SUBROUTINE MOTION(DQ,PCTERR,ETA,DT)
      DIMENSION Y(12),YDOT(12),ETA(12),X1(12),X2(12),X3(12),W(12),A(3,3)
      DIMENSION B(12),VERTPAR(10,3)
      REAL L1
      COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NINT
      COMMON /VARIABL/ RHO,T,V,THETA,X,Z,ALPHAL,ALPHAP,L1
      PRINT 8
      READ 7,TSTOP,ZSTOP
      TSTOP=TSTOP+T
      IF(NINT.GT.0) PRINT 6
      AMARK=1.0
      NMARK=0
      IVERT=1
      ANG=THETA*180./PI
      ID=1
      Y(1)=Y(2)=Y(4)=Y(6)=Y(8)=Y(9)=Y(11)=0.0
      Y(3)=V
      Y(5)=-G*SIN(THETA)/V
      Y(7)=THETA
      Y(10)=X
      Y(12)=Z
      YDOT(4)=YDOT(6)=0.0
      YDOT(5)=G*G*COS(THETA)*SIN(THETA)/(V*V)+G*SIN(THETA)/(V*V)*DQ
      TF=T+DT
      NUMB=IABS(NINT)
    1 DO 2 I=1,NUMB
      CALL INTGRAT(T,Y,TF,12,PCTERR ,ETA,X1,X2,X3,W,YDOT,B,ID,DX,T1,K)
      IF(K.GT.0) RETURN
      CALL COSINES(A,Y)
      V0=V
      R3=Y(12)+L1*A(3,3)
      IF(R3.GT.ZSTOP) CORR=(ZSTOP-RZ)/(R3-RZ)
      IF(T1.GT.TSTOP) CORR=(TSTOP-T)/(T1-T)
      IF(R3.GT.ZSTOP.OR.T1.GT.TSTOP) GO TO 3
      T=T1
      RX=Y(10)+L1*A(1,3)
      RY=Y(11)+L1*A(2,3)
      RZ=R3
      C1=Y(1)+Y(5)*L1
      C2=Y(2)-Y(4)*L1
      VX=C1*A(1,1)+C2*A(1,2)+Y(3)*A(1,3)
      VY=C1*A(2,1)+C2*A(2,2)+Y(3)*A(2,3)
      VZ=C1*A(3,1)+C2*A(3,2)+Y(3)*A(3,3)
      C3=YDOT(1)+Y(5)*Y(3)-Y(6)*Y(2)+YDOT(5)*L1+Y(4)*Y(6)*L1
      C4=YDOT(2)+Y(6)*Y(1)-Y(4)*Y(3)-YDOT(4)*L1+Y(5)*Y(6)*L1
      C5=YDOT(3)+Y(4)*Y(2)-Y(5)*Y(1)-(Y(4)*Y(4)+Y(5)*Y(5))*L1
      AX=C3*A(1,1)+C4*A(1,2)+C5*A(1,3)
      AY=C3*A(2,1)+C4*A(2,2)+C5*A(2,3)
      AZ=C3*A(3,1)+C4*A(3,2)+C5*A(3,3)
      V=SQRT(VX*VX+VY*VY+VZ*VZ)
      AT=SQRT(AX*AX+AY*AY+AZ*AZ)
      IF(V.LT.V0) AT=-AT
      SYSANGL=ACOS(A(3,3))*180./PI
      TRAJANG=ACOS(VZ/V)*180./PI
      IF(IVERT.GT.3) GO TO 15
   12 IF((ABS(SYSANGL)-ABS(ANG))*AMARK.GE.0.0) GO TO 13
      VERTPAR(1,IVERT)=T
      VERTPAR(2,IVERT)=ALT-RZ
      VERTPAR(3,IVERT)=RX
      VERTPAR(4,IVERT)=RY
      VERTPAR(5,IVERT)=RZ
      VERTPAR(6,IVERT)=V
      VERTPAR(7,IVERT)=VX
      VERTPAR(8,IVERT)=VY
      VERTPAR(9,IVERT)=VZ
```

FIG 30 Computer Program Allowing Six Degrees of Freedom for Free Descent Phase (Continued)

```
      VERTPAR(10,IVERT)=AT
      ANG=SYSANGL
      GO TO 15
   13 AMARK=-AMARK
      NMARK=NMARK+1
      GO TO(14,12,14,12,14) NMARK
   14 IVERT=IVERT+1
      ANG=SYSANGL
   15 ID=-1
      NUMB=IABS(NINT)
      IF(NUMB*DX.GT.1.0) NUMB=MAX1(1.,1./DX)
      TF=T+DX
    2 CONTINUE
      ALTMRZ=ALT-RZ
      IF(NINT.GT.0) PRINT 4,T,ALTMRZ,SYSANGL,TRAJANG,RX,RY,RZ,V,VX,VY,VZ
     1,AT
      GO TO 1
    3 T=(T1-T)*CORR+T
      R1=Y(10)+L1*A(1,3)
      R2=Y(11)+L1*A(2,3)
      C1=Y(1)+Y(5)*L1
      C2=Y(2)-Y(4)*L1
      V1=C1*A(1,1)+C2*A(1,2)+Y(3)*A(1,3)
      V2=C1*A(2,1)+C2*A(2,2)+Y(3)*A(2,3)
      V3=C1*A(3,1)+C2*A(3,2)+Y(3)*A(3,3)
      C3=YDOT(1)+Y(5)*Y(3)-Y(6)*Y(2)+YDOT(5)*L1+Y(4)*Y(6)*L1
      C4=YDOT(2)+Y(6)*Y(1)-Y(4)*Y(3)-YDOT(4)*L1+Y(5)*Y(6)*L1
      C5=YDOT(3)+Y(4)*Y(2)-Y(5)*Y(1)-(Y(4)*Y(4)+Y(5)*Y(5))*L1
      A1=C3*A(1,1)+C4*A(1,2)+C5*A(1,3)
      A2=C3*A(2,1)+C4*A(2,2)+C5*A(2,3)
      A3=C3*A(3,1)+C4*A(3,2)+C5*A(3,3)
      RX=(R1-RX)*CORR+RX
      RY=(R2-RY)*CORR+RY
      RZ=(R3-RZ)*CORR+RZ
      VX=(V1-VX)*CORR+VX
      VY=(V2-VY)*CORR+VY
      VZ=(V3-VZ)*CORR+VZ
      AX=(A1-AX)*CORR+AX
      AY=(A2-AY)*CORR+AY
      AZ=(A3-AZ)*CORR+AZ
      V=SQRT(VX*VX+VY*VY+VZ*VZ)
      AT=SQRT(AX*AX+AY*AY+AZ*AZ)
      IF(V.LT.V0) AT=-AT
      SYSANGL=(ACOS(A(3,3))*180./PI-SYSANGL)*CORR+SYSANGL
      TRAJANG=ACOS(VZ/V)*180./PI
      ALTMRZ=ALT-RZ
      IF(NINT.GT.0) PRINT 4,T,ALTMRZ,SYSANGL,TRAJANG,RX,RY,RZ,V,VX,VY,VZ
     1,AT
      PRINT 51
      IVERT1=IVERT-1
      DO 31 J=1,IVERT1
   31 PRINT 5,J,(VERTPAR(I,J),I=1,10)
      RETURN
    4 FORMAT(1X,F8.2,11F11.2)
    5 FORMAT(5X,I1,* VERT/MIN*,3F12.2,3F10.2,4F12.2)
   51 FORMAT(//20X,*TIME(SEC) ALTITUDE(FT)    X(FT)       Y(FT)       Z(FT)
     1 V(FT/SEC)    VX(FT/SEC)   VY(FT/SEC)   VZ(FT/SEC)  A(FT/SEC/SEC)*)
    6 FORMAT(5/ ,4X,*TIME*,5X,*ALTITUDE*,4X,*SYSTEM*,3X,*LOAD TRAJ.*,10X
     1,*LOAD POSITION*,26X,*LOAD VELOCITY*,18X,*LOAD*,/,26X,*ANGLE*,6X,
     2    *ANGLE*    ,80X,*ACCELERATION*,/4X,*(SEC)*,6X,*(FT)*,7X,*(DEG)*
     3,6X,*(DEG)*,18X,*(FT)*,32X,*(FT/SEC)*,17X,*(FT/SEC/SEC)*,/,50X,*X*
     4,10X,*Y*,10X,*Z*,8X,*TOTAL*,8X,*X*,10X,*Y*,10X,*Z*,8X,*TOTAL*5/)
    7 FORMAT(2F10.0)
    8 FORMAT(5/,5X,*NOTE-- POSITIONS,VELOCITIES,ACCELERATIONS,TRAJ. ANGL
     1ES REFER TO LOAD, PREVIOUS RESULTS ARE FOR MASS CENTER*)
      END
```

FIG 30 Computer Program Allowing Six Degrees of Freedom for Free Descent Phase (Continued)

```
      SUBROUTINE EMOTION(Y,YDOT,ISTOP,ISIGNAL)
      DIMENSION Y(12),YDOT(12),A(3,3)
      REAL M,MA,MI,ML,MP,MSS,IXX,IYY,IZZ,IXZ,L1,L2,L3
      COMMON /CONST/ ALT,PI,G,CDP,DNOT,CDSL,LSS,ML,MP,MSS,MST,NOUSE
      COMMON /VARIABL/ RHO,T,V,THETA,X,Z,ALPHAL,ALPHAP,L1
      CALL DENSITY(RHO,ALT-Y(12))
      CALL DYNAMIC(RHO,L1,L2,L3,IXX,IYY,IZZ,IXZ,MI)
      MA=1.375*MI
      M=ML+MP+MSS+MA
      R=MA/M
      B=(ML+MP+MSS)*G/M
      H1=(IZZ-IYY)/IXX
      H2=(IXX-IZZ)/IYY
      H3=(IYY-IXX)/IZZ
      H4=IXZ/IXX
      H5=IXZ/IYY
      H6=IXZ/IZZ
      C=RHO*PI*DNOT*DNOT/8.
      CDNOT=C*DNOT
      E=0.5*RHO*CDSL
      UL=Y(1)+Y(5)*L1
      VL=Y(2)-Y(4)*L1
      UP=Y(1)+Y(5)*L2
      VP=Y(2)-Y(4)*L2
      VL2=UL*UL+VL*VL+Y(3)*Y(3)
      VP2=UP*UP+VP*VP+Y(3)*Y(3)
      ALPHAL=ATAN(-UL/Y(3))
      BETAL=ATAN(VL/Y(3))
      GAMMAL=ATAN(VL/SQRT(UL*UL+Y(3)*Y(3)))
      DELTAL=ATAN(+UL/SQRT(VL*VL+Y(3)*Y(3)))
      ALPHAP=ATAN(-UP/Y(3))
      BETAP=ATAN(VP/Y(3))
      POLANG=ACOS(Y(3)/SQRT(UP*UP+VP*VP+Y(3)*Y(3)))
      CALL COEFFTS(ALPHAP,BETAP,POLANG,CT,CX,CY,CMX,CMY,ISTOP,ISIGNAL)
      IF(ISIGNAL.GT.0) RETURN
      FX=C*CX*VP2
      FY=C*CY*VP2
      TT=C*CT*VP2
      AEROMX=CDNOT*CMX*VP2
      AEROMY=CDNOT*CMY*VP2
      D=E*VL2
      CALL COSINES(A,Y)
      YDOT(1)=B*A(3,1)+D*COS(GAMMAL)*SIN(ALPHAL)/M+FX/M-R*L2*(YDOT(5)+
     1Y(4)*Y(6))-Y(5)*Y(3)+Y(6)*Y(2)
      YDOT(2)=B*A(3,2)-D*COS(DELTAL)*SIN(BETAL)/M+FY/M+R*L2*(YDOT(4)-
     1Y(5)*Y(6))+Y(4)*Y(3)-Y(6)*Y(1)
      YDOT(3)=B*A(3,3)-D*COS(GAMMAL)*COS(ALPHAL)/M-TT/M+R*L2*(Y(4)*Y(4)
     1+Y(5)*Y(5))-Y(4)*Y(2)+Y(5)*Y(1)
      YDOT(4)=-FY*L3/IXX+AEROMX/IXX+D*COS(DELTAL)*SIN(BETAL)*L1/IXX-ML*G
     1*A(3,2)*L1/IXX-MP*G*A(3,2)*L2/IXX+YDOT(6)*H4-Y(5)*Y(6)*H1+Y(4)*Y(5
     2)*H4
      YDOT(5)=FX*L3/IYY+AEROMY/IYY+D*COS(GAMMAL)*SIN(ALPHAL)*L1/IYY+ML*G
     1*A(3,1)*L1/IYY+MP*G*A(3,1)*L2/IYY-Y(4)*Y(6)*H2-(Y(4)*Y(4)-Y(6)*Y(6
     2))*H5
      YDOT(6)=YDOT(4)*H6-Y(4)*Y(5)*H3-Y(5)*Y(6)*H6
      YDOT(7)=Y(5)*COS(Y(8))-Y(6)*SIN(Y(8))
      YDOT(8)=Y(4)+TAN(Y(7))*(Y(5)*SIN(Y(8))+Y(6)*COS(Y(8)))
      YDOT(9)=(Y(5)*SIN(Y(8))+Y(6)*COS(Y(8)))/COS(Y(7))
      YDOT(10)=Y(1)*A(1,1)+Y(2)*A(1,2)+Y(3)*A(1,3)
      YDOT(11)=Y(1)*A(2,1)+Y(2)*A(2,2)+Y(3)*A(2,3)
      YDOT(12)=Y(1)*A(3,1)+Y(2)*A(3,2)+Y(3)*A(3,3)
      RETURN
      END
```

FIG 30 Computer Program Allowing Six Degrees of Freedom for Free Descent Phase (Continued)

```
      SUBROUTINE COSINES(A,Y)
      DIMENSION Y(12),A(3,3)
      A(1,1)=COS(Y(7))*COS(Y(9))
      A(1,2)=SIN(Y(8))*SIN(Y(7))*COS(Y(9))-COS(Y(8))*SIN(Y(9))
      A(1,3)=COS(Y(8))*SIN(Y(7))*COS(Y(9))+SIN(Y(8))*SIN(Y(9))
      A(2,1)=COS(Y(7))*SIN(Y(9))
      A(2,2)=SIN(Y(8))*SIN(Y(7))*SIN(Y(9))+COS(Y(8))*COS(Y(9))
      A(2,3)=COS(Y(8))*SIN(Y(7))*SIN(Y(9))-SIN(Y(8))*COS(Y(9))
      A(3,1)=-SIN(Y(7))
      A(3,2)=SIN(Y(8))*COS(Y(7))
      A(3,3)=COS(Y(8))*COS(Y(7))
      RETURN
      END


      SUBROUTINE COEFFTS(ALPHAP,BETAP,POLANG,CT,CX,CY,CMX,CMY,IPRINT,
     1ISIGNAL)
      ALPHAPD=ALPHAP*57.295779515
      BETAPD=BETAP*57.295779515
      P=POLANG*57.295779515
      IF(ABS(ALPHAPD).LT.85.) GO TO 1
      IF(IPRINT.EQ.1) PRINT 2,ALPHAPD
      ISIGNAL=1
      RETURN
    1 IF(ABS(BETAPD).LT.85.) GO TO 3
      IF(IPRINT.EQ.1) PRINT 2,BETAPD
      ISIGNAL=1
      RETURN
    2 FORMAT(5X,*ANGLE OF ATTACK= *,F6.3,*  , TOO LARGE*)
    3 ISIGNAL=-1
      A=ABS(ALPHAPD)
      IF(A-30.0) 4,5,5
    4 CX=-6.74E-03*A+5.57E-04*A*A-1.53E-05*A*A*A+1.9E-07*A*A*A*A
      CMY=4.844E-03*A-3.94E-04*A*A+1.043E-05*A*A*A-1.32E-07*A*A*A*A
      IF(ALPHAPD.GT.0.0) GO TO 6
      CX=-CX
      CMY=-CMY
      GO TO 6
    5 CX=.0056*(A-30.0)+.04
      CMY=-.0044*(A-30.0)-.034
      IF(ALPHAPD.GT.0.0) GO TO 6
      CX=-CX
      CMY=-CMY
    6 B=ABS(BETAPD)
      IF(B-30.0) 7,8,8
    7 CY=-6.74E-03*B+5.57E-04*B*B-1.53E-05*B*B*B+1.9E-07*B*B*B*B
      CMX=4.844E-03*B-3.94E-04*B*B+1.043E-05*B*B*B-1.32E-07*B*B*B*B
      IF(BETAPD.GT.0.0)GO TO 9
      CY=-CY
      CMX=-CMX
      GO TO 9
    8 CY=.0056*(B-30.0)+.04
      CMX=-.0044*(B-30.0)-.034
      IF(BETAPD.GT.0.0)GO TO 9
      CY=-CY
      CMX=-CMX
    9 IF(P-30.0) 10,11,11
   10 CT=.647-1.2E-05*P+9.15E-04*P*P-7.13E-05*P*P*P+1.33E-06*P*P*P*P
      RETURN
   11 CT=0.62
      RETURN
      END
```

FIG 30 Computer Program Allowing Six Degrees of Freedom for Free Descent Phase (Concluded)

VIII. INPUT DATA CARD FORMAT

Input to the computer program is provided on punched data cards. Somewhat different data is required for each of the four separation-deployment systems. Tables XX through XXIII detail the data cards which are required for the four separation-deployment systems. The numbers listed as card numbers correspond to the order and total number of cards which are required for two-dimensional trajectories with no reefed inflations. Data cards which must be inserted only for three-dimensional trajectories are denoted by 7a and 7b. When reefed inflations are desired, the user must insert the required number of appropriate cards at the points indicated in Tables XX through XXIII.

TABLE XX

Input Data for Static Line System

Card Number	Column Number	Format Representation	Mnemonic	Symbol	Comments
1	1-50	5A10	C1, C2, C3, C4, C5		title of simulation
2	1-10	F10.0	ALT	h_o	release altitude
	11-20	F10.0	VO	v_o	release velocity
3	1-10	F10.0	MST	m_{rs}	mass of load and packed recovery system
	11-20	F10.0	MP	m_p	mass of parachute
	21-30	F10.0	MLS	m_{L_s}	mass of suspension lines
	31-40	F10.0	MR	m_R	mass of risers
	41-50	F10.0	MRX	m_E	mass of riser extensions
	51-60	F10.0	MBR	m_{Br}	mass of load bridle
	61-70	F10.0	ML	m_ℓ	mass of load
4	1-10	F10.0	X1	s_1	reference distance from canopy skirt to suspension line center of mass in fully inflated configuration
	11-20	F10.0	X2	s_2	reference distance from canopy skirt to riser center of mass in fully inflated configuration

TABLE XX (CONT.)

Input Data for Static Line System

Card Number	Column Number	Format Representation	Mnemonic	Symbol	Comments
	21-30	F10.0	X3	s_3	reference distance from canopy skirt to riser extension center of mass in fully inflated configuration
	31-40	F10.0	X4	s_4	reference distance from canopy skirt to load bridle center of mass in fully inflated configuration
	41-50	F10.0	X5	s_5	reference distance from canopy skirt to load center of mass in fully inflated configuration
	51-60	F10.0	IZ	I_Z (IZZ) or (IXZ)	moment of inertia about Z-axis due to masses of load, parachute, and suspension system
	61-70	F10.0	IAZO	$I_{a_Z)_o}$	apparent moment of inertia about Z-axis at mean sea level
5	1-10	F10.0	DNØT	D_o	nominal diameter
	11-20	F10.0	LSS		$L_s + L_R$
	21-30	F10.0	CDP	C_{D_p}	drag coefficient of parachute based on projected area

TABLE XX (CONT.)

Input Data for Static Line System

Card Number	Column Number	Format Representation	Mnemonic	Symbol	Comments
	31-40	F10.0	CDSL	$C_D S_\ell$	drag area of load
	41-50	F10.0	Q1	s_c/D_o	ratio of reference distance from canopy skirt to parachute center of volume in fully inflated condition to D_o
	51-60	F10.0	Q2	$D_{p_{max}}/D_o$	projected diameter ratio in fully inflated configuration
	61-70	F10.0	VOLUME	V	volume of fully inflated parachute
6	1	I1	N		number of degrees of freedom
	2-10	I9	NNN		number of steps used to approximate inflation stages in ØPENING
	11-20	F10.0	DT1	Δt	Δt in EXTRACT
	21-30	F10.0	DT2	Δt	Δt in SNATCH
	31-40	F10.0	DT3	Δt	Δt in ØPENING, MØTIØN
	41-45	I5	NINT		number of calculations made without print; if ≤ 0 suppresses continuous output
7	1-10	F10.0	ETA(1)	η_1	allowable absolute error in integration for U

TABLE XX (CONT.)

Input Data for Static Line System

Card Number	Column Number	Format Representation	Mnemonic	Symbol	Comments
	11-20	F10.0	ETA(2)	η_2	allowable absolute error in integration for W
	21-30	F10.0	ETA(3)	η_3	allowable absolute error in integration for Q
	31-40	F10.0	ETA(4)	η_4	allowable absolute error in integration for Θ
	41-50	F10.0	ETA(5)	η_5	allowable absolute error in integration for x
	51-60	F10.0	ETA(6)	η_6	allowable absolute error in integration for z
7a [1]	1-10	F10.0	ETA(1)	η_1	allowable absolute error in integration for U
	11-20	F10.0	ETA(2)	η_2	allowable absolute error in integration for V
	21-30	F10.0	ETA(3)	η_3	allowable absolute error in integration for W

[1] these cards are required in place of card 7 when six degrees of freedom are allowed, i.e. N = 6

TABLE XX (CONT.)

Input Data for Static Line System

Card Number	Column Number	Format Representation	Mnemonic	Symbol	Comments
	31-40	F10.0	ETA(4)	η_4	allowable absolute error in integration for P
	41-50	F10.0	ETA(5)	η_5	allowable absolute error in integration for Q
	51-60	F10.0	ETA(6)	η_6	allowable absolute error in integration for R
7b [1]	1-10	F10.0	ETA(7)	η_7	allowable absolute error in integration for θ
	11-20	F10.0	ETA(8)	η_8	allowable absolute error in integration for φ
	21-30	F10.0	ETA(9)	η_9	allowable absolute error in integration for ψ
	31-40	F10.0	ETA(10)	η_{10}	allowable absolute error in integration for x
	41-50	F10.0	ETA(11)	η_{11}	allowable absolute error in integration for y
	51-60	F10.0	ETA(12)	η_{12}	allowable absolute error in integration for z

[1] these cards are required in place of card 7 when six degrees of freedom are allowed, i.e. N = 6

TABLE XX (CONT.)

Input Data for Static Line System

Card Number	Column Number	Format Representation	Mnemonic	Symbol	Comments
8	1-10	F10.0	PCTERR	E_p	allowable relative error in integration
9	1-2	I2	ISTATIC		-1
	3-4	I2	IEXTRAC		0
10	1-10	F10.0	LSTATIC	L_{static}	length of static line
	11-20	F10.0	CDSBAG	C_DS_B	drag area of main parachute deployment bag
	21-30	F10.0	CDSP	C_DS_{pilot}	0
	31-40	F10.0	DPILØT	$D_{o\ pilot}$	0
	41-50	F10.0	LSPILØT	$L_{s\ pilot}$	0
	51-60	F10.0	TD	t_D	0
	61-70	F10.0	LRXBR		$L_E + L_{Br}$
11	1	I1	NREEF		number of reefing lines
11a [2]	1-10	F10.0	R0	R_o	initial reefing ratio
	11-20	F10.0	R1	R_1	final reefing ratio
	21-30	F10.0	TCD	t_{CD}	reefing cutter delay time

[2] required only when NREEF $\neq$ 0; must have NREEF cards of type 11a

TABLE XX (CONT.)

Input Data for Static Line System

Card Number	Column Number	Format Representation	Mnemonic	Symbol	Comments
12	1-10	F10.0	TSTØP	t_{stop}	number of seconds after full inflation when simulation is to terminate
	11-20	F10.0	ZSTØP	z_{stop}	altitude loss at which simulation is to terminate

TABLE XXI

Input Data for Static Line Deployed Pilot Chute System

Card Number	Column Number	Format Representation	Mnemonic	Symbol	Comments
1-8					see Table XX
9	1-2	I2	ISTATIC		-1
	3-4	I2	IEXTRAC		0
10	1-10	F10.0	LSTATIC	L_{static}	static line length
	11-20	F10.0	CDSBAG	$C_D S_B$	drag area of main parachute deployment bag
	21-30	F10.0	CDSP	$C_D S_{pilot}$	drag area of pilot chute
	31-40	F10.0	DPILOT	$D_{o\ pilot}$	flat diameter of pilot chute
	41-50	F10.0	LSPILOT	$L_{s\ pilot}$	length of suspension lines of pilot chute
	51-60	F10.0	TD	t_D	time at which coasting period ends; if no coasting period, = 0
	61-70	F10.0	LRXBR		0
11	1-10	F10.0	MPBAG	m_{pb}	mass of pilot parachute and main parachute deployment bag
	11-20	F10.0	CDS2	$C_D S_{II}$	drag area of pilot chute and main parachute deployment bag

TABLE XXI (CONT.)

Input Data for Static Line Deployed Pilot Chute System

Card Number	Column Number	Format Representation	Mnemonic	Symbol	Comments
	21-30	F10.0	K	~~k~~	spring constant of suspension system
	31-40	F10.0	LRXBR		$L_E + L_{Br}$
12	1	I1	NREEF		number of reefing lines
12a[1]	1-10	F10.0	RO	R_o	initial reefing ratio
	11-20	F10.0	R1	R_1	final reefing ratio
	21-30	F10.0	TCD	t_{CD}	reefing cutter delay time
13	1-10	F10.0	TSTØP	t_{stop}	number of seconds after full inflation when simulation is to terminate
	11-20	F10.0	ZSTØP	z_{stop}	altitude loss at which simulation is to terminate

[1] required only when NREEF $\neq$ 0; must have NREEF cards of type 12a

TABLE XXII

Input Data for Extraction Parachute System

Card Number	Column Number	Format Representation	Mnemonic	Symbol	Comments
1-8					see Table XX
9	1-2	I2	ISTATIC		+1
	3-4	I2	IEXTRAC		0
10	1-10	F10.0	LENGTH	L	distance load travels in aircraft
	11-20	F10.0	CDSBAG	$C_D S_B$	drag area of main parachute deployment bag
	21-30	F10.0	CDSEX	$C_D S_{ex}$	drag area of extraction parachute
	31-40	F10.0	TD	t_D	time at which coasting period ends; if no coasting period, = 0
11	1-10	F10.0	MPBAG	m_{pb}	mass of extraction parachute and main parachute deployment bag
	11-20	F10.0	CDS2	$C_D S_{II}$	drag area of extraction parachute and main parachute deployment bag
	21-30	F10.0	K	k	spring constant of suspension system
	31-40	F10.0	LRXBR		$L_E + L_{Br}$

TABLE XXII (CONT.)

Input Data for Extraction Parachute System

Card Number	Column Number	Format Representation	Mnemonic	Symbol	Comments
12	1	I1	NREEF		number of reefing lines
12a[1]	1-10	F10.0	RO	R_o	initial reefing ratio
	11-20	F10.0	R1	R_1	final reefing ratio
	21-30	F10.0	TCD	t_{CD}	reefing cutter delay time
13	1-10	F10.0	TSTØP	t_{stop}	number of seconds after full inflation when simulation is to be terminated
	11-20	F10.0	ZSTØP	z_{stop}	altitude loss at which simulation is to be terminated

[1] required only when NREEF ≠ 0; must have NREEF cards of type 12a

TABLE XXIII

Input Data for Reefed Main Parachute Extraction System

Card Number	Column Number	Format Representation	Mnemonic	Symbol	Comments
1-8					see Table XX
9	1-2	I2	ISTATIC		+1
	3-4	I2	IEXTRAC		+1
10	1-10	F10.0	R	R_{ex}	reefing ratio of main parachute during extraction
	11-20	F10.0	LENGTH	L	distance load travels
	21-30	F10.0	TD	t_D	time at which coasting period ends; if no coasting period, = 0
11	1	I1	NREEF		number of reefing lines
12[1]	1-10	F10.0	RO	R_o	initial reefing ratio
	11-20	F10.0	R1	R_1	final reefing ratio
	21-30	F10.0	TCD	t_{CD}	reefing cutter delay time
13	1-10	F10.0	TSTØP		number of seconds after full inflation when simulation is to terminate
	11-20	F10.0	ZSTØP		altitude loss at which simulation is to terminate

[1] NREEF cards of this type are needed

IX. SAMPLE OUTPUT

Figures 31 through 35 include portions of the computer output related to those calculations which are presented graphically in Volume I of this report. Portions of the data during the free descent phase are omitted since the intent of this Section is only to indicate the type of output which is produced by the computer program.

All physical input data related to the parachute-load system is printed on the computer outputs. Those input values which are required for the specific systems have been discussed in Section VIII. The remaining inputs are left to the discretion of the program user, and the particular values which were used in all of the calculations shown in this section are listed in the following:

NNN = 100
DT1 = 0.001
DT2 = 0.001
DT3 = 0.001
NINT = 50 (determines print increments)
ETA(1) = 0.001
ETA(2) = 0.001
ETA(3) = 0.00001
ETA(4) = 0.0001
ETA(5) = 0.01
ETA(6) = 0.01
PCTERR = 0.001

The above values were chosen after experimentation with a typical calculation showed that smaller values (larger for NNN) did not significantly alter the numerical results but required significantly more computer time for the calculations. These values must, of course, be estimated for the particular application the program user intends.

```
PARACHUTE-LOAD SYSTEM(DEPLOYMENT)-- T-10(STATIC LINE)


TRAJECTORY SIMULATION--T=0,Z=0 IS RELEASE POINT


RELEASE CONDITIONS
     ALTITUDE=      6000. FT
     VELOCITY=    220.00 FT/SEC


MASSES--SLUGS
     TOTAL SYSTEM=       8.343
     LOAD=       7.770
     PARACHUTE=       .364
     SUSP. LINES=        .075
     RISERS=        .031
     RISER EXTENSIONS=          0
     LOAD BRIDLE=            0
     INCLUDED=      7.889(SEA LEVEL)     6.574(  6000.  FT)
     APPARENT=      2.958(SEA LEVEL)     2.465(  6000.  FT)


REFERENCE DISTANCES FROM SKIRT-- FT
     X1=      11.520
     X2=      24.170
     X3=           0
     X4=           0
     X5=      27.800


MOM./PROD. INERTIA--SLUG FT**2
     IXX=       3339.500(SEA LEVEL)       2994.494(  6000.  FT)
     IYY=       3339.500(SEA LEVEL)       2994.494(  6000.  FT)
     IZZ=              0(SEA LEVEL)              0(  6000.  FT)
     IXZ=              0(SEA LEVEL)              0(  6000.  FT)


DIMENSIONS-- FT
     DNOT=      35.000
     SUSP. SYSTEM=      28.000
     L1=      16.689(SEA LEVEL)    15.291(  6000.  FT)
     L2=     -15.766(SEA LEVEL)   -17.164(  6000.  FT)
     L3=      23.889(SEA LEVEL)    22.491(  6000.  FT)


YC/DNOT=        .133
DP/DNOT=        .686
VOLUME=   3317.500 FT**3
PARACHUTE CDP=      1.487

LOAD DRAG AREA=       6.000 FT**2
DEGREES OF FREEDOM=           3



                STATIC LINE=     15.000 FT
                PARACHUTE PACK DRAG AREA=        .330 FT**2
```

FIG 31 Sample Output for the T-10 Parachute with Static Line System

FIG 31 Sample Output for the T-10 Parachute with Static Line System (Continued)

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	C.M. VELOCITY (FT/SEC) TOTAL	X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
.05	5999.96	89.58	89.58	10.96		.04	218.20	218.20		1.60	
.10	5999.84	89.16	89.16	21.82		.16	216.44	216.42		3.19	
.15	5999.64	88.73	88.73	32.60		.36	214.73	214.67		4.77	
.20	5999.37	88.30	88.30	43.29		.63	213.05	212.95		6.33	
.25	5999.01	87.86	87.86	53.90		.99	211.41	211.26		7.88	
.30	5998.58	87.43	87.43	64.42		1.42	209.81	209.59		9.42	
.35	5998.07	86.99	86.99	74.86		1.93	208.24	207.95		10.95	
.40	5997.49	86.54	86.54	85.22		2.51	206.71	206.34		12.47	
.45	5996.83	86.10	86.10	95.49		3.17	205.22	204.75		13.97	
.50	5996.09	85.65	85.65	105.69		3.91	203.77	203.18		15.47	
.55	5995.28	85.19	85.19	115.81		4.72	202.34	201.63		16.95	
.60	5994.40	84.74	84.74	125.86		5.60	200.96	200.11		18.43	
.65	5993.44	84.28	84.28	135.83		6.56	199.60	198.61		19.89	
.70	5992.41	83.82	83.82	145.72		7.59	198.28	197.13		21.35	
.75	5991.31	83.36	83.36	155.54		8.69	196.99	195.67		22.79	
.80	5990.13	82.89	82.89	165.29		9.87	195.73	194.23		24.22	
.85	5988.89	82.42	82.42	174.97		11.11	194.51	192.81		25.65	
.90	5987.57	81.95	81.95	184.57		12.43	193.31	191.41		27.07	
.95	5986.18	81.48	81.48	194.11		13.82	192.15	190.02		28.47	
1.00	5984.72	81.00	81.00	203.58		15.28	191.01	188.66		29.87	
1.05	5983.20	80.53	80.53	212.98		16.80	189.90	187.31		31.26	
1.10	5981.60	80.05	80.05	222.31		18.40	188.83	185.98		32.64	
1.15	5979.93	79.56	79.56	231.58		20.07	187.78	184.67		34.01	
1.20	5978.20	79.08	79.08	240.78		21.80	186.76	183.37		35.38	
1.25	5976.40	78.59	78.59	249.92		23.60	185.76	182.09		36.73	
1.30	5974.53	78.11	78.11	258.99		25.47	184.80	180.83		38.08	
1.35	5972.59	77.62	77.62	268.00		27.41	183.86	179.58		39.42	
1.40	5970.59	77.13	77.13	276.95		29.41	182.94	178.34		40.75	
1.45	5968.52	76.64	76.64	285.84		31.48	182.05	177.12		42.08	
1.50	5966.38	76.14	76.14	294.66		33.62	181.19	175.92		43.39	
1.55	5964.18	75.65	75.65	303.43		35.82	180.35	174.72		44.70	
1.60	5961.91	75.15	75.15	312.14		38.09	179.54	173.54		46.00	
1.65	5959.58	74.66	74.66	320.78		40.42	178.75	172.38		47.30	

	TIME(SEC)	ANGLE(DEG)	X(FT)	Z(FT)	VELOCITY(FT/SEC)
STATIC LINE STRETCH	.81	82.77	167.81	10.18	195.41
PARACHUTE/PILOT CHUTE DEPLOYMENT	1.68	74.35	326.12	41.90	178.27

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	C.M. VELOCITY (FT/SEC) TOTAL	X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
1.76	5954.18	73.53	73.53	339.80		45.82	163.54	156.82		46.37	-212.41

1.85	5950.46	72.67	72.67	352.13		49.54	145.22	138.53		43.25	-239.40
1.93	5947.02	71.74	71.74	362.93		52.98	126.42	120.06		39.60	-234.05
2.01	5943.88	70.73	70.73	372.24		56.12	109.04	102.93		35.99	-211.69
2.09	5941.03	69.60	69.60	380.21		58.97	93.88	87.99		32.73	-183.70
2.18	5938.43	68.35	68.35	387.02		61.57	81.08	75.36		29.91	-156.32
2.26	5936.04	66.97	66.97	392.87		63.96	70.43	64.82		27.55	-132.22
2.34	5933.84	65.46	65.46	397.91		66.16	61.64	56.07		25.60	-112.07
2.42	5931.79	63.82	63.82	402.28		68.21	54.39	48.80		24.00	-95.68
2.50	5929.86	62.04	62.04	406.09		70.14	48.39	42.74		22.68	-82.53
2.59	5928.02	60.15	60.15	409.43		71.98	43.41	37.65		21.61	-72.07
2.67	5926.28	58.15	58.15	412.39		73.72	39.26	33.35		20.72	-63.78
2.75	5924.59	56.06	56.06	415.01		75.41	35.79	29.69		19.98	-57.22
2.83	5922.97	53.89	53.89	417.35		77.03	32.87	26.56		19.37	-52.04
2.92	5921.39	51.66	51.66	419.45		78.61	30.41	23.85		18.86	-47.95
3.00	5919.85	49.39	49.39	421.33		80.15	28.31	21.50		18.43	-44.72
3.08	5918.35	47.10	47.10	423.03		81.65	26.53	19.44		18.06	-42.20
3.16	5916.87	44.81	44.81	424.57		83.13	25.01	17.62		17.74	-40.22
3.25	5915.42	42.54	42.54	425.97		84.58	23.70	16.02		17.46	-38.68
3.33	5913.99	40.30	40.30	427.24		86.01	22.57	14.60		17.21	-37.48

FULL OR REEFED INFLATION

TIME(SEC)	ANGLE(DEG)	X(FT)	Z(FT)	V(FT/SEC)	FMAX(LB)	TF(SEC)
3.33	40.30	427.24	86.01	22.57	1868.	1.65

NOTE-- POSITIONS,VELOCITIES,ACCELERATIONS,TRAJ. ANGLES REFER TO LOAD, PREVIOUS RESULTS ARE FOR MASS CENTER

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	LOAD TRAJ. ANGLE (DEG)	LOAD POSITION (FT) X	Y	Z	LOAD VELOCITY (FT/SEC) TOTAL	X	Y	Z	LOAD ACCELERATION (FT/SEC/SEC) TOTAL
3.61	5895.33	24.34	-15.89	436.69		104.67	23.41	-6.41		22.52	-35.64
4.09	5887.29	-4.11	-48.48	431.55		112.71	16.37	-12.26		10.85	-22.22
4.60	5883.53	-28.21	-35.24	426.95		116.47	7.50	-4.33		6.12	-21.06
5.24	5877.01	-39.67	28.44	428.44		122.99	18.25	8.69		16.04	28.46
6.27	5852.81	-13.64	47.25	447.46		147.19	37.71	27.69		25.60	16.01
7.55	5829.61	35.41	38.24	478.77		170.39	19.94	12.34		15.66	-26.59
8.19	5816.78	39.08	-7.01	481.65		183.22	25.27	-3.08		25.08	28.18
8.57	5806.18	31.69	-22.23	478.74		193.82	31.89	-12.07		29.52	24.38
9.34	5784.40	2.88	-44.87	463.81		215.60	34.24	-24.16		24.26	-15.23
10.30	5766.66	-31.87	-30.57	445.47		233.34	19.18	-9.76		16.52	-24.46
10.87	5755.32	-36.88	8.53	443.73		244.68	23.88	3.54		23.61	26.67
11.39	5741.64	-28.01	27.12	448.44		258.36	32.45	14.80		28.88	22.04
12.15	5720.80	.08	47.02	464.63		279.20	33.60	24.58		22.91	-13.77
13.24	5700.97	33.63	19.55	483.76		299.03	19.51	6.53		18.38	24.99
14.01	5683.22	30.57	-20.86	482.18		316.78	29.41	-10.47		27.49	23.14
14.78	5662.06	6.18	-42.46	468.68		337.94	33.71	-22.76		24.86	-13.97
15.80	5642.01	-27.93	-33.05	448.81		357.99	20.41	-11.13		17.10	-21.77
16.31	5632.23	-33.91	.34	446.00		367.77	21.83	.13		21.82	24.80
16.95	5616.03	-25.57	25.93	450.42		383.97	30.86	13.50		27.76	20.03
17.72	5595.87	-.23	44.60	465.19		404.13	31.95	22.44		22.75	-11.33
18.68	5577.73	28.32	27.14	482.00		422.27	20.06	9.15		17.86	-21.46
19.26	5565.99	32.03	-7.48	483.73		434.01	23.64	-3.08		23.44	23.65

FIG 31 Sample Output for the T-10 Parachute with Static Line System (Continued)

19.77	5552.81	24.05	-25.99	479.49	447.19	30.34	-13.30	27.28	18.89
20.54	5533.04	-.22	-43.78	465.16	466.96	31.13	-21.54	22.48	-10.25
21.50	5514.74	-27.15	-25.61	449.08	485.26	20.17	-8.72	18.19	-20.54
22.07	5502.91	-30.55	7.57	447.47	497.09	23.53	3.10	23.33	22.69
22.59	5489.90	-22.88	25.78	451.63	510.10	29.75	12.94	26.79	17.99
23.35	5470.44	.26	42.89	465.48	529.56	30.48	20.75	22.34	-9.33
24.38	5450.76	26.79	21.38	481.57	549.24	20.15	7.34	18.76	-20.13
25.05	5436.32	27.93	-13.62	482.04	563.68	25.18	-5.93	24.47	20.82
25.56	5423.10	18.25	-29.42	476.64	576.90	30.20	-14.83	26.30	15.55
26.20	5407.38	-.82	-42.05	464.96	592.62	29.71	-19.90	22.06	-8.40
27.23	5387.57	-25.67	-19.87	449.63	612.43	20.25	-6.88	19.04	-19.37
27.87	5373.86	-26.86	12.31	449.11	626.14	24.58	5.24	24.02	20.11
28.25	5364.21	-20.96	24.76	452.44	635.79	28.48	11.93	25.86	16.52
29.02	5345.26	-.16	40.83	465.20	654.74	29.34	19.18	22.20	-7.76
30.04	5325.16	23.87	21.33	480.48	674.84	20.47	7.45	19.07	-18.38
30.62	5313.14	26.27	-7.55	481.75	686.86	23.17	-3.04	22.97	19.52
31.13	5300.61	19.58	-24.70	477.92	699.39	27.97	-11.68	25.41	15.60
31.90	5281.99	-.20	-39.85	465.60	718.01	28.63	-18.35	21.98	-6.90
32.95	5261.14	-23.00	-18.66	450.79	738.86	20.51	-6.57	19.44	-17.79
33.59	5247.50	-24.16	11.10	450.17	752.50	23.83	4.59	23.38	18.09
33.98	5238.17	-19.06	23.32	453.14	761.83	27.10	10.73	24.89	15.13
34.75	5219.74	-.69	38.41	464.69	780.26	28.15	17.49	22.06	-6.30
35.83	5198.00	21.49	18.47	479.53	802.00	20.67	6.55	19.60	-16.91
36.41	5185.89	23.15	-7.81	480.51	814.11	22.88	-3.11	22.67	17.42
36.92	5173.71	16.99	-24.05	476.86	826.29	26.76	-10.91	24.44	13.82
37.69	5155.71	-.53	-37.42	465.60	844.29	27.25	-16.56	21.64	-5.28
38.91	5131.33	-21.34	-10.19	451.31	868.67	20.74	-3.67	20.41	16.59
39.67	5114.26	-18.17	19.09	453.16	885.74	25.12	8.22	23.74	14.35
40.44	5096.23	-3.12	34.66	462.77	903.77	27.06	15.39	22.26	-5.73
41.21	5080.27	12.46	31.18	473.94	919.73	23.18	12.00	19.84	-10.20
41.91	5066.16	19.96	6.42	479.19	933.84	20.97	2.34	20.84	15.68
42.68	5049.03	15.60	-20.33	476.63	950.97	24.94	-8.66	23.38	12.70
43.45	5031.45	1.27	-33.58	467.20	968.55	26.07	-14.42	21.72	-4.19
44.22	5015.61	-12.23	-27.77	457.07	984.39	22.66	-10.56	20.05	-9.78
45.11	4997.15	-17.98	2.86	452.56	1002.85	21.73	1.08	21.71	14.24
46.14	4974.02	-6.22	28.53	460.06	1025.98	25.45	12.16	22.36	6.39
46.91	4957.66	7.00	29.98	469.83	1042.34	23.59	11.79	20.43	-5.85
47.80	4939.29	15.06	9.00	477.02	1060.71	21.27	3.33	21.00	-12.11
48.57	4922.59	12.67	-14.34	476.02	1077.41	23.05	-5.71	22.33	10.53
49.34	4905.55	2.74	-26.84	469.23	1094.45	24.25	-10.95	21.64	-3.47
50.11	4889.45	-7.25	-24.42	461.02	1110.55	22.58	-9.34	20.56	-5.76
51.13	4867.98	-10.18	-3.98	455.33	1132.02	21.63	-1.50	21.58	7.81
51.90	4851.19	-4.73	8.12	456.14	1148.81	22.12	3.12	21.90	3.81
52.79	4832.20	6.34	6.11	459.18	1167.80	20.46	2.18	20.34	-5.65
53.50	4817.91	11.73	-8.65	458.97	1182.09	20.82	-3.13	20.58	8.80
54.01	4807.15	11.17	-19.52	456.22	1192.85	22.73	-7.60	21.43	8.56
55.03	4785.22	.55	-31.98	445.04	1214.78	24.45	-12.95	20.74	-2.42
55.80	4769.81	-8.06	-28.61	435.60	1230.19	22.41	-10.73	19.67	-5.84
56.57	4754.55	-9.70	-14.67	429.40	1245.45	20.83	-5.28	20.15	-7.17
57.59	4733.97	-.69	-3.13	426.76	1266.03	19.75	-1.08	19.72	-1.02
58.36	4718.97	7.10	-9.02	425.43	1281.03	19.81	-3.11	19.56	5.09
59.13	4703.59	9.03	-21.23	421.23	1296.41	22.07	-7.99	20.57	6.78
60.41	4677.09	-1.43	-31.95	407.06	1322.91	23.70	-12.54	20.11	-1.62
61.18	4661.98	-7.75	-26.92	398.21	1338.02	21.82	-9.88	19.46	-5.45
62.46	4636.79	-4.47	-8.67	390.33	1363.21	19.97	-3.01	19.74	-3.25
63.23	4621.76	2.69	-7.64	388.42	1378.24	19.61	-2.61	19.44	1.80
63.99	4606.71	7.38	-15.86	385.42	1393.29	20.69	-5.65	19.90	5.40
64.76	4591.11	6.13	-25.20	379.48	1408.89	22.78	-9.70	20.61	4.74
66.04	4565.16	-4.07	-29.52	365.12	1434.84	22.59	-11.13	19.66	-2.71
66.81	4550.17	-7.38	-21.83	357.72	1449.83	21.02	-7.82	19.51	-5.18
67.83	4530.08	-3.30	-10.23	352.18	1469.92	19.92	-3.54	19.60	-2.37
68.60	4515.10	2.71	-10.14	349.69	1484.90	19.78	-3.48	19.47	1.85
69.37	4500.01	6.29	-17.22	346.11	1499.99	20.86	-6.17	19.92	4.50
70.14	4484.47	4.87	-25.00	340.04	1515.53	22.53	-9.52	20.42	3.81
71.67	4453.73	-5.14	-26.29	323.83	1546.27	21.75	-9.63	19.50	-3.43
72.44	4438.76	-6.10	-18.24	317.62	1561.24	20.57	-6.44	19.53	-4.26

FIG 31 Sample Output for the T-10 Parachute with Static Line System (Continued)

290.04	288.93	-.30	-20.21	-1201.74	5711.07	19.68	-6.80	18.47	-.01
290.55	279.47	-.32	-20.18	-1205.22	5720.53	19.68	-6.79	18.47	-.02
291.07	270.01	-.32	-20.15	-1208.69	5729.99	19.67	-6.78	18.46	-.03
292.09	251.10	-.30	-20.10	-1215.62	5748.90	19.66	-6.75	18.46	-.01
293.11	232.20	-.26	-20.11	-1222.53	5767.80	19.65	-6.76	18.46	-.01
294.14	213.30	-.25	-20.17	-1229.46	5786.70	19.66	-6.78	18.45	.02
295.16	194.40	-.29	-20.21	-1236.41	5805.60	19.66	-6.79	18.45	-.01
296.19	175.51	-.32	-20.18	-1243.36	5824.49	19.64	-6.78	18.44	-.02
297.21	156.63	-.31	-20.12	-1250.29	5843.37	19.63	-6.75	18.43	-.02
299.26	118.88	-.25	-20.14	-1264.11	5881.12	19.63	-6.76	18.43	-.01
300.28	100.01	-.27	-20.19	-1271.04	5899.99	19.63	-6.78	18.42	.01
301.31	81.14	-.30	-20.19	-1277.98	5918.86	19.62	-6.77	18.41	-.01
302.33	62.29	-.31	-20.15	-1284.91	5937.71	19.61	-6.75	18.41	-.02
303.35	43.44	-.29	-20.11	-1291.81	5956.56	19.60	-6.74	18.40	-.01
305.40	5.75	-.26	-20.17	-1305.62	5994.25	19.60	-6.76	18.39	.01
305.71	.00	-.27	-20.18	-1307.74	6000.00	19.60	-6.76	18.39	-.01

	TIME(SEC)	ALTITUDE(FT)	X(FT)	Z(FT)	V(FT/SEC)	VX(FT/SEC)	VZ(FT/SEC)	A(FT/SEC/SEC)
1 VERTICAL/MINIMUM	3.99	5888.44	432.74	111.56	18.04	-12.42	13.09	-24.60
2 VERTICAL/MINIMUM	6.52	5846.66	454.84	153.34	37.00	29.60	22.20	-16.26
3 VERTICAL/MINIMUM	9.34	5784.40	463.81	215.60	34.24	-24.16	24.26	-15.23

FIG 31 Sample Output for the T-10 Parachute with Static Line System (Concluded)

```
PARACHUTE-LOAD SYSTEM(DEPLOYMENT)-- G-12D(STATIC LINE + PILOT CHUTE)

TRAJECTORY SIMULATION--T=0,Z=0 IS RELEASE POINT

RELEASE CONDITIONS
     ALTITUDE=       6000. FT
     VELOCITY=      220.00 FT/SEC

MASSES--SLUGS
     TOTAL SYSTEM=      72.870
     LOAD=      68.386
     PARACHUTE=      2.383
     SUSP. LINES=      .867
     RISERS=      .147
     RISER EXTENSIONS=      .280
     LOAD BRIDLE=      0
     INCLUDED=      41.143(SEA LEVEL)     34.287(  6000.  FT)
     APPARENT=      15.429(SEA LEVEL)     12.858(  6000.  FT)

REFERENCE DISTANCES FROM SKIRT-- FT
     X1=      23.750
     X2=      50.000
     X3=           0
     X4=      56.230
     X5=      57.210

MOM./PROD. INERTIA--SLUG FT**2
     IXX=      84525.147(SEA LEVEL)      74577.364(  6000.  FT)
     IYY=      84525.147(SEA LEVEL)      74577.364(  6000.  FT)
     IZZ=              0(SEA LEVEL)              0(  6000.  FT)
     IXZ=              0(SEA LEVEL)              0(  6000.  FT)

DIMENSIONS-- FT
     DNOT=      64.000
     SUSP. SYSTEM=      56.420
     L1=      25.578(SEA LEVEL)      23.006(  6000.  FT)
     L2=     -39.888(SEA LEVEL)     -42.460(  6000.  FT)
     L3=      32.368(SEA LEVEL)      29.796(  6000.  FT)

YC/DNOT=      .129
DP/DNOT=      .648
VOLUME=  17301.500 FT**3
PARACHUTE CDP=      1.786

LOAD DRAG AREA=      18.900 FT**2
DEGREES OF FREE DOM=      3

               STATIC LINE=      15.000 FT
               PARACHUTE PACK DRAG AREA=      7.146 FT**2
```

FIG 32 Sample Output for the G-12D Cargo Parachute with Static Line Deployed Pilot Chute System

PILOT CHUTE
DRAG AREA= 18.870 FT**2
DIAMETER= 5.660 FT
SUSP. LINES= 14.750 FT
TIME OF PILOT CHUTE RELEASE= 0 SEC

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	C.M. VELOCITY (FT/SEC) TOTAL	X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
.05	5999.96	89.58	89.58	10.98		.04	219.15	219.15		1.61	
.10	5999.84	89.16	89.16	21.92		.16	218.32	218.30		3.20	
.15	5999.64	88.74	88.74	32.81		.36	217.51	217.46		4.80	
.20	5999.36	88.31	88.31	43.66		.64	216.72	216.62		6.38	
.25	5999.01	87.89	87.89	54.47		.99	215.94	215.79		7.97	
.30	5998.57	87.46	87.46	65.24		1.43	215.18	214.97		9.54	
.35	5998.05	87.03	87.03	75.97		1.95	214.44	214.16		11.11	
.40	5997.46	86.60	86.60	86.66		2.54	213.72	213.35		12.67	
.45	5996.79	86.17	86.17	97.31		3.21	213.02	212.54		14.23	
.50	5996.04	85.74	85.74	107.91		3.96	212.33	211.74		15.78	
.55	5995.21	85.30	85.30	118.48		4.79	211.66	210.95		17.33	
.60	5994.31	84.87	84.87	129.01		5.69	211.00	210.16		18.87	
.65	5993.33	84.43	84.43	139.50		6.67	210.37	209.38		20.40	
.70	5992.27	84.00	84.00	149.95		7.73	209.75	208.60		21.93	
.75	5991.13	83.56	83.56	160.36		8.87	209.15	207.83		23.46	
.80	5989.92	83.12	83.12	170.73		10.08	208.56	207.06		24.98	
.85	5988.64	82.68	82.68	181.07		11.36	207.99	206.30		26.49	
.90	5987.28	82.24	82.24	191.36		12.72	207.44	205.54		28.00	
.95	5985.84	81.80	81.80	201.62		14.16	206.90	204.78		29.50	
1.00	5984.33	81.36	81.36	211.84		15.67	206.38	204.04		31.00	
1.05	5982.74	80.92	80.92	222.02		17.26	205.87	203.29		32.49	
1.10	5981.08	80.48	80.48	232.17		18.92	205.38	202.55		33.98	
1.15	5979.34	80.03	80.03	242.28		20.66	204.91	201.82		35.46	
1.20	5977.53	79.59	79.59	252.35		22.47	204.45	201.09		36.94	
1.25	5975.65	79.15	79.15	262.39		24.35	204.01	200.36		38.41	
1.30	5973.70	78.70	78.70	272.39		26.30	203.58	199.64		39.88	
1.35	5971.67	78.26	78.26	282.36		28.33	203.17	198.92		41.34	

	TIME(SEC)	ANGLE(DEG)	X(FT)	Z(FT)	VELOCITY(FT/SEC)
STATIC LINE STRETCH	.92	82.06	195.68	13.32	207.21
PARACHUTE/PILOT CHUTE DEPLOYMENT	1.36	78.13	285.34	28.96	203.05

PARACHUTE PACK MASS= .303 SLUG
PARACHUTE PACK AND PILOT/EXTRACTION CHUTE DRAG AREA= 26.016 FT**2
SPRING CONSTANT= 4777.000 LB/FT
LENGTH OF RISERS, EXTENSIONS AND LOAD BRIDLE= 8.000 FT

FIG 32 Sample Output for the G-12D Cargo Parachute with Static Line Deployed Pilot Chute System (Continued)

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	C.M. VELOCITY (FT/SEC) TOTAL	X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
1.41	5968.92	77.68	77.68	295.26		31.08	202.83	198.16		43.27	
1.46	5966.72	77.24	77.24	305.15		33.28	202.62	197.61		44.76	
1.51	5964.44	76.80	76.80	315.02		35.56	202.42	197.07		46.24	
1.56	5962.09	76.35	76.35	324.86		37.91	202.24	196.53		47.72	
1.61	5959.67	75.91	75.91	334.67		40.33	202.07	195.99		49.19	
1.66	5957.18	75.47	75.47	344.46		42.82	201.91	195.45		50.67	
1.71	5954.61	75.03	75.03	354.22		45.39	201.77	194.92		52.13	
1.76	5951.96	74.58	74.58	363.95		48.04	201.64	194.38		53.60	
1.81	5949.25	74.14	74.14	373.66		50.75	201.52	193.85		55.06	
1.86	5946.46	73.71	73.71	383.34		53.54	201.41	193.32		56.51	
1.91	5943.60	73.27	73.27	392.99		56.40	201.32	192.79		57.96	
1.96	5940.67	72.83	72.83	402.62		59.33	201.24	192.27		59.41	
2.01	5937.66	72.39	72.39	412.22		62.34	201.17	191.74		60.86	
2.06	5934.58	71.95	71.95	421.79		65.42	201.11	191.22		62.30	
2.11	5931.43	71.52	71.52	431.34		68.57	201.07	190.70		63.73	
2.16	5928.21	71.09	71.09	440.86		71.79	201.03	190.18		65.17	
2.21	5924.92	70.65	70.65	450.36		75.08	201.01	189.66		66.59	
2.26	5921.56	70.22	70.22	459.79		78.44	196.84	185.22		66.62	
2.31	5918.22	69.78	69.78	468.99		81.78	194.61	182.62		67.28	
2.36	5914.84	69.33	69.33	478.06		85.16	192.46	180.07		67.94	
2.41	5911.42	68.88	68.88	487.00		88.58	190.38	177.59		68.60	
2.46	5907.98	68.43	68.43	495.82		92.02	188.37	175.17		69.26	
2.51	5904.50	67.97	67.97	504.52		95.50	186.42	172.81		69.92	

	TIME(SEC)	ANGLE(DEG)	X(FT)	Z(FT)	VELOCITY1(FT/SEC)	VELOCITY2(FT/SEC)
SNATCH	2.25	70.31	457.94	77.77	201.00	88.92

SNATCH FORCE= 8293. LB
SNATCH VELOCITY= 197.294 FT/SEC

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	C.M. VELOCITY (FT/SEC) TOTAL	X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
2.61	5897.78	67.09	67.09	520.82		102.22	176.90	162.94		68.86	-136.00
2.69	5892.19	66.33	66.33	533.86		107.81	165.44	151.52		66.42	-160.76
2.78	5886.83	65.54	65.54	545.92		113.17	152.66	138.96		63.21	-171.93
2.86	5881.74	64.71	64.71	556.93		118.26	139.55	126.18		59.61	-172.34
2.94	5876.96	63.84	63.84	566.90		123.04	126.82	113.83		55.91	-165.50
3.02	5872.48	62.91	62.91	575.88		127.52	114.92	102.31		52.32	-154.51
3.10	5868.29	61.93	61.93	583.95		131.71	104.06	91.82		48.97	-141.70

FIG 32 Sample Output for the G-12D Cargo Parachute with Static Line Deployed Pilot Chute System (Continued)

3.19	5864.36	60.88	60.88	591.19		135.64	94.32	82.40		45.91	-128.57
3.27	5860.67	59.76	59.76	597.69		139.33	85.68	74.02		43.15	-116.05
3.35	5857.21	58.58	58.58	603.53		142.79	78.07	66.62		40.70	-104.59
3.43	5853.93	57.32	57.32	608.79		146.07	71.38	60.09		38.54	-94.38
3.52	5850.82	56.01	56.01	613.54		149.18	65.53	54.33		36.63	-85.45
3.60	5847.87	54.63	54.63	617.84		152.13	60.40	49.25		34.96	-77.71
3.68	5845.04	53.20	53.20	621.74		154.96	55.90	44.76		33.48	-71.07
3.76	5842.33	51.72	51.72	625.29		157.67	51.96	40.78		32.19	-65.40
3.85	5839.72	50.19	50.19	628.52		160.28	48.49	37.25		31.04	-60.57
3.93	5837.20	48.63	48.63	631.48		162.80	45.44	34.10		30.03	-56.48
4.01	5834.76	47.03	47.03	634.19		165.24	42.75	31.28		29.14	-53.02
4.09	5832.39	45.42	45.42	636.68		167.61	40.37	28.76		28.34	-50.09
4.17	5830.08	43.79	43.79	638.97		169.92	38.27	26.48		27.62	-47.62

FULL OR REEFED INFLATION	TIME(SEC)	ANGLE(DEG)	X(FT)	Z(FT)	V(FT/SEC)	FMAX(LB)	TF(SEC)
	4.17	43.79	638.97	169.92	38.27	11847.	1.65

NOTE-- POSITIONS,VELOCITIES,ACCELERATIONS,TRAJ. ANGLES REFER TO LOAD, PREVIOUS RESULTS ARE FOR MASS CENTER

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	LOAD TRAJ. ANGLE (DEG)	LOAD POSITION (FT) X	Y	Z	TOTAL	LOAD VELOCITY (FT/SEC) X	Y	Z	LOAD ACCELERATION (FT/SEC/SEC) TOTAL
4.39	5805.53	36.14	12.37	657.59		194.47	36.07	7.73		35.23	-39.83
4.94	5788.65	15.23	-15.45	657.18		211.35	26.84	-7.15		25.87	-25.99
5.51	5777.00	-5.73	-29.53	651.96		223.00	17.69	-8.72		15.39	-14.76
6.28	5766.62	-24.69	11.18	649.22		233.38	14.74	2.86		14.46	20.31
7.05	5751.71	-29.03	33.47	656.77		248.29	30.23	16.67		25.22	23.68
7.82	5728.39	-19.43	40.41	674.48		271.61	44.86	29.08		34.16	16.10
8.71	5697.88	1.71	48.30	704.52		302.12	47.52	35.48		31.62	-8.73
9.48	5675.72	19.03	46.04	729.55		324.28	38.66	27.83		26.84	-16.61
10.41	5650.23	30.80	17.01	747.05		349.77	31.53	9.22		30.15	23.18
11.18	5624.05	28.73	-10.09	747.96		375.95	38.42	-6.73		37.83	21.81
11.94	5593.62	16.53	-27.06	737.26		406.38	44.76	-20.36		39.85	15.02
12.71	5564.78	-.90	-36.51	718.88		435.22	42.94	-25.54		34.51	-9.29
13.86	5530.06	-24.38	-22.21	695.39		469.94	30.77	-11.63		28.49	-19.62
14.63	5506.37	-29.08	6.78	692.45		493.63	34.27	4.05		34.03	22.40
15.27	5482.81	-23.83	22.74	699.06		517.19	42.37	16.38		39.08	19.07
16.55	5434.17	2.07	40.16	730.61		565.83	44.18	28.50		33.77	-8.59
17.93	5393.05	26.31	19.05	760.03		606.95	31.17	10.17		29.46	-20.35
18.76	5365.83	27.50	-9.89	761.61		634.17	36.84	-6.33		36.29	21.10
19.53	5336.25	17.78	-26.55	751.39		663.75	44.12	-19.72		39.47	15.27
20.55	5298.47	-3.45	-38.05	726.35		701.53	42.22	-26.02		33.25	-8.24
21.77	5262.07	-24.51	-19.43	702.33		737.93	31.08	-10.34		29.31	-19.13
22.54	5237.57	-27.11	7.30	700.05		762.43	35.22	4.47		34.93	20.87
23.18	5213.77	-21.20	22.37	706.68		786.23	41.96	15.97		38.81	17.11
24.46	5166.37	3.32	38.05	736.26		833.63	42.01	25.90		33.08	-7.63
25.74	5127.96	24.17	18.20	761.15		872.04	31.15	9.73		29.59	-18.75
26.57	5101.02	25.79	-9.30	762.79		898.98	35.98	-5.81		35.50	19.84
27.34	5072.18	17.18	-25.71	753.22		927.82	42.75	-18.55		38.52	14.53
28.36	5034.91	-2.38	-36.94	729.46		965.09	41.59	-25.00		33.25	-6.86
29.70	4994.31	-23.46	-16.78	704.26		1005.69	31.12	-8.98		29.79	-18.18

FIG 32 Sample Output for the G-12D Cargo Parachute with Static Line Deployed Pilot Chute System (Continued)

170.92	654.88	.62	21.35	1562.43	5345.12	30.83	11.22	28.71	-.37
171.43	640.18	.76	20.89	1568.11	5359.82	30.69	10.94	28.67	-.57
171.94	625.50	.75	20.37	1573.64	5374.50	30.56	10.64	28.64	-.59
172.46	610.83	.60	19.90	1579.01	5389.17	30.45	10.36	28.63	-.49
172.97	596.17	.35	19.56	1584.27	5403.83	30.39	10.18	28.64	-.31
173.99	566.81	-.27	19.51	1594.63	5433.19	30.43	10.16	28.68	.12
174.50	552.11	-.51	19.79	1599.88	5447.89	30.51	10.33	28.71	.39
175.02	537.40	-.64	20.22	1605.23	5462.60	30.63	10.58	28.74	.51
175.53	522.67	-.64	20.69	1610.72	5477.33	30.74	10.86	28.76	.53
176.04	507.94	-.51	21.12	1616.35	5492.06	30.83	11.11	28.76	.45
177.06	478.49	.01	21.57	1627.88	5521.51	30.88	11.35	28.72	.14
177.58	463.79	.29	21.51	1633.69	5536.21	30.82	11.30	28.67	-.18
178.09	449.12	.52	21.26	1639.44	5550.88	30.72	11.14	28.63	-.36
178.60	434.46	.64	20.88	1645.08	5565.54	30.60	10.91	28.59	-.48
179.11	419.82	.65	20.44	1650.60	5580.18	30.49	10.65	28.57	-.50
180.14	390.57	.32	19.73	1661.27	5609.43	30.34	10.24	28.56	-.31
180.65	375.94	.06	19.60	1666.49	5624.06	30.33	10.17	28.57	-.09
181.16	361.30	-.20	19.66	1671.71	5638.70	30.36	10.21	28.59	.14
181.67	346.65	-.41	19.89	1676.97	5653.35	30.43	10.35	28.62	.32
182.18	331.98	-.53	20.24	1682.32	5668.02	30.53	10.56	28.64	.43
183.21	302.63	-.44	21.01	1693.37	5697.37	30.70	11.01	28.66	.39
183.72	287.95	-.25	21.29	1699.05	5712.05	30.74	11.16	28.65	.26
184.23	273.28	-.01	21.42	1704.78	5726.72	30.74	11.23	28.62	-.10
184.74	258.63	.23	21.38	1710.53	5741.37	30.70	11.19	28.58	-.14
185.26	244.00	.43	21.18	1716.23	5756.00	30.61	11.06	28.55	-.30
186.28	214.79	.56	20.49	1727.35	5785.21	30.41	10.65	28.49	-.40
186.79	200.20	.47	20.14	1732.75	5799.80	30.33	10.44	28.48	-.37
187.30	185.61	.30	19.88	1738.05	5814.39	30.28	10.30	28.48	-.25
187.82	171.02	.08	19.75	1743.30	5828.98	30.27	10.23	28.49	-.09
188.33	156.43	-.15	19.79	1748.54	5843.57	30.29	10.25	28.50	.10
189.35	127.21	-.44	20.25	1759.16	5872.79	30.42	10.53	28.54	.31
189.86	112.58	-.46	20.59	1764.61	5887.42	30.51	10.73	28.56	.38
190.38	97.95	-.38	20.92	1770.15	5902.05	30.57	10.91	28.56	.34
190.89	83.33	-.22	21.16	1775.78	5916.67	30.61	11.05	28.55	.23
191.40	68.71	-.02	21.28	1781.45	5931.29	30.61	11.11	28.53	.09
192.42	39.52	.35	21.11	1792.80	5960.48	30.51	10.99	28.46	-.20
192.94	24.95	.46	20.85	1798.38	5975.05	30.43	10.83	28.43	-.33
193.45	10.39	.48	20.54	1803.88	5989.61	30.34	10.64	28.41	-.36
193.81	.00	.43	20.32	1807.74	6000.00	30.29	10.52	28.40	-.34

	TIME(SEC)	ALTITUDE(FT)	X(FT)	Z(FT)	V(FT/SEC)	VX(FT/SEC)	VZ(FT/SEC)	A(FT/SEC/SEC)
1 VERTICAL/MINIMUM	5.32	5780.22	653.74	219.78	20.67	-9.68	18.26	-17.22
2 VERTICAL/MINIMUM	8.58	5702.00	699.97	298.00	48.31	35.57	32.69	-8.20
3 VERTICAL/MINIMUM	12.58	5569.28	722.16	430.72	43.85	-25.52	35.65	-8.78

FIG 32 Sample Output for the G-12D Cargo Parachute with Static Line Deployed Pilot Chute System (Concluded)

```
PARACHUTE-LOAD SYSTEM(DEPLOYMENT)-- G-11A(EXTRACTION)  UNREEFED


TRAJECTORY SIMULATION--T=0,Z=0 IS RELEASE POINT


RELEASE CONDITIONS
     ALTITUDE=     2000. FT
     VELOCITY=    220.00 FT/SEC


MASSES--SLUGS
     TOTAL SYSTEM=    116.697
     LOAD=    108.800
     PARACHUTE=       4.156
     SUSP. LINES=          .643
     RISERS=       1.200
     RISER EXTENSIONS=         .124
     LOAD BRIDLE=          .342
     INCLUDED=     158.613(SEA LEVEL)    149.262(  2000.  FT)
     APPARENT=      59.480(SEA LEVEL)     55.973(  2000.  FT)


REFERENCE DISTANCES FROM SKIRT-- FT
     X1=      16.450
     X2=      61.100
     X3=      99.300
     X4=     113.300
     X5=     119.300


MOM./PROD. INERTIA--SLUG FT**2
     IXX=       936191.608(SEA LEVEL)      907066.874(  2000.  FT)
     IYY=       936191.608(SEA LEVEL)      907066.874(  2000.  FT)
     IZZ=                0(SEA LEVEL)               0(  2000.  FT)
     IXZ=                0(SEA LEVEL)               0(  2000.  FT)


DIMENSIONS-- FT
     DNOT=    100.000
     SUSP. SYSTEM=     95.000
     L1=      79.081(SEA LEVEL)     77.203(  2000.  FT)
     L2=     -53.119(SEA LEVEL)    -54.997(  2000.  FT)
     L3=      59.781(SEA LEVEL)     57.903(  2000.  FT)


YC/DNOT=        .129
DP/DNOT=        .648
VOLUME=  66700.000 FT**3
PARACHUTE CDP=       1.786

LOAD DRAG AREA=     76.800 FT**2
DEGREES OF FREE DOM=           3
```

FIG 33 Sample Output for the Unreefed G-11A Cargo Parachute with Extraction Parachute System

RELEASE DISTANCE IN AIRCRAFT= 15.000 FT
PARACHUTE PACK DRAG AREA= 2.330 FT**2
EXTRACTION CHUTE DRAG AREA= 62.200 FT**2
TIME OF EXTRACTION CHUTE RELEASE= 0 SEC

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	TOTAL	C.M. VELOCITY (FT/SEC) X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
.05	2000.00	90.00	90.00	10.96		0	218.57	218.57			
.10	2000.00	90.00	90.00	21.86		0	217.15	217.15			
.15	2000.00	90.00	90.00	32.68		0	215.75	215.75			
.20	2000.00	90.00	90.00	43.44		0	214.37	214.37			
.25	2000.00	90.00	90.00	54.12		0	213.01	213.01			
.30	2000.00	90.00	90.00	64.74		0	211.67	211.67			
.35	2000.00	90.00	90.00	75.29		0	210.34	210.34			
.40	2000.00	90.00	90.00	85.77		0	209.03	209.03			
.45	2000.00	90.00	90.00	96.19		0	207.73	207.73			
.50	2000.00	90.00	90.00	106.55		0	206.45	206.45			
.55	2000.00	90.00	90.00	116.84		0	205.19	205.19			
.60	2000.00	90.00	90.00	127.07		0	203.94	203.94			
.65	2000.00	90.00	90.00	137.24		0	202.71	202.71			
.70	2000.00	90.00	90.00	147.34		0	201.49	201.49			
.75	2000.00	90.00	90.00	157.39		0	200.29	200.29			
.80	2000.00	90.00	90.00	167.37		0	199.10	199.10			
.85	2000.00	90.00	90.00	177.30		0	197.92	197.92			
.90	2000.00	90.00	90.00	187.17		0	196.76	196.76			
.95	2000.00	90.00	90.00	196.98		0	195.61	195.61			
1.00	2000.00	90.00	90.00	206.73		0	194.48	194.48			
1.05	2000.00	90.00	90.00	216.43		0	193.36	193.36			

	TIME(SEC)	ANGLE(DEG)	X(FT)	Z(FT)	VELOCITY(FT/SEC)
LOAD OUT OF AIRCRAFT	1.07		219.52		193.00
PILOT CHUTE/EXTRACTION CHUTE RELEASE OR MAIN PARACHUTE DISREEF	1.07	90.00	219.52	0	193.00

PARACHUTE PACK MASS= 1.432 SLUG
PARACHUTE PACK AND PILOT/EXTRACTION CHUTE DRAG AREA= 64.520 FT**2
SPRING CONSTANT= 910.700 LB/FT
LENGTH OF RISERS, EXTENSIONS AND LOAD BRIDLE= 28.000 FT

FIG 33 Sample Output for the Unreefed G-11A Cargo Parachute with Extraction Parachute System (Continued)

FIG 33 Sample Output for the Unreefed G-11A Cargo Parachute with Extraction System (Continued)

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	C.M. VELOCITY (FT/SEC) TOTAL	X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
1.12	1999.96	89.52	89.52	229.13		.04	191.56	191.56		1.60	
1.17	1999.84	89.04	89.04	238.67		.16	190.16	190.13		3.19	
1.22	1999.64	88.55	88.55	248.15		.36	188.79	188.73		4.77	
1.27	1999.37	88.06	88.06	257.55		.63	187.46	187.35		6.34	
1.32	1999.01	87.57	87.57	266.88		.99	186.15	185.99		7.90	
1.37	1998.58	87.07	87.07	276.15		1.42	184.88	184.64		9.44	
1.42	1998.07	86.57	86.57	285.35		1.93	183.64	183.32		10.98	
1.47	1997.48	86.07	86.07	294.48		2.52	182.44	182.01		12.50	
1.52	1996.82	85.57	85.57	303.55		3.18	181.26	180.72		14.01	
1.57	1996.08	85.06	85.06	312.56		3.92	180.12	179.45		15.52	
1.62	1995.27	84.55	84.55	321.50		4.73	179.00	178.19		17.01	
1.67	1994.38	84.03	84.03	330.38		5.62	177.92	176.95		18.50	
1.72	1993.42	83.52	83.52	339.19		6.58	176.86	175.73		19.97	
1.77	1992.39	83.00	83.00	347.95		7.61	175.84	174.52		21.44	
1.82	1991.28	82.48	82.48	356.65		8.72	174.84	173.33		22.89	
1.87	1990.10	81.95	81.95	365.29		9.90	173.87	172.15		24.34	
1.92	1988.85	81.43	81.43	373.87		11.15	172.92	170.99		25.78	
1.97	1987.52	80.90	80.90	382.39		12.48	172.01	169.84		27.21	
2.02	1986.13	80.37	80.37	390.85		13.87	171.12	168.71		28.63	
2.07	1984.66	79.84	79.84	399.26		15.34	170.26	167.58		30.04	
2.12	1983.12	79.30	79.30	407.61		16.88	169.42	166.48		31.45	
2.17	1981.52	78.77	78.77	415.91		18.48	168.61	165.38		32.84	
2.22	1979.84	78.23	78.23	424.15		20.16	167.82	164.29		34.23	
2.27	1978.10	77.69	77.69	432.34		21.90	167.06	163.22		35.61	
2.32	1976.28	77.15	77.15	440.47		23.72	166.33	162.16		36.98	
2.37	1974.40	76.61	76.61	448.56		25.60	165.61	161.11		38.35	
2.42	1972.45	76.07	76.07	456.59		27.55	164.92	160.07		39.70	
2.47	1970.43	75.53	75.53	464.56		29.57	164.26	159.05		41.05	
2.52	1968.36	74.98	74.98	472.44		31.64	158.94	153.51		41.19	
2.57	1966.28	74.41	74.41	480.03		33.72	155.90	150.17		41.89	
2.62	1964.17	73.84	73.84	487.46		35.83	153.01	146.97		42.58	
2.67	1962.02	73.26	73.26	494.73		37.98	150.26	143.89		43.28	
2.72	1959.84	72.67	72.67	501.85		40.16	147.63	140.93		43.99	
2.77	1957.63	72.07	72.07	508.83		42.37	145.13	138.08		44.69	
2.82	1955.38	71.46	71.46	515.67		44.62	142.74	135.33		45.39	
2.87	1953.09	70.84	70.84	522.37		46.91	140.46	132.68		46.09	
2.92	1950.77	70.22	70.22	528.94		49.23	138.28	130.12		46.80	
2.97	1948.41	69.59	69.59	535.38		51.59	136.21	127.65		47.50	
3.02	1946.02	68.95	68.95	541.71		53.98	134.22	125.27		48.21	
3.07	1943.59	68.31	68.31	547.91		56.41	132.33	122.96		48.91	

	TIME(SEC)	ANGLE(DEG)	X(FT)	Z(FT)	VELOCITY1(FT/SEC)	VELOCITY2(FT/SEC)
SNATCH	2.50	75.12	470.44	31.11	163.78	52.04

SNATCH FORCE= 2365. LB
SNATCH VELOCITY= 159.753 FT/SEC

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	C.M. VELOCITY (FT/SEC) TOTAL	X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
3.37	1928.75	64.45	64.45	582.44		71.25	113.21	102.14		48.83	-84.95
3.64	1915.82	60.83	60.83	607.89		84.18	94.35	82.38		45.99	-82.64
3.91	1903.74	56.94	56.94	628.28		96.26	78.15	65.50		42.63	-72.28
4.18	1892.55	52.79	52.79	644.47		107.45	65.43	52.11		39.57	-61.52
4.45	1882.13	48.43	48.43	657.39		117.87	55.81	41.76		37.03	-52.93
4.72	1872.35	43.98	43.98	667.78		127.65	48.61	33.76		34.98	-46.74
4.99	1863.07	39.57	39.57	676.21		136.93	43.23	27.53		33.32	-42.51
5.26	1854.21	35.30	35.30	683.10		145.79	39.16	22.63		31.96	-39.69
5.53	1845.69	31.28	31.28	688.78		154.31	36.05	18.72		30.81	-37.85
5.80	1837.47	27.57	27.57	693.49		162.53	33.62	15.56		29.80	-36.66
6.07	1829.50	24.21	24.21	697.41		170.50	31.69	12.99		28.90	-35.89
6.34	1821.78	21.20	21.20	700.69		178.22	30.11	10.89		28.07	-35.38
6.61	1814.27	18.53	18.53	703.44		185.73	28.80	9.15		27.31	-35.04
6.88	1806.96	16.17	16.17	705.75		193.04	27.68	7.71		26.58	-34.80
7.15	1799.84	14.11	14.11	707.70		200.16	26.71	6.51		25.90	-34.62
7.42	1792.91	12.31	12.31	709.35		207.09	25.84	5.51		25.25	-34.47
7.70	1786.14	10.74	10.74	710.75		213.86	25.07	4.67		24.63	-34.36
7.97	1779.54	9.38	9.38	711.93		220.46	24.37	3.97		24.04	-34.25
8.24	1773.10	8.19	8.19	712.94		226.90	23.72	3.38		23.48	-34.15
8.51	1766.81	7.16	7.16	713.80		233.19	23.12	2.88		22.94	-34.06

FULL OR REEFED INFLATION

TIME(SEC)	ANGLE(DEG)	X(FT)	Z(FT)	V(FT/SEC)	FMAX(LB)	TF(SEC)
8.51	7.16	713.80	233.19	23.12	9331.	5.41

NOTE-- POSITIONS,VELOCITIES,ACCELERATIONS,TRAJ. ANGLES REFER TO LOAD, PREVIOUS RESULTS ARE FOR MASS CENTER

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	LOAD TRAJ. ANGLE (DEG)	LOAD POSITION (FT) X	Y	Z	LOAD VELOCITY (FT/SEC) TOTAL	X	Y	Z	LOAD ACCELERATION (FT/SEC/SEC) TOTAL
8.72	1684.68	4.96	-25.41	721.06		315.32	26.60	-11.41		24.02	-4.67
9.27	1672.07	-.71	-28.57	714.54		327.93	25.36	-12.13		22.28	-3.46
9.91	1658.44	-7.08	-25.87	707.33		341.56	22.64	-9.88		20.37	-6.13
10.42	1648.22	-11.44	-17.08	703.19		351.78	20.60	-6.05		19.69	-8.77
11.19	1632.87	-15.94	5.33	701.47		367.13	20.71	1.92		20.62	11.60
11.96	1616.08	-17.35	25.45	706.43		383.92	25.70	11.04		23.21	12.51

FIG 33 Sample Output for the Unreefed G-11A Cargo Parachute with Extraction Parachute System (Continued)

73.46	147.45	5.24	33.91	1220.03	1852.55	26.93	15.02	22.35	-4.17
74.48	124.55	7.13	23.80	1232.90	1875.45	24.57	9.92	22.48	-5.44
75.00	112.95	7.23	17.35	1237.26	1887.05	23.85	7.11	22.76	-5.48
76.02	89.34	5.75	5.00	1241.84	1910.66	23.33	2.03	23.24	-4.32
77.04	65.51	2.49	-2.72	1242.10	1934.49	23.20	-1.10	23.17	-1.83
77.81	47.81	-.53	-3.90	1240.97	1952.19	22.93	-1.56	22.87	-.61
78.58	30.31	-3.44	-.75	1240.15	1969.69	22.70	-.30	22.70	-2.55
79.35	12.82	-5.75	6.09	1240.89	1987.18	23.00	2.44	22.87	4.24
79.86	1.03	-6.73	11.78	1242.73	1998.97	23.66	4.83	23.16	4.85
79.90	.00	-6.77	12.27	1243.00	2000.00	23.74	5.05	23.19	4.88

	TIME(SEC)	ALTITUDE(FT)	X(FT)	Z(FT)	V(FT/SEC)	VX(FT/SEC)	VZ(FT/SEC)	A(FT/SEC/SEC)
1 VERTICAL/MINIMUM	9.14	1674.95	716.10	325.05	25.77	-12.19	22.70	-3.34
2 VERTICAL/MINIMUM	14.52	1550.58	766.50	449.42	39.50	30.93	24.57	3.36
3 VERTICAL/MINIMUM	20.40	1410.30	817.25	589.70	28.49	-14.07	24.77	-2.90

FIG 33 Sample Output for the Unreefed G-11A Cargo Parachute with Extraction Parachute System (Concluded)

```
PARACHUTE-LOAD SYSTEM(DEPLOYMENT)-- G-11A(EXTRACTION)  MULTIPLE REEFING

TRAJECTORY SIMULATION--T=0,Z=0 IS RELEASE POINT

RELEASE CONDITIONS
     ALTITUDE=      2000. FT
     VELOCITY=    169.00 FT/SEC

MASSES--SLUGS
     TOTAL SYSTEM=      116.697
     LOAD=     108.800
     PARACHUTE=         4.156
     SUSP. LINES=          .643
     RISERS=        1.200
     RISER EXTENSIONS=           .124
     LOAD BRIDLE=          .342
     INCLUDED=     158.613(SEA LEVEL)    149.262(  2000.   FT)
     APPARENT=      59.480(SEA LEVEL)     55.973(  2000.   FT)

REFERENCE DISTANCES FROM SKIRT-- FT
     X1=       16.450
     X2=       61.100
     X3=       99.300
     X4=      113.300
     X5=      119.300

MOM./PROD. INERTIA--SLUG FT**2
     IXX=        936191.608(SEA LEVEL)       907066.874(  2000.   FT)
     IYY=        936191.608(SEA LEVEL)       907066.874(  2000.   FT)
     IZZ=     20700000.000(SEA LEVEL)     20658733.868(  2000.   FT)
     IXZ=                 0(SEA LEVEL)                0(  2000.   FT)

DIMENSIONS-- FT
     DNOT=     100.000
     SUSP. SYSTEM=        95.000
     L1=      79.081(SEA LEVEL)     77.203(  2000.   FT)
     L2=     -53.119(SEA LEVEL)    -54.997(  2000.   FT)
     L3=      59.781(SEA LEVEL)     57.903(  2000.   FT)

YC/DNOT=        .129
DP/DNOT=        .648
VOLUME=  66700.000 FT**3
PARACHUTE CDP=        1.786

LOAD DRAG AREA=      76.800 FT**2
DEGREES OF FREE DOM=            3

                  RELEASE DISTANCE IN AIRCRAFT=      15.000 FT
                  PARACHUTE PACK DRAG AREA=       2.330 FT**2
```

FIG 34 Sample Output for the Reefed G-11A Cargo Parachute with Extraction Parachute System

EXTRACTION CHUTE DRAG AREA=   62.200 FT**2
TIME OF EXTRACTION CHUTE RELEASE=   0 SEC

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	TOTAL	C.M. VELOCITY (FT/SEC) X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
.05	2000.00	90.00	90.00	8.43		0	168.15	168.15			
.10	2000.00	90.00	90.00	16.82		0	167.31	167.31			
.15	2000.00	90.00	90.00	25.16		0	166.48	166.48			
.20	2000.00	90.00	90.00	33.47		0	165.66	165.66			
.25	2000.00	90.00	90.00	41.73		0	164.85	164.85			
.30	2000.00	90.00	90.00	49.95		0	164.04	164.04			
.35	2000.00	90.00	90.00	58.13		0	163.24	163.24			
.40	2000.00	90.00	90.00	66.28		0	162.45	162.45			
.45	2000.00	90.00	90.00	74.38		0	161.67	161.67			
.50	2000.00	90.00	90.00	82.44		0	160.89	160.89			
.55	2000.00	90.00	90.00	90.47		0	160.12	160.12			
.60	2000.00	90.00	90.00	98.46		0	159.36	159.36			
.65	2000.00	90.00	90.00	106.41		0	158.61	158.61			
.70	2000.00	90.00	90.00	114.32		0	157.86	157.86			
.75	2000.00	90.00	90.00	122.19		0	157.12	157.12			
.80	2000.00	90.00	90.00	130.03		0	156.39	156.39			
.85	2000.00	90.00	90.00	137.83		0	155.66	155.66			
.90	2000.00	90.00	90.00	145.60		0	154.94	154.94			
.95	2000.00	90.00	90.00	153.33		0	154.23	154.23			
1.00	2000.00	90.00	90.00	161.02		0	153.52	153.52			
1.05	2000.00	90.00	90.00	168.68		0	152.83	152.83			
1.10	2000.00	90.00	90.00	176.31		0	152.13	152.13			
1.15	2000.00	90.00	90.00	183.90		0	151.44	151.44			
1.20	2000.00	90.00	90.00	191.45		0	150.76	150.76			
1.25	2000.00	90.00	90.00	198.97		0	150.09	150.09			
1.30	2000.00	90.00	90.00	206.46		0	149.42	149.42			
1.35	2000.00	90.00	90.00	213.92		0	148.76	148.76			

	TIME(SEC)	ANGLE(DEG)	X(FT)	Z(FT)	VELOCITY(FT/SEC)
LOAD OUT OF AIRCRAFT	1.39		219.56		148.26
PILOT CHUTE/EXTRACTION CHUTE RELEASE OR MAIN PARACHUTE DISREEF	1.39	90.00	219.56	0	148.26

PARACHUTE PACK MASS=   1.432 SLUG
PARACHUTE PACK AND PILOT/EXTRACTION CHUTE DRAG AREA=   64.520 FT**2
SPRING CONSTANT=   910.700 LB/FT
LENGTH OF RISERS, EXTENSIONS AND LOAD BRIDLE=   28.000 FT

FIG 34 Sample Output for the Reefed G-11A Cargo Parachute with Extraction Parachute System (Continued)

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	C.M. VELOCITY (FT/SEC) TOTAL	X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
1.44	1999.96	89.38	89.38	226.95		.04	147.41	147.40		1.60	
1.49	1999.84	88.75	88.75	234.30		.16	146.59	146.56		3.20	
1.54	1999.64	88.12	88.12	241.61		.36	145.80	145.72		4.78	
1.59	1999.36	87.49	87.49	248.87		.64	145.04	144.90		6.36	
1.64	1999.01	86.85	86.85	256.10		.99	144.30	144.08		7.93	
1.69	1998.57	86.21	86.21	263.28		1.43	143.59	143.27		9.49	
1.74	1998.06	85.57	85.57	270.43		1.94	142.90	142.47		11.04	
1.79	1997.47	84.93	84.93	277.53		2.53	142.24	141.68		12.58	
1.84	1996.80	84.28	84.28	284.60		3.20	141.60	140.90		14.12	
1.89	1996.06	83.63	83.63	291.62		3.94	140.99	140.12		15.64	
1.94	1995.24	82.98	82.98	298.61		4.76	140.40	139.35		17.16	
1.99	1994.35	82.33	82.33	305.56		5.65	139.84	138.59		18.67	
2.04	1993.38	81.67	81.67	312.47		6.62	139.30	137.84		20.17	
2.09	1992.33	81.02	81.02	319.34		7.67	138.79	137.09		21.67	
2.14	1991.21	80.36	80.36	326.18		8.79	138.30	136.35		23.16	
2.19	1990.02	79.70	79.70	332.98		9.98	137.83	135.61		24.63	
2.24	1988.75	79.05	79.05	339.74		11.25	137.39	134.89		26.11	
2.29	1987.41	78.39	78.39	346.47		12.59	136.97	134.17		27.57	
2.34	1985.99	77.73	77.73	353.16		14.01	136.57	133.45		29.03	
2.39	1984.51	77.07	77.07	359.81		15.49	136.19	132.74		30.48	
2.44	1982.95	76.41	76.41	366.43		17.05	135.84	132.04		31.92	
2.49	1981.32	75.75	75.75	373.02		18.68	135.51	131.34		33.36	
2.54	1979.61	75.09	75.09	379.57		20.39	135.19	130.64		34.78	
2.59	1977.84	74.43	74.43	386.08		22.16	134.90	129.96		36.21	
2.64	1975.99	73.77	73.77	392.56		24.01	134.63	129.27		37.62	
2.69	1974.08	73.12	73.12	399.01		25.92	134.39	128.59		39.03	
2.74	1972.09	72.46	72.46	405.42		27.91	134.16	127.92		40.43	
2.79	1970.04	71.81	71.81	411.80		29.96	133.95	127.25		41.82	
2.84	1967.91	71.15	71.15	418.15		32.09	133.76	126.59		43.20	
2.89	1965.72	70.50	70.50	424.46		34.28	133.59	125.93		44.58	
2.94	1963.46	69.85	69.85	430.74		36.54	133.43	125.27		45.96	
2.99	1961.13	69.21	69.21	436.99		38.87	133.30	124.62		47.32	
3.04	1958.73	68.56	68.56	443.21		41.27	133.18	123.97		48.68	
3.09	1956.26	67.92	67.92	449.39		43.74	133.09	123.33		50.03	
3.14	1953.72	67.28	67.28	455.54		46.28	133.01	122.68		51.38	
3.19	1951.12	66.64	66.64	461.66		48.88	132.94	122.05		52.71	
3.24	1948.45	66.01	66.01	467.74		51.55	132.90	121.41		54.04	
3.29	1945.79	65.36	65.36	473.63		54.21	128.19	116.51		53.45	
3.34	1943.10	64.70	64.70	479.41		56.90	126.60	114.46		54.10	
3.39	1940.38	64.04	64.04	485.08		59.62	125.09	112.46		54.76	
3.44	1937.63	63.38	63.38	490.66		62.37	123.64	110.53		55.41	
3.49	1934.84	62.71	62.71	496.14		65.16	122.26	108.64		56.06	
3.54	1932.02	62.04	62.04	501.53		67.98	120.94	106.81		56.71	
3.59	1929.17	61.36	61.36	506.82		70.83	119.68	105.03		57.36	
3.64	1926.29	60.68	60.68	512.03		73.71	118.47	103.30		58.01	
3.69	1923.37	60.00	60.00	517.16		76.63	117.33	101.61		58.66	
3.74	1920.42	59.32	59.32	522.20		79.58	116.23	99.97		59.30	
3.79	1917.44	58.64	58.64	527.15		82.56	115.19	98.36		59.95	
3.84	1914.43	57.96	57.96	532.03		85.57	114.20	96.80		60.59	
3.89	1911.39	57.27	57.27	536.84		88.61	113.25	95.27		61.23	
3.94	1908.31	56.59	56.59	541.56		91.69	112.35	93.78		61.87	

FIG 34 Sample Output for the Reefed G-11A Cargo Parachute with Extraction Parachute System (Continued)

		TIME(SEC)	ANGLE(DEG)	X(FT)	Z(FT)	VELOCITY1(FT/SEC)	VELOCITY2(FT/SEC)
SNATCH		3.24	65.95	468.23	51.76	132.90	44.71

SNATCH FORCE= 2084. LB
SNATCH VELOCITY= 129.716 FT/SEC

REEFED INFLATION
REEFING RATIO= .064
REEFED PROJ. DIAM.= 9.231 FT
CUTTER DELAY= 2.000 SEC
TIME OF DISREEF= 5.242 SEC

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	TOTAL	C.M. VELOCITY (FT/SEC) X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
4.05	1901.58	55.13	55.13	551.52		98.42	112.39	92.21		64.25	-13.28
4.13	1896.11	54.01	54.01	559.25		103.89	112.80	91.27		66.29	-14.11
4.21	1890.46	52.91	52.91	566.89		109.54	113.19	90.29		68.26	-14.94
4.30	1884.65	51.84	51.84	574.46		115.35	113.55	89.28		70.16	-15.77
4.38	1878.69	50.78	50.78	581.93		121.31	113.87	88.22		72.00	-16.61
4.47	1872.57	49.75	49.75	589.32		127.43	114.17	87.13		73.77	-17.44
4.55	1866.30	48.73	48.73	596.61		133.70	114.43	86.01		75.48	-18.28
4.63	1859.90	47.74	47.74	603.81		140.10	114.66	84.85		77.11	-19.11
4.72	1853.36	46.76	46.76	610.91		146.64	114.85	83.67		78.68	-19.93
4.80	1846.68	45.80	45.80	617.91		153.32	115.00	82.45		80.17	-20.74
4.89	1839.89	44.87	44.87	624.81		160.11	115.12	81.22		81.60	-21.55
4.97	1832.98	43.95	43.95	631.60		167.02	115.21	79.95		82.95	-22.34
5.05	1825.95	43.04	43.04	638.28		174.05	115.26	78.67		84.23	-23.12
5.14	1818.83	42.16	42.16	644.86		181.17	115.27	77.36		85.45	-23.89
5.22	1811.60	41.29	41.29	651.32		188.40	115.24	76.04		86.59	-24.64
5.31	1804.27	40.44	40.44	657.68		195.73	115.18	74.71		87.67	-25.38
5.39	1796.86	39.60	39.60	663.92		203.14	115.08	73.36		88.67	-26.10
5.48	1789.37	38.78	38.78	670.05		210.63	114.95	72.00		89.61	-26.80
5.56	1781.80	37.97	37.97	676.06		218.20	114.79	70.63		90.49	-27.48
5.64	1774.16	37.18	37.18	681.95		225.84	114.59	69.25		91.30	-28.14

REEFED INFLATION
REEFING RATIO= .127
REEFED PROJ. DIAM.= 17.582 FT
CUTTER DELAY= 4.000 SEC
TIME OF DISREEF= 7.242 SEC

FIG 34 Sample Output for the Reefed G-11A Cargo Parachute with Extraction Parachute System (Continued)

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	TOTAL	C.M. VELOCITY (FT/SEC) X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
5.69	1769.77	36.74	36.74	685.26		230.23	113.93	68.15		91.31	-39.93
5.74	1765.39	36.30	36.30	688.51		234.61	113.22	67.02		91.25	-41.31
5.79	1761.01	35.86	35.86	691.71		238.99	112.45	65.87		91.13	-42.59
5.84	1756.63	35.43	35.43	694.85		243.37	111.62	64.70		90.96	-43.79
5.88	1752.27	35.00	35.00	697.93		247.73	110.75	63.52		90.72	-44.89
5.93	1747.92	34.57	34.57	700.96		252.08	109.83	62.32		90.44	-45.91
5.98	1743.58	34.15	34.15	703.93		256.42	108.88	61.12		90.10	-46.83
6.03	1739.26	33.73	33.73	706.85		260.74	107.89	59.91		89.72	-47.67
6.08	1734.96	33.31	33.31	709.70		265.04	106.86	58.69		89.30	-48.43
6.12	1730.67	32.90	32.90	712.50		269.33	105.81	57.48		88.84	-49.10
6.17	1726.42	32.49	32.49	715.23		273.58	104.74	56.26		88.35	-49.70
6.22	1722.18	32.08	32.08	717.91		277.82	103.64	55.05		87.82	-50.21
6.27	1717.98	31.67	31.67	720.53		282.02	102.53	53.84		87.26	-50.66
6.32	1713.80	31.27	31.27	723.10		286.20	101.40	52.64		86.67	-51.04
6.36	1709.64	30.87	30.87	725.60		290.36	100.27	51.44		86.06	-51.35
6.41	1705.52	30.47	30.47	728.05		294.48	99.12	50.26		85.43	-51.61
6.46	1701.43	30.07	30.07	730.44		298.57	97.97	49.09		84.79	-51.80
6.51	1697.37	29.67	29.67	732.78		302.63	96.82	47.93		84.12	-51.95
6.56	1693.34	29.28	29.28	735.06		306.66	95.67	46.79		83.44	-52.04
6.60	1689.35	28.89	28.89	737.28		310.65	94.52	45.66		82.76	-52.09
6.65	1685.22	28.42	28.42	739.54		314.78	93.71	44.60		82.42	-43.95
6.70	1681.11	27.95	27.95	741.74		318.89	92.95	43.57		82.11	-43.24
6.75	1677.01	27.49	27.49	743.90		322.99	92.23	42.57		81.82	-42.58
6.80	1672.92	27.03	27.03	746.00		327.08	91.55	41.61		81.55	-41.96
6.85	1668.85	26.58	26.58	748.06		331.15	90.90	40.67		81.30	-41.37
6.90	1664.79	26.12	26.12	750.07		335.21	90.29	39.75		81.06	-40.82
6.95	1660.75	25.68	25.68	752.04		339.25	89.71	38.87		80.85	-40.30
7.00	1656.71	25.23	25.23	753.96		343.29	89.16	38.01		80.65	-39.81
7.05	1652.68	24.79	24.79	755.84		347.32	88.64	37.17		80.47	-39.35
7.10	1648.66	24.36	24.36	757.68		351.34	88.14	36.36		80.29	-38.92
7.15	1644.65	23.93	23.93	759.48		355.35	87.68	35.57		80.14	-38.51
7.20	1640.65	23.51	23.51	761.24		359.35	87.23	34.80		79.99	-38.13

REEFED INFLATION
REEFING RATIO= .191
REEFED PROJ. DIAM.= 25.176 FT
CUTTER DELAY= 6.000 SEC
TIME OF DISREEF= 9.242 SEC

FIG 34 Sample Output for the Reefed G-11A Cargo Parachute with Extraction Parachute System (Continued)

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	C.M. VELOCITY (FT/SEC) TOTAL	X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
7.25	1637.04	23.14	23.14	762.79		362.96	86.74	34.08		79.76	-53.91
7.29	1634.19	22.88	22.88	764.00		365.81	85.86	33.38		79.10	-54.24
7.32	1631.36	22.63	22.63	765.19		368.64	84.97	32.69		78.43	-54.58
7.36	1628.56	22.37	22.37	766.35		371.44	84.08	32.00		77.75	-54.85
7.39	1625.78	22.12	22.12	767.49		374.22	83.17	31.32		77.05	-55.07
7.43	1623.03	21.87	21.87	768.60		376.97	82.26	30.64		76.34	-55.24
7.46	1620.31	21.62	21.62	769.69		379.69	81.35	29.98		75.63	-55.35
7.50	1617.61	21.38	21.38	770.76		382.39	80.44	29.32		74.91	-55.42
7.54	1614.93	21.13	21.13	771.80		385.07	79.53	28.67		74.18	-55.44
7.57	1612.28	20.89	20.89	772.82		387.72	78.62	28.03		73.45	-55.42
7.61	1609.66	20.64	20.64	773.81		390.34	77.71	27.40		72.72	-55.37
7.64	1607.07	20.40	20.40	774.78		392.93	76.81	26.78		71.99	-55.28
7.68	1604.50	20.16	20.16	775.73		395.50	75.91	26.17		71.26	-55.16
7.72	1601.95	19.92	19.92	776.66		398.05	75.02	25.57		70.53	-55.02
7.75	1599.44	19.69	19.69	777.57		400.56	74.14	24.98		69.80	-54.84
7.79	1596.95	19.45	19.45	778.46		403.05	73.26	24.40		69.08	-54.65
7.82	1594.48	19.22	19.22	779.32		405.52	72.40	23.83		68.36	-54.43
7.86	1592.04	18.99	18.99	780.17		407.96	71.54	23.27		67.65	-54.20
7.89	1589.63	18.75	18.75	781.00		410.37	70.69	22.73		66.94	-53.95
7.93	1587.24	18.52	18.52	781.80		412.76	69.86	22.20		66.24	-53.68
8.01	1582.33	17.96	17.96	783.42		417.67	68.53	21.13		65.20	-44.62
8.06	1579.09	17.55	17.55	784.46		420.91	67.86	20.46		64.70	-43.75
8.11	1575.86	17.14	17.14	785.47		424.14	67.23	19.81		64.24	-42.94
8.16	1572.66	16.74	16.74	786.44		427.34	66.64	19.19		63.81	-42.19
8.21	1569.48	16.34	16.34	787.39		430.52	66.09	18.60		63.42	-41.50
8.26	1566.32	15.95	15.95	788.31		433.68	65.57	18.02		63.05	-40.86
8.31	1563.17	15.57	15.57	789.19		436.83	65.09	17.47		62.71	-40.27
8.36	1560.05	15.19	15.19	790.05		439.95	64.65	16.94		62.39	-39.72
8.41	1556.93	14.82	14.82	790.89		443.07	64.23	16.43		62.09	-39.21
8.46	1553.84	14.46	14.46	791.70		446.16	63.83	15.94		61.81	-38.74
8.51	1550.75	14.10	14.10	792.48		449.25	63.47	15.46		61.55	-38.30
8.56	1547.68	13.75	13.75	793.24		452.32	63.12	15.00		61.32	-37.89
8.61	1544.62	13.41	13.41	793.98		455.38	62.80	14.56		61.09	-37.51
8.66	1541.57	13.07	13.07	794.70		458.43	62.50	14.14		60.88	-37.15
8.71	1538.53	12.74	12.74	795.40		461.47	62.22	13.72		60.69	-36.82
8.76	1535.50	12.42	12.42	796.07		464.50	61.96	13.32		60.51	-36.51
8.81	1532.48	12.10	12.10	796.73		467.52	61.71	12.94		60.34	-36.23
8.86	1529.47	11.79	11.79	797.37		470.53	61.48	12.56		60.18	-35.96
8.91	1526.46	11.49	11.49	797.99		473.54	61.27	12.20		60.04	-35.71
8.96	1523.46	11.19	11.19	798.59		476.54	61.06	11.85		59.90	-35.48
9.01	1520.47	10.90	10.90	799.17		479.53	60.87	11.51		59.78	-35.26
9.06	1517.49	10.62	10.62	799.74		482.51	60.70	11.18		59.66	-35.06
9.11	1514.51	10.34	10.34	800.29		485.49	60.53	10.87		59.55	-34.87
9.16	1511.53	10.07	10.07	800.83		488.47	60.37	10.56		59.44	-34.69
9.21	1508.56	9.81	9.81	801.35		491.44	60.23	10.26		59.35	-34.53

REEFED INFLATION
REEFING RATIO= .637
REEFED PROJ. DIAM.= 63.661 FT
CUTTER DELAY= -0 SEC
TIME OF DISREEF= 3.262 SEC

FIG 34 Sample Output for the Reefed G-11A Cargo Parachute with Extraction Parachute System (Continued)

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	TOTAL	C.M. VELOCITY (FT/SEC) X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
9.28	1503.99	9.46	9.46	802.13		496.01	59.25	9.74		58.45	-53.57
9.48	1492.61	8.72	8.72	803.96		507.39	55.02	8.34		54.39	-52.41
9.68	1482.02	8.03	8.03	805.54		517.98	51.09	7.14		50.59	-50.76
9.88	1472.16	7.38	7.38	806.88		527.84	47.53	6.10		47.14	-48.87
10.08	1462.97	6.76	6.76	808.03		537.03	44.37	5.23		44.06	-46.98
10.28	1454.36	6.19	6.19	809.02		545.64	41.57	4.48		41.33	-45.22
10.48	1446.28	5.66	5.66	809.86		553.72	39.12	3.86		38.92	-43.64
10.69	1438.65	5.16	5.16	810.59		561.35	36.96	3.32		36.81	-42.25
10.89	1431.43	4.70	4.70	811.22		568.57	35.06	2.87		34.94	-41.05
11.09	1424.56	4.28	4.28	811.77		575.44	33.39	2.49		33.30	-40.02
11.29	1418.01	3.89	3.89	812.24		581.99	31.91	2.16		31.84	-39.13
11.49	1411.74	3.53	3.53	812.65		588.26	30.59	1.88		30.54	-38.38
11.69	1405.71	3.20	3.20	813.01		594.29	29.42	1.64		29.37	-37.73
11.89	1399.91	2.91	2.91	813.32		600.09	28.36	1.44		28.33	-37.18
12.09	1394.31	2.64	2.64	813.59		605.69	27.41	1.26		27.38	-36.70
12.29	1388.89	2.39	2.39	813.83		611.11	26.55	1.11		26.53	-36.29
12.49	1383.64	2.17	2.17	814.04		616.36	25.76	.97		25.74	-35.93
12.69	1378.54	1.96	1.96	814.23		621.46	25.04	.86		25.03	-35.62
12.89	1373.58	1.78	1.78	814.39		626.42	24.38	.76		24.37	-35.35
13.09	1368.75	1.61	1.61	814.54		631.25	23.77	.67		23.76	-35.11

FULL OR REEFED INFLATION

TIME(SEC)	ANGLE(DEG)	X(FT)	Z(FT)	V(FT/SEC)	FMAX(LB)	TF(SEC)
5.64	37.18	681.95	225.84	114.59	3062.	1.68
6.60	28.89	737.28	310.65	94.52	5667.	.96
7.96	18.34	782.44	414.66	69.20	6032.	.72
13.25	1.49	814.64	635.04	23.32	5828.	4.01

NOTE-- POSITIONS,VELOCITIES,ACCELERATIONS,TRAJ. ANGLES REFER TO LOAD, PREVIOUS RESULTS ARE FOR MASS CENTER

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	LOAD TRAJ. ANGLE (DEG)	LOAD POSITION (FT) X	Y	Z	TOTAL	LOAD VELOCITY (FT/SEC) X	Y	Z	LOAD ACCELERATION (FT/SEC/SEC) TOTAL
13.47	1282.06	1.03	-5.67	816.17		717.94	23.72	-2.34		23.60	1.04
14.01	1269.11	-.18	-5.72	814.86		730.89	24.04	-2.40		23.92	.49
14.78	1250.66	-1.88	-3.85	813.25		749.34	24.08	-1.62		24.02	-1.61
15.55	1232.21	-3.32	.15	812.60		767.79	24.00	.06		24.00	-2.62
16.32	1213.75	-4.28	5.71	813.52		786.25	24.15	2.40		24.03	3.30
16.83	1201.43	-4.56	9.79	815.19		798.57	24.45	4.16		24.10	3.45

FIG 34 Sample Output for the Reefed G-11A Cargo Parachute with Extraction Parachute System (Continued)

58.81	219.32	1.04	14.03	1165.23	1780.68	23.65	5.73	22.94	-1.00
59.32	207.56	.40	13.31	1168.08	1792.44	23.59	5.43	22.96	-.45
59.84	195.79	-.28	13.19	1170.84	1804.21	23.60	5.38	22.98	.07
60.35	184.01	-.95	13.67	1173.64	1815.99	23.68	5.59	23.01	.56
60.86	172.21	-1.54	14.69	1176.61	1827.79	23.83	6.04	23.05	1.00
61.88	148.52	-2.34	17.89	1183.48	1851.48	24.36	7.48	23.18	1.52
62.40	136.62	-2.49	19.77	1187.54	1863.38	24.71	8.36	23.25	1.73
62.91	124.68	-2.45	21.63	1192.04	1875.32	25.08	9.24	23.31	1.70
63.42	112.73	-2.23	23.33	1196.99	1887.27	25.42	10.07	23.34	1.54
63.93	100.76	-1.85	24.76	1202.33	1899.24	25.71	10.76	23.34	1.26
64.96	76.88	-.74	26.51	1213.84	1923.12	25.96	11.59	23.24	.57
65.47	64.99	-.11	26.71	1219.80	1935.01	25.91	11.64	23.15	-.19
65.98	53.16	.51	26.44	1225.73	1946.84	25.74	11.46	23.05	-.53
66.49	41.37	1.07	25.70	1231.50	1958.63	25.48	11.05	22.96	-.92
67.00	29.62	1.52	24.55	1237.01	1970.38	25.16	10.46	22.89	-1.25
68.03	6.20	1.98	21.34	1246.96	1993.80	24.50	8.92	22.82	-1.55
68.30	.00	1.93	20.40	1249.16	2000.00	24.35	8.49	22.83	-1.52

	TIME(SEC)	ALTITUDE(FT)	X(FT)	Z(FT)	V(FT/SEC)	VX(FT/SEC)	VZ(FT/SEC)	A(FT/SEC/SEC)
1 VERTICAL/MINIMUM	13.88	1272.17	815.17	727.83	24.00	-2.43	23.87	.46
2 VERTICAL/MINIMUM	19.39	1139.43	836.00	860.57	26.49	11.08	24.06	1.36
3 VERTICAL/MINIMUM	25.53	994.69	882.28	1005.31	23.56	2.62	23.42	-.10

FIG 34 Sample Output for the Reefed G-11A Cargo Parachute with Extraction Parachute System (Concluded)

```
PARACHUTE-LOAD SYSTEM(DEPLOYMENT)-- G-11A(MAIN PARACHUTE EXTRACTION) UNREEFED


TRAJECTORY SIMULATION--T=0,Z=0 IS RELEASE POINT


RELEASE CONDITIONS
     ALTITUDE=      2000. FT
     VELOCITY=    220.00 FT/SEC


MASSES--SLUGS
     TOTAL SYSTEM=     115.265
     LOAD=     108.800
     PARACHUTE=       4.156
     SUSP. LINES=        .643
     RISERS=      1.200
     RISER EXTENSIONS=        .124
     LOAD BRIDLE=        .342
     INCLUDED=    158.613(SEA LEVEL)    149.262(  2000.  FT)
     APPARENT=     59.480(SEA LEVEL)     55.973(  2000.  FT)


REFERENCE DISTANCES FROM SKIRT-- FT
     X1=      16.450
     X2=      61.100
     X3=      99.300
     X4=     113.300
     X5=     119.300


MOM./PROD. INERTIA--SLUG FT**2
     IXX=        936191.608(SEA LEVEL)       907066.874(  2000.  FT)
     IYY=        936191.608(SEA LEVEL)       907066.874(  2000.  FT)
     IZZ=      20700000.000(SEA LEVEL)     20658733.868(  2000.  FT)
     IXZ=                 0(SEA LEVEL)                0(  2000.  FT)


DIMENSIONS-- FT
     DNOT=     100.000
     SUSP. SYSTEM=        95.000
     L1=      79.081(SEA LEVEL)     77.203(  2000.  FT)
     L2=     -53.119(SEA LEVEL)    -54.997(  2000.  FT)
     L3=      59.781(SEA LEVEL)     57.903(  2000.  FT)


YC/DNOT=         .129
DP/DNOT=         .648
VOLUME=  66700.000 FT**3
PARACHUTE CDP=        1.786

LOAD DRAG AREA=      76.800 FT**2
DEGREES OF FREE DOM=           3



               RELEASE DISTANCE IN AIRCRAFT=       15.000 FT
               REEFING RATIO=        .064
```

FIG 35 Sample Output for the G-11A Cargo Parachute with Reefed Main Parachute Extraction System

REEFED PROJ. DIAMETER= 9.231 FT
TIME OF PARACHUTE DISREEF= 4.00 SEC

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	C.M. VELOCITY (FT/SEC) TOTAL	X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
.05	2000.00	90.00	90.00	10.93		0	217.23	217.23			
.10	2000.00	90.00	90.00	21.73		0	214.52	214.52			
.15	2000.00	90.00	90.00	32.39		0	211.89	211.89			
.20	2000.00	90.00	90.00	42.92		0	209.31	209.31			
.25	2000.00	90.00	90.00	53.32		0	206.80	206.80			
.30	2000.00	90.00	90.00	63.60		0	204.35	204.35			
.35	2000.00	90.00	90.00	73.76		0	201.95	201.95			
.40	2000.00	90.00	90.00	83.80		0	199.61	199.61			
.45	2000.00	90.00	90.00	93.73		0	197.33	197.33			
.50	2000.00	90.00	90.00	103.54		0	195.10	195.10			
.55	2000.00	90.00	90.00	113.24		0	192.91	192.91			
.60	2000.00	90.00	90.00	122.83		0	190.78	190.78			
.65	2000.00	90.00	90.00	132.32		0	188.69	188.69			
.70	2000.00	90.00	90.00	141.70		0	186.64	186.64			
.75	2000.00	90.00	90.00	150.99		0	184.64	184.64			
.80	1999.99	89.78	89.78	160.16		.01	182.14	182.14		.70	
.85	1999.92	89.27	89.27	169.19		.08	179.05	179.03		2.29	
.90	1999.77	88.75	88.75	178.07		.23	176.07	176.03		3.84	
.95	1999.54	88.22	88.22	186.80		.46	173.21	173.12		5.38	
1.00	1999.23	87.69	87.69	195.39		.77	170.45	170.31		6.88	
1.05	1998.85	87.14	87.14	203.84		1.15	167.79	167.59		8.37	
1.10	1998.40	86.59	86.59	212.15		1.60	165.24	164.95		9.83	
1.15	1997.87	86.03	86.03	220.34		2.13	162.78	162.39		11.28	
1.20	1997.27	85.46	85.46	228.39		2.73	160.41	159.91		12.70	
1.25	1996.60	84.88	84.88	236.33		3.40	158.13	157.50		14.10	
1.30	1995.86	84.30	84.30	244.15		4.14	155.93	155.16		15.49	
1.35	1995.05	83.71	83.71	251.85		4.95	153.81	152.88		16.86	
1.40	1994.18	83.11	83.11	259.44		5.82	151.77	150.67		18.21	
1.45	1993.23	82.50	82.50	266.92		6.77	149.80	148.52		19.55	
1.50	1992.22	81.89	81.89	274.29		7.78	147.91	146.43		20.87	
1.55	1991.15	81.27	81.27	281.57		8.85	146.08	144.39		22.18	
1.60	1990.01	80.64	80.64	288.74		9.99	144.33	142.41		23.47	
1.65	1988.80	80.01	80.01	295.81		11.20	142.63	140.47		24.75	
1.70	1987.53	79.37	79.37	302.79		12.47	141.01	138.58		26.01	
1.75	1986.20	78.72	78.72	309.67		13.80	139.44	136.74		27.27	
1.80	1984.81	78.07	78.07	316.46		15.19	137.93	134.95		28.51	
1.85	1983.35	77.42	77.42	323.17		16.65	136.47	133.19		29.73	
1.90	1981.84	76.75	76.75	329.78		18.16	135.07	131.48		30.95	
1.95	1980.26	76.09	76.09	336.32		19.74	133.73	129.81		32.15	
2.00	1978.62	75.42	75.42	342.77		21.38	132.44	128.17		33.35	
2.05	1976.93	74.74	74.74	349.14		23.07	131.19	126.57		34.53	
2.10	1975.17	74.06	74.06	355.43		24.83	130.00	125.00		35.70	
2.15	1973.36	73.38	73.38	361.64		26.64	128.85	123.47		36.86	
2.20	1971.49	72.69	72.69	367.78		28.51	127.75	121.97		38.01	
2.25	1969.56	72.00	72.00	373.84		30.44	126.69	120.49		39.15	
2.30	1967.57	71.31	71.31	379.83		32.43	125.68	119.05		40.28	

FIG 35 Sample Output for the G-11A Cargo Parachute with Reefed Main Parachute Extraction System (Continued)

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	C.M. VELOCITY (FT/SEC) TOTAL	X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL
2.35	1965.53	70.61	70.61	385.74		34.47	124.71	117.64		41.40	
2.40	1963.43	69.91	69.91	391.59		36.57	123.78	116.25		42.51	
2.45	1961.28	69.21	69.21	397.37		38.72	122.89	114.89		43.61	
2.50	1959.07	68.51	68.51	403.08		40.93	122.04	113.56		44.71	
2.55	1956.81	67.81	67.81	408.73		43.19	121.23	112.25		45.79	
2.60	1954.50	67.10	67.10	414.31		45.50	120.45	110.96		46.86	
2.65	1952.13	66.40	66.40	419.83		47.87	119.71	109.70		47.93	
2.70	1949.70	65.69	65.69	425.28		50.30	119.00	108.45		48.98	
2.75	1947.23	64.99	64.99	430.67		52.77	118.33	107.23		50.03	
2.80	1944.70	64.28	64.28	436.01		55.30	117.69	106.03		51.07	
2.85	1942.12	63.58	63.58	441.28		57.88	117.08	104.85		52.10	
2.90	1939.49	62.87	62.87	446.49		60.51	116.50	103.69		53.12	
2.95	1936.81	62.17	62.17	451.65		63.19	115.95	102.54		54.14	
3.00	1934.08	61.47	61.47	456.75		65.92	115.44	101.41		55.14	
3.05	1931.30	60.77	60.77	461.79		68.70	114.95	100.31		56.14	
3.10	1928.47	60.07	60.07	466.78		71.53	114.48	99.21		57.13	
3.15	1925.59	59.37	59.37	471.71		74.41	114.05	98.14		58.11	
3.20	1922.66	58.68	58.68	476.59		77.34	113.64	97.07		59.08	
3.25	1919.68	57.98	57.98	481.42		80.32	113.25	96.03		60.04	
3.30	1916.66	57.30	57.30	486.20		83.34	112.89	95.00		61.00	
3.35	1913.58	56.61	56.61	490.92		86.42	112.55	93.98		61.94	
3.40	1910.46	55.93	55.93	495.60		89.54	112.24	92.97		62.88	
3.45	1907.30	55.25	55.25	500.22		92.70	111.95	91.98		63.81	
3.50	1904.08	54.58	54.58	504.80		95.92	111.68	91.01		64.73	
3.55	1900.82	53.91	53.91	509.32		99.18	111.43	90.04		65.65	
3.60	1897.52	53.24	53.24	513.80		102.48	111.20	89.09		66.55	
3.65	1894.17	52.58	52.58	518.23		105.83	110.99	88.15		67.45	
3.70	1890.78	51.92	51.92	522.62		109.22	110.80	87.22		68.34	
3.75	1887.34	51.27	51.27	526.96		112.66	110.63	86.30		69.22	
3.80	1883.85	50.62	50.62	531.25		116.15	110.47	85.39		70.09	
3.85	1880.33	49.98	49.98	535.50		119.67	110.33	84.49		70.95	
3.90	1876.76	49.34	49.34	539.70		123.24	110.21	83.61		71.81	
3.95	1873.15	48.71	48.71	543.86		126.85	110.10	82.73		72.66	
4.00	1869.50	48.08	48.08	547.97		130.50	110.01	81.86		73.49	

	TIME(SEC)	ANGLE(DEG)	X(FT)	Z(FT)	VELOCITY(FT/SEC)
LOAD OUT OF AIRCRAFT	.78		156.14		183.54
PILOT CHUTE/EXTRACTION CHUTE RELEASE OR MAIN PARACHUTE DISREEF	4.00	48.07	548.05	130.58	110.01

REEFED INFLATION

REEFING RATIO= .637
REEFED PROJ. DIAM.= 63.661 FT
CUTTER DELAY= 0 SEC
TIME OF DISREEF= 0 SEC

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	C.M. TRAJ. ANGLE (DEG)	C.M. POSITION (FT) X	Y	Z	C.M. VELOCITY (FT/SEC) TOTAL	X	Y	Z	C.M. ACCELERATION (FT/SEC/SEC) TOTAL

FIG 35 Sample Output for the G-11A Cargo Parachute with Reefed Main Parachute Extraction System (Continued)

4.26	1851.09	45.09	45.09	567.65		148.91	96.77	68.54		68.31	-76.46
4.51	1834.26	42.11	42.11	583.87		165.74	83.35	55.89		61.83	-74.39
4.77	1819.09	39.08	39.08	597.03		180.91	71.58	45.12		55.57	-67.64
5.02	1805.44	36.00	36.00	607.64		194.56	61.96	36.41		50.13	-60.32
5.28	1793.09	32.91	32.91	616.23		206.91	54.33	29.52		45.61	-54.01
5.54	1781.81	29.87	29.87	623.20		218.19	48.34	24.08		41.92	-49.07
5.79	1771.40	26.93	26.93	628.90		228.60	43.64	19.77		38.90	-45.36
6.05	1761.71	24.15	24.15	633.59		238.29	39.91	16.33		36.42	-42.62
6.30	1752.60	21.55	21.55	637.48		247.40	36.93	13.56		34.35	-40.60
6.56	1744.00	19.16	19.16	640.71		256.00	34.51	11.32		32.60	-39.11
6.82	1735.81	16.98	16.98	643.41		264.19	32.51	9.49		31.10	-38.00
7.07	1727.99	15.01	15.01	645.68		272.01	30.84	7.99		29.79	-37.16
7.33	1720.48	13.25	13.25	647.60		279.52	29.43	6.75		28.64	-36.52
7.58	1713.26	11.68	11.68	649.21		286.74	28.20	5.71		27.62	-36.01
7.84	1706.29	10.29	10.29	650.58		293.71	27.14	4.85		26.70	-35.61
8.10	1699.54	9.07	9.07	651.75		300.46	26.20	4.13		25.87	-35.28
8.35	1693.00	7.99	7.99	652.74		307.00	25.35	3.52		25.11	-35.01
8.61	1686.64	7.03	7.03	653.59		313.36	24.59	3.01		24.41	-34.78
8.86	1680.46	6.20	6.20	654.31		319.54	23.90	2.58		23.76	-34.59
9.12	1674.44	5.46	5.46	654.93		325.56	23.27	2.21		23.16	-34.42

	TIME(SEC)	ANGLE(DEG)	X(FT)	Z(FT)	V(FT/SEC)	FMAX(LB)	TF(SEC)
FULL OR REEFED INFLATION	9.12	5.46	654.93	325.56	23.27	8348.	5.12

NOTE-- POSITIONS,VELOCITIES,ACCELERATIONS,TRAJ. ANGLES REFER TO LOAD, PREVIOUS RESULTS ARE FOR MASS CENTER

TIME (SEC)	ALTITUDE (FT)	SYSTEM ANGLE (DEG)	LOAD TRAJ. ANGLE (DEG)	LOAD POSITION (FT) X	Y	Z	LOAD VELOCITY (FT/SEC) TOTAL	X	Y	Z	LOAD ACCELERATION (FT/SEC/SEC) TOTAL
9.34	1592.05	3.79	-19.95	660.50		407.95	25.35	-8.65		23.82	-3.08
9.88	1579.33	-.55	-21.81	655.57		420.67	24.66	-9.16		22.89	-1.85
10.65	1562.17	-6.39	-17.32	649.21		437.83	22.91	-6.82		21.87	-5.13
11.42	1545.45	-10.97	-3.97	645.86		454.55	21.88	-1.51		21.82	-8.26
12.19	1528.29	-13.46	13.50	647.32		471.71	23.64	5.52		22.98	9.86
12.95	1509.97	-13.43	27.73	654.43		490.03	27.88	12.97		24.68	9.72
13.47	1497.08	-12.03	34.51	662.27		502.92	31.02	17.57		25.56	8.75
14.49	1470.63	-6.58	43.39	684.05		529.37	35.34	24.28		25.68	4.67
15.00	1457.64	-3.01	45.98	696.92		542.36	35.84	25.78		24.91	2.67
16.03	1433.29	4.29	47.22	723.12		566.71	33.26	24.41		22.59	-4.34
16.54	1421.94	7.45	44.89	734.97		578.06	30.78	21.72		21.81	-6.19
17.56	1399.66	11.66	31.89	753.36		600.34	26.00	13.73		22.08	-8.88
18.07	1388.14	12.42	21.59	759.21		611.86	24.69	9.08		22.96	-9.39
19.10	1363.59	11.06	.07	763.78		636.41	24.83	.03		24.83	8.23
19.87	1344.26	7.81	-11.90	761.63		655.74	25.82	-5.33		25.27	5.76
20.63	1325.05	3.23	-18.84	756.20		674.95	25.94	-8.37		24.55	-2.65
21.40	1306.66	-1.89	-20.01	749.52		693.34	24.80	-8.49		23.31	-2.31
22.17	1289.08	-6.65	-14.14	743.91		710.92	23.28	-5.69		22.58	-5.23
22.94	1271.67	-10.22	-1.49	741.37		728.33	22.89	-.60		22.88	7.64
23.71	1253.70	-11.93	13.68	743.33		746.30	24.66	5.83		23.96	8.85
24.73	1228.31	-10.89	29.67	753.83		771.69	29.32	14.51		25.48	7.94

FIG 35 Sample Output for the G-11A Cargo Parachute with Reefed Main Parachute Extraction System (Continued)

72.99	91.23	2.06	35.20	1170.09	1908.77	28.04	16.16	22.91	-1.95
74.01	68.03	4.80	30.27	1185.25	1931.97	26.01	13.11	22.46	-3.78
74.52	56.52	5.60	26.06	1191.43	1943.48	25.01	10.99	22.47	-4.32
75.03	44.98	5.94	21.05	1196.48	1955.02	24.22	8.70	22.60	-4.51
75.55	33.35	5.80	15.70	1200.34	1966.65	23.66	6.40	22.78	-4.41
76.57	9.85	4.17	6.17	1204.78	1990.15	23.16	2.49	23.03	-3.16
77.00	.00	3.05	3.40	1205.57	2000.00	23.07	1.37	23.03	-2.32

	TIME(SEC)	ALTITUDE(FT)	X(FT)	Z(FT)	V(FT/SEC)	VX(FT/SEC)	VZ(FT/SEC)	A(FT/SEC/SEC)
1 VERTICAL/MINIMUM	9.75	1582.28	656.75	417.72	24.88	-9.21	23.12	-1.76
2 VERTICAL/MINIMUM	15.00	1457.64	696.92	542.36	35.84	25.78	24.91	2.67
3 VERTICAL/MINIMUM	21.02	1315.73	752.87	684.27	25.50	-8.81	23.93	-1.69

FIG 35 Sample Output for the G-11A Cargo Parachute with Reefed Main Parachute Extraction System (Concluded)

X. REFERENCES

1. Heinrich, H. G.: The Effective Porosity of Parachute Cloth, USAF Technical Report No. AFFDL-TR-65-102, January, 1966.

2. Hildebrand, F. B.: Introduction to Numerical Analysis, McGraw-Hill Book Company, 1956, pp. 236-239.

3. Heinrich, H. G. and Noreen, R. A.: Wind Tunnel Drag and Stability of Solid Flat Circular, T-10, and Ringslot Parachute Models with Centerlines, USAF Technical Report No. AFFDL-TR-73-17, December, 1972.

DISTRIBUTION LIST

	No. of Copies
Director of Defense Research and Engineering Department of Defense Washington, DC 20315	1
Department of the Army Office of the Chief of Research and Development ATTN: DARD-DDA Washington, DC 20310	1
Department of the Army US Army Advanced Materiel Concepts Agency ATTN: AMXAM-AC Washington, DC 20315	1
Commander US Army Foreign Science and Technology Center 220 Seventh Street, NE Federal Building Charlottesville, VA 22312	1
Commander US Army Materiel Command ATTN: AMCRD-FS Washington, DC 20315	1
Commander USA Test and Evaluation Command ATTN: AMSTE-BG Aberdeen Proving Ground, MD 21005	1
President USA Airborne Communications and Electronics Board Fort Bragg, NC 28307	1
Commander Yuma Proving Ground Air Test Division ATTN: STEYP-TAT Yuma, AZ 85364	1

USA CDC Institute of Land Combat
ATTN: Technical Library
301 Taylor Drive
Alexandria, VA 22314 — 1

Commander
USA Combat Developments Command
Institute of Advanced Studies
Carlisle Barracks, PA 17013 — 1

Commander
US Army Combat Developments Command
Institute for Strategic and
Stability Operations
ATTN: ISSO-A
Fort Bragg, NC 28307 — 1

Chief, Systems and Equipment Division
Eustis Directorate
US Army Air Mobility R&D Laboratory
Ft. Eustis, VA 23604 — 1

Commander
US Army Materiel Laboratories
ATTN: Technical Library
Fort Eustis, VA 23604 — 1

Commander
USA Aviation Systems Command
ATTN: AMSAV-FBTD
P. O. Box 209
St. Louis, MO 63166 — 1

Commander
USA Aviation Systems Command
ATTN: AMSAV-L-QRE
P. O. Box 209
St. Louis, MO 63166 — 1

Commander
US Army Aviation Systems Command
ATTN: AMSAV-R-R
P. O. Box 209
St. Louis, MO 63166 — 1

Commander
US Army Aviation Systems Command
ATTN: SAVDL-8
St. Louis, MO 63166 1

Commander
US Army Aviation Systems Command
ATTN: AMSAV-SA (CE) AMRDC
St. Louis, MO 63166 1

Commander
US Army Aviation Systems Command
ATTN: AMCPO-LSE
St. Louis, MO 63166 1

Director
US Army Mobility R&D Laboratory
AMES Research Center
Moffett Field, CA 94035 1

Commander
US Army Missile Command
ATTN: Technical Library
Redstone Arsenal, AL 35809 1

Commander
US Army Munitions Command
ATTN: Technical Library
Dover, NJ 07801 1

Commander
US Army Weapons Command
Research & Development Directorate
ATTN: Technical Library
Rock Island, IL 61201 1

Commander
Frankford Arsenal
Bridge and Tacony Streets
ATTN: Technical Library
Philadelphia, PA 19137 1

Commander
Redstone Scientific Information Center
US Army Missile Command
ATTN: AMSMI-RBLD
Redstone Arsenal, AL 35809 1

Commandant Quartermaster School Airborne Department ATTN: ATSQM-EA Fort Lee, VA 23801	1
Commandant Quartermaster School ATTN: ATSQM-AR-T Fort Lee, VA 23801	1
Commandant Quartermaster School ATTN: ATSQM-AR-D Fort Lee, VA 23801	1
Commander Readiness Command ATTN: STRJ4-T MacDill Air Force Base Tampa, FL 33608	1
Commander Aeronautical Systems Division US Army Natick Laboratories Liaison Office ATTN: ASDL-8 Wright Patterson Air Force Base, OH 45433	6
Commander Army Research Office (Durham) ATTN: Information Processing Office Box CM, Duke Station Durham, NC 27706	1
US Army Standardization Group, UK ATTN: Research/General Materiel Representative Box 65 FPO New York 09510	1
Department of the Air Force Hq, 6511th Test Group (Parachute) (AFSC) Naval Air Facility Army Liaison Office, ATQ El Centro, CA 92243	1

DISTRIBUTION LIST (CONT'D)

Director
Air University Library
Maxwell Air Force Base, AL 36112 1

Headquarters
Tactical Air Command
ATTN: TAC-OA
Langley Air Force Base, VA 23365 1

Commander
USAF Tactical Airlift Center (TAC)
ATTN: DAL
Pope Air Force Base, NC 28308 1

Commander
Military Air Lift Command
ATTN: MAORD
Scott Air Force Base, IL 62225 1

Director
Naval Research Laboratory
ATTN: Technical Information Officer
Anacostia Station
Washington, DC 20390 1

Chief
Office of Naval Research
Department of the Navy
ATTN: Code 423
Washington, DC 20390 1

US Naval Air Systems Command
Department of the Navy
ATTN: AIR 5315A
Washington, DC 20360 1

Director
Development Center
Marine Corps Development and Education Command
Quantico, VA 22134 1

Marine Corps Liaison Officer
US Army Natick Laboratories
Natick, MA 01760 1

Commander
US Army Natick Laboratories
ATTN: STSNL-AOP
Natick, Mass 01760

DISTRIBUTION LIST (CONT'D)

Commander US Army Natick Laboratories ATTN: STSNL-RTL Natick, MA 01760	2
Commander Defense Documentation Center Cameron Station 5010 Duke Station Alexandria, VA 22314	12
Sandia Laboratories Deceleration & Recovery Systems Division Albuquerque, NM 87115	1
Commander Naval Aerospace Recovery Facility ATTN: Code ENAAT El Centro, CA 92243	1
Commander Hdqs Edgewood Arsenal ATTN: Mr. A. Flatau Aero Research Group Aberdeen Proving Ground, MD 21005	1
Commander Aero System Division ATTN: AFFDL/FER (Mr. James De Weese) WPAFB, OH 45433	3
Prof. Helmut G. Heinrich Department of Aeronautics and Engineering Mechanics University of Minnesota Minneapolis, MN 55455	20

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

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

1. ORIGINATING ACTIVITY *(Corporate author)* University of Minnesota	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

DEVELOPMENT OF A TOTAL TRAJECTORY SIMULATION FOR SINGLE RECOVERY PARACHUTE SYSTEMS – VOLUME II: CALCULATION PROCEDURES AND COMPUTER PROGRAM.

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

Final Report 15 Nov 1971 - 30 June 1973

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

Robert A. Noreen

David P. Saari

6. REPORT DATE	7a. TOTAL NO. OF PAGES 241	7b. NO. OF REFS 3

8a. CONTRACT OR GRANT NO. DAAG 17-72-C-0030 b. PROJECT NO. c. 1F162203AA33 d.	9a. ORIGINATOR'S REPORT NUMBER(S) None 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* 74-9-AD(II)

10. DISTRIBUTION STATEMENT

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY US Army Natick Laboratories

13. ABSTRACT

A method of total trajectory simulation was established which is based on the governing equations of the various phases of an airdrop or recovery system. In view of these equations, a computer program capable of predicting the performance characteristics of a parachute-load system from the instant of initiation to the moment of landing was established. Calculations were performed for a number of different aerial delivery systems. The calculated results fall well within the broad ranges of expected performance, based upon familiarity with field test results.

In Volume I, simulation methods and numerical calculation results are presented; in Volume II details of the calculation procedures and computer program are presented. The system is ready to be used for overall prediction of parachute performance characteristics and an intensive comparison of calculated and recorded field test results in highly desirable for validation and improvement of the technique of total trajectory simulation.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Extraction	8					
Cargo	2		9			
Aircraft	1					
Recovery	10		4			
Parachutes	10					
Low Altitude Drop	4					
Airdrop Operations	4		9, 4			
Tests			8			
Equations			8			
Data			8			
Computer Programming			10			
Aerial Delivery			9			
Loads			9			