# GOODYEAR AEROSPACE

(NASA-CR-120261) USERS MANUAL: DYNAMICS OF TWO BODIES CONNECTED BY AN ELASTIC TETHER, SIX DEGREES OF FREEDOM FOREBODY AND FIVE DEGREES OF (Goodyear Aerospace Corp.) 139 p HC $10.00 CSCL 20K

N74-29304

Unclas
G3/32 16556

CODE IDENT NO. 25500

# GOODYEAR AEROSPACE CORPORATION

AKRON 15, OHIO

USERS MANUAL

DYNAMICS OF TWO BODIES CONNECTED

BY AN ELASTIC TETHER - SIX DEGREES OF FREEDOM FOREBODY

AND FIVE DEGREES OF FREEDOM DECELERATOR
(REF. NASA CONTRACT NAS8-29144 S/A1)

BY

GEORGE R. DOYLE, JR.
&
JAMES W. BURBICK

GER- 16047

APRIL 1974

# ABSTRACT

One important aspect to recovering a body falling through the atmosphere, is to decelerate and stabilize it. This is usually accomplished by means of a parachute. The design of the recovery system necessitates a knowledge of the dynamics and loads during parachute deployment and inflation. In many cases, a pitch plane analysis will provide adequate information. However, if the body is in a general tumbling motion, it is necessary to analyze its motion in three dimensions.

This report contains the equations of motion and a computer program for the dynamics of a six degree of freedom body joined to a five degree of freedom body by a quasilinear elastic tether. The forebody is assumed to be a completely general rigid body with six degrees of freedom; the decelerator is also assumed to be rigid, but with only five degrees of freedom (symmetric about its longitudinal axis). The tether is represented by a spring and dashpot in parallel, where the spring constant is a function of tether elongation. Lagrange's equation is used to derive the equations of motion with the Lagrange multiplier technique used to express the constraint provided by the tether. A computer program is included which provides a time history of the dynamics of both bodies and the tension in the tether.

# TABLE OF CONTENTS

# LIST OF FIGURES



E-1D-15(7 71)
REF: E01 380

# NOMENCLATURE

The following is a list of variables used in the computer program and in the derivation of the equations as discussed in this report. A brief description and associated units are included.

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| A | a | Distance along the longitudinal axis of the forebody ($X_b$) from the intersection of the body axes to the tether-forebody confluence point, positive towards the nose | (m) | ft |
| AA(6,4) | | Dummy variables used to express incremental velocities of the forebody in the Runge-Kutta integration | (m/sec) | ft/sec or rad/sec |
| AALPDE(8) | | An array of eight variables signifying angle-of-attack of the forebody used with damping coefficients | | deg |
| AALPFE(16) | | An array of sixteen variables signifying angle-of-attack of the forebody used with force coefficients | | deg |
| AALPME(16) | | An array of sixteen variables signifying angle-of-attack of the forebody used with moment coefficients | | deg |
| AALPPE(8) | | An array of eight variables signifying angles of attack of the decelerator | | deg |
| AAM(8) | | An array of eight variables signifying Mach number of the forebody used with force and moment coefficients | | |
| AAMD(8) | | An array of eight variables signifying Mach number of the forebody used with damping coefficients | | |
| AAMP(8) | | An array of eight variables signifying Mach number of the decelerator | | |
| AERATO | | Suspension Line AE Ratio (AERATO = $AE/AE_{Nylon}$) | | |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| AIPHI | | Number of elements in PPHIE array ( = 2 to 8) | | |
| AIPHID | | Number of elements in PPHIDE array ( = 2 to 8) | | |
| AJALPD | | Number of elements in AALPDE array ( = 8) | | |
| AJALPF | | Number of elements in AALPFE array ( = 8 or 16) | | |
| AJALPM | | Number of elements in AALPME array ( = 8 or 16) | | |
| AKAM | | Number of elements in AAM array ( = 2 to 8) | | |
| AKAMD | | Number of elements in AAMD array ( = 2 to 8) | | |
| ALPE | $\alpha$ | Angle-of-attack of the forebody | | deg |
| ALPPE | $\alpha_p$ | Angle-of-attack of the decelerator | | deg |
| AM | | Mach number of the forebody | | |
| AMAX1 | | Larger ordinate of two points on the longitudinal added mass versus $D_o$ log log plot | kg | slug |
| AMAX2 | | Smaller ordinate of two points on the longitudinal added mass versus $D_o$ log log plot | kg | slug |
| AMAY1 | | Larger ordinate of two points on the lateral added mass versus $D_o$ log log plot | kg | slug |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| AMAY2 | | Smaller ordinate of two points on the lateral added mass versus $D_o$ log log plot | kg | slug |
| AMP | | Mach number of the decelerator | | |
| AP | $a_p$ | Distance along the longitudinal axis of the decelerator ($X_{pb}$) from the c.g. to the tether-decelerator confluence point | (m) | ft |
| AX | | Exponent of longitudinal added mass equation (MPAL = RHOOO * BX * DS ** AX) | | |
| AY | | Exponent of lateral added mass equation (MPAS = RHOOO * BY * DS ** AY) | | |
| B | b | Distance along the lateral axis of the forebody ($Y_b$) from the intersection of the body axes to the tether-forebody confluence point, positive towards the left wing | (m) | ft |
| BB(5,4) | | Dummy variables used to express incremental velocities of the decelerator in the Runge-Kutta integration | (m/sec) | ft/sec or rad/sec |
| BX | | Coefficient of longitudinal added mass equation (MPAL = RHOOO * BX * DS ** AX) | | |
| BY | | Coefficient of lateral added mass equation (MPAS = RHOOO * BY * DS ** AY) | | |
| C | c | Distance along the vertical axis of the forebody ($Z_b$) from the intersection of the body axes to the tether-forebody confluence point, positive up | (m) | ft |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| CA | $C_A$ | Axial force coefficient of forebody | | |
| CAP | $C_{AP}$ | Axial force coefficient of decelerator | | |
| CC(3,3) | $C_{ij}$ | Elements of transformation matrix from inertial coordinates to body coordinates of the forebody | | |
| CAA(8,16,8) | | A three dimensional array of variables signifying axial force coefficients of the forebody corresponding to AAM(8), AALPFE(16), and PPHIE(8) | | |
| CCAP(8,8) | | A two dimensional array of 64 variables signifying axial force coefficients of the decelerator with respect to angle of attack corresponding to AAMP(1) thru AAMP(8) | | |
| CCHI | $C\chi$ | $\cos(\chi)$ | | |
| CCHIP | $C\chi_p$ | $\cos(\chi_p)$ | | |
| CCLL(8,16,8) | | A three dimensional array of variables signifying rolling moment coefficients of the forebody corresponding to AAM(8), AALPME(16), and PPHIE(8) | | |
| CCLLP(8,8,8) | | A three dimensional array of variables signifying roll damping coefficients of the forebody corresponding to AAMD(8), AALPDE(8), and PPHIDE(8) | | |
| CCLM(8,16,8) | | A three dimensional array of variables signifying pitching moment coefficients of the forebody corresponding to AAM(8), AALPME(16), and PPHIE(8) | | |

E-ID-15(7-71)
REF: EOI 380

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| CCLMQ(8,8,8) | | A three dimensional array of variables signifying pitch damping coefficients of the forebody corresponding to AAMD(8), AALPDE(8), and PPHIDE(8) | | |
| CCLN(8,16,8) | | A three dimensional array of variables signifying yawing moment coefficients of the forebody corresponding to AAM(8), AALPME(16), and PPHIE(8) | | |
| CCLNR(8,8,8) | | A three dimensional array of variables signifying yaw damping coefficients of the forebody corresponding to AAM(8), AALPDE(8), and PPHIDE(8) | | |
| CCN(8,16,8) | | A three dimensional array of variables signifying normal force coefficients of the forebody corresponding to AAM(8), AALPFE(16), PPHIE(8) | | |
| CCM(8,8) | | A two dimensional array of 64 variables signifying the pitching moment coefficients of the decelerator with respect to angle of attack corresponding to AAMP(1) thru AAMP(8) | | |
| CCNP(8,8) | | A two dimensional array of 64 variables signifying the normal force coefficient of the decelerator with respect to angle-of attack corresponding to AAMP(1) thru AAMP(8) | | |
| CCP(3,3) | $C_{pij}$ | Elements of transformation matrix from inertial coordinates to body coordinates of the decelerator | | |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| CCRIT | | c/cr = damping ratio ≈ 0.06 | | |
| CCY(8,16,8) | | A three dimensional array of variables signifying side force coefficients of the forebody corresponding to AAM(8), AALPFE(16), and PPHIE(8) | | |
| CDAP | | Drag area of decelerator | $(m^2)$ | $ft^2$ |
| | c.g. | Center of gravity | | |
| CGAM | $C_\gamma$ | $Cos(\gamma)$ | | |
| CGAMP | $C_{\gamma_p}$ | $Cos(\gamma_p)$ | | |
| CHIE | $\chi$ | Flight path angle of forebody in horizontal plane, measured from X axis toward Y axis | | deg |
| CHIPE | $\chi_p$ | Flight path angle of decelerator in horizontal plane, measured from X axis toward Y axis | | deg |
| CLL | $C_\ell$ | Rolling moment coefficient of the forebody | | |
| CLLP | $C_{\ell_p}$ | Rolling damping coefficient of the forebody | | |
| CLM | $C_m$ | Pitching moment coefficient of the forebody | | |
| CLMQ | $C_{m_q}$ | Pitch damping coefficient of the forebody | | |
| CLN | $C_n$ | Yawing moment coefficient of the forebody | | |
| CLNR | $C_{n_r}$ | Yaw damping coefficient of the forebody | | |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| CN | $C_N$ | Normal force coefficient of the forebody | | |
| CNP | $C_{Np}$ | Normal force coefficient of the decelerator | | |
| COM(20) | | Input variable used to define computer simulation - up to eighty figures | | |
| CPHI | $C\phi$ | Cos $(\phi)$ | | |
| CPHII | $C\phi_i$ | Cos $(\phi_i)$ | | |
| CPHIPI | $C\phi_{pi}$ | Cos $(\phi_{pi})$ | | |
| CPSI | $C\psi$ | Cos $(\psi)$ | | |
| CPSIP | $C\psi_p$ | Cos $(\psi_p)$ | | |
| CS | $C_s$ | Damping coefficient of tether | $\frac{\text{N-sec}}{\text{m}}$ | $\frac{\text{lb}_f\text{-sec}}{\text{ft}}$ |
| CSIGP | | Cosine of one half the apex angle of the cone formed by the suspension lines | | |
| CTHE | $C\theta$ | Co $(\theta)$ | | |
| CTHEP | $C\theta_p$ | Cos $(\theta_p)$ | | |
| CY | $C_Y$ | Side force coefficient of forebody | | |
| D | d | Aerodynamic reference length of forebody | (m) | ft |
| Di (6,6) | | A two dimensional array of variables signifying the coefficients of the second derivatives in the equations of motions | (kg) $(\text{kg-m}^2)$ | slug or $\text{slug-ft}^2$ |
| DDP(3,3) | | A two dimensional array of variables signifying the coefficients of the second derivatives in the equations of motion of the decelerator | (kg) $(\text{kg-m}^2)$ | slugs or $\text{slug-ft}^2$ |
| DELSX | | Total suspension line defl .tion array | m | ft |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| DELTX | | Total tether line deflection array | m | ft |
| DLTO | | Initial elongation of tether beyond unstretched length. DLTO is negative if the forebody and decelerator confluence points are closer together than LTO | (m) | ft |
| DLTX | | Tether deflection component in array element (DLX(I) associated with load PX(I) | m | ft |
| DLX | | Effective spring deflection array | m | ft |
| DMD | | Rate of change of longitudinal added mass | kg/sec | slug/sec |
| DP | $d_p$ | Aerodynamic reference length of decelerator | (m) | ft |
| DPR | | Degress per radian - 57.2957795 | | |
| DS | | Parachute diameter associated with SP | m | ft |
| DSP | | Parachute projected diameter associated with DS | m | ft |
| DSX1 | | Larger abscissa of two points on the longitudinal added mass versus $D_o$ log log plot | m | ft |
| DSX2 | | Smaller abscissa of two points on the longitudinal added mass versus $D_o$ log log plot | m | ft |
| DSY1 | | Larger abscissa of two points on the lateral added mass versus $D_o$ log log plot | m | ft |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| DSY2 | | Smaller abscissa of two points on the lateral added mass versus $D_o$ log log plot | m | ft |
| DT | | Integration increment | | sec |
| DTP | | Number of integrations between data output | | |
| DTP1 | | Number of integrations between data output when T ≤ TDTC | | |
| DT1 | | Integration increment when T ≤ TDTC | | sec |
| DTT | | Estimated parachute system period/12 | sec | sec |
| DYPR | $q$ | Dynamic pressure of forebody | $(N/m^2)$ | $lb_f/ft^2$ |
| DYPRP | $q_p$ | Dynamic pressure of decelerator | $(N/m^2)$ | $lb_f/ft^2$ |
| EE(6) | | An array signifying the nonhomogeneous terms in the six equations of motion of the forebody | (N/m) or (N) | $ft\text{-}lb_f$ or $lb_f$ |
| EPL | | Suspension line strain array | m/m | ft/ft |
| EPS | | Number used to check for inconsistent equations in PIVERT Subroutine, $10^{-13}$ | | |
| EPSI | | Number used to check if $\theta$ is approaching a singular point $\theta = \frac{2n+1}{2}\pi$. If $\theta$ is approaching a singular point, the accelerations are kept fixed until this region is passed. EPSI = 0.0000061 freezes the accelerations if $\theta$ is within 0.2° of a singular point. | | |
| EPT | | Tether line strain array | m/m | ft/ft |

E-1D-15(7-71)
REF: EOI 380

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| ETAI | | Number which controls DT if $\theta$ is near a singular point. ETAI = 0.00061 sets DT = $^{DT1}/5$, if $\theta$ is within 2° of a singularity | | |
| FF(5) | | An array signifying the accelerations of the decelerator | (m/sec) | ft/sec or rad/sec |
| FREQP | | Estimated parachute system frequency | 1/sec | 1/sec |
| FSULT | | Ultimate design factor of safety for parachute | | |
| FX | $F_x$ | Generalized force on forebody in X direction | (N) | $lb_f$ |
| FXB | $F_{xb}$ | Body force in direction of $X_b$ due to aerodynamics | (N) | $lb_f$ |
| FXP | $F_{xp}$ | Generalized force on decelerator in X direction | (N) | $lb_f$ |
| FXPB | $F_{xpb}$ | Body force in direction of $X_{pb}$ | (N) | $lb_f$ |
| FY | $F_y$ | Generalized force on forebody in Y direction | (N) | $lb_f$ |
| FYB | $F_{yb}$ | Body force in direction of $Y_b$ due to aerodynamics | (N) | $lb_f$ |
| FYP | $F_{yp}$ | Generalized force on decelerator in Y direction | (N) | $lb_f$ |
| FYPB | $F_{ypb}$ | Body force in direction of $Y_{pb}$ | (N) | $lb_f$ |
| FZ | $F_z$ | Generalized force on forebody in Z direction | (N) | $lb_f$ |
| FZB | $F_{zb}$ | Body force in direction of $Z_b$ due to aerodynamics | (N) | $lb_f$ |

E-1D-15(7-71)
REF: EOI 380

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| FZP | $F_{zp}$ | Generalized force on decelerator in Z direction | (N) | $lb_f$ |
| FZPB | $F_{zpb}$ | Body force in direction of $Z_{pb}$ | (N) | $lb_f$ |
| G | g | Acceleration of gravity at Z | $(m/sec^2)$ | $ft/sec^2$ |
| GAME | $\gamma$ | Flight path angle of forebody in vertical plane | | deg |
| GAMPE | $\gamma_p$ | Flight path angle of decelerator in vertical plane | | deg |
| GLOAD | | Limit design load factor of forebody | | |
| GO | | Acceleration of gravity at earth's surface, 32.17 | $(m/sec^2)$ | $ft/sec^2$ |
| HHH | | Altitude below which simulation is ended | (m) | ft |
| ICXO | | Canopy roll moment of inertia about its C.M. | $kg\text{-}m^2$ | $slug\text{-}ft^2$ |
| ICYO | | Canopy pitch moment of inertia about its C.M. | $kg\text{-}m^2$ | $slug\text{-}ft^2$ |
| IERSW | | Variable signifying whether or not the equations being solved in subroutine PIVERT are consistent | | |
| ILXO | | Parachute lines roll moment of inertia about its C.M. | $kg\text{-}m^2$ | $slug\text{-}ft^2$ |
| ILYO | | Parachute lines pitch moment of inertia about its C.M. | $kg\text{-}m^2$ | $slug\text{-}ft^2$ |
| IXB | $I_{xb}$ | Moment of inertia about $X_b$ axis | $(kg\text{-}m^2)$ | $slug\text{-}ft^2$ |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| IXPB | $I_{xpb}$ | Apparent moment of inertia about $X_{pb}$ axis | $(kg\text{-}m^2)$ | $slug\text{-}ft^2$ |
| IXYB | $I_{xyb}$ | Product of inertia associated with $X_b$ and $Y_b$ axes | $(kg\text{-}m^2)$ | $slug\text{-}ft^2$ |
| IXZB | $I_{xzb}$ | Product of inertia associated with $X_b$ and $Z_b$ axes | $(kg\text{-}m^2)$ | $slug\text{-}ft^2$ |
| IYB | $I_{yb}$ | Moment of inertia about $Y_b$ axis | $(kg\text{-}m^2)$ | $slug\text{-}ft^2$ |
| IYPB | $I_{ypb}$ | Apparent moment of inertia about $Y_{pb}$ axis | $(kg\text{-}m^2)$ | $slug\text{-}ft^2$ |
| IYZB | $I_{yzb}$ | Product of inertia associated with $Y_b$ and $Z_b$ axes | $(kg\text{-}m^2)$ | $slug\text{-}ft^2$ |
| IZB | $I_{zb}$ | Moment of inertia about $Z_b$ axis | $(kg\text{-}m^2)$ | $slug\text{-}ft^2$ |
| KS | $K_s$ | Tether spring constant | (N/m) | $lb_f/ft$ |
| LS | | Suspension line length | m | ft |
| LSCL | | Distance along parachute centerline between the confluence point and the projected diameter plane | m | ft |
| LT | $L_T$ | Tether length - distance between confluence points | (m) | ft |
| LTD | $\dot{L}_T$ | Time rate of change of tether length | (m/sec) | ft/sec |
| LTO | $L_{TO}$ | Unstretched tether length | (m) | ft |
| M | m | Mass of forebody | (kg) | slugs |
| MP | $m_p$ | Real mass of decelerator | (kg) | slugs |
| MPAL | | Added mass of the decelerator along $X_{pb}$ axis | (kg) | slugs |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| MPAS | | Added mass of the decelerator along $Y_{pb}$ or $Z_{pb}$ axis | (kg) | slugs |
| MPL | $m_{p\ell}$ | Apparent longitudinal ($X_{pb}$) mass of decelerator | (kg) | slugs |
| MPS | $m_{ps}$ | Apparent side ($Y_{pb}$ or $Z_{pb}$) mass of decelerator | (kg) | slugs |
| NS | | Number of parachute suspension lines | | |
| NT | | Number of tether lines | | |
| OMETRC | | Option variable: if OMETRC = 1., Input and Output are in the metric system. If OMETRC = 0.0 Input and Output are in the English system. | | |
| OMXBE | $\omega_{xb}$ | Angular velocity about $X_b$ axis | | deg/sec |
| OMYBE | $\omega_{yb}$ | Angular velocity about $Y_b$ axis | | deg/sec |
| OMZBE | $\omega_{zb}$ | Angular velocity about $Z_b$ axis | | deg/sec |
| OPAM | | Option variable: if OPAM = 1., added mass of the decelerator ≠ 0; if OPAM = 0., added mass of decelerator = 0 | | |
| OPDA | | Option variable: if OPDA = 1., damping moment coefficients of the forebody are read in as arrays; if OPDA = 0., damping moment coefficients are read in as constants | | |
| OPOS | | Option variable: if OPOS = 1., at least one of the c.g. offsets or products of inertia of the forebody ≠ 0.; if OPOS = 0., all c.g. offsets and products of inertia = 0. | | |

E-ID-15(7-71)
REF: EOI 380

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| OPPLOT | | Option variable: if OPPLOT = 1., a plot tape can be made; if OPPLOT = 0., no plot tape is made. | | |
| OPPRIN | | Option variable: if OPPRIN = 1., all aerodynamic coefficient arrays are printed out; if OPPRIN = 0., no aerodynamic coefficient arrays are printed out | | |
| OPDT | | Option for automatic DT determination (OPDT = 1.) | | |
| OPSP | | Option for automatic parachute area calculations (OPSP = 1.) | | |
| OPSYM | | Option variable: if OPSYM = 1., the forebody is aerodynamically symmetric such that $C_y = C\ \ = C_m = 0$; if OPSYM = 0., the forebody is not symmetric | | |
| PCTOI | | Parachute overinflation at reefed stage (I). (percent/100) | | |
| PCTO1 | | Parachute overinflation at reefed stage 1. (percent/100) | | |
| PCTO2 | | Parachute overinflation at reefed stage 2. (percent/100) | | |
| PCTO3 | | Parachute overinflation at reefed stage 3. (percent/100) | | |
| PHIAE | | Aerodynamic roll angle of forebody, $0 \leq$ PHIAE $\leq 180°$ | | deg |
| PHIDDE | $\ddot{\phi}$ | Angular acceleration about $X_b$ axis | | deg/sec$^2$ |
| PHIDE | $\dot{\phi}$ | Angular velocity about $X_b$ axis | | deg/sec$^2$ |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| PHIE | $\phi$ | Euler angle rotation about $X_b$ axis | | deg |
| PHIIE | $\phi_i$ | Aerodynamic roll angle of forebody, $-180° \leq \phi_i \leq 180°$ | | deg |
| PHIPI | $\phi_{pi}$ | Aerodynamic roll angle of decelerator, $-180° \leq \phi_{pi} \leq 180°$ | | deg |
| POROS | | Parachute porosity. Use POROS = 0.15 | | |
| PPHIDE(8) | | An array of eight variables signifying forebody roll angle used with damping coefficients | | deg |
| PPHIE(8) | | An array of eight variables signifying forebody roll angle used with force and moment coefficients | | deg |
| PSIDDE | $\ddot{\psi}$ | Angular acceleration of forebody about -Z axis | | deg/sec$^2$ |
| PSIDE | $\dot{\psi}$ | Angular velocity of forebody about -Z axis | | deg/sec |
| PSIE | $\psi$ | Euler angle rotation of forebody about -Z axis | | deg |
| PSIPDE | $\dot{\psi}_p$ | Angular velocity of decelerator about -Z axis | | deg/sec |
| PSIPE | $\psi_p$ | Angular rotation of decelerator about -Z axis | | deg |
| PSPDDE | $\ddot{\psi}_p$ | Angular acceleration of decelerator about -Z axis | | deg/sec$^2$ |
| PULAN | | Angle between tether and forebody centerline | deg | deg |
| PS | | Suspension line load array | N | $lb_f$ |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| PSX | | Total suspension line load array | N | $lb_f$ |
| PT | | Tether line load array | N | $lb_f$ |
| PTX | | Total tether line array | N | $lb_f$ |
| PX | | Effective spring load array | N | $lb_f$ |
| QMAXPB | | Parachute load due to rate of change of mass of the parachute times the relative velocity, XPBDR | N | $lb_f$ |
| QPHI | $Q_\phi$ | Generalized force about $X_b$ axis | (m-N) | ft-$lb_f$ |
| QPSI | $Q_\psi$ | Generalized force of forebody about -Z axis | (m-N) | ft-$lb_f$ |
| QPSIP | $Q_{\psi p}$ | Generalized for of decelerator about -Z axis | (m/N) | ft/$lb_f$ |
| QTHE | $Q_\theta$ | Generalized force of forebody about negative line of modes | (m/N) | ft/$lb_f$ |
| QTHEP | $Q_{\theta p}$ | Generalized force of decelerator about negative line of modes | (m/N) | ft/$lb_f$ |
| RATIO | | Nondimensional length used in the decelerator's body torque expressions | | |
| RE | | Radius of earth - 20,926,435. | (m) | ft |
| RHO | | Density of atmosphere at Z (1962 Standard) | ($kg/m^2$) | slug/$ft^2$ |
| RHOOO | | Air density ratio (RHO/RHOO) | | |
| S | S | Aerodynamic reference area of forebody | ($m^2$) | $ft^2$ |
| SCHI | | sin ($\chi$) | | |
| SCHIP | | sin ($\chi_p$) | | |
| SGAM | | sin ($\gamma$) | | |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| SGAMP | | sin ($\gamma_p$) | | |
| SP | | Parachute drag area | $m^2$ | $ft^2$ |
| SPD | | Time rate of change of parachute drag area | $m^2$/sec | $ft^2$/sec |
| SPHI | SØ | sin (Ø) | | |
| SPHII | $SØ_i$ | sin ($Ø_i$) | | |
| SPHIPI | $SØ_{pi}$ | sin ($Ø_{pi}$) | | |
| SPRO | | Initial parachute area | $m^2$ | $ft^2$ |
| SPR1 | | First reefed stage parachute drag area | $m^2$ | $ft^2$ |
| SPR2 | | Second reefed stage parachute drag area | $m^2$ | $ft^2$ |
| SPR3 | | Third reefed stage parachute drag area | $m^2$ | $ft^2$ |
| SPRL | | Parachute drag area associated with reefed stage (I-1) | $m^2$ | $ft^2$ |
| SPRU | | Parachute drag area associated with reefed stage (I) | $m^2$ | $ft^2$ |
| SPSI | $S\psi$ | sin ($\psi$) | | |
| SPSIP | $S\psi_p$ | sin($\psi_p$) | | |
| SSP(16) | | An array of sixteen variables signifying aerodynamic reference area of the decelerator corresponding to TTIP(16) | ($M^2$) | $ft^2$ |
| STHE | $S\theta$ | sin ($\theta$) | | |
| STHEP | $S\theta_p$ | sin ($\theta_p$) | | |
| T | | Flight time | | sec |
| TENS | | Tension in tether | N | $lb_f$ |
| THEDDE | $\ddot{\theta}$ | Angular acceleration of forebody about negative line of nodes | | $deg/sec^2$ |



E-ID-15(7-71)
REF: EOI 380

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| THEDE | $\dot{\theta}$ | Angular velocity of forebody about negative line of nodes | | $deg/sec^2$ |
| THEE | $\theta$ | Euler angle rotation of forebody about negative line of nodes | | deg |
| THEPDE | $\dot{\theta}_p$ | Angular velocity of decelerator about negative line of nodes | | deg/sec |
| THEPE | $\theta_p$ | Euler angle rotation of decelerator about negative line of nodes | | deg |
| THPDDE | $\ddot{\theta}_p$ | Angular acceleration of decelerator about negative line of nodes | | $deg/sec^2$ |
| TFI | | Parachute inflation time from Stage (I) to Stage (I + 1) | sec | sec |
| TINF | | Time when inflated area first equals SPRU | sec | sec |
| TINT | | Time at start of inflation of reefed stage (I) | sec | sec |
| TNINY | | Total time spent in region where (1-ABS(SIN(THE)). LT.EPSI) | sec | sec |
| TO | | Initial time | sec | sec |
| TOIF | | One half the time spent in the over-inflation of stage I | sec | sec |
| TOTRO | | Time at start of inflation of first reefed stage | sec | sec |
| TOTR1 | | Time at start of inflation of second reefed stage | sec | sec |
| TOTR2 | | Time at start of inflation of third reefed stage | sec | sec |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| TOTR3 | | Time at end . third reefed stage | sec | sec |
| TPD | | Total tether load (tension + damping) | N | $lb_f$ |
| TPDRB | | Component of tether load normal to forebody centerline | N | $lb_f$ |
| TPDXB | | Tether load component along forebody XB axis | N | $lb_f$ |
| TPDYB | | Tether load component along forebody YB axis | N | $lb_f$ |
| TPDZB | | Tether load component along forebody ZB axis | N | $lb_f$ |
| TRO | | Time from "TO" to start of inflation of first stage | sec | sec |
| TR1 | | Time from "TO" to start of inflation of second stage | sec | sec |
| TR2 | | Time from "TO" to start of inflation of third stage | sec | sec |
| TR3 | | Time from "TO" to end of third stage (TR3 > TTT) | sec | sec |
| TTIP(16) | | An array of sixteen variables signifying inflation time events | | sec |
| TXB | $T_{xb}$ | Torque about $X_b$ axis due to aerodynamics | (m-N) | ft-$lb_f$ |
| TTT | | Flight time at which simulation is ended | | sec |
| TYB | $T_{yb}$ | Torque about $Y_b$ axis due to aerodynamics | (m-N) | ft-$lb_f$ |
| TYPB | $T_{ypb}$ | Torque about $X_{pb}$ axis due to aero-dynamics | (m-N) | ft-$lb_f$ |
| TZB | $T_{xb}$ | Torque about $Z_b$ axis due to aerodynamics | (M-N) | ft-$lb_f$ |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| TZPB | $T_{zpb}$ | Torque about $Z_{pb}$ axis due to aerodynamics | (m-N) | $ft\text{-}lb_f$ |
| V | | Total velocity of forebody | (m/sec) | ft/sec |
| VP | | Total velocity of decelerator | (m/sec) | ft/sec |
| VS | | Speed of sound at Z | (m/sec) | ft/sec |
| WT | | Weight of forebody | (N) | lb |
| WTC | | Parachute canopy weight | $kg\cdot m/sec^2$ | lb |
| WTCM | | Mass of parachute canopy | kg | slug |
| WTL | | Parachute suspension lines weight | $kg\cdot m/sec^2$ | lb |
| WTLM | | Mass of parachute suspension lines | kg | slug |
| WTP | | Weight of decelerator | (N) | lb |
| X | X | Down range inertial axis or displacement of forebody | (m) | ft |
| | $X_b$ | Longitudinal body axis or displacement of forebody | (m) | ft |
| XBAR | $\bar{X}$ | c.g. offset along $X_b$ axis | (m) | ft |
| XBD | $\dot{X}_b$ | $X_b$ body axis velocity | (m/sec) | ft/sec |
| XD | $\dot{X}$ | Down range velocity of forebody | (m/sec) | ft/sec |
| XDD | $\ddot{X}$ | Down range acceleration of forebody | ($m/sec^2$) | $ft/sec^2$ |
| XP | $X_p$ | Down range displacement of decelerator | (m) | ft |
| XPBD | $\dot{X}_{pb}$ | $X_{pb}$ body axis velocity of decelerator | (m/sec) | ft/sec |
| XPBDR | | Velocity of air entering or exiting the parachute relative to the parachute velocity | m/sec | ft/sec |



E-ID-15(7-71)
REF: EOI 380

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| XPBDI | | Parachute velocity, XPBD, at T = TINT. It is used to calculate fill time | m/sec | ft/sec |
| XPD | $\dot{X}_p$ | Down range velocity of decelerator | (m/sec) | ft/sec |
| XPDD | $\ddot{X}_p$ | Down range acceleration of decelerator | (m/sec$^2$) | ft/sec$^2$ |
| Y | Y | Cross range inertial axis or displacement of forebody | (m) | ft |
| | $Y_b$ | Lateral body axis or displacement of forebody | (m) | ft |
| YBAR | $\bar{Y}$ | c.g. offset along $Y_b$ axis | (m) | ft |
| YBD | $\dot{Y}_b$ | $Y_b$ body axis velocity | (m/sec) | ft/sec |
| YD | $\dot{Y}$ | Cross range velocity of forebody | (m/sec) | ft/sec |
| YDD | $\ddot{Y}$ | Cross range acceleration of forebody | (m/sec$^2$) | ft/sec$^2$ |
| YP | $Y_p$ | Cross range inertial displacement of decelerator | (m) | ft |
| YPBD | $\dot{Y}_{pb}$ | $Y_{pb}$ body axis velocity of decelerator | (m/sec) | ft/sec |
| YPD | $\dot{Y}_p$ | Cross range velocity of decelerator | (m/sec) | ft/sec |
| YPDD | $\ddot{Y}_p$ | Cross range acceleration of decelerator | (m/sec$^2$) | ft/sec$^2$ |
| Z | | Vertical inertial axis or displacement of forebody | (m) | ft |
| | $Z_b$ | Vertical body axis or displacement of forebody | (m) | ft |

| FORTRAN | STANDARD | DESCRIPTION | METRIC UNITS | ENGLISH UNITS |
|---|---|---|---|---|
| ZBAR | $\bar{Z}$ | c.g. offset along $Z_b$ axis | (m) | ft |
| ZBD | $\dot{Z}_b$ | $Z_b$ body axis velocity | (m/sec) | ft/sec |
| ZD | $\dot{Z}$ | Vertical velocity of forebody | (m/sec) | ft/sec |
| ZDD | $\ddot{Z}$ | Vertical acceleration of forebody | ($m/sec^2$) | $ft/sec^2$ |
| ZP | $Z_p$ | Vertical inertial displacement of decelerator | (m) | ft |
| ZPBD | $\dot{Z}_{pb}$ | $Z_{pb}$ body axis velocity of decelerator | (m/sec) | ft/sec |
| ZPD | $\dot{Z}_p$ | Vertical velocity of decelerator | (m/sec) | ft/sec |
| ZPDD | $\ddot{Z}_p$ | Vertical acceleration of decelerator | ($m/sec^2$) | $ft/sec^2$ |

E-1D-15(7-71)
REF: EOI 380

## CHAPTER I - INTRODUCTION

The system to be simulated is two rigid bodies joined by an elastic tether. The forebody may have a completely general shape and mass characteristics, and will be free to move with six degrees of freedom (three translational, three rotational). The decelerator is assumed to be symmetric in shape and mass characteristics about its longitudinal (roll) axis, and will be free to move with five degrees of freedom (three translational, two rotational). A frictionless swivel is assumed at the decelerator-tether confluence point. Thus the roll motions of the forebody will not couple with the decelerator. The tether is simulated by a spring and dashpot in parallel. Damping coefficients for tether lines are difficult to obtain; but spring constants for a tether can be found from experimental stress strain curves. Consequently; the damping coefficient is assumed constant, while the spring constant is assumed to be a function of elongation in the computer program, thereby introducing a quasilinear spring.

# CHAPTER II DERIVATION OF EQUATIONS OF MOTION

## SECTION 1 - COORDINATE SYSTEM

Figure 1 shows the different coordinate systems used to derive the equations of motion. $\mathfrak{X}\mathfrak{Y}\mathfrak{Z}$ is an inertial orthogonal coordinate system attached to a flat non-rotating earth. XYZ and $X_p$ $Y_p$ $Z_p$ are orthogonal axes fixed to the forebody and decelerater at "O" and "$O_p$" respectively. Coordinate systems XYZ and $X_p$ $Y_p$ $Z_p$ translate with the bodies but do not rotate, always remaining parallel to corresponding inertial axes. The displacements X, Y, Z, $X_p$, $Y_p$, and $Z_p$, as measured from the origin of $\mathfrak{X}\mathfrak{Y}\mathfrak{Z}$, are the six translational degrees of freedom of the two bodies. The reference forebody body axes, longitudinal ($X_b$), lateral ($Y_b$), and vertical ($Z_b$), intersect at "O", the origin of the aerodynamics load system of the forebody. The reference decelerator body axes, longitudinal ($X_{pb}$), lateral ($Y_{pb}$), and vertical ($Z_{pb}$) intersect at "$O_p$", the c.g. of the decelerator. The variables $\overline{X}$, $\overline{Y}$, $\overline{Z}$ are the distances from "O" to the c.g. of the forebody measured positively in the direction of the positive body axes $X_b$, $Y_b$, $Z_b$ respectively. For orientation purposes, the reader should position himself as a pilot in an airplane. In this position, $X_b$ is positive toward the nose, $Y_b$ is positive toward the left wing and $Z_b$ is positive up. $\vec{r}_1$ is the vector distance from the intersection of the longitudinal, lateral, and vertical axes of the forebody ("O") to the tether confluence point of the forebody. $\vec{r}_2$ is the vector distance from the c.g. of the decelerator ("$O_p$") to the tether confluence point of the decelerator; $\vec{r}_2$ lies along $X_{pb}$.

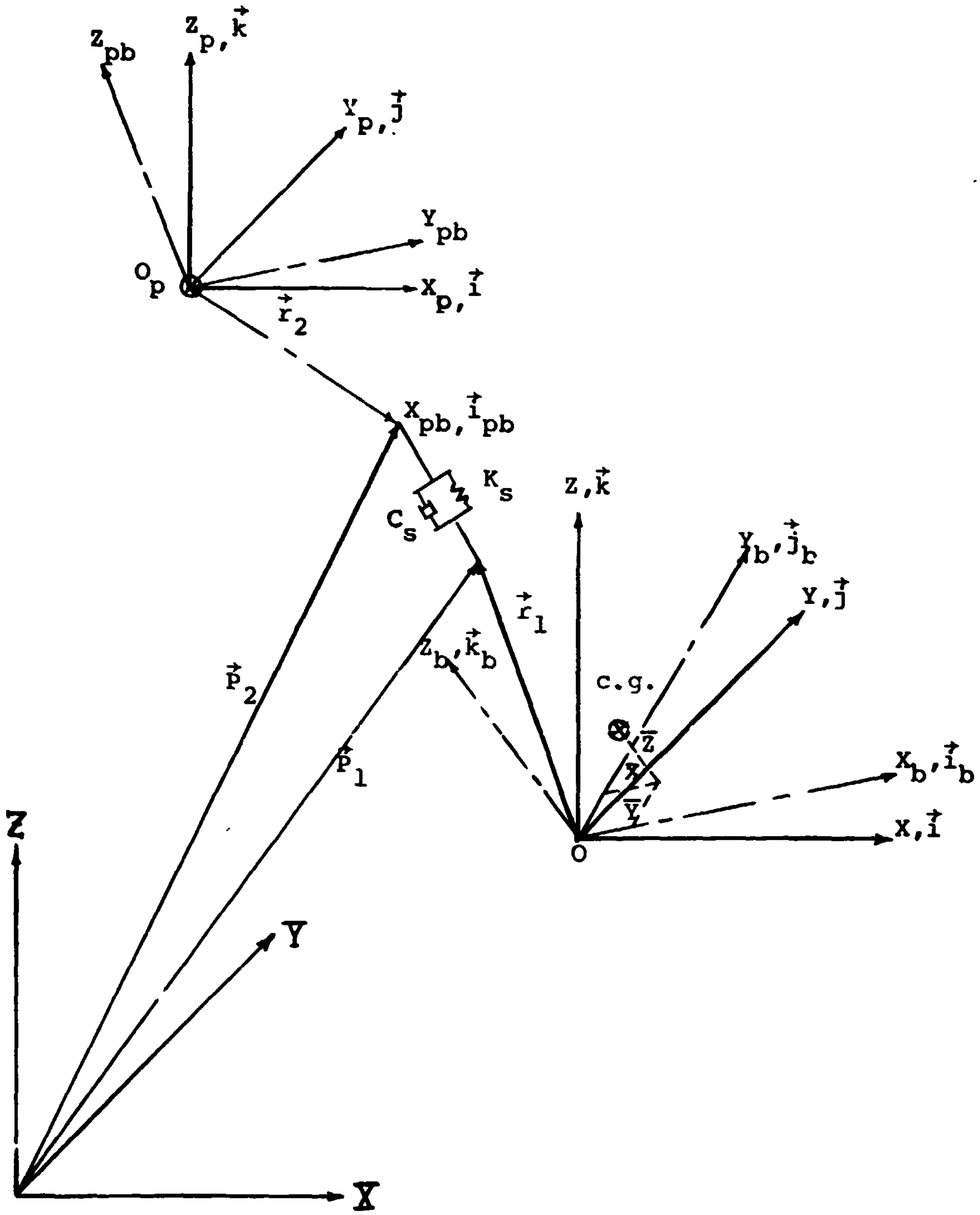


FIGURE 1 - COORDINATE SYSTEMS

## SECTION 2 - EULER ANGLE TRANSFORMATION

In order to specify the angular orientation of a body with reference to a non-rotating coordinate system (X, Y, Z), three successive rotations are made as shown in Figure 2. The first rotation is in the direction, -OZ, such that OX and OY are rotated through an angle $\psi$ into Oa and ON respectively. The second rotation is in the direction, -ON, such that Oa and OZ are rotated through an angle $\theta$ into $OX_b$ and Ob respectively. The final rotation is about $OX_b$ such that ON and Ob are rotated through an angle $\phi$ into $OY_b$ and $OZ_b$ respectively. The three angular rotations ($\psi$, $\theta$, $\phi$) specify the orientation of the body axes ($X_b$, $Y_b$, $Z_b$) with respect to the inertial axes ($\mathbb{X}, \mathbb{Y}, \mathbb{Z}$). Again, from a pilots viewpoint, a positive $\psi$ is a nose to the right yaw; a positive $\theta$ is a nose up pitch; and a positive $\phi$ is a right wing down roll.

The transformation matrix between the body axes and inertial axes is now found by considering one rotation at a time and then combining. The first rotation is given by:

$$\begin{Bmatrix} Oa \\ ON \\ OZ \end{Bmatrix} = \begin{bmatrix} C\psi & -S\psi & 0 \\ S\psi & C\psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} OX \\ OY \\ OZ \end{Bmatrix} \tag{1}$$

where $S\psi = \sin\psi$ and $C\psi = \cos\psi$.

The second rotation is:

$$\begin{Bmatrix} OX_b \\ ON \\ Ob \end{Bmatrix} = \begin{bmatrix} C\theta & 0 & S\theta \\ 0 & 1 & 0 \\ -S\theta & 0 & C\theta \end{bmatrix} \begin{Bmatrix} Oa \\ ON \\ OZ \end{Bmatrix} \tag{2}$$

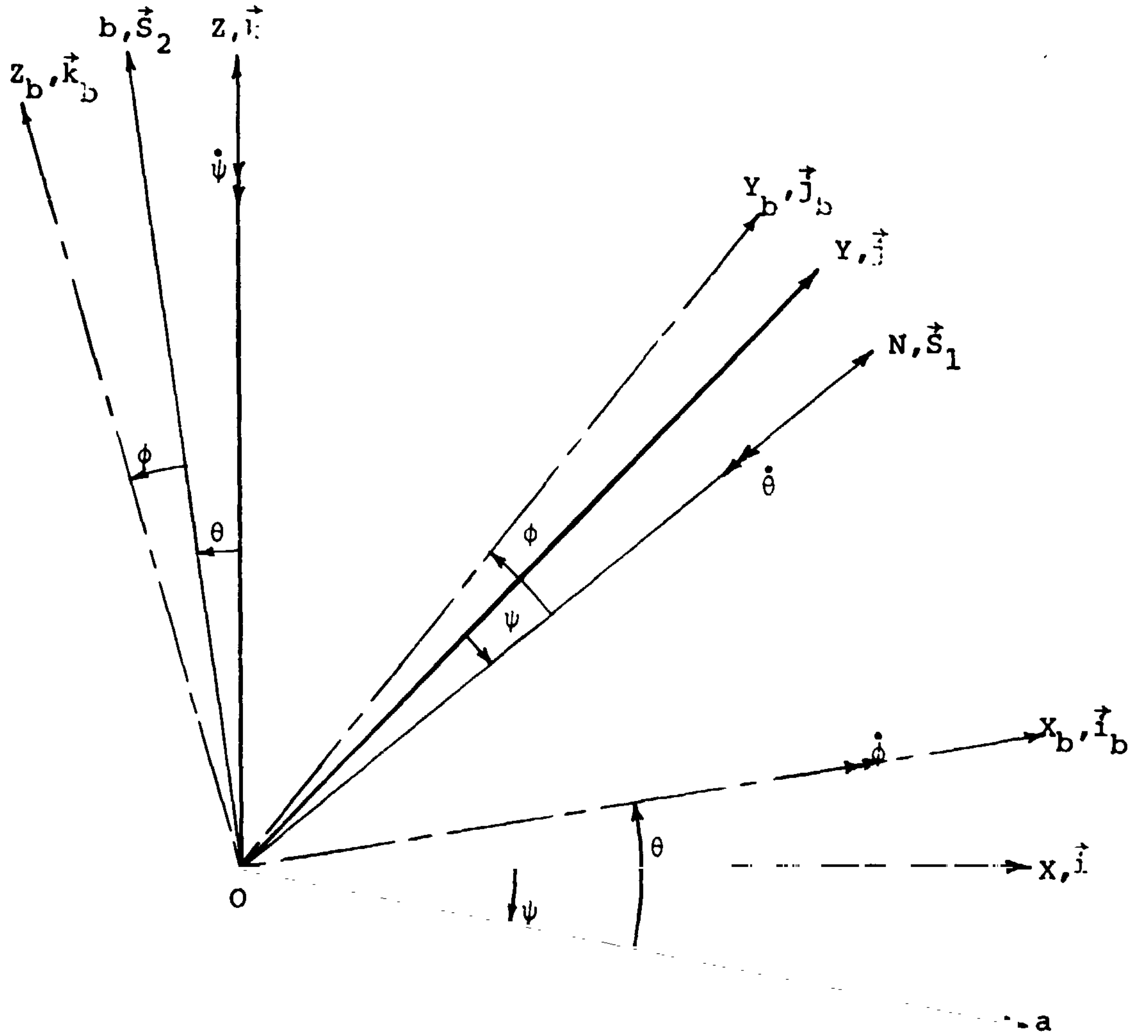


FIGURE 2 - EULER ANGLE ROTATIONS

The final rotation is:

$$\begin{Bmatrix} OX_b \\ OY_b \\ OZ_b \end{Bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & C\phi & S\phi \\ 0 & -S\phi & C\phi \end{bmatrix} \begin{Bmatrix} OX_b \\ ON \\ Ob \end{Bmatrix} \tag{3}$$

By substituting Equation (1) into (2) and (2) into (3), the transformation matrix [C] is formed

$$\begin{Bmatrix} OX_b \\ OY_b \\ OZ_b \end{Bmatrix} = \begin{bmatrix} C\psi C\theta & -S\psi C\theta & S\theta \\ -C\psi S\theta S\phi + S\psi C\phi & S\psi S\theta S\phi + C\psi C\phi & C\theta S\phi \\ -C\psi S\theta C\phi - S\psi S\phi & S\psi S\theta C\phi - C\psi S\phi & C\theta C\phi \end{bmatrix} \begin{Bmatrix} OX \\ OY \\ OZ \end{Bmatrix} \tag{4}$$

Since [C] is a linear orthogonal ( $\sum_{i=1}^{3} C_{ij}\, C_{ik} = \delta_{jk}$; j, k = 1,2,3) transformation, its inverse is equal to its transpose.[1]. Therefore,

$$\begin{Bmatrix} OX \\ OY \\ OZ \end{Bmatrix} = \begin{bmatrix} C\psi C\theta & -C\psi S\theta S\phi + S\psi C\phi & -C\psi S\theta C\phi - S\psi S\phi \\ -S\psi C\theta & S\psi S\theta S\phi + C\psi C\phi & S\psi S\theta C\phi - C\psi S\phi \\ S\theta & C\theta S\phi & C\theta C\phi \end{bmatrix} \begin{Bmatrix} OX_b \\ OY_b \\ OZ_b \end{Bmatrix} \tag{5}$$

For the decelerator, there is no rotation about the longitudinal axis. Consequently, the transformation matrix in (4) is simplified by letting $\phi = 0$. The result is $[C_p]$.

$$\begin{Bmatrix} OX_{pb} \\ OY_{pb} \\ OZ_{pb} \end{Bmatrix} = \begin{bmatrix} C\psi_p C\theta_p & -S\psi_p C\theta_p & S\theta_p \\ S\psi_p & C\psi_p & 0 \\ -C\psi_p S\theta_p & S\psi_p S\theta_p & C\theta_p \end{bmatrix} \begin{Bmatrix} OX_p \\ OY_p \\ OZ_p \end{Bmatrix} \tag{6}$$

The total angular velocity of the forebody is given by:

$$\vec{\omega} = \dot{\psi}\vec{k} - \dot{\theta}\vec{S}_1 + \dot{\phi}\vec{i}_b \tag{7}$$

From the inverse of (3):

$$\vec{S}_1 = C\phi\vec{j}_b - S\phi\vec{k}_b \tag{8}$$

$$\vec{S}_2 = S\phi\vec{j}_b + C\phi\vec{k}_b \tag{9}$$

From the inverse of (2)

$$\vec{k} = S\theta\vec{i}_b + C\theta\vec{S}_2 \tag{10}$$

Substituting (8), (9), and (10) into (7):

$$\vec{\omega} = [-\dot{\psi}(S\theta)+\dot{\phi}]\vec{i}_b + [-\dot{\psi}(C\theta S\phi)-\dot{\theta}(C\phi)]\vec{j}_b + [-\dot{\psi}(C\theta C\phi)+\dot{\theta}(S\phi)]\vec{k}_b \tag{11}$$

The components of angular velocity for the forebody are:

$$\omega_{xb} = -\dot{\psi}(S\theta) + \dot{\phi} \tag{12}$$

$$\omega_{yb} = -\dot{\psi}(C\theta S\phi) - \dot{\theta}(C\phi) \tag{13}$$

$$\omega_{zb} = -\dot{\psi}(C\theta C\phi) + \dot{\theta}(S\phi) \tag{14}$$

Likewise, for the decelerator, the angular velocities are:

$$\omega_{xpb} = -\dot{\psi}_p(S\theta_p) \tag{15}$$

$$\omega_{ypb} = -\dot{\theta}_p \tag{16}$$

$$\omega_{zpb} = -\dot{\psi}_p(C\theta_p) \tag{17}$$

## SECTION 3 - KINETIC ENERGY

The kinetic energy of the system is due to the translational and rotational velocities of the forebody and the decelerator. The forebody is completely general in shape, and products of inertia and c.g. offsets will effect the kinetic energy. On the other hand, the decelerator is assumed to be symmetric about the longitudinal axis and the aerodynamic loads are referenced to the c.g. Therefore, all products of inertia and c.g. offsets are zero. The expression for kinetic energy is:[2]

$$
\begin{aligned}
T = \; & \frac{1}{2} m[\dot{X}^2 + \dot{Y}^2 + \dot{Z}^2] + \frac{1}{2}[I_{xb}\omega_{xb}^2 + I_{yb}\omega_{yb}^2 + I_{zb}\omega_{zb}^2] \\
& - [I_{yzb}\omega_{yb}\omega_{zb} + I_{xzb}\omega_{xb}\omega_{zb} + I_{xyb}\omega_{xb}\omega_{yb}] \\
& + m[\dot{X}_b(\omega_{yb}\overline{Z} - \omega_{zb}\overline{Y}) + \dot{Y}_b(\omega_{zb}\overline{X} - \omega_{xb}\overline{Z}) + \dot{Z}_b(\omega_{xb}\overline{Y} - \omega_{yb}\overline{X})] \\
& + \frac{1}{2} m_{p\ell}[\dot{X}_{pb}^2] + \frac{1}{2} m_{ps}[\dot{Y}_{pb}^2 + Z_{pb}^2] \\
& + \frac{1}{2}[I_{xpb}\omega_{xpb}^2 + I_{ypb}\omega_{ypb} + I_{zpb}\omega_{zpb}^2] \qquad (18)
\end{aligned}
$$

In Equation (18), $m_{p\ell}$ and $m_{ps}$ include directional mass terms due to the air enclosed in the canopy, $I_{xpb}$, $I_{ypb}$, and $I_{zpb}$ are apparent mass moments of inertia.

E-ID-15(7-71)
REF: EOI 380

## SECTION 4 - POTENTIAL ENERGY

The potential energy of the system is due to the gravitational potential of both bodies and the elastic potential of the tether.

$$V = mg[Z + \bar{X}\,(S\theta) + \bar{Y}(C\theta S\phi) + \bar{Z}(C\theta C\phi)] + m_p g Z_p + \frac{1}{2} K_s [L_T - L_{To}]^2 \qquad (19)$$

$L_{To}$ is the unstretched length of the tether; and $L_T$ is the stretched length of the tether as given by the geometry of the system. Referring to Figure 1:

$$L_T = |\vec{P}_2 - \vec{P}_1| \qquad (20)$$

$\vec{P}_1$ and $\vec{P}_2$ are the vectors from the inertial coordinate system ( $\mathfrak{X}\,\mathfrak{Y}\,\mathfrak{Z}$ ) to the confluence points of the forebody and decelerator respectively. For the forebody,

$$\vec{P}_1 = X\vec{i} + Y\vec{j} + Z\vec{k} + \vec{r}_1 \qquad (21)$$

$$\vec{r}_1 = a\vec{i}_b + b\vec{j}_b + c\vec{k}_b \qquad (22)$$

a, b, and c are measured along positive body axes $X_b$, $Y_b$, and $Z_b$ respectively. Using the coordinate transformation matrix (4):

$$\begin{aligned}\vec{P}_1 = {} & [X+a(C\psi C\theta)+b(-C\psi S\theta S\phi+S\psi C\phi) + c(-C\psi S\theta C\phi-S\psi S\phi)]\,\vec{i} \\ & + [Y+a(-S\psi C\theta)+b(S\psi S\theta S\phi+C\psi C\phi)+ c(S\psi S\theta C\phi-C\psi S\phi)]\,\vec{j} \\ & + [Z+a(S\theta)+ b(C\theta S\phi)+ c(C\theta C\phi)]\,\vec{k}\end{aligned} \qquad (23)$$

Similarly for the decelerator:

$$\vec{P}_2 = X_p \vec{i} + Y_p \vec{j} + Z_p \vec{k} + \vec{r}_2 \tag{24}$$

$$\vec{r}_2 = a_p \vec{i}_{pb} \tag{25}$$

Substituting (25) into (24) and using matrix Equation (6),

$$\vec{P}_2 = [X_p+a_p(C\psi_p C\theta_p)]\ \vec{i} + [Y_p+a_p(-S\psi_p C\theta_p)]\ \vec{j} + [Z_p+a_p(S\theta_p)]\vec{k} \tag{26}$$

$$L_T = [L_T \cdot L_T]^{1/2} \tag{27}$$

$$\begin{aligned} L_T = \{ & [X_p+a_p(C\psi_p C\theta_p)-X-a(C\psi C\theta)-b(-C\psi S\theta S\phi+S\psi C\phi)-c(-C\psi S\theta C\phi-S\psi S\phi)]^2 \\ & +[Y_p+a_p(-S\psi_p C\theta_p)-Y-a(-S\psi C\theta)-b(S\psi S\theta S\phi+C\psi C\phi)-c(S\psi S\theta C\phi-C\psi S\phi)]^2 \\ & +[Z_p+a_p(S\theta_p)-Z-a(S\theta)-b(C\theta S\phi)-c(C\theta C\phi)]^2\}^{1/2} \end{aligned} \tag{28}$$

Define the variables $\bar{A}$, $\bar{B}$, and $\bar{C}$ such that:

$$L_T = \{[\bar{A}]^2 + [\bar{B}]^2 + [\bar{C}]^2\}^{1/2} \tag{29}$$

Further on in the derivation it will be necessary to know the total time derivative of $L_T$ and the partial derivatives of $\bar{A}$, $\bar{B}$, and $\bar{C}$ with respect to the generalized coordinates.

$$\dot{L}_T = [\bar{A}\ \dot{\bar{A}} + \bar{B}\ \dot{\bar{B}} + \bar{C}\ \dot{\bar{C}}]/L_T \tag{30}$$

$$\dot{A} = \dot{X}_p+a_p[\dot{\psi}_p(-S\psi_pC\theta_p)+\dot{\theta}_p(-C\psi_pS\theta_p)]-\dot{X}-a[\dot{\psi}(-S\psi C\theta)+\dot{\theta}(-C\psi S\theta)]$$
$$-b[\dot{\psi}(S\psi S\theta S\phi+C\psi C\phi)+\dot{\theta}(-C\psi C\theta S\phi)+\dot{\phi}(-C\psi S\theta C\phi-S\psi S\phi)]$$
$$-c[\dot{\psi}(S\psi S\theta C\phi-C\psi S\phi)+\dot{\theta}(-C\psi C\theta C\phi)+\dot{\phi}(C\psi S\theta S\phi-S\psi C\phi)] \qquad (31)$$

$$\dot{B} = \dot{Y}_p+a_p[\dot{\psi}_p(-C\psi_pC\theta_p)+\dot{\theta}_p(S\psi_pS\theta_p)]-\dot{Y}-a[\dot{\psi}(-C\psi C\theta)+\dot{\theta}(S\psi S\theta)]$$
$$-b[\dot{\psi}(C\psi S\theta S\phi-S\psi C\phi)+\dot{\theta}(S\psi C\theta S\phi)+\dot{\phi}(S\psi S\theta C\phi-C\psi S\phi)]$$
$$-c[\dot{\psi}(C\psi S\theta C\phi+S\psi S\phi)+\dot{\theta}(S\psi C\theta C\phi)+\dot{\phi}(-S\psi S\theta S\phi-C\psi C\phi)] \qquad (32)$$

$$\dot{C} = \dot{Z}_p+a_p[\dot{\theta}_p(C\theta_p)]-\dot{Z}-a[\dot{\theta}(C\theta)]-b[\dot{\theta}(-S\theta S\phi)+\dot{\phi}(C\theta C\phi)]$$
$$-c[\dot{\theta}(-S\theta C\phi)+\dot{\phi}(-C\theta S\phi)] \qquad (33)$$

$$\frac{\partial\bar{A}}{\partial X} = \frac{\partial\bar{B}}{\partial Y} = \frac{\partial\bar{C}}{\partial Z} = -1 \qquad (34)$$

$$\frac{\partial\bar{A}}{\partial X_p} = \frac{\partial\bar{B}}{\partial Y_p} = \frac{\partial\bar{C}}{\partial Z_p} = 1 \qquad (35)$$

$$\frac{\partial\bar{A}}{\partial Y} = \frac{\partial\bar{A}}{\partial Z} = \frac{\partial\bar{A}}{\partial Y_p} = \frac{\partial\bar{A}}{\partial Z_p} = 0$$
$$\frac{\partial\bar{B}}{\partial X} = \frac{\partial\bar{B}}{\partial Z} = \frac{\partial\bar{B}}{\partial X_p} = \frac{\partial\bar{B}}{\partial Z_p} = 0 \qquad (36)$$
$$\frac{\partial\bar{C}}{\partial X} = \frac{\partial\bar{C}}{\partial Y} = \frac{\partial\bar{C}}{\partial X_p} = \frac{\partial\bar{C}}{\partial Y_p} = 0$$

$$\frac{\partial \bar{A}}{\partial \psi} = a(S\psi C\theta)-b(S\psi S\theta S\phi+C\psi C\phi)-c(S\psi S\theta C\phi-C\psi S\phi) \tag{37}$$

$$\frac{\partial \bar{A}}{\partial \theta} = a(C\psi S\theta)+b(C\psi C\theta S\phi)+c(C\psi C\theta C\phi) \tag{38}$$

$$\frac{\partial A}{\partial \phi} = b(C\psi S\theta C\phi+ S\psi S\phi)-c(C\psi S\theta S\phi-S\psi C\phi) \tag{39}$$

$$\frac{\partial \bar{A}}{\partial \psi_p} = a_p(-S\psi_p C\theta_p) \tag{40}$$

$$\frac{\partial \bar{A}}{\partial \theta_p} = a_p(-C\psi_p S\theta_p) \tag{41}$$

$$\frac{\partial \bar{B}}{\partial \psi} : a(C\psi C\theta)-b(C\psi S\theta S\phi-S\psi C\phi)-c(C\psi S\theta C\phi+S\psi S\phi) \tag{42}$$

$$\frac{\partial \bar{B}}{\partial \theta} = a(-S\psi S\theta)-b(S\psi C\theta S\phi)-c(S\psi C\theta C\phi) \tag{43}$$

$$\frac{\partial \bar{B}}{\partial \phi} = -b(S\psi S\theta C\phi-C\psi S\phi)+c(S\psi S\theta S\phi+C\psi C\phi) \tag{44}$$

$$\frac{\partial \bar{B}}{\partial \psi_p} = a_p(-C\psi_p C\theta_p) \tag{45}$$

$$\frac{\partial \bar{B}}{\partial \theta_p} = a_p(S\psi_p S\theta_p) \tag{46}$$

$$\frac{\partial \bar{C}}{\partial \psi} = 0 \tag{47}$$

$$\frac{\partial \bar{C}}{\partial \theta} = a(-C\theta)+b(S\theta S\phi)+c(S\theta C\phi) \tag{48}$$

E-ID-15(7-71)
REF: E01 380

$$\frac{\partial \bar{C}}{\partial \phi} = b(-C\theta C\phi)+c(C\theta S\phi) \tag{49}$$

$$\frac{\partial \bar{C}}{\partial \psi_p} = 0 \tag{50}$$

$$\frac{\partial \bar{C}}{\partial \theta_p} = a_p(C\theta_p) \tag{51}$$

SECTION 5 - RALEIGH'S DISSIPATION FUNCTION

If the viscous damping force is proportional to the velocity of the particle at which the force acts, an expression analogous to the potential energy of a spring may be used. This function, F, is known as Rayleigh's dissipation function, and is defined as (1)

$$F = \frac{1}{2} \sum_{i=1}^{n} C_i \dot{q}_i^{\,2} \tag{52}$$

For this problem, Rayleigh's damping is considered only in the tether.

$$F = \frac{1}{2} C_s \dot{L}_T^{\,2}$$

SECTION 6 - LAGRANGE'S EQUATION

The Lagrange equation for a non-conservative (aerodynamic forces) system with a holonomic (can be expressed as an algebraic expression), scleronomous (independent of time) constraint and Rayleigh's dissipation function (damping in the elastic tether) can be written as: (1)

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_i}\right) - \frac{\partial L}{\partial q_i} - \lambda \frac{\partial \bar{g}}{\partial q_i} + \frac{\partial F}{\partial \dot{q}_i} = Q_i \tag{54}$$

In Equation (54), the term $\lambda \frac{\partial \bar{g}}{\partial q_i}$ expresses the generalized force exerted by the tether on the $i^{th}$ degree of freedom. The constraint equation is:

$$\bar{g} = \{[\bar{A}]^2 + [\bar{B}]^2 + [\bar{C}]^2\}^{1/2} - L_T = 0 \tag{55}$$

$Q_i$ is the generalized force due to the aerodynamics.

$\frac{\partial F}{\partial \dot{q}_i}$ is the force due to damping in the tether.

The Lagrangian is equal to the total kinetic energy of the system (Equation (18)) minus the total potential energy of the system (Equation (19)). With substitutions from Equations (4), (6) and (12) to (17), the Lagrangian is:

$$\begin{aligned} L = {} & \frac{1}{2} m[\dot{X}^2+\dot{Y}^2+\dot{Z}^2]+\frac{1}{2} m_{p\ell}[\dot{X}_p(C\psi_p C\theta_p)+\dot{Y}_p(-S\psi_p C\theta_p)+\dot{Z}_p(S\theta_p)]^2 \\ & + \frac{1}{2}m_{ps}\{[\dot{X}_p(S\psi_p)+\dot{Y}_p(C\psi_p)]^2+[\dot{X}_p(-C\psi_p S\theta_p)+\dot{Y}_p(S\psi_p S\theta_p)+\dot{Z}_p(C\theta_p)]^2\} \\ & + \frac{1}{2}I_{xb}[-\dot{\psi}(S\theta)+\dot{\phi}]^2+\frac{1}{2} I_{yb}[-\dot{\psi}(C\theta S\phi)-\dot{\theta}(C\phi)]^2+\frac{1}{2} I_{zb}[-\dot{\psi}(C\theta C\phi)+\dot{\theta}(S\phi)]^2 \\ & -\{I_{yzb}[-\dot{\psi}(C\theta S\phi)-\dot{\theta}(C\phi)][-\dot{\psi}(C\theta C\phi)+\dot{\theta}(S\phi)]+I_{xzb}[-\dot{\psi}(S\theta)+\dot{\phi}][-\dot{\psi}(C\theta C\phi)+\dot{\theta}(S\phi)] \\ & + I_{xyb}[-\dot{\psi}(S\theta)+\dot{\phi}][-\dot{\psi}(C\theta S\phi)-\dot{\theta}(C\phi)]\} \end{aligned}$$

E-ID-15(7-71)
REF: EOI 380

$$+\frac{1}{2}I_{xpb}[-\dot{\psi}_p^{\,2}(S^2\theta_p \quad +\frac{1}{2}I_{ypb}[\dot{\theta}_p^{\,2}+\dot{\psi}_p^{\,2}(C^2\theta_p)]$$

$$+m\{[\dot{X}(C\psi C\theta)+\dot{Y}(-S\psi C\theta)+\dot{Z}(S\theta)][\overline{Z}(-\dot{\psi}(C\theta S\phi)-\dot{\theta}(C\phi))-\overline{Y}(-\dot{\psi}(C\theta C\phi)+\dot{\theta}(S\phi))]$$

$$+[\dot{X}(-C\psi S\theta S\phi+S\psi C\phi)+\dot{Y}(S\psi S\theta S\phi+C\psi C\phi)+\dot{Z}(C\theta S\phi)][\overline{X}(-\dot{\psi}(C\theta C\phi)+\dot{\theta}(S\phi))-\overline{Z}(-\dot{\psi}(S\theta)+\dot{\phi})]$$

$$+[\dot{X}(-C\psi S\theta C\phi-S\psi S\phi)+\dot{Y}(S\psi S\theta C\phi-C\psi S\phi)+\dot{Z}(C\theta C\phi)][\overline{Y}(-\dot{\psi}(S\theta)+\dot{\phi})-\overline{X}(-\dot{\psi}(C\theta S\phi)-\dot{\theta}(C\phi))]\}$$

$$-mg[Z+\overline{X}(S\theta)+\overline{Y}(C\theta S\phi)+\overline{Z}(C\theta C\phi)]-m_pgZ_p-\frac{1}{2}K_s[L_T-L_{TO}]^2 \qquad (56)$$

Note: $I_{ypb} = I_{zpb}$ due to decelerator symmetry.

## SECTION 7 - GENERAL EQUATIONS OF MOTION

Equation (56) displays all of the generalized coordinates explicitly except those appearing in $L_T$. The terms to be substituted into Equation (54) are now developed.

### X Equation

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{X}}\right) = \ddot{X}\{m\}+\ddot{\psi}\{m[\overline{X}(-S\psi C\theta)+\overline{Y}(S\psi S\theta S\phi+C\psi C\phi)+\overline{Z}(S\psi S\theta C\phi-C\psi S\phi)]\}$$

$$+\ddot{\theta}\{m[\overline{X}(-C\psi S\theta)+\overline{Y}(-C\psi C\theta S\phi)+\overline{Z}(-C\psi C\theta C\phi)]\}$$

$$+\ddot{\phi}\{m[\overline{Y}(-C\psi S\theta C\phi-S\psi S\phi)+\overline{Z}(C\psi S\theta S\phi-S\psi S\phi)]\}$$

$$+\dot{\psi}\dot{\theta}\{m[\overline{X}(2S\psi S\theta)+\overline{Y}(2S\psi C\theta S\phi)+\overline{Z}(2S\psi C\theta C\phi)]\}$$

E-ID-15(7-71)
REF: EOI 380

$$+\dot{\psi}\dot{\phi}\{m[\overline{Y}(2S\psi S\theta C\phi-2C\psi S\phi)+\overline{Z}(-2S\psi S\theta S\phi-2C\psi C\phi)]\}$$

$$+\dot{\theta}\dot{\phi}\{m[\overline{Y}(-2C\psi C\theta C\phi)+\overline{Z}(2C\psi C\theta S\phi)]\}$$

$$+\dot{\psi}^2\{m[\overline{X}(-C\psi C\theta)+\overline{Y}(C\psi S\theta S\phi-S\psi C\phi)+\overline{Z}(C\psi S\theta C\phi+S\psi S\phi)]\}$$

$$+\dot{\theta}^2\{m[\overline{X}(-C\psi C\theta)+\overline{Y}(C\psi S\theta S\phi)+\overline{Z}(C\psi S\theta C\phi)]\}$$

$$+\dot{\phi}^2\{m[\overline{Y}(C\psi S\theta S\phi-S\psi C\phi)+\overline{Z}(C\psi S\theta C\phi+S\psi S\phi)]\} \tag{57}$$

$$\frac{\partial L}{\partial X} = 0 \tag{58}$$

$$\frac{\partial \overline{q}}{\partial X} = \frac{-\overline{A}}{L_T} \tag{59}$$

$$\frac{\partial F}{\partial \dot{X}} = 0 \tag{60}$$

Y Equation

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{Y}}\right) = \ddot{Y}\{m\}+\ddot{\psi}\{m[\overline{X}(-C\psi C\theta)+\overline{Y}(C\psi S\theta S\phi-S\psi C\phi)+\overline{Z}(C\psi S\theta C\phi+S\psi S\phi)]\}$$

$$+\ddot{\theta}\{m[\overline{X}(S\psi S\theta)+\overline{Y}(S\psi C\theta S\phi)+\overline{Z}(S\psi C\theta C\phi)]\}$$

$$+\ddot{\phi}\{m[\overline{Y}(S\psi S\theta C\phi-C\psi S\phi)+\overline{Z}(-S\psi S\theta S\phi-C\psi C\phi)]\}$$

$$+\dot{\psi}\dot{\theta}\{m[\overline{X}(2C\psi S\theta)+\overline{Y}(2C\psi C\theta S\phi)+\overline{Z}(2C\psi C\theta C\phi)]\}$$

$$+\dot{\psi}\dot{\phi}\{m[\overline{Y}(2C\psi S\theta C\phi+2S\psi S\phi)+\overline{Z}(-2C\psi S\theta S\phi+2S\psi C\phi)]\}$$

$$+\dot{\theta}\dot{\phi}\{m[\overline{Y}(2S\psi C\theta C\phi)+\overline{Z}(-2S\psi C\theta S\phi)]\}$$

$$+\dot{\psi}^2\{m[\overline{X}(S\psi C\theta)+\overline{Y}(-S\psi S\theta S\phi-C\psi C\phi)+\overline{Z}(-S\psi S\theta C\phi+C\psi S\phi)]\}$$

$$+\dot{\theta}^2\{m[\overline{X}(S\psi C\theta)+\overline{Y}(-S\psi S\theta S\phi)+\overline{Z}(-S\psi S\theta C\phi)]\}$$

$$+\dot{\phi}^2\{m[\overline{Y}(-S\psi S\theta S\phi-C\psi C\phi)+\overline{Z}(-S\psi S\theta C\phi+C\psi S\phi)\} \tag{61}$$

$$\frac{\partial L}{\partial Y} = 0 \tag{62}$$

$$\frac{\partial \overline{q}}{\partial Y} = \frac{-\overline{B}}{L_T} \tag{63}$$

$$\frac{\partial F}{\partial \dot{Y}} = 0 \tag{64}$$

<u>Z Equation</u>

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{Z}}\right) = \ddot{Z}\{m\}+\ddot{\theta}\{m[\overline{X}(C\theta)+\overline{Y}(-S\theta S\phi)+\overline{Z}(-S\theta C\phi)]\}$$

$$+\ddot{\phi}\{m[\overline{Y}(C\theta C\phi)+\overline{Z}(-C\theta S\phi)]\}$$

$$+\dot{\theta}\dot{\phi}\{m[\overline{Y}(-2S\theta C\phi)+\overline{Z}(S\theta S\phi)]\}$$

$$+\dot{\theta}^2\{m[\overline{X}(-S\theta)+\overline{Y}(-C\theta S\phi)+\overline{Z}(-C\theta C\phi)]\}$$

$$+\dot{\phi}^2\{m[\overline{Y}(-C\theta S\phi)+\overline{Z}(-C\theta C\phi)]\} \tag{65}$$

$$\frac{\partial L}{\partial Z} = -mg \tag{66}$$

$$\frac{\partial \bar{q}}{\partial Z} = -\frac{\bar{C}}{L_T} \tag{67}$$

$$\frac{\partial F}{\partial \dot{Z}} = 0 \tag{68}$$

<u>$X_p$ Equation</u>

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{X}_p}\right) = \ddot{X}_p\{m_{p\ell}[C^2\psi_p C^2\theta_p]+m_{ps}[S^2\psi_p+C^2\psi_p S^2\theta_p]\}$$

$$+\ddot{Y}_p\{[m_{p\ell}-m_{ps}][-\tfrac{1}{2}S2\psi_p C^2\theta_p]$$

$$+\ddot{Z}_p\{[m_{p\ell}-m_{ps}][\tfrac{1}{2}C\psi_p S2\theta_p]\}$$

$$+\dot{X}_F\dot{\psi}_p\{[m_{p\ell}-m_{ps}][-S2\psi_p C^2\theta_p]\}$$

$$+\dot{X}_p\dot{\theta}_p\{[m_{p\ell}-m_{ps}][-C^2\psi_p S2\theta_p]\}$$

$$+\dot{Y}_p\dot{\psi}_p\{[m_{p\ell}-m_{ps}][-C2\psi_p C^2\theta_p]\}$$

$$+\dot{Y}_p\dot{\theta}_p\{[m_{p\ell}-m_{ps}][\tfrac{1}{2}S2\psi_p S2\theta_p]\}$$

$$+\dot{Z}_p\dot{\psi}_p\{[m_{p\ell}-m_{ps}][-\tfrac{1}{2}S\psi_p S2\theta_p]\}$$

$$+\dot{Z}_p\dot{\theta}_p\{[m_{p\ell}-m_{ps}][C\psi_p C2\theta_p]\} \tag{69}$$

E-1D-15(7-71)
REF: EOI 380

$$\frac{\partial L}{\partial X_p} = 0 \tag{70}$$

$$\frac{\partial \bar{q}}{\partial X_p} = \frac{\bar{A}}{L_T} \tag{71}$$

$$\frac{\partial F}{\partial \dot{X}_p} = 0 \tag{72}$$

## $Y_p$ Equation

$$\begin{aligned}
\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{Y}_p}\right) = \; & \ddot{X}_p\{[m_{p\ell}-m_{ps}][-\tfrac{1}{2}S2\psi_p C^2\theta_p]\} \\
& +\ddot{Y}_p\{m_{p\ell}[S^2\psi_p C^2\theta_p]+m_{ps}[C^2\psi_p+S^2\psi_p S^2\theta_p]\} \\
& +\ddot{Z}_p\{m_{p\ell}-m_{ps}][-\tfrac{1}{2}S\psi_p S2\theta_p]\} \\
& +\dot{X}_p\dot{\psi}_p\{[m_{p\ell}-m_{ps}][-C2\psi_p C^2\theta_p]\} \\
& +\dot{X}_p\dot{\theta}_p\{[m_{p\ell}-m_{ps}][\tfrac{1}{2}S2\psi_p S2\theta_p]\} \\
& +\dot{Y}_p\dot{\psi}_p\{[m_{p\ell}-m_{ps}][S2\psi_p C^2\theta_p]\} \\
& +\dot{Y}_p\dot{\theta}_p\{[m_{p\ell}-m_{ps}][-S^2\psi_p S2\theta_p]\} \\
& +\dot{Z}_p\dot{\psi}_p\{[m_{p\ell}-m_{ps}][-\tfrac{1}{2}C\psi_p S2\theta_p]\} \\
& +\dot{Z}_p\dot{\theta}_p\{[m_{p\ell}-m_{ps}][-S\psi_p C2\theta_p]\}
\end{aligned} \tag{73}$$

E-ID-15(7-71)
REF: EOI 380

$$\frac{\partial L}{\partial Y_p} = 0 \tag{74}$$

$$\frac{\partial \bar{q}}{\partial Y_p} = \frac{\bar{B}}{L_T} \tag{75}$$

$$\frac{\partial F}{\partial \dot{Y}_p} = 0 \tag{76}$$

$Z_p$ Equation

$$\begin{aligned}
\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{Z}_p}\right) = {} & \ddot{X}_p\{[m_{p\ell} - m_{ps}][\tfrac{1}{2}\, C\psi_p S2\theta_p]\} \\
& + \ddot{Y}_p\{[m_{p\ell} - m_{ps}][-\tfrac{1}{2}\, S\psi_p S2\theta_p]\} \\
& + \ddot{Z}_p\{m_{p\ell}[S^2\theta_p] + m_{ps}[C^2\theta_p]\} \\
& + \dot{X}_p\dot{\psi}_p\{[m_{p\ell} - m_{ps}][-\tfrac{1}{2} S\psi_p S2\theta_p]\} \\
& + \dot{X}_p\dot{\theta}_p\{[m_{p\ell} - m_{ps}][C\psi_p C2\theta_p]\} \\
& + \dot{Y}_p\dot{\psi}_p\{[m_{p\ell} - m_{ps}][-\tfrac{1}{2} C\psi_p S2\theta_p]\} \\
& + \dot{Y}_p\dot{\theta}_p\{[m_{p\ell} - m_{ps}][-S\psi_p C2\theta_p]\} \\
& + \dot{Z}_p\dot{\theta}_p\{[m_{p\ell} - m_{ps}][S2\theta_p]\}
\end{aligned} \tag{77}$$

E-ID-15(7-71)
REF: EOI 380

$$\frac{\partial L}{\partial Z_p} = -m_p g \tag{78}$$

$$\frac{\partial \bar{q}}{\partial Z_p} = \frac{\bar{C}}{L_T} \tag{79}$$

$$\frac{\partial F}{\partial \dot{Z}_p} = 0 \tag{80}$$

$\psi$ Equation

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\psi}}\right) = \ddot{\psi}\{I_{xb}(S^2\theta)+[I_{yb}(S^2\phi)+I_{zb}(C^2\phi)](C^2\theta)+I_{yzb}(-C^2\theta S2\phi)$$
$$+[I_{xzb}(C\phi)+I_{xyb}(S\phi)](-S2\theta)\}$$
$$+\ddot{\theta}\{[(I_{yb}-I_{zb})(\tfrac{1}{2}S2\phi)-I_{yzb}(C2\phi)](C\theta)+[I_{xzb}(S\phi)-I_{xyb}(C\phi)](S\theta)\}$$
$$+\ddot{\phi}\{I_{xb}(-S\theta)+[I_{xzb}(C\phi)+I_{xyb}(S\phi)](C\theta)\}$$
$$+\ddot{X}\{m[\bar{X}(-S\psi C\theta)+\bar{Y}(S\psi S\theta S\phi+C\psi C\phi)+\bar{Z}(S\psi S\theta C\phi-C\psi S\phi)]\}$$
$$+\ddot{Y}\{m[-\bar{X}(C\psi C\theta)-\bar{Y}(-C\psi S\theta S\phi+S\psi C\phi)-\bar{Z}(-C\psi S\theta C\phi-S\psi S\phi)]\}$$
$$+\dot{\psi}\dot{\theta}\{[I_{xb}-I_{yb}(S^2\phi)-I_{zb}(C^2\phi)+I_{yzb}(S2\phi)](S2\theta)-[I_{xzb}(C\phi)+I_{xyb}(S\phi)](2C2\theta)\}$$
$$+\dot{\psi}\dot{\phi}\{[(I_{yb}-I_{zb})(S2\phi)-I_{yzb}(2C2\phi)](C^2\theta)+[I_{xzb}(S\phi)-I_{xyb}(C\phi)](S2\theta)\}$$
$$+\dot{\theta}\dot{\phi}\{[-I_{xb}+(I_{yb}-I_{zb})(C2\phi)+I_{yzb}(2S2\phi)](C\theta)\}$$

$$+\dot{\theta}^2\{[(I_{yb}-I_{zb})(-\tfrac{1}{2}S2\phi)+I_{yzb}(C2\phi)](S\theta)+I_{xzb}(C\theta S\phi)-I_{xyb}(C\theta C\phi)]\}$$

$$+\dot{\phi}^2\{I_{xyb}(C\theta C\phi)-I_{xzb}(C\theta S\phi)\}$$

$$+\dot{X}\dot{\psi}\{m[-\overline{X}(C\psi C\theta)-\overline{Y}(-C\psi S\theta S\phi+S\psi C\phi)-\overline{Z}(-C\psi S\theta C\phi-S\psi S\phi)]\}$$

$$+\dot{X}\dot{\theta}\{m[\overline{X}(S\psi S\theta)+\overline{Y}(S\psi C\theta S\phi)+\overline{Z}(S\psi C\theta C\phi)]\}$$

$$+\dot{X}\dot{\phi}\{m[\overline{Y}(S\psi S\theta C\phi-C\psi S\phi)-\overline{Z}(S\psi S\theta S\phi+C\psi C\phi)]\}$$

$$+\dot{Y}\dot{\psi}\{m[-\overline{X}(-S\psi C\theta)-\overline{Y}(S\psi S\theta S\phi+C\psi C\phi)-\overline{Z}(S\psi S\theta C\phi-C\psi S\phi)]\}$$

$$+\dot{Y}\dot{\theta}\{m[\overline{X}(C\psi S\theta)+\overline{Y}(C\psi C\theta S\phi)+\overline{Z}(C\psi C\theta C\phi)]\}$$

$$+\dot{Y}\dot{\phi}\{m[-\overline{Y}(-C\psi S\theta C\phi-S\psi S\phi)+\overline{Z}(-C\psi S\theta S\phi+S\psi C\phi)] \tag{81}$$

$$\frac{\partial L}{\partial \psi} = \dot{X}\dot{\psi}\{m[-\overline{X}(C\psi C\theta)-\overline{Y}(-C\psi S\theta S\phi+S\psi C\phi)-\overline{Z}(-C\psi S\theta C\phi-S\psi S\phi)]\}$$

$$+\dot{X}\dot{\theta}\{m[\overline{X}(S\psi S\theta)+\overline{Y}(S\psi C\theta S\phi)+\overline{Z}(S\psi C\theta C\phi)]\}$$

$$+\dot{X}\dot{\phi}\{m[\overline{Y}(S\psi S\theta C\phi-C\psi S\phi)-\overline{Z}(S\psi S\theta S\phi+C\psi C\phi)]\}$$

$$+\dot{Y}\dot{\psi}\{m[-\overline{X}(-S\psi C\theta)-\overline{Y}(S\psi S\theta S\phi+C\psi C\phi)-\overline{Z}(S\psi S\theta C\phi-C\psi S\phi)]\}$$

$$+\dot{Y}\dot{\theta}\{m[\overline{X}(C\psi S\theta)+\overline{Y}(C\psi C\theta S\phi)+\overline{Z}(C\psi C\theta C\phi)]$$

$$+\dot{Y}\dot{\phi}\{m[-\overline{Y}(-C\psi S\theta C\phi-S\psi S\phi)+\overline{Z}(-C\psi S\theta S\phi+S\psi C\phi)]\} \tag{82}$$

$$\frac{\partial \overline{q}}{\partial \psi} = \{\overline{A}\,\frac{\partial \overline{A}}{\partial \psi} + \overline{B}\,\frac{\partial \overline{B}}{\partial \psi}\}\,/L_T \tag{83}$$

$$\frac{\partial F}{\partial \dot{\psi}} = 0 \tag{84}$$

E-ID-15(7-71)
REF: EOI 380

## θ Equation

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\theta}}\right) = \ddot{\psi}\{[(I_{yb}-I_{zb})(\tfrac{1}{2}S2\phi)-I_{yzb}(C2\phi)](C\theta)-[I_{xyb}(C\phi)-I_{xzb}(S\phi)](S\theta)\}$$

$$+\ddot{\theta}\{I_{yb}(C^2\phi)+I_{zb}(S^2\phi)+I_{yzb}(S2\phi)\}$$

$$+\ddot{\phi}\{I_{xyb}(C\phi)-I_{xzb}(S\phi)\}$$

$$+\ddot{X}\{m[\overline{X}(-C\psi S\theta)+\overline{Y}(-C\psi C\theta S\phi)+\overline{Z}(-C\psi C\theta C\phi)]\}$$

$$+\ddot{Y}\{m[\overline{X}(S\psi S\theta)+\overline{Y}(S\psi C\theta S\phi)+\overline{Z}(S\psi C\theta C\phi)]\}$$

$$+\ddot{Z}\{m[\overline{X}(C\theta)+\overline{Y}(-S\theta S\phi)+\overline{Z}(-S\theta C\phi)]\}$$

$$+\dot{\psi}\dot{\theta}\{[(I_{yb}-I_{zb})(-\tfrac{1}{2}S2\phi)+I_{yzb}(C2\phi)](S\theta)+[I_{xyb}(C\phi)-I_{xzb}(S\phi)](-C\theta)\}$$

$$+\dot{\psi}\dot{\phi}\{[(I_{yb}-I_{zb})(C2\phi)+I_{yzb}(2S2\phi)](C\theta)+[I_{xyb}(S\phi)+I_{xzb}(C\phi)](S\theta)\}$$

$$+\dot{\theta}\dot{\phi}\{[I_{yb}-I_{zb}](-S2\phi)+I_{yzb}(2C2\phi)\}$$

$$+\dot{\phi}^2\{-I_{xyb}(S\phi)-I_{xzb}(C\phi)\}$$

$$+\dot{X}\dot{\psi}\{m[\overline{X}(S\psi S\theta)+\overline{Y}(S\psi C\theta S\phi)+\overline{Z}(S\psi C\theta C\phi)]\}$$

$$+\dot{X}\dot{\theta}\{m[\overline{X}(-C\psi C\theta)+\overline{Y}(C\psi S\theta S\phi)+\overline{Z}(C\psi S\theta C\phi)]\}$$

$$+\dot{X}\dot{\phi}\{m[\overline{Y}(-C\psi C\theta C\phi)+\overline{Z}(C\psi C\theta S\phi)]\}$$

$$+\dot{Y}\dot{\psi}\{m[\overline{X}(C\psi S\theta)+\overline{Y}(C\psi C\theta S\phi)+\overline{Z}(C\psi C\theta C\phi)]\}$$

$$+\dot{Y}\dot{\theta}\{m[\overline{X}(S\psi C\theta)+\overline{Y}(-S\psi S\theta S\phi)+\overline{Z}(-S\psi S\theta C\phi)]\}$$

$$+\dot{Y}\dot{\phi}\{m[\overline{Y}(S\psi C\theta C\phi)+\overline{Z}(-S\psi C\theta S\phi)]\}$$

$$+\dot{Z}\dot{\theta}\{m[-\overline{X}(S\theta)-\overline{Y}(C\theta S\phi)-\overline{Z}(C\theta C\phi)]\}$$

$$+\dot{Z}\dot{\phi}\{m[\overline{Y}(-S\theta C\phi)+\overline{Z}(S\theta S\phi)]\} \qquad (85)$$

$$\frac{\partial L}{\partial \theta} = \dot{\psi}\dot{\theta}\{[I_{zb}-I_{yb}](\tfrac{1}{2}S\theta S2\phi)+[-I_{xyb}(C\phi)+I_{xzb}(S\phi)](C\theta)+[I_{yzb}](S\theta C2\phi)\}$$

$$+\dot{\psi}\dot{\phi}\{[I_{xb}](-C\theta)+[I_{xzb}(C\phi)+I_{xyb}(S\phi)](-S\theta)\}$$

$$+\dot{\psi}^2\{[I_{xb}-I_{yb}(S^2\phi)-I_{zb}(C^2\phi)+I_{yzb}(S2\phi)](\tfrac{1}{2}S2\theta)-[I_{xzb}(C\phi)+I_{xyb}(S\phi)](C2\theta)\}$$

$$+\dot{X}\dot{\psi}\{m[\overline{X}(S\psi S\theta)+\overline{Y}(S\psi C\theta S\phi)+\overline{Z}(S\psi C\theta C\phi)]\}$$

$$+\dot{X}\dot{\theta}\{m[\overline{X}(-C\psi C\theta)+\overline{Y}(C\psi S\theta S\phi)+\overline{Z}(C\psi S\theta C\phi)]\}$$

$$+\dot{X}\dot{\phi}\{m[\overline{Y}(-C\psi C\theta C\phi)+\overline{Z}(C\psi C\theta S\phi)]\}$$

$$+\dot{Y}\dot{\psi}\{m[\overline{X}(C\psi S\theta)+\overline{Y}(C\psi C\theta S\phi)+\overline{Z}(C\psi C\theta C\phi)]\}$$

$$+\dot{Y}\dot{\theta}\{m[\overline{X}(S\psi C\theta)+\overline{Y}(-S\psi S\theta S\phi)+\overline{Z}(-S\psi S\theta C\phi)]\}$$

$$+\dot{Y}\dot{\phi}\{m[\overline{Y}(S\psi C\theta C\phi)+\overline{Z}(-S\psi C\theta S\phi)]\}$$

$$+\dot{Z}\dot{\theta}\{m[\overline{X}(-S\theta)+\overline{Y}(-C\theta S\phi)+\overline{Z}(-C\theta C\phi)]\}$$

$$+\dot{Z}\dot{\phi}\{m[\overline{Y}(-S\theta C\phi)+\overline{Z}(S\theta S\phi)]\}$$

$$-mg[\overline{X}(C\theta)+\overline{Y}(-S\theta S\phi)+\overline{Z}(-S\theta C\phi)] \qquad (86)$$

$$\frac{\partial g}{\partial \theta} = \{\overline{A}\,\frac{\partial \overline{A}}{\partial \theta} + \overline{B}\,\frac{\partial \overline{B}}{\partial \theta} + \overline{C}\,\frac{\partial \overline{C}}{\partial \theta}\}\,/L_T \tag{87}$$

$$\frac{\partial F}{\partial \dot{\theta}} = 0 \tag{88}$$

<u>$\phi$ Equation</u>

$$\begin{aligned}
\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\phi}}\right) = \; & \ddot{\psi}\{I_{xb}(-S\theta)+I_{xyb}(C\theta S\phi)+I_{xzb}(C\theta C\phi)\} \\
& +\ddot{\theta}\{I_{xyb}(C\phi)-I_{xzb}(S\phi)\}+\ddot{\phi}\{I_{xb}\} \\
& +\ddot{X}\{m[\overline{Y}(-C\psi S\theta C\phi-S\psi S\phi)+\overline{Z}(C\psi S\theta S\phi-S\psi C\phi)]\} \\
& +\ddot{Y}\{m[\overline{Y}(S\psi S\theta C\phi- C\psi S\phi)+\overline{Z}(-S\psi S\theta S\phi-C\psi C\phi)]\} \\
& +\ddot{Z}\{m[\overline{Y}(C\theta C\phi)+\overline{Z}(-C\theta S\phi)]\} \\
& +\dot{\psi}\dot{\theta}\{I_{xb}(-C\theta)+[I_{xyb}(S\phi)+I_{xzb}(C\phi)](-S\theta)\} \\
& +\dot{\psi}\{[I_{xyb}(C\phi)-I_{xzb}(S\phi)](C\theta)\} \\
& +\dot{\theta}\dot{\phi}\{-I_{xyb}(S\phi)-I_{xzb}(C\phi)\} \\
& +\dot{X}\dot{\psi}\{m[\overline{Y}(S\psi S\theta C\phi-C\psi S\phi)+\overline{Z}(-S\psi S\theta S\phi-C\psi C\phi)]\} \\
& +\dot{X}\dot{\theta}\{m(\overline{Y}(-C\psi C\theta C\phi)+\overline{Z}(C\psi C\theta S\phi)]\} \\
& +\dot{X}\dot{\phi}\{m[\overline{Y}(C\psi S\theta S\phi-S\psi C\phi)+\overline{Z}(C\psi S\theta C\phi+S\psi S\phi)]\}
\end{aligned}$$

$$+\dot{Y}\dot{\psi}\{m[\overline{Y}(C\psi S\theta C\phi+S\psi S\phi)+\overline{Z}(-C\psi S\theta S\phi+S\psi C\phi)]\}$$

$$+\dot{Y}\dot{\theta}\{m[\overline{Y}(S\psi C\theta C\phi)+\overline{Z}(-S\psi C\theta S\phi)]\}$$

$$+\dot{Y}\dot{\phi}\{m[\overline{Y}(-S\psi S\theta S\phi-C\psi C\phi)+\overline{Z}(-S\psi S\theta C\phi+C\psi S\phi)]\}$$

$$+\dot{Z}\dot{\theta}\{m[\overline{Y}(-S\theta C\phi)+\overline{Z}(S\theta S\phi)]\}+\dot{Z}\dot{\phi}\{m[\overline{Y}(-C\theta S\phi)+\overline{Z}(-C\theta C\phi)]\} \tag{89}$$

$$\frac{\partial L}{\partial \phi} = \dot{\psi}\dot{\theta}\{[(I_{yb}-I_{zb})(C2\phi)+I_{yzb}(2S2\phi)](C\theta)+[I_{xyb}(S\phi)+I_{xzb}(C\phi)](S\theta)\}$$

$$+\dot{\psi}\dot{\phi}\{[I_{xyb}(C\phi)-I_{xzb}(S\phi)](C\theta)\}$$

$$+\dot{\theta}\dot{\phi}\{-I_{xyb}(S\phi)-I_{xzb}(C\phi)\}$$

$$+\dot{\psi}^2\{[(I_{yb}-I_{zb})(\tfrac{1}{2}S2\phi)-I_{yzb}(C2\phi)](C^2\theta)+[I_{xzb}(S\phi)-I_{xyb}(C\phi)](\tfrac{1}{2}S2\theta)\}$$

$$+\dot{\theta}^2\{(I_{yb}-I_{zb})(-\tfrac{1}{2}S2\phi)+I_{yzb}(C2\phi)\}$$

$$+\dot{X}\dot{\psi}\{m[\overline{Y}(S\psi S\theta C\phi-C\psi S\phi)+\overline{Z}(-S\psi S\theta S\phi-C\psi C\phi)]\}$$

$$+\dot{X}\dot{\theta}\{m[\overline{Y}(-C\psi C\theta C\phi)+\overline{Z}(C\psi C\theta S\phi)]\}$$

$$+\dot{X}\dot{\phi}\{m[\overline{Y}(C\psi S\theta S\phi-S\psi C\phi)+\overline{Z}(C\psi S\theta C\phi+S\psi S\phi)]$$

$$+\dot{Y}\dot{\psi}\{m[\overline{Y}(C\psi S\theta C\phi+S\psi S\phi)+\overline{Z}(-C\psi S\theta S\phi+S\psi C\phi)]\}$$

$$+\dot{Y}\dot{\theta}\{m(\overline{Y}(S\psi C\theta C\phi)+\overline{Z}(-S\psi C\theta S\phi)]\}$$

$$+\dot{Y}\dot{\phi}\{m[\overline{Y}(-S\psi S\theta S\phi-C\psi C\phi)+\overline{Z}(-S\psi S\theta C\phi+C\psi S\phi)]\}$$

$$+\dot{Z}\dot{\theta}\{m[\overline{Y}(-S\theta C\phi)+\overline{Z}(S\theta S\phi)]\}$$

$$+\dot{Z}\dot{\phi}\{m[\overline{Y}(-C\theta S\phi)+\overline{Z}(-C\theta C\phi)]\}$$

$$-mg[\overline{Y}(C\theta C\phi)-\overline{Z}(C\theta S\phi)]\} \quad (90)$$

$$\frac{\partial \overline{g}}{\partial \phi} = \{\overline{A}\frac{\partial \overline{A}}{\partial \phi} + \overline{B}\frac{\partial \overline{B}}{\partial \phi} + \overline{C}\frac{\partial \overline{C}}{\partial \phi}\}/L_T \quad (91)$$

$$\frac{\partial F}{\partial \dot{\phi}} = 0 \quad (92)$$

<u>$\psi_p$ Equation</u>

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\psi}_p}\right) = \ddot{\psi}_p\{I_{xpb}(S^2\theta_p)+I_{ypb}(C^2\theta_p)\}$$

$$+\dot{\psi}_p\dot{\theta}_p\{[I_{xpb}-I_{ypb}](S2\theta_p)\} \quad (93)$$

$$\frac{\partial L}{\partial \psi_p} = \dot{X}_p^{\,2}\{[m_{p\ell}-m_{ps}][-\tfrac{1}{2}S2\psi_p C^2\theta_p]\}$$

$$+\dot{Y}_p^{\,2}\{[m_{p\ell}-m_{ps}][\tfrac{1}{2}S2\psi_p C^2\theta_p]\}$$

$$+\dot{X}_p\dot{Y}_p\ [m_{p\ell}-m_{ps}][-C2\psi_p C^2\theta_p]\}$$

$$+\dot{X}_p\dot{Z}_p\{[m_{p\ell}-m_{ps}][-\tfrac{1}{2}S\psi_p S2\theta_p]\}$$

$$+\dot{Y}_p\dot{Z}_p\ [m_{p\ell}-m_{ps}][-\tfrac{1}{2}C\psi_p S2\theta_p]\} \quad (94)$$

$$\frac{\partial \bar{q}}{\partial \psi_p} = \{\bar{A}\,\frac{\partial \bar{A}}{\partial \psi_p} + \bar{B}\,\frac{\partial \bar{B}}{\partial \psi_p}\}/L_T \qquad (95)$$

$$\frac{\partial F}{\partial \dot{\psi}_p} = 0 \qquad (96)$$

<u>$\theta_p$ Equation</u>

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\theta}_p}\right) = I_{ypb}\ddot{\theta}_p \qquad (97)$$

$$\begin{aligned}
\frac{\partial L}{\partial \theta_p} = {} & \dot{X}_p^{\;2}\{[m_{p\ell}-m_{ps}][-\tfrac{1}{2}C^2\psi_p S2\theta_p]\} \\
& +\dot{Y}_p^{\;2}\{[m_{p\ell}-m_{ps}][-\tfrac{1}{2}S^2\psi_p S2\theta_p]\} \\
& +\dot{Z}_p^{\;2}\{[m_{p\ell}-m_{ps}][\tfrac{1}{2}S2\theta_p]\} \\
& +\dot{X}_p\dot{Y}_p\{[m_{p\ell}-m_{ps}][\tfrac{1}{2}S2\psi_p S2\theta_p]\} \\
& +\dot{X}_p\dot{Z}_p\{[m_{p\ell}-m_{ps}][C\psi_p C2\theta_p]\} \\
& +\dot{Y}_p\dot{Z}_p\{[m_{p\ell}-m_{ps}][-S\psi_p C2\theta_p]\} \\
& +\dot{\psi}_p^{\;2}\{[I_{xpb}-I_{ypb}][\tfrac{1}{2}S2\theta_p]\}
\end{aligned} \qquad (98)$$

$$\frac{\partial \bar{q}}{\partial \theta_p} = \{\bar{A}\,\frac{\partial \bar{A}}{\partial \theta_p} + \bar{B}\,\frac{\partial \bar{B}}{\partial \theta_p} + \bar{C}\,\frac{\partial \bar{C}}{\partial \theta_p}\}/L_T \qquad (99)$$

$$\frac{\partial F}{\partial \dot{\theta}_p} = 0 \qquad (100)$$

$L_T$ Equation

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{L}_T}\right) = 0 \tag{101}$$

$$\frac{\partial L}{\partial L_T} = -K_s(L_T - L_{TO}) \tag{102}$$

$$\frac{\partial \bar{q}}{\partial L_T} = -1 \tag{103}$$

$$\frac{\partial F}{\partial \dot{L}_T} = C_s \dot{L}_T \tag{104}$$

Substituting Equations (101) to (104) irto (54) yields:

$$\lambda = -[K_s(L_T - L_{TO}) + C_s \dot{L}_T] \tag{105}$$

The value of λ in Equation (54) is now defined and is expressed in terms of the eleven generalized coordinator and their time derivatives. The eleven simultaneous, nonlinear, coupled differential equations of motion are then written as:

1. X Equation

$$\ddot{X}\{m\}+\ddot{\psi}\{m[\overline{X}\ C_{12}+\overline{Y}\ C_{22}+\overline{Z}\ C_{32}]\}$$

$$+\ddot{\theta}\{m[\overline{X}(-C\psi S\theta)+\overline{Y}(-C\psi C\theta S\phi)+\overline{Z}(-C\psi C\theta C\phi)]\}+\ddot{\phi}\{m[\overline{Y}C_{31}-\overline{Z}C_{21}]\}$$

$$= \dot{\psi}\dot{\theta}\{-2m[\overline{X}(S\psi S\theta)+\overline{Y}(S\psi C\theta S\phi)+\overline{Z}(S\psi C\theta C\phi)]\}+\dot{\psi}\dot{\phi}\{-2m[\overline{Y}C_{32}-\overline{Z}C_{22}]\}$$

$$+\dot{\theta}\dot{\phi}\{2m[\overline{Y}(C\psi C\theta C\phi)-\overline{Z}(C\psi C\theta S\phi)]\}+\dot{\psi}^2\{m[\overline{X}C_{11}+\overline{Y}C_{21}+\overline{Z}C_{31}]\}$$

$$+\dot{\theta}^2\{m[\overline{X}C_{11}+\overline{Y}(-C\psi S\theta S\phi)+\overline{Z}(-C\psi S\theta C\phi)]\}+\dot{\phi}^2\{m[\overline{Y}C_{21}+\overline{Z}C_{31}]\}$$

$$+[K_s(L_T-L_{TO})+C_s\dot{L}_T][\overline{A}/L_T]+F_x \tag{106}$$

2. Y Equation

$$\ddot{Y}\{m\}+\ddot{\psi}\{-m[\overline{X}C_{11}+\overline{Y}C_{21}+\overline{Z}C_{31}]\}$$

$$+\ddot{\theta}\{m[\overline{X}(S\psi S\theta)+\overline{Y}(S\psi C\theta S\phi)+\overline{Z}(S\psi C\theta C\phi)]\}+\ddot{\phi}\{m[\overline{Y}C_{32}-\overline{Z}C_{22}]\}$$

$$=\dot{\psi}\dot{\theta}\{-2m[\overline{X}(C\psi S\theta)+\overline{Y}(C\psi C\theta S\phi)+\overline{Z}(C\psi C\theta C\phi)]\}+\dot{\psi}\dot{\phi}\{2m[\overline{Y}C_{31}-\overline{Z}C_{21}]\}$$

$$+\dot{\theta}\dot{\phi}\{-2m[\overline{Y}(S\psi C\theta C\phi)-\overline{Z}(S\psi C\theta S\phi)]\}+\dot{\psi}^2\{m[\overline{X}C_{12}+\overline{Y}C_{22}+\overline{Z}C_{32}]\}$$

$$+\dot{\theta}^2\{m[\overline{X}C_{12}+\overline{Y}(S\psi S\theta S\phi)+\overline{Z}(S\psi S\theta C\phi)]\}+\dot{\phi}^2\{m[\overline{Y}C_{22}+\overline{Z}C_{32}]\}$$

$$+[K_s(L_T-L_{TO})+C_s\dot{L}_T][\overline{B}/L_T]+F_Y \qquad (107$$

3. Z Equation

$$\ddot{Z}\{m\}+\ddot{\theta}\{m[\overline{X}(C\theta)+\overline{Y}(-S\theta S\phi)+\overline{Z}(-S\theta C\phi)]\}+\ddot{\phi}\{m[\overline{Y}C_{33}-\overline{Z}C_{23}]\}$$

$$=\dot{\theta}\dot{\phi}\{2m[\overline{Y}(S\theta C\phi)-\overline{Z}(S\theta S\phi)]\}+\dot{\theta}^2\{m[\overline{X}C_{13}+\overline{Y}C_{23}+\overline{Z}C_{33}]\}$$

$$+\dot{\phi}^2\{m[\overline{Y}C_{23}+\overline{Z}C_{33}]\}+[K_s(L_T-L_{TO})+C_s\dot{L}_T][\overline{C}/L_T]-mg+F_Z \tag{108}$$

4. $X_p$ Equation

$$\ddot{X}_p\{m_{p\ell}[C^2\psi_p C^2\theta_p]+m_{ps}[S^2\psi_p+C^2\psi_p S^2\theta_p]\}$$

$$+\ddot{Y}_p\{[m_{p\ell}-m_{ps}][-\tfrac{1}{2}S2\psi_p C^2\theta_p]\}+\ddot{Z}_p\{[m_{p\ell}-m_{ps}][\tfrac{1}{2}C\psi_p S2\theta_p]\}$$

$$=[m_{p\ell}-m_{ps}]\{\dot{X}_p\dot{\psi}_p[S2\psi_p C^2\theta_p]+\dot{X}_p\dot{\theta}_p[C^2\psi_p S2\theta_p]+\dot{Y}_p\dot{\psi}_p[C2\psi_p C^2\theta_p]$$

$$+\dot{Y}_p\dot{\theta}_p[-\tfrac{1}{2}S2\psi_p S2\theta_p]+\dot{Z}_p\dot{\psi}_p[\tfrac{1}{2}S\psi_p S2\theta_p]+\dot{Z}_p\dot{\theta}_p[-C\psi_p C2\theta_p]\}$$

$$-[K_s(L_T-L_{TO})+C_s\dot{L}_T][\overline{A}/L_T] + F_{xp} \tag{109}$$

5. $Y_p$ Equation

$$\ddot{X}_p\{[m_{p\ell}-m_{ps}][-\tfrac{1}{2}S2\psi_p C^2\theta_p]\}+\ddot{Y}_p\{m_{p\ell}[S^2\psi_p C^2\theta_p]+m_{ps}[C^2\psi_p+S^2\psi_p S^2\theta_p]\}$$

$$+\ddot{Z}_p\{[m_{p\ell}-m_{ps}][-\tfrac{1}{2}S\psi_p S2\theta_p]\}$$

$$= [m_{p\ell}-m_{ps}]\{\dot{X}_p\dot{\psi}_p[C2\psi_p C^2\theta_p]+\dot{X}_p\dot{\theta}_p[-\tfrac{1}{2}S2\psi_p S2\theta_p]+\dot{Y}_p\dot{\psi}_p[-S2\psi_p C^2\theta_p]$$

$$+\dot{Y}_p\dot{\theta}_p[S^2\psi_p S2\theta_p]+\dot{Z}_p\dot{\psi}_p[\tfrac{1}{2}C\psi_p S2\theta_p]+\dot{Z}_p\dot{\theta}_p[S\psi_p C2\theta_p]\}$$

$$-[K_s(L_T-L_{TO})+C_s\dot{L}_T][\overline{B}/L_T]+F_{yp} \tag{110}$$

E-1D-15(7-71)
REF: EOI 380

6. $Z_p$ Equation

$$\ddot{X}_p\{[m_{p\ell}-m_{ps}][\tfrac{1}{2}C\psi_p S2\theta_p]\}+\ddot{Y}_p\{[m_{p\ell}-m_{ps}][-\tfrac{1}{2}S\psi_p S2\theta_p]\}$$

$$+\ddot{Z}_p\{m_{p\ell}[S^2\theta_p]+m_{ps}[C^2\theta_p]\}$$

$$= [m_{p\ell}-m_{ps}]\{\dot{X}_p\dot{\psi}_p[\tfrac{1}{2}S\psi_p S2\theta_p]+\dot{X}_p\dot{\theta}_p[-C\psi_p C2\theta_p]+\dot{Y}_p\dot{\psi}_p[\tfrac{1}{2}C\psi_p S2\theta_p]$$

$$+\dot{Y}_p\dot{\theta}_p[S\psi_p C2\theta_p]+\dot{Z}_p\dot{\theta}_p[-S2\theta_p]\}$$

$$-[K_s(L_T-L_{TO})+C_s\dot{L}_T][\overline{C}/L_T]-m_p g + F_{zp} \qquad (111)$$

7. $\psi$ Equation

$$\ddot{\psi}\{I_{xb}(S^2\theta)+[I_{yb}(S^2\phi)+I_{zb}(C^2\phi)](C^2\theta)+I_{yzb}(-C^2\theta S2\phi)$$

$$+[I_{xzb}(C\phi)+I_{xyb}(S\phi)](-S2\theta)\}+\ddot{\theta}\{[(I_{yb}-I_{zb})(\tfrac{1}{2}S2\phi)-I_{yzb}(C2\phi)](C\theta)$$

$$+[I_{xzb}(S\phi)-I_{xyb}(C\phi)](S\theta)\}+\ddot{\phi}\{-I_{xb}C_{13}+I_{xyb}C_{23}+I_{xzb}C_{33}\}$$

$$+\ddot{X}\{m[\overline{X}C_{12}+\overline{Y}C_{22}+\overline{Z}C_{32}]\}+\ddot{Y}\{-m[\overline{X}C_{11}+\overline{Y}C_{21}+\overline{Z}C_{31}]\}$$

$$= \dot{\psi}\dot{\theta}\{[I_{xb}-I_{yb}(S^2\phi)-I_{zb}(C^2\phi)+I_{yzb}(S2\phi)](-S2\theta)+[I_{xzb}(C\phi)$$

$$+I_{xyb}(S\phi)](2C2\theta)\}+\dot{\psi}\dot{\phi}\{[(I_{yb}-I_{zb})(S2\phi)-I_{yzb}(2C2\phi)](-C^2\theta)$$

$$+[I_{xzb}(S\phi)-I_{xyb}(C\phi)](-S2\theta)\}+\dot{\theta}\dot{\phi}\{[I_{xb}-(I_{yb}-I_{zb})(C2\phi)-I_{yzb}(2S2\phi)](C\theta)\}$$

$$+\dot{\theta}^2\{[(I_{yb}-I_{zb})(\tfrac{1}{2}S2\phi)-I_{yzb}(C2\phi)](S\theta)-I_{xzb}C_{23}+I_{xyb}C_{33}\}$$

$$+\dot{\phi}^2\{-I_{xyb}C_{33} + I_{xzb}C_{23}\}$$

$$-[K_s(L_T-L_{TO})+C_s\dot{L}_T][\bar{A}\frac{\partial\bar{A}}{\partial\psi} + \bar{B}\frac{\partial\bar{B}}{\partial\psi}]/L_T + Q_\psi \quad (112)$$

8. $\theta$ Equation

$$\ddot{X}\{m[\bar{X}(-C\psi S\theta)+\bar{Y}(-C\psi C\theta S\phi)+\bar{Z}(-C\psi C\theta C\phi)]\}$$

$$+\ddot{Y}\{m[\bar{X}(S\psi S\theta)+\bar{Y}(S\psi C\theta S\phi)+\bar{Z}(S\psi C\theta C\phi)]\}$$

$$+\ddot{Z}\{m[\bar{X}(C\theta)+\bar{Y}(-S\theta S\phi)+\bar{Z}(-S\theta C\phi)]\}$$

$$+\ddot{\psi}\{[(I_{yb}-I_{zb})(\tfrac{1}{2}S2\phi)-I_{yzb}(C2\phi)](C\theta)+[I_{xyb}(C\phi)-I_{xzb}(S\phi)](-S\theta)\}$$

$$+\ddot{\theta}\{I_{yb}(C^2\phi)+I_{zb}(S^2\phi)+I_{yzb}(S2\phi)\}+\ddot{\phi}\{I_{xyb}(C\phi)-I_{xzb}(S\phi)\}$$

$$= \dot{\psi}\dot{\phi}\{[I_{xb}+(I_{yb}-I_{zb})(C2\phi)+I_{yzb}(2S2\phi)](-C\theta)+[I_{xzb}(C\phi)+I_{xyb}(S\phi)](-2S\theta)\}$$

$$+\dot{\theta}\dot{\phi}\{(I_{yb}-I_{zb})(S2\phi)-I_{yzb}(2C2\phi)\}$$

$$+\dot{\psi}^2\{[I_{xb}-I_{yb}(S^2\phi)-I_{zb}(C^2\phi)+I_{yzb}(S2\phi)](\tfrac{1}{2}S2\theta)+[I_{xzb}(C\phi)$$

$$+I_{xyb}(S\phi)](-C2\theta)\}+\dot{\phi}^2\{I_{xyb}(S\phi)+I_{xzb}(C\phi)\}-mg[\bar{X}(C\theta)+\bar{Y}(-S\theta S\phi)+\bar{Z}(-S\theta C\phi)]$$

$$-[K_s(L_T-L_{TO})+C_s\dot{L}_T][\bar{A}\frac{\partial\bar{A}}{\partial\theta} + \bar{B}\frac{\partial\bar{B}}{\partial\theta} + \bar{C}\frac{\partial\bar{C}}{\partial\theta}]/L_T + Q_\theta \quad (113)$$

9. $\phi$ Equation

$$\ddot{X}\{m[\bar{Y}\bar{C}_{31}-\bar{Z}C_{21}]\}+\ddot{Y}\{m[\bar{Y}C_{32}-\bar{Z}C_{22}]\}+\ddot{Z}\{m[\bar{Y}C_{33}-\bar{Z}C_{23}]\}$$

$$+\ddot{\psi}\{-I_{xb}C_{13}+I_{xyb}C_{23}+I_{xzb}\,C_{33}\}+\ddot{\theta}\{I_{xyb}(C\phi)-I_{xzb}(S\phi)\}+\ddot{\phi}\{I_{xb}\}$$

$$= \dot{\psi}\dot{\theta}\{[I_{xb}+(I_{yb}-I_{zb})(C2\phi)+I_{yzb}(2S2\phi)](C\theta)+[I_{xyb}(S\phi)+I_{xzb}(C\phi)](2S\theta)\}$$

$$+\dot{\psi}^2\{[(I_{yb}-I_{zb})(\tfrac{1}{2}S2\phi)-I_{yzb}(C2\phi)](C^2\theta)+[I_{xzb}(S\phi)-I_{xyb}(C\phi)](\tfrac{1}{2}S2\theta)\}$$

$$+\dot{\theta}^2\{(I_{yb}-I_{zb})(-\tfrac{1}{2}S2\phi)+I_{yzb}(C2\phi)\}-mg[\overline{Y}C_{33}-\overline{Z}C_{23}]$$

$$-[K_s(L_T-L_{TO})+C_s\dot{L}_T][\overline{A}\frac{\partial\overline{A}}{\partial\phi}+\overline{B}\frac{\partial\overline{B}}{\partial\phi}+\overline{C}\frac{\partial\overline{C}}{\partial\phi}]/L_T+Q_\phi \qquad (114)$$

10. $\psi_p$ Equation

$$\ddot{\psi}_p\{I_{xpb}(S^2\theta_p)+I_{ypb}(C^2\theta_p)\}$$

$$= \dot{\psi}_p\dot{\theta}_p\{(I_{xpb}-I_{ypb})(-S2\theta_p)\}+[m_{p\ell}-m_{ps}]\{\dot{X}_p\dot{Y}_p[-C2\psi_pC^2\theta_p]$$

$$+\dot{X}_p\dot{Z}_p[-\tfrac{1}{2}S\psi_pS2\theta_p]+\dot{Y}_p\dot{Z}_p[-\tfrac{1}{2}C\psi_pS2\theta_p]+\dot{X}_p^{\,2}[-\tfrac{1}{2}S2\psi_pC^2\theta_p]+\dot{Y}_p^{\,2}[\tfrac{1}{2}S2\psi_pC^2\theta_p]\}$$

$$-[K_s(L_T-L_{TO})+C_s\dot{L}_T][\overline{A}\frac{\partial\overline{A}}{\partial\psi_p}\ \ \overline{B}\frac{\partial\overline{B}}{\partial\psi_p}]/L_T+Q_{\psi p} \qquad (115)$$

11. $\theta_p$ Equation

$$\ddot{\theta}_p\{I_{ypb}\}$$

$$= \dot{\psi}_p^2\ \{(I_{xpb}-I_{ypb})(\tfrac{1}{2}S2\theta_p)\}+[m_{p\ell}-m_{ps}]\{\dot{X}_p\dot{Y}_p[\tfrac{1}{2}S2\psi_pS2\theta_p]+\dot{X}_p\dot{Z}_p[C\psi_pC2\theta_p]$$

$$+\dot{Y}_p\dot{Z}_p[-S\psi_pC2\theta_p]+\dot{X}_p^{\,2}[-\tfrac{1}{2}C^2\psi_pS2\theta_p]+\dot{Y}_p^{\,2}[-\tfrac{1}{2}S^2\psi_pS2\theta_p]+\dot{Z}_p^{\,2}[\tfrac{1}{2}S2\theta_p]\}$$

$$-[K_s(L_T-L_{TO})+C_s\dot{L}_T][\overline{A}\frac{\partial\overline{A}}{\partial\theta_p}+\overline{B}\frac{\partial\overline{B}}{\partial\theta_p}+\overline{C}\frac{\partial\overline{C}}{\partial\theta_p}]/L_T+Q_{\theta p} \qquad (116)$$

E-1D-15(7-71) REF: E01 380

## SECTION 8 - SIMPLIFIED EQUATIONS OF MOTION

Equations (106) to (116) are for the most general situation possible, and as a result, are quite lengthy. Under some circumstances, these equations can be simplified. If this can be accomplished, a significant decrease in computer time will be realized. The first simplification occurs if the forebody's aerodynamic (body) reference axes are principal axes. In this case $\overline{X} = \overline{Y} = \overline{Z} = 0$ and $I_{xyb} = I_{xzb} = I_{yzb} = 0$. Equations (106), (107), (108), (112), (113), and (114) become:

$$\ddot{X}\{m\} = [K_s(L_T - L_{TO}) + C_s\dot{L}_T][\overline{A}/L_T] + F_x \tag{117}$$

$$\ddot{Y}\{m\} = [K_s(L_T - L_{TO}) + C_s\dot{L}_T][\overline{B}/L_T] + F_y \tag{118}$$

$$\ddot{Z}\{m\} = [K_s(L_T - L_{TO}) + C_s\dot{L}_T][\overline{C}/L_T] - mg + F_z \tag{119}$$

$$\begin{aligned}
&\ddot{\psi}\{I_{xb}(S^2\theta) + [I_{yb}(S^2\phi) + I_{zb}(C^2\phi)](C^2\theta)\} + \ddot{\theta}\{(I_{yb} - I_{zb})(\tfrac{1}{2}C\theta S2\phi)\} + \ddot{\phi}\{-I_{xb}C_{13}\} \\
&= \dot{\psi}\dot{\theta}\{[I_{xb} - I_{yb}(S^2\phi) - I_{zb}(C^2\phi)](-S2\theta)\} + \dot{\psi}\dot{\phi}\{(I_{yb} - I_{zb})(-C^2\theta S2\phi)\} \\
&\quad + \dot{\theta}\dot{\phi}\{[I_{xb} - (I_{yb} - I_{zb})(C2\phi)](C\theta)\} + \dot{\theta}^2\{(I_{yb} - I_{zb})(\tfrac{1}{2}S\theta S2\phi)\} \\
&\quad - [K_s(L_T - L_{TO}) + C_s\dot{L}_T][\overline{A}\frac{\partial\overline{A}}{\partial\psi} + \overline{B}\frac{\partial\overline{B}}{\partial\psi}]/L_T + Q_\psi
\end{aligned} \tag{120}$$

$$\begin{aligned}
&\ddot{\psi}\{(I_{yb} - I_{zb})(\tfrac{1}{2}C\theta S2\phi)\} + \ddot{\theta}\{I_{yb}(C^2\phi) + I_{zb}(S^2\phi)\} \\
&= \dot{\psi}\dot{\phi}\{[I_{xb} + (I_{yb} - I_{zb})(C2\phi)](-C\theta)\} + \dot{\theta}\dot{\phi}\{(I_{yb} - I_{zb})(S2\phi)\} \\
&\quad \dot{\psi}^2\{[I_{xb} - I_{yb}(S^2\phi) - I_{zb}(C^2\phi)](\tfrac{1}{2}S2\theta)\}
\end{aligned}$$

E-1D-15(7-71)
REF: EOI 380

$$-[K_s(L_T-L_{TO})+C_s\dot{L}_T][\bar{A}\frac{\partial\bar{A}}{\partial\theta}+\bar{B}\frac{\partial\bar{B}}{\partial\theta}+\bar{C}\frac{\partial\bar{C}}{\partial\theta}]/L_T+Q_\theta \tag{121}$$

$$\ddot{\psi}\{-I_{xb}C_{13}\}+\ddot{\phi}\{I_{xb}\}$$

$$=\dot{\psi}\dot{\theta}\{[I_{xb}+(I_{yb}-I_{zb})(C2\phi)](C\theta)\}+\dot{\psi}^2\{(I_{yb}-I_{zb})(\tfrac{1}{2}C^2\theta S2\phi)\}$$

$$+\dot{\theta}^2\{(I_{yb}-I_{zb})(-\tfrac{1}{2}S2\phi)\}$$

$$-[K_s(L_T-L_{TO})+C_s\dot{L}_T][\bar{A}\frac{\partial\bar{A}}{\partial\phi}+\bar{B}\frac{\partial\bar{B}}{\partial\phi}+\bar{C}\frac{\partial\bar{C}}{\partial\phi}]/L_T+Q_\phi \tag{122}$$

The above six equations of motion have not only been shortened, but they also have been uncoupled in the translational accelerations making them easier to solve. The second simplification involves the decelerator degrees of freedom. If the added masses of the decelerator are ignored ($m_{p\ell}= m_{ps} = m_p$), Equations (109), (110), (111), (115), and (116) become:

$$\ddot{X}_p\{m_p\}=-[K_s(L_T-L_{TO})+C_s\dot{L}_T](\bar{A}/L_T]+F_{xp} \tag{123}$$

$$\ddot{Y}_p\{m_p\}=-[K_s(L_T-L_{TO})+C_s\dot{L}_T][\bar{B}/L_T]+F_{yp} \tag{124}$$

$$\ddot{Z}_p\{m_p\}=-[K_s(L_T-L_{TO})+C_s\dot{L}_T][\bar{C}/L_T]-m_pg+F_{zp} \tag{125}$$

E-ID-15(7-71)
REF: EOI 380

$$\ddot{\psi}_p\{I_{xpb}(S^2\theta_p)+I_{ypb}(C^2\theta_p)\} = \dot{\psi}_p\dot{\theta}_p\{(I_{xpb}-I_{ypb})(-S2\theta_p)\}$$

$$-[K_s(L_T-L_{TO})+C_s\dot{L}_T][\bar{A}\frac{\partial\bar{A}}{\partial\psi_p} + \bar{B}\frac{\partial\bar{B}}{\partial\psi_p}]/L_T + Q_{\psi p} \qquad (126)$$

$$\ddot{\theta}_p\{I_{ypb}\} = \dot{\psi}_p^{\,2}\{(I_{xpb}-I_{ypb})(\tfrac{1}{2}S2\theta_p)\}$$

$$-[K_s(L_T-L_{TO})+C_s\dot{L}_T][\bar{A}\frac{\partial\bar{A}}{\partial\theta_p} + \bar{B}\frac{\partial\bar{B}}{\partial\theta_p} + \bar{C}\frac{\partial\bar{C}}{\partial\theta_p}]/L_T + Q_{\theta p} \qquad (127)$$

Like the simplified equation for the forebody, the decelerator equations have also shortened. Furthermore, they have completely uncoupled in the second derivatives making numerical integration easy.

SECTION 9 - GENERALIZED FORCES - AERODYNAMICS

The nonconservative forces acting on the forebody are due to aerodynamics. The aerodynamics and the convention used in this report apply to the Space Shuttle Solid Rocket Booster (S.R.B.). If a different body is to be simulated, the aerodynamic coefficients and possibly the convention used to define them, would change.

For the S.R.B., the aerodynamics are a function of roll angle, angle-of-attack, and Mach number. The angle-of-attack is measured from the total velocity vector to the positive longitudinal axis ($X_b$) as shown in Figure 3.

$$\alpha = \tan^{-1}\left[\frac{(\dot{Y}_b^{\,2} + \dot{Z}_b^{\,2})^{1/2}}{\dot{X}_b}\right] \tag{128}$$

The normal force coefficient, $C_N$, is in the plane formed by the velocity vector and the longitudinal axis, and is perpendicular to the longitudinal axis ($X_b$). The roll angle, $\phi_i$, is then measured from the normal force coefficient to the $Z_b$ body axis. The axial force coefficient is defined as usual, positive in the negative $X_b$ direction. Finally, the side force coefficient is perpendicular to the $X_b$ body axis and to the normal force, such that the directions of $C_A$, $C_N$, $C_Y$ form a right-handed orthogonal coordinate system. Mathematically, the aerodynamics roll angle is given by:

$$\phi_i = \tan^{-1}\left[-\dot{Y}_b/-\dot{Z}_b\right] \tag{129}$$

E-1D-15(7-71)
REF: EOI 380

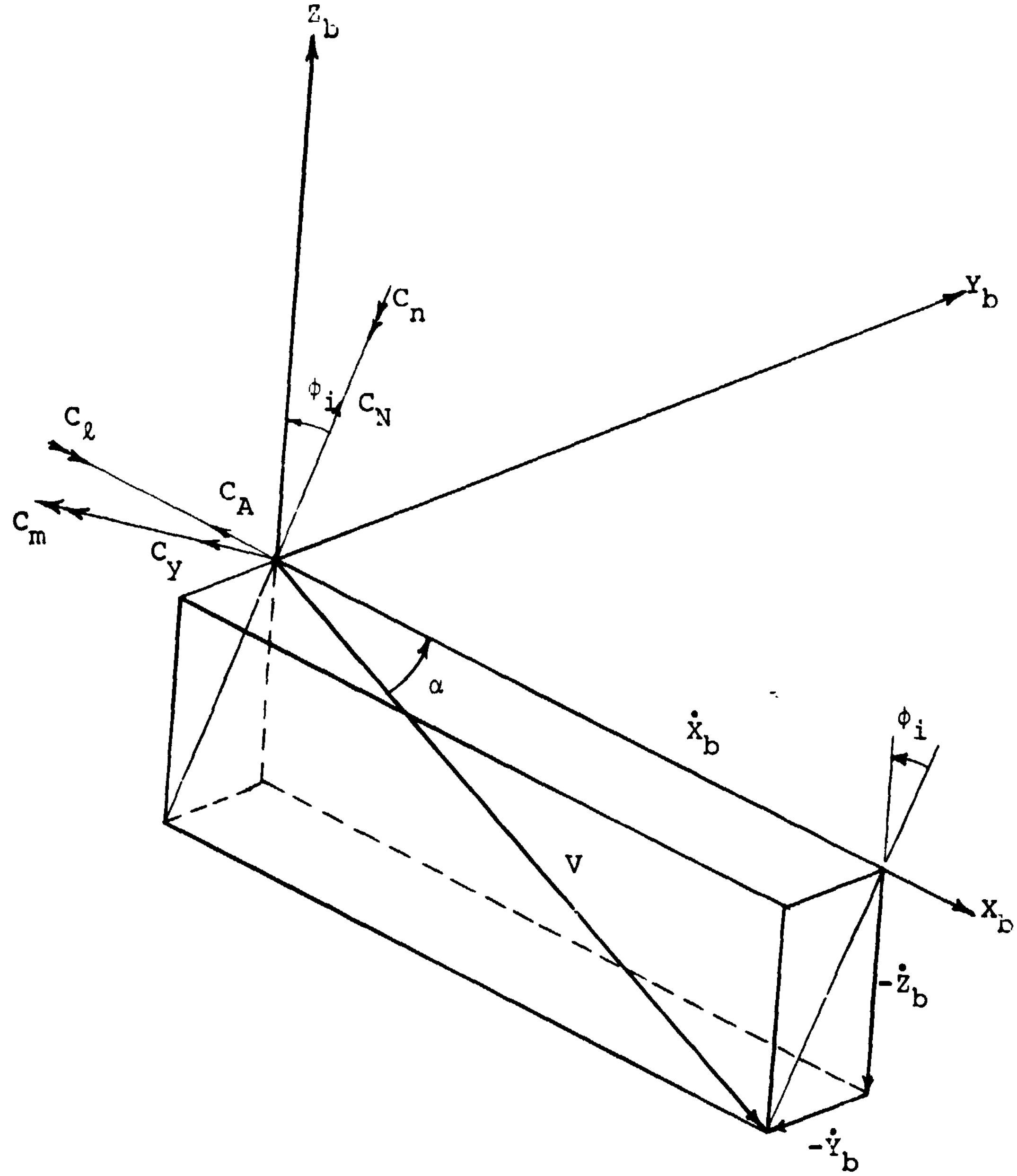


FIGURE 3 - AERODYNAMIC COORDINATE SYSTEM

E-ID-15(7-71)
REF: EOI 380

The positive directions of the moment coefficients are shown in Figure 3 as double arrows. Damping ent coefficients are about the body axes ($X_b$, $Y_b$, $Z_b$). Aerodynamic body axes forces are given as:

$$F_{xb} = -q\ S\ C_A \tag{130}$$

$$F_{yb} = qS[-C_y C\phi_i + C_N S\phi_i] \tag{131}$$

$$F_{zb} = qS[C_y S\phi_i + C_N\ C\phi_i] \tag{132}$$

The body axes forces are converted to inertial axes force using the elements of [C], Equation 4.

$$F_x = F_{xb}\ C_{11} + F_{yb}\ C_{21} + F_{zb}\ C_{31} \tag{133}$$

$$F_y = F_{xb}\ C_{12} + F_{yb}\ C_{22} + F_{zb}\ C_{32} \tag{134}$$

$$F_z = F_{xb}\ C_{13} + F_{yb}\ C_{23} + F_{zb}\ C_{33} - mg \tag{135}$$

Body axes torques are:

$$T_{xb} = qSd[C_\ell + C_{\ell p}(\frac{\omega_{xb}\ d}{2V})] \tag{136}$$

$$T_{yb} = qSd[-C_m C\phi_i - C_n S\phi_i + C_{m_q}(\frac{\omega_{yb} d}{2V})] \tag{137}$$

$$T_{zb} = qSd[C_m S\phi_i - C_n C\phi_i + C_{n_r}(\frac{\omega_{zb} d}{2V})] \tag{138}$$

The body axis torques are transformed to generalized torques using Equations (5) and (1) and noting sign conventions.

$$Q_{\psi} = -[T_{xb}C_{13} + T_{yb}C_{23} + T_{zb}C_{33}] \tag{139}$$

$$Q_{\theta} = -T_{yb}C\phi + T_{zb}S\phi \tag{140}$$

$$Q_{\phi} = T_{xb} \tag{141}$$

The aerodynamics of a decelerator (parachute) are not well known because a parachute is not a rigid body, and does not lend itself to easily obtainable test data, especially under dynamic conditions. Consequently the aerodynamics of a symmetric decelerator tend to be relatively simple due to a lack of better understanding rather than the inability to use available information. If better aerodynamic data is attainable, it is a simple matter to alter the body forces and torques appropriately.

For this report, the decelerator body forces and torques are:

$$F_{xpb} = -q_p\ S_p\ C_{Ap} \tag{142}$$

$$F_{ypb} = q_p\ S_p\ C_{NP}\ S\phi_{pi} \tag{143}$$

$$F_{zpb} = q_p\ S_p\ C_{Np}\ C\phi_{pi} \tag{144}$$

$$T_{ypb} = -q_p\ S_p\ d_p\ \ (C_{MP} - 0.1 * \dot{\theta}_p * D_p/V_p)\ \ C\phi_{pi} \tag{145}$$

$$T_{zpb} = q_p\ S_p d_p\ \ (C_{MP} - 0.1 * \dot{\theta}_p * D_p/V_p)\ \ S\phi_{pi} \tag{146}$$

$$\phi_{pi} = \tan^{-1}[-\dot{Y}_{pb}/-\dot{Z}_{pb}] \tag{147}$$

The generalized forces for the decelerator are:

$$F_{xp} = F_{xpb} C_{p11} + F_{ypb} C_{p21} + F_{zpb} C_{p31} \quad (148)$$

$$F_{yp} = F_{xpb} C_{p12} + F_{ypb} C_{p22} + F_{zpb} C_{p32} \quad (149)$$

$$F_{zp} = F_{xpb} C_{p13} + F_{zpb} C_{p33} - m_p g \quad (150)$$

$$Q_{\psi p} = -T_{zpb} C_{p33} \quad (151)$$

$$Q_{\theta p} = -T_{ypb} \quad (152)$$

# CHAPTER III COMPUTER PROGRAM

## SECTION 1 - FEATURES OF THE COMPUTER PROGRAM

The computer program contains the following features.

1. The program has many options which simplify the input of data or decrease the program run time. Use of the options are contained in the listing of the program as comment cards. These options are:

   a. Options are included which change the dimensions of the aerodynamic coefficient arrays as dictated by input requirements.

   b. An option is provided (OPDT = 1.0) which automatically determines the magnitude of the integration time interval, DT.

   c. An option is provided (OPSP = 1.0) which calculates the parachute drag area (SP) time history. If this option is not used the drag area versus time is input into the program in the form of look-up arrays.

   d. An option for including longitudinal and lateral added air mass effects on the parachute (OPAM = 1.0) is included in the program.

   e. A provision is made to use simplified equations of motion (OPOS = 0.0) to reduce run time, if all the forebody products of inertia and center of mass offsets are equal to zero.

   f. An option (OPPLOT = 1.0) for making a plot tape is available.

   g. English or metric systems may be used for data input and out by equating OMETRC to 0.0 or 1.0 respectively.

2. All aerodynamic coefficients are read into the program as functions of angle of attack, roll angle, and mach number in the form of three dimensional look-up arrays.

3. The initial start conditions for the forebody and aft body are completely general.

4. The stacking of design cases is possible.

5. The attachment location of the tether to the forebody is completely general.

6. The tether load and the angle it makes with the centerline of the forebody are program outputs.

7. All load and trajectory data are output at pre-selected times.

8. Termination of a design case occurs at a predetermined time or altitude.

9. The program calculates the effective system spring constant.

10. The program calculates the parachute physical properties as the parachute inflates as a function of time.

11. The parachute may have three stages of reefing, if the automatic drag area versus time option is chosen.

12. As the parachute inflates, the drag area versus time follows a second degree curve ($y = ax^2$).

E-1D-15(7-71)
REF: EO1 380

## SECTION 2 - INPUT

Except for the variable COM, all inputs are read in under the format statement 8F10.0. COM is an 80 column header card. All of the following variables are defined in the nomenclature.

| INPUT ITEM | VARIABLE | NUMBER OF CARDS |
|---|---|---|
| a) | AIPHI, AIPHID, AJALPF, AJALPM, AKAM, AKAMD, OPSYM, OPDA | 1 card |
| b) | PPHIE | 1 card |
| c) | AALPFE | 1 or 2 cards |
| d) | AALPME | 1 or 2 cards |
| e) | AAM | 1 card |
| f) | CCA | 4 to 128 cards |
| g) | CCN | 4 to 128 cards |
| h) | CCLM | 4 to 128 cards |
| i) | CCY | 0 or 4 to 128 cards |
| j) | CCLL | 0 or 4 to 128 cards |
| k) | CCLN | 0 or 4 to 128 cards |
| l) | CLLP, CLMQ, CLNR | 0 or 1 card |
| m) | PPHIDE | 0 or 1 card |
| n) | AALPDE | 0 or 1 card |
| o) | AAMD | 0 or 1 card |
| p) | CCLLP | 0 or 4 to 64 cards |
| q) | CCLMQ | 0 or 4 to 64 cards |
| r) | CCLNR | 0 or 4 to 64 cards |
| s) | AALPPE | 1 card |
| t) | AAMP | 1 card |
| u) | CCAP | 2 to 8 cards |
| v) | CCNP | 2 to 8 cards |
| w) | CCMP | 2 to 8 cards |

E-ID-15(7-71)
REF: EOI 380

| INPUT ITEM | VARIABLE | NUMBER OF CARDS |
|---|---|---|
| x) | PS, PT, EPL, EPT | 1 card |
| y) | X, Y, X, V, GAME, CHIE, EPSI, ETAI | 1 card |
| z) | WT, IXB, IYB, IZB, IXYB, IXZB, IYZB | 1 card |
| aa) | S, D, XBAR, YBAR, ZBAR, OPPRIN, OPPLOT, OPOS | 1 card |
| bb) | PSIE, THEE, PHIE, OMXBE, OMYBE, OMZBE | 1 card |
| cc) | A, B, C, OPAM, OMETRC | 1 card |
| dd) | PSIPE, THEPE, PSIPDE, THEPDE, VP, GAMPE, CHIPE | 1 card |
| ee) | LS, LTO, DLTO, NS, NT, DP, CCRIT | 1 card |
| ff) | AMAX1, AMAX2, DSX1, DSX2, AMAY1, AMAY2, DSY1, DSY2 | 1 card |
| gg) | WTC, WTL, OPSP, OPDT | |
| | IF (OPSP.EQ.0.0) GO TO ITEM kk) | |
| hh) | TR0, TR1, TR2, TR3 | 1 card |
| jj) | SPR0, SPR1, SPR2, SPR3, PCT01, PCT02, PCT03, POROS | 1 card |
| kk) | TTIP, SSP | 4 cards |
| | IF (OPDT.EQ.0.0) GO TO ITEM mm) | |
| ll) | GLOAD, FSULT, AERATO, TO, DTP1, TTT, HHH | 1 card |
| mm) | DT1, TO, DTP1, TTT, HHH | 1 card |
| nn) | COM | 1 card |

The values of the variables read in input item "a" determine, in part, the sizes of the aerodynamic arrays. The axial and moment coefficients have the option of using either eight or sixteen angles-of-attack (one or two cards). If, for example, five or eleven angles-of-attack are needed, one or two cards are needed respectively. The roll and Mach number arrays may vary from two to eight. As an example consider the array CCA where the value of $C_A$ depends on five roll angles ($\phi_i$), eleven angles-of-attack ($\alpha$) and seven Mach numbers (AM). The array PPHIE would be read in on one card containing five distinct roll angles, the last three fields of ten digits would be blanks. The array AALPFE would be read in on two cards. The first card would contain eight distinct angles-of-attack, and the second card would contain three distinct angles-of-attack and five blank fields of ten digits. The array AAM would be read in on one card containing seven distinct Mach numbers and one blank field of ten digits. The first element in each of the above arrays should start at zero and increase numerically until the highest possible value expected to be encountered is specified. In this particular example, the array size used will be CCA(5, 16, 7). The proper read sequence is to first read two cards containing the values of $C_A$ at eleven angle -of-attack, the initial roll angle (zero) and the initial Mach number (zero). These cards are followed by two cards containing values of $C_A$ at eleven angles-of-attack, the second roll angle and the initial Mach number. This is continued for five roll angles at the initial Mach number. After these ten cards, the same procedure is followed for the s :ond Mach number, and the third, etc. up to seven sets of ten cards.

All the aerodynamic coefficient arrays are read similarly. However, notice that the angle-of-attack array associated with the moment coefficients is different than that associated with the force coefficients. Also, the damping moment coefficient arrays (input items "p", "q", and "r") may not be read in at all, depending on the value of OPDA. Instead, input item "l" can be used if the damping coefficients are constant. Finally, the damping coefficients correspond to the arrays read in input items "m", "n", and "o".

Figure 4 helps to clarify the meaning of the input parameters associated with the added air mass on the parachute (Ref. Input Item ff).

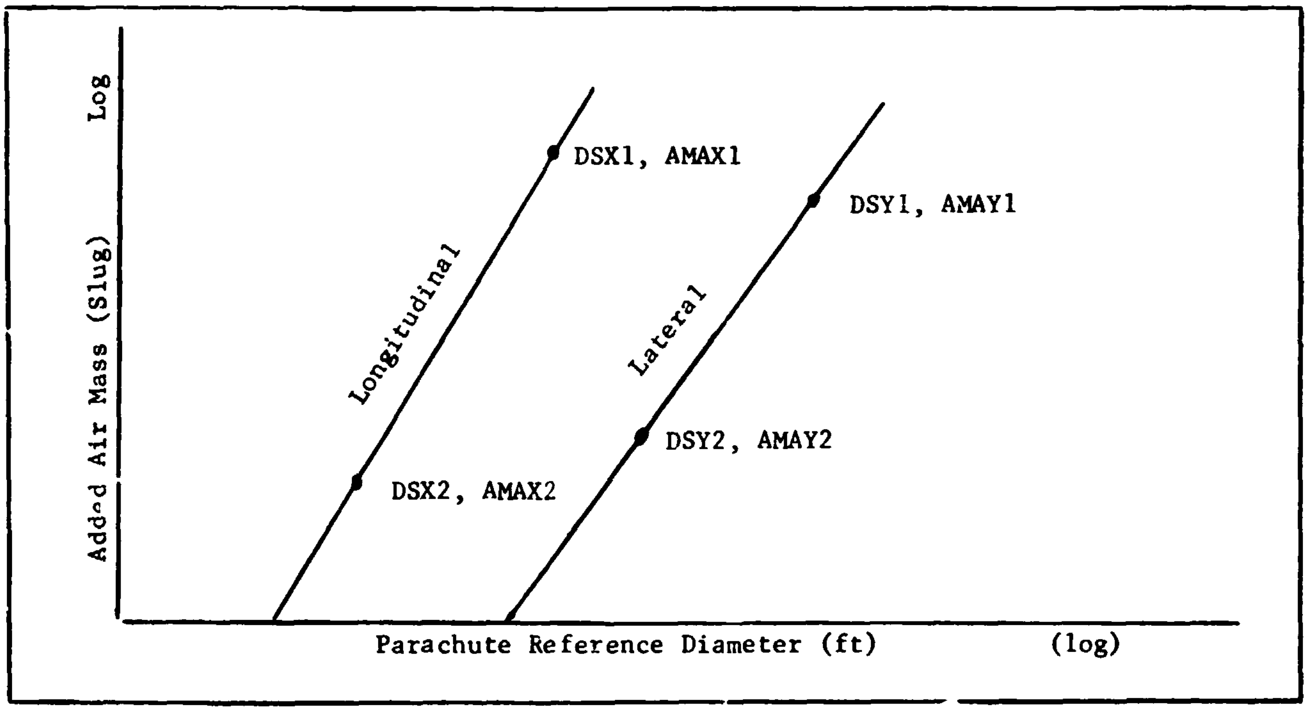


Figure 4. Input Parameters for Parachute Added Air Mass

Figure 5 helps to clarify the meaning of the parameters associated with OPSO = 1.0 which directs the program to calculate the parachute area time history as time advances (Reference Input Items hh and jj).

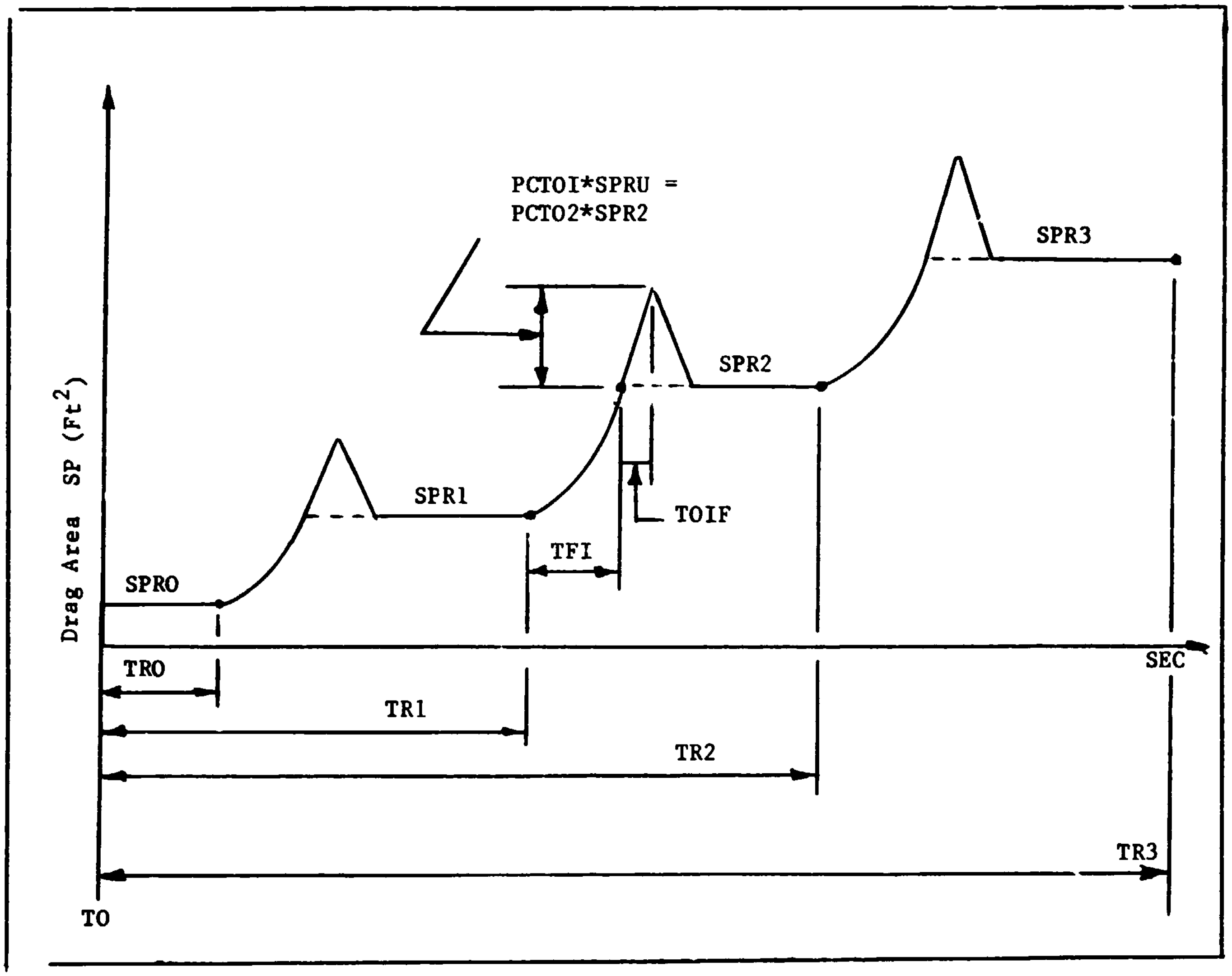


Figure 5. Parameters for Program Calculated Parachute Drag Area Time History

# SECTION 3 - OUTPUT

All output variables are defined in the nomenclature. Before beginning the simulation, the following variables, specifying the characteristics of the rigid body and initial parameters, are printed out.

| | |
|---|---|
| Line 1. | COM |
| Line 2. | IXB, IXYB, XBAR, S, CLIP, OPPRIN, OPSYM, AIPHI, AIPHID, DT1 EPSI |
| Line 3. | IYB, IXZB, YBAR, D, CLMQ, OPPLOT, OPDA, AJALPF, AJALPM, AJALPD, TTT, ETA1 |
| Line 4. | IZB, IYZB, ZBAR, WT, CLNR, OPOS, OMETRC, AKAM, AKAMD, HHH |

If CLLP, CLMQ, and CLNR are constants for the simulation, their values are printed out in the appropriate place. If the damping coefficients are found from interpolation of three dimensional arrays, CLLP, CLMQ, and CLNR are set equal to zero for this printout only. Several variables dealing with the decelerator are then printed out.

| | |
|---|---|
| Line 5. | A, LTO, LS, AMAX1, AMAX2, AMAY1, AMAY2, AP, GLOAD, FREQP, OPAM, PCTO1 |
| Line 6. | B, NT, NS, DSK1, DSK2, DSY1, DSY2, CHIPE, FSULT, POROS, OPDT, PCTO2 |
| Line 7. | C, DLTO, DP, WTC, WTL, WTP, CCRIT, VP, AERATO, TO OPSO, PCTO3 |
| Line 8. | TRO, TR1, TR2, TR3, SPRO, SPR1, SPR2, SPR3 |

The parachute suspension line load and strain arrays are printed out next on Lines 9 and 10.

| | |
|---|---|
| Line 9. | PS(I) |
| Line 10. | EPL(I) |

The tether line load and strain arrays are printed out next on Lines 11 and 12.

| | |
|---|---|
| Line 11. | PT(I) |
| Line 12. | EPT(I) |

The parachute inflation time history array and drag area array are printed out next. If the option (OPSP = 1.0) the arrays are set equal to zero because they are not known before initial time TO.

Line 13. TTIP(I)

Line 14. SSP(I)

The computer program then checks the option variable OPPRIN. If OPPRIN = 1., all the aerodynamic data is listed as follows:

PPHIE(I)
AALPFE(J)
AALPME(J)
AAM(K)

CCA(I,J,K)
CCN(I,J,K)
CCLM(I,J,K)

If OPSYM = 0., the following aerodynamic data is listed

CCY(I,J,K)
CCLL(I,J,K)
CCLN(I,J,K)

In the above aerodynamic coefficient arrays, AALPFE(J) is associated with CCA, CCN, and CCY; AALPME(J) is associated with CCLM, CCLL, and CCLN.

If OPDA = 1., the damping aerodynamics is listed.

PPHIDE(I)
AALPDE(J)
AAMD(K)

CCLLP(I,J,K)
CCLMQ(I,J,K)
CCLNR(I,J,K)

The aerodynamic arrays associated with the decelerator then follow.

AALPPE(I)

AAMP(I)

CCAP(I)

CCNP(I)

CCMP(I)

After the listing of the input data, the computer program begins numerically integrating. At T = $T_o$ and at predetermined time increments, the following data is printed out.

| | |
|---|---|
| Line 1. | T, X, XD, XDD, FX, CA, V, TENS, XP, XPD, XPDD, FXP, CDAP, CMP |
| Line 2. | TXB, Y, YD, YDD, FY, CN, AM, LT, YP, YPD, YPDD, FYP, CNP, AMP |
| Line 3. | TYB, Z, ZD, ZDD, FZ, CY, DYPR, TPD, ZP, ZPD, ZPDD, FZP, TYPB, DYPRP |
| Line 4. | TZB, PSIE, PSIDE, PSIDDE, QPSI, CLN, ALPE, OMXBE, PSIPE, PSIPDE, PSPDDE, QPSIP, TZPB, ALPPE |
| Line 5. | GAME, THEE, THEDE, THEDDE, QTHE, CLM, PHIIE, OMYBE, THEPE, THEPDE, THPDDE, QTHEP, TPDXB, GAMPE |
| Line 6. | CHIE, PHIE, PHIDE, PHIDDE, QPHI, CLL, PHIAE, OMZBE, KS, CLLP, CLMQ, CLNR, TYPDRB, PULAN |
| Line 7. | MPAL, MPAS, DMD, QMAXPB, IXPB, IYPB, SPD, SP, SPRU, SPRL, TINT, TNINY, TFI, XPBDI |

When the simulation reaches HHH or TTT, the computer will write out "RUN ENDED BY CONSTRAINTS". It will then attempt to read in more data cards, to initialize for another simulation, starting with input item "y". If there are no data cards available, the program will CALL EXIT.

## SECTION 4 - NUMERICAL SOLUTION

For the most general type rigid body, there are six second order differential equations, coupled in the acceleration terms. These six equations can be written as:

$$\sum_{i=1}^{6} D_{ij} \ddot{U}_i = v_j \qquad j = 1,2,\ldots, 6 \qquad (153)$$

and solved simultaneously using the PIVERT subroutine. PIVERT uses Gauss elimination with complete pivoting to obtain the largest diagonal elements. After solving for the accelerations ($\ddot{U}_i$ in equation (153)), the results are numerically integrated using Runge-Kutta, fourth order techniques[3].

If the forebody has the properties that $\bar{X} = \bar{Y} = \bar{Z} = I_{xyb} = I_{xzb} = I_{yzb} = 0.$, the equations of motion greatly simplify for the forebody. In the case of integrating the Euler angles, three equations remain coupled in the acceleration terms, and are separated using PIVERT. The three translational accelerations are already in a suitable form to integrate immediately. A simpler situation occurs if the added masses of the decelerator are neglected. All five equations of motion are uncoupled in the second derivative and are easily integrated by 4th order Runge-Kutta.

SECTION 5 - PLOTTING ROUTINE

If OPPLOT = 1., eleven variables are saved in arrays. At the end of the simulation, any or all of these variables are plotted by calling PLTRAJ and setting the appropriate arguments. PLTRAJ was originally written for use on a CALCOMP 563 plotter and 750 tape drive. It has been modified for use at M.S.F.C. where a SC 4020 plotter is the preferred plotter. The original PLTRAJ will plot up to 4 variables versus time on one graph for each call to PLTRAJ. The modified PLTRAJ for the SC 4020 plotter plots only one variable versus time per plot; therefore four plots will be made instead of one for each call to PLTRAJ. Two hundred data points are plotted on each graph per variable.

## SECTION 6 - ENGLISH TO METRIC CONVERSION

The computer program operates in either English or Metric units. The program input and output is in English units unless the option parameter, OMETRC, is set equal to 1. If OMETRC = 1. the input and output is in the Metric System. A conversion table from English to Metric is given below for commonly used engineering parameters.

ENGLISH TO METRIC CONVERSION
REFERENCE NASA SP 7012
*EXACT

| | | | |
|---|---|---|---|
| FORCE | (LB) X 4.4482216152605* | = (1) NEWTON | N |
| LENGTH | (FT) X .30480000 * | = (1) METER | m |
| MASS | (SLUG) X 14.5939029 | = (1) KILOGRAM | kg |
| SPEED | (FT/SEC) X .3048 | = (1) METERS SEC | m/sec |
| PRESSURE | ($LB/FT^2$) X 47.880258 | = (1) $NEWTON/METER^2$ | $N/m^2$ |
| volume | ($FT^3$) x .028316846592* | = $METERS^3$ | $m^3$ |
| AREA | ($FT^2$) X .09290304* | = $METERS^2$ | $m^2$ |
| ACCELERATION | ($FT/SEC^2$) X .3048* | = $METER/SEC^2$ | $m/sec^2$ |
| INERTIA | ($SLUG\text{-}FT^2$) X 1.355817945 | = $KILOGRAM\text{-}METER^2$ | $kg\text{-}m^2$ |
| TORQUE | (FT-LB) X 1.355817948 | = METER - NEWTON | m-N |
| DENSITY | ($SLUG/FT^3$) X 515.379 | = $KILOGRAM/METER^3$ | $kg/m^3$ |
| viscosity | (SLUG/FT-SEC) X 47.880258 | = NEWTON $SEC/METER^2$ | $(N\text{-}sec)/m^2$ |
| SPRING CONSTANT | (LB/FT) X 14.59390293 | = NEWTON/METER | N/m |

* Exact Numbers - No round offs

SECTION 7 - CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are made for use of the 6+5 D.O.F. computer program.

1. The (6+5) DOF loads assessment computer program should be used primarily to analyze the loads induced on a wobbling or spinning body when the body is stabilized by the deployment of a drogue parachute.

2. After the body has been stabilized by the drogue, further parachute deployments (main chutes) should be analyzed using the planer (3+3) DOF computer program. The (3+3) program should be used because of the following reasons:

   a. The (3+3) program is faster and easier to use than the (6+5) program.

   b. Terminal descent with the forebody pitch angle equal to $\pm 90^\circ$ presents no mathematical solution problem using the (3+3) DOF program.

3. It should be noted here that the (6+5) DOF program has a mathematical singularity point at a forebody pitch angle of $\pm 90^\circ$. To permit passage through this point the six forebody accelerations are frozen at their last value when the pitch angle is in the region of $89.8^\circ < \theta < 90.2^\circ$. This induces some error in the translational coordinates and attitude of the forebody, but it has been shown to be small for normal velocity passes through this point. A time counter (TNINY) for the time spent in this region is a program output.

E-1D-15(7-71)
REF: E01 380

## CHAPTER IV - PROGRAM LISTING AND SAMPLE COMPUTER RUN

The following program listing is for the Univac 1108 at M.S.F.C. and adapted from the IBM 360 listing used by Goodyear Aerospace Corporation.

The sample problem, SRB Stabilization by 54' Drogue Parachute, represents the deployment of a 54' drogue from a SRB which is wobbling and flying broadside to the wind vector. The trajectory of the SRB is nearly vertical. The drogue is starting to inflate and is stretched out normal to the SRB centerline. The drogue has one stage of reefing (0.82 of full open area).

Some of the more important initial conditions are given in the table below.

| | | |
|---|---|---|
| Atltitude | Ft | 19,000. |
| Velocity | Ft/Sec | 553. |
| Angle of Attack | Deg. | 90. |
| Flight Path Angle | Deg. | - 85. |
| Body Axis Rates | | |
| Pitch | Deg/Sec | - 1.0 |
| Yaw | Deg/Sec | 0.0 |
| Roll | Deg/Sec | 0.0 |

The output from the sample problem starts on Page 57, and selected portions of the trajectory are found starting on page 107.

```
0002 D 000016 THED      0000 R 004513 THEDDE    0000 R 004510 THEDE     0000 R 004427 THEE      0002 D 000040 THEP
0002 D 000052 THEPD     0000 R 004437 THEPDE    0000 R 004435 THEPE     0000 R 004521 THPDDE    0002   020163 TINF
0002 R 020162 TINT      0002 R 020173 TNINY     0002 R 017354 TPD       0000 R 004531 TPDHB     0002 R 017355 TPDXB
0002 R 017356 TPDYB     0002 R 017357 TPDZB     0002 R 020136 TRO       0002 R 020137 TR1       0002 R 020140 TR2
0002 R 020141 TR3       0002 R 017701 TTIP      0000 R 004445 TTT       0002 R 000215 TXB       0002 R 000216 TYB
0002 R 000220 TYPB      0002 R 000217 TZB       0002 R 000221 TZPB      0002 R 020135 TO        0002 R 020166 TOTHO
0002 R 020167 TOTR1     0002 R 020170 TO R2     0002 R 020171 TOTR3     0002 R 000164 V         0000 R 004527 VD
0002 R 000165 VP        0000 R 004533 VPD       0000 R 004423 WT        0002 R 020124 WTC       0002 R 020127 WTCM
0002 R 020125 WTL       0002 R 020130 WTLM      0000 R 004450 WTP       0002 D 000006 X         0000 R 000140 XA
0002 R 000152 XBAR      0002 D 000022 XD        0000 R 004515 XDD       0002 D 000030 XP        0002 R 020165 XPBDI
0002   020156 XPBDR     0002 D 000042 XPD       0000 R 004522 XPDD      0002 D 000010 Y         0002 R 000153 YBAR
0002 D 000024 YD        0000 R 004516 YDD       0002 D 000032 YP        0002 D 000044 YPD       0000 R 004523 YPDD
0000 R 004452 YY        0000 R 000440 Y1        0000 R 004050 Y10       0000 R 000750 Y2        0000 R 001260 Y3
0000 R 001570 Y4        0000 R 002100 Y5        0000 R 002410 Y6        0000 R 002720 Y7        0000 R 003230 Y8
0000 R 003540 Y9        0002 D 000012 Z         0002 R 000154 ZBAR      0002 D 000026 ZD        0000 R 004517 ZDD
0002 D 000034 ZP        0002 D 000046 ZPD       0000 R 004524 ZPDD


00000  *DIAGNOSTIC*  THE NAME IZMXR APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00000  *DIAGNOSTIC*  THE NAME IXMYR APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00000  *DIAGNOSTIC*  THE NAME LSCL APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00000  *DIAGNOSTIC*  THE NAME ICYO APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00000  *DIAGNOSTIC*  THE NAME ICXO APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00000  *DIAGNOSTIC*  THE NAME ILYO APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00000  *DIAGNOSTIC*  THE NAME ILXO APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00100      1*     C   SIMULATION OF A RIGID BODY WITH 6 D.O.F. CONNECTED TO A RIGID PARACHUTE
00100      2*     C   WITH 5 D.O.F. BY AN ELASTIC TETHER USING LAGRANGE'S EQUATION
00100      3*     C
00101      4*           REAL M,IXB,IYB,IZB,IXYB,IXZB,IYZB,IYMZB,IZMXB,IXMYB
00101      5*          1,MP,MPAL,MPAS,MPL,MPS,MLMMSP,LT,LTO,LTO,KS,IXPB,IYPB,IXMYPB
00101      6*          2,LSCL,LS,NS,NT,LSCLO,ICYO,ICXO,ILYO,ILXO
00103      7*           DOUBLE PRECISION PSI,THE,PHI,X,Y,Z,PSID,THED,PHID,XD,YD,ZD,XP,YP,
00103      8*          1ZP,PSIP,THEP,XPD,YPD,ZPD,PSIPD,THEPD,EE(6),FF(5),T,DT
00103      9*          2,AA(6,4),BB(5,4)
00104     10*           DIMENSION XA(200),Y1(200),Y2(200),Y3(200),Y4(200),Y5(200),
00104     11*          1Y6(200),Y7(200),Y8(200),Y9(200),Y10(200)
00105     12*           DIMENSION COM(14)
00106     13*           COMMON PSI,THE,PHI,X,Y,Z,PSID,THED,PHID,XD,YD,ZD,XP,YP,
00106     14*          1ZP,PSIP,THEP,XPD,YPD,ZPD,PSIPD,THEPD,T,DT,EL,FF
00107     15*           COMMON ALP ,CA,CN,CY,CLM,CLN,CLL,CAP,CNP,CMP,CLMQ,CLNR,CLLP,CS,
00107     16*          2IXB,IYB,IZB,IXYB,IXZB,IYZB,IXPB,OPOS,OPAM,OPSYM,OPDA,OMETRC,
00107     17*          3IYPB,IYMZB,IXMYPB,M,MP,MLMMSP,LT,LTO,LTO,KS,XBAR,YBAR,ZBAR,A,B,
00107     18*          4C,AP,TENS,RE,GO,V,VP,AM,AMP,DYPR,DYPRP,RHO,S,SP,D,DP,ALPE,MPL,MPS,
00107     19*          6PHIIE,EPR,OMXB,OMYB, MZB,FX,FY,FZ,FXP,FYP,FZP,TXB,TYB,TZB,TYPB,
00107     20*          7TZPB,QPSI,QTHE,QPHI,QPSIP,QTHEP,EPSI,PHIAE,IIN,IOUT
00110     21*           COMMON CC(3,3),AALPFE(16),AALPHE(16),AALPDE(8),PPHIE(8),AAM(8)
00110     22*          1,AAMD(8),CCA(8,16,8),CCN(8,16,8),CCY(8,16,8),CCLM(8,16,8),
00110     23*          2CCLL(8,16,8),CCLN(8,16,8),CCL.P(8,8,8),CCLMQ(8,8,8),
00110     24*          3CCLNR(8,8,8),PPHIDE(8),TPD,TPDXB,TPDYB,TPDZB
00110     25*          4,AAMP(8),CCAP(8,8),CCNP(8,8),CCMP(8,8),CCP(3,3),TTIP(16),SSP(16),
00110     26*          5        KKS,MMPAL,MMPAS,IIXPB,IIYPB,AALPPE(8),MPAL
00110     27*          6,DS,SPD,RHOOO,RHOO,AMAX1,AMAX2,DSX1,DSX2,AMAY1,AMAY2,DSY1,DSY2,
00110     28*          7 AX,BX,AY,BY,MPAS,DMD,QMAXPB,DSP,CSIGP,PS(8),PT(8),EPL(8),EPT(8),
00110     29*          8 PSX(8),PTX(8),DELSX(8),DELTX(8),PX(8),DLX(8),WTC,WTL,LSCLO
```

```
00110        9 ,WTCM,WTLM,CCRIT,LS,NS,NT,TD,TRD,TR1,TH2,TH3,SPRO,SPR1,SPR2,SPR3
00110        A ,PCTO1,PCTO2,PCTO3,POROS,GLOAD,FSULT,AERATO,FREQP,XPBDR,DTI
00110        B,SPRU,SPRL,TINT,TINF,TFI,XPBDI,TOTRO,TOTRI,TOTH2,TOTR3,OPSP,TNINY
00111       1 FORMAT(8F10.0)
00112       2 FORMAT(13A6,A2)
00113      50 FORMAT(1H1,5X,'TIME',5X,'X',8X,'XD',7X,'XDD',6X,'FX',7X,'CA',7X,
00113          'V',8X,'TENS',5X,'XP',7X,'XPD',6X,'XPDD',5X,'FXP',6X,'CDAP',5X,
00113         2'CMP'/
00113         36X,'TXB',6X,'Y',8X,'YD',7X,'YDD',6X,'FY',7X,'CN',7X,'AM',7X,'LT',
00113         47X,'YP',7X,'YPD',6X,'YPDD',5X,'FYP',6X,'CNP',6X,'AMP'/
00113         56X,'TYB',6X,'Z',8X,'ZD',7X,'ZDD',6X,'FZ',7X,'CY',7X,'DYPR',5X,
00113         6'TPD',6X,'ZP',7X,'ZPD',6X,'ZPDD',5X,'FZP',6X,'TYPB',5X,'DYPNP'/
00113         76X,'TZB',6X,'PSIE',5X,'PSIDE',4X,'PSIDDE',3X,'QPSI',5X,'CLN',6X,
00113         8'ALPE',5X,'OMXBE',4X,'PSIPE',4X,'PSIPDE',3X,'PSPDDE',3X,'QPSIP',
00113         94X,'TZPB',5X,'ALPPE'/
00113         A5X,'GAME',5X,'THEE',5X,'THEDE',4X,'THEDDE',3X,'QTHE',5X,'CLM',6X,
00113         B'PHIIE',4X,'OMYBE',4X,'THEPE',4X,'THEPDE',3X,'THPDDE',3X,'QTHEP',
00113         C4X,'TPDXB',4X,'GAMPE /
00113         D6X,'CHIE',5X,'PHIE',5X,'PHIDE',4X,'PHIDDE',3X,'QPHI',5X,'CLL',6X,
00113         E'PHIAE',4X,'OMZBE',4X,'KS',7X,'CLLP',5X,'CLMQ',5X,'CLNR',
00113         F 5X,'TPDRB',4X,'PULAN'/6X,'MPAL',5X,'MPAS',5X,'DMD',6X,'QMAXPB',
00113         G 3X,'IXPB',5X,'IYPB',5X,'SPD',6X,'SP',7X,'SPRU',5X,'SPRL',5X,
00113         H 'TINT',4X,'TNINY',5X,'TF1',6X,'XPBDI'//)
00114      51 FORMAT(3X,F9.4,F9.0,2F9.3,F9.0,F9.3,F9.2,2F9.0,2F9.2,F9.0,F9.3,
00114         1F9.3/
00114         23X,2F9.0,2F9.3,F9.0,3F9.3,F9.0,2F9.2,F9.0,2F9.3/
00114         33X,2F9.0,2F9.3,F9.0,F9.3,F9.2,2F9.0,2F9.2,2F9.0,F9.2/
00114         43X,F9.0,3F9.3,F9.0,6F9.3,2F9.0,F9.3/
00114         53X,4F9.3,F9.0,6F9.3,F9.0,F9.0,F9.3/
00114         6 3X,4F9.3,F9.0,3F9.3,F9.0,3F9.3,2F9.0/
00114         7 3X,2F9.1,F9.2,4F9.1,3F9.2,3F9.5,F9.2/)
00114    C
00114    C    AIPHI IS THE NO. OF ELEMENTS IN PPHIE ARRAY (2. TO 8.)
00114    C    AIPHID IS THE NO. OF ELEMENTS IN PPHIDE ARRAY (2. TO 8.)
00114    C    AJALPF IS THE NO. OF ELEMENTS IN AALPFE ARRAY (8. OR 16.)
00114    C    AJALPM IS THE NO. OF ELEMENTS IN AALPME ARRAY (8. OR 16.)
00114    C    AKAM IS THE NO. OF ELEMENTS IN THE AAM ARRAY (2. TO 8.)
00114    C    AKAMD IS THE NO. OF ELEMENTS IN THE AAMD ARRAY (2. TO 8.)
00114    C
00114    C    OPSYM EQUAL 1. IF BODY IS SYMMETRIC SUCH THAT CY=CLL=CLN=0.
00114    C    OPSYM EQUAL 0. IF BODY IS NOT SYMMETRIC
00114    C
00114    C    OPDA EQUAL 1. TO READ  AMPING COEFFICIENTS AS A FUNCTION OF
00114    C                   ROLL ANGLE, ANGLE-OF-ATTACK, AND MACH NUMBER
00114    C    OPDA EQUAL 0. TO READ  AMPING COEFFICIENTS AS CONSTANTS
00114    C
00115           CALL PHARG('66','4','2')
00116           IIN = 5
00117           IOUT= 6
00120           IUSED = 0
00121           READ(IIN,1) AIPHI,AIPHID,AJALPF,AJALPM,AKAM,AKAM ,OPSYM,OPDA
00133           IPHI=AIPHI
00134           IPHID=AIPHID
00135           JALPF=AJALPF
00136           JALPM=AJALPM
00137           AJALPD=8.
```

```
00140      86.            JALPD=AJALPD
00141      87.            KAM=AKAM
00142      88.            KAMD=AKAMD
00143      89.            READ(IIN,1)(PPHIE(I),I=1,IPHI)
00151      90.            READ(IIN,1)(AALPFE(J ,J=1,JALPF)
00157      91.            READ(IIN,1)(AALPHE(J),J=1,JALPH)
00165      92.            READ(IIN,1)(AAM(K),K=1,KAM)
00173      93.            READ(IIN,1)(((CCA(I,J,K),J=1,JALPF),I=1,IPHI),K=1,KAM)
00207      94.            READ(IIN,1)(((CCN(I,J,K),J=1,JALPF),I=1,IPHI),K=1,KAM)
00223      95.            READ(IIN,1)(((CCLM(I,J,K),J=1,JALPH),I=1,IPHI),K=1,KAM)
00237  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00237      96.            IF(OPSYM.EQ.1.) GO TO 98
00241      97.            READ(IIN,1)(((CCY(I,J,K),J=1,JALPF),I=1,IPHI),K=1,KAM)
00255      98.            READ(IIN,1)(((CCLL(I,J,K),J=1,JALPH),I=1,IPHI),K=1,KAM)
00271      99.            READ(IIN,1)(((CCLN(I,J,K),J=1,JALPH),I=1,IPHI),K=1,KAM)
00305     100.         98 CONTINUE
00306  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00306     101.            IF(OFUA.EQ.1.) GO TO 97
00310     102.            READ(IIN,1) CLLP,CLMQ,CLNR
00315     103.            GO TO 96
00316     104.         97 READ(IIN,1)(PPHIDE(I),I=1,IPHID)
00324     105.            READ(IIN,1)(AALPDE(J ,J=1,JALPD)
00332     106.            READ(IIN,1)(AAMD(K),K=1,KAMD)
00340     107.            READ(IIN,1)(((CCLLP(I,J,K),J=1,JALPD),I=1,IPHID),K=1,KAMD)
00354     108.            READ(IIN,1)(((CCLMQ(I,J,K),J=1,JALPD),I=1,IPHID),K=1,KAMD)
00370     109.            READ(IIN,1)(((CCLNR(I,J,K),J=1,JALPD),I=1,IPHID),K=1,KAMD)
00404     110.            CLLP=0.
00405     111.            CLMQ=0.
00406     112.            CLNR=0.
00407     113.         96 CONTINUE
00410     114.            READ(IIN,1)(AALPPE(I),I=1,8)
00416     115.            READ(IIN,1)(AAMP(I),I=1,8)
00424     116.            READ(IIN,1)((CCAP(I,J),J=1,8),I=1,8)
00435     117.            READ(IIN,1)((CCNP(I,J),J=1,8),I=1,8)
00446     118.            READ(IIN,1)((CCMP(I,J),J=1,8),I=1,8)
00446     119.      C
00446     120.      C   OPPRIN = 1. TO PRINT OUT AERODYNAMIC COEFFICIENTS
00446     121.      C   OPPRIN = 0. TO NOT PRINT OUT AERODYNAMIC COEFFICIENTS
00446     122.      C
00446     123.      C   OPPLOT = 1. TO MAKE PLOT TAPE
00446     124.      C   OPPLOT = 0. TO NOT MAKE PLOT TAPE
00446     125.      C
00446     126.      C   OPOS = 1. IF ONE PRODUCT OF INERTIA OR C.G. OFFSET NOT = 0.
00446     127.      C   OPOS = 0. IF ALL PRODUCTS OF INERTIA AND C.G. OFFSETS = 0.
00446     128.      C
00446     129.      C   OPAM = 1. IF ADDED MASS OF PARACHUTE NOT EQUAL 0.
00446     130.      C   OPAM = 0. IF ADDED MASS OF PARACHUTE EQUAL 0.
00446     131.      C
00446     132.      C     OPDT= 1. PROGRAM CALCULATES AN ESTIMATE FOR DT
00446     133.      C     OPDT= 0.0 IF DT IS READ INTO PROGRAM
00446     134.      C
00446     135.      C     OPSP= 1. PROGRAM CALCULATES PARACHUTE DRAG AREA (SP)
00446     136.      C     OPSP= 0.0 SSP(16),TTIP(16) ARRAYS ARE READ INTO PROGRAM
00446     137.      C
00446     138.      C     OMETRC = 1. IF METRIC UNITS ARE USED
00446     139.      C     OMETRC = 0.0 IF ENGLISH UNITS ARE USED
```

```
00446        C
00457              READ(IIN,1) PS,PT,EPL,EPT
00465           99 READ(IIN,1,END=1000) X,Y,Z,V,GAME,CHIE,EPSI,ETAI
00477              READ(IIN,1) WT,IXB,IYB,IZB,IXYB,IXZB,IYZB
00510              READ(IIN,1) S,D,XBAR,YBAR,ZBAR,OPPRIN,OPPLOT,OPOS
00522              READ(IIN,1) PSIE,THEE,FHIE,OMXBE,OMYBE,OMZBE
00532              READ(IIN,1) A,B,C,OPAM,OMETRC
00541              READ(IIN,1) PSIPE,THEPE,PSIPDE,THEPDE,VP,GAMPE,CHIPE
00552              READ(IIN,1) LS,LTC,DLTO,NS,NT,DP,CCRIT
00563              READ(IIN,1) AMAX1,AMAX2,DSX1,DSX2,AMAY1,AMAY2,DSY1,DSY2
00575              READ(IIN,1) WTC,WTL,OPSP,OPUT
00603 *DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00603              IF(OPSP.EQ.0.0) GO TO 91
00605              READ(IIN,1)TR0,TR1,TR2,TR3
00613              READ(IIN,1) SPR0,SPR1,SPR2,SPR3,PCTO1,PCTO2,PCTO3,POROS
00625              DO 64 I=1,16
00630              TTIP(I)=0.0
00631           64 SSP(I)= 0.0
00633              CONTINUE
00634              GO TO 92
00635           91 READ(IIN,1) TTIP,SSP
00641              TR0=0.0
00642              TR1=0.0
00643              TR2=0.0
00644              TR3=0.0
00645              SPR0=0.0
00646              SPR1=0.0
00647              SPR2=0.0
00650              SPR3=0.0
00651              PCTO1=0.0
00652              PCTO2=0.0
00653              PCTO3=0.0
00654              POROS=0.0
00655           92 CONTINUE
00656 *DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00656              IF(OPDT.EQ.0.0) GO TO 93
00660              READ(IIN,1) GLOAD,FSULT,AERATO,TO,DTP1,TTT,MHH
00671              GO TO 94
00672           93 READ(IIN,1) DT1,TO,D P1,TTT,MHH
00701              GLOAD= 0.0
00702              FSULT= 0.0
00703              AERATO=0.0
00704           94 CONTINUE
00705              READ(IIN,2) COM
00710              N=0
00711              WTP= WTL+ WTC
00712              T = TO
00713              TOTR0= TO+TR0
00714              TOTR1= TO+TR1
00715              TOTR2= TO+TR2
00716              TOTR3= TO+TR3
00716        C
00716        C      AUTOMATIC DETERMINATION OF DT
00717 *DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00717              IF(OPDT.EQ.1.) GO TO 60
00721              GO TO 63
```

```
00722           60  DTT= .04735*SQRT((LS*WTP)/(GLOAD*WT*FSULT*AERATO))
00723               FREQP= 1./(12.*DTT)
00724               YY= DTT
00725               I=0
00726           61  NN= YY
00727               IF(NN.GE.1) GO TO 62
00731               I=I+1
00732               YY= YY*10.
00733               GO TO 61
00734           62  DTI= NN/10.**I
00735           63  CONTINUE
00736               GO=32.17
00737               RHOO=.002378
00740               RE=20926435.
00741  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00741               IF(OMETRC.EQ.1.) GO TO 140
00743               GO TO 141
00744          140  RE=6378377.
00745               RHOO=1.22557
00746               GO=9.8054160
00747          141  DPR= 57.2957795
00750               M=WT/GO
00751               MP=WTP/GO
00752               WTCM= WTC/32.17
00753               WTLM= WTL/32.17
00754               LSCLO= SQRT(LS*LS-.10176*DP*DP)
00755               AP= (WTC*(.1595*DP+LSCLO)+ .5*LSCLO*WTL)/(WTC+WTL)
00756               AX= (ALOG10(AMAX1)-ALOG10(AMAX2))/(ALOG10(DSX1)-ALOG10(DSX2))
00757               BX= AMAX1/(DSX1**AX)
00760               AY= (ALOG10(AMAY1)-ALOG10(AMAY2))/(ALOG10(DSY1)-ALOG10(DSY2))
00761               BY= AMAY1/(DSY1**AY)
00762               PSI=PSIE/DPR
00763               THE=THEE/DPR
00764               PHI=PHIE/DPR
00765               PSIP=PSIPE/DPR
00766               THEP=THEPE/DPR
00767               OMXB=OMXBE/DPR
00770               OMYB=OMYBE/DPR
00771               OMZB=OMZBE/DPR
00772               THEPD=THEPDE/DPR
00773               PSIPD=PSIPDE/DPR
00774               GAM=GAME/DPR
00775               CHI=CHIE/DPR
00776               GAMP=GAMPE/DPR
00777               CHIP=CHIPE/DPR
01000               SGAM=SIN(GAM)
01001               CGAM=COS(GAM)
01002               SCHI=SIN(CHI)
01003               CCHI=COS(CHI)
01004               SGAMP=SIN(GAMP)
01005               CGAMP=COS(GAMP)
01006               SCHIP=SIN(CHIP)
01007               CCHIP=COS(CHIP)
01010               XD=V*CGAM*CCHI
01011               YD=V*CGAM*SCHI
01012               ZD=V*SGAM
```

```
01013          XPD=VP*CGAMP*CCHIP
01014          YPD=VP*CGAMP*SCHIP
01015          ZPD=VP*SGAMP
01016          SPSI=SIN(SNGL(PSI))
01017          STHE=SIN(SNGL(THE))
01020          SPHI=SIN(SNGL(PHI))
01021          SPSIP=SIN(SNGL(PSIP))
01022          STHEP=SIN(SNGL(THEP))
01023          CPSI=COS(SNGL(PSI))
01024          CTHE=COS(SNGL(THE))
01025          CPHI=COS(SNGL(PHI))
01026          CPSIP=COS(SNGL(PSIP))
01027          CTHEP=COS(SNGL(THEP))
01030          CC(1,1)=CPSI*CTHE
01031          CC(1,2)=-SPSI*CTHE
01032          CC(1,3)=STHE
01033          CC(2,1)=-CPSI*STHE*SPHI+SPSI*CPHI
01034          CC(2,2)=SPSI*STHE*SPHI+CPSI*CPHI
01035          CC(2,3)=CTHE*SPHI
01036          CC(3,1)=-CPSI*STHE*CPHI-SPSI*SPHI
01037          CC(3,2)=SPSI*STHE*CPHI-CPSI*SPHI
01040          CC(3,3)=CTHE*CPHI
01041          CCP(1,1)=CPSIP*CTHEP
01042          CCP(1,2)=-SPSIP*CTHEP
01043          CCP(1,3)=STHEP
01044          XP=X+A*CC(1,1)+B*CC(2,1)+C*CC(3,1)-(LTO+DLTO+AP)*CCP(1,1)
01045          YP=Y+A*CC(1,2)+B*CC(2,2)+C*CC(3,2)-(LTO+DLTO+AP)*CCP(1,2)
01046          ZP=Z+A*CC(1,3)+B*CC(2,3)+C*CC(3,3)-(LTO+DLTO+AP)*CCP(1,3)
01047          PSID=-(OMYB*SPHI+OMZB*CPHI)/CTHE
01050          THED=(-OMYB*CPHI+OMZB*SPHI)
01051          PHID=OMXB-STHE*(OMYB*SPHI+OMZB*CPHI)/CTHE
01052          DT=DT1
01053          TNINY= 0.0
01054          DTP=DTP1
01055          IYMZB=IYB-IZB
01056          DTPC=0.
01057          CONSTR=-1.
01060          JJJ=1
01061          JJ=1
01061    C
01061    C     WRITE OUT BODY CHARACTERISTICS AND CONTROL VARIABLES
01061    C
01062          WRITE(IOUT,14)
01064       14 FORMAT(1H1,5X,'TRAJECTORY OF A RIGID BODY WITH 6 D.O.F. CONNECTED
01064         1TO A RIGID PARACHUTE WITH 5 D.O.F. BY AN ELASTIC TETHER'//)
01065          WRITE(IOUT,31) COM
01070       31 FORMAT(23X,13A6,A2//)
01071          WRITE(IOUT,11)
01073       11 FORMAT(7X,'IXB',7X,'IXYB',8X,'XBAR',6X,'S',9X,'CLLP',6X,'OPPRIN',
01073         14X,'OPSYM',5X,'AIPHI ,15X,'AIPHID',4X,'DT1',7X,'EPSI'/
01073         27X,'IYB',7X,'IXZB',8X,'YBAR',6X,'D',9X,'CLMQ',6X,'OPPLOT',4X,
01073         3'OPDA',6X,'AJALPF',4X,'AJALPM',4X,'AJALPD',4X,'TTT',7X,'ETA1'/
01073         47X,'IZB',7X,'IYZB',8X,'ZBAR',6X,'WEIGHT',4X,'CLNR',6X,'OPUS',6X,
01073         5'OMETPC',4X,'AKAM',16X,'AKAMD',5X,'MHH'/)
01074          WRITE(IOUT,13) IXB,IXYB,XBAR,S,CLLP,OPPRIN,OPSYM,AIPHI,AIPHID,DT1,
01074         1EPSI,IYB,IXZB,YBAR,D,CLMQ,OPPLOT,OPDA,AJALPF,AJALPM,AJALPD,TTT,
```

```
01074   ZETAI,IZL IYZB,ZBAR,WT,CLNR,OPOS,OMETRC,AKAM,AKAMD,HHH
01137   13 FORMAT(2X,F10.1,2X,F10.1,3F10.3,4X,3(F4.0,6X),10X,F4.0,2X,F10.4,
01137   1F10.6/2X,F10.1,2X,F10.1,3F10.3,4X,4(F4.0,6X),F4.0,2X,F10.4,F10.6/
01137   22X,F10.1,2X,F10.1,F10.3,F10.2,F10.3,4X,F4.0,6X,F4.0,6X,F4.0 ,
01137   316X,F4.0,2X,2F10.1)
01140      WRITE(IOUT,18)
01142   18 FORMAT(////,1CX,'A',9X,'LTO',7X,'LS',6X,'AMAX1',5X,'AMAX2',5X,
01142   1'AMAY1',5X,'AMAY2',8X,'AP',5X,'GLOAD',5X,'FREWP',6X,'UPAM',
01142   A 6X,'PCTO1'/
01142   2 10'  D',10X,'NT',7X,'NS',7X,'DSX1',6X,'DSX2',6X,'DSY1',6X,
01142   3 'D    5X,'CHIPE',5X,'FSULT',5X,'POROS',6X,'OPDT',5X,'PCTO2'/
01142   4 10X,  ',3X,'DLTO',7X,'DP',8X,'WTC',7X,'WTL',7X,'WTP',5X,'CCRIT'
01142   B ,8X,'VP',4X,'AERATO ,8X,'TO',6X,'OPSP',5X,'PCTO3'/
01142   5 10X,'TRO',7X,'TR1',7X,'TR2',7X,'TR3',6X,'SFRO',6X,'SPR1',6X,
01142   6 'SPR2',6X,'SPR3'/)
01143      WRITE(IOUT,19) A,LTO,LS,AMAX1,AMAX2,AMAY1,AMAY2,AP,
01143   1 GLOAD,FREQP,UPAM,PC O1,B,NT,NS,DSX1,DSX2,DSY1,DSY2,CHIPE,FSULT,
01143   2 POROS,CPDT,PCTO2,C,DLTO,DP,WTC,WTL,WTP,CCRIT,VP,AERATO,TO,UPSP,
01143   3 PCTO3,TRO,TR1,TR2,TR3,SPRO,SPR1,SPR2,SPR3
01221   19 FORMAT(6X,12F10.3/6X,12F10.3/6X,12F10.3/6X,12F10.3/)
01222      WRITE(IOUT,12) PS,EPL,PT,EPT
01230   12 FORMAT(//'5X,'PARACHUTE SUSPENSION LINE LOAD AND STRAIN ARRAYS'
01230   1//  8X,'PS(8)',2X,8F10.2/8X,'EPL(8)',1X,8F10.4//
01230   2 15X,'TETHER LINE LOAD AND STRAIN ARRAYS'//8X,'PT(8)'2X,
01230   3 8F10.2/8X,'EPT(8)',7X,8F10.4//)
01231      WRITE(IOUT,21) TTIP,SSP
01235   21 FORMAT(//20X,'PARACHUTE INFLATION TIME HISTORY ARRAY,TTIP'//
01235   1 2X,16F8.4///20X,'PARACHUTE AERODYNAMIC REF. AREA ARRAY, SSP'//
01235   2 2X,16F8.1///)
01235         C
01235         C    WRITE OUT AERODYNAMIC COEFFICIENTS IF 'OPPRIN' = 1.
01235         C
01236   *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
01236      IF(OPPRIN.EQ.0.) GO TO 46
01240      WRITE(IOUT,15)
01242   15 FORMAT(1H1,30X,'AERODYNAMIC COEFFICIENTS OF FOREBODY'///)
01243      WRITE(IOUT,5)
01245    5 FORMAT(10X,'PPHIE (R LL ANGLE-DEGREES)'/)
01246      WRITE(IOUT,10)(PPHIE(I),I=1,IPHI)
01254      WRITE(IOUT,4)
01256    4 FORMAT(/10X,'AALPFE (ANGLE OF ATTACK-DEGREES)'/)
01257      WRITE(IOUT,10)(AALPFE(J),J=1,JALPF)
01265   10 FORMAT(1X,16F8.3/)
01266      WRITE(IOUT,7)
01270    7 FORMAT(/10X,'AALPME (ANGLE OF ATTACK-DEGREES)'/)
01271      WRITE(IOUT,10)(AALPME(J),J=1,JALPM)
01277      WRITE(IOUT,6)
01301    6 FORMAT(/10X,'AAM (MACH NUMBER)'/)
01302      WRITE(IOUT,10)(AAM(K),K=1,KAM)
01310      DO 40 K=1,KAM
01313      WRITE(IOUT,16)
01315   16 FORMAT(///,40X,'CA (AXIAL COEF. ARRAY (IPHI,JALPF,KAM))'/)
01316      WRITE(IOUT,17) AAM(K)
01321   17 FORMAT(40X,'MACH NO. ',F6.3//)
01322      DO 40 I=1,IPHI
01325   40 WRITE(IOUT,10)(CCA(I,J,K),J=1,JALPF)
```

```
01335          DO 41 K=1,KAM
01340          WRITE(IOUT,20)
01342       20 FORMAT(///,40X,'CN (NORMAL COEF. ARRAY(IPHI,JALPF,KAM))'/)
01343          WRITE(IOUT,17) AAM(K)
01346          DO 41 I=1,IPHI
01351       41 WRITE(IOUT,10)(CCN(I,J,K),J=1,JALPF)
01361          DO 44 K=1,KAM
01364          WRITE(IOUT,26)
01366       26 FORMAT(///,40X,'CLM (PITCH MOM. COEF. ARRAY(IPHI,JALPM,KAM))'/)
01367          WRITE(IOUT,17) AAM(K)
01372          DO 44 I=1,IPHI
01375       44 WRITE(IOUT,10)(CCLM(I,J,K),J=1,JALPM)
01405 *DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
01405          IF(OPSYM.EQ.1.) GO TO 95
01407          DO 42 K=1,KAM
01412          WRITE(IOUT,22)
01414       22 FORMAT(///,40X,'CY (LATERAL COEF. ARRAY(IPHI,JALPF,KAM))'/)
01415          WRITE(IOUT,17) AAM(K)
01420          DO 42 I=1,IPHI
01423       42 WRITE(IOUT,10)(CCY(I,J,K),J=1,JALPF)
01433          DO 43 K=1,KAM
01436          WRITE(IOUT,24)
01440       24 FORMAT(///,40X,'CLL (ROLL MOM. COEF. ARRAY(IPHI,JALPM,KAM))'/)
01441          WRITE(IOUT,17) AAM(K)
01444          DO 43 I=1,IPHI
01447       43 WRITE(IOUT,10)(CCLL(I,J,K),J=1,JALPM)
01457          DO 45 K=1,KAM
01462          WRITE(IOUT,28)
01464       28 FORMAT(///,40X,'CLN (YAW MOM. COEF. ARRAY(IPHI,JALPM,KAM))'/)
01465          WRITE(IOUT,17) AAM(K)
01470          DO 45 I=1,IPHI
01473       45 WRITE(IOUT,10)(CCLN(I,J,K),J=1,JALPM)
01503       95 CONTINUE
01504 *DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
01504          IF(OPDA.EQ.1.) GO TO 39
01506          GO TO 38
01507       39 CONTINUE
01510          WRITE(IOUT,8)
01512        8 FORMAT(1H1,10X,'PPHIDE (ROLL ANGLE-DEGREES)'/)
01513          WRITE(IOUT,10)(PPHIDE(I),I=1,IPHID)
01521          WRITE(IOUT,9)
01523        9 FORMAT(/,10X,'AALPDE (ANGLE OF ATTACK-DEGREES)'/)
01524          WRITE(IOUT,10)(AALPDE(J),J=1,JALPD)
01532          WRITE(IOUT,65)
01534       65 FORMAT(/,10X,'AAMD (MACH NUMBER)'/)
01535          WRITE(IOUT,10)(AAMD(K),K=1,KAMD)
01543          DO 47 K=1,KAMD
01546          WRITE(IOUT,30)
01550       30 FORMAT(///,30X,'CLLP (ROLL DAMPING MOM. COEF. ARRAY(IPHID,JALPD,KA
01550         1MD))'/)
01551          WRITE(IOUT,17) AAMD(K)
01554          DO 47 I=1,IPHID
01557       47 WRITE(IOUT,34)(CCLLP(I,J,K),J=1,JALPD)
01567       34 FORMAT(1X,8F10.3/)
01570          DO 48 K=1,KAMD
01573          WRITE(IOUT,33)
```

```
   33 FORMAT(///,30X,'CLMQ (PITCH DAMPING MOM. COEF. ARRAY(IPHID,JALPD,K
     1AMD))'/)
      WRITE(IOUT,17) AAMD(K)
      DO 48 I=1,IPHID
   48 WRITE(IOUT,34)(CCLMQ(I,J,K),J=1,JALPD)
      DO 49 K=1,KAMD
      WRITE(IOUT,32)
   32 FORMAT(///,30X,'CLNR (YAW DAMPING MOM. COEF. ARRAY(IPHI,JALPD,KAMD
     1))'/)
      WRITE(IOUT,17) AAMD(K)
      DO 49 I=1,IPHID
   49 WRITE(IOUT,34)(CCLNR(I,J,K),J=1,JALPD)
   38 WRITE(IOUT,66)
   66 FORMAT(/////,30X,'AE ODYNAMICS OF PARACHUTE'///)
      WRITE(IOUT,67) AALPPE,AAMP,CCAP,CCNP,CCMP
   67 FORMAT(20X,'ANGLE OF ATTACK ARRAY (AALPPE(8))'//,10X,8F10.3///,
     A20X,'MACH NUMBER ARRAY(AAMP(8)'//,10X,8F10.3///,
     120X,'AXIAL COEFF. ARRAY (CCAP(8,8))'//,8(10X,8F10.3/)///,
     220X,'NORMAL COEFF. ARRAY (CCNP(8,8))'//,8(10X,8F10.3/)///,
     320X,'PITCH MOM. COEFF. ARRAY (CCMP(8,8))'//,8(10X,8F10.3/))
   46 CONTINUE
      WRITE(IOUT,50)
  100 IF(Z.LT.HHH) CONSTR=0.
      IF(T.GT.TTT) CONSTR=0.
      IF(JJ.EQ.1) GO TO 101
      DTPC=DTPC+1.
      IF (DTPC.LT.DTP) GO  O 110
      JJJ=JJJ+1
      DTPC=0.
      IF(JJJ.LE.6) GO TO 101
      WRITE(IOUT,50)
      JJJ=1
C
C     CALCULATE AND WRITE OUTPUT
C
  101 CALL SUBR
      PSIE=PSI*DPR
      THEE=THE*DPR
      PHIE=PHI*DPR
      PSIPE=PSIP*DPR
      THEPE=THEP*DPR
      PSIDE=PSID*DPR
      THEDE=THED*DPR
      PHIDE=PHID*DPR
      PSIPDE=PSIPD*DPR
      THEPDE=THEPD*DPR
      PSIDDE=EE(1)*DPR
      THEDDE=EE(2)*DPR
      PHIDDE=EE(3)*DPR
      XDD=EE(4)
      YDD=EE(5)
      ZDD=EE(6)
      PSPDDE=FF(1)*DPR
      THPDDE=FF(2)*DPR
      XPDD=FF(3)
      YPDD=FF(4)
```

```
01723            ZPDD=FF(5)
01724            CHIF=ATAN2(SNGL(YD), NGL(XD))*DPR
01725            GAM=ATAN2(SNGL(ZD),SQRT(SNGL(XD**2+YD**2)))
01726            IF(XD.LT.0.) GAM=3.14159265-GAM
01730            GAMP=ATAN2(SNGL(ZPD),SQRT(SNGL(XPD**2+YPD**2)))
01731            IF(XPD.LT.0.) GAMP=3.14159265-GAMP
01733            GAME=GAM*DPR
01734            ALPPE=ALPP*DPR
01735            GAMPE=GAMP*DPR
01736            OMXBE=OMXB*DPR
01737            OMYBE=OMYB*DPR
01740            OMZBE=OMZB*DPR
01741            CDAP=CAP*SP
01742            VD=SQRT(XDD**2+YDD**2+ZDD**2)
01743            VPD=SQRT(XPDD**2+YPDD**2+ZPDD**2)
01744            TPDRB=SQRT(TPDYB**2+ TPDZB**2)
01745            IF(LT.LT.LTL) GO TO  3
01747            PULAN= ATAN2(TPDRB,TPDXB)*DPR
01750            GO TO 54
01751         53 PULAN= 180.
01752         54 CONTINUE
01753            WRITE(IOUT,51)T,X,XD,XDD,FX,CA,V,TENS,XP,XPD,XPDD,FXP,CDAP,CMP,
01753           1TXB,Y,YD,YDD,FY,CN,AM,LT,YP,YPD,YPDD,FYP,CNP,AMP,
01753           2TYB,Z,ZD,ZDD,FZ,CY,DYPR,TPD,ZP,ZPD,ZPDD,FZP,TYPB,DYPRP,
01753           3TZB,PSIE,PSIDE,PSIDDE,QPSI,CLN,ALPE,OMXBE,PSIPE,PSIPDE,PSPDDE,
01753           4QPSIP,TZPB,ALPPE,
01753           5GAME,THEE,THEDE,THEDDE,QTHE,CLM,PHIIE,OMYBE,THEPE,THEPDE,THPDDE,
01753           6QTHEP,TPDXB,GAMPE,
01753           7CHIE,PHIE,PHIDE,PHIDDE,QPHI,CLL,PHIAE,OMZBE,KS,CLLP,CLMQ,CLNR
01753           8,TPDRB,PULAN,MPAL,MPAS,DMD,QMAXPB,IXPB,IYPB,SPD
01753           9, SP,SPRU,SPRL,TINT,TNINY,TFI,XPBD)
02117            JJ=2
02117      C
02117      C   SPECIFY VARIABLES FOR  LOT TAPE
02117      C
02120  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
02120            IF (OPPLOT.EQ.0.) GO TO 110
02122            N=N+1
02123            XA(N)=T
02124            Y1(N)=PSIE
02125            Y2(N)=THEE
02126            Y3(N)=PHIE
02127            Y4(N)=ALPE
02130            Y5(N)=Z
02131            Y6(N)=AM
02132            Y7(N)=GAME
02133            Y8(N)=DYPR
02134            Y9(N)=TPD
02135            Y10(N)=ALPPE
02136        110 IF (CONSTR)113,111,111
02141        111 WRITE(IOUT,52)
02143         52 FORMAT(/5X,'RUN ENDED BY CONSTRAINTS'/)
02144            IF (OPPLOT) 99, 99,112
02147        112 IF (N.LE.1) GO TO 99
02151            IRET = 0
02152            GO TO 116
```

```
02153          113 IF (OPPLOT)103,103,114
02156          114 IF (N -200)103,115,115
02161          115 IRET = 1
02162          116 IUSED = 1
02163              CALL PLTRAJ(XA,Y1,Y2,Y3,Y4,N,10,2,3,4,5,COM)
02164              CALL PLTRAJ(XA,Y5,Y6,Y7,Y8,N,10,1,6,7,8,COM)
02165              CALL PLTRAJ(XA,Y9,Y10,Y3,Y4,N,10,9,11,0,0,COM)
02166              N = 0
02167              IF (IRET) 99, 99,103
02167        C
02167        C      RUNGE KUTTA INTEGRATION (4TH ORDER)
02167        C
02172          103 DO 74 J=1,4
02175  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
02175              IF(J.EQ.1.AND.DTPC.EQ.0.) GO TO 77
02177              CALL SUBR
02200           77 DO 75 I=1,6
02203           75 AA(I,J)=EE(I)*DT
02205              DO 76 I=1,5
02210           76 BB(I,J)=FF(I)*DT
02212              GO TO (71,72,73,74),J
02213           71 PSI=PSI+.5*PSID*DT
02214              THE=THE+.5*THED*DT
02215              PHI=PHI+.5*PHID*DT
02216              X=X+.5*XD*DT
02217              Y=Y+.5*YD*D
02220              Z=Z+.5*ZD*DT
02221              PSIP=PSIP+.5*PSIPD*DT
02222              THEP=THEP+.5*THEPD*DT
02223              XP=XP+.5*XPD*DT
02224              YP=YP+.5*YPD*DT
02225              ZP=ZP+.5*ZPD*DT
02226              PSID=PSID+.5*AA(1,1)
02227              THED=  D+.5*AA(2,1)
02230              PHID=  D+.5*AA(3,1)
02231              XD=XD+.5*AA(4,1)
0223               YD=YD+.5*AA(5,1)
02233              ZD=ZD+.5*AA(6,1)
02234              PSIPD=PSIPD+.5*BB(1,1)
02235              THEPD=THEPD+.5*BB(2,1)
02236              XPD=XPD+.5*BB(3,1)
02237              YPD=YPD+.5*BB(4,1)
02240              ZPD=ZPD+.5*BB(5,1)
02241              T=T+.5*DT
02242              GO TO 74
02243           72 PSI=PSI+.25*AA(1,1)*DT
02244              THE=THE+.25*AA(2,1)*DT
02245              PHI=PHI+.25*AA(3,1)*DT
02246              X=X+.25*AA(4,1)*DT
02247              Y=Y+.25*AA(5,1)*DT
02250              Z=Z+.25*A  ,1)*DT
02251              PSIP=PSIP+.25*BB 1,1)*DT
02252              THE     P+.25*BB(2,1)*DT
02253              XP=X      *BB(3,1)*DT
02254              YP=Y       (4,1)*DT
02255              ZP=ZP      (5,1)*DT
```

```
02256        PSID=PSID+.5*(AA(1,2)-AA(1,1))
02257        THED=THED+.5*(AA(2,2)-AA(2,1))
02260        PHID=PHID+.5*(AA(3,2)-AA(3,1))
02261        XD=XD+.5*(AA(4,2)-AA(4,1))
02262        YD=YD+.5*(AA(5,2)-AA(5,1))
02263        ZD=ZD+.5*(AA(6,2)-AA(6,1))
02264        PSIPD=PSIPD+.5*(BB(1,2)-BB(1,1))
02265        THEPD=THEPD+.5*(BB(2,2)-BB(2,1))
02266        XPD=XPD+.5*(BB(3,2)-BB(3,1))
02267        YPD=YPD+.5*(BB(4,2)-BB(4,1))
02270        ZPD=ZPD+.5*(BB(5,2)-BB(5,1))
02271        GO TO 74
02272     73 PSI=PSI+DT*(.5*PSID+.25*(AA(1,2)-AA(1,1)))
02273        THE=THE+DT*(.5*THED+.25*(AA(2,2)-AA(2,1)))
02274        PHI=PHI+DT*(.5*PHID+.25*(AA(3,2)-AA(3,1)))
02275        X=X+DT*(.5*XD+.25*(AA(4,2)-AA(4,1)))
02276        Y=Y+DT*(.5*YD+.25*(AA(5,2)-AA(5,1)))
02277        Z=Z+DT*(.5*ZD+.25*(AA(6,2)-AA(6,1)))
02300        PSIP=PSIP+DT*(.5*PSIPD+.25*(BB(1,2)-BB(1,1)))
02301        THEP=THEP+DT*(.5*THEPD+.25*(BB(2,2)-BB(2,1)))
02302        XP=XP+DT*(.5*XPD+.25*(BB(3,2)-BB(3,1)))
02303        YP=YP+DT*(.5*YPD+.25*(BB(4,2)-BB(4,1)))
02304        ZP=ZP+DT*(.5*ZPD+.25*(BB(5,2)-BB(5,1)))
02305        PSID=PSID-.5*AA(1,2)+AA(1,3)
02306        THED=THED-.5*AA(2,2)+AA(2,3)
02307        PHID=PHID-.5*AA(3,2)+AA(3,3)
02310        XD=XD-.5*AA(4,2)+AA(4,3)
02311        YD=YD-.5*AA(5,2)+AA(5,3)
02312        ZD=ZD-.5*AA(6,2)+AA(6,3)
02313        PSIPD=PSIPD-.5*BB(1,2)+BB(1,3)
02314        THEPD=THEPD-.5*BB(2,2)+BB(2,3)
02315        XPD=XPD-.5*BB(3,2)+BB(3,3)
02316        YPD=YPD-.5*BB(4,2)+BB(4,3)
02317        ZPD=ZPD-.5*BB(5,2)+BB(5,3)
02320        T=T+.5*DT
02321     74 CONTINUE
02323        PSID=PSID-AA(1,3)
02324        THED=THED-AA(2,3)
02325        PHID=PHID-AA(3,3)
02326        XD=XD-AA(4,3)
02327        YD=YD-AA(5,3)
02330        ZD=ZD-AA(6,3)
02331        PSIPD=PSIPD-BB(1,3)
02332        THEPD=THEPD-BB(2,3)
02333        XPD=XPD-BB(3,3)
02334        YPD=YPD-BB(4,3)
02335        ZPD=ZPD-BB(5,3)
02336        PSI=PSI-DT*(PSID+.5*AA(1,2))
02337        THE=THE-DT*(THED+.5*AA(2,2))
02340        PHI=PHI-DT*(PHID+.5*AA(3,2))
02341        X=X-DT*(XD+.5*AA(4,2))
02342        Y=Y-DT*(YD+.5*AA(5,2))
02343        Z=Z-DT*(ZD+.5*AA(6,2))
02344        PSIP=PSIP-DT*(PSIPD+.5*BB(1,2))
02345        THEP=THEP-DT*(THEPD+.5*BB(2,2))
02346        XP=XP-DT*(XPD+.5*BB(3,2))
```

```
02347   635.          YP=YP-DT*(YPD+.5*BB(4,2))
02350   636.          ZP=ZP-DT*(ZPD+.5*BB(5,2))
02351   637.          PSI=PSI+DT*(PSID+(AA(1,1)+AA(1,2)+AA(1,3))/6.)
02352   638.          THE=THE+DT*(THED+(AA(2,1)+AA(2,2)+AA(2,3))/6.)
02353   639.          PHI=PHI+DT*(PHID+(AA(3,1)+AA(3,2)+AA(3,3))/6.)
02354   640.          X=X+DT*(XD+(AA(4,1)+AA(4,2)+AA(4,3))/6.)
02355   641.          Y=Y+DT*(YD+(AA(5,1)+AA(5,2)+AA(5,3))/6.)
02356   642.          Z=Z+DT*(ZD+(AA(6,1)+AA(6,2)+AA(6,3))/6.)
02357   643.          PSIP=PSIP+DT*(PSIPD+(BB(1,1)+BB(1,2)+BB(1,3))/6.)
02360   644.          THEP=THEP+DT*(THEPD+(BB(2,1)+BB(2,2)+BB(2,3))/6.)
02361   645.          XP=XP+DT*(XPD+(BB(3,1)+BB(3,2)+BB(3,3))/6.)
02362   646.          YP=YP+DT*(YPD+(BB(4,1)+BB(4,2)+BB(4,3))/6.)
02363   647.          ZP=ZP+DT*(ZPD+(BB(5,1)+BB(5,2)+BB(5,3))/6.)
02364   648.          PSID=PSID+(AA(1,1)+2.*(AA(1,2)+AA(1,3))+AA(1,4))/6.
02365   649.          THED=THED+(AA(2,1)+2.*(AA(2,2)+AA(2,3))+AA(2,4))/6.
02366   650.          PHID=PHID+(AA(3,1)+2.*(AA(3,2)+AA(3,3))+AA(3,4))/6.
02367   651.          XD=XD+(AA(4,1)+2.*(AA(4,2)+AA(4,3))+AA(4,4))/6.
02370   652.          YD=YD+(AA(5,1)+2.*(AA(5,2)+AA(5,3))+AA(5,4))/6.
02371   653.          ZD=ZD+(AA(6,1)+2.*(AA(6,2)+AA(6,3))+AA(6,4))/6.
02372   654.          PSIPD=PSIPD+(BB(1,1)+2.*(BB(1,2)+BB(1,3))+BB(1,4))/6.
02373   655.          THEPD=THEPD+(BB(2,1)+2.*(BB(2,2)+BB(2,3))+BB(2,4))/6.
02374   656.          XPD=XPD+(BB(3,1)+2.*(BB(3,2)+BB(3,3))+BB(3,4))/6.
02375   657.          YPD=YPD+(BB(4,1)+2.*(BB(4,2)+BB(4,3))+BB(4,4))/6.
02376   658.          ZPD=ZPD+(BB(5,1)+2.*(BB(5,2)+BB(5,3))+BB(5,4))/6.
02377   659.          IF(1.-ABS(SIN(SNGL(T (1)))).LT.E.AI) DT=DT1/5.
02401   660.          IF(1.-ABS(SIN(SNGL(T (1)))).GT.ETAI) DT=DT1
02403   661.          GO TO 100
02404   662.     1000 CONTINUE
02405   663.          IF(IUSED.EQ.0) GO TO 1010
02405   664.    C     END ALL PLOTTING BEFORE EXIT
02407   665.          CALL ENDJOB
02410   666.     1010 STOP
02411   667.          END

     END OF COMPILATION:          18 DIAGNOSTICS.
```

```
@FOR,US SUBR
HSD 11A -03/27/79-00:19:12 (0,1)

   SUBROUTINE SUBR        ENTRY POINT 006176

   STORAGE USED: CODE(1) 006210; DATA(0) 000576; BLANK COMMON(2) 020174

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003    DENS
    0004    DENSH
    0005    INTERP
    0006    PIVERT
    0007    SIN
    0010    COS
    0011    SQRT
    0012    ATAN2
    0013    NWDUS
    0014    NIO2$
    0015    NSTOP$
    0016    XPRR
    0017    NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001    000346 10L      0001    002563 100L     0001    000575 101L     0001    001547 102L     0001    000641 103L
    0001    001551 104L     0001    002354 11L      0001    001640 110L     0001    001652 111L     0001    000547 14L
    0001    000555 15L      0001    001630 151L     0001    001011 160L     0001    001047 161L     0001    001105 162L
    0001    001143 163L     0001    001156 190L     0001    001333 191L     0001    001421 194L     0001    001361 195L
    0000    000354 196F     0001    001376 197L     0001    001414 198L     0001    001431 200L     0001    001663 210L
    0001    001675 211L     0001    002015 214L     0001    002026 215L     0001    003306 30L      0001    003373 300L
    0001    002405 301L     0001    003310 31L      0001    004162 40L      0001    002150 400L     0001    004362 401L
    0001    005311 41L      0001    005431 42L      0001    004130 43L      0001    000627 50L      0001    004042 500L
    0001    002054 501L     0000    000376 51F      0000    000411 52F      0001    002065 600L     0001    002077 601L
    0001    003207 61L      0001    003221 62L      0001    003242 66L      0001    003162 665G     0001    003254 67L
    0001    003203 676G     0001    002110 700L     0001    002122 701L     0001    000637 80L      0001    002325 800L
    0001    002337 801L     0001    002675 81L      0001    000707 82L      0001    000721 84L      0001    004133 900L
    0001    002145 901L     0001    002471 96L      0001    002323 97L      0001    002313 98L      0001    002316 99L
    0002 R  000155 A        0002 R  000304 AALPDE   0002 R  000244 AALPFE   0002 R  000264 AALPME   0002 R  017746 AALPPE
    0002 R  000324 AAM      0002 R  000334 AAMD     0002 R  017360 AAMP     0000 R  000277 ABAR     0000 R  000302 ABAND
    0002    020154 AERATO   0002 R  000177 ALPE     0000 R  000261 ALPFSL   0000 R  000264 ALPMSL   0002 R  000106 ALPP
    0000 R  000231 ALPPE    0000 R  000252 ALPPSL   0000 R  000266 ALPSL    0002 R  000166 AM       0002    017763 AMAX1
    0002    017764 AMAX2    0002    017767 AMAY1    0002    017770 AMAY2    0002 R  000167 AMP      0000 R  000250 AMPSL
    0000 R  000260 AMSL     0002 R  000160 AP       0002 R  017773 AX       0002 R  017775 AY       0002 R  000156 B
    0000 R  000300 BBAR     0000 R  000303 BBARD    0002 R  017774 BX       0002 R  017776 BY       0002 R  000157 C
    0002 R  000107 CA       0002 R  000115 CAP      0000 R  000303 CBAR     0000 R  000304 CBARD    0002 R  000233 CC
    0002 R  000344 CCA      0002 R  017370 CCAP     0002 R  010344 CCLL     0002 R  014344 CCLLP    0002 R  006344 CCLM
    0002 R  015344 CCLMQ    0002 R  012344 CCLN     0002 R  016347 CCLNR    0002 R  017570 CCMP     0002 R  002344 CCN
    0002 R  017470 CCNP     0002 R  017670 CCP      0002 R  020131 CCRIT    0002 R  004344 CCY      0000 R  000265 CF
    0002 R  000114 CLL      0002 R  000122 CLLP     0002 R  000112 CLM      0002 R  000120 CLMW     0002 R  000113 CLN
    0002 R  000121 CLNR     0002 R  000117 CMP      0002 R  000110 CN       0002 R  000116 CNP      0000 R  000162 CPHI
    0000 R  000270 CPHI1    0000 R  000253 CPHIPI   0000 R  000171 CPHI2    0000 R  000160 CPSI     0000 R  000163 CPSIP
```

| | | | | |
|---|---|---|---|---|
| 0000 R 000334 CPSIP2 | 0002 R 000123 CS | 0002 R 020003 CSIGP | 0000 R 000161 CTHE | 0000 R 000164 CTHEP |
| 0000 R 000172 CTHEP2 | 0000 R 000170 CT E2 | 0002 R 000111 CY | 0000 R 000213 C1C2C3 | 0000 R 000212 C1C2S3 |
| 0000 R 000207 C1S2 | 0000 R 000211 C1S2C3 | 0000 R 000210 C1S2S3 | 0000 R 000177 C2PHI | 0000 R 000336 C2PSIP |
| 0000 R 000176 C2THE | 0000 R 000337 C2THEP | 0002 R 000175 D | 0000 R 000314 DADPHI | 0000 R 000312 DADPSI |
| 0000 R 000315 DADPSP | 0000 R 000313 DADTHE | 0000 R 000316 DADTHP | 0000 R 000311 DAMP | 0000 R 000321 DBDPHI |
| 0000 R 000317 DBDPSI | 0000 R 000322 DBDPSP | 0000 R 000320 DBDTHE | 0000 R 000323 DBDTHP | 0000 R 000325 DCDPHI |
| 0000 R 000324 DCDTHE | 0000 R 000326 DCDTHP | 0000 D 000005 DD | 0000 D 000115 DDP | 0000 R 000246 DELSP |
| 0000 R 000247 DELSPO | 0002 R 020064 DELSX | 0002 R 020074 DELTX | 0000 R 000305 DLT | 0000 R 000307 DLTX |
| 0002 R 020114 DLX | 0000 R 000317 DLXSL | 0002 R 020000 DMD | 0002 R 000176 DP | 0002 R 000203 DPR |
| 0002 R 017757 DS | 0002 R 020002 DSP | 0002 017765 DSX1 | 0002 017766 DSX2 | 0002 017771 DSY1 |
| 0002 017772 DSY2 | 0002 D 000056 DT | 0002 020157 DT1 | 0002 R 000170 DYPX | 0002 R 000171 DYPXP |
| 0002 D 000060 EE | 0000 D 000137 EEP | 0002 R 020124 EPL | 0000 D 000145 EPS | 0002 R 000227 EPS1 |
| 0002 R 020034 EPT | 0002 D 000074 FF | 0002 020155 FNEWP | 0002 020153 FSULT | 0002 R 000207 FX |
| 0000 R 000271 FXB | 0002 R 000212 FXP | 0000 R 000274 FXPB | 0002 R 000210 FY | 0000 R 000272 FYB |
| 0002 R 000213 FYP | 0000 R 000275 FYPB | 0002 R 000211 FZ | 0000 R 000273 FZB | 0002 R 000214 FZP |
| 0000 R 000276 FZPB | 0000 R 000217 G | 0002 020152 GLOAD | 0002 R 000163 GO | 0000 I 000233 I |
| 0000 R 000002 ICXO | 0000 R 000001 ICYO | 0000 I 000332 IERSW | 0002 000231 IIN | 0002 017744 IIXPA |
| 0002 017745 IIYPB | 0000 R 000004 ILXO | 0000 R 000003 ILYO | 0000 000425 INJPS | 0002 I 000232 IOUT |
| 0002 R 000124 IXB | 0002 R 000142 IXMYPB | 0002 R 000132 IXPB | 0002 R 000127 IXYB | 0002 R 000130 IXZB |
| 0002 R 000125 IYB | 0002 R 000141 IYMZB | 0002 R 000140 IYPB | 0002 R 000131 IYZB | 0002 R 000126 IZB |
| 0000 I 000251 J | 0000 I 000263 JJ | 0000 I 000257 K | 0002 017741 KKS | 0002 R 000151 LS |
| 0002 R 020132 LS | 0000 R 000000 LSCL | 0002 R 020126 LSCLO | 0002 R 000146 LT | 0002 R 000150 LTD |
| 0002 R 000147 LTO | 0002 R 000143 M | 0002 R 000145 MLMMSP | 0002 017742 MMPAL | 0002 017743 MMPAS |
| 0002 R 000144 MP | 0002 R 017756 MPAL | 0002 R 017777 MPAS | 0002 R 000200 MPL | 0002 R 000201 MPS |
| 0002 R 020133 NS | 0002 R 020134 NT | 0002 R 000137 OMETRC | 0002 R 000204 OMXB | 0002 R 000205 OMYB |
| 0002 R 000206 OMZB | 0002 R 000134 OPAM | 0002 R 000136 OPDA | 0002 R 000133 OPOS | 0002 R 020172 OPSP |
| 0002 R 000135 OPSYM | 0000 R 000235 PC OI | 0002 R 020146 PCTU1 | 0002 R 020147 PCTU2 | 0002 R 020150 PCTO3 |
| 0002 D 000004 PHI | 0002 R 000230 PHIAF | 0002 D 000020 PHID | 0000 R 000151 PHIU2 | 0000 R 000256 PHI1 |
| 0002 R 000202 PHIIE | 0000 R 000232 PHIPI | 0000 R 000262 PHISL | 0002 R 020151 POROS | 0002 R 017344 PPHIDE |
| 0002 R 000314 PPHIE | 0000 R 000223 PR | 0002 R 020004 PS | 0000 R 000215 PSDPHD | 0000 R 000214 PSDTD |
| 0002 D 000000 PSI | 0002 D 000014 PS D | 0000 R 000147 PSID2 | 0002 D 000036 PSIP | 0002 D 000050 PSIPD |
| 0000 R 000152 PSIPD2 | 0002 R 020044 PSX | 0002 R 020014 PT | 0002 R 020054 PTX | 0000 R 000306 PTXSL |
| 0002 R 020104 PX | 0002 R 020031 QMAXPB | 0002 R 000224 QPHI | 0002 R 000222 QPSI | 0002 R 000225 QPSIP |
| 0002 R 000223 QTHE | 0002 R 000226 QT EP | 0002 R 000162 RE | 0002 R 000172 RHO | 0002 R 017762 RHOO |
| 0002 R 017761 RHOOO | 0002 R 000173 S | 0002 R 000174 SP | 0002 R 017760 SPD | 0000 R 000241 SPDEL |
| 0000 R 000245 SPDINF | 0000 R 000155 SPHI | 0000 R 000267 SPHI1 | 0000 R 000254 SPHIP1 | 0000 R 000166 SPHI2 |
| 0000 R 000244 SPOI | 0002 R 020161 SPRL | 0002 R 020160 SPRU | 0002 R 020142 SPRG | 0002 R 020143 SPR1 |
| 0002 R 020144 SPR2 | 0002 R 020145 SPR3 | 0000 R 000153 SPSI | 0000 R 000156 SPSIP | 0000 R 000333 SPSIP2 |
| 0002 R 017721 SSP | 0000 R 000154 STHE | 0000 R 000157 STHEP | 0000 R 000167 STHEP2 | 0000 R 000165 STHE2 |
| 0000 R 000204 S1C2C3 | 0000 R 000203 S1C2S3 | 0000 R 000200 S1S2 | 0000 R 000202 S1S2C3 | 0000 R 000201 S1S2S3 |
| 0000 R 000206 S2C3 | 0000 R 000174 S2PHI | 0000 R 000335 S2PSIP | 0000 R 000205 S2S3 | 0000 R 000173 S2THE |
| 0000 R 000175 S2THEP | 0002 D 000054 T | 0000 R 000216 TDPHD | 0002 R 000161 TENS | 0002 R 020164 TF1 |
| 0000 R 000242 TFMT1 | 0002 D 000002 THE | 0002 D 000016 THED | 0000 R 000150 THED2 | 0002 D 000040 THEP |
| 0002 D 000052 THEPD | 0002 R 020163 TINF | 0002 R 020162 TINT | 0002 R 020173 TNINY | 0000 R 000243 TOI |
| 0000 R 000237 TOIF | 0000 R 000236 TOIR | 0002 R 017354 TPD | 0000 R 000327 TPDX | 0002 R 017365 TPDXB |
| 0000 R 000330 TPDY | 0002 R 017356 TPDYB | 0000 R 000331 TPDZ | 0002 R 017357 TPDZB | 0000 R 000240 TRU |
| 0002 020136 TRO | 0002 020137 TR1 | 0002 020140 TR2 | 0002 020141 TR3 | 0000 R 000234 TSL |
| 0002 R 017701 TTIP | 0002 R 000215 TXB | 0002 R 000216 TYB | 0002 R 000220 TYPB | 0002 R 000217 TZB |
| 0002 R 000221 TZPB | 0002 R 020135 TO | 0002 R 020166 TOTRO | 0002 R 020167 TOTR1 | 0002 R 020170 TOTR2 |
| 0002 R 020171 TOTR3 | 0002 R 000164 V | 0002 R 000165 VP | 0000 R 000255 VPXB | 0000 R 000230 VPXPB |
| 0000 R 000221 VS | 0002 020124 WTC | 0002 R 020127 WTCM | 0002 020125 WTL | 0002 R 020130 WTLM |
| 0002 D 000006 X | 0002 R 000152 XBAR | 0000 R 000222 XBD | 0002 D 000022 XD | 0002 D 000030 XP |
| 0000 R 000225 XPBD | 0002 R 020165 XPBDI | 0002 R 020156 XPBDR | 0002 D 000042 XPD | 0000 R 000343 XPDYPD |
| 0000 R 000344 XPDZPD | 0000 R 000340 XPD2 | 0000 R 000346 XPPSPD | 0000 R 000347 XPTHPD | 0002 D 000010 Y |
| 0000 R 000153 YBAR | 0000 R 000223 YBD | 0002 D 000024 YD | 0002 D 000032 YP | 0000 R 000226 YPBD |
| 0002 D 000044 YPD | 0000 R 000345 YPDZPD | 0000 R 000341 YPD2 | 0000 R 000350 YPPSPD | 0000 R 000351 YPTHPD |

```
0002 D 000012 Z          0002 R 000154 ZBAR       0000 R 000224 ZBD        0002 D 000026 ZD         0002 U 000034 ZP
0000 R 000227 ZPBD       0002 D 000046 ZPD        0000 R 000342 ZPD2       0000 R 000352 ZPPSPD     0000 R 000363 ZPTHPD

00000  *DIAGNOSTIC*  THE NAME IZMXR APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00000  *DIAGNOSTIC*  THE NAME IXMYR APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00101          SUBROUTINE SUBR
00103          REAL M,IXB,IYB,IZB,IXYB,IXZB,IYZB,IYMZB,IZMXB,IXMYB
00103         1,MP,MPAL,MPAS,MPL,MPS,MLMMSP,LT,LTO,LTD,KS,IXPB,IYPB,IXMYPB
00103         2,LSCL,LS,NS,NT,LSCLO,ICYO,ICXO,ILYO,ILXO
00104          DOUBLE PRECISION PSI,THE,PHI,X,Y,Z,PSID,THED,PHID,XD,YD,ZD,XP,YP,
00104         1ZP,PSIP,THEP,XPD,YPD,ZPD,PSIPD,THEPD,EE(6),FF(5),T,DT
00104         2,DD(6,6),DDP(3,3),EEP(3),EPS
00105          COMMON PSI,THE,PHI,X,Y,Z,PSID,THED,PHID,XD,YD,ZD,XP,YP,
00105         1ZP,PSIP,THEP,XPD,YPD,ZPD,PSIPD,THEPD,T,DT,EE,FF
00106          COMMON ALPP,CA,CN,CY,CLM,CLN,CLL,CAP,CNP,CMP,CLMQ,CLNR,CLLP,CS,
00106         2IXB,IYB,IZB,IXYB,IXZB,IYZB,IXPB,OPOS,OPAM,OPSYM,OPDA,OMETRC,
00106         3IYPB,IYMZB,IXMYPB,M,MP,MLMMSP,LT,LTO,LTD,KS,XBAR,YBAR,ZBAR,A,B,
00106         4C,AP,TENS,RE,GO,V,VP,AM,AMP,DYPR,DYPRP,RHO,S,SP,D,DP,ALPE,MPL,MPS,
00106         6PHIIE,DPR,OMXB,OMYB, MZB,FX,FY,FZ,FXP,FYP,FZP,TXB,TYB,TZB,TYPB,
00106         7TZPB,QPSI,QTHE,QPHI,QPSIP,QTHEP,EPSI,PHIAE,IIN,IOUT
00107          COMMON CC(3,3),AALPFE(16),AALPME(16),AALPDE(8),PPHIE(8),AAM(8)
00107         1,AAMD(8),CCA(8,16,8),CCN(8,16,8),CCY(8,16,8),CCLM(8,16,8),
00107         2CCLL(8,16,9),CCLN(8,16,8),CCLLP(8,8,8),CCLMQ(8,8,8),
00107         3CCLNR(8,8,8),PPHIDE(8),TPD,TPDXB,TPDYB,TPDZB
00107         4,AAMP(8),CCAP(8,8),CCNP(8,8),CCMP(8,8),CCP(3,3),TTIP(16),SSP(16),
00107         5        KKS,MMPAL,MMPAS,IIXPB,IIYPB,AALPPE(6),MPAL
00107         6,DS,SPD,RHOOO,RHOO,AMAX1,AMAX2,DSX1,DSX2,AMAY1,AMAY2,DSY1,DSY2,
00107         7 AX,BX,AY,BY,MPAS,DMD,QMAXPB,DSP,CSIGP,PS(8),PT(8),EPL(8),EPT(8),
00107         8 PSX(8),PTX(8),DELSX(8),DELTX(8),PX(8),DLX(6),WTC,WTL,LSCLD
00107         9 ,WTCM,WTLM,CCRIT,LS,NS,NT,TO,TRO,TR1,TR2,TR3,SPRU,SPR1,SPR2,SPR3
00107         A ,PCTO1,PCTO2,PCTO3,POROS,GLOAD,FSULT,AERATO,FREQP,XPBDR,DT1
00107         B,SPRU,SPRL,TINT,TINF,TFI,XPBD1,TOTRO,TOTR1,TOTR2,TOTR3,OPSP,TNINY
00110          EPS=.1D-12
00111          PSID2=PSID**2
00112          THED2=THED**2
00113          PHID2=PHID**2
00114          PSIPD2=PSIPD**2
00115          SPSI=SIN(SNGL(PSI))
00116          STHE=SIN(SNGL(THE))
00117          SPHI=SIN(SNGL(PHI))
00120          SPSIP=SIN(SNGL(PSIP))
00121          STHEP=SIN(SNGL(THEP))
00122          CPSI=COS(SNGL(PSI))
00123          CTHE=COS(SNGL(THE))
00124          CPHI=COS(SNGL(PHI))
00125          CPSIP=COS(SNGL(PSIP))
00126          CTHEP=COS(SNGL(THEP))
00127          STHE2=STHE**2
00130          SPHI2=SPHI**2
00131          STHEP2=STHEP**2
00132          CTHE2=CTHE**2
00133          CPHI2=CPHI**2
00134          CTHEP2=CTHEP**2
```

```
P0135          S2THE=2.*STHE*CTHE
P0136          S2PHI=2.*SPHI*CPHI
P0137          S2THEP=2.*STHEP*CTHEP
P0140          C2THE=CTHE2-STHE2
P0141          C2PHI=CPHI2-SPHI2
P0142          S1S2=SPSI*STHE
P0143          S1S2S3=SPSI*STHE*SPHI
P0144          S1S2C3=SPSI*STHE*CPHI
P0145          S1C2S3=SPSI*CTHE SPHI
P0146          S1C2C3=SPSI*CTHE*CPHI
P0147          S2S3=STHE*SPHI
P0150          S2C3=STHE*CPHI
P0151          C1S2=CPSI*STHE
P0152          C1S2S3=CPSI*STHE*SPHI
P0153          C1S2C3=CPSI*STHE*CPHI
P0154          C1C2S3=CPSI*CTHE*SPHI
P0155          C1C2C3=CPSI*CTHE*CPHI
P0156          PSDTD=PSID*THED
P0157          PSDPHD=PSID*PHID
P0160          TDPHD=THED*PHID
P0160     C
P0160     C  CALCULATE TRANSFORMATION MATRICES
P0160     C
P0161          CC(1,1)=CPSI*CTHE
P0162          CC(1,2)=-SPSI*CTHE
P0163          CC(1,3)=STHE
P0164          CC(2,1)=-C1S2S3-SPSI*CPHI
P0165          CC(2,2)=S1S2S3+CPSI*CPHI
P0166          CC(2,3)=CTHE*SPHI
P0167          CC(3,1)=-C1S2C3-SPSI*SPHI
P0170          CC(3,2)=S1S2C3+CPSI* PHI
P0171          CC(3,3)=CTHE*CPHI
P0172          CCP(1,1)=CPSIP*CTHEP
P0173          CCP(1 2)=-SPSIP*CTHEP
P0174          CCP(1,3)=STHEP
P0175          CCP(2,1)=SPSIP
P0176          CCP(2,2)=CPSIP
P0177          CCP(3,1)=-CPSIP*STHEP
P0200          CCP(3,2)=SPSIP*STHEP
P0201          CCP(3,3)=CTHEP
P0202          G=GO*(RE/(Z+RE))**2
P0203 *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
P0203          IF(OMETRC.EQ.1.) GO  O 10
P0205          CALL DENS(Z,PR,RHO,VS)
P0206          GO TO 11
P0207       10 CALL DENSM(Z,PR,RHO, S)
P0210       11 CONTINUE
P0211          V=SQRT(SNGL(XD**2+YD**2+ZD**2))
P0212          VP=SQRT(SNGL(XPD**2+YPD**2+ZPD**2))
P0213          AM=V/VS
P0214          AMP=VP/VS
P0215          DYPR=.5*RHO*V**2
P0216          DYPRP=.5*RHO*VP**2
P0217          XBD=XD*CC(1,1)+YD*CC(1,2)+ZD*CC(1,3)
P0220          YBD=XD*CC(2,1)+YD*CC(2,2)+ZD*CC(2,3)
P0221          ZBD=XD*CC(3,1)+YD*CC(3,2)+ZD*CC(3,3)
```

```
00222             XPBD=XPD*CCP(1,1)+YPD*CCP(1,2)+ZPD*CCP(1,3)
00223             YPBD=XPD*CCP(2,1)+YPD*CCP(2,2)
00224             ZPBD=XPD*CCP(3,1)+YPD*CCP(3,2)+ZPD*CCP(3,3)
00225             VPXPB=SQRT(YPBD**2+ZPBD**2)
00226             ALPP=ATAN2(VPXPB,XPBD)
00227             ALPPE = ALPP*DPR
00230             IF (VPXPB) 13,13,14
00233          13 PHIPI = 0.
00234             GO TO 15
00235          14 PHIPI = ATAN2(-YPBD,-ZPBD)
00236          15 CONTINUE
00236       C
00237 *DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00237             IF(OPSP.EQ.1.0) GO TO 103
00237       C
00241             I=2
00242         100 IF(T.LE.TTIP(I)) GO  0 101
00244             I=I+1
00245             GO TO 100
00246         101 TSL=(T-TTIP(I-1))/(TTIP(I)-TTIP(I-1))
00247             SP=SSP(I-1)+(SSP(I)-SSP(I-1))*TSL
00250             SPD=  (SSP(I)-SSP(I-1))/(TTIP(I)-TTIP(I-1))
00251             XPBDR= XPBD
00252             IF(SPD.LT.0.0) GO TO 50
00254             GO TO 151
00255          50 XPBDR= 0.0
00256         151 CONTINUE
00257             GO TO 200
00260         103  CONTINUE
00261             IF(T.GT.TOTRO) GO TO 80
00263             GO TO 84
00264          80 IF(T.GT.TINT.AND.T.LT.TINF) GO TO 81
00266 *DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00266             IF(PCTOI.EQ.0.0) GO  0 84
00270             IF(T.GE.TINF.AND.T.LT.TOIR) GO TO 82
00272          81 IF((TFI/DT).LE.2.) DT= DT/2.
00274             GO TO 84
00275          82 IF((TOIF/DT).LE.2.) DT= DT/2.
00277             GO TO 84
00300          84 CONTINUE
00301              IF(T.LE.TOTRO.AND.T.GE.TO) GO TO 160
00303              IF(T.LE.TOTR1.AND.T.GT.TOTRO) GO TO 161
00305              IF(T.LE.TOTR2.AND.T.GT.TOTR1) GO TO 162
00307              IF(T.LE.TOTR3.AND.T.GT.TOTR2) GO TO 163
00311         160  SP=SPRO
00312              SPD= 0.0
00313             TINT= 0.0
00314             TINF= 0.0
00315             PCTOI= 0.0
00316             XPBDI= 0.0
00317             TFI= 0.0
00320             SPRL= 0.0
00321             SPRU= 0.0
00322              IF(T.LE.TOTRO.AND.T.GT.(TOTRO-DT)) XPBDI=XPBD
00324             GO TO 200
00325         161  TINT = TOTRO
```

```
00326          SPRL = SPRO
00327          SPRU = SPR1
00330          PCTOI= PCTO1
00331          TRU= TOTR1
00332          IF(T.LE.TOTR1.AND.T.GT.(TOTR1-DT)) XPBDI=XPBD
00334          GO TO 190
00335      162 TINT= TOTR1
00336          SPRL= SPR1
00337          SPRU= SPR2
00340          PCTOI= PCTO2
00341          TRU= TOTR2
00342          IF(T.LE.TOTR2.AND.T.GT.(TOTR2-DT)) XPBDI= XPBD
00344          GO TO 190
00345      163 TINT= TOTR2
00346          SPRL= SPR2
00347          SPRU= SPR3
00350          PCTOI= PCTO3
00351          TRU= TOTR3
00352          GO TO 190
00353      190 SPDEL = SPRU-SPRL
00354          TFI= 65.*1.1284*(SQRT(SPDEL))*POROS/XPBD)
00355          TINF= TINT+TFI
00356          TFMTI= TINF-TINT
00357          TOIF= .5*PCTOI*TFMTI
00360         TOI= TINF+ TOIF
00361         TOIR= TINF+ 2.*TOIF
00362          SPOI= PCTOI*SPDEL
00363          SPDINF= 2.*SPDEL/TFMTI
00364          IF((TRU-TOIR).LT.0.0) GO TO 194
00366          IF(T.LE.TINF.AND.T.GT.TINT) GO TO 191
00370 *DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00370         IF(PCTOI.EQ.0.0.AND.T.GT.TINF.AND.T.LE.TRU) GO TO 198
00372          IF(T.LE.TOI.AND.T.GT.TINF) GO TO 195
00374          IF(T.LE.TOIR.AND.T.GT.TOI) GO TO 197
00376          IF(T.LE.TRU.AND.T.GT.TOIR) GO TO 198
00400      191 DELSP=(SPDEL*(T-TINT)**2)/TFMTI**2
00401          SP= SPRL + DELSP
00402          SPD=(2*(SPDEL)*(T-TINT))/(TFMTI**2)
00403         XPADR= XPBD
00404          GO TO 200
00405      195 DELSPO = SPDINF*(T-TINF)
00406          SP= SPRU+ DELSPO
00407          SPD= SPDINF
00410         XPADR= XPBD
00411          GO TO 200
00412      197 DELSPO= SPOI- SPDINF*(T-TOI))
00413          SP= SPRU + DELSPO
00414          SPD= -SPDINF
00415         XPADR= 0.0
00416          GO TO 200
00417      198 SP= SPRU
00420          SPD= 0.0
00421         XPADR= 0.0
00422          GO TO 200
00423      196 FORMAT(//,2X, 'TERMINATION REQUESTED BY PROGRAM , TRU=',1X,F10.4
00423        1 ,2X,'GIVES NEGATIVE TIME ON REEFED STAGE'/)
```

```
00426          194 WRITE(3,196) TRU
00427              STOP
00430          200  CONTINUE
00431              IF((1.-ABS(STHE)).LT.EPSI) TNINY=TNINY+DT
00433              DS= SQRT(1.27324*SP)
00434              DSP= .638*DS
00435              LSCL= SQRT(LS*LS-.25*DSP*DSP)
00436              CSIGP= LSCL/LS
00437              RHOOO= RHO/RHOO
00440              MPAL = RHOOO*BX*DS**AX
00441              MPAS = RHOOO*BY*DS**AY
00442              DMD = RHOOO*AX*BX*SPD*(1./SQRT(3.14159*SP))*DS**(AX-1)
00443              QMAXPB = DMD*XPBDR
00444 *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00444              IF(OPAM.EQ.0.C) GO TO 102
00446              GO TO 104
00447          102 MPAL= 0.0
00450              MPAS= 0.0
00451          104 CONTINUE
00452              MPL=MPAL+MP
00453              MPS=MPAS+MP
00454              MLMMSP=MPL-MPS
00455              ICYO= .104167*WTCM*D P*DSP
00456              ICXO= .625*ICYO
00457              ILYO= WTLM*(.C8333*LS*LS+.03125*DSP*DSP)
00460              ILXO= .125*WTLM*DSP*DSP
00461              IYPB= ICYO+ILYO+WTLM*(AP-.5*LS*CSIGP)**2+(MPAS+WTCM)*
00461             1 (.25*DSP+LS*CSIGP-AP)**2
00462              IXPB= ICXO+ILXO
00463              IXMYPB=IXPB-IYPB
00464              I=2
00465          110 IF(AMP.LE.AAMP(I)) GO TO 111
00467              I=I+1
00470              GO TO 110
00471          111 AMPSL=(AMP-AAMP(I-1))/(AAMP(I)-AAMP(I-1))
00472              J=2
00473          210 IF(ALPPE.LE.AALPPE(J)) GO TO 211
00475              J=J+1
00476              GO TO 210
00477          211 ALPPSL= (ALPPE-AALPPE(J-1))/(AALPPE(J)-AALPPE(J-1))
00500              CAP=(CCAP(I,J-1)-CCAP(I-1,J-1))*AMPSL+CCAP(I-1,J-1)+((CCAP(I,J)-
00500             1CCAP(I-1,J))*AMPSL+C AP(I-1,J)-((CCAP(I,J-1)-CCAP(I-1,J-1))*AMPSL+
00500             2CCAP(I-1,J-1)))*ALPPSL
00501              CNP=(CCNP(I,J-1)-CCNP(I-1,J-1))*AMPSL+CCNP(I-1,J-1)+((CCNP(I,J)-
00501             1CCNP(I-1,J))*AMPSL+CCNP(I-1,J)-((CCNP(I,J-1)-CCNP(I-1,J-1))*AMPSL+
00501             2CCNP(I-1,J-1)))*ALPPSL
00502              CMP=(CCMP(I,J-1)-CCMP(I-1,J-1))*AMPSL+CCMP(I-1,J-1)+((CCMP(I,J)-
00502             1CCMP(I-1,J))*AMPSL+CCMP(I-1,J)-((CCMP(I,J-1)-CCMP(I-1,J-1))*AMPSL+
00502             2CCMP(I-1,J-1)))*ALPPSL
00503              CMP= CMP+(CNP*AP/DP)
00504              CPHIPI=COS(PHIPI)
00505              SPHIPI=SIN(PHIPI)
00506              VPXB=SQRT(YBD**2+ZBD**2)
00507              ALPE=ATAN2(VPXB,XBD)*DPR
00510              IF (VPXB) 213,213,214
00513          213 PHII = 0.
```

```
00514        GO TO 215
00515    214 PHII = ATAN2(-YBD,-ZBD)
00516    215 CONTINUE
00517        PHIIE=PHII*DPR
00520        PHIAE=PHIIE
00521        IF(PHIIE.LT.0.) PHIAE=-PHIIE
00521     C
00521     C  THE ABOVE STATEMENT SHOULD BECOME A COMMENT CARD IF THERE IS NO
00521     C  AERODYNAMIC PLANE OF SYMMETRY
00521     C
00521     C  AERODYNAMICS
00521     C
00523        K=2
00524    500 IF(AM.LE.AAM(K)) GO TO 501
00526        K=K+1
00527        GO TO 500
00530    501 AMSL=(AM-AAM(K-1))/(AAM(K)-AAM(K-1))
00531        J=2
00532    600 IF(ALPE.LE.AALPFE(J)) GO TO 601
00534        J=J+1
00535        GO TO 600
00536    601 ALPFSL=(ALPE-AALPFE(J-1))/(AALPFE(J)-AALPFE(J-1))
00537        I=2
00540    700 IF(PHIAE.LE.PPHIE(I)) GO TO 701
00542        I=I+1
00543        GO TO 700
00544    701 PHISL=(PHIAE-PPHIE(I-1))/(PPHIE(I)-PPHIE(I-1))
00545        JJ=2
00546    900 IF(ALPE.LE.AALPME(JJ)) GO TO 901
00550        JJ=JJ+1
00551        GO TO 900
00552    901 ALPMSL=(ALPE-AALPME(JJ-1))/(AALPME(JJ)-AALPME(JJ-1))
00552     C
00552     C  THE FIFTH, SIXTH, AND SEVENTH ARGUMENTS OF SUBROUTINE 'INTERP'
00552     C  MUST AGREE WITH THE DIMENSIONS OF THE FIRST ARGUMENT
00552     C
00553        CALL INTERP(CCA,AMSL,ALPFSL,PHISL,8,16,8,I,J,K,CF)
00554        CA=CF
00555        CALL INTERP(CCN,AMSL,ALPFSL,PHISL,8,16,8,I,J,K,CF)
00556        CN=CF
00557        CALL INTERP(CCLM,AMSL,ALPMSL,PHISL,8,16,8,I,JJ,K,CF)
00560        CLM=CF
00561  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00561        IF(OPSYM.EQ.1.) GO TO 98
00563        CALL INTERP(CCY,AMSL,ALPFSL,PHISL,8,16,8,I,J,K,CF)
00564        CY=CF
00565        CALL INTERP(CCLL,AMSL,ALPMSL,PHISL,8,16,8,I,JJ,K,CF)
00566        CLL=CF
00567        CALL INTERP(CCLN,AMSL,ALPMSL,PHISL,8,16,8,I,JJ,K,CF)
00570        CLN=CF
00571        GO TO 99
00572     98 CY=0.
00573        CLL=0.
00574        CLN=0.
00575     99 CONTINUE
00576  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
```

```
      IF(OPDA.EQ.1.) GO TO 97
      GO TO 96
   97 J=2
  800 IF(ALPE.LE.AALPDE(J)) GO TO 801
      J=J+1
      GO TO 800
  801 ALPSL=(ALPE-AALPDE(J-1))/(AALPDE(J)-AALPDE(J-1))
      K=2
  400 IF(AM.LE.AAMD(K)) GO TO 401
      K=K+1
      GO TO 400
  401 AMSL=(AM-AAMD(K-1))/(AAMD(K)-AAMD(K-1))
      I=2
  300 IF(PHIAE.LE.PPHIDE(I)) GO TO 301
      I=I+1
      GO TO 300
  301 PHISL=(PHIAE-PPHIDE(I))/(PPHIDE(I)-PPHIDE(I-1))
      CALL INTERP(CCLLP,AMSL,ALPSL,PHISL,8,8,8,I,J,K,CF)
      CLLP=CF
      CALL INTERP(CCLMQ,AMSL,ALPSL,PHISL,8,8,8,I,J,K,CF)
      CLMQ=CF
      CALL INTERP(CCLNR,AMSL,ALPSL,PHISL,8,8,8,I,J,K,CF)
      CLNR=CF
   96 SPHII=SIN(PHII)
      CPHII=COS(PHII)
C
C     CALCULATE GENERALIZED FORCES
C
      FXB=-DYPR*S*CA
      FYB=DYPR*S*(CN*SPHII-CY*CPHII)
      FZB=DYPR*S*(CN*CPHII+CY*SPHII)
      OMXB=PHID-PSID*CC(1,3)
      OMYB=-THED*CPHI-PSID*CC(2,3)
      OMZB=THED*SPHI-PSID*CC(3,3)
      TXB=DYPR*S*D*(CLL+CLLP*OMXB*D/(2.*V))
      TYB=DYPR*S*D*(-CLM*CPHII-CLN*SPHII+CLMQ*OMYB*D/(2.*V))
      TZB=DYPR*S*D*(CLM*SPHII-CLN*CPHII+CLNR*OMZB*D/(2.*V))
      FXPB= -DYPRP*SP*CAP- HAXPB
      FYPB=DYPRP*SP*CNP*SPHIPI
      FZPB=DYPRP*SP*CNP*CPHIPI
      TYPB=-DYPRP*SP*DP*(CMP-.1*THEPD*DP/VP)*CPHIPI
      TZPB= DYPRP*SP*DP*(CMP-.1*THEPD*DP/VP)*SPHIPI
      ABAR=XP+AP*CCP(1,1)-X-A*CC(1,1)-B*CC(2,1)-C*CC(3,1)
      BBAR=YP+AP*CCP(1,2)-Y-A*CC(1,2)-B*CC(2,2)-C*CC(3,2)
      CBAR=ZP+AP*CCP(1,3)-Z-A*CC(1,3)-B*CC(2,3)-C*CC(3,3)
      ABARD=XPD+AP*(PSIPD*CCP(1,2)+THEPD*CCP(3,1))-XD-A*(PSID*
     1CC(1,2)-THED*C1S2)-B*(PSID*CC(2,2)+PHID*CC(3,1)-THED*C1C2S3)
     2-C*(PSID*CC(3,2)-PHID*CC(2,1)-THED*C1C2C3)
      BBARD=YPD-AP*(PSIPD*CCP(1,1)-THEPD*CCP(3,2))-YD+A*(PSID*
     1CC(1,1)-THED*S1S2)-B*(PSID*CC(2,1)+PHID*CC(3,2)+THED*S1C2S3)
     2-C*(-PSID*CC(3,1)-PHID*CC(2,[illegible])+THED*S1C2C3)
      CBARD=ZPD+AP*THEPD*CTHEP-ZD-A*THED*CTHE-B*(-THED*S2S3+PHID*
     1CC(3,3))+C*(THED*S2C3+PHID*CC(2,3))
      LT=SQRT(ABAR**2+BBAR**2+CBAR**2)
      LTD=(ABAR*ABARD+BBAR*BBARD+CBAR*CBARD)/LT
      DLT=LT-LTD
```

```
00642        IF(LT.LT.LTO) GO TO  0
00662  C
00662  C   SPRING CONSTANT AS A FUNCTION OF ELONGATION
00662  C
00664        DO 60 I=1,8
00667        PSX(I)= PS(I)*NS*CSIGP
00670        PTX(I)= PT(I)*NT
00671        DELSX(I)= EPL(I)*LS*CSIGP
00672        DELTX(I)= EPT(I)*LTO
00673     60 CONTINUE
00675        DO 65 I=1,8
00700        PX(I)=PSX(I)
00701        J=2
00702     61 IF(PX(I).LE.PTX(J)) GO TO 62
00704        J=J+1
00705        GO TO 61
00706     62 PTXSL= (PX(I)-PTX(J-1))/(PTX(J)-PTX(J-1))
00707        DLTX = DELTX(J-1)+(DELTX(J)-DELTX(J-1))*PTXSL
00710        DLX(I)= DELSX(I)+ DLTX
00711     65 CONTINUE
00713        I=2
00714     66 IF(DLT.LE.DLX(I)) GO TO 67
00716        I=I+1
00717        GO TO 66
00720     67 DLXSL= (DLT-DLX(I-1))/(DLX(I)-DLX(I-1))
00721        TENS= PX(I-1)+(PX(I)-PX(I-1))*DLXSL
00722        KS= TENS/DLT
00723        CS= 2.*CCRIT*SQRT(KS*MPL)
00724        DAMP=CS*LTD
00725        GO TO 31
00726     30 TENS=0.
00727        DAMP=0.
00730     31 FX=FXB*CC(1,1)+FYB*CC(2,1)+FZB*CC(3,1)
00731        FY=FXB*CC(1,2)+FYB*CC(2,2)+FZB*CC(3,2)
00732        FZ=FXB*CC(1,3)+FYB*CC(2,3)+FZB*CC(3,3)-M*G
00733        FXP=FXPB*CCP(1,1)+FYPB*CCP(2,1)+FZPB*CCP(3,1)
00734        FYP=FXPB*CCP(1,2)+FYPB*CCP(2,2)+FZPB*CCP(3,2)
00735        FZP=FXPB*CCP(1,3)+FZPB*CCP(3,3)-MP*G
00736        QPSI=-(TXB*CC(1,3)+TYB*CC(2,3)+TZB*CC(3,3))
00737        QTHE=-TYB*CPHI+TZB*SPHI
00740        QPHI=TXB
00741        QPSIP=-TZPB*CCP(3,3)
00742        QTHEP=-TYPB
00743        DADPSI=-A*CC(1,2)-B*CC(2,2)-C*CC(3,2)
00744        DADTHE=A*C1S2+B*C1C2S3+C*C1C2C3
00745        DADPHI=-B*CC(3,1)+C*CC(2,1)
00746        DADPSP=AP*CCP(1,2)
00747        DADTHP=AP*CCP(3,1)
00750        DBDPSI=A*CC(1,1)+B*CC(2,1)+C*CC(3,1)
00751        DBDTHE=-A*S1S2-B*S1C2S3-C*S1C2C3
00752        DBDPHI=-B*CC(3,2)+C*CC(2,2)
00753        DBDPSP=-AP*CCP(1,1)
00754        DBDTHP=AP*CCP(3,2)
00755        DCDTHE=-A*CTHE+B*S2S3+C*S2C3
00756        DCDPHI=-B*CC(3,3)+C*CC(2,3)
00757        DCDTHP=AP*CCP(3,3)
```

```
00760          TPD=TENS+DAMP
00761          TPDX=TPD*ABAR/LT
00762          TPDY=TPD*BBAR/LT
00763          TPDZ=TPD*CBAR/LT
00764          TPDXB=TPDX*CC(1,1)+TPDY*CC(1,2)+TPDZ*CC(1,3)
00765          TPDYB=TPDX*CC(2,1)+TPDY*CC(2,2)+TPDZ*CC(2,3)
00766          TPDZB=TPDX*CC(3,1)+TPDY*CC(3,2)+TPDZ*CC(3,3)
00767   *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00767          IF(OPOS.EQ.1.) GO TO 40
00767     C
00767     C    EQUATIONS OF MOTION FOR SIMPLE FOREBODY
00767     C
00771          IF((1.-ABS(STHE)).LT.EPS1) GO TO 43
00773          DD(1,1)=IXB*STHE2+(IYB*SPHI2+IZB*CPHI2)*CTHE2
00774          DD(1,2)=CTHE*IYMZB*.5*S2PHI
00775          DD(1,3)=-IXB*CC(1,3)
00776          DD(2,1)=DD(1,2)
00777          DD(2,2)=IYB*CPHI2+IZB*SPHI2
01000          DD(2,3)=0.
01001          DD(3,1)=DD(1,3)
01002          DD(3,2)=0.
01003          DD(3,3)=IXB
01004          EE(1)=PSDTD*(IXB-IYB*SPHI2-IZB*CPHI2)*(-S2THE)+PSDPHD*IYMZB*
01004         1(-CTHE2*S2PHI)+TDPHD*(CTHE*(IXB-IYMZB*C2PHI))+THED2*.5*STHE*IYMZB*
01004         1S2PHI-TPD*(ABAR*DADPSI+BBAR*DBDPSI)/LT+WPSI
01005          EE(2)=PSDPHD*CTHE*(-IXB-IYMZB*C2PHI)+TDPHD*IYMZB*S2PHI+PSID2*.5*
01005         1S2THE*(IXB-IYB*SPHI2-IZB*CPHI2)-TPD*(ABAR*DADTHE+BBAR*DBDTHE+
01005         2CBAR*DCDTHE)/LT+QTHE
01006          EE(3)=PSDTD*CTHE*(IXB+IYMZB*C2PHI)+PSID2*(CTHE2*IYMZB*.5*S2PHI)+
01006         1THED2*(-.5*S2PHI*IYMZB)-TPD*(ABAR*DADPHI+BBAR*DBDPHI+CBAR*DCDPHI)/
01006         2LT+QPHI
01007          CALL PIVERT(DD,EE,3,6,1,EPS,IERSW)
01010          IF(IERSW.EQ.0) GO TO 43
01012          WRITE(IOUT,51) IERSW
01015       51 FORMAT(//5X,'INCONSISTENT EQUATIONS ON FOREBODY'//20X,'IERSW=',I2)
01016          STOP
01017       43 EE(4)=(FX+TPD*ABAR/LT)/M
01020          EE(5)=(FY+TPD*BBAR/LT)/M
01021          EE(6)=(FZ+TPD*CBAR/LT)/M
01022          GO TO 41
01023       40 CONTINUE
01023     C
01023     C    EQUATIONS OF MOTION FOR GENERAL FOREBODY
01023     C
01024          IF((1.-ABS(STHE)).LT.EPS1) GO TO 41
01026          DD(1,1)=STHE2*IXB+CTHE2*(IYB*SPHI2+IZB*CPHI2-IYZB*S2PHI)
01026         1-S2THE*(IXYB*SPHI+IXZB*CPHI)
01027          DD(1,2)=CTHE*(IYMZB*.5*S2PHI-IYZB*C2PHI)-IXYB*S2C3+IXZB*S2S3
01030          DD(1,3)=-IXB*CC(1,3)+IXYB*CC(2,3)+IXZB*CC(3,3)
01031          DD(1,4)=M*(XBAR*CC(1,2)+YBAR*CC(2,2)+ZBAR*CC(3,2))
01032          DD(1,5)=M*(-XBAR*CC(1,1)-YBAR*CC(2,1)-ZBAR*CC(3,1))
01033          DD(1,6)=0.
01034          DD(2,1)=DD(1,2)
01035          DD(2,2)=IYB*CPHI2+IZB*SPHI2+IYZB*S2PHI
01036          DD(2,3)=IXYB*CPHI-IXZB*SPHI
01037          DD(2,4)=M*(-XBAR*C1S2-YBAR*C1C2S3-ZBAR*C1C2C3)
```

```
01040          DD(2,5)=M*(XBAR*S1S2+YBAR*S1C2S3+ZBAR*S1C2C3)
01041          DD(2,6)=M*(XBAR*CTHE-YBAR*S2S3-ZBAR*S2C3)
01042          DD(3,1)=DD(1,3)
01043          DD(3,2)=DD(2,3)
01044          DD(3,3)=IXB
01045          DD(3,4)=M*(YBAR*CC(3,1)-ZBAR*CC(2,1))
01046          DD(3,5)=M*(YBAR*CC(3,2)-ZBAR*CC(2,2))
01047          DD(3,6)=M*(YBAR*CC(3,3)-ZBAR*CC(2,3))
01050          DD(4,1)=DD(1,4)
01051          DD(4,2)=DD(2,4)
01052          DD(4,3)=DD(3,4)
01053          DD(4,4)=M
01054          DD(4,5)=0.
01055          DD(4,6)=0.
01056          DD(5,1)=DD(1,5)
01057          DD(5,2)=DD(2,5)
01060          DD(5,3)=DD(3,5)
01061          DD(5,4)=0.
01062          DD(5,5)=M
01063          DD(5,6)=0.
01064          DD(6,1)=0.
01065          DD(6,2)=DD(2,6)
01066          DD(6,3)=DD(3,6)
01067          DD(6,4)=0.
01070          DD(6,5)=0.
01071          DD(6,6)=M
01072          EE(1)=PSDTD*((-S2THE)*(IXB-IYB*SPHI2-IZB*CPHI2+IYZB*S2PHI)
01072         1+(2.*C2THE)*(IXYB*SPHI+IXZB*CPHI))+PSDPHD*((-CTHE2)*(S2PHI*IYMZB
01072         2-IYZB*2.*C2PHI)+(S2THE)*(IXYB*CPHI-IXZB*SPHI))+TDPHD*(CTHE*(IXB
01072         3-IYMZB*C2PHI-IYZB*2.*S2PHI))+THED2*(STHE*((IYMZB)*.5*S2PHI
01072         4-IYZB*C2PHI)+IXYB*CC(3,3)-IXZB*CC(2,3))+PHID2*(-IXYB*CC(3,3)
01072         5+IXZB*CC(2,3))-TPD*(ABAR*DADPSI+BBAR*DBDPSI)/LT+QPSI
01073           EE(2)=PSDPHD*(CTHE*(-IXB-IYMZB*C2PHI-IYZB*2.*S2PHI)-2.*STHE*(
01073         1IXYB*SPHI+IXZB*CPHI) +TDPHD*(IYMZB*S2PHI-IYZB*2.*C2PHI)+PSID2*(
01073         2.5*S2THE*(IXB-IYB*SPHI2-IZB*CPHI2+IYZB*S2PHI)-C2THE*(IXYB*SPHI
01073         3+IXZB*CPHI))+PHID2*(IXYB*SPHI+IXZB*CPHI)-DD(6,2)*G
01073         4-TPD*(ABAR*DADTHE+BBAR*DBDTHE+CBAR*DCDTHE)/LT+QTHE
01074           EE(3)=PSDTD*(CTHE*(IXB+IYMZB*C2PHI+2.*IYZB*S2PHI)+2.*STHE*(
01074         1IXYB*SPHI+IXZB*CPHI) +PSID2*(CTHE2*(IYMZB*.5*S2PHI-IYZB*C2PHI)
01074         2-.5*S2THE*(IXYB*CPHI-IXZB*SPHI))+THED2*(-.5*S2PHI*IYMZB+IYZB*
01074         3C2PHI)-DD(6,3)*G-TPD*(ABAR*DADPHI+BBAR*DBDPHI+CBAR*DCDPHI)/LT+QPHI
01075           EE(4)=-2.*(PSDTD*DD(5,2)+PSDPHD*DD(5,3))-PSID2*DD(5,1)+M*(2.*
01075         1TDPHD*(YBAR*C1C2C3-ZBAR*C1C2S3)+THED2*(XBAR*CC(1,1)-YBAR*C1S2S3
01075         2-ZBAR*C1S2C3)+PHID2*(YBAR*CC(2,1)+Z AR  C(3,1)))+FX+TPD*ABAR/LT
01076           EE(5)=2.*(PSDTD*DD(4,2)+PSDPHD*DD(4    SID2*DD(4,1)+M*(2.*
01076         1TDPHD*(-YBAR*S1C2C3+ZBAR*S1C2S3)+T EC      AR*CC(1,2)+YBAR*S1S2S3
01076         2+ZBAR*S1S2C3)+PHID2*(YBAR*CC(2,2)+ZBA      ,2)))+FY+TPD*BBAR/LT
01077           EE(6)=M*(2.*TDPHD*(YBAR*S2C3-ZBAR*S2S3)+ ED2*(XBAR*CC(1,3)
01077         1+YBAR*CC(2,3)+ZBAR*CC(3,3))+PHID2*(YBAR*CC(2,3)+ZBAR*CC(3,3)))+FZ
01077         2+TPD*CBAR/LT
01100           CALL PIVERT(DD,EE,6,6,1,EPS,IERSW)
01101           IF(IERSW.EQ.0)  GO TO 41
01103           WRITE(IOUT,51) IERSW
01106           STOP
01107  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
01107        41 IF(OPAM.EQ.1.) GO TO 42
```

```
01107   C
01107   C     EQUATIONS OF MOTION IF NO ADDED MASS IS INCLUDED ON PARACHUTE
01107   C
01111         FF(1)=(-PSIPD*THEPD*S2THEP*IXMYPB-TPD*(ABAR*DADPSP+BBAR*DBDPSP)/
01111        1LT+QPSIP)/(IXPB*STHEP2+IYPB*CTHEP2)
01112         FF(2)=(PSIPD2*.5*S2THEP*IXMYPB-TPD*(ABAR*DADTHP+BBAR*DBDTHP+
01112        1CBAR*DCDTHP)/LT+QTHEP)/IYPB
01113         FF(3)=(-TPD*ABAR/LT+FXP)/MP
01114         FF(4)=(-TPD*BBAR/LT+FYP)/MP
01115         FF(5)=(-TPD*CBAR/LT+FZP)/MP
01116         RETURN
01117      42 CONTINUE
01117   C
01117   C     EQUATIONS OF MOTION IF ADDED MASS IS INCLUDED ON PARACHUTE
01117   C
01120         SPSIP2=SPSIP**2
01121         CPSIP2=CPSIP**2
01122         S2PSIP=2.*SPSIP*CPSIP
01123         C2PSIP=CPSIP2-SPSIP2
01124         C2THEP=CTHEP2-STHEP2
01125         XPD2=XPD**2
01126         YPD2=YPD**2
01127         ZPD2=ZPD**2
01130         XPDYPD=XPD*YPD
01131         XPDZPD=XPD*ZPD
01132         YPDZPD=YPD*ZPD
01133         XPPSPD=XPD*PSIPD
01134         XPTHPD=XPD*THEPD
01135         YPPSPD=YPD*PSIPD
01136         YPTHPD=YPD*THEPD
01137         ZPPSPD=ZPD*PSIPD
01140         ZPTHPD=ZPD*THEPD
01141         DDP(1,1)=MPL*CTHEP2*CPSIP2+MPS*(SPSIP2+STHEP2*CPSIP2)
01142         DDP(1,2)=-MLMMSP*.5*S2PSIP*CTHEP2
01143         DDP(1,3)=MLMMSP*.5*S2THEP*CPSIP
01144         DDP(2,1)=DDP(1,2)
01145         DDP(2,2)=MPL*CTHEP2* PSIP2+MPS*(CPSIP2+SPSIP2*STHEP2)
01146         DDP(2,3)=-MLMMSP*.5* PSIP*S2THEP
01147         DDP(3,1)=DDP(1,3)
01150         DDP(3,2)=DDP(2,3)
01151         DDP(3,3)=MPL*STHEP2+MPS*CTHEP2
01152         EEP(1)=-2.*XPPSPD*DDP(1,2)-ZPPSPD*DDP(2,3)+MLMMSP*(XPTHPD*S2THEP
01152        1*CPSIP2+YPPSPD*C2PSIP*CTHEP2-YPTHPD*.5*S2THEP*S2PSIP-ZPTHPD*
01152        2C2THEP*CPSIP)-TPD*ABAR/LT+FXP
01153         EEP(2)=2.*YPPSPD*DDP(1,2)+ZPPSPD*DDP(1,3)+MLMMSP*(XPPSPD*C2PSIP
01153        1*CTHEP2-XPTHPD*.5*S2THEP*S2PSIP+YPTHPD*S2THEP*SPSIP2+ZPTHPD*
01153        2SPSIP*C2THEP)-TPD*BBAR/LT+FYP
01154         EEP(3)=-XPPSPD*DDP(2,3)+YPPSPD*DDP(1,3)+MLMMSP*(-XPTHPD*CPSIP*
01154        1C2THEP+YPTHPD*SPSIP*C2THEP-ZPTHPD*S2THEP)-TPD*CBAR/LT+FZP
01155         FF(1)=(-PSIPD*THEPD*S2THEP*IXMYPB-MLMMSP*XPDYPD*CTHEP2*C2PSIP+
01155        1XPDZPD*DDP(2,3)-YPDZPD*DDP(1,3)+(XPD2-YPD2)*DDP(1,2)
01155        2-TPD*(ABAR*DADPSP+BBAR*DBDPSP)/LT+QPSIP)/(IXPB*STHEP2+IYPB*CTHEP2)
01156         FF(2)=(PSIPD2*.5*S2THEP*IXMYPB+MLMMSP*(.5*(XPDYPD*S2THEP*S2PSIP
01156        1-XPD2*S2THEP*CPSIP2-YPD2*S2THEP*SPSIP2+ZPD2*S2THEP)+XPDZPD*CPSIP
01156        2*C2THEP-YPDZPD*SPSIP*C2THEP)-TPD*(ABAR*DADTHP+BBAR*DBDTHP+
01156        3CBAR*DCDTHP)/LT+QTHEP)/IYPB
```

```
01157      CALL PIVERT(DDP,EEP,3,3,1,EPS,IERSW)
01160      IF(IERSW.NE.0) WRITE(IOUT,52)
01163      IF(IERSW.NE.0) STOP
01165   52 FORMAT(//5X,'INCONSISTENT EQUATIONS ON PARACHUTE'//20X,'IERSW=',
01165     1I2)
01166      FF(3)=EEP(1)
01167      FF(4)=EEP(2)
01170      FF(5)=EEP(3)
01171      RETURN
01172      END

     END OF COMPILATION:        11 DIAGNOSTICS.
```

```
@FOR,US PLTRAJ
HSD 11A -03/27/79-00:19:25 (0,1)

   SUBROUTINE PLTRAJ    ENTRY POINT 000172

   STORAGE USED: CODE(1) 000235; DATA(0) 000161; BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   IDENT
    0004   QUIK3V
    0005   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001   000013 150L     0001    000156 550L     0001   000156 900L     0000 R 000000 ADARY    0000 R 000026 FLDX
    0000 R 000042 FLDY     0000    000142 INJP$    0000 I 000137 ISYM     0000 I 000136 ITIME    0000 R 000056 LABELS

00000  *DIAGNOSTIC*  THE NAME BUFF APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00101                  SUBROUTINE PLTRAJ(X,Y1,Y2,Y3,Y4,N,IX,IY1,IY2,IY3,IY4,HDR)
00101            C
00101            C    X IS THE ARRAY CONTAINING THE ABSCISSA VALUES
00101            C
00101            C    Y1,Y2,Y3,Y4 ARE THE ARRAYS CONTAINING THE ORDINATE VALUES FOR THE
00101            C                FOUR POSSIBLE ORDINATE AXES CORRESPONDING TO X
00101            C                Y1 IS THE RIGHT MOST AXIS
00101            C
00101            C    N IS THE NUMBER OF POINTS PER ARRAY
00101            C
00101            C    IX SPECIFIES THE TITLE OF THE ABSCISSA AXIS
00101            C       IF IX=10 , THE TITLE IS 'TIME SEC'
00101            C
00101            C    IY1,IY2,IY3,IY4 SPECIFY THE TITLES OF THE FOUR ORDINATE AXES RESPECTIVELY
00101            C                     IF ONLY ONE ORDINATE IS DESIRED , SET IY2=IY3=IY4=0
00101            C                     IF ONLY TWO ORDINATES ARE DESIRED , SET IY3=IY4=0
00101            C                     IF ONLY THREE ORDINATES ARE DESIRED , SET IY4=0
00101            C
00101            C    HDR IS AN ALPHAMERIC ARRAY USED AS A TITLE TO THE PLOT
00101            C
00101            C    ALL SCALING IS AUTOMATIC
00101            C
00103                  DIMENSION X(1),Y1(1),Y2(1),Y3(1),Y4(1),HDR(1),BUFF(500)
00104                  DIMENSION ADARY(22),FLDX(12),FLDY(12)
00105                  REAL LABELS (4,12)
00106                  DATA ADARY /'9 INCH','PAPER',', 1 CO','PY    ','      ','      ',
00106                 1  '      ','      ','      ','      ','      ','      ','      ',
00106                 2  '      ','      ','      ','      ','      ','      ','      ',
00106                 3  '      ','      '/
00110                  DATA FLDX  /'      ','      ','      ','      ','      ','      ',
```

```
00110      31*          1           '          ','          ','          ','          ','          ','        '/
00112  *DIAGNOSTIC*  THE LIST CONTAINS AN ILLEGAL ITEM.
00112      32*             DATA FLDY    '          ','          ','          ','          ','          ','        ',
00112      33*          1           '          ','          ','          ','          ','          ','        '/
00112  *DIAGNOSTIC*  A LIST IN THE ABOVE STATEMENT IS TOO LONG.
00114      34*             DATA LABELS /'ALTITU ,'DE  M ','          ','          ',
00114      35*          2                  'YAW AT','TITUDE','  DEG ','          ',
00114      36*          3                  'PITCH ','ATTITU','DE  DE','G         ',
00114      37*          4                  'ROLL A','TTITUD','E  DEG','          ',
00114      38*          5                  'ANGLE ','OF ATT','ACK  D','EG        ',
00114      39*          6                  'MACH N','UMBER ','          ','          ',
00114      40*          7                  'FLIGHT',' PATH ','ANGLE ',' DEG      ',
00114      41*          8                  'DYNAM.',' PRESS','.  LB/','FT**2     ',
00114      42*          9                  'TENSIO','N  LB ','          ','          ',
00114      43*          A                  'TIME  ','SEC   ','          ','          ',
00114      44*          B                  'CHUTE ','ANG. O','F ATT.','  DEG '/
00114  *DIAGNOSTIC*  A LIST IN THE ABOVE STATEMENT IS TOO LONG.
00116      45*             DATA ITIME/0/
00120      46*             IF (IX .LE. 0) GO TO 900
00122      47*             IF(ITIME)100,100,150
00125      48*         100 CALL IDENT(9,ADARY)
00126      49*         150 ITIME = ITIME + 1
00126      50*       C
00127      51*             ISYM = 34
00130      52*             FLDX(1) = LABELS(1,IX)
00131      53*             FLDX(2) = LABELS(2,IX)
00132      54*             FLDX(3) = LABELS(3,IX)
00133      55*             FLDX(4) = LABELS(4,IX)
00134      56*             IF(IY1)550,550,510
00137      57*         510 CONTINUE
00140      58*             FLDY(1) = LABELS(1,IY1)
00141      59*             FLDY(2) = LABELS(2,IY1)
00142      60*             FLDY(3) = LABELS(3,IY1)
00143      61*             FLDY(4) = LABELS(4,IY1)
00144      62*             CALL QUIK3V(1,ISYM,FLDX,FLDY,N,X,Y1)
00145      63*             IF(IY2)550,550,520
00150      64*         520 CONTINUE
00151      65*             FLDY(1) = LABELS(1,IY2)
00152      66*             FLDY(2) = LABELS(2,IY2)
00153      67*             FLDY(3) = LABELS(3,IY2)
00154      68*             FLDY(4) = LABELS(4,IY2)
00155      69*             CALL QUIK3V(1,ISYM,FLDX,FLDY,N,X,Y2)
00156      70*             IF(IY3)550,550,530
00161      71*         530 CONTINUE
00162      72*             FLDY(1) = LABELS(1,IY3)
00163      73*             FLDY(2) = LABELS(2,IY3)
00164      74*             FLDY(3) = LABELS(3,IY3)
00165      75*             FLDY(4) = LABELS(4,IY3)
00166      76*             CALL QUIK3V(1,ISYM,FLDX,FLDY,N,X,Y3)
00167      77*             IF(IY4)550,550,540
00172      78*         540 CONTINUE
00173      79*             FLDY(1) = LABELS(1,IY4)
00174      80*             FLDY(2) = LABELS(2,IY4)
00175      81*             FLDY(3) = LABELS(3,IY4)
00176      82*             FLDY(4) = LABELS(4,IY4)
00177      83*             CALL QUIK3V(1,ISYM,FLDX,FLDY,N,X,Y4)
```

```
00200      84.        550 CONTINUE
00200      85.      C
00201      86.        900 CONTINUE
00202      87.            RETURN
00203      88.            END

      END OF COMPILATION:          4 DIAGNOSTICS.
```

```
@FOR,US INTERP
MSD 11A -03/27/79-0(119128 (0,1)

   SUBROUTINE INTERP     ENTRY POINT 000113

   STORAGE USED: CODE(1) 000125; DATA(0) 000017; BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000 R 000000 CF1        0000 R 000001 CF2        0000    000002 INJP$


00101                SUBROUTINE INTERP(CCF,AMSL,ALPSL,PHISL,II,JJ,KK,I,J,K,CF)
00101          C
00101          C   THREE DIMENSIONAL LINEAR INTERPOLATION TO FIND AERO. COEFF.
00101          C
00103                DIMENSION CCF(II,JJ,KK)
00104                CF1=(CCF(I,J-1,K)-CCF(I-1,J-1,K))*PHISL+CCF(I-1,J-1,K)
00104               1+((CCF(I,J,K)-CCF(I-1,J,K))*PHISL+CCF(I-1,J,K)-((CCF(I,J-1,K)
00104               2-CCF(I-1,J-1,K))*PHISL+CCF(I-1,J-1,K)))*ALPSL
00105                CF2=(CCF(I,J-1,K-1)-CCF(I-1,J-1,K-1))*PHISL+CCF(I-1,J-1,K-1)+
00105               1((CCF(I,J,K-1)-CCF(I-1,J,K-1))*PHISL+CCF(I-1,J,K-1)-((CCF(I,
00105               2J-1,K-1)-CCF(I-1,J-1,K-1))*PHISL+CCF(I-1,J-1,K-1)))*ALPSL
00106                CF=AMSL*(CF1-CF2)+CF2
00107                RETURN
00110                END

     END OF COMPILATION:       NO  DIAGNOSTICS.
```

```
@FOR,US PIVERT
MSO 11A -03/27/79-00:19:30 (0,1)

   SUBROUTINE PIVERT     ENTRY POINT 000690

   STORAGE USED: CODE(1) 000705; DATA(0) 000111; BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001   000064 116G     0001   000243 120L     0001   000067 121G     0001   000123 137G     0001   000416 150L
    0001   000205 157G     0001   000232 176G     0001   000451 180L     0001   000275 205G     0001   000371 217G
    0001   000605 220L     0001   000376 223G     0001   000610 230L     0001   000423 240G     0001   000464 254G
    0001   000537 261G     0001   000567 266G     0001   000103 30L      0001   000137 70L      0000 I 000021 I
    0000 I 000025 II       0000 I 000026 III      0000   000034 INJP$    0000 I 000016 IJ     0000 I 000017 I2
    0000 I 000022 J        0000 I 000020 K        0000 I 000024 KI       0000 I 000023 L      0000 I 000014 LI
    0000 I 000015 L2       0000 D 000002 ONE      0000 D 000004 PIV      0000 D 000006 PIVI   0000 D 000010 TB
    0000 D 000012 TOL      0000 D 000000 ZERO

00101          SUBROUTINE PIVERT(A,R,M,MD,N,EPS,IER)
00101    C
00101    C        TO SOLVE A GENERAL SYSTEM OF SIMULTANEOUS LINEAR EQUATIONS.  GELG  70
00101    C        SOLUTION IS DONE BY MEANS OF GAUSS-ELIMINATION WITH          GELG 470
00101    C        COMPLETE PIVOTING.                                            GELG 480
00101    C                                                                      GELG 110
00101    C     DESCRIPTION OF PARAMETERS                                        GELG 120
00101    C        A      - THE M BY M COEFFICIENT MATRIX.  (DESTROYED)          GELG 150
00101    C        R      - THE M BY N MATRIX OF RIGHT HAND SIDES.  (DESTROYED)GELG 130
00101    C                 ON RETURN R CONTAINS THE SOLUTION OF THE EQUATIONS.GELG 140
00101    C        M      - THE NUMBER OF EQUATIONS IN THE SYSTEM.               GELG 160
00101    C        MD     - THE DIMENSION OF A
00101    C        N      - THE NUMBER OF RIGHT HAND SIDE VECTORS.               GELG 170
00101    C        EPS    - AN INPUT CONSTANT WHICH IS USED AS RELATIVE          GELG 180
00101    C                 TOLERANCE FOR TEST ON LOSS OF SIGNIFICANCE.          GELG 190
00101    C        IER    - RESULTING ERROR PARAMETER CODED AS FOLLOWS           GELG 200
00101    C                 IER=0  - NO ERROR,                                   GELG 210
00101    C                 IER=-1 - NO RESULT BECAUSE OF M LESS THAN 1 OR       GELG 220
00101    C                          PIVOT ELEMENT AT ANY ELIMINATION STEP       GELG 230
00101    C                          EQUAL TO 0,                                 GELG 240
00101    C                 IER=K  - WARNING DUE TO POSSIBLE LOSS OF SIGNIFI-    GELG 250
00101    C                          CANCE INDICATED AT ELIMINATION STEP K+1,    GELG 260
00101    C                          WHERE PIVOT ELEMENT WAS LESS THAN OR        GELG 270
00101    C                          EQUAL TO THE INTERNAL TOLERANCE EPS TIMES   GELG 280
00101    C                          ABSOLUTELY GREATEST ELEMENT OF MATRIX A.    GELG 290
00101    C                                                                      GELG 300
00101    C     REMARKS                                                          GELG 310
```

```
00101      C                THIS IS A MODIFICATION OF GELG (FROM IBM-SSP)
00101      C          INPUT MATRICES R AND A ARE ASSUMED TO BE STORED COLUMNWISE  GELG 320
00101      C          THE PROCEDURE GIVES RESULTS IF THE NUMBER OF EQUATIONS M IS GELG 350
00101      C          GREATER THAN 0 AND PIVOT ELEMENTS AT ALL ELIMINATION STEPS  GELG 360
00101      C          ARE DIFFERENT FROM 0. HOWEVER WARNING IER=K - IF GIVEN -    GELG 370
00101      C          INDICATES POSSIBLE LOSS OF SIGNIFICANCE. IN CASE OF A WELL  GELG 380
00101      C          SCALED MATRIX A AND APPROPRIATE TOLERANCE EPS, IER=K MAY BE GELG 390
00101      C          INTERPRETED THAT MATRIX A HAS THE RANK K. NO WARNING IS     GELG 400
00101      C          GIVEN IN CASE M=1.                                          GELG 410
00101      C                                                                      GELG 420
00101      C    ..................................................................GELG 500
00101      C                                                                      GELG 510
00103           DIMENSION A(MD,MD),R(MD,N)
00104           DOUBLE PRECISION A,R,EPS,ZERO,ONE,PIV,PIVI,TB,TOL
00105           DATA ZERO,ONE/0.0D0, 1.0D0/
00110           IF(M)230,230,10
00110      C
00110      C    SEARCH FOR GREATEST ELEMENT IN MATRIX A                           GELG 580
00113        10 IER = 0
00114           PIV = ZERO
00115           DO 30 L1=1,M
00120           DO 30 L2=1,M
00123           TB= DABS(A(L1,L2))
00124           IF(TB - PIV)30,30,20
00127        20 PIV = TB
00130           I1 = L1
00131           I2 = L2
00132        30 CONTINUE
00135           TOL = EPS*PIV
00135      C
00135      C    A(I) IS PIVOT ELEMENT. PIV CONTAINS THE ABSOLUTE VALUE OF A(I).   GELG 700
00135      C
00135      C    START ELIMINATION LOOP                                            GELG 730
00136           DO 170 K=1,M
00136      C
00136      C    TEST ON SINGULARITY                                               GELG 770
00141           IF(PIV)230,230,40
00144        40 IF(IER)70,50,70
00147        50 IF(PIV - TOL)60,60,70
00152        60 IER = K-1
00153        70 PIVI = ONE/A(I1,I2)
00154           I = I1-K
00155           J = I2-K
00155      C    I+K IS ROW-INDEX, J+K COLUMN-INDEX OF PIVOT ELEMENT               GELG 860
00155      C                                                                      GELG 870
00155      C    PIVOT ROW REDUCTION AND ROW INTERCHANGE IN RIGHT HAND SIDE R      GELG 880
00156           DO 80 L=1,N
00161           TB =  PIVI*R(I1,L)
00162           R(I1,L) = R(K,L)
00163        80 R(K,L) = TB
00163      C
00163      C    IS ELIMINATION TERMINATED                                         GELG 950
00165           IF(K-M)90,180,180
00165      C
00165      C    COLUMN INTERCHANGE IN MATRIX A                                    GELG 980
00170        90 CONTINUE
```

```
00171          IF(J)120,120,100
00174      100 CONTINUE
00175          DO 110 L=K,M
00200          TB = A(L,K)
00201          A(L,K) = A(L,I2)
00202      110 A(L,I2) = TB
00202    C
00202    C     ROW INTERCHANGE AND PIVOT ROW REDUCTION IN MATRIX A            GELG1080
00204      120 DO 130 L=K,M
00207          TB = PIVI*A(I1,L)
00210          A(I1,L) = A(K,L)
00211      130 A(K,L) = TB
00211    C
00211    C     SAVE COLUMN INTERCHANGE INFORMATION                            GELG1150
00213          A(K,K) = J
00213    C
00213    C     ELEMENT REDUCTION AND NEXT PIVOT SEARCH                        GELG1180
00214          PIV = ZERO
00215          K1 = K+1
00216          DO 160 II=K1,M
00221          PIVI = -A(II,K)
00222          DO 150 L=K1,M
00225          A(II,L) = A(II,L) + PIVI*A(K,L)
00226          TB=DABS(A(II,L))
00227          IF(TB - PIV)150,150,140
00232      140 PIV = TB
00233          I1 = II
00234          I2 = L
00235      150 CONTINUE
00237          DO 160 L=1,N
00242      160 R(II,L) = R(II,L) + PIVI*R(K,L)
00245      170 CONTINUE
00245    C     END OF ELIMINATION LOOP                                        GELG1380
00245    C
00245    C     BACK SUBSTITUTION AND BACK INTERCHANGE                         GELG1410
00247      180 IF(M-1)230,220,190
00252      190 CONTINUE
00253          DO 210 I=2,M
00256          II = M+1 - I
00257          L = A(II,II) + .5
00260          DO 210 J=1,N
00263          TB = R(II,J)
00264          III = II+1
00265          DO 200 K=III,M
00270      200 TB = TB - A(II,K)*R(K,J)
00272          R(II,J) = R(II+L,J)
00273      210 R(II+L,J) = TB
00276      220 RETURN
00276    C
00276    C     ERROR RETURN                                                   GELG1620
00277      230 IER = -1
00300          RETURN
00301          END
```

END OF COMPILATION:        NO  DIAGNOSTICS.

```
@FOR,US DENS
MSD 11A -03/27/79-00:19:34 (0,1)

   SUBROUTINE DENS      ENTRY POINT 000106

   STORAGE USED: CODE(1) 000121; DATA(0) 000 011 BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   EXP
    0004   XPRR
    0005   SQRT
    0006   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001   000011 121G     0001   000022 2L      0001   000050 3L      0001   000060 4L      0000 R 000102 A
    0000 R 000130 B        0000 R 000160 DH    0000 R 000156 H     0000 R 000000 HB    0000 I 000157 I
    0000   000170 INJP$    0000 R 000026 PB    0000 R 000162 T     0000 R 000054 TB    0000 R 000161 TEMP


00101           SUBROUTINE DENS(Z, P, RHO, CS)
00103           DOUBLE PRECISION Z
00104           DIMENSION HB(22), PB(22), TB(22), A(22), B(22)
00105           DATA HB/0.,36089.239,65616.798,104986.88,154199.48,170603.67,
00105          1     200131.23,259186.35,291153.40,323002.75,354753.59,366406.39,
00105          2     480781.04,512046.16,543215.48,605268.46,728243.91,939894.75,
00105          3     1234619.4,1520799.4,1798726.4,2068776.6/
00107           DATA PB/2116.217,472.67922,114.34505,16.128852,2.3162994,
00107          1     1.2322512,.38032173,.021672818,.0034331482,.00062812953,
00107          2     .00015359986,.000052646807,.000010571582,.0000077157071,
00107          3     .0000058324672,.0000035196139,.0000014537l,.39343987E-6,
00107          4     .84176667E-7,.22884174E-7,.72058936E-8,.24891264E-8/
00111           DATA TB/288.15,2*216.65,228.65,2*270.65,252.65,2*180.65,210.65,
00111          1     260.65,360.65,960.65,1110.65,1210.65,1350.65,1550.65,1830.65,
00111          2     2160.65,2420.65,2590.65,2700.65/
00113           DATA A/-.68755856E-5,0.,.14068775E-5,.37325169E-5,0.,
00113          1     -.22523554E-5,-.48256481E-5,0.,.52141408E-5,.74757236E-5,
00113          2     .12120769E-4,.17128281E-4,.49941997E-5,.28886537E-5,
00113          3     .18635746E-5,.12041172E-5,.85314774E-6,.61163347E-6,
00113          4     .42048419E-6,.25268889E-6,2*.1572315E-6/
00115           DATA B/5.255886,-.48063102E-4,-34.163232,-12.201179,-.38473567E-4,
00115          1     17.081627,8.540804,-.57641135E-4,-11.055226,-6.6127901,
00115          2     -3.2961763,-1.6390858,-2.1764464,-3.2456979,-4.6156949,
00115          3     -6.4033868,-7.8733154,-9.3039039,-11.4627,-17.025198,
00115          4     2*-25.562133/
00115     C
00117           H = 20855531.E0*Z/(20855531.E0 + Z)
00120           DO 1 I = 2, 22
00123           IF(H-HB(I))2,1,1
```

```
00126    30.        1    CONTINUE
00130    31.             I = 23
00131    32.           2 I = I - 1
00132    33.             DH = H - HB(I)
00133    34.             TEMP = 1. + A(I)*DH
00134    35.             T = TB(I)*TEMP
00135    36.             IF(A(I))3,6,3
00140    37.           6 TEMP = EXP(B(I)*DH)
00141    38.             GO TO 4
00142    39.           3 TEMP = TEMP**B(I)
00143    40.           4 P = PB(I)*TEMP
00144    41.             RHO = .3236414E-3*P/T
00145    42.             CS = 65.770322E0*SQRT(T)
00146    43.             RETURN
00147    44.             END

     END OF COMPILATION:        NO  DIAGNOSTICS.
```

```
@FOR,US DENSM
HSO 11A -03/27/79-00:19:37 (0,1)

   SUBROUTINE DENSM     ENTRY POINT 000111

   STORAGE USED: CODE(1) 000124; DATA(0) 000 061 BLANK COMMON(2) 000000

   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   EXP
    0004   XPRR
    0005   SQRT
    0006   NERR3$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001     000013 122G    0001     000024 2L    0001     000052 3L    0001     000062 4L    0000 R 000104 A
    0000 R 000132 B         0000 R 000162 DH    0000 R 000160 H     0000 R 000002 HB    0000 I 000161 I
    0000     000175 INJP$   0000 R 000030 PB    0000 R 000164 T     0000 R 000056 TB    0000 R 000163 TEMP
    0000 D 000000 Z

00101             SUBROUTINE DENSM(Z1, P, RHO, CS)
00103             DOUBLE PRECISION Z,Z1
00104             DIMENSION HB(22), PB(22), TB(22), A(22), B(22)
00105             DATA HB/0.,36089.239,65616.798,104986.88,154199.48,170603.67,
00105            1     200131.23,259186.35,291153.40,323002.75,354753.59,386406.39,
00105            2     480781.04,512046.16,543215.48,605268.46,728243.91,939894.75,
00105            3     1234619.4,1520799.4,1798726.4,2068776.6/
00107             DATA PB/2116.217,472.67922,114.34505,18.128852,2.3162994,
00107            1     1.2322512,.38032173,.021672818,.0034331482,.00062812953,
00107            2     .00015359986,.000052666807,.000010571582,.0000077157071,
00107            3     .0000058324672,.0000035196139,.0000014537I,.39343987E-6,
00107            4     .84176667E-7,.22884174E-7,.72058936E-8,.24891264E-8/
00111             DATA TB/288.15,2*216.65,228.65,2*270.65,252.65,2*180.65,210.65,
00111            1     260.65,360.65,960.65,1110.65,1210.65,1350.65,1550.65,1830.65,
00111            2     2160.65,2420.65,2590.65,2700.65/
00113             DATA A/-.68755856E-5,0.,.14068775E-5,.37325169E-5,0.,
00113            1     -.22523554E-5,-.48256481E-5,0.,.52141408E-5,.74757236E-5,
00113            2     .12120769E-4,.17 28281E-4,.49941997E-5,.28886537E-5,
00113            3     .18635746E-5,.12041172E-5,.85314774E-6,.61116347E-6,
00113            4     .42048419E-6,.25268889E-6,2*.1572315E-6/
00115             DATA B/5.255886,-.48063102E-4,-34.163232,-12.201179,-.38473567E-4,
00115            1     17.081627,8.540804,-.57641135E-4,-11.055226,-6.6127901,
00115            2     -3.2961763,-1.6390858,-2.1704464,-3.2456979,-4.6156949,
00115            3     -6.4033868,-7.8733154,-9.3039039,-11.4627,-17.025198,
00115            4     2*-25.562133/
00115       C
00117             Z = Z1*3.28084
00120             H = 20855531.E0*Z/(20855531.E0 + Z)
```

```
00121    29*          DO 1 I = 2, 22
00124    30*          IF(H-HB(I))2,1,1
00127    31*    1     CONTINUE
00131    32*          I = 23
00132    33*        2 I = I - 1
00133    34*          DH = H - HB(I)
00134    35*          TEMP = 1. + A(I)*DH
00135    36*          T = TB(I)*TEMP
00136    37*          IF(A(I))3,6,3
00141    38*        6 TEMP = EXP(B(I)*DH)
00142    39*          GO TO 4
00143    40*        3 TEMP = TEMP**B(I)
00144    41*        4 P = PB(I)*TEMP*47.88025
00145    42*          RHO = .0034836497*P/T
00146    43*          CS = 20.04679*SQRT(T)
00147    44*          RETURN
00150    45*          END

      END OF COMPILATION:      NO  DIAGNOSTICS.
```

@PRT,T
FURPUR 24H1-03/27-00:19

1HNTSV443021*TPFS ELEMENT TABLE

| D | NAME | VERSION | TYPE | DATE | TIME | SEQ # | SIZE-PRE | TEXT | (CYCLE | WORD) | PSRMODE | LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * | PL6DOF | | FOR SYMB | 27 MAR 74 | 00:17:06 | 1 | | 168 | 5 | 0 | 1 | 1792 |
| * | PL6DOF | | RELOCATABLE | 27 MAR 74 | 00:17:16 | 2 | 2 | 204 | | | | 1960 |
| * | SUBR | | FOR SYMB | 27 MAR 74 | 00:17:20 | 3 | | 147 | 5 | 0 | 1 | 2166 |
| * | SUBR | | RELOCATABLE | 27 MAR 74 | 00:17:31 | 4 | 2 | 176 | | | | 2313 |
| * | PLTRAJ | | FOR SYMB | 27 MAR 74 | 00:17:33 | 5 | | 24 | 5 | 0 | 1 | 2491 |
| * | PLTRAJ | | RELOCATABLE | 27 MAR 74 | 00:17:35 | 6 | 1 | 13 | | | | 2515 |
| * | INTERP | | FOR SYMB | 27 MAR 74 | 00:17:36 | 7 | | 5 | 5 | 0 | 1 | 2529 |
| * | INTERP | | RELOCATABLE | 27 MAR 74 | 00:17:37 | 8 | 1 | 5 | | | | 2534 |
| * | PIVERT | | FOR SYMB | 27 MAR 74 | 00:17:55 | 9 | | 41 | 5 | 0 | 1 | 2540 |
| * | PIVERT | | RELOCATABLE | 27 MAR 74 | 00:17:58 | 10 | 1 | 25 | | | | 2581 |
| * | DENS | | FOR SYMB | 27 MAR 74 | 00:18:01 | 11 | | 14 | 5 | 0 | 1 | 2607 |
| * | DENS | | RELOCATABLE | 27 MAR 74 | 00:18:03 | 12 | 1 | 10 | | | | 2621 |
| * | DENSM | | FOR SYMB | 27 MAR 74 | 00:18:16 | 13 | | 14 | 5 | 0 | 1 | 2632 |
| * | DENSM | | RELOCATABLE | 27 MAR 74 | 00:18:19 | 14 | 1 | 11 | | | | 2646 |
| | A | | MAP SYMB | 27 MAR 74 | 00:18:20 | 15 | | 1 | 5 | 0 | 1 | 2658 |
| | CHUTE | | ABSOLUTE | 27 MAR 74 | 00:18:37 | 16 | | 868 | | | | 2659 |
| | PL6DOF | | FOR SYMB | 27 MAR 74 | 00:19:03 | 17 | | 168 | 5 | 1 | 2 | 3527 |
| | PL6DOF | | RELOCATABLE | 27 MAR 74 | 00:19:12 | 18 | 2 | 204 | | | | 3695 |
| | SUBR | | FOR SYMB | 27 MAR 74 | 00:19:15 | 19 | | 147 | 5 | 1 | 2 | 3901 |
| | SUBR | | RELOCATABLE | 27 MAR 74 | 00:19:25 | 20 | 2 | 176 | | | | 4048 |
| | PLTRAJ | | FOR SYMB | 27 MAR 74 | 00:19:26 | 21 | | 24 | 5 | 1 | 2 | 4226 |
| | PLTRAJ | | RELOCATABLE | 27 MAR 74 | 00:19:27 | 22 | 1 | 13 | | | | 4250 |
| | INTERP | | FOR SYMB | 27 MAR 74 | 00:19:28 | 23 | | 5 | 5 | 1 | 2 | 4264 |
| | INTERP | | RELOCATABLE | 27 MAR 74 | 00:19:30 | 24 | 1 | 5 | | | | 4269 |
| | PIVERT | | FOR SYMB | 27 MAR 74 | 00:19:31 | 25 | | 41 | 5 | 1 | 2 | 4275 |
| | PIVERT | | RELOCATABLE | 27 MAR 74 | 00:19:34 | 26 | 1 | 25 | | | | 4316 |
| | DENS | | FOR SYMB | 27 MAR 74 | 00:19:35 | 27 | | 14 | 5 | 1 | 2 | 4342 |

TRA[illegible]ORY OF A RIGID BODY WITH 6 D.O.F. CONNECTED TO A RIG. PARACHUTE WITH 5 D.O.F. BY AN ELASTIC TETHER

54-FT. DROGUE DEPLOYMENT

| IXB<br>IYB<br>IZB | IXYB<br>IXZB<br>IYZB | XBAR<br>YBAR<br>ZBAR | S<br>D<br>WEIGHT | CLLP<br>CLMQ<br>CLNR | OPPRIN<br>OPPLOT<br>OPOS | OPSYM<br>OPDA<br>OMETRC | AIPHI<br>AJALPF<br>AKAM | AJALPM | AIPHID<br>AJALPD<br>AKAMD | DTI<br>TTT<br>HHH | EPSI<br>ETAI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 171149.0 | .0 | -2.000 | 116.260 | .000 | 1. | 0. | 2. | | 2. | .0100 | .000006 |
| 8539000.0 | .0 | .000 | 12.167 | .000 | 0. | 0. | 16. | 16. | 8. | 20.0000 | .000610 |
| 8539000.0 | .0 | .000 | 163300.00 | .000 | 1. | 0. | 6. | | 2. | 6000.0 | |

| A<br>B<br>C<br>TRO | LTO<br>NT<br>DLTO<br>TR1 | LS<br>NS<br>DP<br>TR2 | AMAX1<br>DSX1<br>WTC<br>TR3 | AMAX2<br>DSX2<br>WTL<br>SPR0 | AMAY1<br>DSY1<br>WTP<br>SPR1 | AMAY2<br>DSY2<br>CCRIT<br>SPR2 | AP<br>CHIPE<br>VP<br>SPR3 | GLOAD<br>FSULT<br>AERATO | FREQP<br>POROS<br>TO | OPAM<br>OPDT<br>OPSP | PCT01<br>PCT02<br>PCT03 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 83.800 | 6.500 | 100.000 | 660.000 | 16.500 | 720.000 | 11.500 | 63.819 | .000 | .000 | 1.000 | .000 |
| .000 | 3.000 | 56.000 | 150.000 | 43.000 | 210.000 | 52.000 | .000 | .000 | .150 | .000 | .000 |
| .000 | .010 | 54.000 | 219.000 | 651.000 | 870.000 | .060 | 552.300 | .000 | .000 | 1.000 | .000 |
| .000 | 13.000 | 100.000 | 100.000 | 6.000 | 1879.100 | 2290.200 | .000 | | | | |

PARACHUTE SUSPENSION LINE LOAD AND STRAIN ARRAYS

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PS(8) | .00 | 1000.00 | 2000.00 | 4000.00 | 6000.00 | 10000.00 | 12000.00 | 12900.00 |
| EPL(8) | .0000 | .0230 | .0560 | .0890 | .1090 | .1370 | .1600 | .1600 |

TETHER LINE LOAD AND STRAIN ARRAYS

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PT(8) | .00 | 20000.00 | 35000.00 | 60000.00 | 80000.00 | 120000.00 | 160000.00 | 200[illegible] |
| EPT(8) | .0000 | .0250 | .0500 | .0750 | .0900 | .1100 | .1200 | |

PARACHUTE INFLATION TIME HISTORY ARRAY,TTIP

.0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000

PARACHUTE AERODYNAMIC REF. AREA ARRAY, SSP

.0 .0 .0 .0 .0 .0 .0 .0 .0 .0 .0 .0 .0 .0 .0 .0

TRAJECTORY OF A RIGID BODY WITH 6 D.O.F. CONNECTED TO A RIGID PARACHUTE WITH 5 D.O.F. BY AN ELASTIC TETHER

54-FT. DROGUE DEPLOYMENT

| IXB<br>IYB<br>IZB | IXYB<br>IXZB<br>IYZB | XBAR<br>YBAR<br>ZBAR | S<br>D<br>WEIGHT | CLLP<br>CLMQ<br>CLNR | OPPRIN<br>OPPLOT<br>OPOS | OPSYM<br>OPDA<br>OMETRC | AIPHI<br>AJALPF<br>AKAM | AJALPM | AIPHID<br>AJALPD<br>AKAMD | DTI<br>TTT<br>HHH | EPSI<br>ETAI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 171199.0 | .0 | -2.000 | 116.260 | .000 | 1. | 0. | 2. | | 2. | .0100 | .000086 |
| 8539000.0 | .0 | -.000 | 12.1e7 | .000 | 0. | 0. | 16. | 16. | 8. | 5.0000 | .000610 |
| 8539000.0 | .0 | .000 | 163300.00 | .000 | 1. | 0. | 6.[illegible] | | 2. | 10000.0 | |

| A<br>B<br>C<br>TRO | LTO<br>NT<br>DLTO<br>TR1 | LS<br>NS<br>DP<br>TR2 | AMAX1<br>DSX1<br>WTC<br>TR3 | AMAX2<br>DSX2<br>WTL<br>SPRO | AMAY1<br>DSY1<br>WTP<br>SPR1 | AMAY2<br>DSY2<br>CCRIT<br>SPR2 | AP<br>CHIPE<br>VP<br>SPR3 | GLOAD<br>FSULT<br>AERATO | FREQP<br>POROS<br>TO | OPAM<br>OPDT<br>OPSP | PCT01<br>PCT02<br>PCT03 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 83.800 | 6.500 | 100.000 | 660.000 | 16.500 | 720.000 | 11.500 | 63.819 | 3.000 | 7.234 | 1.000 | .100 |
| .000 | 3.000 | 56.000 | 150.000 | 43.000 | 210.000 | 52.000 | .000 | 3.000 | .100 | 1.000 | .000 |
| .000 | .010 | 54.000 | 219.000 | 651.000 | 870.000 | .060 | 552.300 | 1.000 | .000 | 1.000 | .000 |
| .000 | 13.000 | 100.000 | 100.000 | 8.000 | 1879.100 | 2290.200 | .000 | | | | |

PARACHUTE SUSPENSION LINE LOAD AND STRAIN ARRAYS

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PS(8) | .00 | 1000.00 | 2000.00 | 4000.00 | 6000.00 | 10000.00 | 12000.00 | 12900.00 |
| EPL(8) | .0000 | .0230 | .0560 | .0890 | .1090 | .1370 | .1600 | .1800 |

TETHER LINE LOAD AND STRAIN ARRAYS

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PT(8) | .00 | 20000.00 | 35000.00 | 60000.00 | 80000.00 | 120000.00 | 160000.00 | 200000.00 |
| EPT(8) | .0000 | .0250 | .0500 | .0750 | .0900 | .1100 | .1200 | .1370 |

PARACHUTE INFLATION TIME HISTORY ARRAY,TTIP

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |

PARACHUTE AERODYNAMIC REF. AREA ARRAY, SSP

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

AERODYNAMIC COEFFICIENTS OF FOREBODY

PPHIE (ROLL ANGLE-DEGREES)

.000 360.000

AALPFE (ANGLE OF ATTACK-DEGREES)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | 30.000 | 60.000 | 80.000 | 85.000 | 90.000 | 95.000 | 100.000 | 120.000 | 150.000 | 180.000 | .000 | .000 | .000 | .000 | .000 |

AALPHE (ANGLE OF ATTACK-DEGREES)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | 30.000 | 60.000 | 80.000 | 85.000 | 90.000 | 95.000 | 100.000 | 120.000 | 150.000 | 180.000 | .000 | .000 | .000 | .000 | .000 |

AAM (MACH NUMBER)

.000 .400 .600 .900 1.200 1.960

CA (AXIAL COEF. ARRAY (IPHI,JALPF,KAM))

MACH NO.= .000

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .800 | .750 | -.200 | .200 | .350 | .250 | .050 | -.200 | -1.550 | -2.400 | -.800 | .000 | .000 | .000 | .000 | .000 |
| .800 | .750 | -.200 | .200 | .350 | .250 | .050 | -.200 | -1.550 | -2.400 | -.800 | .000 | .000 | .000 | .000 | .000 |

CA (AXIAL COEF. ARRAY (IPHI,JALPF,KAM))

MACH NO.= .400

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .800 | .750 | -.200 | .200 | .350 | .250 | .050 | -.200 | -1.550 | -2.400 | -.800 | .000 | .000 | .000 | .000 | .000 |
| .800 | .750 | -.200 | .200 | .350 | .250 | .050 | -.200 | -1.550 | -2.400 | -.800 | .000 | .000 | .000 | .000 | .000 |

CA (AXIAL COEF. ARRAY (IPHI,JALPF,KAM))

MACH NO.= .600

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .800 | .750 | -.250 | .300 | .300 | .100 | -.100 | -.350 | -1.450 | -2.500 | -1.350 | .000 | .000 | .000 | .000 | .000 |
| .800 | .750 | -.250 | .300 | .300 | .100 | -.100 | -.350 | -1.450 | -2.500 | -1.350 | .000 | .000 | .000 | .000 | .000 |

CA (AXIAL COEF. ARRAY (IPHI,JALPF,KAM))

MACH NO.= .900

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | .900 | .150 | .600 | .650 | .600 | .400 | .200 | -1.400 | -2.600 | -1.550 | .000 | .000 | .000 | .000 | .000 |
| 1.000 | .900 | .150 | .600 | .650 | .600 | .400 | .200 | -1.400 | -2.600 | -1.550 | .000 | .000 | .000 | .000 | .000 |

CA (AXIAL COEF. ARRAY (IPHI,JALPF,KAM))

MACH NO.= 1.200

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.550 | 1.400 | .500 | .600 | .450 | .250 | .050 | -.200 | -1.500 | -2.850 | -2.100 | .000 | .000 | .000 | .000 | .000 |
| 1.550 | 1.400 | .500 | .600 | .450 | .250 | .050 | -.200 | -1.500 | -2.850 | -2.100 | .000 | .000 | .000 | .000 | .000 |

CA (AXIAL COEF. ARRAY (IPHI,JALPF,KAM))

MACH NO.= 1.960

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.100 | 1.200 | 1.100 | .600 | .450 | .250 | .050 | -.150 | -1.300 | -2.700 | -2.300 | .000 | .000 | .000 | .000 | .000 |
| 1.100 | 1.200 | 1.100 | .600 | .450 | .250 | .050 | -.150 | -1.300 | -2.700 | -2.300 | .000 | .000 | .000 | .000 | .000 |

CN (NORMAL COEF. ARRAY(IPHI,JALPF,KAM))

MACH NO.= .000

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | 3.200 | 7.600 | 5.800 | 5.700 | 5.700 | 5.700 | 5.800 | 8.200 | 3.200 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | 3.200 | 7.600 | 5.800 | 5.700 | 5.700 | 5.700 | 5.800 | 8.200 | 3.200 | .000 | .000 | .000 | .000 | .000 | .000 |

CN (NORMAL COEF. ARRAY(IPHI,JALPF,KAM))

MACH NO.= .400

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | 3.200 | 7.600 | 5.800 | 5.700 | 5.700 | 5.700 | 5.800 | 8.200 | 3.200 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | 3.200 | 7.600 | 5.800 | 5.700 | 5.700 | 5.700 | 5.800 | 8.200 | 3.200 | .000 | .000 | .000 | .000 | .000 | .000 |

CN (NORMAL COEF, ARRAY(IPHI,JALPF,KAM))

MACH NO.= .600

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | 3.500 | 9.600 | 10.800 | 10.800 | 10.700 | 10.600 | 10.500 | 9.500 | 3.600 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | 3.500 | 9.600 | 10.800 | 10.800 | 10.700 | 10.600 | 10.500 | 9.500 | 3.600 | .000 | .000 | .000 | .000 | .000 | .000 |

CN (NORMAL COEF, ARRAY(IPHI,JALPF,KAM))

MACH NO.= .900

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | 4.600 | 19.200 | 17.900 | 18.100 | 18.300 | 17.900 | 17.200 | 13.700 | 4.300 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | 4.600 | 19.200 | 17.900 | 18.100 | 18.300 | 17.900 | 17.200 | 13.700 | 4.300 | .000 | .000 | .000 | .000 | .000 | .000 |

CN (NORMAL COEF, ARRAY(IPHI,JALPF,KAM))

MACH NO.= 1.200

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | 5.800 | 16.500 | 20.400 | 20.800 | 21.000 | 20.700 | 20.300 | 15.900 | 6.000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | 5.800 | 16.500 | 20.400 | 20.800 | 21.000 | 20.700 | 20.300 | 15.900 | 6.000 | .000 | .000 | .000 | .000 | .000 | .000 |

CN (NORMAL COEF, ARRAY(IPHI,JALPF,KAM))

MACH NO.= 1.960

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | 7.200 | 16.100 | 20.200 | 20.600 | 20.800 | 20.500 | 20.000 | 15.700 | 6.100 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | 7.200 | 16.100 | 20.200 | 20.600 | 20.800 | 20.500 | 20.000 | 15.700 | 6.100 | .000 | .000 | .000 | .000 | .000 | .000 |

CLM (PITCH MOM. COEF. ARRAY(IPHI,JALPM,KAM))

MACH NO.= .000

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | 5.100 | 10.000 | 5.700 | 4.300 | 2.500 | .200 | -2.100 | -8.200 | -3.600 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | 5.100 | 10.000 | 5.700 | 4.300 | 2.500 | .200 | -2.100 | -8.200 | -3.600 | .000 | .000 | .000 | .000 | .000 | .000 |

CLM (PITCH MOM. COEF. ARRAY(IPHI,JALPM,KAM))

MACH NO.= .400

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | 5.100 | 10.000 | 5.700 | 4.300 | 2.500 | .200 | -2.100 | -8.200 | -3.600 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | 5.100 | 10.000 | 5.700 | 4.300 | 2.500 | .200 | -2.100 | -8.200 | -3.600 | .000 | .000 | .000 | .000 | .000 | .000 |

CLM (PITCH MOM. COEF. ARRAY(IPHI,JALPM,KAM))

MACH NO.= .600

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | 4.700 | 12.900 | 10.700 | 9.200 | 7.100 | 4.900 | 2.600 | -8.300 | -3.000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | 4.700 | 12.900 | 10.700 | 9.200 | 7.100 | 4.900 | 2.600 | -8.300 | -3.000 | .000 | .000 | .000 | .000 | .000 | .000 |

CLM (PITCH MOM. COEF. ARRAY(IPHI,JALPM,KAM))

MACH NO.= .900

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | 7.600 | 23.100 | 14.000 | 11.200 | 8.200 | 5.300 | .800 | -9.500 | -3.300 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | 7.600 | 23.100 | 14.000 | 11.200 | 8.200 | 5.300 | .800 | -9.500 | -3.300 | .000 | .000 | .000 | .000 | .000 | .000 |

CLM (PITCH MOM. COEF. ARRAY(IPHI,JALPM,KAM))

MACH NO.= 1.200

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | 8.000 | 19.000 | 12.100 | 10.700 | 9.400 | 7.700 | 6.000 | -2.900 | -5.700 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | 8.000 | 19.000 | 12.100 | 10.700 | 9.400 | 7.700 | 6.000 | -2.900 | -5.700 | .000 | .000 | .000 | .000 | .000 | .000 |

CLM (PITCH MOM. COEF. ARRAY(IPHI,JALPM,KAM))

MACH NO.= 1.960

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | 7.400 | 10.800 | 11.400 | 10.600 | 9.600 | 8.400 | 7.000 | 2.800 | -1.300 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | 7.400 | 10.800 | 11.400 | 10.600 | 9.600 | 8.400 | 7.000 | 2.800 | -1.300 | .000 | .000 | .000 | .000 | .000 | .000 |

CY (LATERAL COEF. ARRAY(IPHI,JALPF,KAM))

MACH NO.= .000

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CY (LATERAL COEF. ARRAY(IPHI,JALPF,KAM))

MACH NO.= .400

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CY (LATERAL COEF. ARRAY(IPHI,JALPF,KAM))

MACH NO.= .600

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CY (LATERAL COEF. ARRAY(IPHI,JALPF,KAM))

MACH NO.= .900

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CY (LATERAL COEF. ARRAY(IPHI,JALPF,KAM))

MACH NO.= 1.200

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CY (LATERAL COEF. ARRAY(IPHI,JALPF,KAM))

MACH NO.= 1.960

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CLL (ROLL MOM. COEF. ARRAY(IPHI,JALPH,KAM))

MACH NO.= .000

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CLL (ROLL MOM. COEF. ARRAY(IPHI,JALPH,KAM))

MACH NO.= .400

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CLL (ROLL MOM. COEF. ARRAY(IPHI,JALPH,KAM))

MACH NO.= .600

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .080 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CLL (ROLL MOM. COEF. ARRAY(IPHI,JALPH,KAM))

MACH NO.= .900

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CLL (ROLL MOM. COEF. ARRAY(IPHI,JALPH,KAM))

MACH NO.= 1.200

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CLL (ROLL MOM. COEF. ARRAY(IPHI,JALPH,KAM))

MACH NO.= 1.960

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CLN (YAW MOM. COEF. ARRAY(IPHI,JALPH,KAM))

MACH NO.= .000

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .080 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CLN (YAW MOM. COEF. ARRAY(IPHI,JALPM,KAM))

MACH NO.= .400

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CLN (YAW MOM. COEF. ARRAY(IPHI,JALPM,KAM))

MACH NO.= .600

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CLN (YAW MOM. COEF. ARRAY(IPHI,JALPM,KAM))

MACH NO.= .900

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CLN (YAW MOM. COEF. ARRAY(IPHI,JALPM,KAM))

MACH NO.= 1.200

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

CLN (YAW MOM. COEF. ARRAY(IPHI,JALPM,KAM))

MACH NO.= 1.960

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .080 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

AERODYNAMICS OF PARACHUTE

ANGLE OF ATTACK ARRAY (AALPPE(8))

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| .000 | 10.000 | 40.000 | 90.000 | 140.000 | 170.000 | 180.000 | .000 |

MACH NUMBER ARRAY(AAMP(8)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| .000 | 10.000 | .000 | .000 | .000 | .000 | .000 | .000 |

AXIAL COEFF. ARRAY (CCAP(8,8))

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| .550 | .550 | .000 | .000 | .000 | .000 | .000 | .000 |
| .500 | .500 | .000 | .000 | .000 | .000 | .000 | .000 |
| .300 | .300 | .000 | .000 | .000 | .000 | .000 | .000 |
| .100 | .100 | .000 | .000 | .000 | .000 | .000 | .000 |
| -.300 | -.300 | .000 | .000 | .000 | .000 | .000 | .000 |
| -.500 | -.500 | .000 | .000 | .000 | .000 | .000 | .000 |
| -.550 | -.550 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

NORMAL COEFF. ARRAY (CCNP(8,8))

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .050 | .050 | .000 | .000 | .000 | .000 | .000 | .000 |
| .320 | .320 | .000 | .000 | .000 | .000 | .000 | .000 |
| 1.000 | 1.000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .320 | .320 | .000 | .000 | .000 | .000 | .000 | .000 |
| .050 | .050 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

PITCH MOM. COEFF. ARRAY (CCMP(8,8))

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| -.050 | -.050 | .000 | .000 | .000 | .000 | .000 | .000 |
| -.320 | -.320 | .000 | .000 | .000 | .000 | .000 | .000 |
| -1.000 | -1.000 | .000 | .000 | .000 | .000 | .000 | .000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| -.320 | -.320 | .000 | .000 | .000 | .000 | .000 | .000 |
| -.050 | -.050 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME | X | XD | XDD | FX | CA | V | TENS | XP | XPD | XPDD | FXP | CDAP | CMP |
| TXB | Y | YD | YDD | FY | CN | AM | LT | YP | YPD | YPDD | FYP | CNP | AMP |
| TYB | Z | ZD | ZDD | FZ | CY | DYPR | TPD | ZP | ZPD | ZPDD | FZP | TYPR | DYPRP |
| TZB | PSIE | PSIDE | PSIDDE | QPSI | CLN | ALPE | OMXBE | PSIPE | PSIPDE | PSPDDE | QPSIP | TZPB | ALPPE |
| GAME | THEE | THEDE | THEDDE | QTHE | CLM | PHIIE | OMYBE | THEPE | THEPDE | THPDDE | QTHEP | TPDXB | GAMPE |
| CHIE | PHIE | PHIDE | PHIDDE | QPHI | CLL | PHIAE | OMZBE | KS | CLLP | CLMU | CLNR | TPDRB | PULAN |
| MPAL | MPAS | DMD | QMAXPB | IXPB | IYPB | SPD | SP | SPRU | SPRL | TINT | TNINY | TFI | XPBDI |
| .0000 | 0. | 48.162 | -4.320 | -21711. | .152 | 552.60 | 228. | 77. | 48.14 | -2.45 | -77. | 4.400 | .000 |
| 0. | 0. | .000 | .000 | 0. | 8.970 | .531 | 6.510 | 0. | .00 | .00 | 0. | .000 | .531 |
| -1559374. | 19000. | -550.497 | 9.274 | 44601. | .000 | 200.12 | 119. | 19077. | -550.20 | -4.08 | 8. | 8. | 199.91 |
| 0. | .000 | .000 | .000 | 0. | .000 | 90.000 | .000 | .000 | .000 | .000 | 0. | 0. | .000 |
| -85.000 | 5.000 | 1.000 | 13.364 | 1559374. | 5.509 | .000 | -1.000 | 275.008 | .000 | -.000 | 0. | 0. | -85.000 |
| .000 | .000 | .000 | .000 | 0. | .000 | .000 | .000 | 22842. | .000 | .000 | .000 | 119. | 90. |
| .0 | .0 | .00 | .0 | 12.3 | 29878.0 | .0 | 8.00 | .00 | .00 | .00000 | .00000 | .00000 | 552.30 |
| .0100 | 0. | 48.119 | -4.322 | -21729. | .151 | 552.50 | 0. | 78. | 48.11 | -3.25 | -88. | 4.755 | .000 |
| 0. | 0. | .000 | .000 | 0. | 8.968 | .531 | 6.497 | 0. | .00 | .00 | 0. | .000 | .530 |
| -1556639. | 18994. | -550.405 | 9.228 | 44500. | .000 | 200.09 | 0. | 19072. | -550.17 | 5.03 | 136. | -0. | 199.92 |
| 0. | .000 | .000 | .000 | 0. | .000 | 90.014 | .000 | .000 | .000 | .000 | 0. | 0. | .003 |
| -85.004 | 5.011 | 1.133 | 13.276 | 1556639. | 5.500 | .000 | -1.133 | 275.000 | .000 | .000 | 0. | 0. | -85.003 |
| .000 | .000 | .000 | .000 | 0. | .000 | .000 | .000 | 22842. | .000 | .000 | .000 | 0. | 180. |
| .0 | .0 | .10 | 57.5 | 13.3 | 29908.7 | 129.2 | 8.65 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .0200 | 1. | 48.076 | -4.326 | -21750. | .151 | 552.41 | 0. | 78. | 48.07 | -4.16 | -112. | 5.821 | .000 |
| 0. | 0. | .000 | .000 | 0. | 8.965 | .531 | 6.482 | 0. | .00 | .00 | 0. | .000 | .530 |
| -1553739. | 18989. | -550.313 | 9.207 | 44398. | .000 | 200.06 | 0. | 19066. | -550.08 | 15.41 | 417. | -1. | 199.89 |
| 0. | .000 | .000 | .000 | 0. | .000 | 90.030 | .000 | .000 | .000 | .000 | 0. | 0. | .006 |
| -85.007 | 5.023 | 1.265 | 13.255 | 1553739. | 5.491 | .000 | -1.265 | 275.000 | .000 | .001 | 1. | 0. | -85.006 |
| .000 | .000 | .000 | .000 | 0. | .000 | .000 | .000 | 22842. | .000 | .000 | .000 | 0. | 180. |
| .0 | .0 | .23 | 126.7 | 16.3 | 29938.8 | 258.5 | 10.58 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .0300 | 1. | 46.033 | -4.331 | -21775. | .190 | 552.31 | 0. | 79. | 48.02 | -5.58 | -151. | 7.598 | .000 |
| 0. | 0. | .000 | .000 | 0. | 8.962 | .531 | 6.465 | 0. | .00 | .00 | 0. | .000 | .530 |
| -1550674. | 18983. | -550.221 | 9.186 | 44296. | .000 | 200.03 | 0. | 19061. | -549.85 | 31.73 | 858. | -1. | 199.76 |
| 0. | .000 | .000 | .000 | 0. | .000 | 90.047 | .000 | .000 | .000 | .000 | 0. | 0. | .009 |
| -85.011 | 5.036 | 1.398 | 13.233 | 1550674. | 5.481 | .000 | -1.398 | 275.000 | .000 | .002 | 1. | 0. | -85.009 |
| .000 | .000 | .000 | .000 | 0. | .000 | .000 | .000 | 22842. | .000 | .000 | .000 | 0. | 180. |
| .0 | .0 | .39 | 215.7 | 21.3 | 29984.6 | 387.7 | 13.82 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .0400 | 2. | 47.989 | -4.337 | -21804. | .190 | 552.22 | 0. | 79. | 47.96 | -7.53 | -204. | 10.085 | .000 |
| 0. | 0. | .000 | .000 | 0. | 8.959 | .530 | 6.449 | 0. | .00 | .00 | 0. | .000 | .530 |
| -1547443. | 18978. | -550.129 | 9.165 | 44194. | .000 | 200.00 | 0. | 19055. | -549.42 | 54.08 | 1463. | -2. | 199.48 |
| 0. | .000 | .000 | .000 | 0. | .000 | 90.065 | .000 | .000 | .000 | .000 | 0. | 0. | .012 |
| -85.015 | 5.051 | 1.530 | 13.210 | 1547443. | 5.470 | .000 | -1.530 | 275.000 | .000 | .003 | 2. | 0. | -85.012 |
| .000 | .000 | .000 | .000 | 0. | .000 | .000 | .000 | 22842. | .000 | .000 | .000 | 0. | 180. |
| .0 | .0 | .60 | 328.9 | 28.3 | 30040.2 | 516.9 | 18.34 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .0500 | 2. | 47.946 | -4.344 | -21836. | .189 | 552.12 | 0. | 80. | 47.87 | -10.01 | -271. | 13.283 | .000 |
| 0. | 0. | .000 | .000 | 0. | 8.956 | .530 | 6.435 | 0. | .00 | .00 | 0. | .000 | .529 |
| -1544047. | 18972. | -550.037 | 9.144 | 44091. | .000 | 199.96 | 0. | 19050. | -548.74 | 82.46 | 2232. | -3. | 199.03 |
| 0. | .000 | .000 | .000 | 0. | .000 | 90.085 | .000 | .000 | .000 | .000 | 0. | 0. | .015 |
| -85.018 | 5.067 | 1.662 | 13.186 | 1544047. | 5.459 | .000 | -1.662 | 275.000 | .000 | .005 | 3. | 0. | -85.015 |
| .000 | .000 | .000 | .000 | 0. | .000 | .000 | .000 | 22842. | .000 | .000 | .000 | 0. | 180. |
| .0 | .0 | .85 | 468.2 | 37.2 | 30104.6 | 646.2 | 24.15 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |

| TIME | X | XD | XDD | FX | CA | V | TENS | XP | XPD | XPDD | FXP | CDAP | CMP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TXB | Y | YD | YDD | FY | CN | AM | LT | YP | YPD | YPDD | FYP | CNP | AMP |
| TYB | Z | ZD | ZDD | FZ | CY | DYPR | TPD | ZP | ZPD | ZPDD | FZP | TYPB | DYPRP |
| TZB | PSIE | PSIDE | PSIDDE | QPSI | CLN | ALPE | OMXBE | PSIPE | PSIPDE | PSPDDE | QPSIP | TZPR | ALPPE |
| GAME | THEE | THEDE | THEDDE | QTHE | CLM | PHIIE | OMYBE | THEPE | THEPDE | THPDDE | QTHEP | TPDXB | GAMPE |
| CHIE | PHIE | PHIDE | PHIDDE | QPHI | CLL | PHIAE | OMZBE | KS | CLLP | CLMQ | CLNR | TPDRB | PULAN |
| MPAL | MPAS | DMD | QMAXPB | IXPB | IYPB | SPD | SP | SPRU | SPRL | TINT | TNINY | TFI | XPBDI |
| .4200 | 20. | 45.878 | -7.825 | -27309. | .049 | 545.28 | 113529. | 96. | 41.38 | -13.98 | -10339. | 631.144 | .000 |
| 0. | 0. | .000 | .000 | 0. | 8.749 | .523 | 12.471 | 0. | .00 | .00 | 0. | .000 | .469 |
| -1145181. | 18770. | -543.346 | 32.453 | 34862. | .000 | 196.37 | 116745. | 18857. | -487.00 | 120.36 | 120362. | -2364. | 157.77 |
| 0. | .000 | .000 | .000 | 0. | .000 | 92.710 | .000 | .000 | .000 | .000 | 0. | 0. | .031 |
| -85.174 | 7.536 | 15.705 | 77.686 | 1145181. | 4.123 | .000 | -15.705 | 274.888 | -1.108 | -6.814 | 2364. | 5494. | -85.143 |
| .000 | .000 | .000 | .000 | 0. | .000 | .000 | .000 | 19014. | .000 | .000 | .000 | 116616. | 87. |
| 6.5 | 2.6 | 45.21 | 22097.3 | 1768.5 | 37907.0 | 5427.9 | 1147.86 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .4300 | 20. | 45.799 | -8.117 | -27659. | .043 | 544.94 | 124111. | 97. | 41.31 | -1.42 | -10798. | 661.388 | .000 |
| 0. | 0. | .000 | .000 | 0. | 8.739 | .523 | 12.803 | 0. | .00 | .00 | 0. | .000 | .469 |
| -1121099. | 18765. | -543.011 | 34.627 | 34358. | .000 | 196.16 | 127302. | 18852. | -486.56 | -26.00 | 125964. | -2538. | 157.51 |
| 0. | .000 | .000 | .000 | 0. | .000 | 92.876 | .000 | .000 | .000 | .000 | 0. | 0. | .024 |
| -85.179 | 7.697 | 16.512 | 83.593 | 1121099. | 4.041 | .000 | -16.512 | 274.877 | -1.173 | -6.216 | 8538. | 6363. | -85.147 |
| .000 | .000 | .000 | .000 | 0. | .000 | .000 | .000 | 19692. | .000 | .000 | .000 | 127143. | 87. |
| 6.9 | 2.8 | 47.34 | 23116.0 | 1853.1 | 38360.0 | 5557.1 | 1202.78 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .4400 | 21. | 45.716 | -8.400 | -28024. | .036 | 544.58 | 134125. | 97. | 41.34 | 7.03 | -11317. | 692.350 | .000 |
| 0. | 0. | .000 | .000 | 0. | 8.728 | .523 | 13.116 | 0. | .00 | .00 | 0. | .000 | .469 |
| -1095795. | 18759. | -542.654 | 36.639 | 33821. | .000 | 195.93 | 137143. | 18847. | -487.37 | -126.36 | 132299. | -2710. | 158.06 |
| 0. | .000 | .000 | .000 | 0. | .000 | 93.051 | .000 | .000 | .000 | .000 | 0. | 0. | .016 |
| -85.184 | 7.867 | 17.375 | 89.076 | 1095795. | 3.954 | .000 | -17.375 | 274.864 | -1.234 | -5.921 | 2710. | 7284. | -85.151 |
| .000 | .000 | .000 | .000 | 0. | .000 | .000 | .000 | 20272. | .000 | .000 | .000 | 136950. | 87. |
| 7.4 | 2.9 | 49.51 | 24217.8 | 1939.7 | 38832.1 | 5686.4 | 1259.00 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .4500 | 21. | 45.631 | -8.667 | -28405. | .029 | 544.20 | 143220. | 98. | 41.44 | 11.10 | -11882. | 724.029 | .000 |
| 0. | 0. | .000 | .000 | 0. | 8.716 | .522 | 13.401 | 0. | .00 | .00 | 0. | .000 | .471 |
| -1069230. | 18754. | -542.279 | 38.423 | 33255. | .000 | 195.69 | 145961. | 18842. | -488.93 | -178.32 | 139207. | -2890. | 159.10 |
| 0. | .000 | .000 | .000 | 0. | .000 | 93.235 | .000 | .000 | .000 | .000 | 0. | 0. | .008 |
| -85.190 | 8.045 | 18.291 | 93.956 | 1069230. | 3.863 | .000 | -18.291 | 274.852 | -1.294 | -6.171 | 2890. | 8240. | -85.156 |
| .000 | .000 | .000 | .000 | 0. | .000 | .000 | .000 | 20752. | .000 | .000 | .000 | 145728. | 87. |
| 7.9 | 3.1 | 51.74 | 25386.3 | 2028.3 | 39323.8 | 5815.6 | 1316.51 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .4600 | 22. | 45.543 | -8.916 | -28804. | .021 | 543.80 | 151200. | [illegible] | 41.55 | 11.08 | -12474. | 756.418 | .000 |
| 0. | 0. | .000 | .000 | 0. | 8.704 | .522 | 13.651 | 0. | .00 | -.00 | -0. | .000 | .473 |
| -1041376. | 18748. | -541.887 | 39.948 | 32663. | .000 | 195.44 | 153608. | 18837. | -490.78 | -185.40 | 146485. | 3137. | 160.33 |
| 0. | .000 | .000 | .000 | 0. | .000 | 93.429 | .000 | .000 | -.000 | .000 | 0. | -0. | .000 |
| -85.196 | 8.233 | 19.252 | 98.149 | 1041376. | 3.767 | .000 | -19.252 | 274.839 | -1.374 | -16.085 | -3137. | 9220. | -85.161 |
| .000 | .000 | .000 | .000 | 0. | .000 | .000 | .000 | 21143. | .000 | .000 | .000 | 153331. | 87. |
| 8.5 | 3.4 | 54.01 | 26601.1 | 2118.9 | 39835.8 | 5944.8 | 1375.31 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .4700 | 22. | 45.452 | -9.148 | -29221. | .014 | 543.39 | 158017. | 98. | 41.65 | 8.08 | -13073. | 789.406 | .000 |
| 0. | -0. | .000 | -.000 | -0. | 8.692 | .521 | 13.865 | -0. | .00 | -.00 | -0. | .000 | .474 |
| -1012217. | 18743. | -541.481 | 41.213 | 32047. | .000 | 195.18 | 160081. | 18833. | -492.51 | -155.75 | 153906. | 3796. | 161.49 |
| -0. | .000 | -.000 | .000 | 0. | -.000 | 93.632 | .000 | .000 | -.000 | .000 | 0. | -0. | .009 |
| -85.202 | 8.430 | 20.252 | 101.653 | 1012217. | 3.666 | -.000 | -20.252 | 274.824 | -1.545 | -18.043 | -3796. | 10212. | -85.167 |
| .000 | .000 | -.000 | .000 | 0. | .000 | .000 | .000 | 21456. | .000 | .000 | .000 | 159755. | 86. |
| 9.0 | 3.6 | 56.33 | 27841.4 | 2211.5 | 40368.4 | 6078.1 | 1435.41 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |

| TIME | X | XD | XDD | FX | CA | V | TENS | XP | XPD | XPDD | FXP | COAP | CMP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TZB | Y | YD | YDD | FY | CN | AM | LT | YP | YPD | YPDD | FYP | CNP | AMP |
| TYB | Z | ZD | ZDD | FZ | CY | DYPR | TPD | ZP | ZPD | ZPDD | FZP | TYPB | DYPRP |
| TZB | PSIE | PSIDE | PSIDDE | QPSI | CLN | ALPE | OMXBE | PSIPE | PSIPDE | PSPDDE | QPSIP | TZPB | ALPPE |
| GAME | THEE | THEDE | THEDDE | QTHE | CLM | PHIIE | OMYBE | THEPE | THEPDE | THPDDE | QTHEP | TPDXB | GAMPE |
| CHIE | PHIE | PHIDE | PHIDDE | QPHI | CLL | PHIAE | OMZBE | KS | CLLP | CLMQ | CLNR | TPORB | PULAN |
| MPAL | MPAS | DMD | QMAXPB | IXPB | IYPB | SPD | SP | SARU | SPRL | TINT | THINY | TFI | XPBDI |
| .4800 | 23. | 45.360 | -9.366 | -29659. | .005 | 542.96 | 163744. | 99. | 41.70 | 2.99 | -13662. | 823.088 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.679 | .521 | 14.044 | -0. | .00 | -.00 | -0. | .000 | .476 |
| -981742. | 18737. | -541.063 | 42.244 | 31411. | .000 | 194.97 | 165492. | 18828. | -493.81 | -99.06 | 161289. | 4562. | 162.37 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 93.846 | .000 | .000 | -.000 | .000 | 0. | -0. | .020 |
| -85.208 | 8.638 | 21.283 | 104.532 | 981742. | 3.561 | -.000 | -21.283 | 274.808 | -1.733 | -19.466 | -4562. | 11209. | -85.173 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 21706. | .000 | .000 | .000 | 165112. | 86. |
| 9.6 | 3.8 | 58.70 | 29087.6 | 2306.1 | 40922.4 | 6203.3 | 1496.79 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .4900 | 23. | 45.265 | -9.573 | -30116. | -.003 | 542.53 | 168541. | 99. | 41.70 | -3.24 | -14228. | 857.462 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.666 | .521 | 14.193 | -0. | .00 | -.00 | -0. | .000 | .476 |
| -949945. | 18732. | -540.637 | 43.080 | 30754. | .000 | 194.64 | 170030. | 18823. | -494.44 | -26.28 | 168465. | 5430. | 162.81 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 94.070 | .000 | .000 | -.000 | .000 | 0. | -0. | .032 |
| -85.214 | 8.856 | 22.341 | 106.894 | 949945. | 3.450 | -.000 | -22.341 | 274.789 | -1.933 | -20.300 | -5430. | 12216. | -85.199 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 21907. | .000 | .000 | .000 | 169590. | 86. |
| 10.2 | 4.0 | 61.11 | 30323.6 | 2402.6 | 41498.2 | 6332.5 | 1559.47 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .5000 | 23. | 45.168 | -9.775 | -30594. | -.012 | 542.09 | 172625. | 100. | 41.64 | -9.81 | -14759. | 892.521 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.652 | .520 | 14.321 | -0. | .00 | -.00 | -0. | .000 | .476 |
| -916819. | 18727. | -540.202 | 43.774 | 30086. | .000 | 194.36 | 173927. | 18818. | -494.31 | 52.38 | 175314. | 6391. | 162.75 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 94.305 | .000 | .000 | -.000 | .000 | 0. | -0. | .056 |
| -85.220 | 9.085 | 23.420 | 108.675 | 916819. | 3.335 | -.000 | -23.420 | 274.769 | -2.138 | -20.640 | -6391. | 13246. | -85.185 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 22072. | .000 | .000 | .000 | 173422. | 84. |
| 10.8 | 4.3 | 63.58 | 31537.7 | 2501.2 | 42096.5 | 6461.8 | 1623.44 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .5100 | 24. | 45.070 | -9.974 | -31093. | -.022 | 541.64 | 176235. | 100. | 41.51 | -16.07 | -15250. | 928.264 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.638 | .520 | 14.433 | -0. | .00 | -.00 | -0. | .000 | .475 |
| -882359. | 18721. | -539.761 | 44.379 | 29401. | .000 | 194.07 | 177429. | 18813. | -493.40 | 128.37 | 181768. | 7436. | 162.18 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 94.551 | .000 | .000 | -.000 | .000 | 0. | -0. | .062 |
| -85.227 | 9.324 | 24.517 | 110.613 | 882359. | 3.214 | -.000 | -24.517 | 274.747 | -2.344 | -20.648 | -7436. | 143.4. | -85.191 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 22214. | .000 | .000 | .000 | 176850. | 85. |
| 11.5 | 4.6 | 66.09 | 32723.3 | 2601.7 | 42717.7 | 6591.0 | 1688.71 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .5200 | 24. | 44.967 | -10.176 | -31613. | -.032 | 541.15 | 179603. | 101. | 41.32 | -21.62 | -15700. | 964.688 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.624 | .519 | 14.538 | -0. | .00 | -.00 | -0. | .000 | .479 |
| -846557. | 18716. | -539.315 | 44.943 | 28702. | .000 | 193.78 | 180762. | 18808. | -491.77 | 195.40 | 187809. | 8559. | 161.14 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 94.809 | .000 | .000 | -.000 | .000 | 0. | -0. | .081 |
| -85.234 | 9.575 | 25.632 | 112.241 | 846557. | 3.088 | -.000 | -25.632 | 274.722 | -2.550 | -20.574 | -8559. | 15441. | -85.197 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 22344. | .000 | .000 | .000 | 180102. | 85. |
| 12.1 | 4.8 | 68.65 | 33878.5 | 2704.3 | 43362.5 | 6720.2 | 1755.26 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .5300 | 25. | 44.866 | -10.381 | -32140. | -.043 | 540.73 | 182932. | 101. | 41.08 | -26.22 | -16109. | 1001.790 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.611 | .519 | 14.642 | -0. | .00 | -.00 | -0. | .001 | .471 |
| -809148. | 18710. | -538.862 | 45.512 | 28005. | .000 | 193.49 | 184123. | 18803. | -489.54 | 249.55 | 193461. | 9760. | 159.70 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 95.078 | .000 | .000 | -.000 | .000 | 0. | -0. | .101 |
| -85.240 | 9.837 | 26.762 | 113.867 | 809148. | 2.956 | -.000 | -26.762 | 274.696 | -2.756 | -20.691 | -9760. | 16648. | -85.203 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 22460. | .000 | .000 | .000 | 183369. | 85. |
| 12.8 | 5.1 | 71.26 | 35005.4 | 2808.8 | 44031.4 | 6849.5 | 1823.11 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |

| TIME | X | XD | XDD | FX | CA | V | TENS | XP | XPD | XPDD | FXP | CDAP | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TXB | Y | YD | YDD | FY | CN | AM | LT | YP | YPD | YPDD | FYP | CNP | AMP |
| TYB | Z | ZD | ZDD | FZ | CY | DYPR | TPD | ZP | ZPD | ZPDD | FZP | TYPB | DYPRP |
| TZB | PSIL | PSIDE | PSIDDE | QPSI | CLN | ALPE | OMXBE | PSIPE | PSIPDE | PSPDDE | QPSIP | TZPB | ALPPE |
| GAME | THEE | THEDE | THEDDE | QTHE | CLM | PHIIE | OMYBE | THEPE | THEPDE | THPDDE | QTHE' | TPDXB | GAMPE |
| CHIE | PHIE | PHIDE | PHIDDE | QPHI | CLL | PHIAE | OMZBE | KS | CLLP | CLMQ | CLNR | TPDRB | PULAN |
| HPAL | HPAS | DMD | QMAXPB | IXPB | I PB | SPD | SP | SPRU | SPRL | TINT | TNINY | TFI | XPBDI |
| .5400 | 25. | 44.761 | -10.585 | -32649. | -.057 | 540.26 | 186387. | 101. | 40.80 | -29.56 | -16473. | 1039.559 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.598 | .518 | 14.749 | -0. | .00 | -.00 | -0. | .001 | .469 |
| -769719. | 18705. | -538.404 | 46.123 | 27339. | .000 | 193.19 | 187661. | 18798. | -486.84 | 286.07 | 198659. | 11096. | 157.97 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 95.358 | .000 | .000 | -.000 | .000 | 0. | -0. | .123 |
| -85.248 | 10.110 | 27.909 | 115.574 | 769719. | 2.817 | -.000 | -27.909 | 274.6674 | -2.966 | -21.234 | -11096. | 17954. | -85.210 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 22594. | .000 | .000 | .000 | 186800. | 85. |
| 13.6 | 5.4 | 73.65 | 35983.2 | 2915.3 | 44724.8 | 6954.3 | 1892.23 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .5500 | 26. | 44.654 | -10.798 | -33178. | -.071 | 539.79 | 190070. | 102. | 40.50 | -30.96 | -16763. | 1077.531 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.586 | .518 | 14.869 | -0. | .00 | -.00 | -0. | .001 | .466 |
| -728879. | 18700. | -537.940 | 46.785 | 26662. | .000 | 192.89 | 191451. | 18793. | -483.92 | 295.58 | 203051. | 12431. | 156.11 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 95.650 | .000 | .000 | -.000 | .000 | 0. | -0. | .147 |
| -85.255 | 10.395 | 29.074 | 117.408 | 728879. | 2.671 | -.000 | -29.074 | 274.636 | -3.183 | -22.372 | -12431. | 19376. | -85.217 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 22724. | .000 | .000 | .000 | 190468. | 84. |
| 14.3 | 5.7 | 74.94 | 36393.7 | 3022.4 | 45434.6 | 6954.3 | 1961.77 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .5600 | 26. | 44.545 | -11.019 | -33726. | -.086 | 539.31 | 194009. | 102. | 40.18 | -31.74 | -17028. | 1115.474 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.574 | .617 | 14.987 | -0. | .00 | -.00 | -0. | .001 | .463 |
| -686607. | 18694. | -537.468 | 47.499 | 25972. | .000 | 192.58 | 195500. | 18788. | -480.96 | 294.18 | 207261. | 13934. | 154.23 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 95.954 | .000 | .000 | -.000 | .000 | 0. | -0. | .172 |
| -85.262 | 10.692 | 30.258 | 119.371 | 686607. | 2.521 | -.000 | -30.258 | 274.603 | -3.415 | -24.191 | -13934. | 20922. | -85.224 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 22860. | .000 | .000 | .000 | 194377. | 84. |
| 15.1 | 6.0 | 76.21 | 36782.6 | 3129.6 | 46156.4 | 6954.3 | 2031.32 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .5700 | 27. | 44.434 | -11.244 | -34294. | -.101 | 538.82 | 198155. | 103. | 40.00 | 45.76 | -13940. | 1115.348 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.561 | .517 | 15.117 | -0. | .00 | -.00 | -0. | .001 | .462 |
| -642887. | 18689. | -536.990 | 48.206 | 25268. | .000 | 192.27 | 199536. | 18784. | -479.75 | -692.20 | 169743. | 15124. | 153.48 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 96.270 | .000 | .000 | -.000 | .000 | 0. | -0. | .198 |
| -85.270 | 11.001 | 31.462 | 121.307 | 642887. | 2.364 | -.000 | -31.462 | 274.568 | -3.669 | -26.910 | -15124. | 22571. | -85.234 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 22995. | .000 | .000 | .000 | 198255. | 84. |
| 15.1 | 6.0 | -76.23 | .0 | 3129.9 | 46160.9 | -6954.3 | 2031.56 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .5800 | 27. | 44.321 | -11.414 | -34882. | -.117 | 538.33 | 200315. | 103. | 40.47 | 48.12 | -13795. | 1076.945 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.548 | .516 | 15.187 | -0. | .00 | -.00 | -0. | .001 | .469 |
| -597733. | 18684. | -536.507 | 48.268 | 24556. | .000 | 191.95 | 200600. | 18779. | -487.02 | -750.37 | 168932. | 16147. | 158.19 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 96.599 | .000 | .000 | -.000 | .000 | 0. | -0. | .221 |
| -85.278 | 11.321 | 32.677 | 121.519 | 597733. | 2.201 | -.000 | -32.677 | 274.530 | -3.956 | -30.489 | -16147. | 23971. | -85.250 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 23062. | .000 | .000 | .000 | 199163. | 83. |
| 14.3 | 5.7 | -74.97 | .0 | 3022.8 | 45442.7 | -6954.3 | 1962.02 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .5900 | 27. | 44.206 | -11.528 | -35491. | -.134 | 537.85 | 199456. | 103. | 40.94 | 44.81 | -13633. | 1038.552 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.535 | .516 | 15.160 | -0. | .00 | -.00 | -0. | .001 | .476 |
| -551209. | 18678. | -536.027 | 47.661 | 23843. | .000 | 191.64 | 198581. | 18774. | -494.52 | -738.12 | 167987. | 17249. | 163.12 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 96.940 | .000 | .000 | -.000 | .000 | 0. | -0. | .249 |
| -85.286 | 11.654 | 33.886 | 119.947 | 551209. | 2.033 | -.000 | -33.886 | 274.489 | -4.280 | -34.301 | -17248. | 25052. | -85.267 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 23031. | .000 | .000 | .000 | 196995. | 83. |
| 13.6 | 5.4 | -73.72 | .0 | 2915.7 | 44736.2 | -6954.3 | 1892.47 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME | X | XD | XDD | FX | CA | V | TENS | XP | XPD | XPDD | FXP | COAP | CMP |
| TXA | Y | YD | YDD | FY | CN | AM | LT | YP | YPD | YPDD | FYP | CNP | AMP |
| TYB | Z | ZD | ZDD | FZ | CY | DYPR | TPO | ZP | ZPD | ZPDD | FZP | TYPB | DYPRP |
| TZB | PSIE | PSIDE | PSIDDE | QPSI | CLN | ALPE | OMXBE | PSIPE | PSIPDE | PSPDDE | QPSIP | TZPA | ALPPE |
| GAME | THEE | THEDE | THEDDE | QTHE | CLM | PHIIE | OMYBE | THEPE | THEPDE | THPDDE | QTHEP | TPDXA | GAMPE |
| CHIE | PHIE | PHIDE | PHIDDE | QPHI | CLL | PHIAE | OMZBE | KS | CLLP | CLMQ | CLNR | TPDRB | PULAN |
| MPAL | MPAS | DMC | QMAXPB | IXPB | IYPB | SPD | SP | SPRU | SPNL | TINT | TNINY | TFI | XPBDI |
| .6000 | 28. | 44.090 | -11.592 | -36123. | -.151 | 537.37 | 195616. | 104. | 41.31 | 27.38 | -13801. | 1030.975 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.523 | .516 | 15.040 | -0. | .00 | -.00 | -0. | .001 | .482 |
| -503392. | 18673. | -535.556 | 46.445 | 23136. | .000 | 191.33 | 193740. | 18769. | -501.05 | -541.47 | 171240. | 18943. | 167.47 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 97.293 | .000 | .000 | -.000 | .000 | 0. | -0. | .269 |
| -85.294 | 11.999 | 35.071 | 116.745 | 503393. | 1.860 | -.000 | -35.071 | 274.444 | -4.640 | -37.691 | -18943. | 25783. | -85.287 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 22907. | .000 | .000 | .000 | 192017. | 82. |
| 13.5 | 5.3 | .00 | .0 | 2895.1 | 44603.1 | .0 | 1879.10 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .6100 | 28. | 43.974 | -11.619 | -36777. | -.169 | 536.90 | 189307. | 104. | 41.48 | 6.94 | -13930. | 1030.707 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.511 | .515 | 14.844 | -0. | .00 | -.00 | -0. | .001 | .486 |
| -454367. | 18667. | -535.099 | 44.776 | 22443. | .000 | 191.04 | 186798. | 18764. | -505.25 | -299.57 | 174126. | 20846. | 170.32 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 97.657 | .000 | .000 | -.000 | .000 | 0. | -0. | .298 |
| -85.302 | 12.355 | 36.217 | 112.330 | 454367. | 1.681 | -.000 | -36.217 | 274.396 | -5.032 | -40.526 | -20846. | 26201. | -85.307 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 22698. | .000 | .000 | .000 | 184951. | 82. |
| 13.5 | 5.3 | .00 | .0 | 2895.1 | 44604.8 | .0 | 1879.10 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .6200 | 29. | 43.858 | -11.624 | -37453. | -.188 | 536.46 | 181559. | 105. | 41.45 | -12.29 | -13919. | 1030.402 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.499 | .515 | 14.598 | -0. | .00 | -.00 | -0. | .002 | .488 |
| -404213. | 18662. | -534.661 | 42.829 | 21768. | .000 | 190.75 | 178552. | 18759. | -507.07 | -66.30 | 175364. | 22799. | 171.56 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 98.038 | .000 | .000 | -.000 | .000 | 0. | -0. | .330 |
| -85.311 | 12.723 | 37.315 | 107.163 | 404213. | 1.498 | -.000 | -37.315 | 274.343 | -5.449 | -42.724 | -22799. | 26371. | -85.326 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 22421. | .000 | .000 | .000 | 176594. | 82. |
| 13.5 | 5.3 | .00 | .0 | 2895.1 | 44606.6 | .0 | 1879.10 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .6300 | 29. | 43.742 | -11.622 | -38152. | -.207 | 536.03 | 172933. | 105. | 41.24 | -29.08 | -13779. | 1030.055 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.488 | .514 | 14.326 | -0. | .00 | -.00 | -0. | .002 | .488 |
| -353003. | 18657. | -534.243 | 40.766 | 21112. | .000 | 190.48 | 169753. | 18754. | -506.66 | 142.36 | 175053. | 24766. | 171.31 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 98.421 | .000 | .000 | -.000 | .000 | 0. | -0. | .367 |
| -85.319 | 13.102 | 38.359 | 101.675 | 353003. | 1.310 | -.000 | -38.359 | 274.287 | -5.884 | -44.246 | -24766. | 26371. | -85.346 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 22094. | .000 | .000 | .000 | 167692. | 81. |
| 13.5 | 5.3 | .00 | .0 | 2895.1 | 44608.3 | .0 | 1879.10 | 1879.10 | 8.00 | .00000 | 00000 | .53811 | 552.30 |
| .6400 | 30. | 43.625 | -11.625 | -38871. | -.226 | 535.63 | 164118. | 105. | 40.88 | -42.71 | -13530. | 1029.665 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.478 | .514 | 14.050 | -0. | .00 | -.00 | -0. | .002 | .485 |
| -300801. | 18651. | -533.846 | 38.728 | 20476. | .000 | 190.23 | 161058. | 18749. | -504.34 | 315.55 | 173410. | 26716. | 169.77 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 98.918 | .000 | .000 | -.000 | .000 | 0. | -0. | .409 |
| -85.328 | 13.490 | 39.349 | 96.243 | 300801. | 1.118 | -.000 | -39.349 | 274.226 | -6.331 | -45.137 | -26716. | 26289. | -85.366 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 21738. | .000 | .000 | .000 | 158898. | 81. |
| 13.5 | 5.3 | .00 | .0 | 2895.1 | 44610.1 | .0 | 1879.10 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |
| .6500 | 30. | 43.509 | -11.642 | -39611. | -.246 | 535.24 | 155738. | 104. | 40.40 | -52.86 | -13197. | 1029.229 | .000 |
| 0. | 0. | .000 | -.000 | -0. | 8.467 | .513 | 13.788 | -0. | .00 | -.00 | -0. | .002 | .482 |
| -247662. | 18646. | -533.468 | 36.831 | 19859. | .000 | 189.99 | 153001. | 18744. | -500.49 | 447.16 | 170718. | 28627. | 167.20 |
| -0. | -.000 | -.000 | .000 | 0. | .000 | 99.226 | .000 | .000 | -.000 | .000 | 0. | -0. | .455 |
| -85.337 | 13.888 | 40.285 | 91.171 | 247662. | .922 | -.000 | -40.285 | 274.160 | -6.785 | -45.610 | -28627. | 26210. | -85.385 |
| .000 | -.000 | -.000 | .000 | 0. | .000 | .000 | .000 | 21376. | .000 | .000 | .000 | 150740. | 80. |
| 13.5 | 5.4 | .00 | .0 | 2895.1 | 44611.8 | .0 | 1879.10 | 1879.10 | 8.00 | .00000 | .00000 | .53811 | 552.30 |

REFERENCES

1) Goldstein, H., Classical Mechanics, Addison-Wesley Publishing Company Inc., Seventh Printing, 1960.

2) Wells, Dave A., Lagrangian Dynamics, Schaum Publishing Company, N.Y., N.Y., 1967.

3) Korn, G. A., Mathematical Handbook for Scientists and Engineers, McGraw-Hill Inc., 1961.

4) Doyle, G. R., Jr., Three Dimensional Dynamics of Two Bodies Connected by an Elastic Tether - Six Degrees of Freedom Forebody and Five Degrees of Freedom Decelerator, GER-15957, July 1973.