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**A SIX-DEGREE-OF-FREEDOM
DIGITAL COMPUTER PROGRAM
FOR
TRAJECTORY SIMULATION**

by

**Louis D. Duncan
and
Bernard F. Engebos**

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**ATMOSPHERIC SCIENCES LABORATORY
WHITE SANDS MISSILE RANGE, NEW MEXICO**

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ABSTRACT

A documentation of a six-degree-of-freedom model for digital simulation of the trajectory of an unguided, fin-stabilized, wind-sensitive rocket is presented. This model was developed by the Atmospheric Sciences Laboratory, White Sands Missile Range, New Mexico, to study both theoretical and empirical performance characteristics of unguided rockets.

The basic equations of motion and their mathematical formulation for this model are presented without derivation.

A general flow chart, a listing of the program, a list of the principal flads used, and a listing of a typical input data deck are included.

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INTRODUCTION

In recent years many theories and computer programs have been developed to simulate missile trajectories. These models range from the extremely simple to the very complex, the degree of complexity usually depending upon the specific simulation requirement placed upon the developer.

This report describes a six-degree-of-freedom computer program developed by the Atmospheric Sciences Laboratory, White Sands Missile Range, New Mexico, to simulate the trajectory of an unguided, fin-stabilized, wind-sensitive rocket. The simulation theory upon which the program is based is presented in reference 1. The references may be consulted for derivations of the equations and coordinate transformations; however, the coordinate systems used and the principal equations which are evaluated by the program are included for completeness.

The system is programmed in Fortran IV language. It consists of a main program (monitor), two subprograms which serve as submonitors for specific simulation options, and a group of subroutines, each designed for a specific task.

An attempt has been made in this report to present a reasonably complete program documentation without boring the reader with trivia. With this goal in mind most of the routines are documented in four parts: (1) a statement of the purpose of the routine and the equations to be evaluated; (2) definition of the principal flads; (3) a macro subroutine; and (4) a listing of the program instructions. It will be observed that in some of the minor routines (2) and/or (3) have been deleted.

COORDINATE SYSTEMS AND TRANSFORMATIONS

Three right-hand coordinate systems are used in the program. These are: (1) The launcher system (denoted X' , Y' , Z') which has its origin at the launcher and rotates with the earth. The positive X' -axis points east; the positive Y' -axis points north; and the positive Z' -axis along the outward normal of the earth. The X' - Y' plane is tangent to the earth at the launcher. (2) The inertial system (X , Y , Z) has its origin at the center of the earth. The system is oriented so that the X - Y plane lies in the earth's equatorial plane

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with the positive Y-axis pointing initially through the longitude of the launcher. The Z-axis is coincident with the earth's axis of rotation and is positive toward the North Pole. This system does not rotate with the earth. (3) The body system (x, y, z) has its origin at the center of gravity of the rocket. The x-axis coincides with the longitudinal axis of the rocket and is positive toward the nose. The position of the y- and z-axes is determined by the rocket's motion. The initial positions of these axes are defined as follows. Let θ be the angle between the x-axis and the positive Z'-axis measured from the Z'-axis. The y-axis lies in the X'-Y' plane and is positive in the direction of positive θ . It is easy to see that the angle between the positive Y'- and y-axes is the launch azimuth measured clockwise from the Y'-axis.

The transformation between any pair of these coordinate systems depends upon, among other things, the assumed earth model. The program considers the earth to be an oblate spheroid with an equatorial radius of 20,926,428 feet and an eccentricity of .00672267. The transformation from the launcher system to the inertial system is easy to obtain from the geometry of the problem. This transformation is, in matrix form,

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} -\cos \lambda_g & \sin \lambda_g \sin \omega t & -\cos \lambda_g \sin \omega t \\ -\sin \omega t & -\sin \lambda_g \cos \omega t & \cos \lambda_g \cos \omega t \\ 0 & \cos \lambda_g & \sin \lambda_g \end{bmatrix} \begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix}$$

where λ_g is the geodetic latitude of the launcher, ω is the earth's rotation speed and t is time after launch. The derivation of the preceding transformation, except for the assumption of a spherical earth, is presented in reference 1.

The transformation from the body system to the inertial system is obtained by integrating the derivatives of the elements of the transformation matrix -- the direction cosines. This transformation is denoted by

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} \ell_1 & m_1 & n_1 \\ \ell_2 & m_2 & n_2 \\ \ell_3 & m_3 & n_3 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

It is shown in [1] that the required derivatives are

$$\left. \begin{aligned} \dot{\ell}_i &= r m_i - q n_i \\ \dot{m}_i &= p n_i - r \ell_i \\ \dot{n}_i &= q \ell_i - p m_i \end{aligned} \right\} \quad i = 1, 2, 3$$

where p, q, r are the x, y, z components of the rotation of the body system with respect to the inertial system.

It is shown in reference 1 that the initial conditions for these direction cosines are

$$\begin{bmatrix} \ell_1 & m_1 & n_1 \\ \ell_2 & m_2 & n_2 \\ \ell_3 & m_3 & n_3 \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -\sin \lambda_g & \cos \lambda_g \\ 0 & \cos \lambda_g & \sin \lambda_g \end{bmatrix} \begin{bmatrix} \sin \theta_0 \sin \alpha_0 & \cos \alpha_0 & \sin \alpha_0 \cos \theta_0 \\ \sin \theta_0 \cos \alpha_0 & -\sin \alpha_0 & \cos \alpha_0 \cos \theta_0 \\ \cos \theta_0 & 0 & -\sin \theta_0 \end{bmatrix}$$

where θ_0 is the launcher elevation angle and α_0 is the launcher azimuth angle measured clockwise from north.

THE MAIN PROGRAM LRBM

LRBM is used to monitor the other routines, to initialize the trajectory simulation, and to monitor the type of trajectory desired.

INITIALIZATION

Initially the x -axis and Z' -axis form an angle θ_0 (this is the elevation of the x -axis angle and is measured from the Z' -axis); and

the projection of the x-axis in the X'Y' plane forms an angle α_0 with the Y'-axis (this is the azimuth angle of the x-axis and is measured clockwise from the Y'-axis). Since the y-axis lies initially in the X'Y' plane, it forms an angle $\alpha_0 + 90$ with the Y'-axis. (See Figure 1). Thus initially,

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} \sin\theta_0 \sin\alpha_0 & \sin\theta_0 \cos\alpha_0 & \cos\theta_0 \\ \cos\alpha_0 & -\sin\alpha_0 & 0 \\ \sin\alpha_0 \cos\theta_0 & \cos\alpha_0 \cos\theta_0 & -\sin\theta_0 \end{bmatrix} \begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix}$$

and

$$X = -X'$$

$$Y = -Y' \sin\lambda_g + Z' \cos\lambda_g$$

$$Z = -Y' \cos\lambda_g + Z' \sin\lambda_g$$

$$\dot{X} = \ell_1 U_0 + wX$$

$$\dot{Y} = \ell_2 U_0 + wY$$

$$\dot{Z} = \ell_3 U_0$$

where λ_g is the geodetic latitude of the launcher, U_0 is initial x component of velocity in body system, and w is the angular rate of the earth's rotation.

The initial conditions for $\ell_i, m_i, n_i, i = 1, 2, 3$, are given by

$$\begin{bmatrix} \ell_1 & \ell_2 & \ell_3 \\ m_1 & m_2 & m_3 \\ n_1 & n_2 & n_3 \end{bmatrix} = \begin{bmatrix} \sin\theta_0 \sin\alpha_0 & \sin\theta_0 \cos\alpha_0 & \cos\theta_0 \\ \cos\alpha_0 & -\sin\alpha_0 & 0 \\ \sin\alpha_0 \cos\theta_0 & \cos\alpha_0 \cos\theta_0 & -\sin\theta_0 \end{bmatrix} \begin{bmatrix} -1 & 0 & 0 \\ 0 & -\sin\lambda_g & \cos\lambda_g \\ 0 & -\cos\lambda_g & \sin\lambda_g \end{bmatrix}$$

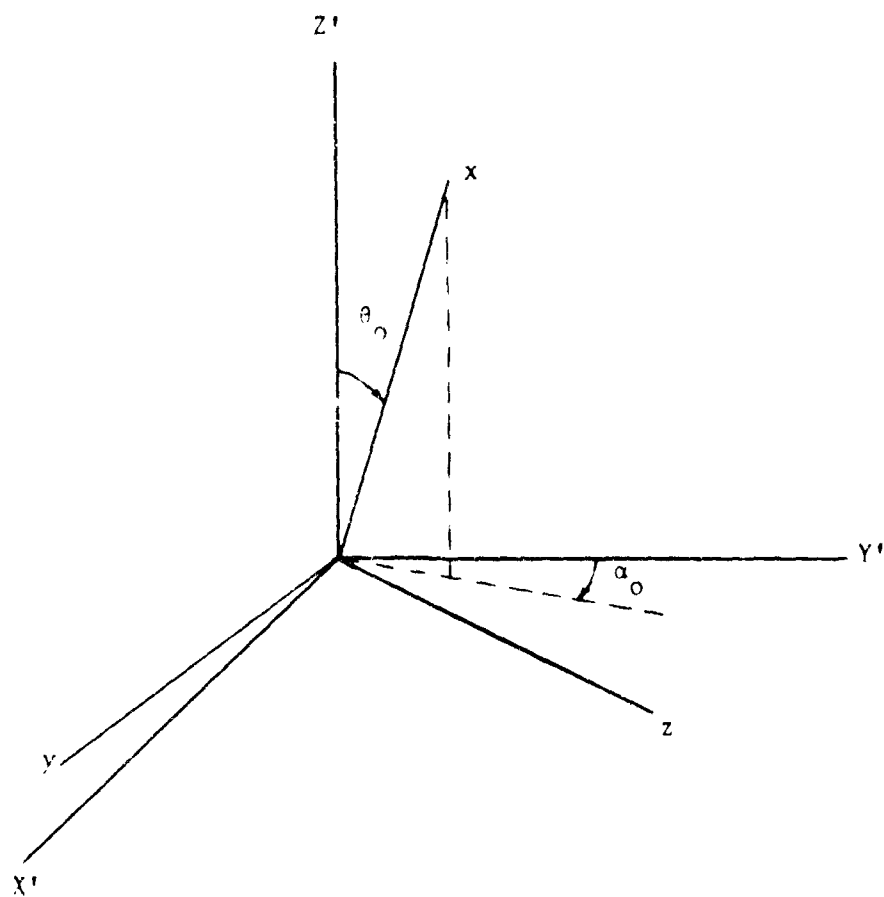


FIGURE 1
INITIAL POSITION OF THE BODY SYSTEM

NTYPE is an indicator, read in the input routine, that determines the type of trajectory to be simulated (1, a regular trajectory; 2, an angular displacement table; 3, iterative type trajectory; 4, the ballistic factor option; or 5, a parameter variability type trajectory). LRBM uses NTYPE to monitor the program and obtains the desired type of trajectory simulation.

The equations of motion of an unguided rocket are numerically integrated by a Runge-Kutta integration technique. This technique is discussed in the section, the Integration Routines. LRBM sets up the initial integration interval for each phase and monitors the integration henceforth.

Several arrays used by all routines are defined. They are the Y, DY, and ROFF1 arrays. All three arrays have double subscripts. The second subscript, J, denotes the step in the Runge-Kutta integration. The Y array then has the following definitions:

Y(1,J) - time of the trajectory simulation.

Y(2,J) - x component of velocity vector in body system.

Y(3,J) - y component of velocity vector in body system.

Y(4,J) - z component of velocity vector in body system.

Y(5,J) - x component of the rotation of body system with respect to the inertial system.

Y(6,J) - y component of the rotation of the body system with respect to the inertial system.

Y(7,J) - z component of the rotation of the body system with respect to the inertial system.

Y(8,J), Y(9,J), Y(10,J) - direction cosines of the body X-axis with respect to the inertial axes.

Y(11,J), Y(12,J), Y(13,J) - direction cosines of the body Y-axis with respect to the inertial axes.

Y(14,J), Y(15,J), Y(16,J) - direction cosines of the body Z-axis with respect to the inertial axes.

Y(17,J) - X component of the inertial position.

Y(18,J) - Y component of the inertial position.

Y(19,J) - Z component of the inertial position.

Each DY(I,J), I equals 2 through 19, is the derivative of the corresponding Y(I,J) entry.

Each ROFFI(I,J), I equals 2 through 19, is the round-off error associated with the corresponding Y(I,J) entry due to the Runge-Kutta integration. The principal flads are:

AL - Azimuth angle of rocket on launcher.

BHI - Current height for cutoff of wind profile for ballistic factor option.

CLAT - Cosine of geocentric latitude of launcher.

CLATG - Cosine of geodetic latitude of launcher.

CNTR - Number of the previous trajectory.

DELC - Cross unit wind effect (m/mph)

DELH - Head unit wind effect (m/mph)

DELT - Tail unit wind effect (m/mph)

DONE - Indicates if integration should be continued (1) or not (2).

DYSTOR(22) - Storage of DY array for future use.

ENF - Indicates whether the winds in the subroutine, AOPTUN, have been iterated for (1) or not (0).

EPSQ - Square of the eccentricity of the earth.

GCONI, GNU - Constants used in evaluation of gravity for geodetic earth.

H - Integration interval (sec).

HP(50) - Heights in wind table (ft).

I1,I2,I3,I4 - Last entry used in atmospheric, wind, Mach, and time tables.

IBFEND - Indicates if all wind profiles of ballistic factor option have been simulated (1) or not (0).

IFOUT - Indicates print out only at end of each phase (1).

IHI - Indicates whether to call ballistic factor option (2) or not (1).

IOUT - Indicates print out (2) or not (1), end of phase (3), or impact (4).

IWIND - Entry of wind currently being used in ballistic factor option.

IXWD, IYWD - X and Y entry in table for angular displacement table.

J1 - Phase currently being used.

J2 - Phase at which to pick up trajectory for ballistic factor option.

NBST - Phase end of which booster drops off.

NFAZE - Total number of phases for trajectory.

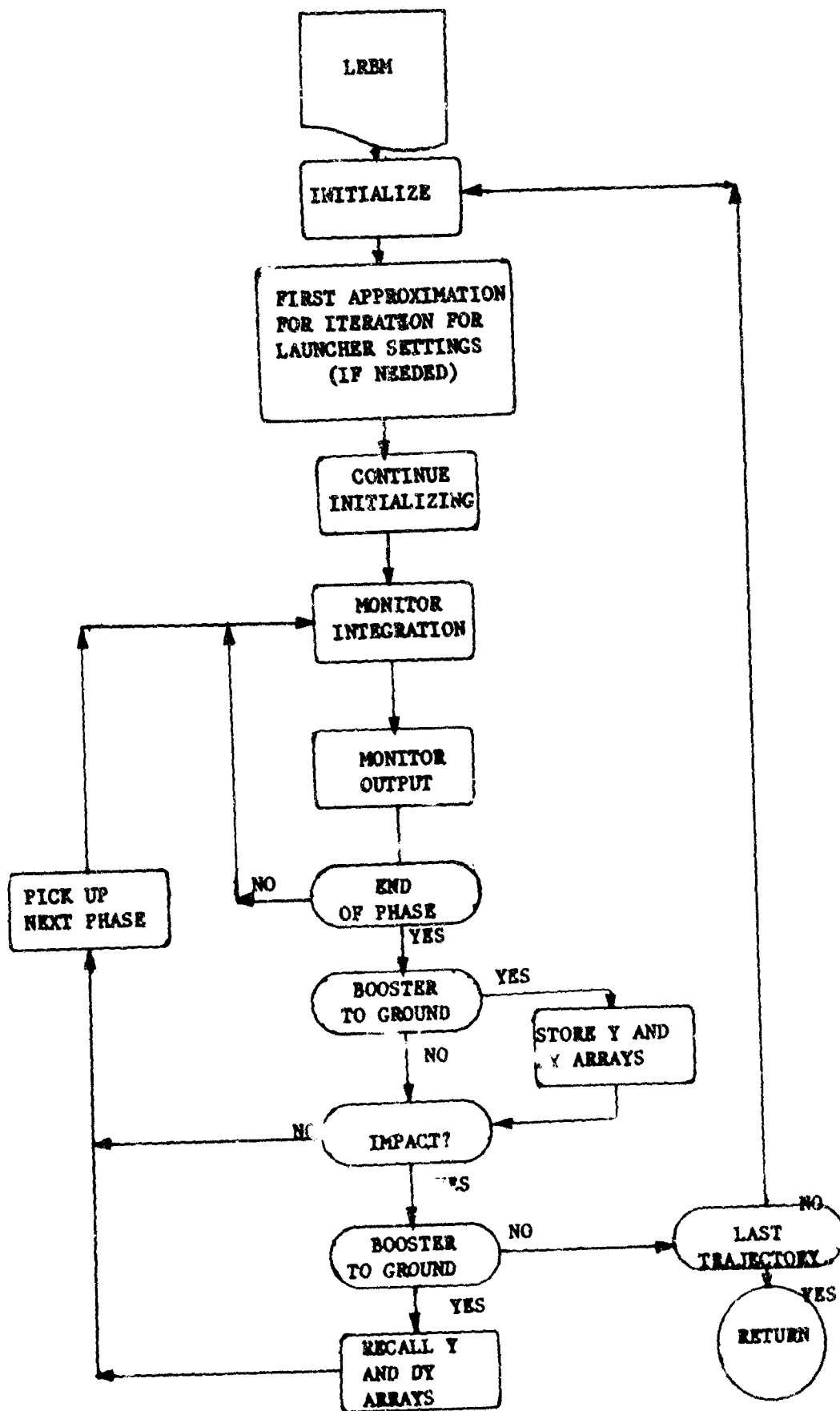
NOGOOD - Indicates whether integration is accepted (1) or not (2).

NTYPE - Indicates whether a regular trajectory (1), iterative type trajectory (2), an angular displacement table (3), the ballistic factor option (4), or a parameter variability trajectory (5) is to be simulated.

NUF - Indicates if the height of the simulated trajectory is less than or equal to height of impact area (1) or not (0).

PI - Print interval (sec).

PSL	- Atmospheric pressure at sea level (lbs).
RANGE	- Distance to desired impact point. (ft).
REQ	- Radius of earth at equator (ft).
RO	- Magnitude of radius vector of oblate earth along radius vector to rocket.
ROA	- Sum of RO and height above sea level of impact area.
ROFSTR(22)	- Storage of ROFF1 array for future use.
SLAT	- Sine of geocentric latitude of launcher.
SLATG	- Sine of geodetic latitude of launcher.
TBO	- Time, end of current phase.
TH	- Tilt angle of rocket on launcher.
TIME	- Current time of simulated trajectory (sec).
TIMEO	- Time rocket leaves launcher (sec).
TO	- Time of end of last phase.
TOWTIL	- Tower tilt effect (ft/radian).
UO,VO,W0	- Initial body coordinates of aerodynamic velocity.
W	- Angular rate of rotation of earth.
WR	- Theoretical range displacement due to wind (ft).
WXS, WYS	- E-W and N-S components of wind in launcher coordinate system (mph).
XDIF, YDIF	- Theoretical E-W and N-S components of wind displacement of rocket (ft).
XLAT	- Geocentric latitude of launcher.
XLATG	- Geodetic latitude of launcher.
XNO	- Total number of trajectories.



XUW, YUW - Cross and range Unit wind effects (m/mph).
XWANT, YWANT - E-W and N-S components of desired impact point (ft).
ZL - Height f impact area above sea level (ft).

THE TWO SUBMONITORS

For convenience of the user, techniques are available for simulating a series of trajectories from one computer submission. The first of these techniques simply consists of submitting a number of consecutive data decks - one for each trajectory. Two other techniques are available for computing a series of trajectories of a specialized nature. These computations are controlled by the submonitors, BALFAC and AOPTUN.

SUBROUTINE BALFAC (INTA)

This subroutine is used to monitor the calculations of ballistic factors (wind weighting factors) and unit wind effects. A complete trajectory is simulated for each entry in the wind table (see section on Input). Each card in the wind table has an entry of wind and height. The trajectory corresponding to a given entry in the wind table is computed for a wind profile having the wind value of the entry when the simulated altitude is below the specified height and a value of zero when the simulated altitude is above this height. The first entry in the wind table should have zero winds, i.e., a no-wind trajectory is required.

The X and Y components of impact for each entry are subtracted from the no-wind impact point to obtain a range displacement. The range displacement of each trajectory is then divided by the range displacement of the final trajectory to obtain a ratio or percentage of the total range displacement. Each ratio is then subtracted from the previous ratio to give the ballistic factor for that layer.

The unit wind effect is obtained by dividing the last range displacement by the magnitude of the wind.

Three indicators are used by the subroutine to control the logic flow. These are INTA, IWIND and IBFEND.

The routine is entered after the completion of each integration step. INTA determines the entry point into the subroutine. During the simulation of a given trajectory the value of INTA is 1. When impact is detected, by LREM, INTA is set equal to 2 and EALFAC is entered to store the impact point and establish the initial conditions for the next simulation.

IWIND is the indicator to determine which wind table entry to use for a given trajectory.

IBFEND is an indicator which tells the routine if the simulations have been completed. This determination is made in LREM. If the simulations have been completed, IBFEND is set equal to 1 and EALFAC is entered to compute the ballistic factors and unit wind effect.

SUBROUTINE AOPTUN (K)

The simulation model contains a technique for determining the launcher settings necessary to compensate for a given wind profile so that the computed impact will be in a desired area. The launcher settings are determined by an iterative procedure which is discussed in reference 3.

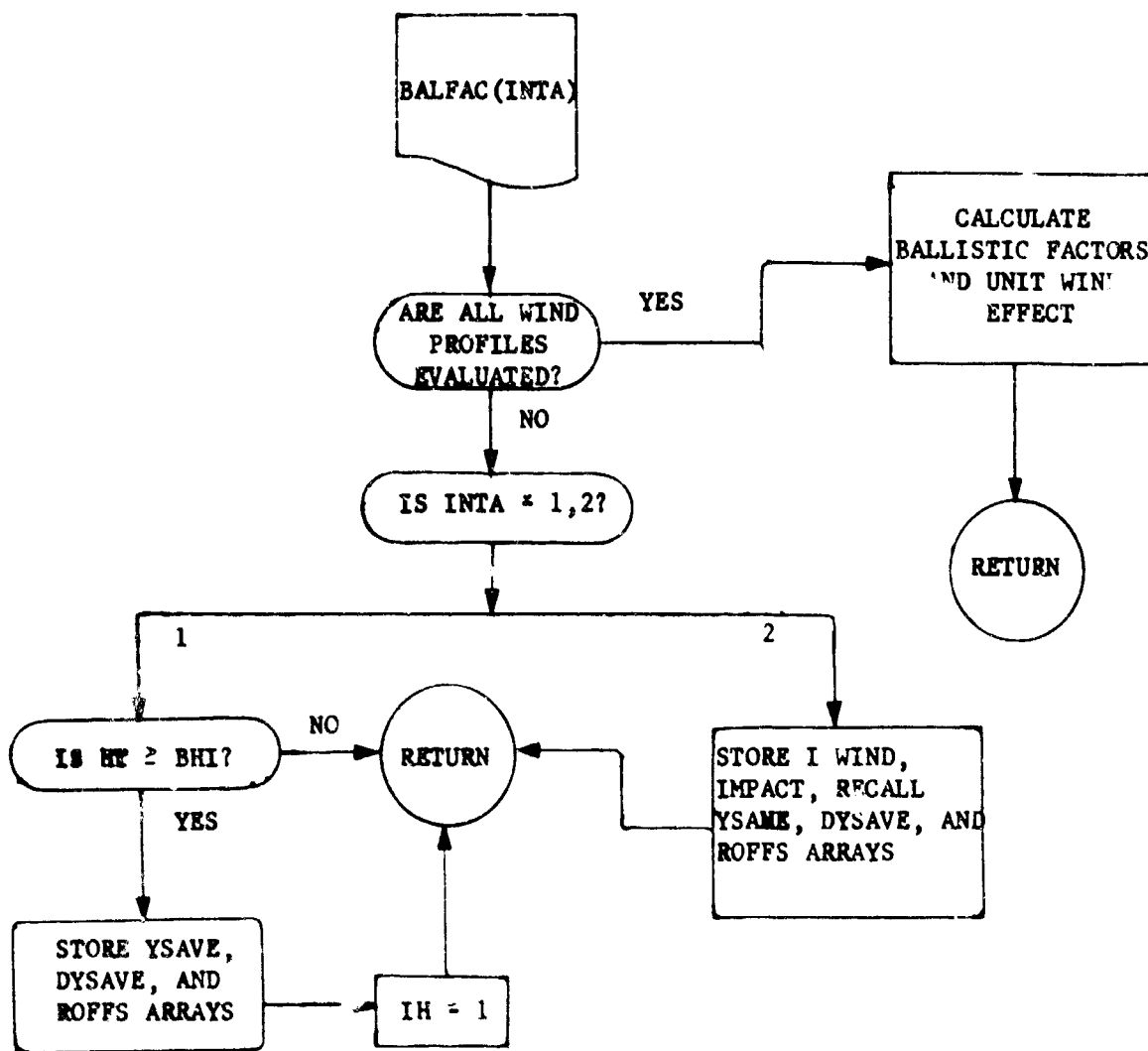
This subroutine is used to monitor the iteration procedure. In addition it is used to monitor the computation of a nomogram of launcher angles versus ballistic winds. (See reference 4) These latter calculations are referred to as angular displacement trajectories.

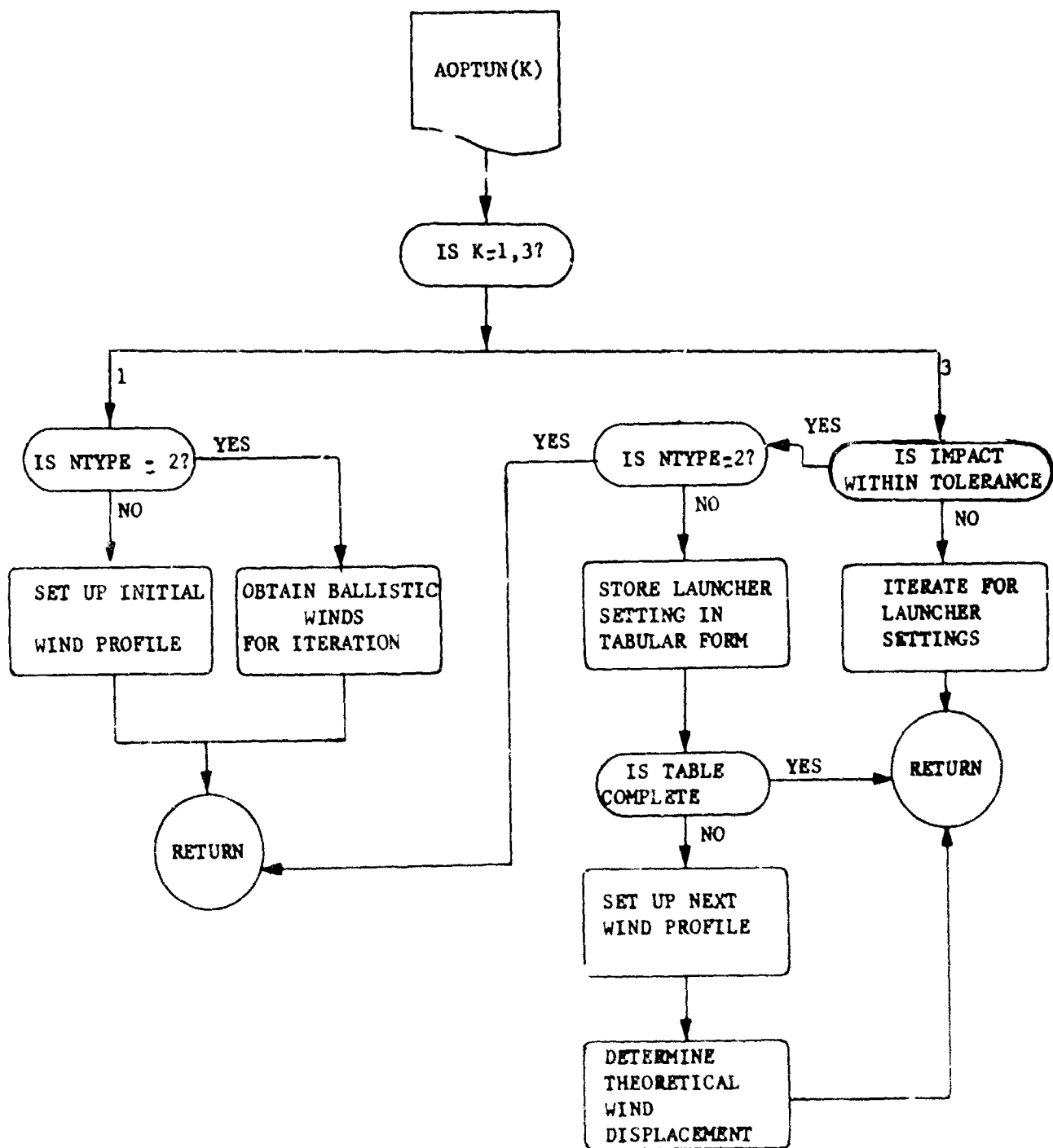
K is an indicator used to determine the entry point to the subroutine and has admissible values of 1 and 3. When K is equal to 1 the initial approximation of the launcher setting is made and the wind profile is set up. The subroutine is entered with a value of K = 3 at impact and a check is made to determine if the simulated impact is within a required tolerance of the desired impact. If it is not, a new set of launcher angles is determined and the iteration is continued. If the tolerance is met and an iterative trajectory is being computed, a return is generated. If a nomogram is being generated, the launcher setting is stored in tabular form and the next wind profile is set up unless the nomogram has been completed; whereupon a return is generated. The first approximation for the launcher settings for this profile is made and the new trajectory is begun. The principal flads for the two submonitors are:

AL - Azimuth angle of rocket.

ALPHA (11,11)- Storage of azimuth angles in tabular form for angular displacement option.

BF(50)	- Ballistic factors of the rocket.
BFACT	- Ballistic factor.
BHI	- Height of current entry in wind table (feet).
DELC	- Cross unit wind effect (m/mph).
DELI	- Head unit wind effect (m/mph).
DELR	- Ballistic wind displacement of current trajectory (miles).
DELT	- Tail unit wind effect (m/mph).
DIFX	- E-W ballistic wind displacement of current trajectory (miles).
DIFY	- N-S ballistic wind displacement of current trajectory (miles).
ENF	- Indicator, set equal to one when angular displacement table finished.
HP(50)	- Heights used in the wind table (feet).
HT	- Height of rocket above oblate earth (feet).
IBFEND	- Indicates whether or not the entire wind table has been used.
IH	- Indicates whether to use wind or not.
IWIND	- Entry in wind table currently being used.
NEF	- Number of entries in ballistic factor table.
NTYPE	- Indicates type of trajectory to be simulated.
NW	- Number of entries in wind table.
RANGE	- Same as DELR.
RATIO	- Percentage of wind effect.





SUMX	- E-W component of ballistic wind.
SUMY	- N-S component of ballistic wind.
TESTVA	- Range difference between simulated and desired impact.
RII	- Tilt angle of rocket.
THETA (11,11)	- Storage of tilt angles in tabular form for angular displacement option.
TOWTIL	- Tower tilt effect (ft/rad).
UNIT	- Unit wind effect (m/mph).
WIND	- Magnitude of wind (mph).
WXP(50), WYP(50)	- Entries of E-W and N-S components of wind.
WXS - WYS	- Value of E-W and N-S components of wind.
XDIF - YDIF	- E-W and N-S components of difference between simulated and desired impact.
XCIANG - YCIANG	- Increments of E-W and N-S component of wind for angular displacement option.
XFIRST - XLAST	- Initial and terminal values of E-W component of wind for angular displacement option.
XUW - YUW	- Cross and range component of unit wind effect.
XWANT - YWANT	- E-W and N-S components of desired impact.
XYZ(1) - XYZ(2)	- E-W and N-S components of simulated impact.

THE EVAL ROUTINE

The subroutine EVAL is used to evaluate the rocket equations of motion and to compute the derivatives of the direction cosine matrix which specifies the transformation from the body coordinate system to the earth-centered inertial system. The derivation of the equations can be found in reference 2.

Let $\vec{V}$ represent the velocity of the rocket and let $\vec{W}$ represent the rotation of the x, y, z system with respect to the X, Y, Z system. The x, y, z components of $\vec{V}$ and $\vec{W}$ are designated by u, v, w and p, q, r , respectively.

The equations of motion derived in [1] are

$$\begin{aligned}\dot{mu} &= m(rv - qw) + F_x \\ \dot{mv} &= m(pw - ru) + F_y \\ \dot{mw} &= m(qu - pv) + F_z \\ I_{xx}\dot{p} &= (I_{yy} - I_{zz})qr - \dot{I}_{xx}p + L \\ I_{yy}\dot{q} &= (I_{zz} - I_{xx})pr - \dot{I}_{yy}q + M \\ I_{zz}\dot{r} &= (I_{xx} - I_{yy})pq - \dot{I}_{zz}r + N\end{aligned}$$

where m is the rocket mass, I_{xx}, I_{yy}, I_{zz} are the moments of inertia, F_x, F_y and F_z are the body components of the applied forces and L, M, N are the body components of the moments. The forces and moments are computed from the equations

$$\begin{aligned}F_x &= C_x q' S + T - mg_x \\ F_y &= -C_{n_\alpha} \sin \beta q' S - mg_y \\ F_z &= -C_{n_\alpha} \sin \alpha q' S - mg_z \\ L &= C_{\ell_\delta} \delta + C_{\ell_p} \left(\frac{pd}{2v_a} \right) \\ M &= [C_{m_\alpha} \sin \alpha + C_{m_q} \left(\frac{qd}{2v_a} \right)] q' S d + \dot{m}(1-cg)^2 q \\ N &= [-C_{m_\alpha} \sin \beta + C_{m_q} \left(\frac{qd}{2v_a} \right)] q' S d + \dot{m}(1-cg)^2 r\end{aligned}$$

where

$q' = 1/2 \rho v^2$ is the dynamic pressure,

S is the reference area,

d is the reference length, and

v_a is the magnitude of the aerodynamic velocity.

$\dot{m}(1-cg)q$ and $\dot{m}(1-cg)\dot{r}$ are jet damping terms.

The thrust, T , is computed from the

formula

$$T = T_{s.l.} + A_e (P_{s.l.} - P_a)$$

where

$T_{s.l.}$ is sea level thrust

$P_{s.l.}$ is sea level pressure

P_a is atmospheric pressure

and A_e is the area of the exit nozzle.

The body components of the acceleration due to gravity are designated g_x , g_y , and g_z . These are obtained from the inertial components of gravity which are assumed to be

$$g_x = \frac{\gamma_g \text{ Me } X}{R^3} [1 - 3 R_{eq}^2 v(1 - 3 \cos 2 \lambda)/R^2]$$

$$g_y = \frac{\gamma_g \text{ Me } Y}{R^3} [1 - 3 R_{eq}^2 v(1 - 3 \cos 2 \lambda)/R^2]$$

$$g_z = \frac{\gamma_g \text{ Me } Z}{R^3} [1 - 3 R_{eq}^2 (1 - 3 \cos 2 \lambda)/R^2]$$

where $\gamma_g = 1.40775 \times 10^{16} \text{ ft}^3/\text{sec}^2$

$$v = .273 \times 10^{-3}$$

λ is geodetic latitude.

Wind enters the equation in the terms $\sin \beta$, $\sin \alpha^*$ and v_a . A precise formulation is presented in [1]. The wind components and the atmospheric pressure and atmospheric density, ρ , are obtained from a table using the subroutine TABL. The wind components in the body system are obtained by applying the transformations described in the section "Coordinate Systems and Transformations."

The stability derivatives C_x , C_{n_α} , C_{ℓ_δ} , C_{ℓ_p} , C_{m_α} and C_{m_q} , which are defined in the section on Input, are also obtained by a table lookup. The routine has an option of either obtaining C_{m_α} from the table or computing this value from

$$C_{m_\alpha} = -C_{n_\alpha} |C_g - C_p|$$

The derivatives of the direction cosines are computed from the formulas

$$\dot{l}_i = r m_i - q n_i \quad i = 1, 2, 3$$

$$\dot{m}_i = p n_i - r l_i \quad i = 1, 2, 3$$

$$\dot{n}_i = q l_i - p m_i \quad i = 1, 2, 3$$

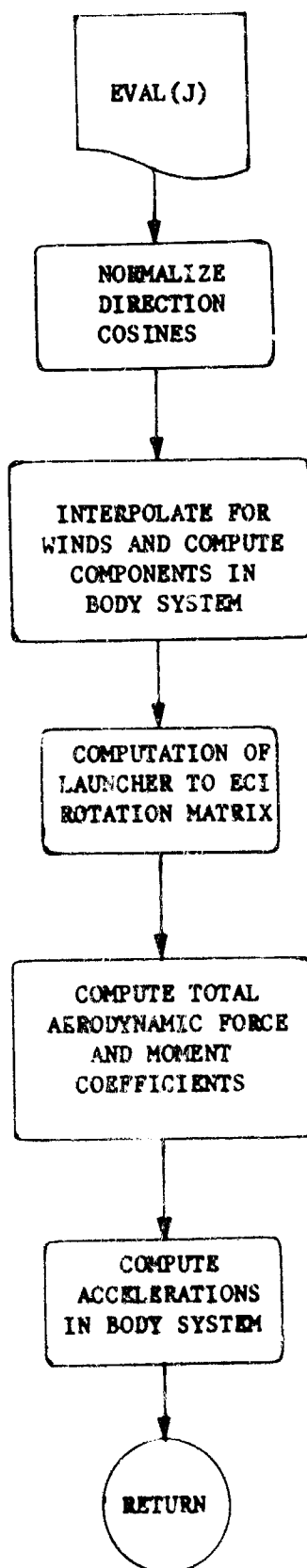
The inertial component of the accelerations are obtained by applying the body-to-inertial transformation.

The only input parameter to the routine which is not transmitted through Common is the integer J which appears in the calling sequence. This parameter indicates the step in the Runge-Kutta integration routine at which EVAL was called. The principal flads are:

- AE - Exit area of motor nozzle (sq. ft.).
- CG - Center of gravity (feet from nose).

CHEK	- Magnitude of radius vector to rocket (feet).
CLAT	- Cosine of geocentric latitude.
CMA	- Center of pressure (feet from nose).
CMQ	- Damping moment coefficient.
CNA	- Normal force coefficient.
CP	- Center of pressure (feet from nose).
CX	- Axial force coefficient.
DAMP	- Jet damping term.
DMKOMK (3)	- Derivatives of moments of inertia.
DSQ	- Reference area of aerodynamics.
EPSQ	- Square of the eccentricity of the earth.
FLOW	- Mass flow rate.
FM	- Mass.
FX	- Moment of inertia about x-axis.
FY	- Moment of inertia about y-axis.
FZ	- Moment of inertia about z-axis.
G	- Gravity.
GCON1 } GNU }	- Constants used in evaluation of gravity for geodetic earth.
HRO	- Magnitude of radius vector to rocket.
HIT	- Height of rocket above oblate earth.
III	- Indicates whether to call ballistic factor option (2) or not (1).
IWIND	- Entry of wind currently being used in ballistic factor option.

KAN	- Indicates if burning (1) or coasting (2) phase.
MAL	- Indicates if CP (1) or CMA (2) is input.
NTYPE	- Indicates what type of trajectory being simulated.
p	- x-component of the rotation of the body system with respect to the inertial system.
PA	- Atmospheric pressure.
PSL	- Atmospheric pressure at sea level.
q	- y-component of rotation of body system with respect to inertial system.
QP	- Dynamic pressure.
r	- z-component of rotation of body system with respect to inertial system.
REFL	- Reference length for aerodynamics.
REQ	- Radius of earth at equator.
RHO	- Atmospheric density.
RM	- Mach number.
RS	- Radius of oblate spheroid along radius vector to rocket.
SA	- Sine α^* .
SB	- Sine β .
SLAT	- Sine of geocentric latitude of launcher.
SLATG	- Sine of geodetic latitude of launcher.
TIMEO	- Time rocket leaves end of launcher.
TSL	- Thrust at sea level.
UP, VP, WP	- Body coordinate system components of aerodynamic velocity.
VA	- Atmospheric velocity.



VS - Speed of sound.

W - Angular rotation of the earth.

WDOT (1-3) - Body components of p, q and r.

WDOT (4-6) - Body components of $\dot{p}$, $\dot{q}$, $\dot{r}$.

WX, WY, WZ - Components of wind in inertial coordinate system.

WXP (50), WYP(50)- Components of wind in launcher coordinate system.

XLT - Length of rocket (feet).

THE INPUT SYSTEM

The data required for a simulation is read into the computer at the beginning of the program. These data are stored in memory for later use. The data required for a given phase (a specific portion of the trajectory) are extracted from this storage area and placed into the working storage area at the beginning of the phase.

SUBROUTINE Pintrj

This subroutine is used to read in all input data and to store the data phasewise. All card formats are in columns of eight with a few minor exceptions. The first six columns of all data cards can be used for identification purposes. The first card of the input deck, containing the number of distinct trajectories in the job, is read in the monitor routine, LRBH, in columns 17-24.

Description of the Input Deck

The second input card determines the type of trajectory and an indicator to determine if the regular printout is desired or not. If column 9 contains a:

- 1 - a regular trajectory is calculated.
- 2 - an iteration for launcher angles is run.
- 3 - an angular displacement table is computed.
- 4 - the ballistic factors and unit wind effect are calculated.
- 5 - a dispersion analysis is run.

If also on the second card, column 17 contains a 1, printouts occur only at the end of each phase.

The input for cards 3 through 6 is as follows:

<u>Card</u>	<u>Column</u>	<u>Parameter</u>	<u>Description (Units)</u>
3	1-72	IDEN	Alphanumeric information used for identification.
4	9-16	TO	Time (sec) rocket leaves end of launcher.
	17-24	ZL	Mean sea level altitude at end of launcher (ft).
	25-32	ZIM	Mean sea level altitude of impact area (ft).
	33-40	XLAT	Geocentric latitude of launcher (degrees).
	41-48	XLONG	Geocentric longitude of launcher (radians).
	49-50	NFAZE	Total number of phases (right justified).
	57-58	NBST	Phase, end of which, to pick up booster (right justified).
5	9-16	UO	x component of velocity in body system at end of launcher (ft/sec).
	17-24	VO	y component of velocity in body system at end of launcher (ft/sec).
	25-32	WO	z component of velocity in body system at end of launcher (ft/sec).
	33	MAL	Indicator; if equals 1, input CP; if equals 2, input CMA.

<u>Card</u>	<u>Column</u>	<u>Parameter</u>	<u>Description (Units)</u>
6	9-16	TII	Tilt angle (degrees).
	17-24	AL	Azimuth angle (degrees).
	25-32	XWANT	East-west component of desired impact (ft).
	33-40	YWANT	North-south component of desired impact (ft).
	41-48	DELTA	Iteration tolerance.
	49-54	TOWTIL	Tower tilt effect (ft/radian).

The remainder of the input consists mainly of tables. All tables use one card for each value of the independent parameter (height, Mach number, or time). The first card of each table contains a right justified integer in columns 7 and 8 which indicates the number of cards in the table.

There are five types of tables:

1. Atmospheric Table

<u>Column</u>	<u>Parameter</u>	<u>Description (Units)</u>
9-16	HH	Height above sea level (ft).
17-24	RHO	Density (slugs/ft ³).
25-32	VS	Speed of sound (ft/sec).
33-40	PA	Pressure (lbs/sq ft).

2. Wind Table

9-16	HIP	Height above sea level (ft).
17-24	WXP	East-west component of wind (mph).
25-32	WYP	North-south component of wind (mph).

3. Mach Table

<u>Column</u>	<u>Parameter</u>	<u>Description (Units)</u>
9-16	PM	Mach number.
17-24	CX	Axial force coefficient.
25-32	CNA	Normal force coefficient (per radian).
33-40	CMA	Restoring moment coefficient or center of pressure (ft from nose).
41-48	CMQ	Pitch damping moment coefficient.
49-56	CLD	Roll driving coefficient.
56-64	CLP	Roll damping coefficient.

4. Time Table

9-16	T	Time (sec)
17-24	FX	Roll moment of inertia (slug/ft ²).
25-32	FY	Pitch moment of inertia (slug/ft ²).
33-40	TSL	Thrust (lbs).
41-48	CG	Center of gravity (ft from nose).
49-56	FM	Mass (slugs).

5. Ballistic Factor Table

9-16	BF	Ballistic factor.
------	----	-------------------

For each phase there are two Phase Cards containing in:

1-8	TBO	Time phase terminates (sec).
9-16	AE	Area of motor exit nozzle (sq ft).
17-24	DSQ	Reference area used in aerodynamic calculations (sq ft).
25-32	REFL	Reference length used in aerodynamic calculations (ft).

<u>Column</u>	<u>Parameter</u>	<u>Description (Units)</u>
33-40	XLENTH	Length of rocket (ft).
41-48	EPTINY	Integration tolerances for Runge-Kutta-Gill numerical integration.
49-56	EPBIG	
57-64	FINC	
65-72	TMII	Maximum integration interval (sec).
73-80	PI	Print interval (sec).
1-8	TFP	Time of first print (sec).
9	KAN	Indicator; if equals 1, input Mach and time tables; if equals 2, Mach table only.

Depending on the type of trajectory desired, several other cards may be necessary. These cards include:

Unit Wind Effects Card

<u>Column</u>	<u>Parameter</u>	<u>Description (Units)</u>
9-16	DELC	Cross unit wind effect (m/mph).
17-24	DELT	Tail unit wind effect (m/mph).
25-32	DELH	Head unit wind effect (m/mph).

Angular Displacement Wind Card

9-16	XFIRST	The first E-W wind used (mph).
17-24	XLAST	The last E-W wind used (mph).
25-32	XCHANG	Increment for E-W wind change (mph).
33-40	YFIRST	The first N-S wind used (mph).
41-48	YLAST	The last N-S wind used (mph).
49-56	YCHANG	Increment for N-S wind change (mph).

The input for a regular trajectory is as follows:

Cards 1-6

Atmospheric Table

Wind Table

Phase Cards

Mach Table

Time Table (if KAN is 1)

} Repeated for each phase as
needed

The input for the interactive type run is as follows:

Cards 1-6

Atmospheric Table

Wind Table

Ballistic Factor Table

Unit Wind Effect Card

Phase Cards

Mach Table

Time Table (if KAN is 1)

} Repeated for each phase as
needed

The input for the angular displacement table is as follows:

Cards 1-6

Atmospheric Table

Angular Displacement Wind Card

Unit Wind Effects Card

Phase Cards

Mach Table

Time Table (if KAN is 1)

} Repeated for each phase as
needed

The input for the ballistic factor option is the same as for the regular trajectory. The first card of the wind table should contain a zero wind. The remainder of the cards of the wind table should contain winds of constant magnitude and direction.

The input for the dispersion analysis is the same as for the regular trajectory except after each Mach and time table, another card follows. This card contains a percentage of change in decimal form plus one in the same field as the parameter to be changed. That is, if 1.1 appears in columns 17-24 on the card following the Mach table, the axial force coefficient is increased ten percent. If the parameter is not to be changed, a 1. must appear in the same field as the parameter itself.

If one also desires to bring the booster to impact, another phase must be added. This phase follows the last regular phase and consists of:

Phase Cards	}	Repeated as required.
Mach Table		
Time Table (if KAN is 1)		

On card 2, the value of NFAZE, should include the booster phases.

SUBROUTINE Phasin (J)

This subroutine selects the data required for the Jth phase and places these data in working storage areas. Recall that all data input is at the beginning of the trajectory. The principal flads for the input system:

AE	- Area of exit nozzle (sq ft).
AEB(10)	- Storage of AE for all phases.
CG(40)	- Entries of center of gravity in time tables.
CGB(40,10)	- Storage of CG for all phases.
CMA(20)	- Entries of center of pressure in Mach table.
CMAB(20,10)	- Storage of CMA for all phases.
CMQ(20)	- Entries of coefficient of damping moment in Mach table.
CMQB(20,10)	--Storage of CMQ for all phases.

CNA(20)	- Entries of coefficient of normal force in Mach table.
CNAB(20,10)	- Storage of CNA for all phases.
CX(20)	- Entries of coefficient of axial force in Mach table.
CXB(20,10)	- Storage of CX for all phases.
DSQ	- Reference area used in aerodynamic calculations.
DSQB(10)	- Storage of DSQ for all phases.
EPBIG } EPTINY }	- Integration tolerances for Runge-Kutta-Gill numerical integration.
EPBIGB(10) } EPTINB(10) }	- Storage of EPBIG and EPTINY for all phases.
FM(40)	- Entries of mass in time tables.
FMB(40,10)	- Storage of FM for all phases.
FX(40)	- Entries of pitch moment of inertia about x-axis in time table.
FXB(40,10)	- Storage of FX for all phases.
FY(40)	- Entries of pitch moment of inertia about y-axis in time table.
FYB(40,10)	- Storage of FY for all phases.
IOPTUB(10)	- Storage of IOPTUN for all phases.
KAN	- Indicator, if equal to two, only Mach table is necessary.
KANB(10)	- Storage of KAN for all phases.
NM	- Number of values in Mach table.
NMB(10)	- Storage of NM for all phases.
NT	- Number of values in time table.
NTB(10)	- Storage of NT for all phases.
PI	- Print interval.

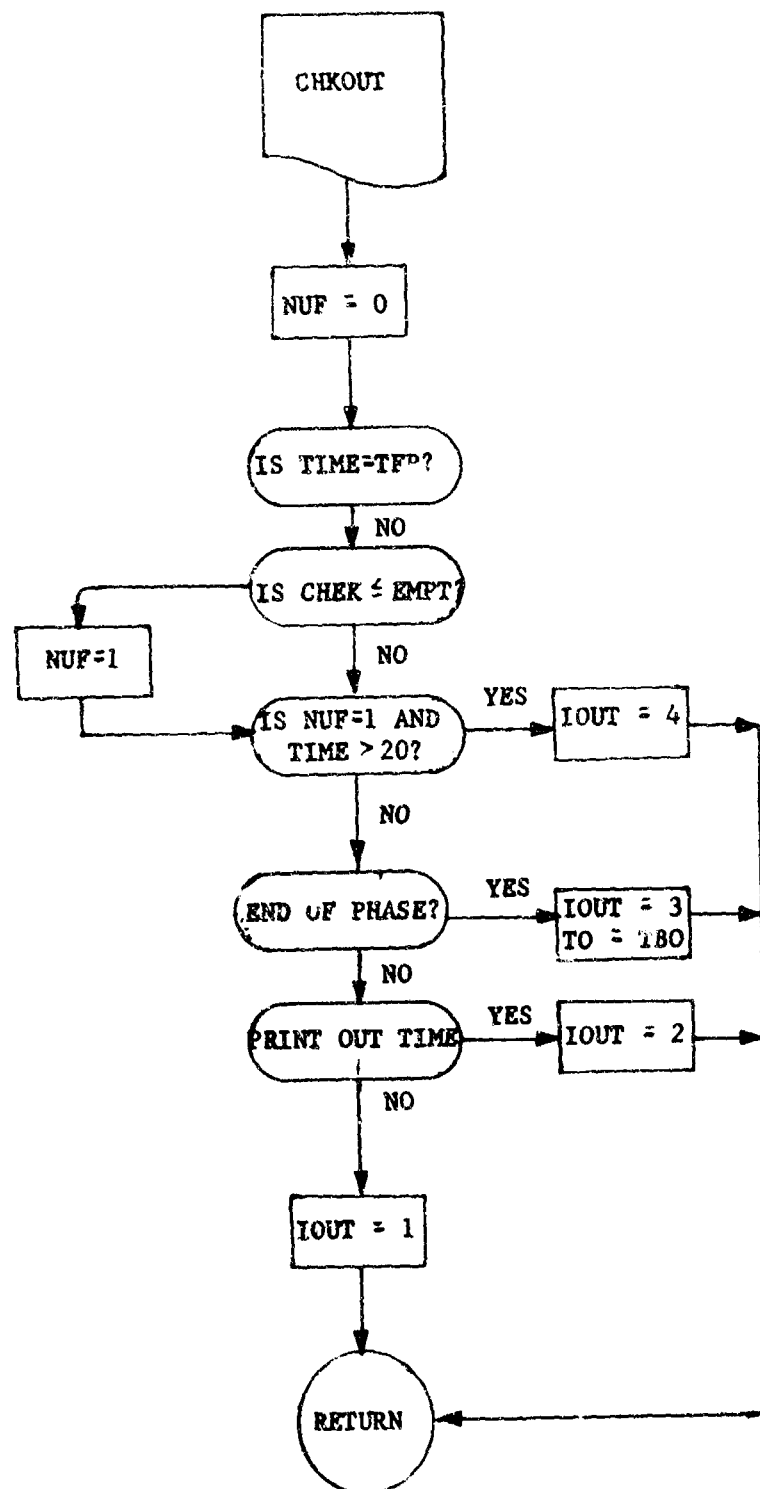
PIB(10) - Storage of PI for all phases.
 PM(20) - Entries of Mach number in Mach table.
 PMB(20,10) - Storage of PM for all phases.
 T(40) - Entries of time in time table.
 TB(40,10) - Storage of T for all phases.
 TBO - Time at end of phase.
 TBOB(10) - Storage of TBO for all phases.
 TFP - Time of first print to be used in phase.
 TFPB(10) - Storage of TFP for all phases.
 TMII - Maximum integration interval.
 TMIIB(10) - Storage of maximum integration interval.
 TSL(40) - Entries of thrust in time tables.
 TSLB(40,10) - Storage of TSL for all phases.
 XLT(10) - Entries of length of rocket.
 XLNTH - Length of the rocket.

THE OUTPUT SYSTEM

The output from the simulation is a printed record of the simulation at discrete preselected times. The output is referenced to the launcher coordinate system. Three subroutines are used in the output system. These are: (1) CHKOUT is used to determine when output is required. (2) TI2L transforms the data from the Inertial System to the Launcher System. (3) XOUT prepares the magnetic tape for the printer. XOUT and CHKOUT are called by LRBM; TI2L is called by XOUT.

SUBROUTINE CHKOUT

Output from the trajectory is required at the following times: (1) specified intervals within a phase; (2) end of each phase; and, (3) impact. The subroutine CHKOUT is called at the end of each integration interval to see if any of these conditions have been met.



An indicator IOUT is set equal to 2, 3, or 4, respectively, if condition (1), (2) or (3) is satisfied and set equal to 1 otherwise. The logic flow of LRBM is, of course, affected by the value of IOUT. In performing the checks it is assumed that impact will not occur before a simulated time of 20 seconds.

The integration interval is also controlled by CHKOUT. This control is limited to control necessary to preclude "jumping over" (1) or (2).

SUBROUTINE TI2L (KWIND, JF).

This subroutine is used to convert values of position, velocity, and acceleration from the earth-centered inertial coordinate system to the launcher coordinate system for use in the subroutine, XOUT. The total aerodynamic velocity and the azimuth and elevation angles of the velocity vector are also calculated.

The position, velocity, and acceleration in the launcher system are obtained from the following equations:

$$\vec{R}_L = T(\vec{R}_I - \vec{R}_O)$$

$$\dot{\vec{R}}_L = T(\dot{\vec{R}}_I - \vec{\omega} \times \vec{R}_I)$$

$$\ddot{\vec{R}}_L = T(\ddot{\vec{R}}_I - \vec{\omega} \times (\vec{\omega} \times \vec{R}_I) - 2\vec{\omega} \times \dot{\vec{R}}_I)$$

where $\vec{R}_L$ is the position vector in the launcher system,

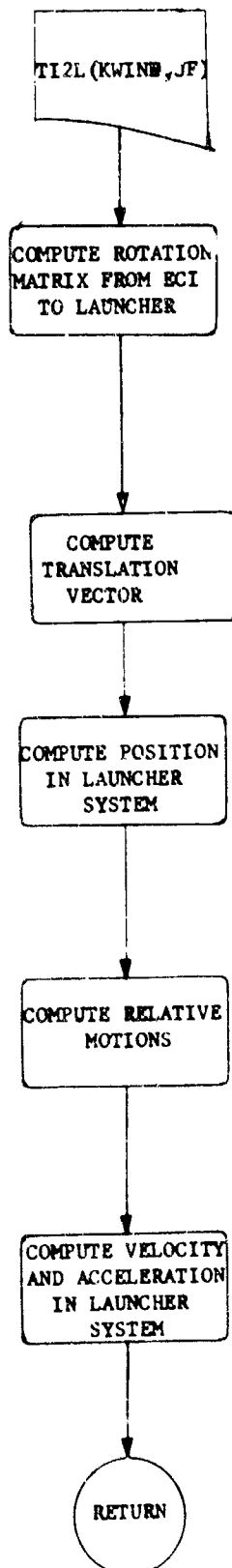
$\vec{R}_I$ is the position vector in the inertial system,

$\vec{\omega}$ is the earth's rotation vector,

T is the linear transformation from the inertial to the launcher coordinate system, and

$\vec{R}_O$ is the radius vector from the inertial to the launcher system.

KWIND is an indicator used in the calling sequence to determine if the accelerations should be computed in the launcher system or



not. Only when KWIND equals one are these accelerations computed. The principal flads of the output system are:

AH	- Azimuth angle of velocity vector (deg).
B(1)-B(2)-B(3)	- Launcher coordinates of aerodynamic acceleration (ft/sec/sec).
CHEK	- Magnitude of radius vector to rocket (ft).
CLAT - CLATG	- Cosine of geocentric and geodetic latitude.
D(1)-D(2)-D(3)	- Launcher coordinates of aerodynamic velocity (ft/sec).
DIF	- Difference between the time of the simulated trajectory and the time of the beginning of the phase (sec).
EMPT	- Sum of the radius of the oblate spheroid along radius vector to the rocket and the height of the impact area above sea level (ft).
ENDPH	- Difference between current time of simulated trajectory and time of the end of the phase (sec).
EPSQ	- Square of the eccentricity of the earth.
H	- Integration interval (sec).
IDEN	- Alphanumeric information used for indentification.
IJK	- Current line of print out on page.
NUF	- Set equal to 1 if CHEK is less than or equal to EMPT.
PI	- Print interval (sec).
PO	- If PO equals zero, print out occurs.
RO	- Radius of earth (ft).
RS	- Radius vector of oblate spheroid along radius vector to rocket (ft).

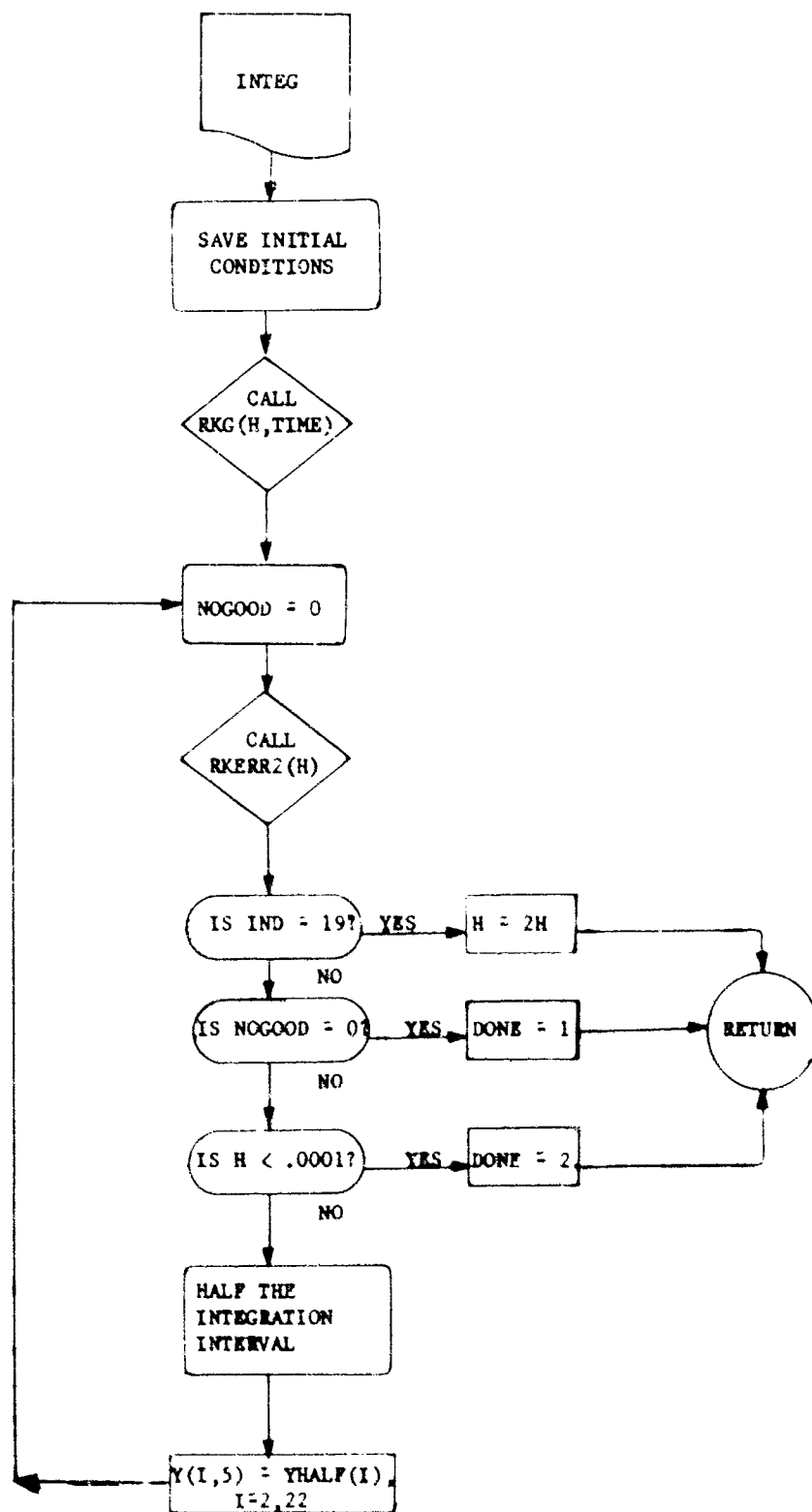
SLAT	- Sine of geocentric latitude of launcher.
SLATG	- Sine of geodetic latitude of launcher.
TBO	- Time of end of current phase (sec).
TFP	- Time of first print out for current phase (sec)..
TH	- Elevation angle of velocity vector (deg).
TIMEO	- Time (sec) rocket leaves end of launcher.
TO	- Time of beginning of phase (sec).
V	- Aerodynamic velocity in launcher coordinate system.
W	- Omega, rate of angular rotation of earth.
WT	- Distance earth rotates in time, T.
WXS, WYS	- E-W and N-S components of wind (mph).
XL, YL, ZL	- Translation vectors from earth-centered inertial coordinate system to launcher coordinate system.
XYZ (3)	- Launcher coordinates of position of rocket (ft).
YD (6)	- Relative motion velocities of inertial system with respect to launcher system.
ZIM	- Impact height above sea level of impact area (ft).

THE INTEGRATION ROUTINES

The trajectory is determined by integrating 15 differential equations of motion. Three are of second order, while the other 12 are first order. Iterated integration is used for the second order equations. The integration is monitored by LRBM through the subroutine INTEG.

The subroutine INTEG monitors the mechanics of the numerical integration through the routines RKG and RKERR2.

The SUBROUTINE RKG (II, TIME) is used to integrate the equations of motion and uses the fourth order Runge-Kutta-Gill numerical integration scheme. RKG calls upon EVAL for evaluation of the equations



of motion. H is the integration interval currently being used. TIME is the current time in the trajectory simulation.

The SUBROUTINE RKERR(H) is used to check the validity of the integration. This check is performed by comparing the value, say Y_I , obtained for an interval of length H with the value, say Y_{II} , obtained by performing two integrations using the value $H/2$. Specifically the following ratio

$(Y_{II} - Y_I)/Y_{II}$ is compared with two tolerance values ϵ_1 and ϵ_2 .

(This comparison is made separately for each of the integrated values.)

If $(Y_{II} - Y_I)/Y_{II}$ is greater than ϵ_1 for any of the parameters, H is replaced by $H/2$ and the integration is redone. If all values of $(Y_{II} - Y_I)/Y_{II} < \epsilon_2$ then not only is the integration accepted but the integration interval for the next step is doubled.

If at any time during the simulation H becomes less than .0001, a message is sent to LRB!! using the indicator DONE to terminate the simulation. The indicator NOGOOD is used to tell whether the integration is acceptable or not.

SUBROUTINE Mtrxl (A1, A2, NC2, PRO)

This subroutine is used to multiply two matrices. A1, A2, NC2, and PRO are variables used in the calling statement. A1 is a 3 x 3 matrix. A2 is either a 3x1, 3x2, or 3x3 matrix depending on whether NC2 is equal to one, two, or three. The product of these two matrices, A1 and A2, is then stored in the matrix, PRO.

SUBROUTINE TABL (LOOKUP, J)

This subroutine is used to interpolate linearly for values from the atmosphere, wind, Mach, and time tables. The parameter LOOKUP is used to designate which table is to be used.

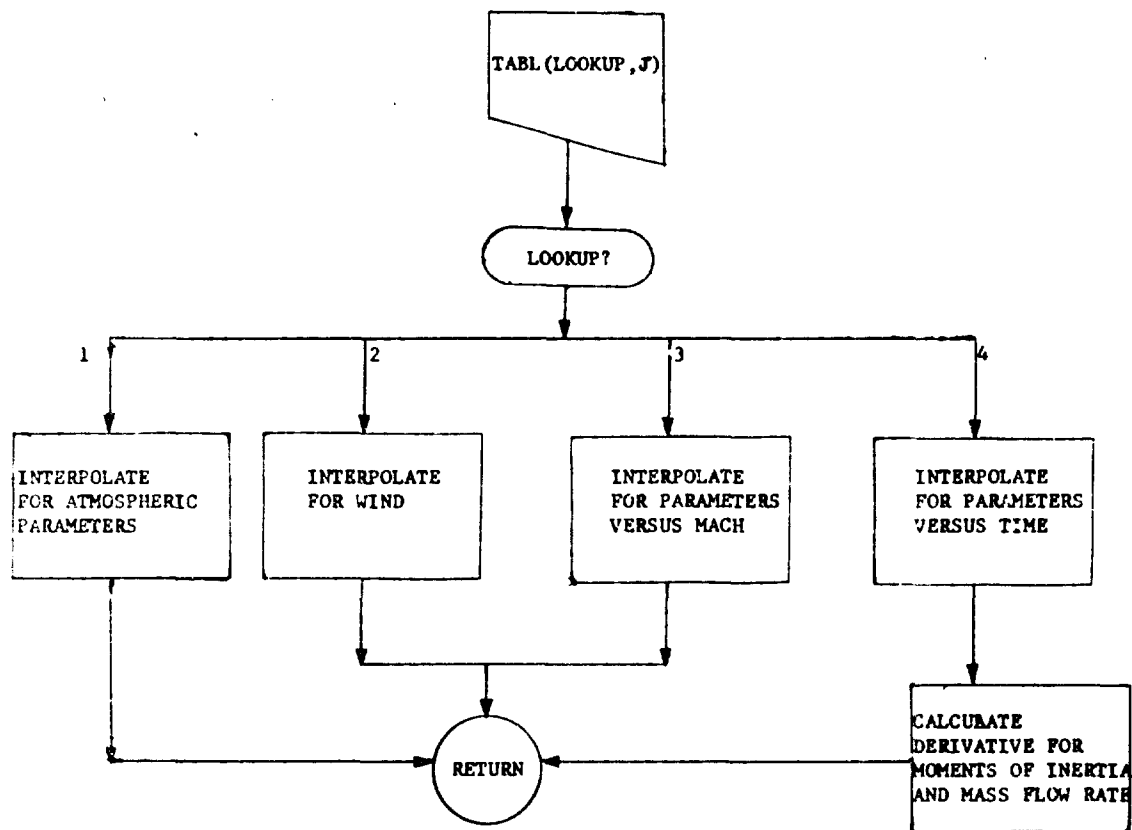
To conserve computer time the routine is programmed to "remember" the arguments used in the previous entry to the table. The "search" is either forward or backward depending upon the present value of the independent variable.

Suppose the independent variable lies outside the arguments of the table. For values from the Mach or atmosphere tables linear extrapolation is used; for the wind tables the value is set to zero; and, for the time tables the last value of the table is chosen.

The interpolation routine for the time table also provides for the calculations of the derivatives of the moments of inertia, and of the mass flow rate. The principal flads are:

CD	- Interpolated value of axial force coefficient.
CG (40)	- Entries of center of gravity in time table.
CL	- Interpolated value of normal force coefficient.
CLD	- Roll driving moment.
CLP	- Roll damping moment.
CMA(20)	- Entries of center of pressure in Mach table.
CMQ(20)	- Entries of coefficient of pitch damping moment in Mach table.
CMT	- Interpolated value of coefficient of pitch damping moment.
CNA(20)	- Entries of normal force coefficient in Mach table.
CND(40)	- Entries of roll driving coefficient.
CNP(40)	- Entries of roll damping coefficient.
CON	- Constant used for interpolation.
CP	- Interpolated value of center of pressure.
CX(20)	- Entries of coefficient of drag in Mach table.
DENS	- Interpolated value of atmospheric density.
DDMKOMK(3)	- Derivatives of moments of inertia.
FM(40)	- Entries of mass in time table.
FX(40)	- Entries of moment of inertia about x-axis in time table.

FY(40) - Entries of moment of inertia about y-axis in time table.
 IH(44) - Entries of height in atmospheric table.
 HP(50) - Entries of height in wind table.
 HT - Height of rocket above oblate earth.
 I1,I2,I3,I4 - Entry last used in the various tables.
 LOOKUP - Indicates which table to interpolate.
 N - Number of entries in the atmospheric table.
 NM - Number of entries in the Mach table.
 NT - Number of entries in the time table.
 NW - Number of entries in the wind table.
 PA(44) - Entries of pressure in atmospheric table.
 PM(20) - Entries of Mach number in Mach table.
 PRES - Interpolated value of pressure.
 RIO(44) - Entries of atmospheric density in atmospheric table.
 RM - Mach number.
 SPD - Interpolated value of speed of sound.
 T(40) - Entries of time in time table.
 TME(6) - Interpolated values of moment of inertia about the x-
 and y-axes, thrust, center of gravity, mass, and center
 of gravity of the propellant.
 TSL(40) - Entries of thrust in time table.
 WXP(50) - Entries of E-W components of wind.
 WXS - Interpolated value of E-W components of wind.
 WYP(50) - Entries of N-S components of wind.
 WYS - Interpolated value of N-S components of wind.



LISTING OF PROGRAM INSTRUCTIONS

\$ATEND	00000.77777.6.DUMP	00020
\$EXECUTE	1BJOB	00030
\$1BJOB	GO,LOGIC,MAP	00040
\$1BFTC LRHM	LIST,REF,DECK	00050
	COMMON Y(22.5),DY(22.5),ROFF1(22.5)	00060
C		00070
C	IN ALL COMMON STATEMENTS D=DRIVER,A=AOPTON,B=BFACT,E=EVAL,C=CHK,I=INT	00080
C	R2=KERR2,R=RKG,T=TABL,F=PHASIN,P=PINTRJ,X=XOUT,AND L=T12LP	00090
C		00100
	COMMON/DA/ IXWD,IYWD,SITHP,COTHP,ENF,THP,ALP	00110
C		00120
	COMMON/DAP/TH,AL,XWANT,YWANT,DELC,DELT,DELH,TOWTIL	00130
C		00140
	COMMON/DAEP/NTYPE	00150
C		00160
	COMMON/DAETX/ WXS,WYS	00170
C		00180
	COMMON/DB/ YSTOR(22),DYSTOR(22),RDFSTR(22),1BFEND	00190
C		00200
	COMMON/DBE/IWIND,IH,BHI	00210
C		00220
	COMMON/DBTP/NW,HP(50)	00230
C		00240
	COMMON/DE/REQ,PSL,GCON1,GNU	00250
C		00260
	COMMON/DEL/ SLAT,CLAT,SLATG,CLATG,TIMEO,W	00270
C		00280
	COMMON/DCP/ TO	00290
C		00300
	COMMON/DC/ NUF,IOUT	00310
C		00320
	COMMON/DCF/PI,TBO	00330
C		00340
	COMMON/DCI/ H	00350
C		00360
	COMMON/DI/ DONE	00370
C		00380
	COMMON/DIX/ TIME	00390
C		00400
	COMMON/DIR2/ NOGOOD	00410
C		00420
	COMMON/DT/ 11,12,13,14	00430
C		00440
	COMMON/DP/ UO,VO,WO,ZL,XLAT,NFAZE,NBST,IFOUT	00450
C		00460
	COMMON/DF/ TM11	00470
C		00480
	COMMON/DX/ IJK	00490
C		00500
	COMMON/DL/ RO	00510
C		00520
	COMMON/DEC/EPSQ	00530
C		00540

DIMENSION AIC(3,3),BIC(3,3)	00550
C	00560
C INITIALIZE	00570
C	00580
CNTR=0.	00590
READ(5,600)XNO	00600
600 FORMAT(16XF8.0)	00610
101 CALL PINTRJ	00620
DATA REQ,PSL,W,EPSQ,GCON1,GNU/20926428.,2116.,.72921E-04.,.00672207	00630
1.1,40775E 16.,.273E-03/	00640
TH=TH*.01745329	00650
AL=AL*.01745329	00660
XLAT=XLAT *.01745329	00670
SLAT=SIN(XLAT)	00680
CLAT=COS(XLAT)	00690
EPSQ=EPSQ**2	00700
TEN=EPSQ*SLAT*CLAT	00710
FIVE=1.-EPSQ*(CLAT**2)	00720
DLTA=ATAN2(TEN,FIVE)	00730
XLATG=XLAT+DLTA	00740
SLATG=SIN(XLATG)	00750
CLATG=COS(XLATG)	00760
RO=REQ/(1.+EPSQ*SLAT*SLAT/(1.-EPSQ))**.5	00770
ROA=RO+ZL	00780
BIC(1,1)=-1.0	00790
BIC(2,1)=0.0	00800
BIC(3,1)=0.0	00810
BIC(1,2)=0.0	00820
BIC(2,2)=-SLATG	00830
BIC(3,2)=CLATG	00840
BIC(1,3)=0.0	00850
BIC(2,3)=CLATG	00860
BIC(3,3)=SLATG	00870
TIMEO=TO	00880
C	00890
C SET UP FIRST APPROXIMATION FOR ITERATION FOR LAUNCHER SETTINGS	00900
C	00910
IF (INTYPE.EQ.2) GO TO 105	00920
IF (INTYPE.NE.3) GO TO 1	00930
IYWD=1	00940
IXWD=1	00950
THP=TH	00960
ALP=AL	00970
105 RANGE=SQRT(XWANT*XWANT+YWANT*YWANT)	00980
SITHP=XWANT/RANGE	00990
COTHP=YWANT/RANGE	01000
CALL AOPTUN(1)	01010
WR=WYS*COTHP+WXS*SITHP	01020
IF (WR.GE.0.) GO TO 102	01030
DETH=DELT	01040
GO TO 103	01050
102 DETH=DELT	01060
103 YUW=DETH*COTHP-DELC*SITHP	01070

XUW=DETH*SITHP+DELC*COTHP	01080
XDIF=XS*XUW*528 .	01090
YDIF=YS*YUW*528 .	01100
STCA=SIN(TH)*COS(AL)	01110
COST=COS(TH)	01120
TH1=ATAN2(STCA,COST)	01130
STSA=SIN(TH)*SIN(AL)	01140
TH2=ATAN2(STSA,COST)	01150
TH1=TH1-YDIF/TOWTIL	01160
TH2=TH2-XDIF/TOWTIL	01170
STH2=SIN(TH2)	01180
CTH1=COS(TH1)	01190
CTH2=COS(TH2)	01200
STH1=SIN(TH1)	01210
STCT21=STH2*CTH1	01220
CTS21=CTH2*STH1	01230
AL=ATAN2(STCT21,CTS21)	01240
COAST=COS(AL)	01250
STOCT1=STH1/CTH1	01260
BSTOR=ABS (STOCT1/COAST)	01270
TH=ATAN(BSTOR)	01280
C	01290
C CNTR,WHICH TRAJECTORY IN-- NUF=1,IMPACT--IJK IS LINE OF OUTPUT ON PA	01300
C	01310
C CONTINUE INITIALIZING	01320
C	01330
100 NUF=0	01340
1JK=0	01350
11=1	01360
12=1	01370
13=1	01380
14=1	01390
Y(1.5)=TIMEO	01400
STH=SIN(TH)	01440
CTH=COS(TH)	01450
SAL=SIN(AL)	01460
CAL=COS(AL)	01470
Y(17.5)=0.0	01480
Y(18.5)=ROA*CLAT	01490
Y(19.5)=ROA*SLAT	01500
AIC(1.1)=STH*SAL	01510
AIC(2.1)=STH*CAL	01520
AIC(3.1)=CTH	01530
AIC(1.2)=CAL	01540
AIC(2.2)=-SAL	01550
AIC(3.2)=0.0	01560
AIC(1.3)=SAL*CTH	01570
AIC(2.3)=CAL*CTH	01580
AIC(3.3)=-STH	01590
CALL MTRXL (BIC,AIC,3,Y(8.5))	01600
DY(17.5)=Y(8.5)*UO-W*Y(18.5)	
DY(18.5)=Y(9.5)*UO+W*Y(17.5)	
DY(19.5)=Y(10.5)*UO	

Y(2.5)=Y(8.5)*DY(17.5)+Y(9.5)*DY(18.5)+Y(10.5)*DY(19.5)	
Y(3.5)=Y(11.5)*DY(17.5)+Y(12.5)*DY(18.5)+Y(13.5)*DY(19.5)	
Y(4.5)=Y(14.5)*DY(17.5)+Y(15.5)*DY(18.5)+Y(16.5)*DY(19.5)	
Y(5.5)=0.	
Y(6.5)=0.	
Y(7.5)=W	
Y(20.5)=DY(17.5)	
Y(21.5)=DY(18.5)	
Y(22.5)=DY(19.5)	
DO 3 I=2,22	
ROFF1(I.5)=0.0	01640
3 CONTINUE	01650
CALL PHASIN(1)	01660
DO 2000 I=1,22	01670
YSTOR(I)=Y(I.5)	01680
DYSTOR(I)=DY(I.5)	01690
ROFSTR(I)=ROFF1(I.5)	01700
2000 CONTINUE	01710
J1=1	01720
IF (INTYPE.NE.4) GO TO 1	01730
C	01740
C IWIND WHAT ENTRY AT IN BALL FAC SUBROUTINE (HEIGHT TABLE)	01750
C	01760
IWIND=1	01770
J2=1	01780
C J1 IS THE PHASE WE ARE CURRENTLY WORKING IN	01790
C J2 IS THE PHASE (BF) TO PICK UP TRAJECTORY AT FOR BF PROGRAM	01800
11 BHI=HP(IWIND)	01810
C	01820
C IH=2 IN BALLISTIC FACTOR ROUTINE	01830
C	01840
10 IH=1	01850
CALL EVAL(5)	01860
CALL XOUT(5.0)	01870
C	01880
C MONITOR THE INTEGRATION	01890
C	01900
1 H=AMINI(PI, TMII)	01910
50 IF (IH.NE.2) GO TO 990	01920
2 CALL BALFAC(1)	01930
IF (IH.EQ.1) TMII=TMII*10.	01940
J2=J1	01945
990 TIME=Y(1.5)	01950
C	01960
C NOGOOD=0 INTEGRATION INTERVAL ACCEPTED =1 SET H=H/2.	01970
C	01980
991 NOGOOD=0	01990
5 CALL INTEG	02000
IF (DONE.EQ.2.) GO TO 9	02010
C	02020
C MONITOR OUTPUT	02030
C	02040
C IOUT=1. NO OUTPUT--IOUT=2. PRINT OUTPUT	02050
	02060

C IOUT=3. END OF PHASE--IOUT=4. IMPACT	02070
C	02080
CALL CHKOUT	02090
GO TO (50,6,7,8),IOUT	02100
9 CALL XOUT(5,1)	02110
GO TO 8	02120
C	02130
C IFOUT=1,PRINT OUT ONLY AT END OF PHASE	02140
C	02150
6 IF (IFOUT.EQ.1) GO TO 5	02160
CALL XOUT(5,0)	02170
GO TO 50	02180
7 J1=J1+1	02190
CALL XOUT(5,0)	02200
C	02210
C NFAZE IS THE NUMBER OF PHASES USED (TOTAL)	02220
C NBST PHASE END OF WHICH BOOSTER IS TO BE PICKED AT	02230
C	02240
IF (J1.GT.NFAZE) GO TO 1100	02250
IF (NBST.EQ.(J1-1))GO TO 20	02260
25 CALL PHASIN(J1)	02270
CALL EVAL(5)	02280
CALL XOUT(5,0)	02290
GO TO 1	02300
C	02310
C STORE Y AND DY ARRAYS FOR BOOSTER TO GROUND	02320
C	02330
20 DO 160 K=1,22	02340
YSTOR(K)=Y(K,5)	02350
160 CONTINUE	02360
DO 161 L=2,22	02370
DYSTOR(L)=DY(L,5)	02380
ROFSTR(L)=ROFF1(L,5)	02390
161 CONTINUE	02400
GO TO 25	02410
8 CALL XOUT(5,0)	02420
IF (INTYPE.EQ.4) GO TO 12	02430
IF (INTYPE.EQ.3) GO TO 13	02440
IF (INTYPE.EQ.2) GO TO 13	02450
IF (NBST.EQ.0) GO TO 11	02460
C UNSTORE Y,DY,T ETC FOR BOOSTER	02470
C	02480
DO 151 K=1,22	02490
151 Y(K,5)=YSTOR(K)	02500
DO 152 L=2,22	02510
DY(L,5)=DYSTOR(L)	02520
ROFF1(L,5)=ROFSTR(L)	02530
152 CONTINUE	02540
J1=J1+1	02550
TO=Y(1,5)	02560
CALL PHASIN(J1)	02570
CALL XOUT(5,0)	02580
GO TO 1	02590

13 CALL AOPTUN(3)	02600
C	02610
C ENF=1 FINISHED	02620
C	02630
IF (ENF.EQ.1.) GO TO 11	02640
GO TO 100	02650
C	02660
C IH IS INDICATOR TO CHECK IF WE ARE PAST HEIGHT OF CURRENT BF	02670
C	02680
12 CALL BALFAC(2)	02690
J1=J2	02700
C	02710
C IWIND IS THE ENTRY OF WIND TABLE CURRENTLY USING	02720
C	02730
IF (IWIND.GT.NW)IBFEND=1	02740
IF (IBFEND.EQ.1) GO TO 1010	02750
CALL PHASIN(J1)	02760
TMII=TMII/10.	02761
H=AMIN1 (PI,TMII)	02762
TO=TIMEO	02763
CALL CHKOUT	02764
I1=1	02770
I2=1	02780
I3=1	02790
I4=1	02800
IH=2	02810
BH1=HP(IWIND)	02820
CALL EVAL(5)	02830
CALL XOUT(5,0)	02840
GO TO 990	02850
1010 CALL BALFAC(1)	02860
1100 CNTR=CNTR+1.	02870
IF(CNTR.LT.XNO) GO TO 101	02880
RETURN	02890
END	02900
\$IBFTC AOPSWN LIST,REF,DECK	02910
SUBROUTINE AOPTUN(K)	02920
C	02930
C IN ALL COMMON STATEMENTS D=DRIVER,A=AOPTUN,B=BFACT,E=EVAL,C=CHK,I=INT	02940
C R2=RKERR2,R=RKG,T=TABL,F=PHASIN,P=PINTRJ,X=XOUT,AND L=TI2LP	02950
C	02960
COMMON/DA/ IXWD,IYWD,SITHP,COTHP,ENF,THP,ALP	02970
C	02980
COMMON/DAP/TH,AL,XWANT,YWANT,DELC,DELT,DELH,TOWTIL	02990
C	03000
COMMON/DAEP/NTYPE	03010
C	03020
COMMON/DAETX/ WXS,WYS	03030
C	03040
COMMON/AP/ XFIRST, FIRST,XCHANG,YCHANG,XLAST,YLAST,NBF,BF(50),	03050
1DELTA	03060
C	03070
COMMON/ABETP/ WXP(50),WYP(50)	03080

C	COMMON/ABXL/ XYZ(3)	03090
C	DIMENSION THETA(11,11),ALPHA(11,11)	03100
	GO TO (1,2,3),K	03110
	1 IF (NTYPE.EQ.2) GO TO 6	03120
C	SET UP INITIAL WIND PROFILE	03130
C	WXS=XFIRST	03140
	WYS=YFIRST	03150
	RETURN	03160
C	SET UP SUBSEQUENT WIND PROFILE	03170
C	2 IF (WXS.EQ.XLAST) GO TO 10	03180
	IXWD=IXWD+1	03190
	WXS=WXS+XCHANG	03200
	GO TO 21	03210
	10 IF (WYS.GE.YLAST) GO TO 11	03220
	IYWD=IYWD+1	03230
	IXWD=1	03240
	WXS=XFIRST	03250
	WYS=WYS+YCHANG	03260
	GO TO 21	03270
C	OBTAIN BALLISTIC WINDS FOR ITERATIVE	03280
C	60 SUMX=0.	03290
	SUMY=0.	03300
	DO 61 I=1,NBF	03310
	SUMX=SUMX+WXP(I)*BF(I)	03320
	SUMY=SUMY+WYP(I)*BF(I)	03330
	61 CONTINUE	03340
	WXS=SUMX	03350
	WYS=SUMY	03360
	RETURN	03370
C	PRINT OUT ANGLES	03380
C	11 DO 75 M=1,IYWD	03390
	DO 75 N=1,IXWD	03400
	THETA(N1,M1)=THETA(N1,M1)*57.29578	03410
	ALPHA(N1,M1)=ALPHA(N1,M1)*57.29578	03420
	75 CONTINUE	03430
	DO 71 M=1,IYWD	03440
	WRITE (6,70) (THETA(I,M),ALPHA(I,M),I=1,IXWD)	03450
	70 FORMAT (1H0,2X,11(F8.3,2X)/(11(2X,F8.3)))	03460
	71 CONTINUE	03470
C	ENF=1 FINISHED TABLE	03480
C	12 ENF=1.	03490
		03500
		03510
		03520
		03530
		03540
		03550
		03560
		03570
		03580
		03590
		03600
		03610

RETURN	03620
C	03630
C CHECK IF IMPACT IS WITHIN TOLERANCE	03640
C	03650
3 XDIF=XYZ(1)-XWANT	03660
YDIF=XYZ(2)-YWANT	03670
TESTVA=SQRT(XDIF**XDIF+YDIF**YDIF)	03680
IF (TESTVA.LE.DELTA) GO TO 20	03690
C	03700
C ITERATIVE TECHNIQUE FOR COMPUTING LAUNCHER SETTINGS	03710
C	03720
30 STCA=SIN(TH)*COS(AL)	03730
COST=COS(TH)	03740
TH1=ATAN2(STCA,COST)	03750
STSA=SIN(TH)*SIN(AL)	03760
TH2=ATAN2(STSA,COST)	03770
TH1=TH1-YDIF/TOWTIL	03780
TH2=TH2-XDIF/TOWTIL	03790
STH2=SIN(TH2)	03800
CTH1=COS(TH1)	03810
CTH2=COS(TH2)	03820
STH1=SIN(TH1)	03830
STCT21=STH2*CTH1	03840
CTS21=CTH2*STH1	03850
AL=ATAN2(STCT21,CTS21)	03860
COAST=COS(AL)	03870
STOCT1=STH1/CTH1	03880
BSTOR=ABS (STOCT1/COAST)	03890
TH=ATAN(BSTOR)	03900
RETURN	03910
20 IF (NTYPE.EQ.2) GO TO 12	03920
C	03930
C STORE LAUNCHER SETTING FOR ANGULAR OUTPUT IN TABLE	03940
C	03950
THETA(IXWD,IYWD)=TH	03960
ALPHA(IXWD,IYWD)=AL	03970
GO TO 2	03980
C	03990
C DETERMINE APPROXIMATE THEORETICAL DISPLACEMENT FOR NEXT TRAJECTORY	04000
C	04010
21 IF (WXS.EQ.0..AND.WYS.EQ.0.) GO TO 23	04020
IF (IYWD.EQ.1) GO TO 22	04030
TH=THETA(IXWD,IYWD-1)	04040
AL=ALPHA(IXWD,IYWD-1)	04050
IF(COTHP.GE.0.) GO TO 41	04060
DETH=DELT	04070
GO TO 42	04080
23 THETA(IXWD,IYWD)=THP	04090
ALPHA(IXWD,IYWD)=ALP	04100
GO TO 2	04110
41 DETH=DELH	04120
42 YUW=DELT*COTHP-DELC*SITHP	04130
YDIF=YCHANG*YUW*5280.	04140

XDIF=0.	04150
GO TO 30	04160
22 TH=THETA(XWD-1,IYWD)	04170
AL=ALPHA(XWD-1,IYWD)	04180
IF(SITHP.GE.0.) GO TO 51	04190
DETH=DELT	04200
GO TO 52	04210
51 DETH=DELM	04220
52 XUW=DELC*COTHP+DETH*SITHP	04230
YDIF=0.	04240
XDIF=XCHANG*XUW*5280.	04250
GO TO 30	04260
END	04270
*IBFTC BFACT LIST,REF,DECK	04280
SUBROUTINE BALFAC(INTA)	04290
COMMON Y(22,5),DY(22,5),ROFF1(22,5)	04300
C	04310
C IN ALL COMMON STATEMENTS D=DRIVER,A=AOPTUN,B=BFACT,E=EVAL,C=CHK,I=INT	04320
C R2=RKERR2,R=RKG,T=TABL,F=PHASIN,P=PINTRJ,X=XOUT,AND L=T12LP	04330
C	04340
COMMON/DB/ YSTOR(22),DYSTOR(22),ROFSTR(22),IBFEND	04350
C	04360
COMMON/DBE/IWIND,IH,BHI	04370
C	04380
COMMON/DBTP/NW,HP(50)	04390
C	04400
COMMON/ABETP/ WXP(50),WYP(50)	04410
C	04420
COMMON/ABXL/ XYZ(3)	04430
C	04440
COMMON/BET/ HT	04450
C	04460
COMMON/BIR2/ YSAVE(22),DYSAVE(22),ROFFS(22)	04470
C	04480
COMMON/BPX/ IDEN	04490
C	04500
DIMENSION XIMPAT(50),YIMPAT(50)	04510
C	04520
C BALFAC MONITORS BALLISTIC FACTOR PROGRAM	04530
C IBFEND=1 WE FINISHED LAST TRAJECTORY	04540
C	04550
IF (IBFEND.EQ.1) GO TO 102	04560
IF (INTA.EQ.2) GO TO 15	04570
C	04580
C CHECK HEIGHT OF SIMULATED TRAJECTORY VERSUS HEIGHT OF CURRENT WIND PR	04590
C	04600
IF (HT.GE.BHI) GO TO 18	04610
GO TO 101	04620
C	04630
C STORE Y AND DY ARRAYS FOR NEXT TRAJECTORY	04640
C	04650
180 DO 103 I=1,22	04660
103 YSTOR(I)=YSAVE(I)	04670

DO 104 M=2.22	04680
DYSTOR(M)=DYSAVE(M)	04690
ROFSTR(M)=ROFFS(M)	04700
104 CONTINUE	04710
IH=1	04720
101 RETURN	04730
C	04740
C CALCULATE BALLISTIC FACTORS AND UNIT WIND EFFECT	04750
C	04760
102 WRITE (6,110) IDEN	04770
DIFX=XIMPAT(NW)-XIMPAT(1)	04780
DIFY=YIMPAT(NW)-YIMPAT(1)	04790
DIFX=DIFX/5280.	04800
DIFY=DIFY/5280.	04810
DELR=SQRT(DIFX**2+DIFY**2)	04820
WIND=SQRT(WXP(NW)**2+WYP(NW)**2)	04830
UNIT=DELR/WIND	04840
DENOM=0.	04850
DO 105 I=1,NW	04860
DIFX=XIMPAT(I)-XIMPAT(1)	04870
DIFY=YIMPAT(I)-YIMPAT(1)	04880
DIFX=DIFX/5280.	04890
DIFY=DIFY/5280.	04900
RANGE=SQRT(DIFX**2+DIFY**2)	04910
RATIO=RANGE/DELR	04920
BFACT=RATIO-DENOM	04930
WRITE (6,111) HP(I),XIMPAT(I),YIMPAT(I),DIFX,DIFY,RANGE,RATIO.	04940
BFACT	04950
DENOM=RATIO	04960
105 CONTINUE	04970
WRITE (6,120) UNIT	04980
120 FORMAT (1H0/1H01 X17HUNIT WIND EFFECT=F10.6)	04990
RETURN	05000
C	05010
C STORE CURRENT IMPACT AND UNSTORE Y AND DY ARRAYS FOR NEXT TRAJECTORY	05020
C	05030
C IWIND IS THE ENTRY OF WIND TABLE CURRENTLY USING	05040
C	05050
150 IWIND=IWIND+1	05060
XIMPAT(IWIND-1)=XYZ(1)	05070
YIMPAT(IWIND-1)=XYZ(2)	05080
DO 151 K=1,22	05090
Y(K,5)=YSTOR(K)	05100
151 CONTINUE	05110
DO 152 L=2.22	05120
DY(L,5)=DYSTOR(L)	05130
ROFF1(L,5)=ROFSTR(L)	05140
152 CONTINUE	05150
GO TO 101	05160
110 FORMAT (1H1/1H012A6/1H0/1H010X,6HHEIGHT,13X,1HX,13X,1HY,14X,	7H 05170
1DELTA X,8X,7HDELTA Y,9X,5HRANGE,10X,5HRATIO,11X,4HBF./1H0)	05180
111 FORMAT (1H05XF10.2,7F15.4)	05190
END	05200

SIBFTC EVALU LIST,REF,DECK	05210
SUBROUTINE EVAL (J)	05220
COMMON Y(22,5),DY(22,5),ROFF1(22,5)	05230
C	05240
C IN ALL COMMON STATEMENTS D=DRIVER,A=AOPTUN,B=BFACT,E=EVAL,C=CHK,I=INT	05250
C R2=RKERR2,R=RKG,T=TABL,F=PHASIN,P=PINTRJ,X=XOUT,AND L=TI2LP	05260
C	05270
COMMON/DAEP/NTYPE	05280
C	05290
COMMON/DAETX/ WXS,WYS	05300
C	05310
COMMON/DBE/IWIND,TH,BHI	05320
C	05330
COMMON/DE/REQ,PSL,GCON1,GNU	05340
C	05350
COMMON/DEL/ SLAT,CLAT,SLATG,CLATG,TIMEO,W	05370
C	05380
COMMON/ABETP/ WXP(50),WYP(50)	05390
C	05400
COMMON/BET/ HT	05410
C	05420
COMMON/EC/ CHEK,RS	05430
C	05440
COMMON/EP/ MAL	05450
C	05460
COMMON/DEC/EP SQ	05470
C	
COMMON/ET/RHO,VS,PA,CX,CNA,CMA,CMQ,FX,FY,TSL,CG,FM,RM,DMKOMK(3),	
IFLOW,CLD,CLP	
C	05500
COMMON/EFT/KAN	05510
C	05520
COMMON/EF/ REFL,AE,DSQ,XLT,FINC	
C	05540
DIMENSION A(3,3),F(3),E(3),AM(3,3),WS(3)	05550
EQUIVALENCE (E(1),WX),(E(2),WY),(E(3),WZ)	05570
DIMENSION WDOT(6)	
EQUIVALENC (WDOT(1),P),(WDOT(2),Q),(WDOT(3),R)	
C	05580
C NORMALIZE DIRECTION COSINES	05590
C	05600
DO 1 I=8,14,3	05610
JP=I+2	05620
AY=SQRT(Y(1,J)**2+Y(I+1,J)**2+Y(JP,J)**2)	05630
DO 1 K=1,JP	05640
1 Y(K,J)=Y(K,J)/AY	05650
C	05660
C INTERPOLATE FOR WINDS AND COMPUTE COMPONENTS IN BODY SYSTEM	05670
C	05680
CHEK=SQRT(Y(17,J)**2+Y(18,J)**2+Y(19,J)**2)	05690
RS=20926428./((1.+EPSQ*(Y(19,J)/CHEK)**2/(1.-EPSQ))**.5)	05700
HRO= SQRT(Y(17,J)**2+Y(18,J)**2+Y(19,J)**2)	05710
HT=HRO-RS	05720

CALL TABL(1,J)	05730
IF (NTYPE.EQ.3) GO TO 12	05740
IF (NTYPE.NE.4) GO TO 11	05750
IF (IH.NE.2) GO TO 13	05760
IF (HT.GT.8H1) GO TO 13	05765
WXS=WXP(IWIND)	05770
WYS=WYP(IWIND)	05780
GO TO 12	05790
13 WXS=0.	05800
WYS=0.	05810
GO TO 12	05820
11 CALL TABL(2,J)	05830
12 WS(1)=WXS	05840
WS(2)=WYS	05850
WS(3)=0.	05860
WT=W*(Y(1,J)-TIMEO)	05870
C	05880
C COMPUTATION OF LAUNCHERTO ECI ROTATION MATRIX	05890
C	05900
A(1,1)= -COS(WT)	05910
A(2,1)= -SIN(WT)	05920
A(3,1)= 0.0	05930
A(3,2)= CLATG	05940
A(3,3)= SLATG	05950
A(1,2)= -A(3,3)*A(2,1)	05960
A(2,2)= A(3,3) *A(1,1)	05970
A(1,3)= A(3,2)*A(2,1)	05980
A(2,3)= -A(3,2)*A(1,1)	05990
CALL MTRXL (A,WS,1,F)	06000
F(1)=-F(1)*1.466667-W*Y(18,J)	
F(2)=-F(2)*1.466667+W*Y(17,J)	
F(3)=-F(3)*1.466667	
WXINT=F(1)	
WYINT=F(2)	
WZINT=F(3)	
DO 2 I=1,3	06010
AM(1,I)=Y(I+7,J)	06020
AM(2,I)=Y(I+10,J)	06030
2 AM(3,I)=Y(I+13,J)	06040
CALL MTRXL (AM,F,1,E)	06050
DY(17,J)=Y(20,J)	
DY(18,J)=Y(21,J)	
DY(19,J)=Y(22,J)	
CALL MTRXL (AM,DY(17,J),1,Y(2,J))	
UP=Y(2,J)-WX	
VP=Y(3,J)-WY	
WP=Y(4,J)-WZ	
VA=SQRT (UP**2+VP**2+WP**2)	06090
SB=VP/VA	06100
SA=WP/VA	06110
QP=(.5*RHO*VA)*VA	06120
RM=VA/VS	06130
CALL TABL(3,J)	06140

CALL MTRXL (AM,Y(5,J),1,WDOT(1))	
DV=REFL*.5/VA	06150
PD=P*DV	06160
CD=CNP*PD	06170
DB=PD*SB	06180
CY=CNA*SB-CD*SA	06190
CZ=CNA*SA+CD*SB	06200
GO TO(200,200,2 1,200,200).J	06210
200 CALL TABL(4,J)	06220
C	06230
C COMPUTE TOTAL AERODYNAMIC FORCE AND MOMENT COEFFICIENTS	06240
C	06250
C MAL=1 INPUT CENTER OF PRESSURE , MAL=2 INPUT RESTORING MOMENT COEFFIC	06260
C	06270
201 GO TO (3,4),MAL	06280
3 CP=CMA	06290
CMA=-CNA*ABS(CG-CP)/REFL	06300
4 CMY=CMA*SA+CMQ*3*DV	06310
CMX=CLD*F INC+(1-REFL*.5/VA)*CLP	
CMZ=CMQ*R*DV-CMA*SB	06330
CT=TSL+AE*(PSL-PA)	06340
C	06350
C COMPUTE ACCELERATIONS IN BODY SYSTEM	06360
C	06370
IF (KAN.EQ.2) CT=0.	06380
COS2L= (Y(17,J)*Y(17,J)+Y(18,J)*Y(18,J)-Y(19,J)*Y(19,J))/(HRO**2)	06390
G=GCON1/HRO**3*(1.-3.*REQ*REQ*GNU*(1.-3.*COS2L)/HRO**2)	06400
CALL MTRXL (AM,Y(17,J),1,F)	06410
FQA=QP*DSQ	06450
FQR=FQA*REFL	06460
FZ=FY	06470
DY(2,J)= -F(1)*G+(CT-CX*FQA)/FM	06480
DY(3,J)= -F(2)*G-(CY*FQA)/FM	06490
DY(4,J)= -F(3)*G-(CZ*FQA)/FM	06500
WDOT(4)=((FY-FZ)*Q*R+CMX*FQR)/FX	
WDOT(5)=((FZ-FX)*P*R+CMY*FQR)/FY	
WDOT(6)=((FX-FY)*P*Q+CMZ*FQR)/FZ	
IF(KAN.EQ.2) GO TO 41	06540
WDOT(4)=WDOT(4)-DMKOMK(1)*P	06550
WDOT(5)=WDOT(5)-DMKOMK(2)*Q	06560
WDOT(6)=WDOT(6)-DMKOMK(2)*R	06570
501 DAMP=FLOW*(XLT-CG)**2	
WDOT(5)=WDOT(5)+DAMP*Q/FY	
WDOT(6)=WDOT(6)+DAMP*R/FZ	
41 CALL MTRXL(Y(8,J),WDOT(4),1,DY(5,J))	
DO 5 KA=8,10	06580
KD=KA+3	06590
KE=KA+6	06600
DY(KA,J)=R*Y(KD,J)-Q*Y(KE,J)	06610
DY(KD,J)=P*Y(KE,J)-R*Y(KA,J)	06620
5 DY(KE,J)=Q*Y(KA,J)-P*Y(KD,J)	06630
CALL MTRXL (Y(8,J),DY(2,J),1,DY(20,J))	
RETURN	06700

END	06710
\$IE IT	
\$IBFTC MTR LIST,REF,DECK	06720
SUBROUTINE MTRXL(A1,A2,NC2,PRO)	06730
DIMENSION A1(3,3),A2(3,3),PRO(3,3)	06740
DO 1 I=1,3	06750
DO 1 J=1,NC2	06760
PRO(I,J)= 0.0	06770
DO 1 K=1,3	06780
1 PRO(I,J) = PRO(I,J)+A1(I,K)*A2(K,J)	06790
RETURN	06800
END	06810
\$IBFTC CHK LIST,REF,DECK	06820
SUBROUTINE CHKOUT	06830
COMMON Y(22,5),DY(22,5),ROFF1(22,5)	06840
C	06850
C IN ALL COMMON STATEMENTS D=DRIVER,A=AOPTUN,B=BFACT,E=EVAL,C=CHK,I=INT	06860
C R2=RKERR2,R=RKG,T=TABL,F=PHASIN,P=PINTRJ,X=XOUT,AND L=TI2LP	06870
C	06880
COMMON/DCP/ TO	06890
C	06900
COMMON/DC/ NUF,IOUT	06910
C	06920
COMMON/DCF/PI,TBO	06930
C	06940
COMMON/DCI/ H	06950
C	06960
COMMON/EC/ CHEK,RS	06970
C	06980
COMMON/CF/ TFP	06990
C	07000
COMMON/PC/ ZIM	07010
C	07020
COMMON/DEC/EPSQ	07030
C	07040
C	07050
C IOUT=1, NO OUTPUT--IOUT=2, PRINT OUTPUT	07060
C IOUT=3, END OF PHASE--IOUT=4, IMPACT	07070
C	07080
NUF=0	07090
IF(Y(1,5).EQ.TFP)GO TO 5	07100
CHEK=SQRT(Y(17,5)**2+Y(18,5)**2+Y(19,5)**2)	07110
RS=20926428./((1.+EPSQ*(Y(19,5)/CHEK)**2/(1.-EPSQ))**.5)	07120
EMPT=RS+ZIM	07130
IF(CHEK.LE.EMPT)NUF=1	07140
IF(NUF.EQ.1.AND.Y(1,5).GT.20.)GO TO 2	07150
ENDPH=ABS(TBO-Y(1,5))	07160
IF(ENDPH.LT..001)GO TO 3	07170
DIF=ABS(Y(1,5)-T0)	07180
P0=AMOD(DIF,PI)	07190
IF(ABS(P0-PI).LT..0001)GO TO 4	07200
IF(P0.LT..001)GO TO 4	07210
P0=PI-P0	07220

H=AMIN1(H,PO,ENDPH)	07230
IOUT=1	07240
GO TO 1	07250
4 IOUT=2	07260
H=AMIN1(H,PI,ENDPH)	07270
GO TO 1	07280
3 IOUT=3	07290
TO=TBO	07300
GO TO 1	07310
2 IOUT=4	07320
GO TO 1	07330
5 TO=TFP	07340
ENDPH=TBO-TFP	07350
GO TO 4	07360
1 RETURN	07370
END	07380
\$1BFTC INTEGR LIST,REF,DECK	07390
SUBROUTINE INTEG	07400
COMMON Y(22,5),DY(22,5),ROFF1(22,5)	07410
C	07420
C IN ALL COMMON STATEMENTS D=DRIVER,A=AOPTUN,B=BFACT,E=EVAL,C=CHK,I=INT	07430
C R2=RKERR2,R=RKG,T=TABL,F=PHASIN,P=PINTRJ,X=XOUT,AND L=T12LP	07440
C	07450
COMMON/DC1/ H	07460
C	07470
COMMON/D1/ DONE	07480
C	07490
COMMON/DIX/ TIME	07500
C	07510
COMMON/DIR2/ NOGOOD	07520
C	07530
COMMON/BIR2/ YSAVE(22),DYSAVE(22),ROFFS(22)	07540
C	07550
COMMON/IR2/ IND,YHALF(22)	07560
C	07570
C INTEG IS THE INTEGRATION MONITOR WHIC CONTROLS THE RUNGA KUTT INTEGRAT	07580
C AND THE EKROR CHECK	07590
C SAVE THE INITIAL CONDITIONS	07600
DO 1 I=1,22	07610
YSAVE(I)=Y(I,5)	07620
DYSAVE(I)=DY(I,5)	07630
1 ROFFS(I)=ROFF1(I,5)	07640
CALL RKG(H,TIME)	07650
3 NOGOOD=0	07660
CALL RKERR2(H)	07670
IF(IND.EQ.19)GO TO 24	07680
IF(NOGOOD.EQ.0) GO TO 23	07690
C IF NOGOOD EQUALS 0 THE INTEGRATION IS ACCEPTABLE. IF IN ADDITION IND I	07700
C EQUAL TO 19 DT IS DOUBLED FOR THE NEXT PASS.	07710
IF(H.LT..0001) GO TO 25	07720
H=H/2.	07730
Y(1,1)=TIME	07740
DO 2 I=2,22	07750

2 Y(1,5)=YHALF(1)	07760
GO TO 3	07770
25 DONE=2.0	07780
C DONE IS AN INDICATOR TO TELL IF THE SIMULATION SHOULD BE CONTINUED 1.Y	07790
RETURN	07800
24 H=2.0*H	07810
23 DONE=1.0	07820
RETURN	07830
END	07840
\$IBFTC RKER2 LIST,REF,DECK	07850
SUBROUTINE RKERR2 (H)	07860
COMMON Y(22,5),DY(22,5),ROFF1(22,5)	07870
C	07880
C IN ALL COMMON STATEMENTS D=DRIVER,A=AOPTUN,B=BFACT,E=EVAL,C=CHK,I=INT	07890
C R2=RKERR2,R=RKG,T=TABL,F=PHASIN,P=PINTRJ,X=XOUT,AND L=T12LP	07900
C	07910
COMMON/BIR2/ YSAVE(22),DYSAVE(22),ROFFS(22)	07920
C	07930
COMMON/IR2/ IND,YHALF(22)	07940
C	07950
COMMON/FR2/EPTINY,EPBIG	07960
C	07970
COMMON/DIR2/ NOGOOD	07980
C	07990
DIMENSION YI(22),TRUNC(22),YII(22)	08000
YI(1)=Y(1,5)	08010
DO 1 I=2,22	08020
YI(I)=Y(I,5)	08030
1 CONTINUE	08040
DO 7 K=2,22	08050
Y(K,5)=YSAVE(K)	08060
DY(K,5)=DYSAVE(K)	08070
ROFF1(K,5)=ROFFS(K)	08080
7 CONTINUE	08090
IND=1	08100
HALF=H/2.	08110
CALL RKG (HALF,Y(1,1))	08120
DO 10 K=1,22	08130
10 YHALF(K)=Y(K,5)	08140
CALL RKG (HALF,Y(1,5))	08150
YII(1)=Y(1,5)	08160
DO 3 II=2,22	08170
YII(II)=Y(II,5)	08180
3 CONTINUE	08190
DO 4 I=5,22	
IF(ABS(YII(I))-YI(I)).LT..000001) GO TO 2	08210
TRUNC(I)=.02222222 *ABS((YII(I)-YI(I))/YI(I))	08220
IF(TRUNC(I).GT.EPBIG)GO TO 5	08230
IF(TRUNC(I).LT.EPTINY)IND=IND+1	08240
GO TO 4	08250
2 IND=IND+1	08260
4 CONTINUE	08270
GO TO 6	08280

5 NOGOOD=1	08290
6 RETURN	08300
END	08310
\$IBFTC RKGA LIST,REF,DECK	08320
SUBROUTINE RKG (H,TIME)	08330
COMMON Y(22,5),DY(22,5),ROFF1(22,5)	08340
DIMENSION A(4),B(4),C(4)	08350
DATA A(1),B(1),C(1),A(2),B(2),C(2),A(3),B(3),C(3),A(4),B(4),C(4)/	08360
1.5,2.,.5.,.2928932,1.,.2928932,1.7071068,1.,.1.7071068.,.16666666,2.	08370
2.,.5/	08380
J=1	08390
99 GO TO (1,2,3,4),J	08400
1 Y(1,1)=TIME	08410
DO 11 I=2,22	08420
Y(1,1)=Y(1,5)	08430
DY(1,1)=DY(1,5)	08440
ROFF1(1,1)=ROFF1(1,5)	08450
11 CONTINUE	08460
GO TO 5	08470
2 Y(1,2)=Y(1,1)+H/2.	08480
GO TO 6	08490
3 Y(1,3)=Y(1,2)	08500
GO TO 6	08510
4 Y(1,4)=Y(1,3)+H/2.	08520
6 CALL EVAL (J)	08530
5 DO 50 I=5,22	
Y(1,J+1)=Y(1,J)+H*(A(J)*(DY(1,J)-B(J)*ROFF1 (1,J)))	08550
ROFF1(1,J+1) = ROFF1(1,J)+3.*(A(J)*(DY(1,J)-B(J)*ROFF1(1,J)))	08560
1-C(J)*DY(1,J)	08570
50 CONTINUE	08580
IF(J.EQ.4)GO TO 52	08590
GO TO 53	08600
52 JT=J+1	08610
Y(1,5)=Y(1,4)	08620
CALL EVAL (JT)	08630
GO TO 100	08640
53 J=J+1	08650
GO TO 99	08660
100 RETURN	08670
END	08680
\$IBFTC TAB LIST,REF,DECK	08690
SUBROUTINE TABL(LOOKUP,J)	08700
COMMON Y(22,5),DY(22,5),ROFF1(22,5)	08710
C	08720
C IN ALL COMMON STATEMENTS D=DRIVER,A=AOPTUN,B=BFACT,E=EVAL,C=CHK,I=INT	08730
C R2=RKERR2,R=RKG,T=TABL,F=PHASIN,P=PINTRJ,X=XOUT,AND L=T12LP	08740
C	08750
COMMON/PT/ N,HH(44),RHO(44),VS(44),PA(44)	08760
C	08770
COMMON/DAETX/ WXS,WYS	08780
C	08790
COMMON/DBTP/NW,HP(50)	08800
C	08810

	COMMON/DT/ I1,I2,I3,I4	08820
C		08830
	COMMON/ABETP/ WXP(50),WYP(50)	08840
C		08850
	COMMON/BET/ HT	08860
	COMMON /FT/ PM(20),CX(20),CNA(20),CMA(20),CMQ(20),T(40),FX(40),	08870
	IFY(40),TSL(40),CG(40),FM(40),NM,NT,CND(20),CNP(20)	
C		08880
	COMMON/ET/DENS,SPD,PRES,CD,CL,CP,CMT,TME(5),RM,DMKOMK(3),FLOW	088
	1,CLD,CLP	
C		08900
C		08920
	COMMON/EFT/KAN	08930
C		08940
C	I1,I2,I3,I4 IS WHAT LAST ENTRY FROM THE ATMOS,WIND,MACH AND TIME TAB	08950
C		08960
	GO TO (I1,I2,I3,I4),LOOKUP	08970
C		08980
C	INTERPRET FOR ATMOSPHERIC PARAMETERS	08990
C		09000
	1 IF (HH(I1).LT.HT) GO TO 5	09010
	7 IF (HH(I1-1).LT.HT) GO TO 6	09020
	IF (I1.EQ.2) GO TO 6	09030
	I1=I1-1	09040
	GO TO 7	09050
	5 IF (I1.EQ.N) GO TO 6	09060
	I1=I1+1	09070
	IF (I1.LT.N) GO TO 1	09080
	6 CON=(HH(I1-1)-HT)/(HH(I1-1)-HH(I1))	09090
	DENS=RHO(I1-1)-(RHO(I1-1)-RHO(I1))*CON	09100
	SPD=VS(I1-1)-(VS(I1-1)-VS(I1))*CON	09110
	PRES=PA(I1-1)-(PA(I1-1)-PA(I1))*CON	09120
	RETURN	09130
C		09140
C	INTERPRET FOR WIND	09150
C		09160
	2 IF (NW.EQ.1) GO TO 15	09170
	14 IF (HP(I2).LT.HT) GO TO 10	09180
	12 IF (HP(I2-1).LT.HT) GO TO 11	09190
	I2=I2-1	09200
	IF (I2.EQ.1) GO TO 17	09210
	GO TO 12	09220
	10 IF (I2.EQ.NW) GO TO 16	09230
	I2=I2+1	09240
	GO TO 14	09250
	11 CON=(HP(I2-1)-HT)/(HP(I2-1)-HP(I2))	09260
	WXS=WXP(I2-1)-(WXP(I2-1)-WXP(I2))*CON	09270
	WYS=WYP(I2-1)-(WYP(I2-1)-WYP(I2))*CON	09280
	GO TO 13	09290
	17 I2=2	09295
	16 WXS=0.	09300
	WYS=0.	09310
	GO TO 13	09320

15	WXS=WXP(1)	09330
	WYS=WYP(1)	09340
13	RETURN	09350
C		09360
C	INTERPRET FOR PARAMETERS VERSUS MACH	09370
C		09380
3	IF (PM(I3).LT.RM)GO TO 20	09390
22	IF (PM(I3-1).LT.RM) GO TO 21	09400
	IF (I3.EQ.2) GO TO 21	09410
	I3=I3-1	09420
	GO TO 22	09430
20	IF (I3.EQ.NM) GO TO 21	09440
	I3=I3+1	09450
	IF (I3.LT.NM)GO TO 3	09460
21	CON=(PM(I3-1)-RM)/(PM(I3-1)-PM(I3))	09470
	CD=CX(I3-1)-(CX(I3-1)-CX(I3))*CON	09480
	CL=CNA(I3-1)-(CNA(I3-1)-CNA(I3))*CON	09490
	CP=CMA(I3-1)-(CMA(I3-1)-CMA(I3))*CON	09500
	CMT=CMQ(I3-1)-(CMQ(I3-1)-CMQ(I3))*CON	09510
	CLD=CND(I3-1)-(CND(I3-1)-CND(I3))*CON	
	CLP=CNP(I3-1)-(CNP(I3-1)-CNP(I3))*CON	
	RETURN	09520
C		09530
C	INTERPRET FOR PARAMETERS VERSUS TIME	09540
C		09550
4	IF (NT.EQ.1) GO TO 40	09560
32	IF (T(I4).LT.Y(1,J)) GO TO 30	09570
	IF (T(I4-1).LT.Y(1,J)) GO TO 31	09580
	IF (I4.EQ.2) GO TO 31	09590
	I4=I4-1	09600
	GO TO 32	09610
30	IF (I4.EQ.NT) GO TO 33	09620
	I4=I4+1	09630
	IF (I4.LT.NT)GO TO 32	09640
31	CON=(T(I4-1)-Y(1,J))/(T(I4-1)-T(I4))	09650
	TME(1)=FX(I4-1)-(FX(I4-1)-FX(I4))*CON	09660
	TME(2)=FY(I4-1)-(FY(I4-1)-FY(I4))*CON	09670
	TME(3)=TSL(I4-1)-(TSL(I4-1)-TSL(I4))*CON	09680
	TME(4)=CG(I4-1)-(CG(I4-1)-CG(I4))*CON	09690
	TME(5)=FM(I4-1)-(FM(I4-1)-FM(I4))*CON	09700
34	DMKOMK(1)=(FX(I4-1)-FX(I4))/(T(I4-1)-T(I4))/FX	09720
	DMKOMK(2)=(FY(I4-1)-FY(I4))/(T(I4-1)-T(I4))/FY	09730
	DMKOMK(3)=DMKOMK(2)	09740
	FLOW=(FM(I4-1)-FM(I4))/(T(I4-1)-T(I4))	
	GO TO 13	09750
33	TME(1)=FX(NT)	09760
	TME(2)=FY(NT)	09770
	TME(3)=TSL(NT)	09780
	TME(4)=CG(NT)	09790
	TME(5)=FM(NT)	09800
	IF (KAN.EQ.2) GO TO 201	09820
	GO TO 34	09830
40	TME(1)=FX(1)	09840

TME(2)=FY(1)	09850
TME(3)=TSL(1)	09860
TME(4)=CG(1)	09870
TME(5)=FM(1)	09880
201 DO 200 I=1,3	09900
200 DMKOMK(1)=0.	09910
RETURN	09920
END	09930
\$1BFTC FAZIN LIST,REF,DECK	09940
SUEROUTINE PHASIN(J)	09950
C	09960
C IN ALL COMMON STATEMENTS D=DRIVER,A=AOPTUN,B=BFACT,E=EVAL,C=CHK,I=INT	09970
C R2=RKERR2,R=RKG,T=TABL,F=PHASIN,P=PINTRJ,X=XOUT,AND L=T12LP	09980
C	09990
COMMON/DCF/PI,TBO	10000
C	10010
COMMON/DF/ TMI	10020
C	10030
COMMON/CF/ TFP	10040
C	10050
COMMON/FR2/EPT:NY,EPBIG	10060
C	10070
COMMON /FT/ PM(20),CX(20),CNA(20),CMA(20),CMQ(20),T(40),FX(40),	10080
IFY(40),TSL(40),CG(40),FM(40), NM,NT,CND(20),CNP(20)	
C	10100
COMMON /PF/ TBOB(10),AEB(10),DSQB(10),REFLB(10),TMIIB(10),	10110
1PIB(10),EPTINB(1),EPBIGB(10),TFPB(10),KANB(10), NMB(10)	10120
2,PMB(20,10),CXB(20,10),CNAB(20,10),CMAB(20,10),CMQB(20,10),	10130
3NTB(10),TB(40,10),FXB(40,10),FYB(40,10),TSLB(40,10),CG(40,10),	10140
4FMB(40,20),XLT(1),CNDB(20,10),CNPB(20,10),FINCB(10)	
C	10160
COMMON/EFT/KAN	10170
C	10180
COMMON/EF/ REFL,AE,DSQ,XLNTH,FINC	
C	10200
TBO=TBOB(J)	10210
AE=AEB(J)	10220
DSQ=DSQB(J)	10230
REFL=REFLB(J)	10240
KAN=KANB(J)	10250
TMI=TMIIB(J)	10260
PI=PIB(J)	10270
EPBIG=EPBIGB(J)	10280
EPTINY=EPTINB(J)	10290
FINC=FINCB(J)	
TFP=TFPB(J)	10300
XLNTH=XLT(J)	10315
NM=NMB(J)	10320
DO 200 I=1,NM	10330
PM(I)=PMB(I,J)	10340
CX(I)=CXB(I,J)	10350
CNA(I)=CNAB(I,J)	10360
CMA(I)=CMAB(I,J)	10370

CMQ(I)=CMQB(I,J)	10380
CNB(I)=CNBB(I,J)	
200 CONTINUE	10390
IF (KAN.EQ.2) GO TO 202	10400
201 NT=NTB(J)	10410
DO 203 I=1,NT	10420
T(I)=TB(I,J)	10430
FX(I)=FXB(I,J)	10440
FY(I)=FYB(I,J)	10450
TSL(I)=TSLB(I,J)	10460
CG(I)=CGB(I,J)	10470
FM(I)=FMB(I,J)	10480
203 CONTINUE	10500
202 RETURN	10510
END	10520
910FTC PINTR LIST,REF,DECK	10530
SUBROUTINE PINTRJ	10540
C	10550
C IN ALL COMMON STATEMENTS D=DRIVER,A=AOPTUN,B=BFACT,E=EVAL,C=CHK,I=INT	10560
C R2=RKERR2,R=RKG,T=TABL,F=PHASIN,P=PINTRJ,X=XOUT,AND L=T12LP	10570
C	10580
COMMON/PT/ N,HH(44),RHO(44),VS(44),PA(44)	10590
C	10600
COMMON/DAP/TH,AL,XWANT,YWANT,DELC,DELT,DELH,TOWTIL	10610
C	10620
COMMON/DAEP/NTYPE	10630
C	10640
COMMON/DBTF/NW,HP(50)	10650
C	10660
COMMON/DCP/ TO	10670
C	10680
COMMON/AP/ XFIRST,YFIRST,XCHANG,YCHANG,XLAST,YLAST,NBF,BF(50),	10690
1DELTA	10700
C	10710
COMMON/DP/ UO,VO,W0,ZL,XLAT,NFAZE,NBST,IFOUT	10720
C	10730
COMMON/ABETP/ WXP(50),WYP(50)	10740
C	10750
COMMON/EP/ MAL	10760
C	10770
COMMON/PC/ ZIM	10780
C	10790
COMMON/BPX/ IDEN	10800
C	10810
COMMON /PF/ TBOB(10),AEB(10),DSQB(10),REFLB(10),TMIIB(10),	10820
1PIB(10),EPTINB(1),EPBIGB(10),TFPB(10),KANB(10), NMB(10)	10830
2,PMB(20,10),CXB(20,10),CNAB(20,10),CMAB(20,10),CMQB(20,10),	10840
3NTB(10),TB(40,10),FXB(40,10),FYB(40,10),TSLB(40,10),CGB(40,10),	10850
4FMB(40,20),XLT(1),CNDB(20,10),CNPB(20,10),FINCB(10)	
C	10870
DIMENSION DMACH(6),DIME(5),IDEN(10),CND(20),CNP(20)	
DIMENSION PM(20),CX(20),CNA(20),CMA(20),CMQ(20),T(40),	10890
1FX(40),FY(40),TSL(40),CG(40),F(40)	

C		10910
C	NTYPE -TYPE OF OUTPUT DESIRED (=1,REGULAR TRAJ),(=2,INTERATES)	10920
C	(=3,ANGULAR OUTPUT),(=4,BALL FACTORS),(=5,PARAMETER VARIABILITY,D)	10930
C	IFOUT=1 CONTINUE PRINTING AT END OF PHASE-NO SKIP TO NEXT PAGE	10940
C		10950
	1 READ(5,1000)NTYPE,IFOUT	10960
	READ(5,1500)IDEN	10970
	WRITE(6,499)IDEN	10980
C		10990
C	NFAZE IS THE TOTAL OF THE PHASES-- NBST IS PHASE TO PICK BOOSTER UP AT	11000
C		11010
	READ (5,2000) TO,ZL,ZIM,XLAT,XLONG,NFAZE,NBST	11020
	WRITE (6,500) TO,ZL,ZIM,XLAT,XLONG,NFAZE,NBST	11030
	J=1	11040
C		11050
C	MAL=1 INPUT CP MAL=2 INPUT CMA	11060
C		11070
	READ(5,7000)UO,VO,WO,MAL	11080
	WRITE(6,510)UO,VO,WO,MAL	11090
	READ(5,3000)TH,AL,XWANT,YWANT,DELTA,TOWTIL	11100
	WRITE(6,520)TH,AL,XWANT,YWANT,DELTA,TOWTIL	11110
	READ(5,2500)N,(HH(1),RHO(1),VS(1),PA(1),I=1,N)	11120
	WRITE(6,530)N,(HH(1),RHO(1),VS(1),PA(1),I=1,N)	11130
	IF(NTYPE.NE.3)GO TO 2	11140
	READ(5,3000)XFIRST,XLAST,XCHANG,YFIRST,YLAST,YCHANG	11150
	WRITE(6,540)XFIRST,XLAST,XCHANG,YFIRST,YLAST,YCHANG	11160
	GO TO 12	11170
	2 READ(5,3500)NW,(HP(1),WXP(1),WYP(1),I=1,NW)	11180
	WRITE(6,550)NW,(HP(1),WXP(1),WYP(1),I=1,NW)	11190
	IF(NTYPE.NE.2)GO TO 4	11200
	READ(5,4000)NBF,(BF(1),I=1,NBF)	11210
	WRITE(6,560)NBF,(BF(1),I=1,NBF)	11220
	12 READ(5,3000)DELC,DELT,DELM	11230
	WRITE(6,570)DELC,DELT,DELM	11240
C		11250
C	TFP=TIME OF FIRST PRINT KAN=1,MACH AND TIME TABLES KAN=2,MACH ONLY	11260
C	IOPTUN=3D TO GROUND	11270
C		11280
	4 READ (5,4500) TBO,AE,DSQ,REFL,XLENTN,EPTINY,EPBIG,FINC,TMII,PI,TFP	
	1,KAN	
	WRITE (6,580) TBO,AE,DSQ,REFL,XLENTN,EPTINY,EPBIG,FINC,TMII,PI,TFP	
	1,KAN	
	READ (5,5000) NM,(PM(1),CX(1),CNA(1),CMA(1),CMQ(1),CND(1),CNP(1),I	
	=1,NM)	
	WRITE (6,590) NM,(PM(1),CX(1),CNA(1),CMA(1),CMQ(1),CND(1),CNP(1),I	
	=1,NM)	
	IF(NTYPE.NE.5)GO TO 7	11330
	READ(5,5500)(DMACH(1),I=1,6)	
	WRITE(6,600)(DMACH(1),I=1,6)	
	DO 8 K=1,NM	11360
	CX(K)=CX(K)*DMACH(1)	11370
	CNA(K)=CNA(K)*DMACH(2)	11380
	CMA(K)=CMA(K)*DMACH(3)	11390

CMQ(K)=CMQ(K)*DMACH(4)	
CND(K)=CND(K)*DMACH(5)	
8 CNP(K)=CNP(K)*DMACH(6)	
7 TBOB(J)=TBO	11410
AEB(J)=AE	11420
DSQB(J)=DSQ	11430
REFLB(J)=REFL	11440
TMIR(J)=TMI	11450
PIB(J)=PI	11460
EPTINB(J)=EPTINY	11470
EPBIGB(J)=EPBIG	11480
FINCR(J)=FINC	
TFPB(J)=TFP	11490
KANB(J)=KAN	11500
XLT(J)=XLENTH	11515
NMB(J)=NM	11520
DO 10 I=1,NM	11530
PMB(I,J)=PM(I)	11540
CXB(I,J)=CX(I)	11550
CNAB(I,J)=CNA(I)	11560
CMAB(I,J)=CMA(I)	11570
CMQB(I,J)=CMQ(I)	
CNQB(I,J)=CNP(I)	
10 CNPB(I,J)=CNP(I)	
IF(KAN.NE.1)GO TO 6	11590
READ(5,6000)NT,(T(1),FX(1),FY(1),TSL(1),CG(1),FM(1),	I=1,NT) 11600
WRITE(6,610)NT,(T(1),FX(1),FY(1),TSL(1),CG(1),FM(1),	I=1,NT) 11610
IF(NTYPE.NE.5)GO TO 9	11620
READ(5,6500)(DTIME(I),I=1,5)	
WRITE(6,620)(DTIME(I),I=1,5)	
DO 15 K=1,NT	11650
FX(K)=FX(K)*DTIME(1)	11660
FY(K)=FY(K)*DTIME(2)	11670
TSL(K)=TSL(K)*DTIME(3)	11680
CG(K)=CG(K)*DTIME(4)	11690
FM(K)=FM(K)*DTIME(5)	11700
15 CONTINUE	
9 NTB(J)=NT	11720
DO 20 I=1,NT	11730
TB(I,J)=T(I)	11740
FXB(I,J)=FX(I)	11750
FYB(I,J)=FY(I)	11760
TSLB(I,J)=TSL(I)	11770
CGB(I,J)=CG(I)	11780
FMB(I,J)=FM(I)	11790
20 CONTINUE	
6 J=J+1	11810
IF(J.LE.NFAZE)GO TO 4	11820
RETURN	11830
499 FORMAT(1H1,10X,12A6)	11840
500 FORMAT(11X,F11.2,2F11.2,2F11.5,7X,14,7X,14)	11850
510 FORMAT(11X,3F11.5,7X,14)	11860
520 FORMAT(11X,4F11.2,F11.0,F11.1)	11870

530	FORMAT(5X,14,2X,F9.0,2X,F11.9,2F11.3/(11X,F9.0,2X,F11.9,2F11.3))	11880
540	FORMAT(11X,6F11.)	11890
550	FORMAT(5X,14,2X,3F11.2/(11X,3F11.2))	11900
560	FORMAT(5X,14,2X,F11.6/(11X,F11.6))	11910
570	FORMAT(11X,3F11.5)	11920
580	FORMAT (11X,F11.2,2F11.7,4F11.4,F11.8,2F11.4/F11.4,11)	
590	FORMAT (5X,14,2X,F11.3,F11.5,F11.2,F11.3, 11,2,F11.3,F11.3/(11X,F11.3,F11.5,F11.2,F11.3,F11.2,F11.3,F11.3))	
600	FORMAT (11X,6F11.2)	
610	FORMAT(5X,14,2X,F11.2,F11.3,F11.1,F11.2,F11.4,F11.3 1 (11X,F11.2,F11.3,F11.1,F11.2,F11.4,F11.3))	119
620	FORMAT(11X,6F11.3)	11990
1000	FORMAT(8X,2(11,7X))	12000
1500	FORMAT(12A6)	12010
2000	FORMAT (8X,5F8.0,2(12,6X))	12020
2500	FORMAT(6X,12,4F8.0/(8X,4F8.0))	12030
3000	FORMAT(8X,6F8.0)	12040
3500	FORMAT(6X,12,3F8.0/(8X,3F8.0))	12050
4000	FORMAT(6X,12,F8.)	12060
4500	FORMAT (10F8.0/F8.0, (11,7X))	
5000	FORMAT (6X,12,7F8.0/(8X,7F8.0))	
5500	FORMAT (16X,6F8.)	
6000	FORMAT(6X,12,6F8.0/(8X,6F8.0))	
6500	FORMAT(16X,6F8.0)	12110
7000	FORMAT(8X,3F8.0,11)	12120
	END	12130
\$IBFTC	XOUTP LIST,REF,DECK	12140
	SUBROUTINE XOUT (JF,IX)	12150
	COMMON Y(22,5),DY(22,5),ROFF1(22,5)	12160
C		12170
C	IN ALL COMMON STATEMENTS D=DRIVER,A=AOPTUN,B=BFACT,E=EVAL,C=CHK,I=INT	12180
C	R2=RKERR2,R=RKG,T=TABL,F=PHASIN,P=PINTRJ,X=XOUT,AND L=T12LP	12190
C		12200
	COMMON/XL/ TH,AH,D(3),B(3),V	12210
C		12220
	COMMON/DAETX/ WXS,WYS	12230
C		12240
	COMMON/DIX/ TIME	12250
C		12260
	COMMON/DX/ IJK	12270
C		12280
	COMMON/ABXL/ XYZ(3)	12290
C		12300
	COMMON/BPX/ IDEN	12310
C		12320
	DIMENSION IDEN(12)	
695	FORMAT(23X,3F15.2)	12330
696	FORMAT(22X,3F15.1,2X,2F15.3)	12340
697	FORMAT(/9X,F15.3,F13.1,2F15.1,2X,3F15.3)	12350
698	FORMAT(1H0,17X,4HTIME,12X,1HX,13X,1HY,12X,1HZ,17X,3HWXS,10X,5HTHET 1A,11X,5HALPHA/33X,2HXD,12X,2HYD,11X,2HZD,16X,3HWYS,10X,1HV/33X,3HX 2DD,11X,3HYDD,10X,3HZDD)	12360 12370 12380
699	FORMAT (///40X40HINTEGRATION INTERVAL IS LESS THAN .00001)	12390

IF(IX.EQ.1)GO TO 11	12400
CALL T12L(1,5)	12410
IJKM=MOD(IJK,13)	12420
TIME=Y(1,JF)	12430
IF(IJKM.GT.0)GO TO 10	12440
WRITE (6,700)IDEN	12450
700 FORMAT (1H112A6)	12460
WRITE (6,698)	12470
10 WRITE(6,697)TIME,XYZ(1),XYZ(2),XYZ(3),WXS,TH,AH	12480
WRITE(6,696)D(1),D(2),D(3),WYS,V	12490
WRITE(6,695)B(1),B(2),B(3)	12500
GO TO 12	12510
11 WRITE (6,699)	12520
12 IJK=IJK+1	12530
RETURN	12540
END	12550
\$1BFTC T12LP LIST,REF,DECK	12560
SUBROUTINE T12L(KWIND,JF)	12570
COMMON Y(22,5),DY(22,5),ROFF1(22,5)	12580
C	12590
C IN ALL COMMON STATEMENTS D=DRIVER,A=AOPTUN,B=BFACT,E=EVAL,C=CHK,I=INT	12600
C R2=RKERR2,R=RKG,T=TABL,F=PHASIN,P=PINTRJ,X=XOUT,AND L=T12LP	12610
C	12620
COMMON/XL/ TH,AH,D(3),B(3),V	12630
C	12640
COMMON/DEL/ SLAT,CLAT,SLATG,CLATG,TIMEO,W	12650
C	12660
COMMON/DL/ RO	12670
C	12680
COMMON/ABXL/ XYZ(3)	12690
C	12700
DIMENSION A(3,3),YD(6)	12710
C	12720
C IF KWIND=1, THE SECOND DERIVATIVES WILL BE COMPUTED	12730
C COMPUTATION OF THE ROTATION MATRIX FROM THE ECI TO THE LAUNCHER SYSTEM	12740
C W=ROTATION OF EARTH\$RS=RADIUS TO LAUNCHER SYSTEM\$CLAT=COS(GEOD LAT)\$	12750
C SLAT=SIN(GEOD LAT) CLATG=COS(GEOD LAT) SLATG=SIN(GEOD LAT) ARE ALL D	12760
C IN DRIVER	12770
C	12780
WT=W*(Y(1,JF)-TIMEO)	12790
A(1,1)= -COS(WT)	12800
A(1,2)= -SIN(WT)	12810
A(1,3)= 0.0	12820
A(2,3)= CLATG	12830
A(3,3)= SLATG	12840
A(2,1)=-A(3,3)*A(1,2)	12850
A(3,1)= A(2,3)*A(1,2)	12860
A(3,2)=-A(2,3)*A(1,1)	12870
A(2,2)= A(3,3)*A(1,1)	12880
C	12890
C COMPUTATION OF TRANSLATION VECTOR	12900
C	12910
XL=RO*CLAT*A(1,2)	12920

YL=-RO*CLAT*A(1,1)	12930
ZL=RO*SLAT	12940
C	12950
C COMPUTATION OF POSITION IN LAUNCHER SYSTEM	12960
C	12970
B(1)=Y(17,JF)-XL	12980
B(2)=Y(18,JF)-YL	12990
B(3)=Y(19,JF)-ZL	13000
CALL MTRXL (A,B,1,XYZ)	13010
C	13020
C RELATIVE MOTION COMPUTATIONS	13030
C	13040
YD(1)=DY(17,JF)+W*Y(18,JF)	13050
YD(2)=DY(18,JF)-W*Y(17,JF)	13060
YD(3)=DY(19,JF)	13070
IF(KWIND.NE.1)GO TO 10	13080
YD(4)=DY(20,JF)+2.*W*YD(2)+W*W*Y(17,JF)	13090
YD(5)=DY(21,JF)-2.*W*YD(1)+W*W*Y(18,JF)	13100
YD(6)=DY(22,JF)	13110
C	13120
C COMPUTATION OF VELOCITY AND ACCELERATION IN LAUNCHER SYSTEM	13130
C	13140
CALL MTRXL(A,YD(4),1,B)	13150
10 CALL MTRXL(A,YD(1),1,D)	13160
IF(KWIND.NE.1)GO TO 20	13170
V=SQRT (D(1)**2+D(2)**2+D(3)**2)	13180
TH=57.2957795*ARCSIN(D(3)/V)	13190
20 AH=57.2957795*ATAN2(D(1),D(2))	13200
RETURN	13210
END	13220
*DATA	13230
XNO 1.	
1	
AEROBEE NASA 4.195 GAGI	
TO-Z-LAT1. 4143. 4000. 32.403921.8558 3	
VEL 283. 0. . 1	
2.90 348.	
ATMOS 404001. .00210161100.99 1821.09	
ATMOS 4501. .00207931099.04 1787.51	
ATMOS 5001. .00204811097.09 1754.34	
ATMOS 6002. .00198681093.18 1689.76	
ATMOS 7002. .00192681089.25 1627.03	
ATMOS 8003. .00186831085.31 1566.21	
ATMOS 10005. .00175531077.39 1448.71	
ATMOS 12007. .00164761069.4 1341.01	
ATMOS 14009. .00154 41061.36 1238.69	
ATMOS 16012. .00144741053.25 1142.77	
ATMOS 19017. .00131 1040.97 1010.27	
ATMOS 22023. .00118271028.55 890.17	
ATMOS 25030. .00106511015.98 782.48	
ATMOS 29040. .0009225998.96 655.2	
ATMOS 33052. .000795 981.65 545.24	
ATMOS 37066. .0006759968.08 450.8	

ATMOS	41081.	.0005577968.08	371.95
ATMOS	45097.	.00046 1968.08	306.9
ATMOS	50120.	.00037 4968.08	241.34
ATMOS	55145.	.0002845968.08	189.77
ATMOS	60173.	.0002237968.08	149.24
ATMOS	65203.	.000176 968.08	117.36
ATMOS	70236.	.0001384971.06	92.14
ATMOS	75271.	.0001063974.44	72.89
ATMOS	80308.	.0000856977.82	57.46
ATMOS	85348.	.0000665981.19	45.44
ATMOS	90390.	.0000515984.54	35.99
ATMOS	100482.	.0000314991.21	22.68
ATMOS	120695.	.00001231022.01	9.28
ATMOS	140946.	.00000521057.52	4.03
ATMOS	160222.	.00000241082.02	1.92
ATMOS	180550.	.00000121071.74	.89
ATMOS	200917.	.00000 61046.84	.4
ATMOS	220303.	.00000 3999.33	.17
ATMOS	240748.	.00000 1945.08	.067
ATMOS	260720.	0.	.889.
ATMOS	280216.	0.	.884.
ATMOS	299233.	0.	.892.8
ATMOS	506000.	0.	.922.7
ATMOS	1000000.	0.	.922.7

264196.	3.0	6.5
4325.	2.0	5.5
4500.	2.5	8.5
4700.	2.5	8.0
5000.	1.0	6.5
5400.	1.0	6.5
5800.	1.5	7.0
6250.	0.0	3.5
6750.	1.5	2.5
7250.	5.0	3.
7750.	5.5	2.
8500.	6.0	3.5
11500.	7.0	2.5
16500.	0.0	18.0
21500.	-4.0	21.5
26500.	6.5	18.0
31500.	9.5	11.5
36500.	7.0	12.0
41500.	0.0	16.0
46500.	-9.5	10.5
51500.	-8.5	10.0
59000.	10.0	1.5
69000.	4.0	.0
79000.	10.0	1.5
89000.	14.0	2.5
99000.	0.0	13.0

2.5	.296875	1.5625	1.25	31.2142	.0001	.001	1.	1.
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1								
MACH 1	60.0	.389	21.31	26.15	-1300.			

MACH 1	.25	.389	21.50	26.5125	-1355.	
MACH 1	.5	.389	22.10	26.68125	-1425.	
MACH 1	.75	.400	23.09	26.8125	-1510.	
MACH 1	1.0	.557	24.87	27.35	-1650.	
MACH 1	2.0	.558	18.45	27.35	-1650.	
TIME 1	40.	14.2	4350.	20050.	21.5	69.72185
TIME 1	1.	13.65	3980.	20050.	21.042	66.16309
TIME 1	2.	13.18	3620.	20050.	20.5	62.28208
TIME 1	2.5	12.8	3425.	20050.	20.25	60.34158
51.8	.296875	1.5625	1.25	28.2142	.0001	.001

1. 1.

MACH 2	17.5	.28	16.0428	24.075	-1300.	
MACH 2	.75	.293	17.1887	24.275	-1380.	
MACH 2	1.	.445	19.3659	25.2	-1520.	
MACH 2	1.15	.657	19.8243	25.6375	-1650.	
MACH 2	2.0	.438	12.3071	23.7875	-1148.	
MACH 2	2.5	.3825	10.1127	22.6875	-977.	
MACH 2	3.	.338	8.9095	21.8375	-912.	
MACH 2	3.5	.302	8.1360	21.0875	-860.	
MACH 2	4.	.271	7.3625	20.33125	-828.	
MACH 2	4.5	.244	6.7895	19.6	-805.	
MACH 2	5.0	.220	6.3885	18.9125	-786.	
MACH 2	5.5	.206	6.0447	18.4	-772.	
MACH 2	6.0	.194	5.8155	17.925	-762.	
MACH 2	6.5	.185	5.5577	17.4375	-754.	
MACH 2	7.0	.181	5.3572	17.1875	-749.	
MACH 2	7.5	.180	5.1566	17.0	-747.	
MACH 2	8.	.176	4.9274	16.85	-745.	
TIME 2	102.5	11.2	1750.	4100.	17.8333349	91629
TIME 2	5.	10.9	1740.	4100.	17.9083348	30503
TIME 2	10.	10.35	1725.	4100.	18.0	45.08253
TIME 2	15.	9.78	1710.	4100.	17.9583341	86003
TIME 2	20.	9.2	1690.	4100.	17.8416738	63752
TIME 2	25.	8.64	1660.	4100.	17.6666735	41502
TIME 2	30.	8.07	1620.	4100.	17.3916732	19252
TIME 2	40.	6.93	1460.	4100.	16.4833325	74751
TIME 2	50.	5.8	1120.	4100.	14.4666719	30250
TIME 2	51.8	5.76	1000.	4100.	14.15	18.14240
1000.		1.5625	1.25	28.2142	.001	.01

1. 4.

MACH 3	132.	.475	12.3071	23.7875	-1148.	
MACH 3	2.5	.414	10.1127	22.6875	-977.	
MACH 3	3.	.365	8.9095	21.8375	-912.	
MACH 3	3.5	.325	8.1360	21.0875	-860.	
MACH 3	4.	.289	7.3625	20.33125	-828.	
MACH 3	4.5	.259	6.7895	19.6	-805.	
MACH 3	5.	.235	6.3885	18.9125	-786.	
MACH 3	5.5	.216	6.0447	18.4	-772.	
MACH 3	6.	.200	5.8155	17.925	-762.	
MACH 3	6.5	.190	5.5577	17.4375	-754.	
MACH 3	7.	.186	5.3572	17.1875	-749.	
MACH 3	7.5	.185	5.1566	17.0	-747.	
MACH 3	8.	.184	4.9274	16.85	-745.	

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A documentation of a six-degree-of-freedom model for digital simulation of the trajectory of an unguided, fin-stabilized, wind-sensitive rocket is presented. This model was developed by the Atmospheric Sciences Laboratory, White Sands Missile Range, New Mexico, to study both theoretical and empirical performance characteristics of unguided rockets. The basic equations of motion and their mathematical formulation for this model are presented without derivation. A general flow chart, a listing of the program, a list of the principal flads used, and a listing of a typical input data deck are included.		

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