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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

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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.

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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 descri, ,ion 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})		

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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	α	Angle-of-attack of the forebody		deg
ALPPE	α_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)		

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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_γ	$\cos(\gamma)$		
CGAMP	C_{γ_p}	$\cos(\gamma_p)$		
CHIE	χ	Flight path angle of forebody in horizontal plane, measured from X axis toward Y axis		deg
CHIPE	χ_p	Flight path angle of decelerator in horizontal plane, measured from X axis toward Y axis		deg
CLL	C_ℓ	Rolling moment coefficient of the forebody		
CLLP	C_{ℓ_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 (ϕ)		
CPHII	$C\phi_i$	Cos (ϕ_i)		
CPHIPI	$C\phi_{pi}$	Cos (ϕ_{pi})		
CPSI	$C\psi$	Cos (ψ)		
CPSIP	$C\psi_p$	Cos (ψ_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 (θ)		
CTHEP	$C\theta_p$	Cos (θ_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) (kg-m^2)	slug or 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) (kg-m^2)	slugs or slug-ft^2
DELSX		Total suspension line defl .tion array	m	ft

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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

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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) (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 θ is approaching a singular point $\theta = \frac{2n+1}{2}\pi$. If θ is approaching a singular point, the accelerations are kept fixed until this region is passed. EPSI = 0.0000061 freezes the accelerations if θ is within 0.2° of a singular point.		
EPT		Tether line strain array	m/m	ft/ft

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FORTRAN	STANDARD	DESCRIPTION	METRIC UNITS	ENGLISH UNITS
ETAI		Number which controls DT if Θ is near a singular point. ETAI = 0.00061 sets DT = $^{DT1}/5$, if Θ 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

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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	γ	Flight path angle of forebody in vertical plane		deg
GAMPE	γ_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	$(kg\text{-}m^2)$	$slug\text{-}ft^2$

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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	ω_{xb}	Angular velocity about X_b axis		deg/sec
OMYBE	ω_{yb}	Angular velocity about Y_b axis		deg/sec
OMZBE	ω_{zb}	Angular velocity about Z_b axis		deg/sec
OPAM		Option variable: if OPAM = 1., added mass of the decelerator $\neq$ 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 $\neq$ 0.; if OPOS = 0., all c.g. offsets and products of inertia = 0.		

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	ϕ	Euler angle rotation about X_b axis		deg
PHIIE	ϕ_i	Aerodynamic roll angle of forebody, $-180° \leq \phi_i \leq 180°$		deg
PHIPI	ϕ_{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	ψ	Euler angle rotation of forebody about -Z axis		deg
PSIPDE	$\dot{\psi}_p$	Angular velocity of decelerator about -Z axis		deg/sec
PSIPE	ψ_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_ϕ	Generalized force about X_b axis	(m-N)	ft-lb_f
QPSI	Q_ψ	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_θ	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 (χ)		
SCHIP		sin (χ_p)		
SGAM		sin (γ)		

FORTRAN	STANDARD	DESCRIPTION	METRIC UNITS	ENGLISH UNITS
SGAMP		sin (γ_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 (ψ)		
SPSIP	$S\psi_p$	sin(ψ_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 (θ)		
STHEP	$S\theta_p$	sin (θ_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

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FORTRAN	STANDARD	DESCRIPTION	METRIC UNITS	ENGLISH UNITS
THEDE	$\dot{\theta}$	Angular velocity of forebody about negative line of nodes		deg/sec^2
THEE	θ	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	θ_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	$\dot{X}_b$	$\dot{X}_b$ 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	$\dot{X}_{pb}$	$\dot{X}_{pb}$ 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

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

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. $\mathfrak{XYZ}$ 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 $\mathfrak{XYZ}$, 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 $\bar{X}$, $\bar{Y}$, $\bar{Z}$ 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}.

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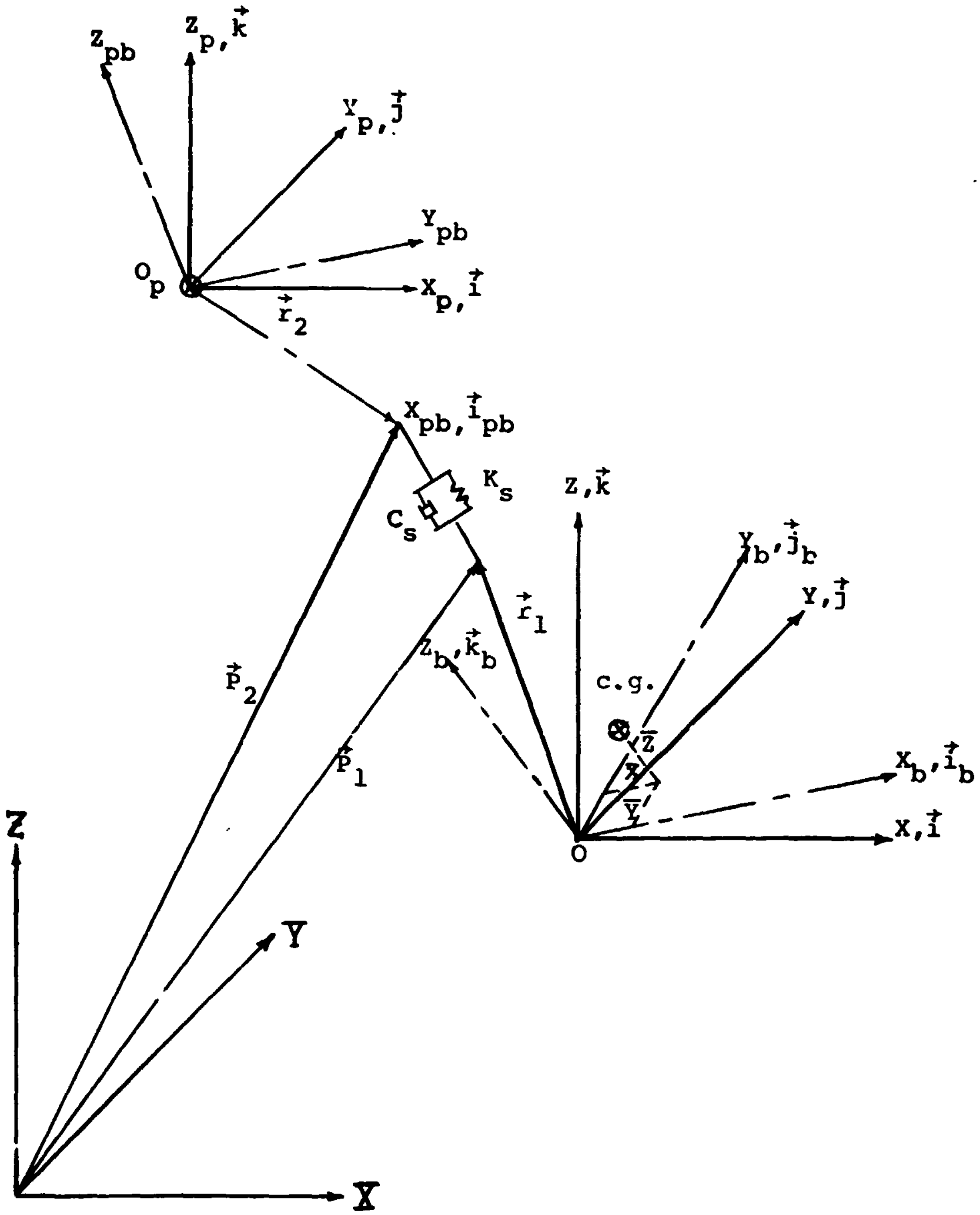

FIGURE 1 - COORDINATE SYSTEMS

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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 ψ into Oa and ON respectively. The second rotation is in the direction, -ON, such that Oa and OZ are rotated through an angle θ into OX_b and Ob respectively. The final rotation is about OX_b such that ON and Ob are rotated through an angle ϕ into OY_b and OZ_b respectively. The three angular rotations (ψ, θ, ϕ) specify the orientation of the body axes (X_b, Y_b, Z_b) with respect to the inertial axes ($\mathfrak{X}$, $\mathfrak{Y}$, $\mathfrak{Z}$). Again, from a pilots viewpoint, a positive ψ is a nose to the right yaw; a positive θ is a nose up pitch; and a positive ϕ 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:

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

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

The second rotation is:

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

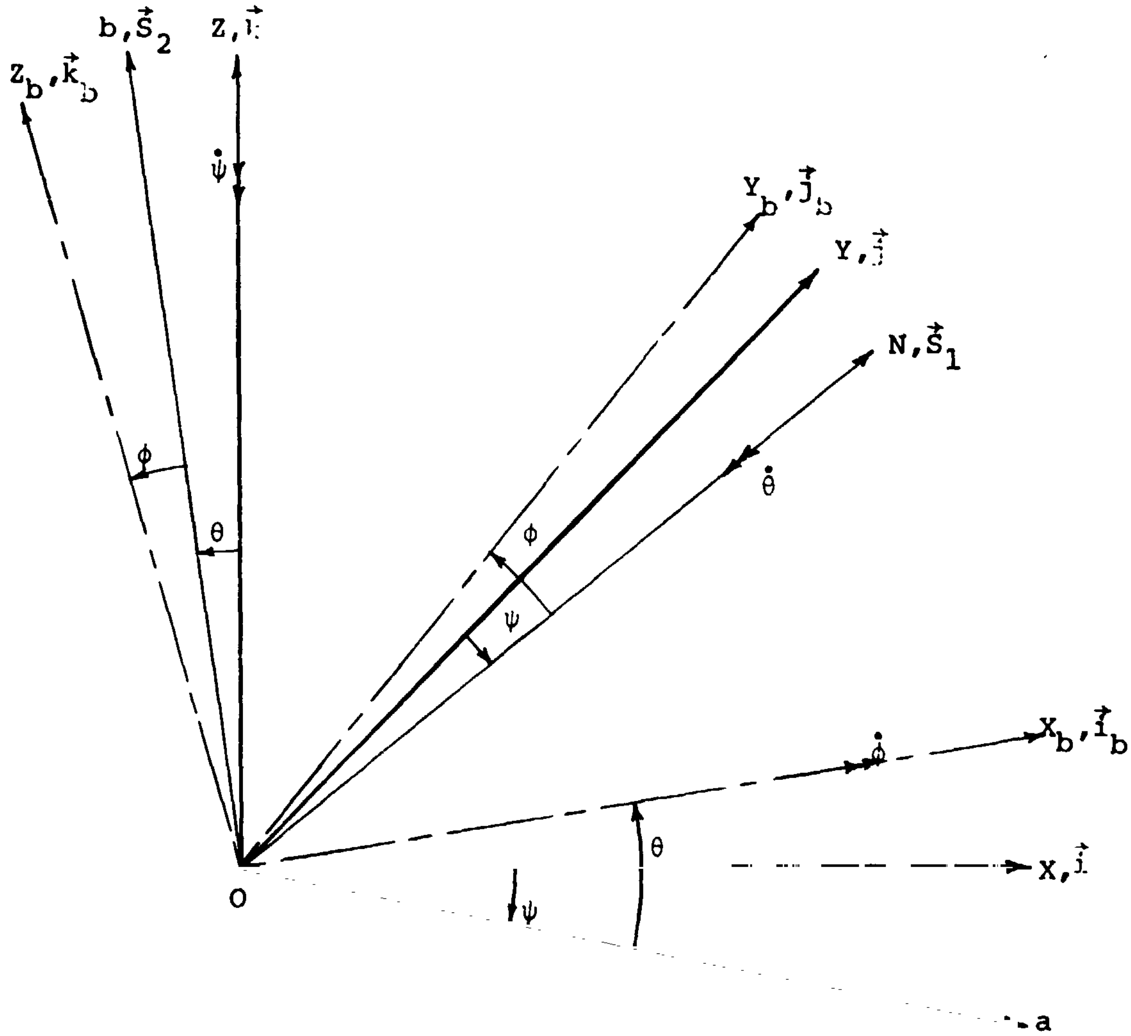

FIGURE 2 - EULER ANGLE ROTATIONS

The final rotation is:

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

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

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

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,

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

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 $[C_p]$.

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

The total angular velocity of the forebody is given by:

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

From the inverse of (3):

$$\vec{S}_1 = C\phi\vec{j}_b - S\phi\vec{k}_b \qquad (8)$$

$$\vec{S}_2 = S\phi\vec{j}_b + C\phi\vec{k}_b \qquad (9)$$

From the inverse of (2)

$$\vec{k} = S\theta\vec{i}_b + C\theta\vec{S}_2 \qquad (10)$$

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

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

The components of angular velocity for the forebody are:

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

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

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

Likewise, for the decelerator, the angular velocities are:

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

$$\omega_{ypb} = -\dot{\theta}_p \qquad (16)$$

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

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]

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

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.

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.

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

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:

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

$\vec{P}_1$ 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,

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

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

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

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

Similarly for the decelerator:

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

$$\vec{r}_2 = a_p \vec{i}_{pb} \quad (25)$$

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

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

$$L_T = [L_T \cdot L_T]^{1/2} \quad (27)$$

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

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

$$L_T = \{[\overline{A}]^2 + [\overline{B}]^2 + [\overline{C}]^2\}^{1/2} \quad (29)$$

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

$$\dot{L}_T = [\overline{A}\ \dot{\overline{A}} + \overline{B}\ \dot{\overline{B}} + \overline{C}\ \dot{\overline{C}}]/L_T \quad (30)$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\frac{\partial \bar{C}}{\partial \psi} = 0 \quad (47)$$

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

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

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

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

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:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\frac{\partial L}{\partial X} = 0 \qquad (58)$$

$$\frac{\partial \overline{q}}{\partial X} = \frac{-\overline{A}}{L_T} \qquad (59)$$

$$\frac{\partial F}{\partial \dot{X}} = 0 \qquad (60)$$

Y Equation

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

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

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

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

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

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

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

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

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

$$\frac{\partial L}{\partial Y} = 0 \qquad (62)$$

$$\frac{\partial \overline{q}}{\partial Y} = \frac{-\overline{B}}{L_T} \qquad (63)$$

$$\frac{\partial F}{\partial \dot{Y}} = 0 \qquad (64)$$

<u>Z Equation</u>

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

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

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

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

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

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

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

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

<u>X_p Equation</u>

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

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

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

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

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

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

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

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

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

$$\frac{\partial L}{\partial X_p} = 0 \qquad (70)$$

$$\frac{\partial \bar{q}}{\partial X_p} = \frac{\bar{A}}{L_T} \qquad (71)$$

$$\frac{\partial F}{\partial \dot{X}_p} = 0 \qquad (72)$$

Y_p Equation

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{Y}_p}\right) = \ddot{X}_p\{[m_{p\ell}-m_{ps}][-\tfrac{1}{2}S2\psi_p C^2\theta_p]\}$$

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

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

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

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

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

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

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

$$+\dot{Z}_p\dot{\theta}_p\{[m_{p\ell}-m_{ps}][-S\psi_p C2\theta_p]\} \qquad (73)$$

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

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

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

Z_p Equation

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

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

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

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

<u>ψ Equation</u>

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\psi}}\right) = \ddot{\psi}\{I_{xb}(S^2\theta)+[I_{yb}(S^2\phi)+I_{zb}(C^2\phi)](C^2\theta)+I_{yzb}(-C^2\theta S2\phi)$$

$$+[I_{xzb}(C\phi)+I_{xyb}(S\phi)](-S2\theta)\}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\frac{\partial F}{\partial \dot{\psi}} = 0 \qquad (84)$$

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θ Equation

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

<u>ϕ Equation</u>

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\phi}}\right) = \ddot{\psi}\{I_{xb}(-S\theta)+I_{xyb}(C\theta S\phi)+I_{xzb}(C\theta C\phi)\}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

<u>ψ_p Equation</u>

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

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

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

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

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

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

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

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

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

<u>θ_p Equation</u>

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

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

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

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

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L_T Equation

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

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

$$\frac{\partial \bar{q}}{\partial L_T} = -1 \quad (103)$$

$$\frac{\partial F}{\partial \dot{L}_T} = C_s \dot{L}_T \quad (104)$$

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

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

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

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

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

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

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

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

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

2. Y Equation

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

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

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

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

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

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

3. Z Equation

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

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

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

4. X_p Equation

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

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

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

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

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

5. Y_p Equation

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

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

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

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

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

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. ψ Equation

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

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

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

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

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

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

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

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

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

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

8. θ Equation

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

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

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

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

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

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

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

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

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

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

9. φ Equation

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

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

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

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

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

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

10. ψ_p Equation

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

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

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

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

11. θ_p Equation

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

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

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

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

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:

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

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

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

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

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

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

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

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

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

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

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:

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

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

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

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

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

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

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

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, ϕ_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:

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

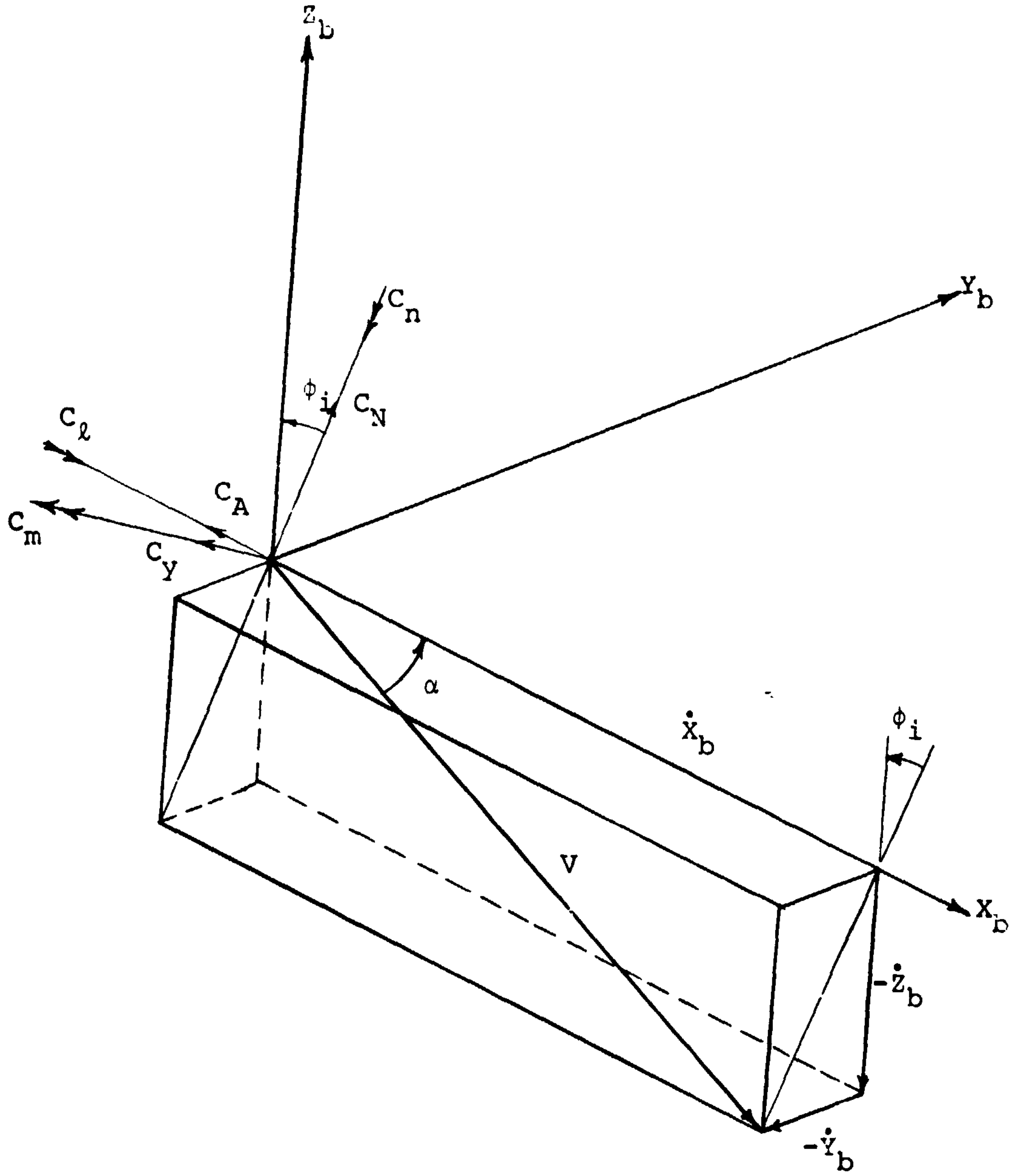

FIGURE 3 - AERODYNAMIC COORDINATE SYSTEM

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.

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

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

$$Q_\phi = T_{xb} \quad (141)$$

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:

$$F_{xpb} = -q_p\ S_p\ C_{Ap} \quad (142)$$

$$F_{ypb} = q_p\ S_p\ C_{NP}\ S\phi_{pi} \quad (143)$$

$$F_{zpb} = q_p\ S_p\ C_{NP}\ C\phi_{pi} \quad (144)$$

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

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

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

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 ($y = ax^2$).

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

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)	TRO, TR1, TR2, TR3	1 card
jj)	SPRO, SPR1, SPR2, SPR3, PCTO1, PCTO2, PCTO3, 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 (ϕ_i), eleven angles-of-attack (α) 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 angles-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 <u>second</u> 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 second 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).

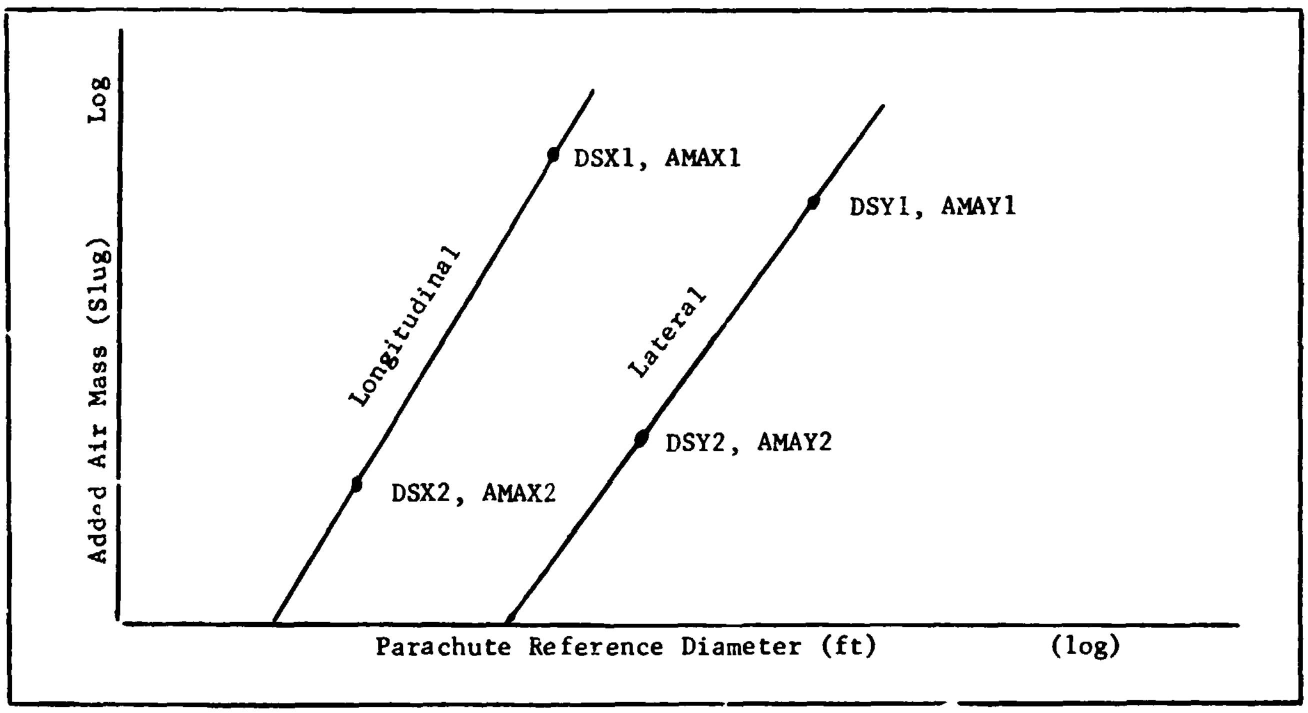

Figure 4. Input Parameters for Parachute Added Air Mass

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).

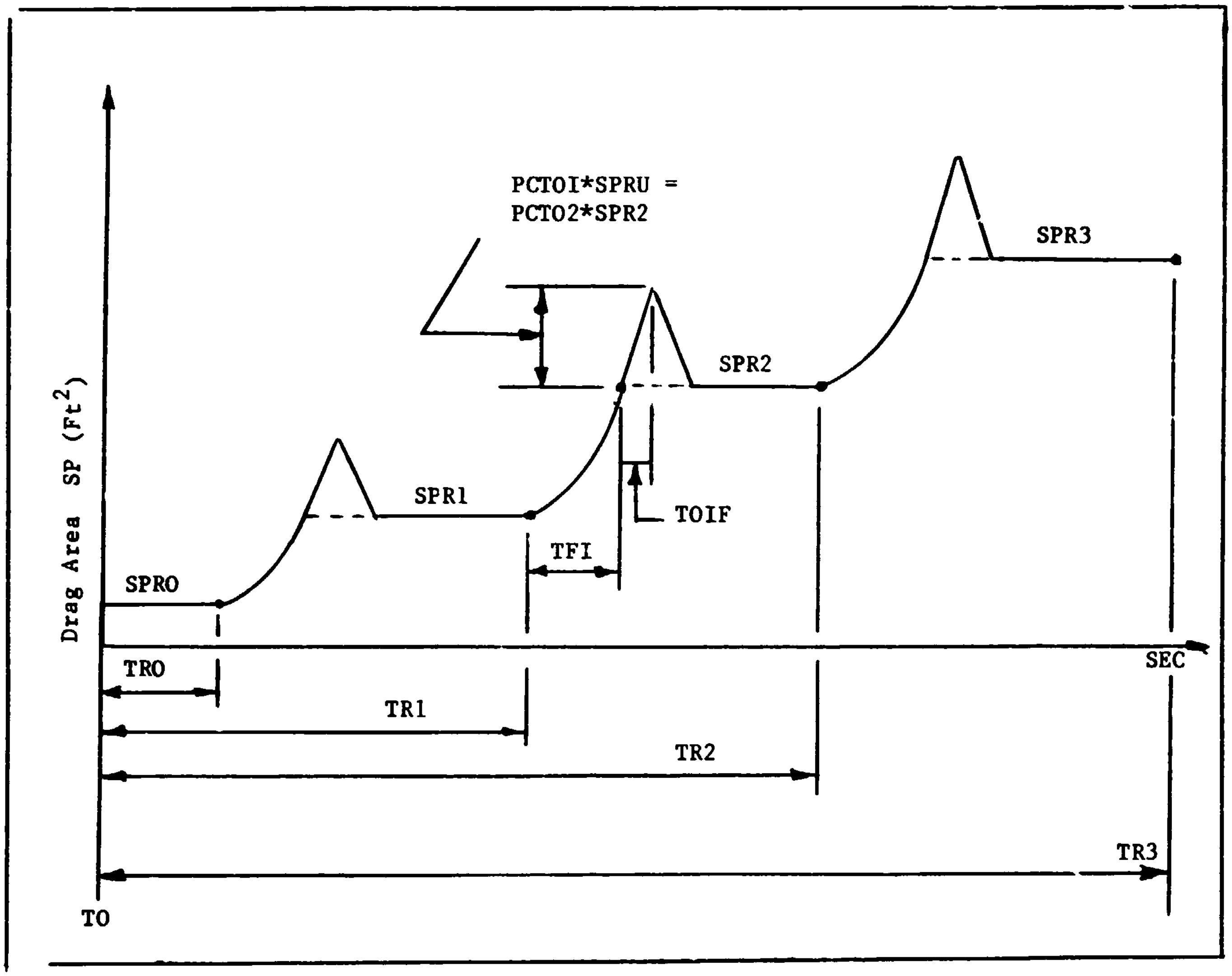

Figure 5. Parameters for Program Calculated Parachute Drag Area Time History

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.

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

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:

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

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 $\overline{X} = \overline{Y} = \overline{Z} = I_{xyb} = I_{xzb} = I_{yzb} = 0.$, 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	($SLUG-FT^2$) X 1.355817945	= $KILOGRAM-METER^2$	$kg-m^2$
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 $SEC/METER^2$	$(N-sec)/m^2$
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.

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 000057 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 TR0      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 TOTNO
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,CPR,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*           ",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
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00110          9 ,WTCM,WTLM,CCRIT,LS,NS,NT,TD,TRD,TH1,TH2,TH3,SPRO,SPR1,SPR2,SPR3
00110          A ,PCTO1,PCTO2,PCTO3,POROS,GLOAD,FSULT,AERATO,FREQP,XPBDR,DT1
00110          B,SPRU,SPRL,TINT,TINF,TF1,XPBD1,TOTRO,TOTR1,TOTR2,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,'XPBD1'//)
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.
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00140                      JALPD=AJALPD
00141                      KAM=AKAM
00142                      KAMD=AKAMD
00143                      READ(IIN,1)(PPHIE(I),I=1,IPHI)
00151                      READ(IIN,1)(AALPFE(J ,J=1,JALPF)
00157                      READ(IIN,1)(AALPHE(J),J=1,JALPH)
00165                      READ(IIN,1)(AAM(K),K=1,KAM)
00173                      READ(IIN,1)(((CCA(I,J,K),J=1,JALPF),I=1,IPHI),K=1,KAM)
00207                      READ(IIN,1)(((CCN(I,J,K),J=1,JALPF),I=1,IPHI),K=1,KAM)
00223                      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                      IF(OPSYM.EQ.1.) GO TO 98
00241                      READ(IIN,1)(((CCY(I,J,K),J=1,JALPF),I=1,IPHI),K=1,KAM)
00255                      READ(IIN,1)(((CCLL(I,J,K),J=1,JALPH),I=1,IPHI),K=1,KAM)
00271                      READ(IIN,1)(((CCLN(I,J,K),J=1,JALPH),I=1,IPHI),K=1,KAM)
00305                   98 CONTINUE
00306  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00306                      IF(OPUA.EQ.1.) GO TO 97
00310                      READ(IIN,1) CLLP,CLMQ,CLNR
00315                      GO TO 96
00316                   97 READ(IIN,1)(PPHIDE(I),I=1,IPHID)
00324                      READ(IIN,1)(AALPDE(J ,J=1,JALPD)
00332                      READ(IIN,1)(AAMD(K),K=1,KAMD)
00340                      READ(IIN,1)(((CCLLP(I,J,K),J=1,JALPD),I=1,IPHID),K=1,KAMD)
00354                      READ(IIN,1)(((CCLMQ(I,J,K),J=1,JALPD),I=1,IPHID),K=1,KAMD)
00370                      READ(IIN,1)(((CCLNR(I,J,K),J=1,JALPD),I=1,IPHID),K=1,KAMD)
00404                      CLLP=0.
00405                      CLMQ=0.
00406                      CLNR=0.
00407                   96 CONTINUE
00410                      READ(IIN,1)(AALPPE(I),I=1,8)
00416                      READ(IIN,1)(AAMP(I),I=1,8)
00424                      READ(IIN,1)((CCAP(I,J),J=1,8),I=1,8)
00435                      READ(IIN,1)((CCNP(I,J),J=1,8),I=1,8)
00446                      READ(IIN,1)((CCMP(I,J),J=1,8),I=1,8)
00446             C
00446             C     OPPRIN = 1. TO PRINT OUT AERODYNAMIC COEFFICIENTS
00446             C     OPPRIN = 0. TO NOT PRINT OUT AERODYNAMIC COEFFICIENTS
00446             C
00446             C     OPPLOT = 1. TO MAKE PLOT TAPE
00446             C     OPPLOT = 0. TO NOT MAKE PLOT TAPE
00446             C
00446             C     OPOS = 1. IF ONE PRODUCT OF INERTIA OR C.G. OFFSET NOT = 0.
00446             C     OPOS = 0. IF ALL PRODUCTS OF INERTIA AND C.G. OFFSETS = 0.
00446             C
00446             C     OPAM = 1. IF ADDED MASS OF PARACHUTE NOT EQUAL 0.
00446             C     OPAM = 0. IF ADDED MASS OF PARACHUTE EQUAL 0.
00446             C
00446             C       OPDT= 1. PROGRAM CALCULATES AN ESTIMATE FOR DT
00446             C       OPDT= 0.0 IF DT IS READ INTO PROGRAM
00446             C
00446             C       OPSP= 1. PROGRAM CALCULATES PARACHUTE DRAG AREA (SP)
00446             C       OPSP= 0.0 SSP(16),TTIP(16) ARRAYS ARE READ INTO PROGRAM
00446             C
00446             C       OMETRC = 1. IF METRIC UNITS ARE USED
00446             C       OMETRC = 0.0 IF ENGLISH UNITS ARE USED
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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)TRO,TR1,TR2,TR3
00613              READ(IIN,1) SPRO,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              TRO=0.0
00642              TR1=0.0
00643              TR2=0.0
00644              TR3=0.0
00645              SPRO=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,HHH
00671              GO TO 94
00672           93 READ(IIN,1) DT1,TO,D P1,TTT,HHH
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              TOTRO= TO+TRO
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
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00722    193.        60  DTT= .04735*SQRT((LS*WTP)/(GLOAD*WT*FSULT*AERATO))
00723    194.            FREQP= 1./(12.*DTT)
00724    195.             YY= DTT
00725    196.             I=0
00726    197.        61  NN= YY
00727    198.             IF(NN.GE.1) GO TO 62
00731    199.             I=I+1
00732    200.             YY= YY*10.
00733    201.             GO TO 61
00734    202.        62  DTI= NN/10.**I
00735    203.        63  CONTINUE
00736    204.            GO=32.17
00737    205.            RHOO=.002378
00740    206.            RE=20926435.
00741  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00741    207.            IF(OMETRC.EQ.1.) GO TO 140
00743    208.            GO TO 141
00744    209.       140  RE=6378377.
00745    210.            RHOO=1.22557
00746    211.            GO=9.8054160
00747    212.       141  DPR= 57.2957795
00750    213.            M=WT/GO
00751    214.            MP=WTP/GO
00752    215.            WTCM= WTC/32.17
00753    216.            WTLM= WTL/32.17
00754    217.            LSCLO= SQRT(LS*LS-.10176*DP*DP)
00755    218.            AP= (WTC*(.1595*DP+LSCLO)+ .5*LSCLO*WTL)/(WTC+WTL)
00756    219.            AX= (ALOG10(AMAX1)-ALOG10(AMAX2))/(ALOG10(DSX1)-ALOG10(DSX2))
00757    220.            BX= AMAX1/(DSX1**AX)
00760    221.            AY= (ALOG10(AMAY1)-ALOG10(AMAY2))/(ALOG10(DSY1)-ALOG10(DSY2))
00761    222.            BY= AMAY1/(DSY1**AY)
00762    223.            PSI=PSIE/DPR
00763    224.            THE=THEE/DPR
00764    225.            PHI=PHIE/DPR
00765    226.            PSIP=PSIPE/DPR
00766    227.            THEP=THEPE/DPR
00767    228.            OMXB=OMXBE/DPR
00770    229.            OMYB=OMYBE/DPR
00771    230.            OMZB=OMZBE/DPR
00772    231.            THEPD=THEPDE/DPR
00773    232.            PSIPD=PSIPDE/DPR
00774    233.            GAM=GAME/DPR
00775    234.            CHI=CHIE/DPR
00776    235.            GAMP=GAMPE/DPR
00777    236.            CHIP=CHIPE/DPR
01000    237.            SGAM=SIN(GAM)
01001    238.            CGAM=COS(GAM)
01002    239.            SCHI=SIN(CHI)
01003    240.            CCHI=COS(CHI)
01004    241.            SGAMP=SIN(GAMP)
01005    242.            CGAMP=COS(GAMP)
01006    243.            SCHIP=SIN(CHIP)
01007    244.            CCHIP=COS(CHIP)
01010    245.            XD=V*CGAM*CCHI
01011    246.            YD=V*CGAM*SCHI
01012    247.            ZD=V*SGAM
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      XPD=VP*CGAMP*CCHIP
      YPD=VP*CGAMP*SCHIP
      ZPD=VP*SGAMP
      SPSI=SIN(SNGL(PSI))
      STHE=SIN(SNGL(THE))
      SPHI=SIN(SNGL(PHI))
      SPSIP=SIN(SNGL(PSIP))
      STHEP=SIN(SNGL(THEP))
      CPSI=COS(SNGL(PSI))
      CTHE=COS(SNGL(THE))
      CPHI=COS(SNGL(PHI))
      CPSIP=COS(SNGL(PSIP))
      CTHEP=COS(SNGL(THEP))
      CC(1,1)=CPSI*CTHE
      CC(1,2)=-SPSI*CTHE
      CC(1,3)=STHE
      CC(2,1)=-CPSI*STHE*SPHI+SPSI*CPHI
      CC(2,2)=SPSI*STHE*SPHI+CPSI*CPHI
      CC(2,3)=CTHE*SPHI
      CC(3,1)=-CPSI*STHE*CPHI-SPSI*SPHI
      CC(3,2)=SPSI*STHE*CPHI-CPSI*SPHI
      CC(3,3)=CTHE*CPHI
      CCP(1,1)=CPSIP*CTHEP
      CCP(1,2)=-SPSIP*CTHEP
      CCP(1,3)=STHEP
      XP=X+A*CC(1,1)+B*CC(2,1)+C*CC(3,1)-(LTO+DLTO+AP)*CCP(1,1)
      YP=Y+A*CC(1,2)+B*CC(2,2)+C*CC(3,2)-(LTO+DLTO+AP)*CCP(1,2)
      ZP=Z+A*CC(1,3)+B*CC(2,3)+C*CC(3,3)-(LTO+DLTO+AP)*CCP(1,3)
      PSID=-(OMYB*SPHI+OMZB*CPHI)/CTHE
      THED=(-OMYB*CPHI+OMZB*SPHI)
      PHID=OMXB-STHE*(OMYB*SPHI+OMZB*CPHI)/CTHE
      DT=DTI
      TNINY= 0.0
      DTP=DTPI
      IYMZB=IYB-IZB
      DTPC=0.
      CONSTR=-1.
      JJJ=1
      JJ=1
C
C   WRITE OUT BODY CHARACTERISTICS AND CONTROL VARIABLES
C
      WRITE(IOUT,14)
   14 FORMAT(1H1,5X,'TRAJECTORY OF A RIGID BODY WITH 6 D.O.F. CONNECTED
     1TO A RIGID PARACHUTE WITH 5 D.O.F. BY AN ELASTIC TETHER'//)
      WRITE(IOUT,31) COM
   31 FORMAT(23X,13A6,A2//)
      WRITE(IOUT,11)
   11 FORMAT(7X,'IXB',7X,'IXYB',8X,'XBAR',6X,'S',9X,'CLLP',6X,'OPPRIN',
     14X,'OPSYM',5X,'AIPHI ,15X,'AIPHID',4X,'DT1',7X,'EPSI'/
     27X,'IYB',7X,'IXZB',8X,'YBAR',6X,'D',9X,'CLMQ',6X,'OPPLOT',4X,
     3'OPDA',6X,'AJALPF',4X,'AJALPM',4X,'AJALPD',4X,'TTT',7X,'ETA1'/
     47X,'IZB',7X,'IYZB',8X,'ZBAR',6X,'WEIGHT',4X,'CLNR',6X,'OPDS',6X,
     5'OMETPC',4X,'AKAM',16X,'AKAMD',5X,'HHH'/)
      WRITE(IOUT,13) IXB,IXYB,XBAR,S,CLLP,OPPRIN,OPSYM,AIPHI,AIPHID,DT1,
     1EPSI,IYB,IXZB,YBAR,D,CLMQ,OPPLOT,OPDA,AJALPF,AJALPM,AJALPD,TTT,
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01074          ZETAI,IZL ,YZB,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(////,10X,'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 10X,'C',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,'SPRO',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,OPDT,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)'/)
[illegible]    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=LE(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=3.1159265-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[illegible]
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=[illegible]D+.5*AA(2,1)
02230             PHID=[illegible]D+.5*AA(3,1)
02231             XD=XD+.5*AA(4,1)
02232             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*[illegible],1)*DT
02251             PSIP=PSIP+.25*BB(1,1)*DT
02252             THE[illegible]+.25*BB(2,1)*DT
02253             XP=X[illegible]*BB(3,1)*DT
02254             YP=Y[illegible](4,1)*DT
02255             ZP=ZP[illegible](5,1)*DT
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```
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))
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02347   635.           YP=ZP-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 ...))).LT.E.AI) DT=DT1/5.
02401   660.           IF(1.-ABS(SIN(SNGL(T ...))).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.
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@FOR,US SUBR
MSD 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     DENSM
      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   000563 100L     0001   000575 101L     0001   001547 102L     0001   000641 103L
      0001   001551 104L     0001   000354 11L      0001   001640 110L     0001   001652 111L     0001   000547 14L
      0001   000555 15L      0001   000630 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   000675 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 AALPHE   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 ALPHSL   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 000301 CBAR     0000 R 000304 CBAND    0002 R 000233 CC
      0002 R 000344 CCA      0002 R 017370 CCAP     0002 R 010344 CCLL     0002 R 014344 CCLLP    0002 R 036344 CCLM
      0002 R 015344 CCLMQ    0002 R 012344 CCLN     0002 R 016344 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 000140 CPS1     0000 R 000163 CPSIP
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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 EPSI
0002 R 020034 EPT	0002 D 000074 FF	0002 020155 FKEUP	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 GD	0000 I 000233 I
0000 R 000002 ICXO	0000 R 000001 ICYO	0000 I 000332 IERSW	0002 000231 IIN	0002 017744 IIXP
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 [illegible]
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 PCTO1	0002 R 020147 PCTO2	0002 R 020150 PCTO3
0002 D 000004 PHI	0002 R 000230 PHIAF	0002 D 000020 PHID	0000 R 000151 PHID2	0000 R 000256 PHII
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 022031 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 TT1P	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

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0002 D 000012 Z          0002 R 000154 ZBAR       0000 R 000224 ZBD        0002 D 000026 ZD         0002 D 000034 ZP
0000 R 000227 ZPBD       0002 D 000046 ZPD        0000 R 000342 ZPD2       0000 R 000352 ZPPSPD     0000 R 000353 ZPTHPD


00000  *DIAGNOSTIC*  THE NAME IZMXB APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00000  *DIAGNOSTIC*  THE NAME IXMYB 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,OMD,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
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00135     49*          S2THE=2.*STHE*CTHE
00136     50*          S2PHI=2.*SPHI*CPHI
00137     51*          S2THEP=2.*STHEP*CTHEP
00140     52*          C2THE=CTHE2-STHE2
00141     53*          C2PHI=CPHI2-SPHI2
00142     54*          S1S2=SPSI*STHE
00143     55*          S1S2S3=SPSI*STHE*SPHI
00144     56*          S1S2C3=SPSI*STHE*CPHI
00145     57*          S1C2S3=SPSI*CTHE SPHI
00146     58*          S1C2C3=SPSI*CTHE*CPHI
00147     59*          S2S3=STHE*SPHI
00150     60*          S2C3=STHE*CPHI
00151     61*          C1S2=CPSI*STHE
00152     62*          C1S2S3=CPSI*STHE*SPHI
00153     63*          C1S2C3=CPSI*STHE*CPHI
00154     64*          C1C2S3=CPSI*CTHE*SPHI
00155     65*          C1C2C3=CPSI*CTHE*CPHI
00156     66*          PSDTD=PSID*THED
00157     67*          PSDPHD=PSID*PHID
00160     68*          TDPHD=THED*PHID
00160     69*    C
00160     70*    C   CALCULATE TRANSFORMATION MATRICES
00160     71*    C
00161     72*          CC(1,1)=CPSI*CTHE
00162     73*          CC(1,2)=-SPSI*CTHE
00163     74*          CC(1,3)=STHE
00164     75*          CC(2,1)=-C1S2S3+SPSI*CPHI
00165     76*          CC(2,2)=S1S2S3+CPSI*CPHI
00166     77*          CC(2,3)=CTHE*SPHI
00167     78*          CC(3,1)=-C1S2C3-SPSI*SPHI
00170     79*          CC(3,2)=S1S2C3+CPSI* PHI
00171     80*          CC(3,3)=CTHE*CPHI
00172     81*          CCP(1,1)=CPSIP*CTHEP
00173     82*          CCP(1 2)=-SPSIP*CTHEP
00174     83*          CCP(1,3)=STHEP
00175     84*          CCP(2,1)=SPSIP
00176     85*          CCP(2,2)=CPSIP
00177     86*          CCP(3,1)=-CPSIP*STHEP
00200     87*          CCP(3,2)=SPSIP*STHEP
00201     88*          CCP(3,3)=CTHEP
00202     89*          G=GO*(RE/(Z+RE))**2
00203  *DIAGNOSTIC*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00203     90*          IF(OMETRC.EQ.1.) GO  O 10
00205     91*          CALL DENS(Z,PR,RHO,VS)
00206     92*          GO TO 11
00207     93*       10 CALL DENSM(Z,PR,RHO, S)
00210     94*       11 CONTINUE
00211     95*          V=SQRT(SNGL(XD**2+YD**2+ZD**2))
00212     96*          VP=SQRT(SNGL(XPD**2+YPD**2+ZPD**2))
00213     97*          AM=V/VS
00214     98*          AMP=VP/VS
00215     99*          DYPR=.5*RHO*V**2
00216    100*          DYPRP=.5*RHO*VP**2
00217    101*          XBD=XD*CC(1,1)+YD*CC(1,2)+ZD*CC(1,3)
00220    102*          YBD=XD*CC(2,1)+YD*CC(2,2)+ZD*CC(2,3)
00221    103*          ZBD=XD*CC(3,1)+YD*CC(3,2)+ZD*CC(3,3)
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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  O 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  O 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
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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)
  355                  TINF= TINT+TFI
   56                  TFMTI= TINF-TINT
  357                  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                 XPBDR= XPBD
00404                  GO TO 200
00405             195  DELSPO = SPDINF*(T-TINF)
00406                  SP= SPRU+ DELSPO
00407                  SPD= SPDINF
00410                 XPBDR= XPBD
00411                  GO TO 200
00412             197  DELSPO= SPOI- SPDINF*(T-TOI)
00413                  SP= SPRU + DELSPO
00414                  SPD= -SPDINF
00415                 XPBDR= 0.0
00416                  GO TO 200
00417             198  SP= SPRU
00420                  SPD= 0.0
00421                 XPBDR= 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'/)
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00424        194 WRITE(3,196) TRU
00427            STOP
00430        200  CONTINUE
00431            IF((1.-ABS(STHE)).LT.EPSI) TNINY=TNINY+DT
00433            DS= SWRT(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.0.0) 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*(.08333*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.
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```
      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- MAXPB
      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(2,2)+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-LTO
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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)
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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.EPSI) 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.EPSI) 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)
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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 BAR 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 ED      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
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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*S2T EP*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)
0115.            FF(2)=(PSIPD2*.5*S2T EP*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
HSO 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    NERR3S

   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 INJPS     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
MSD IIA -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 II        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 ZE O

00101      1*            SUBROUTINE PIVERT(A,R,M,MD,N,EPS,IER)
00101      2*      C
00101      3*      C           TO SOLVE A GENERAL SYSTEM OF SIMULTANEOUS LINEAR EQUATIONS. GELG  70
00101      4*      C           SOLUTION IS DONE BY MEANS OF GAUSS-ELIMINATION WITH         GELG 470
00101      5*      C           COMPLETE PIVOTING.                                          GELG 480
00101      6*      C                                                                       GELG 110
00101      7*      C        DESCRIPTION OF PARAMETERS                                      GELG 120
00101      8*      C           A        - THE M BY M COEFFICIENT MATRIX.  (DESTROYED)      GELG 150
00101      9*      C           R        - THE M BY N MATRIX OF RIGHT HAND SIDES.  (DESTROYED)GELG 130
00101     10*      C                      ON RETURN R CONTAINS THE SOLUTION OF THE EQUATIONS.GELG 140
00101     11*      C           M        - THE NUMBER OF EQUATIONS IN THE SYSTEM.           GELG 160
00101     12*      C           MD       - THE DIMENSION OF A
00101     13*      C           N        - THE NUMBER OF RIGHT HAND SIDE VECTORS.           GELG 170
00101     14*      C           EPS      - AN INPUT CONSTANT WHICH IS USED AS RELATIVE      GELG 180
00101     15*      C                      TOLERANCE FOR TEST ON LOSS OF SIGNIFICANCE.      GELG 190
00101     16*      C           IER      - RESULTING ERROR PARAMETER CODED AS FOLLOWS       GELG 200
00101     17*      C                      IER=0  - NO ERROR,                               GELG 210
00101     18*      C                      IER=-1 - NO RESULT BECAUSE OF M LESS THAN 1 OR   GELG 220
00101     19*      C                               PIVOT ELEMENT AT ANY ELIMINATION STEP   GELG 230
00101     20*      C                               EQUAL TO 0,                             GELG 240
00101     21*      C                      IER=K  - WARNING DUE TO POSSIBLE LOSS OF SIGNIFI- GELG 250
00101     22*      C                               CANCE INDICATED AT ELIMINATION STEP K+1, GELG 260
00101     23*      C                               WHERE PIVOT ELEMENT WAS LESS THAN OR    GELG 270
00101     24*      C                               EQUAL TO THE INTERNAL TOLERANCE EPS TIMES GELG 280
00101     25*      C                               ABSOLUTELY GREATEST ELEMENT OF MATRIX A. GELG 290
00101     26*      C                                                                       GELG 300
00101     27*      C        REMARKS                                                        GELG 310
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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
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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
HSD 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 1216    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     200131.23,259186.35,291153.40,323002.75,354753.59,386406.39,
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/2116.217,472.67922,114.34505,16.128852,2.3162994,
00107          1     1.2322512,.38032173,.021672818,.0034331482,.00062812953,
00107          2     .00015359986,.000052646807,.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,-.88256481E-5,0.,.52141408E-5,.74757236E-5,
00113          2     .12120769E-4,.17828281E-4,.49941997E-5,.28886537E-5,
00113          3     .18635746E-5,.12041172E-5,.85314774E-6,.61163470E-6,
00113          4     .42048419E-6,.25268889E-6,2*.15723I5E-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         1   CONTINUE
00130             I = 23
00131           2 I = I - 1
00132             DH = H - HB(I)
00133             TEMP = 1. + A(I)*DH
00134             T = TB(I)*TEMP
00135             IF(A(I))3,6,3
00140           6 TEMP = EXP(B(I)*DH)
00141             GO TO 4
00142           3 TEMP = TEMP**B(I)
00143           4 P = PB(I)*TEMP
00144             RHO = .3236414E-3*P/T
00145             CS = 65.770322E0*SQRT(T)
00146             RETURN
00147             END

      END OF COMPILATION;        NO  DIAGNOSTICS.
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```
@FOR,US DENSM
MSO 11A -03/27/79-00119137 (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 1226      0001     000024 2L      0001     000052 3L      0001     000062 4L      0000 R 000164 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,.000052666837,.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,.17 28281E-4,.49941997E-5,.28886537E-5,
00113               3    .18635746E-5,.12041172E-5,.85314774E-6,.61116347E-6,
00113               4    .42048419E-6,.25268889E-6,2*.15723l5E-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 = .003483647*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	00:18:10	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

TRAJECTORY 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 IYB IZB	IXYB IXZB IYZB	XBAR YBAR ZBAR	S D WEIGHT	CLLP CLMQ CLNR	OPPRIN OPPLOT OPOS	OPSYM OPDA OMETRC	AIPHI AJALPF AKAM	AJALPH	AIPHID AJALPD AKAMD	DTI TTT HHH	EPSI 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 B C TRO	LTO NT DLTO TR1	LS NS DP TR2	AMAX1 DSX1 WTC TR3	AMAX2 DSX2 WTL SPR0	AMAY1 DSY1 WTP SPR1	AMAY2 DSY2 CCRIT SPR2	AP CHIPE VP SPR3	GLOAD FSULT AERATO	FREQP POROS TO	OPAM OPDT OPSP	PCT01 PCT02 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 IYB IZB	IXYB IXZB IYZB	XBAR YBAR ZBAR	S D WEIGHT	CLLP CLMQ CLNR	OPPRIN OPPLOT OPOS	OPSYM OPDA OMETRC	AIPHI AJALPF AKAM	 AJALPM 	AIPHID AJALPD AKAMD	DTI TTT HHH	EPSI ETAI
171199.0	.0	-2.000	116.260	.000	1.	0.	2.		2.	.0100	.000086
8539000.0	.0	-.000	12.1.7	.000	0.	0.	16.	16.	8.	5.0000	.000610
8539000.0	.0	.000	163300.00	.000	1.	0.	[illegible]		2.	10000.0	

A B C TRO	LTO NT DLTO TR1	LS NS DP TR2	AMAX1 DSX1 WTC TR3	AMAX2 DSX2 WTL SPR0	AMAY1 DSY1 WTP SPR1	AMAY2 DSY2 CCRIT SPR2	AP CHIPE VP SPR3	GLOAD FSULT AERATO	FREQP POROS TO	OPAM OPDT OPSP	PCT01 PCT02 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	1200..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	.C900	.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	-.280	-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	17.400	18.100	18.300	17.900	17.200	13.700	4.300	.000	.000	.000	.000	.000	.000
.000	4.600	19.200	17.400	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.= 1.760

.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	7.900	10.800	11.900	10.600	9.600	8.900	7.000	2.800	-1.300	.000	.000	.000	.000	.000	.000
.000	7.900	10.800	11.900	10.600	9.600	8.900	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,JALPM,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,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

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

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
.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.= .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,JALPH,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,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

CLN (YAW 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

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

MACH NO.= 1.960

.080	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0C0	.000	.000	.000	.000
.000	.000	.000	.C00	.000	.000	.000	.0C0	.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	.D00	.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	.0C0	.000	.000	.C00	.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))

.0C0	.000	.000	.000	.000	.000	.000	.000
.050	.050	.000	.0C0	.000	.000	.000	.000
.320	.320	.000	.000	.000	.000	.000	.C00
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	.050	.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 TXB TYB TZB GAME CHIE MPAL	X Y Z PSIE THEE PHIE MPAS	XD YD ZD PSIDE THEDE PHIDE DMD	XDD YDD ZDD PSIDDE THEDDE PHIDDE QMAXPB	FX FY FZ QPSI QTHE QPHI IXPB	CA CN CY CLN CLM CLL IYPB	V AM DYPR ALPE PHIIE PHIAE SPD	TENS LT TPD OMXBE OMYBE OMZBE SP	XP YP ZP PSIPE THEPE KS SPRU	XPD YPD ZPD PSIPDE THEPDE CLLP SPRL	XPDD YPDD ZPDD PSPDDE THPDDE CLMW TINT	FXP FYP FZP QPSIP QTHEP CLNR TNINY	CDAP CNP TYPR TZPB TPDXB TPDRB TFI	CMP AMP DYPRP ALPPE GAMPE PULAN 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.	48.033	-4.331	-21775.	.150	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	29984.0	387.7	13.82	1879.10	8.00	.00000	.00000	.53811	552.30
.0400	2.	47.989	-4.337	-21804.	.150	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.	.149	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.	8.	.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
TRB	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	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	8.095	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.	98.	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 TXB TYB TZB GAME CHIE MPAL	X Y Z PSIE THEE PHIE MPAS	XD YD ZD PSIDE THEDE PHIDE DMD	XDD YDD ZDD PSIDDE THEDDE PHIDDE QHAXPB	FX FY FZ QPSI QTHE QPHI IXPB	CA CN CY CLN CLM CLL IYPB	V AM DYPR ALPE PHIIE PHIAE SPD	TENS LT TPD OMXBE OMYBE OMZBE SP	XP YP ZP PSIPE THEPE KS SRRU	XPD YPD ZPD PSIPDE THEPDE CLLP SPRL	XPDD YPDD ZPDD PSPDDE THPDDE CLMQ TINT	FXP FYP FZP QPSIP QTHEP CLNR THINY	CDAP CNP TYPB TZPB TPDXB TPDRB TFI	CMP AMP DYPRP ALPPE GAMPE PULAN 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.	.046
-86.220	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.	44.969	-10.176	-31613.	-.032	541.19	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
-86.234	9.575	25.632	112.241	846557.	3.088	-.000	-25.632	274.722	-2.550	-20.574	-8559.	15441.	-85.187
.000	-.000	-.000	.000	0.	.000	.000	.000	22349.	.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	-20.671	-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
MPAL	MPAS	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.	.197
-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	-25.910	-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.	8.549	.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	-74.9	.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.	17245.	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	CDAP	CMP
TXB	Y	YD	YDD	FY	C	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	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	TPDRB	PULAN
MPAL	MPAS	DMC	QMAXPB	IXPB	IYPB	SPD	SP	SPRU	SPRL	TINT	TNINY	TPI	XPBDI
.6000	28.	44.090	-11.592	-36123.	-.151	537.37	195614.	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
-503393.	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	.000	.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.	1744.	-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

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