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COMPUTER PROGRAM DEVELOPMENT AND USER'S MANUAL FOR PROGRAM PARACH

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16. ABSTRACT

A user's manual is provided for program PARACH, a Fortran digital computer program operational on the Univac 1108. A description of the program and operating instructions for it are included. Program PARACH has been extensively used to study the interaction dynamics of a parachute and its payload during terminal descent. Operating instructions, required input data, program options and limitations, and output data are described. Subroutines used in this program are also listed and explained.

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Computer Program Development and User's Manual for Program PARACH

I. INTRODUCTION

This user's manual furnishes complete documentation on Program PARACH, a digital simulation currently being used to investigate the interaction dynamics of a parachute-spent Solid Rocket Booster (SRB) during terminal descent. Program PARACH is written in Fortran and is operational on the Univac 1108 and EMR 6050 computers. The EMR 6050 is used because of the graphic display capabilities of the computer.

Section II presents a discussion of the mathematical model and a summary of resulting equations, while Section III furnishes a description of the program's subroutines. Section IV is a listing of input variables used in the program and their definitions. Finally, Section V gives a program flow chart and a listing of the program.

II. MATHEMATICAL MODEL

The math model simulates a SRB with two parachutes attached at different points on the SRB. Runs made up to now only use one parachute. The other one is zeroed out.

Assumptions - Several assumptions are made to simplify the 3 dimensional math model formulation and its implementation into a digital computer simulation called Program PARACH. These are:

- All bodies are considered as rigid bodies,
- The mass and aerodynamic forces of the suspension lines are neglected,
- The center of pressure and center of volume for the parachute canopy are assumed to be located at the center of mass of the canopy material.

Parachute Configuration - The program regards the parachute configuration as a rigid body. It has six degrees of freedom; three translational and three rotational. The main disturbance is due to aerodynamic forces and moments. Use of chute apparent mass and inertia properly distinguishes the parachute from a conventional rigid body.

Booster Configuration - This program also regards the booster as a rigid body. It has six degrees of freedom, 3 translational and 3 rotational. There are aerodynamic forces and moments computed on this rigid body.

System Configuration - The system configuration considers the three rigid bodies to be joined by frictionless attachments that transmit no moments. The attach point constraint relationships are formed by requiring the inertial velocities of the bodies to be the same at the attach point.

Atmospheric Mass Density - Density is calculated using the following equation: $\rho = K * EXP\ (A_0 + A_1\ Z + A_2\ Z^2 + A_3\ Z^3 + A_4\ Z^4 + A_5\ Z^5)$. The capability to use a constant density and omit the equation is also available.

Parachute and Payload Drag - Drag is a function of velocity, mass density of air, angle-of-attack, reference area, and other factors. Wake effects on either body were not considered.

Rotational Damping Coefficient - The damping on payload and parachute due to rotational velocities is currently set to zero. However, the program includes the provisions to include the rotational damping derivatives.

Retro Thrusters on the Payload - The program has the capability of having eight retro-rockets on the payload, positioned and skewed as desired. There can be more if the appropriate dimension statements are enlarged. At ignition, each thruster follows the thrust profile in the THR table.

Wind Model

Table Look-Up (Subroutine TBL) - A wind table is used as an alternative to a programmed wind profile. The wind table uses subroutine TBL which is an interpolation scheme. The subroutine is used in every other table look-up in this program.

Parachute Side Force - Side forces are considered in this program as part of the parachute dynamics. It is presented here as a function of the angle-of-attack (see figure 1).

Program Equations - The following program equations are computed, accounting for inertial, reaction, gravity, aerodynamic, and thruster forces. The program equations are computed for both the booster and the parachute yielding both translational and rotational accelerations and the sum of the forces acting on the two bodies.

$$\dot{\Omega} = M^{-1} \left(F^{(I)} + F^{(R)} + F^{(A)} + F^{(C)} + F^{(G)}\right)$$

Where: M^{-1} = an 18 x 18 diagonal matrix whose elements are the mass and inertia values for the SRB and the two parachutes.
$F^{(I)}$ = Inertial Forces and Moments (18 x 1 vector)
$F^{(R)}$ = Reaction Forces and Moments (18 x 1 vector)
$F^{(A)}$ = Aerodynamic Forces and Moments (18 x 1 vector)
$F^{(C)}$ = Control Forces and Moments (18 x 1 vector)
$F^{(G)}$ = Gravity Forces and Moments (18 x 1 vector)

$$\Omega^T = (U_1, V_1, W_1, P_1, Q_1, R_1, U_2, V_2, W_2, P_2, Q_2, R_2, U_3, V_3, W_3, P_3, Q_3, R_3)$$

The following equations are used to compute the Inertial Forces and Moments ($F^{(I)}$).

$$F^{(I)} = \left|\begin{array}{l} F_1^{(I)} \\ L_1^{(I)} \\ F_2^{(I)} \\ L_2^{(I)} \\ F_3^{(I)} \\ L_3^{(I)} \end{array}\right| \begin{array}{l} \text{Vehicle} \\ \\ \text{Parachute A} \\ \\ \text{Parachute B} \\ \end{array}$$

Where:

$$F_i^{(I)} = -M_i \tilde{\Omega}_i V_i \qquad L_i^{(I)} = -\tilde{\Omega}_i I_i \Omega_i$$

$$\tilde{\Omega}_i = \begin{vmatrix} 0 & -R_i & Q_i \\ R_i & 0 & -P_i \\ -Q_i & P_i & 0 \end{vmatrix} \qquad I_i = \begin{vmatrix} I_{xi} & 0 & 0 \\ 0 & I_{yi} & 0 \\ 0 & 0 & I_{zi} \end{vmatrix}$$

$$M_i = \begin{vmatrix} m_i & 0 & 0 \\ 0 & m_i & 0 \\ 0 & 0 & m_i \end{vmatrix} \qquad \underline{\Omega}_i = \begin{vmatrix} P_i \\ Q_i \\ R_i \end{vmatrix}$$

$$\underline{V}_i = \begin{vmatrix} U_i \\ V_i \\ W_i \end{vmatrix}$$

$i = 1, 2, 3$

and: U_i, V_i, W_i are the linear velocities of the respective bodies, M_i is the mass term and P_i, Q_i, R_i are the angular velocities of the respective bodies.

Coordinate Transformations:

The general transformation between any two Euclidean coordinate systems is written in terms of Euler parameters (quaternions) as:

$$G_i = \begin{bmatrix} (q_1^i)^2 - (q_2^i)^2 - (q_3^i)^2 + (q_4^i)^2 & 2\,(q_1^i\, q_2^i + q_3^i\, q_4^i) & 2\,(q_1^i\, q_3^i - q_2^i\, q_4^i) \\ 2\,(q_1^i\, q_2^i - q_3^i\, q_4^i) & -(q_1^i)^2 + (q_2^i)^2 - (q_3^i)^2 + q_4^i)^2 & 2\,(q_2^i\, q_3^i + q_1^i\, q_4^i) \\ 2\,(q_1^i\, q_3^i + q_2^i\, q_4^i) & 2\,(q_2^i\, q_3^i - q_1^i\, q_4^i) & -(q_1^i)^2 - (q_2^i)^2 + (q_3^i)^2 + (q_4^i)^2 \end{bmatrix}$$

Where:

G_1 (transformation from inertial to SRB frame)
G_2 (transformation from inertial to parachute A frame)
G_3 (Transformation from inertial to parachute B frame)
$G_1^2 = G_2\, G_1^T$ (transformation from SRB to parachute A)
$G_1^3 = G_3\, G_1^T$ (transformation from SRB to parachute B)

The q's in the coordinate transformation matrices are quaternions given by the following equations:

$$q_1^i = \sin\frac{\varphi_i}{2}\cos\frac{\psi_i}{2}\cos\frac{\theta_i}{2} - \sin\frac{\psi_i}{2}\sin\frac{\theta_i}{2}\cos\frac{\varphi_i}{2}$$

$$q_2^i = \sin\frac{\theta_i}{2}\cos\frac{\psi_i}{2}\cos\frac{\varphi_i}{2} + \sin\frac{\psi_i}{2}\sin\frac{\varphi_i}{2}\cos\frac{\theta_i}{2}$$

$$q_3^i = \sin\frac{\psi_i}{2}\cos\frac{\theta_i}{2}\cos\frac{\varphi_i}{2} - \sin\frac{\theta_i}{2}\sin\frac{\varphi_i}{2}\cos\frac{\psi_i}{2}$$

$$q_4^i = \cos\frac{\psi_i}{2}\cos\frac{\theta_i}{2}\cos\frac{\varphi_i}{2} + \sin\frac{\psi_i}{2}\sin\frac{\theta_i}{2}\sin\frac{\varphi_i}{2}$$

Where θ_i, φ_i, and ψ_i are the Euler angles
i = 1 refers to the SRB
i = 2 refers to parachute A
i = 3 refers to parachute B

The differential equation governing the evolution of the quarternions as a function of time is given by:

$$\begin{vmatrix} \dot{q}_1^i \\ \dot{q}_2^i \\ \dot{q}_3^i \\ \dot{q}_4^i \end{vmatrix} = \begin{vmatrix} 0 & -R_i & Q_i & -P_i \\ R_i & 0 & -P_i & Q_i \\ -Q_i & P_i & 0 & -R_i \\ P_i & Q_i & R_i & 0 \end{vmatrix} \cdot \begin{vmatrix} q_1^i \\ q_2^i \\ q_3^i \\ q_4^i \end{vmatrix}$$

Likewise, the Gravity Forces and Moments ($F^{(G)}$) are derived from the following:

$$F^{(G)} = \begin{vmatrix} F_1^{(G)} \\ 0 \\ F_2^{(G)} \\ 0 \\ F_3^{(G)} \\ 0 \end{vmatrix}$$

Where: $F_i^{(G)} = \begin{vmatrix} G_i \end{vmatrix} \cdot \begin{vmatrix} 0 \\ 0 \\ m_i g \end{vmatrix}$

m_i is the appropriate actual mass term

g is the gravitational force

The thrust vector due to retro-rockets is computed using the following equations

$$
F_i^{(C)} = \begin{cases}
F_1^{(C)} = \text{THR}(t) \cdot \sum_{i=1}^{M} \text{DCOSX}(i) \\
F_2^{(C)} = \text{THR}(t) \sum_{i=1}^{M} \text{DCOSY}(i) \\
F_3^{(C)} = \text{THR}(t) \sum_{i=1}^{M} \text{DCOSZ}(i) \\
F_4^{(C)} = \text{THR}(t) \sum_{i=1}^{M} (\text{YR}(i)\,\text{DCOSZ}(i) - \text{ZR}(i)\,\text{DCOSY}(i)) \\
F_5^{(C)} = \text{THR}(t) \sum_{i=1}^{M} (\text{ZR}(i)\,\text{DCOSX}(i) - \text{XR}(i)\,\text{DCOSZ}(i)) \\
F_6^{(C)} = \text{THR}(t) \sum_{i=1}^{M} (\text{XR}(i)\,\text{DCOSY}(i) - \text{YR}(i)\,\text{DCOSX}(i)) \\
F_7^{(C)} = 0 \\
\vdots \\
F_{18}^{(C)} = 0
\end{cases}
$$

Where: THR(t) is the thrust profile as a function of time (t).

DCOSX(i), DCOSY(i), and DCOSZ(i) are the direction cosines of the thrust vector.

XR(i), YR(i), ZR(i) are the moment arms of the retro-rockets.

The aerodynamic forces and moment vectors are computed using the following equations:

$$
F^{(A)} = \begin{vmatrix}
F_1^{(A)} \\
L_1^{(A)} \\
F_2^{(A)} \\
L_2^{(A)} \\
F_3^{(A)} \\
L_3^{(A)}
\end{vmatrix}
$$

Where:

$$f_i^{(A)} = \begin{vmatrix} f_{xi} \\ f_{yi} \\ f_{zi} \end{vmatrix} \quad \text{and} \quad L_i^{(A)} = \begin{vmatrix} L_i \\ M_i \\ N_i \end{vmatrix}$$

Define:

$$f_{xi} = -\tfrac{1}{2}\rho V^2 S C_{N(i)} \frac{\hat{U}_i}{(\hat{U}_i^2 + \hat{V}_i^2)^{\frac{1}{2}}}$$

$$f_{yi} = -\tfrac{1}{2}\rho V^2 S C_{N(i)} \frac{\hat{V}_i}{(\hat{U}_i^2 + \hat{V}_i^2)^{\frac{1}{2}}}$$

$$f_{zi} = \tfrac{1}{2}\rho V^2 S C_{A(i)}$$

$$L_i = \tfrac{1}{2}\rho V^2 S \ell C_{M(i)} \frac{\hat{V}_i}{(\hat{U}_i^2 + \hat{V}_i^2)^{\frac{1}{2}}}$$

$$M_i = -\tfrac{1}{2}\rho V^2 S \ell C_{M(i)} \frac{\hat{U}_i}{(\hat{U}_i^2 + \hat{V}_i^2)^{\frac{1}{2}}}$$

$$N_i = 0.0$$

$$V^2 = (\hat{U}_i^2 + \hat{V}_i^2 + \hat{W}_i^2)$$

S = Reference Area (May be computed as a function of time (reefing))

ℓ = Reference Length

The calculation of the reaction force is quite a bit more complicated as far as computational procedures are concerned and is given by the following equations

$$F^{(R)} = T_1 (F^{(I)} + F^{(A)} + F^{(C)} + F^{(G)}) + T_2 . \Omega$$

Where:

$$T_1 = (-B^T K^{-1})\ (BM^{-1})$$

$$T_2 = -B^T K^{-1} \dot{B}$$

$$K = BM^{-1} B^T$$

$$B = \begin{vmatrix} G_1^2 & G_1^2 . \tilde{\ell}_1 & -E_3 & \tilde{\ell}_{A_1} & 0 & 0 \\ G_1^3 & -G_1^3 . \tilde{\ell}_2 & 0 & 0 & -E_3 & \tilde{\ell}_{B_1} \end{vmatrix}$$

$$\tilde{\ell}_i = \begin{vmatrix} 0 & -\ell_{iz} & \ell_{iy} \\ \ell_{iz} & 0 & \ell_{ix} \\ -\ell_{iy} & \ell_{ix} & 0 \end{vmatrix}$$

$$\tilde{\ell}_{Al} = \begin{vmatrix} 0 & -\ell_{Al_Z} & \ell_{Al_Y} \\ \ell_{Al_Z} & 0 & \ell_{Al_X} \\ -\ell_{Al_Y} & \ell_{Al_X} & 0 \end{vmatrix}$$

$$\tilde{\ell}_{Bl} = \begin{vmatrix} 0 & -\ell_{Bl_Z} & \ell_{Bl_Y} \\ \ell_{Bl_Z} & 0 & \ell_{Bl_X} \\ -\ell_{Bl_Y} & \ell_{Bl_X} & 0 \end{vmatrix}$$

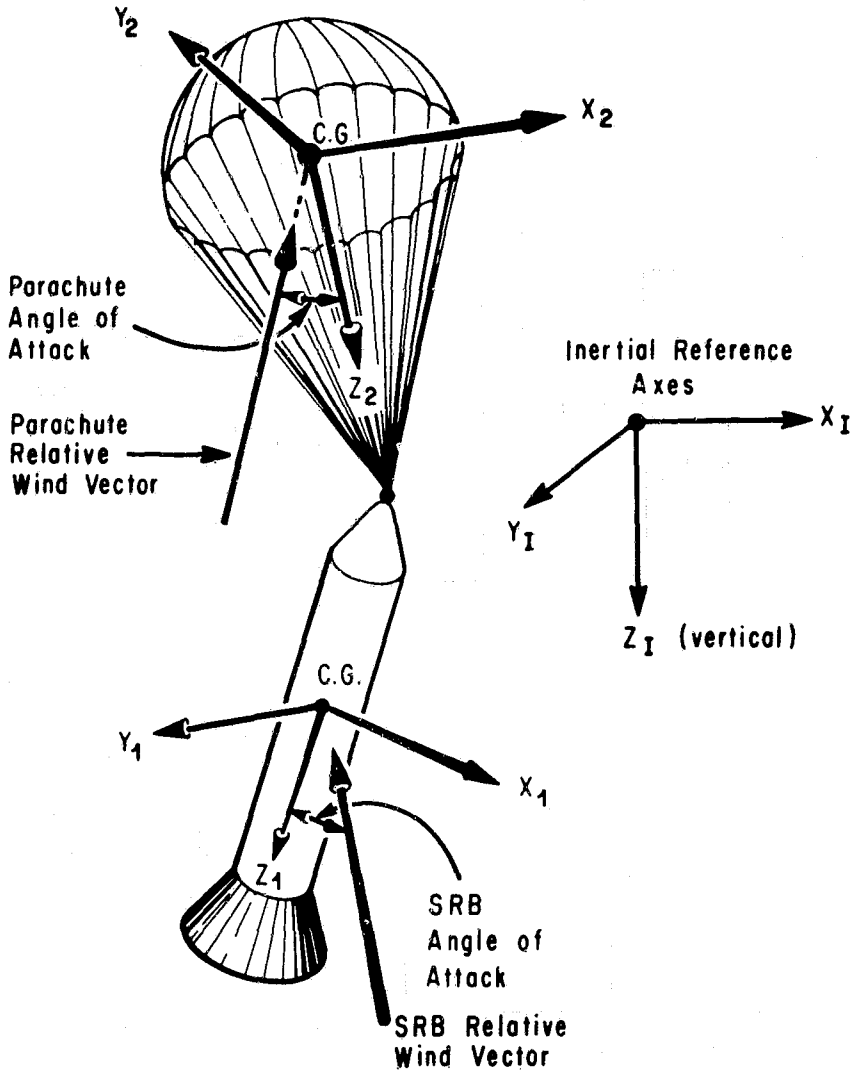


FIG. 1. PROGRAM COORDINATE SYSTEMS

III. PROGRAM SUBROUTINES

Subroutine: RUNGE

Purpose: Subroutine RUNGE is a subroutine used to integrate the differential equations and produces a table of integrated values.

Use: RUNGE (KUTTA, TIME, DT, NVAR, NDVAR)

Description of Parameters:

KUTTA - is a control integer (controls the number of times through integration loop)

TIME - is time of integration

DT - is the time increment

NVAR - is the number of variables to be integrated once

NDVAR - is the number of variables to be integrated twice

Remarks: Fourth-order RUNGE-KUTTA

Subroutine: TBL

Purpose: This subroutine provides a linear interpolation between data points in a tabular function of one variable.

Use: TBL (X, Y, X1, N, Y1)

Description of Parameters:

X - is the independent variable

Y - is the dependent variable

X1 - is the X argument

N - is the number of data points in the table

Y - is the result desired

Remarks: The X array of data must be in ascending order.

Subroutine: LINSYS

Purpose: This subroutine takes the inverse of a matrix.

Use: LINSYS (A, NROWSA, NCOLSA, DET, B, ARRAY)

Description of Parameters:

A - is the array containing the coefficients of the linear system.

NROWSA - is the number of rows of the square Matrix A.

NCOLSB - is the number of columns of the Matrix B in the equation A*X = B.

DET - is the determinate of Matrix A

B - is the Matrix B = A*X

NARRAY - is the number of rows of the arrays in which A and B are stored in the calling program.

Subroutine: XTAN 2

Purpose: This subroutine is used to define correct quadrant.

Use: XTAN 2 (A, B)

Description of Parameters:

A - is the value of the numerator of the angle.

B - is the value of the denominator of the angle.

IV. INPUT PARAMETERS

FØRTRAN MNEMONIC	ENGINEERING SYMBOLS	TYPE	DEFINITIONS
X1	X_1	R	Inertial Location of SRB CG in the x Direction
Y1	Y_1	R	Inertial Location of SRB CG in the y Direction
Z1	Z_1	R	Inertial Location of SRB CG in the z Direction
U1	U_1	R	Inertial Velocity of the SRB CG in the x Direction
V1	V_1	R	Inertial Velocity of the SRB CG in the y Direction
W1	W_1	R	Inertial Velocity of the SRB CG in the z Direction
X2	X_2	R	Inertial Location of Parachute A CG in the x Direction
Y2	Y_2	R	Inertial Location of Parachute A CG in the y Direction
Z2	Z_2	R	Inertial Location of Parachute A CG in the z Direction
U2	U_2	R	Inertial Velocity of Parachute A CG in the x Direction
V2	V_2	R	Inertial Velocity of Parachute A CG in the y Direction
W2	W_2	R	Inertial Velocity of Parachute A CG in the z Direction

Note: Any consistent set of units may be used.

FØRTRAN MNEMONIC	ENGINEERING SYMBOLS	TYPE	DEFINITIONS
X3	X_3	R	Inertial Location of Parachute B CG in the x Direction
Y3	Y_3	R	Inertial Location of Parachute B CG in the y Direction
Z3	Z_3	R	Inertial Location of Parachute B CG in the z Direction
N	N	I	(9) Number of Data Points in Table
N1	N_1	I	(41) Number of Data Points in Table
U3	u_3	R	Inertial Velocity of Parachute B CG in the x Direction
V3	v_3	R	Inertial Velocity of Parachute B CG in the y Direction
W3	w_3	R	Inertial Velocity of Parachute B CG in the z Direction
P1	P_1	R	Angular velocity of SRB About the x1 Axis
Q1	Q_1	R	Angular velocity of SRB About the y1 Axis
R1	R_1	R	Angular velocity of SRB About the z1 Axis
THI1	Θ_1	R	2nd Euler Angle of SRB
PHI1	ϕ_1	R	3rd Euler Angle of SRB
PSI1	ψ_1	R	1st Euler Angle of SRB
P2	P_2	R	Angular Rotation of Parachute A about the x2 Axis

FØRTRAN MNEMONIC	ENGINEERING SYMBOLS	TYPE	DEFINITIONS
Q2	Q_2	R	Angular velocity of Parachute A About the y2 Axis
R2	R_2	R	Angular velocity of Parachute A About the z2 Axis
THI2	Θ_2	R	2nd Euler Angle of Parachute A
PHI2	ϕ_2	R	3rd Euler Angle of Parachute A
PSI2	ψ_2	R	1st Euler Angle of Parachute A
P3	P_3	R	Angular velocity of Parachute B About the x3 Axis
Q3	Q_3	R	Angular velocity of Parachute B About the y3 Axis
R3	R_3	R	Angular velocity of Parachute B About the z3 Axis
THI3	Θ_3	R	2nd Euler Angle of Parachute B
PHI3	ϕ_3	R	3rd Euler Angle of Parachute B
PSI3	ψ_3	R	1st Euler Angle of Parachute B
XIX1	I_{x_1}	R	Moment of Inertia About x_1 Axis of SRB
XIY1	I_{y_1}	R	Moment of Inertia About y_1 Axis of SRB
XIZ1	I_{z_1}	R	Moment of Inertia About z_1 Axis of SRB
XIX2	I_{x_2}	R	Moment of Inertia About x_2 Axis of Parachute A

FØRTRAN MNEMONIC	ENGINEERING SYMBOLS	TYPE	DEFINITIONS
XIY2	I_{y_2}	R	Moment of Inertia About y_2 Axis of Parachute A
XIZ2	I_{z_2}	R	Moment of Inertia About z_2 Axis of Parachute A
XIX3	I_{x_3}	R	Moment of Inertia About x_3 Axis of Parachute B
XIY3	I_{y_3}	R	Moment of Inertia About y_3 Axis of Parachute B
XIZ3	I_{z_3}	R	Moment of Inertia About z_3 Axis of Parachute B
S1	S_1	R	Surface Area of SRB
S2	S_2	R	Surface Area of Parachute A
S3	S_3	R	Surface Area of Parachute B
YL	1	R	Reference Diameter of SRB
YPL	2	R	Reference Diameter of Parachute A
YPL3	3	R	Reference Diameter of Parachute B
XXW2	M_{1g}	R	Weight of Parachute A
XXW3	M_{2g}	R	Weight of Parachute B
XM1	M_1	R	*Mass of SRB
XM21	M_{x2}	R	*Mass of Parachute A in x Direction
XM22	M_{y2}	R	*Mass of Parachute A in y Direction
XM23	M_{z2}	R	*Mass of Parachute A in z Direction

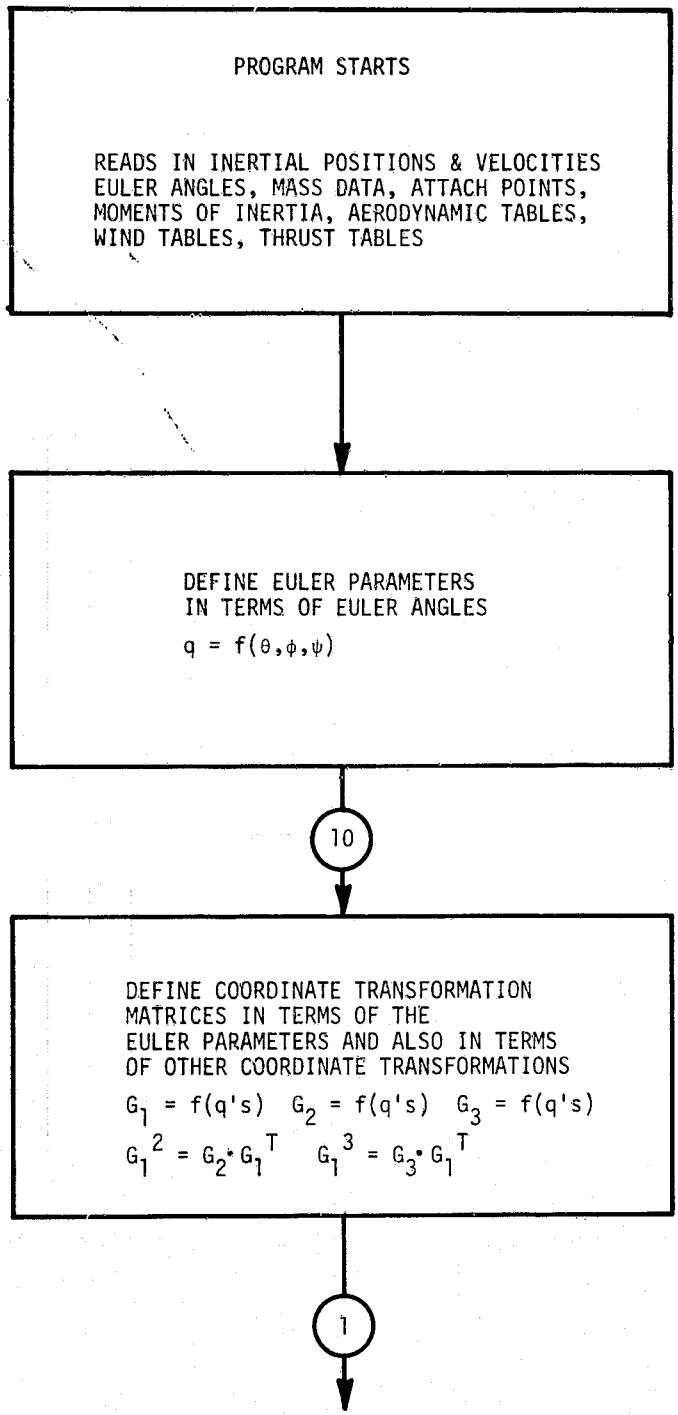
* Mass is equal to total mass plus apparent mass

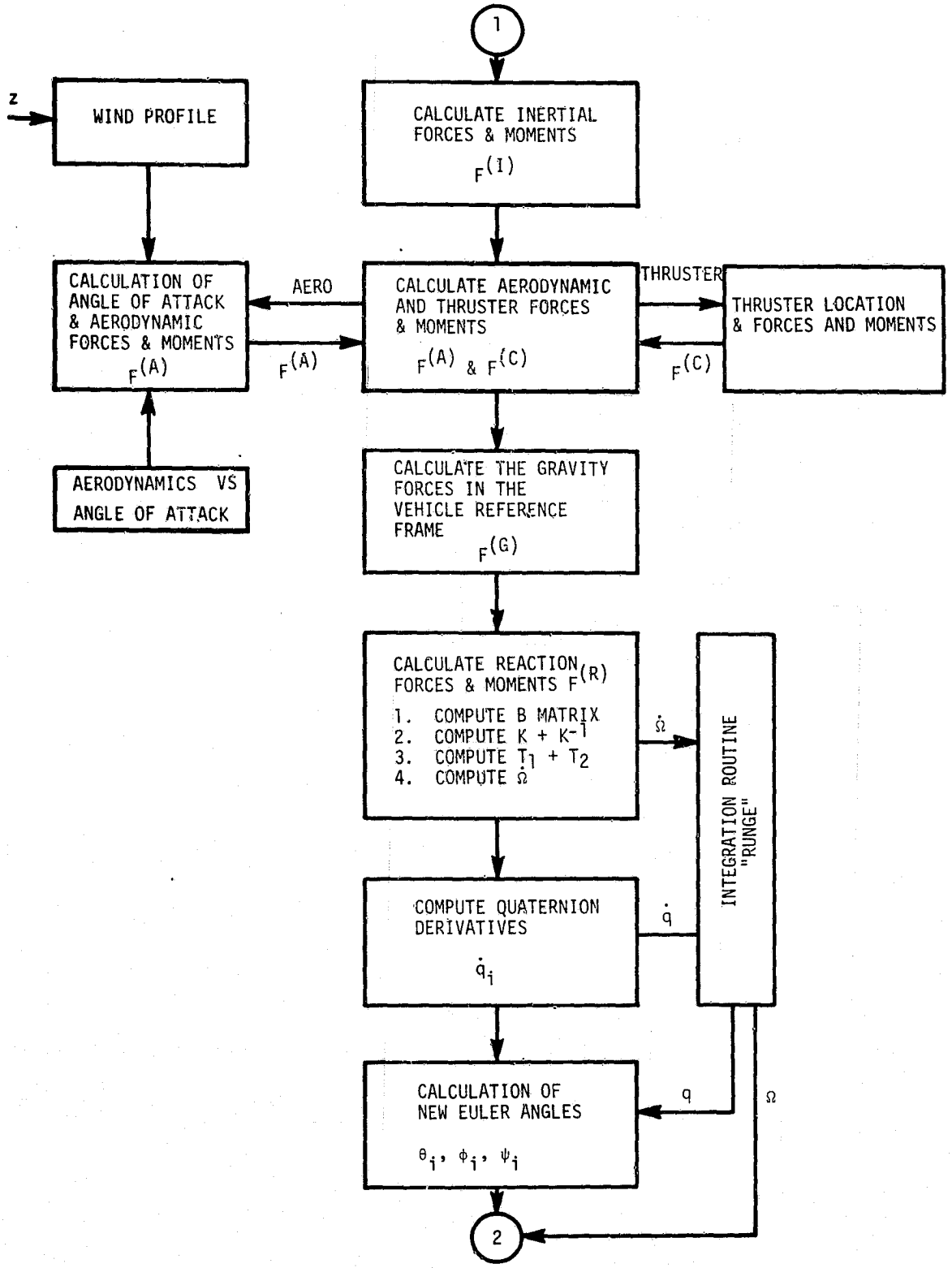
FØRTRAN MNEMONIC	ENGINEERING SYMBOLS	TYPE	DEFINITIONS
XM31	M_{x_3}	R	Mass of Parachute B in x Direction
XM32	M_{y_3}	R	Mass of Parachute B in y Direction
XM33	M_{z_3}	R	Mass of Parachute B in z Direction
G	g	R	Gravity
XLX1	L_{x1}	R	x1 Distance From CG of SRB to Attach Point of Parachute A
XLY1	L_{y1}	R	y1 Distance From CG of SRB to Attach Point of Parachute A
XLZ1	L_{z1}	R	z1 Distance From CG of SRB to Attach Point of Parachute A
XLX2	L_{x2}	R	x1 Distance From CG of SRB to Attach Point of Parachute B
XLY2	L_{y2}	R	y1 Distance From CG of SRB to Attach Point of Parachute B
XLZ2	L_{z2}	R	z1 Distance From CG of SRB to Attach Point of Parachute B
XLAX1	L_{xA}	R	x2 Distance From Attach Point to CG of Parachute A
XLAY1	L_{yA}	R	y2 Distance From Attach Point to CG of Parachute A
XLAZ1	L_{zA}	R	z2 Distance From Attach Point to CG of Parachute A
XLBX1	L_{xB}	R	x3 Distance From Attach Point to CG of Parachute B

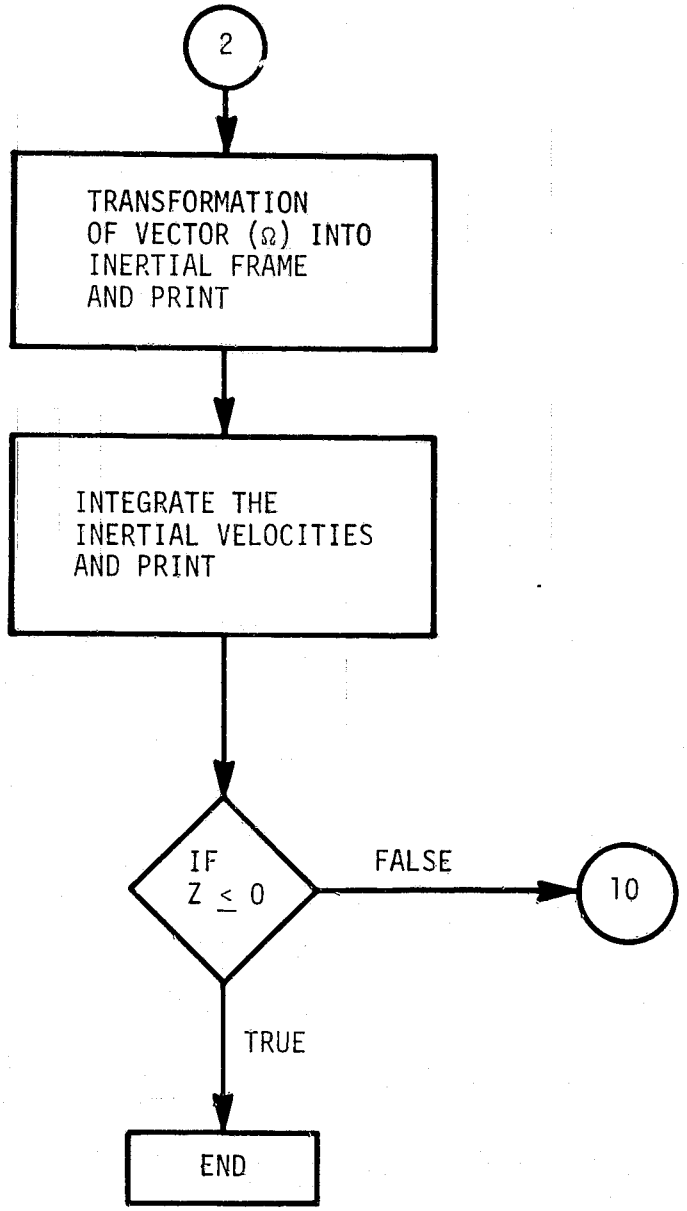
FØRTRAN MNEMONIC	ENGINEERING SYMBOLS	TYPE	DEFINITIONS
XLBX1	L_{xB}	R	y3 Distance From Attach Point to CG of Parachute B
XLBY1	L_{yB}	R	z3 Distance From Attach Point to CG of Parachute B
XLBZ1	L_{zB}	R	Direction Cosines of the Eight Retro-Rockets (I = 1,8)
DCOSX(I)	D cos x(i)	R	Direction Cosines of the Eight Retro-Rockets (I = 1,8)
DCOSY(I)	D cos y(i)	R	Direction Cosines of the Eight Retro-Rockets (I = 1,8)
DCOSZ(I)	D cos z(i)	R	Distance From CG of SRB to Retro-Rockets
LCX(I)	x(i)	R	Distance From CG of SRB to Retro-Rockets
LCY(I)	y(i)	R	Distance From CG of SRB to Retro-Rockets
TIMX(I)	t	R	Time Table
THR(I)	T_{hr}	R	Thrust Table
Z(I)	Z	R	Altitude Table
UWD(I)	U_w	R	u Wind Table
VWD(I)	V_w	R	v Wind Table
AL(I)	α	R	Alpha Table
FCNA1(I)	$C_{N_{\alpha 1}}$	R	Table of Aerodynamic Forces Acting or SRB (Normal)

FØRTRAN MNEMONIC	ENGINEERING SYMBOLS	TYPE	DEFINITIONS
FCAAL(I)	$C_{A_{\alpha 1}}$	R	Table of Aerodynamic Forces Acting or SRB (Axial)
FCMA1(I)	$C_{M_{\alpha 1}}$	R	Table of Aerodynamic Forces Acting or SRB (Moment)
FCNA2(I)	$C_{N_{\alpha 2}}$	R	Table of Aerodynamic Forces Acting on Parachute A (Normal)
FCAA2(I)	$C_{A_{\alpha 2}}$	R	Table of Aerodynamic Forces Acting on Parachute A (Axial)
FCMA2(I)	$C_{M_{\alpha 2}}$	R	Table of Aerodynamic Forces Acting on Parachute A (Moment)
FCNA3(I)	$C_{N_{\alpha 3}}$	R	Table of Aerodynamic Forces Acting on Parachute B (Normal)
FCAA3(I)	$C_{A_{\alpha 3}}$	R	Table of Aerodynamic Forces Acting on Parachute B (Axial)
FCMA3(I)	$C_{M_{\alpha 3}}$	R	Table of Aerodynamic Forces Acting on Parachute B (Moment)

V. FLOW CHART AND PROGRAM LISTING




1
z
WIND PROFILE
CALCULATE INERTIAL FORCES & MOMENTS
$F^{(I)}$
CALCULATION OF ANGLE OF ATTACK & AERODYNAMIC FORCES & MOMENTS
$F^{(A)}$
AERO
$F^{(A)}$
CALCULATE AERODYNAMIC AND THRUSTER FORCES & MOMENTS
$F^{(A)}$ & $F^{(C)}$
THRUSTER
$F^{(C)}$
THRUSTER LOCATION & FORCES AND MOMENTS
AERODYNAMICS VS ANGLE OF ATTACK
CALCULATE THE GRAVITY FORCES IN THE VEHICLE REFERENCE FRAME
$F^{(G)}$
CALCULATE REACTION FORCES & MOMENTS $F^{(R)}$
1. COMPUTE B MATRIX
2. COMPUTE K + K^{-1}
3. COMPUTE T_1 + T_2
4. COMPUTE $\dot{\Omega}$
$\dot{\Omega}$
INTEGRATION ROUTINE "RUNGE"
COMPUTE QUATERNION DERIVATIVES
$\dot{q}_i$
$\dot{q}$
CALCULATION OF NEW EULER ANGLES
θ_i, ϕ_i, ψ_i
q
Ω
2

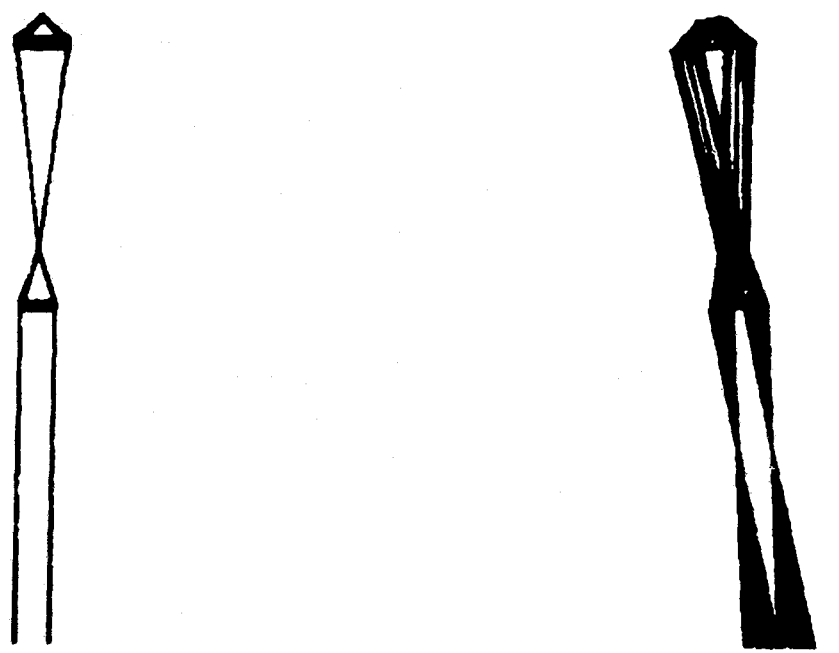

2
TRANSFORMATION OF VECTOR (Ω) INTO INERTIAL FRAME AND PRINT
INTEGRATE THE INERTIAL VELOCITIES AND PRINT
IF Z ≤ 0
FALSE
10
TRUE
END

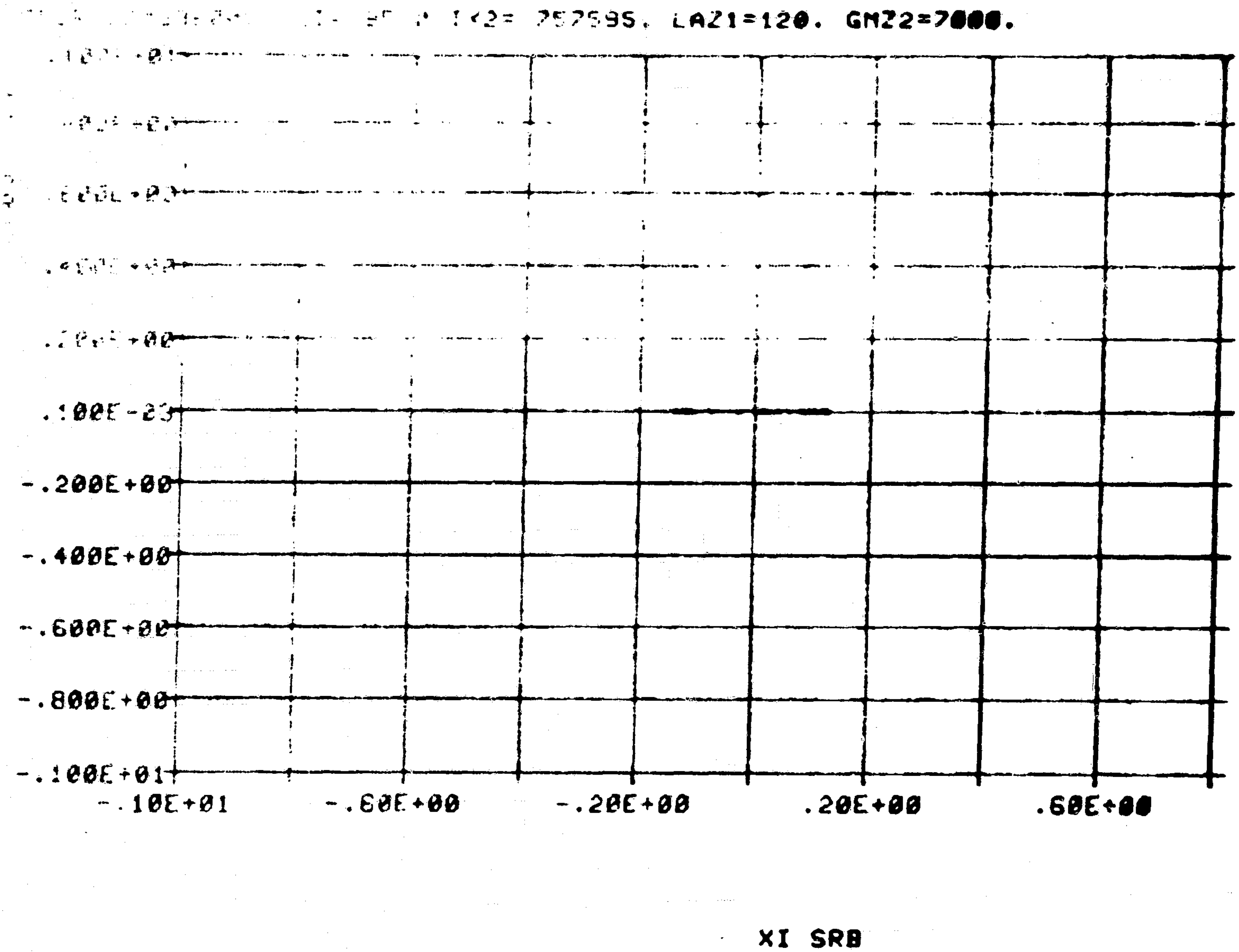
Graphics Display for "PARACH"
(Sample Results)

The following plots were made on the ERR-6050 computer. These are included to illustrate the graphics display capability of the computer.

The curves shown are representative results for one parachute with the appropriate parachute characteristics listed at the top of each graph.

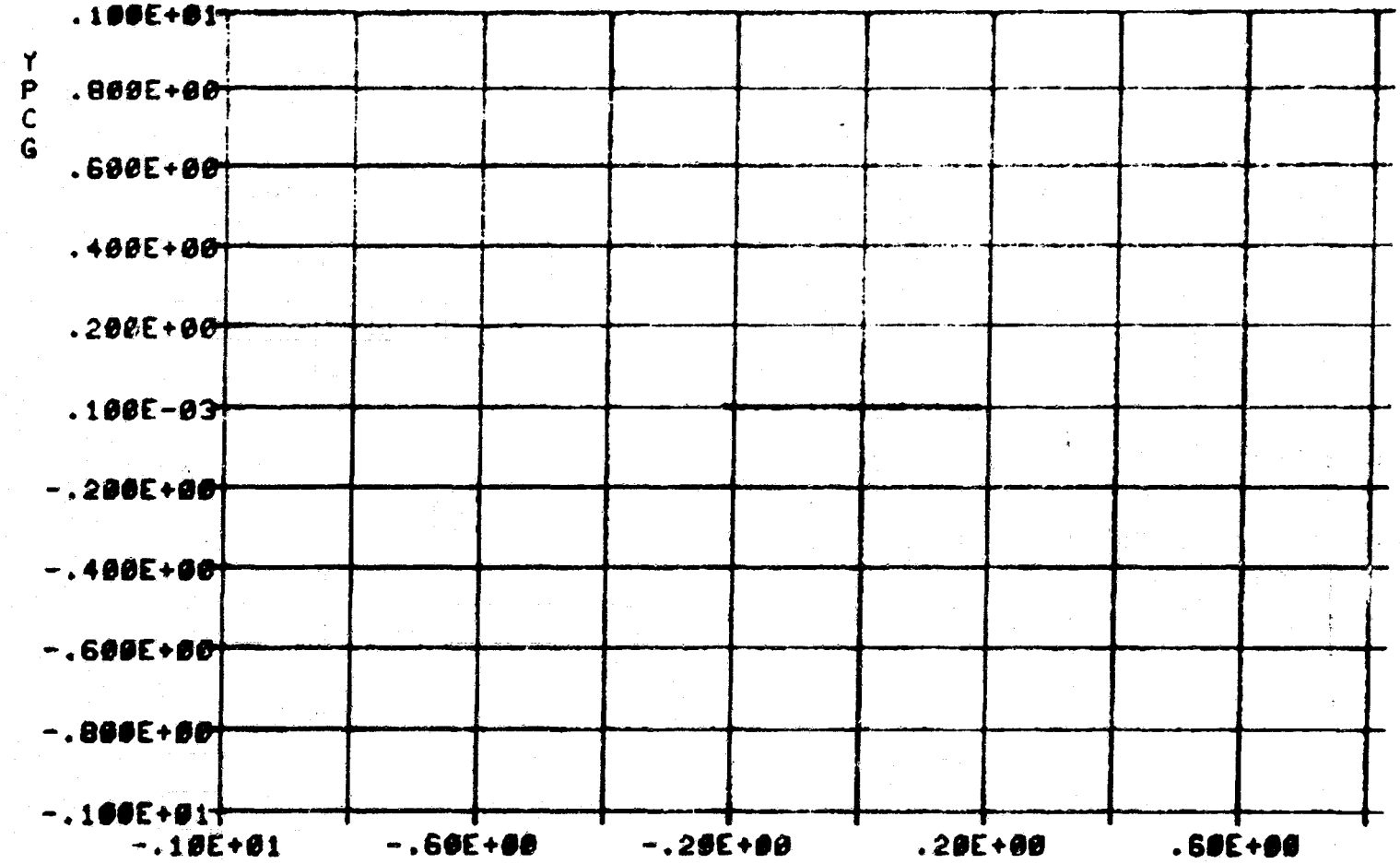
9 19/75SRFC2=39800. W2I= 85.0 IX2= 758[illegible]. LAZ1=120. GMZ2=?000.

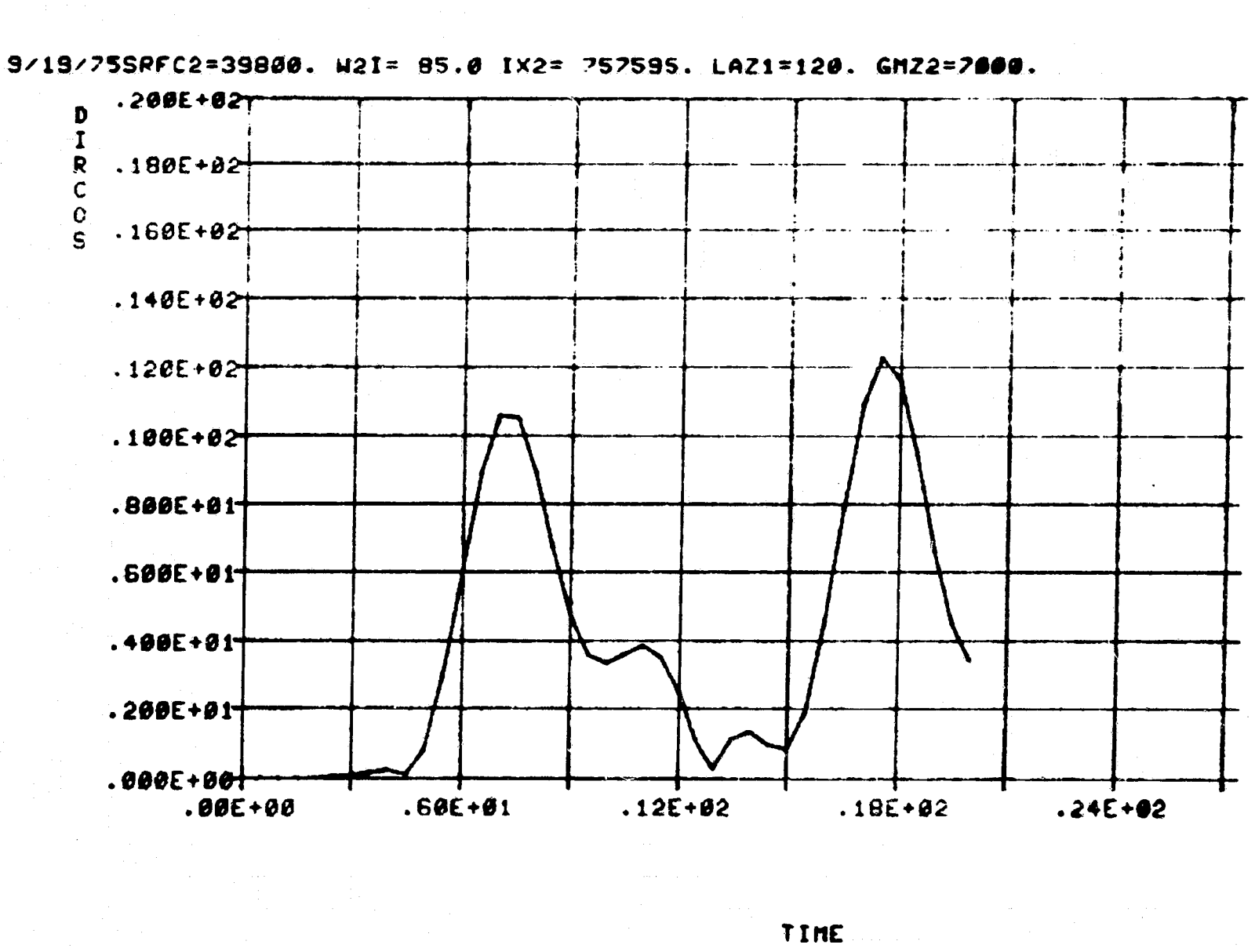


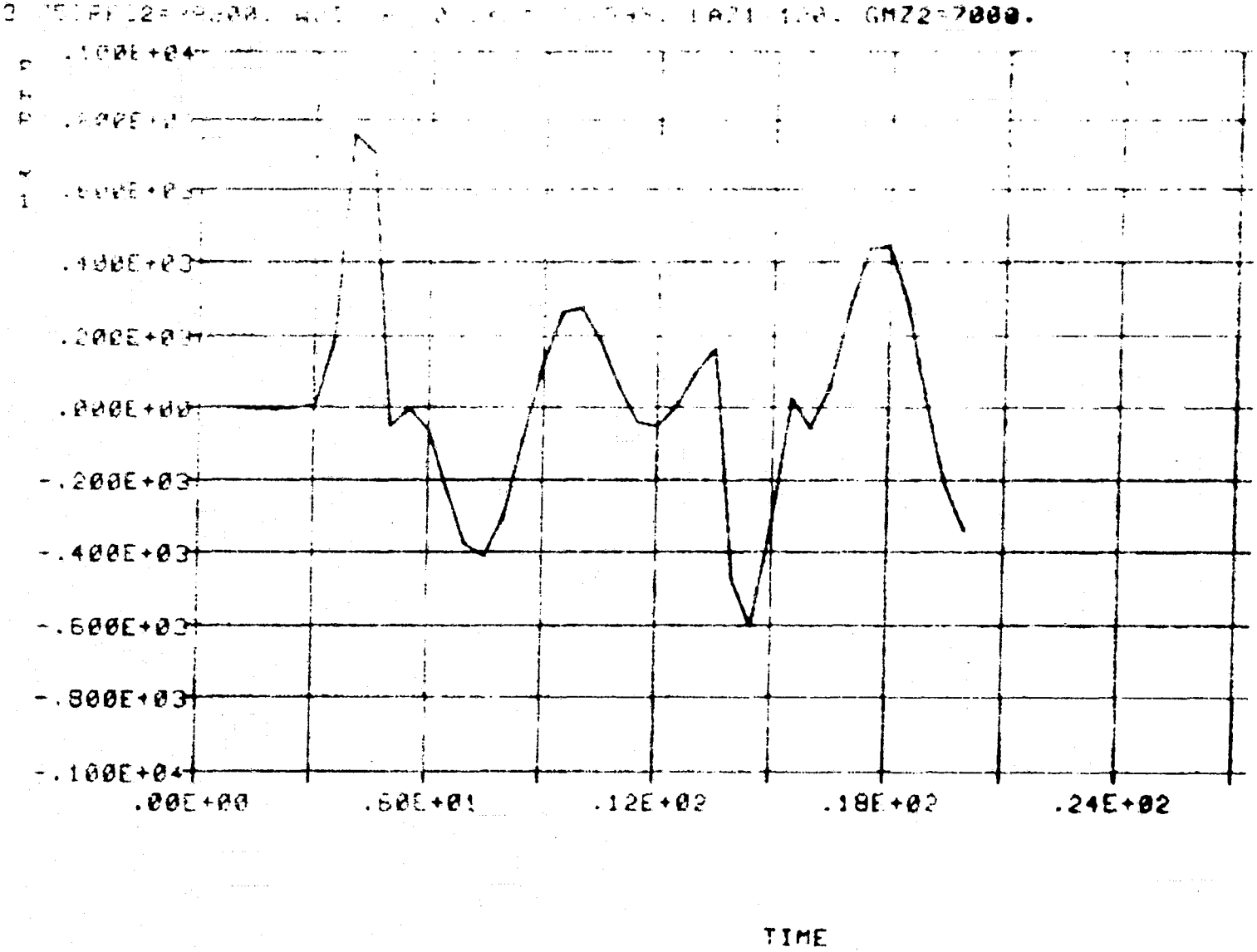


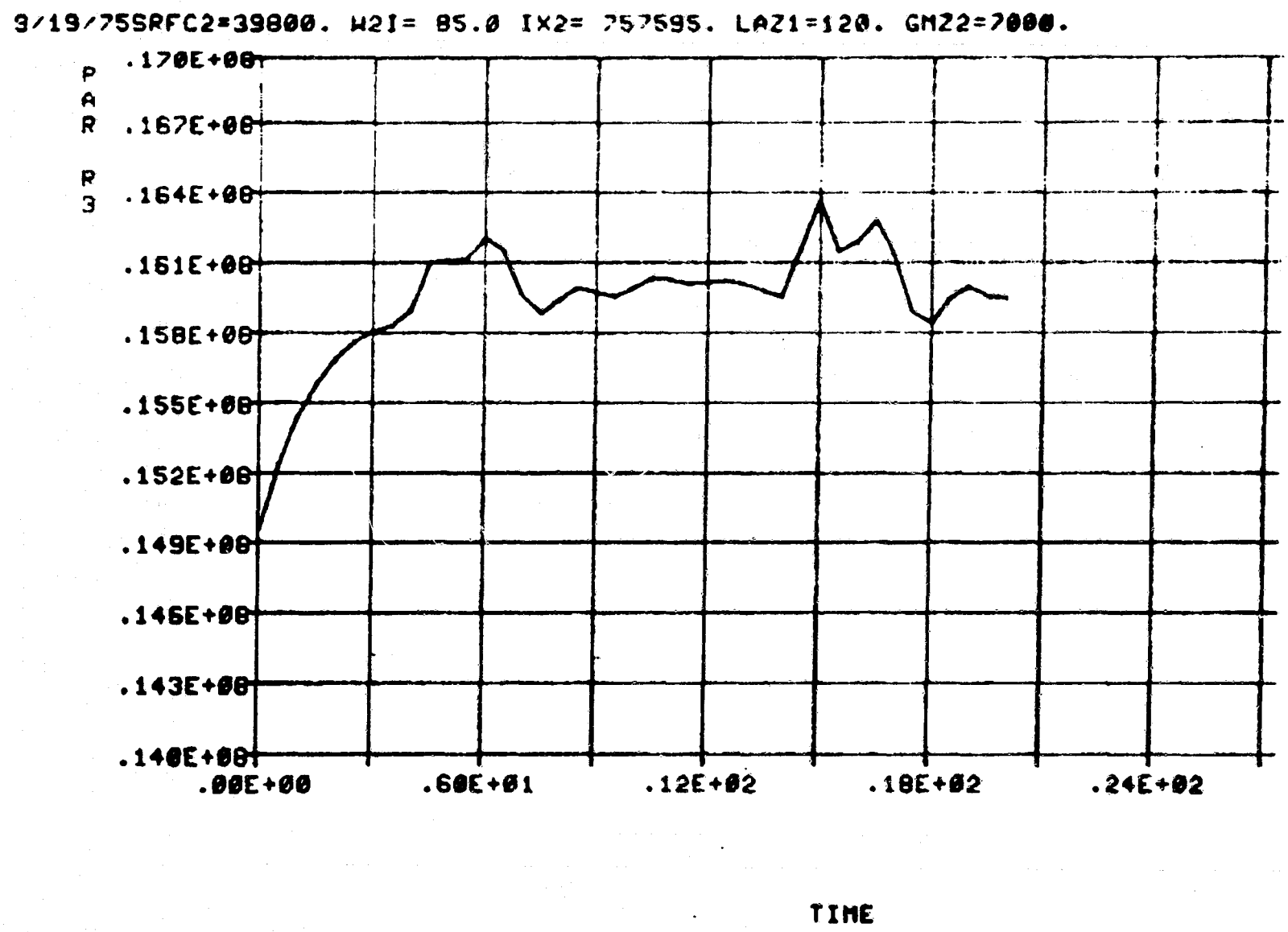
REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

9/19/75SRFC2=39000. W2I= 95.0 IX2= 757595. LAZ1=120. GM22=7000.

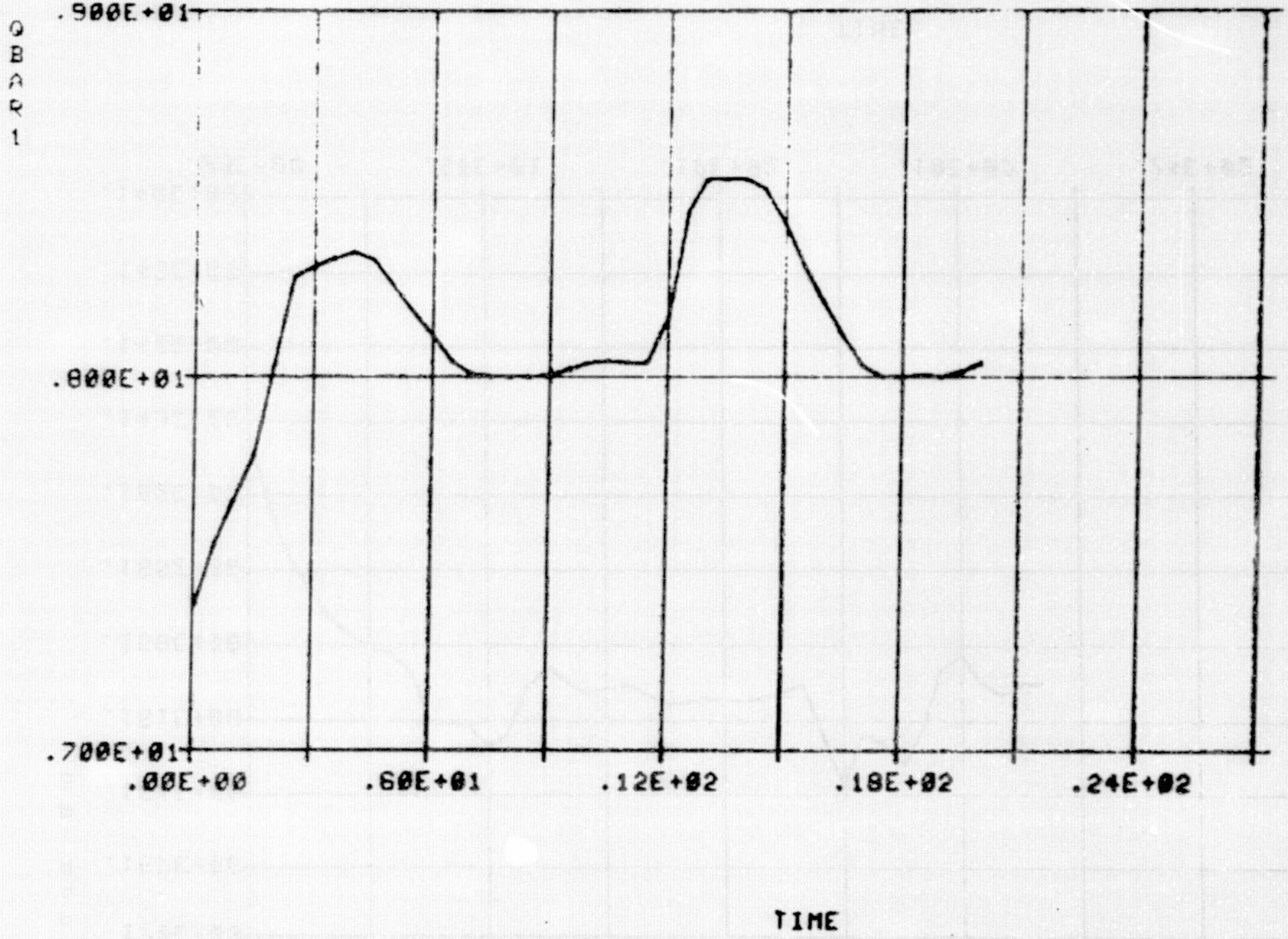


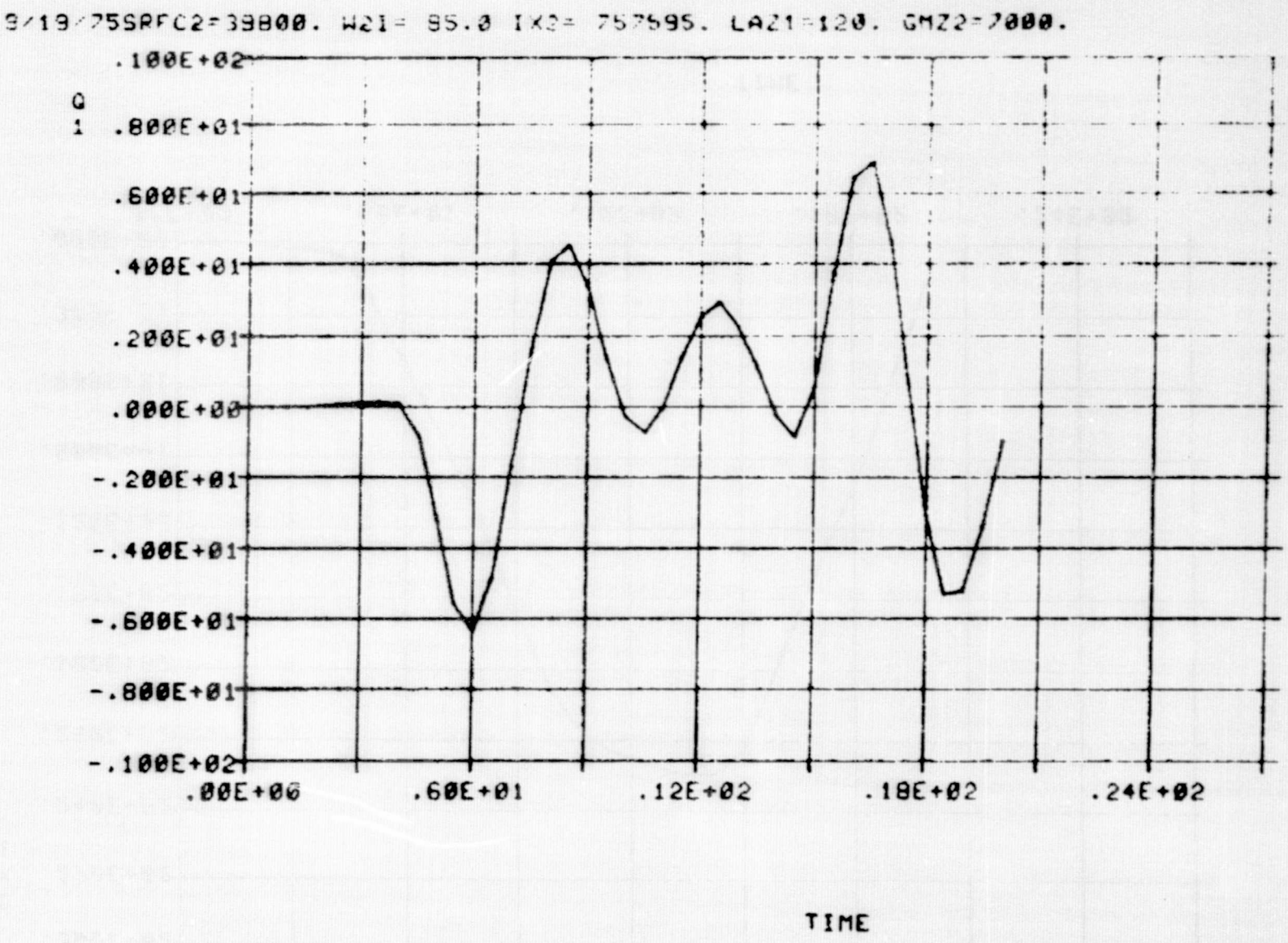

9/19/75SRFC2=39800. W2I= 85.0 IX2= 757595. LAZ1=120. GMZ2=7000.
DIRCOS
.200E+02
.180E+02
.160E+02
.140E+02
.120E+02
.100E+02
.800E+01
.600E+01
.400E+01
.200E+01
.000E+00
.00E+00
.60E+01
.12E+02
.18E+02
.24E+02
TIME



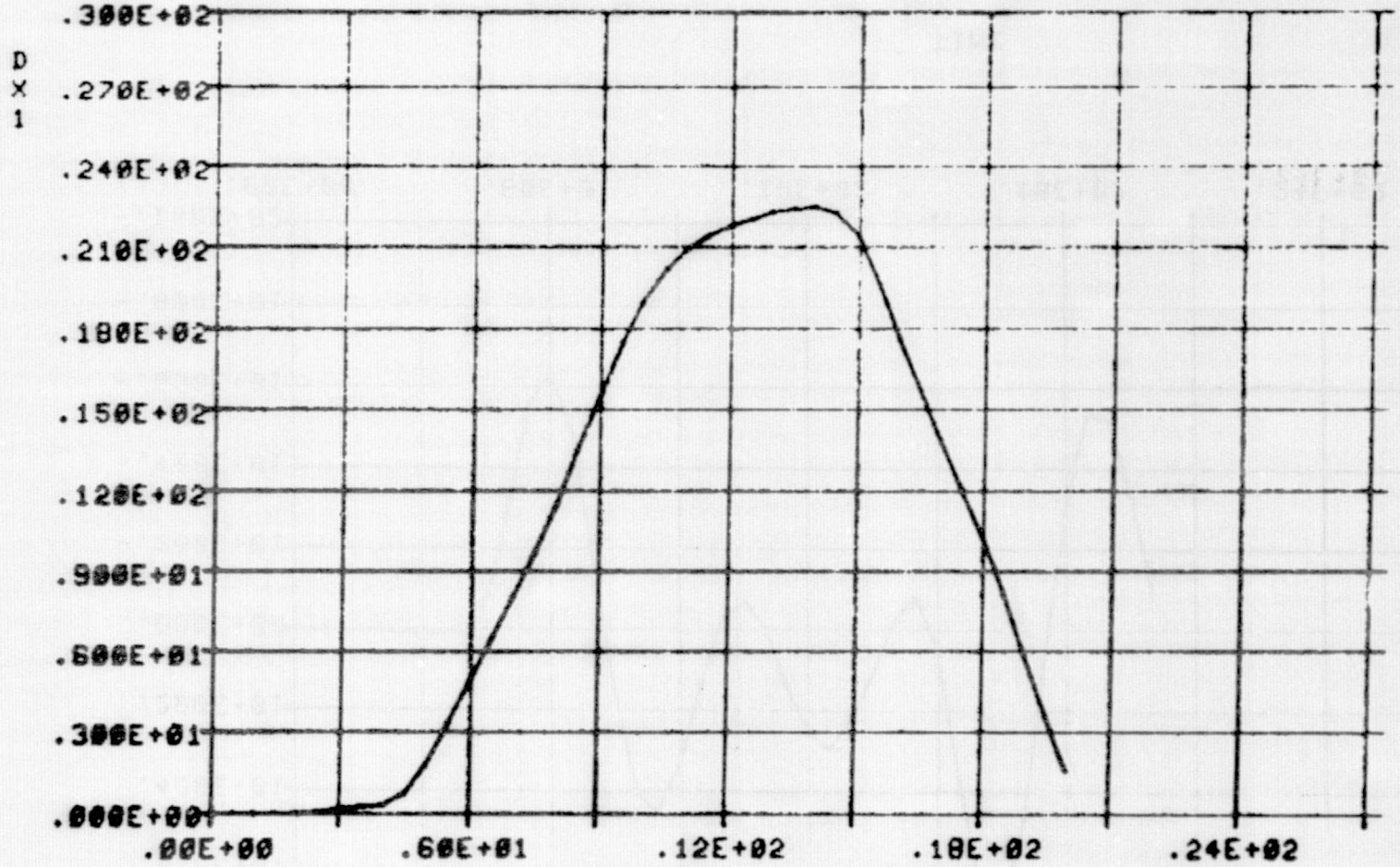

3/19/75SRFC2=39800. W2I= 85.0 IX2= 757595. LAZ1=120. GM22=7000.
PAR R3
.170E+00
.167E+00
.164E+00
.161E+00
.158E+00
.155E+00
.152E+00
.149E+00
.146E+00
.143E+00
.140E+00
.00E+00
.60E+01
.12E+02
.18E+02
.24E+02
TIME

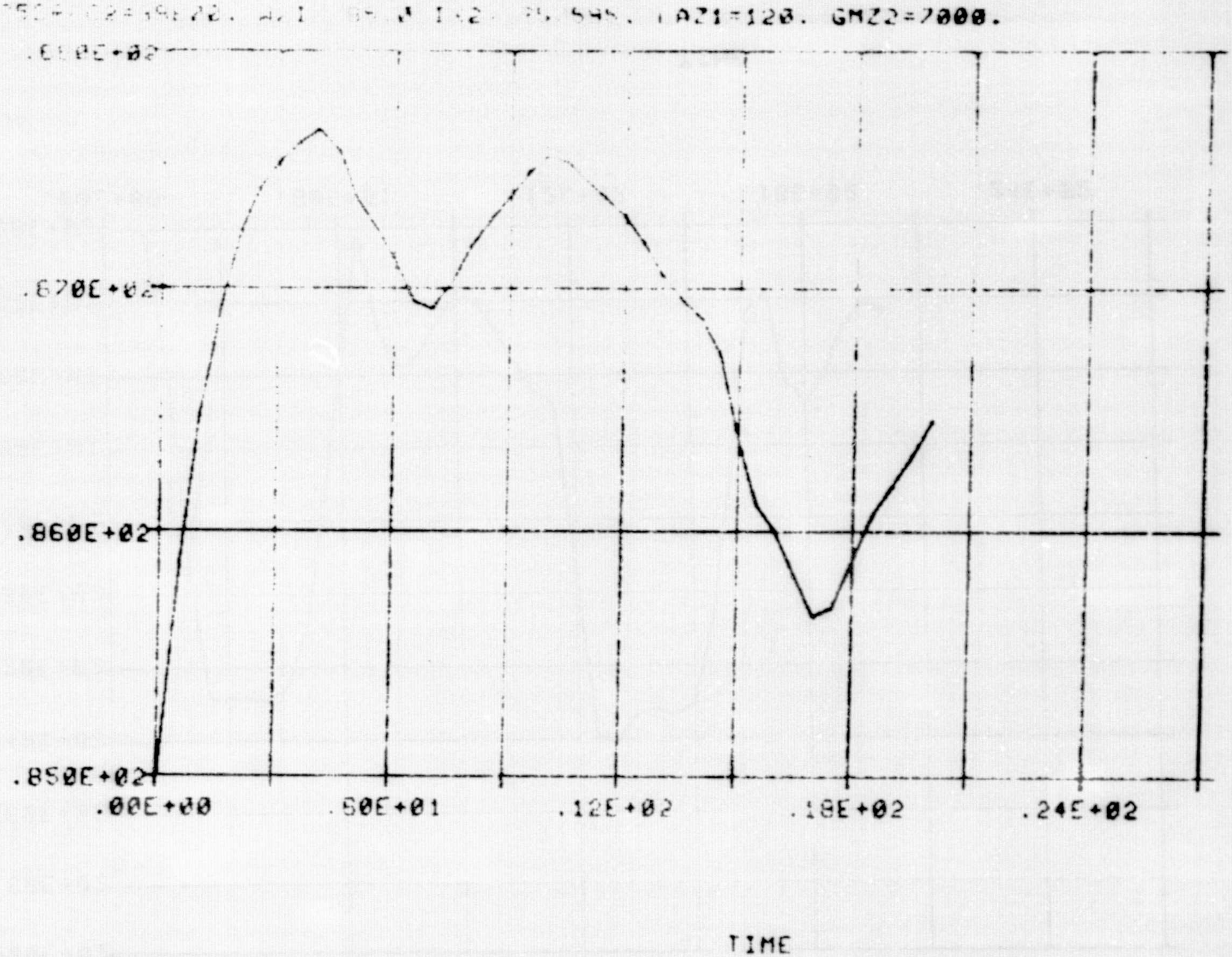
9/19/75SRFC2=38800. W2I= 85.0 IX2= 757595. LAZ1=120. GMZ2=7000.

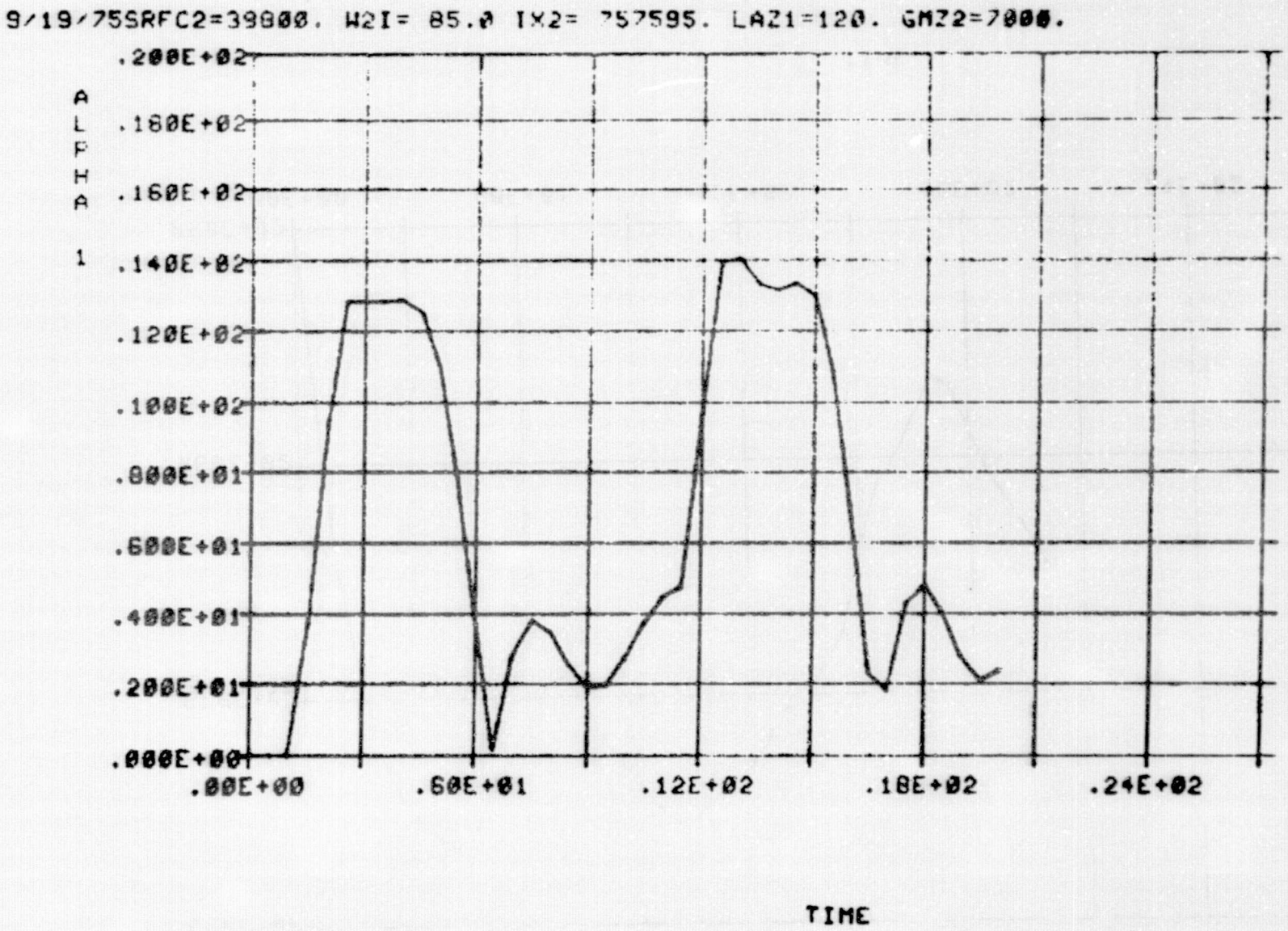


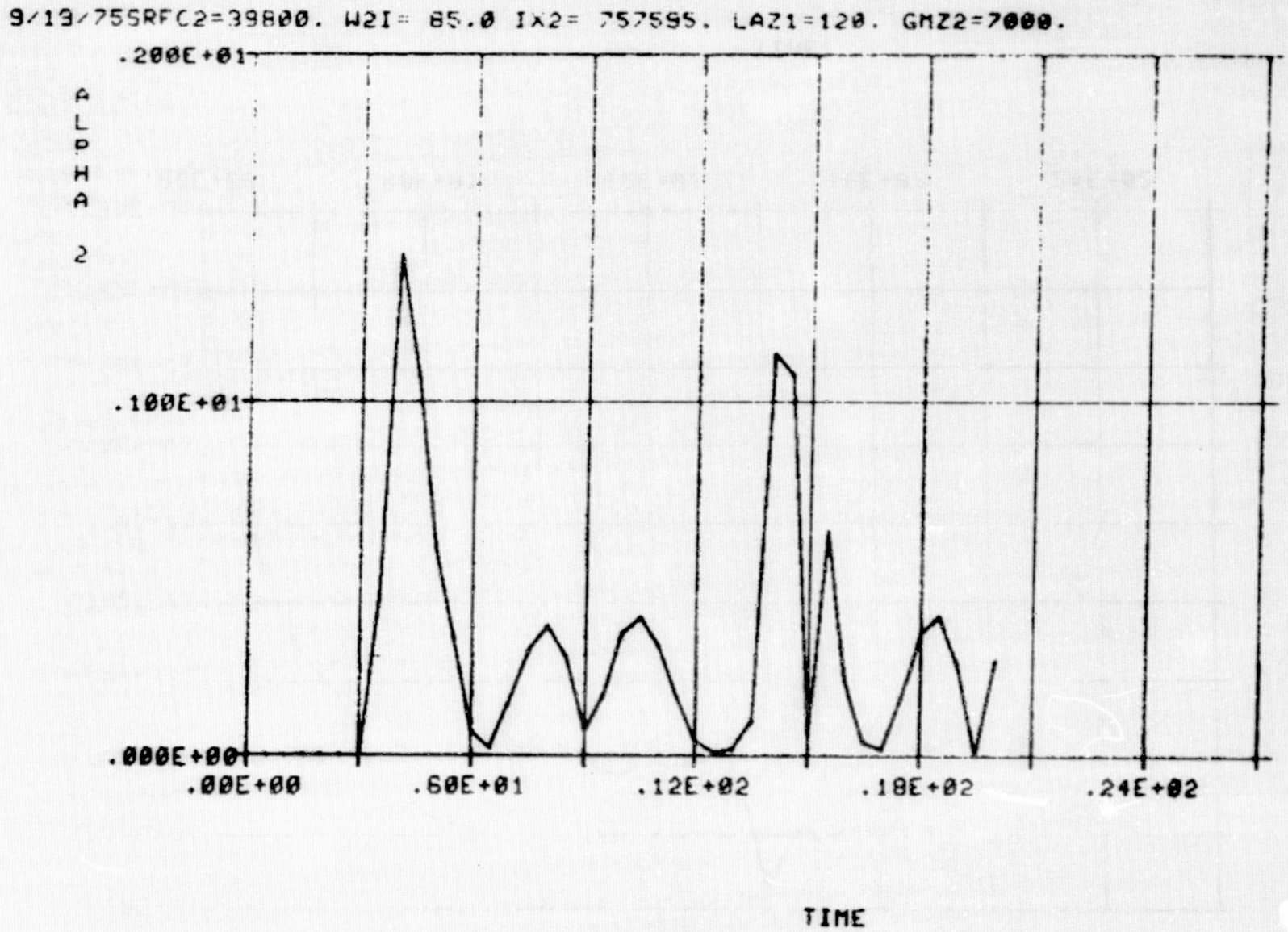

9/19/75SRFC2=39800. W21= 85.0 IX2= 757595. LA21=120. GMZ2=7000.
.100E+02
Q
1 .800E+01
.600E+01
.400E+01
.200E+01
.000E+00
-.200E+01
-.400E+01
-.600E+01
-.800E+01
-.100E+02
.00E+00
.60E+01
.12E+02
.18E+02
.24E+02
TIME

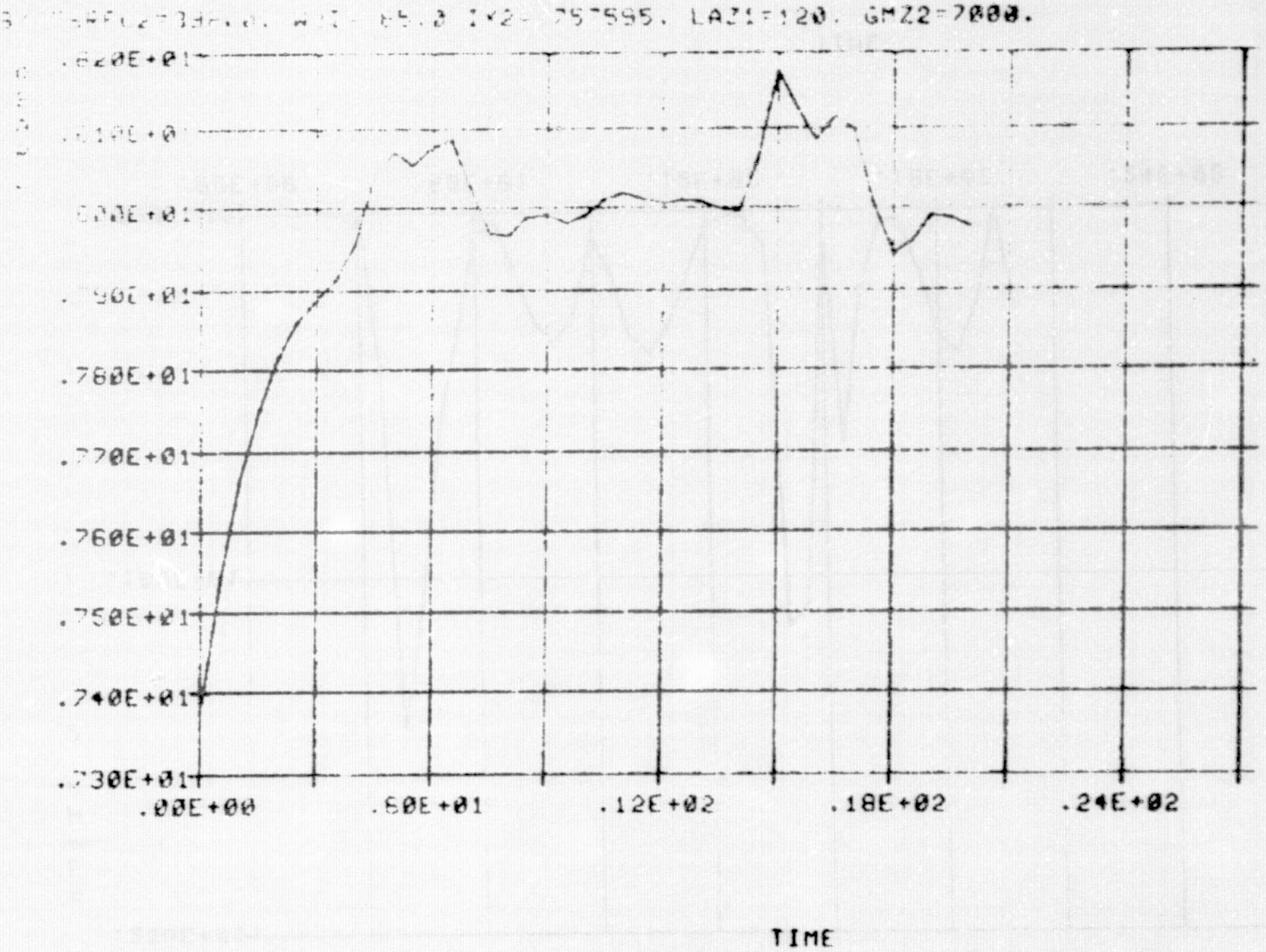
9/19/75SRFC2=39800. W2I= 85.0 IX2= 757595. LAZ1=120. GMZ2=7000.

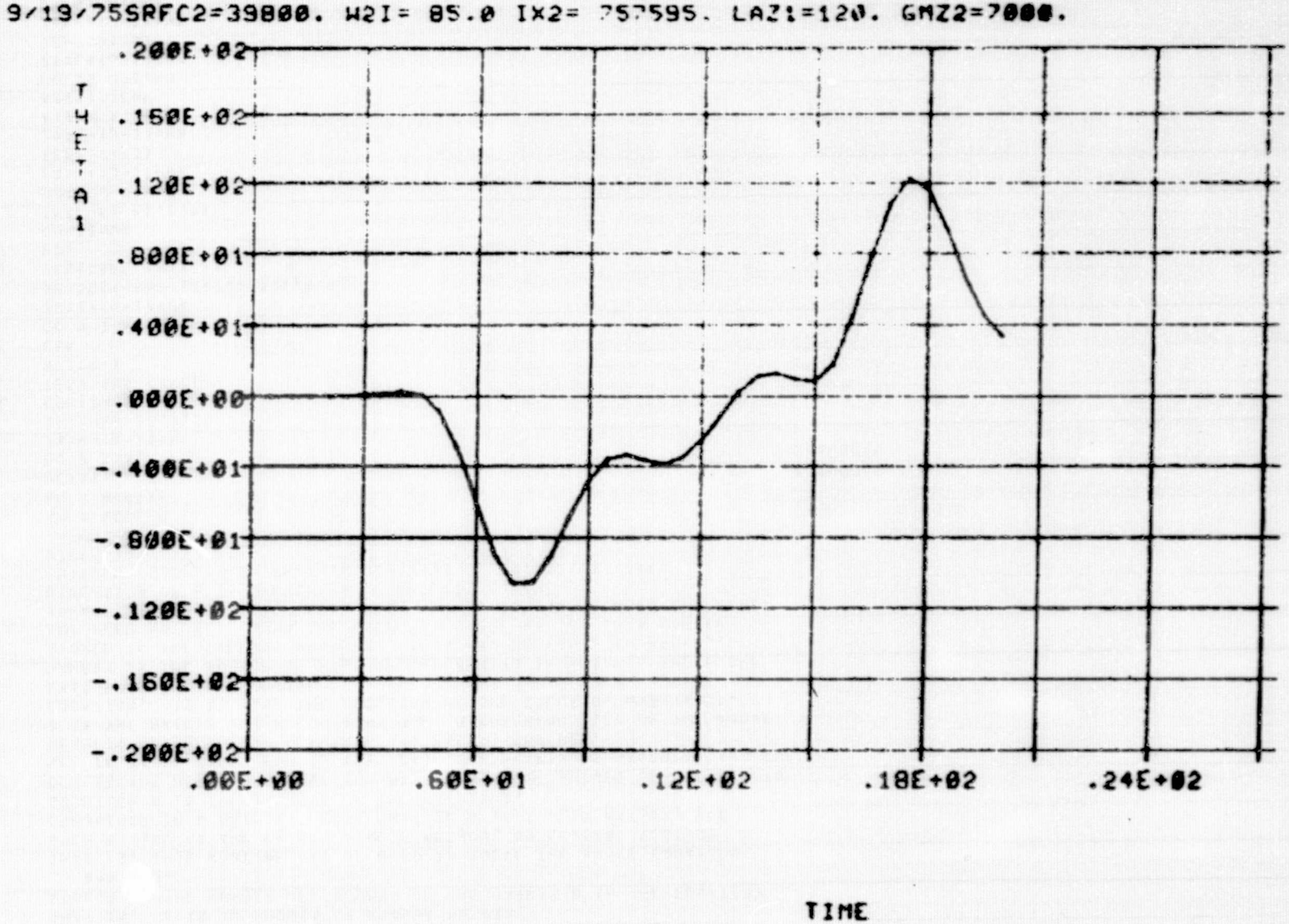





9/19/75SRFC2=39000. W2I= 85.0 IX2= 757595. LAZ1=120. GMZ2=7000.
.200E+02
.180E+02
.160E+02
.140E+02
.120E+02
.100E+02
.800E+01
.600E+01
.400E+01
.200E+01
.000E+00
ALPHA 1
.00E+00
.60E+01
.12E+02
.18E+02
.24E+02
TIME




.820E+01
.810E+01
.800E+01
.790E+01
.780E+01
.770E+01
.760E+01
.750E+01
.740E+01
.730E+01
.00E+00
.60E+01
.12E+02
.18E+02
.24E+02
TIME


9/19/75SRFC2=39800. W2I= 85.0 IX2= 757595. LAZ1=120. GMZ2=7000.
.200E+02
.160E+02
.120E+02
.800E+01
.400E+01
.000E+00
-.400E+01
-.800E+01
-.120E+02
-.160E+02
-.200E+02
THETA1
.00E+00
.60E+01
.12E+02
.18E+02
.24E+02
TIME

```
MURPHY.BIN206*TPF$(0).LINSYS
      1          SUBROUTINE LINSYS(A,NROWSA,NCOLSB,DET,B,NARRAY)
      2      C   A IS THE ARRAY CONTAINING THE COEFFICIENTS OF THE LINEAR SYSTEM.
      3      C   NROWSA IS THE NUMBER OF ROWS (OR COLUMNS) OF THE SQUARE MATRIX A.
      4      C   THAT IS,  A IS AN NROWSA BY NROWSA MATRIX.
      5      C   NCOLSB IS THE NUMBER OF COLUMNS OF THE MATRIX B IN THE EQUATION
      6      C       A*X = B.
      7      C   THAT IS, THIS ROUTINE MAY BE USED TO SOLVE THE ABOVE EQUATION
      8      C   WHEN B (AND X) ARE EITHER SINGLE VECTORS OR SEVERAL VECTORS
      9      C   CONJOINED IN A MATRIX.  NOTE THAT IF B IS A UNIT MATRIX, THE
     10      C   SOLUTION X IS THE INVERSE OF THE MATRIX A.
     11      C   DET IS THE DETERMINANT OF THE MATRIX A.  DET SHOULD BE CHECKED TO
     12      C   SEE IF IT IS ZERO, FOR IN THIS CASE THE MATRIX IS SINGULAR AND THE
     13      C   RESULTS RETURNED ARE MEANINGLESS, EXCEPT FOR DET.
     14      C   B IS THE MATRIX WHICH CONTAINS THE  RIGHT HAND SIDE OF THE ABOVE
     15      C   EQUATION.  IT IS ALSO THE LOCATION OF THE SOLUTION MATRIX, X, ON
     16      C   EXIT FROM THE SUBROUTINE.
     17      C   NARRAY IS THE NUMBER OF ROWS OF THE ARRAYS IN WHICH A AND B ARE
     18      C   STORED IN THE CALLING PROGRAM.  THIS MAY BE EQUAL TO NROWSA,
     19      C   BUT NEED NOT BE.  THUS THE USER MAY STORE A(I,J) IN A LARGER
     20      C   ARRAY THAN IS STRICTLY NECESSARY.  THIS IS USEFUL WHEN THE EXACT
     21      C   DIMENSION OF A IS UNKNOWN AT COMPILATION TIME.
     22          INTEGER Z1,Z2,Z3,Z4,Z5,Z6,Z7,Z8,Z9,Z10,Z11,Z12,Z13,Z14
     23          DIMENSION A(1),B(1)
     24             N = NROWSA
     25          NN = NCOLSB
     26          NK = NARRAY
     27          DET=1.                                                  IJ100050
     28          DO 2 K=1,N                                              IJ100060
     29          Z1=K+(K-1)*NK
     30          IF(K-N) 30,3,30
     31       30 CONTINUE
     32          TEST=ABS (A(Z1))
     33          KP1=K+1
     34          L=K
     35          DO 4 I=KP1,N
     36          Z2=I+(K-1)*NK
     37          IF(TEST-ABS (A(Z2)))31,4,4
     38       31 TEST=ABS (A(Z2))
     39          L=I
     40        4 CONTINUE
     41          IF(L-K) 41,3,41
     42       41 DO 5 J = K,N
     43          Z3=L+(J-1)*NK
     44          TEMP=A(Z3)
     45          Z4=K+(J-1)*NK
     46          A(Z3)=A(Z4)
     47        5 A(Z4)=TEMP
     48          DO 15 J=1,NN
     49          Z5=L+(J-1)*NK
     50          TEMP=B(Z5)
     51          Z6=K+(J-1)*NK
     52          B(Z5)=B(Z6)
     53       15 B(Z6)=TEMP
     54          DET = -DET
     55        3  DET=DET*A(Z1)
     56          A(Z1)=1./A(Z1)
```

```
      IF(K-N) 35,19,35
   35 DO 6 J = KP1,N
      Z7=K+(J-1)*NK
      A(Z7)=A(Z7)*A(Z1)
    6 CONTINUE
   19 DO 16 J=1,NN
      Z9=K+(J-1)*NK
   16 B(Z9)=B(Z9)*A(Z1)
      DO 7 I=1,N
      Z10=I+(K-1)*NK
      IF(I-K) 160,7,160
  160 FAC=A(Z10)
      DO 8 J=KP1,N
      Z11=I+(J-1)*NK
      Z12=K+(J-1)*NK
      E=A(Z11)
      D=E-FAC*A(Z12)
      IF(1.0E-9*ABS (E)-ABS (D))162,161,161
  161 D = 0.
  162 A(Z11)=D
    8 CONTINUE
      DO 18 J = 1,NN
      Z13=I+(J-1)*NK
      Z14=K+(J-1)*NK
   18 B(Z13)=B(Z13)-FAC*B(Z14)
    7 CONTINUE
    2 CONTINUE
      RETURN
      END

@HDG,P     MAIN

@PRT,S    MAIN
FURPUR 27R3DE33 SL73R1 04/03/79 18:29:28
```

```
MURPHYBIN2L6*TPFS(0),MAIN
      1           REAL  NPARA
      2           REAL KAPP,KOV1,KOV2,KOV3,MZDOT
      3           REAL MACH1
      4           REAL LCX(8),LCY(8),LCZ(8)
      5           REAL M(18,18),M1(3,3),M2(3,3),M3(3,3),MI(18,18),KINV(6,6),K(6,6)  M0000000
      6           DIMENSION PFR7(50),PFR8(50),PFR9(50),PFRL7(12),PFRL8(12),PFRL9(12)
      7          1,PS2(50),PS2L(12),PQBAR1(50),PQBA1L(12),PQBAR2(50),PQBA2L(12),
      8          2PZ2(50),PZ2L(12),PDX1(50),PDX1L(12),PAL1(50),PAL1L(12),
      9          3PR1(50),PR1L(12),PDY1(50),PDY1L(12),PAL2(50),PAL2L(12),
     10          4PQ1(50),PQ1L(12),PDZ1(50),PDZ1L(12),
     11          5PP1(50),PP1L(12)
     12           DIMENSION PTIME(50),PZ1(50),TIMEL(12),Z1L(12)
     13           DIMENSION ZCMA2(36),ZCNA2(36),ZCAA2(36),PERAL2(12),NAZ2(2),NSZ2(2)
     14          *,ZXA2(2)
     15           DIMENSION ZCNA(45),ZCMA(45),ZCAA(45),XMAAL(18),NAZ(2),ZXA(2),NSZ(2
     16          *)
     17           DIMENSION T2(18,18),T1(18,18),BB1(18,6),CC1(18,18),XOMC(18,1)      M0000010
     18           DIMENSION BB(3,3),XOM(18,1),XOM11(3,1),XOM21(3,1)                  M0000050
     19           DIMENSION G1(3,3),G2(3,3),G3(3,3),G12(3,3),G13(3,3),E3(3,3)        M0000060
     20           DIMENSION XL1(3,3),XL2(3,3),XLA1(3,3),XLB1(3,3),B11(3,3),B12(3,3)  M0000070
     21           DIMENSION B13(3,3),B14(3,3),B15(3,3),B16(3,3),B21(3,3),B22(3,3)    M0000080
     22           DIMENSION B23(3,3),B24(3,3),B25(3,3),B26(3,3),XOM1(3,3),XOM2(3,3)  M0000090
     23           DIMENSION XOM3(3,3),BD11(3,3),BD12(3,3),BD13(3,3),BD14(3,3)        M0000100
     24           DIMENSION BD15(3,3),BD16(3,3),BD21(3,3),BD22(3,3),BD23(3,3)        M0000110
     25           DIMENSION BD24(3,3),BD25(3,3),BD26(3,3),B(6,18),BD(6,18),AA(3,3)   M0000120
     26           DIMENSION XOM31(3,1),XV1(3,3),XV2(3,3),XV3(3,3),XI1(3,3),XI2(3,3)  M0000130
     27           DIMENSION XI3(3,3),F1I(3,1),F2I(3,1),F3I(3,1),XL1I(3,1),XL2I(3,1)  M0000140
     28           DIMENSION XL3I(3,1),FI(18,1),XG1(3,1),XG2(3,1),XG3(3,1),FG1(3,1)   M0000150
     29           DIMENSION FG2(3,1),FG3(3,1),FG(18,1),V1M(3,1),V2M(3,1),V3M(3,1)    M0000160
     30           DIMENSION FA(18,1),Z(41),WD(41),WIN1(3,1),WIN2(3,1),WIN3(3,1)      M0000170
     31           DIMENSION AL(15),FCNA2(15),FCNA3(15),FCAA2(15),FCAA3(15),
     32          1FCMA2(15),FCMA3(15)
     33           DIMENSION XOMD(18,1),FS1(18,1),FR(18,1)                            M0000200
     34           DIMENSION AIA(6,18),BIB(18,6),FS(18,1),FR1(18,1),FR2(18,1)         M0000210
     35           DIMENSION XOMT(18,18),XOMF(18,1)                                   M0000220
     36           DIMENSION DCOSX(8),DCOSY(8),DCOSZ(8),FC(18,1),TIMX(9),THR(9)
     37           COMMON/FUNT/Y(39),DUM1(21)                                         M0000230
     38           COMMON/FIRT/F(39),DUM2(21)                                         M0000240
     39           EQUIVALENCE (ZXA2(1),PER),(ZXA2(2),AL2)
     40           EQUIVALENCE (ZXA(1),MACH1),(ZXA(2),AL1)
     41           EQUIVALENCE (XOMD(1),F(1)),(QD11,F(19)),(QD12,F(20)),(QD13,F(21)),M0000250
     42          1(QD21,F(22)),(QD22,F(23)),(QD23,F(24)),(QD31,F(25)),(QD32,F(26)), M0000260
     43          2(QD33,F(27)),(QD41,F(28)),(QD42,F(29)),(QD43,F(30))               M0000270
     44           EQUIVALENCE              (Q11,Y(19)),(Q12,Y(20)),(Q13,Y(21)),     M0000280
     45          1(Q21,Y(22)),(Q22,Y(23)),(Q23,Y(24)),(Q31,Y(25)),(Q32,Y(26)),      M0000290
     46          2(Q33,Y(27)),(Q41,Y(28)),(Q42,Y(29)),(Q43,Y(30))                   M0000300
     47           EQUIVALENCE (Y(1),XOM(1),U1),(XOM(2),V1),(XOM(3),W1),(XOM(4),XOM11M0000310
     48          *(1,1),P1),(XOM(5),Q1),(XOM(6),R1),(XOM(7),U2),(XOM(8),V2),(XOM(9),M0000320
     49          *W2),(XOM(10),XOM21(1,1),P2),(XOM(11),Q2),(XOM(12),R2),(XOM(13),U3)M0000330
     50          *,(XOM(14),V3),(XOM(15),W3),(XOM(16),XOM31(1,1),P3),(XOM(17),Q3),  M0000340
     51          7(X1D,F(31)),(Y1D,F(32)),(Z1D,F(33)),
     52          7(X2D,F(34)),(Y2D,F(35)),(Z2D,F(36)),
     53          7(X3D,F(37)),(Y3D,F(38)),(Z3D,F(39)),
     54          7(X1,Y(31)),(Y1,Y(32)),(Z1,Y(33)),
     55          7(X2,Y(34)),(Y2,Y(35)),(Z2,Y(36)),
     56          7(X3,Y(37)),(Y3,Y(38)),(Z3,Y(39)),(XOM(18),R3)
```

```
      EQUIVALENCE (FA(17,1),YM3),(FA(18,1),YN3),
     1(FA( 1,1),FX1),(FA( 2,1),FY1),(FA( 3,1),FZ1),(FA( 4,1),YL1),      M0000380
     1(FA( 5,1),YM1),(FA( 6,1),YN1),(FA( 7,1),FX2),(FA( 8,1),FY2),      M0000390
     1(FA( 9,1),FZ2),(FA(10,1),YL2),(FA(11,1),YM2),(FA(12,1),YN2),      M0000400
     1(FA(13,1),FX3),(FA(14,1),FY3),(FA(15,1),FZ3),(FA(16,1),YL3),      M0000410
     1(FG( 1,1),FG1(1,1)),(FG( 2,1),FG1(2,1)),(FG( 3,1),FG1(3,1)),
     1(FG( 7,1),FG2(1,1)),(FG( 8,1),FG2(2,1)),(FG( 9,1),FG2(3,1)),
     1(FG(13,1),FG3(1,1)),(FG(14,1),FG3(2,1)),(FG(15,1),FG3(3,1)),
     1(FI( 1,1),F1I(1,1)),(FI( 2,1),F1I(2,1)),(FI( 3,1),F1I(3,1)),
     1(FI( 7,1),F2I(1,1)),(FI( 8,1),F2I(2,1)),(FI( 9,1),F2I(3,1)),
     1(FI(13,1),F3I(1,1)),(FI(14,1),F3I(2,1)),(FI(15,1),F3I(3,1)),
     1(FI( 4,1),XL1I(1,1)),(FI( 5,1),XL1I(2,1)),(FI( 6,1),XL1I(3,1)),
     1(FI(10,1),XL2I(1,1)),(FI(11,1),XL2I(2,1)),(FI(12,1),XL2I(3,1)),
     1(FI(16,1),XL3I(1,1)),(FI(17,1),XL3I(2,1)),(FI(18,1),XL3I(3,1))
      EQUIVALENCE (V1M(1,1),U1),(V1M(2,1),V1),(V1M(3,1),W1)
      EQUIVALENCE (V2M(1,1),U2),(V2M(2,1),V2),(V2M(3,1),W2)
      EQUIVALENCE (V3M(1,1),U3),(V3M(2,1),V3),(V3M(3,1),W3)
      EQUIVALENCE (XOM1I(2,1),Q1),(XOM1I(3,1),R1),
     1            (XOM2I(2,1),Q2),(XOM2I(3,1),R2),
     2            (XOM3I(2,1),Q3),(XOM3I(3,1),R3)
      DATA PFRL7/6HPAR R1,11*6H      /
      DATA PFRL8/6HPAR R2,11*6H      /
      DATA PFRL9/6HPAR R3,11*6H      /
      DATA PS2L/6HS2    ,11*6H       /
      DATA PQBA1L/6HQBAR1 ,11*6H      /
      DATA PQBA2L/6HQBAR2 ,11*6H      /
      DATA PZ2L/6HZ2    ,11*6H       /
      DATA PP1L/6HP1    ,11*6H       /
      DATA PQ1L/6HQ1    ,11*6H       /
      DATA PR1L/6HR1    ,11*6H       /
      DATA PDX1L/6HDX1   ,11*6H      /
      DATA PDY1L/6HDY1   ,11*6H      /
      DATA PDZ1L/6HDZ1   ,11*6H      /
      DATA PAL1L/6HAL1   ,11*6H      /
      DATA PAL2L/6HAL2   ,11*6H      /
      DATA TIMEL/6HTIME  ,11*6H      /
      DATA Z1L/6HZ1    ,11*6H      /
      DATA ( THR (I),I=1,9)/0.,39400.,39400.,0.,0.,0.,0.,0.,0.,/
      DATA (    AL(I),I=1,15)/0.,10.,20.,30.,40.,50.,60.,70.,80.,90.,
     *100.,110.,120.,130.,150./
      DATA(DCOSX(I) ,I = 1,8)/8*0./
      DATA(DCOSY(I) ,I = 1,8)/8*0./
      DATA(DCOSZ(I) ,I = 1,8)/8*-1./
      DATA (LCX (I),I=1,8)/8*.2/
      DATA (LCY (I),I=1,8)/8*.0/
      DATA (LCZ (I),I=1,8)/8*.0/
      DATA (FCAA2(I),I=1,15)/.55,.525,.475,.385,.275,0.,0.,0.,0.,0.,0.,
     *0.,0.,0.,0./
      DATA (FCNA2(I),I=1,15)/0.,.05,.125,.19,.25,10*.3/
      DATA (FCMA2(I),I=1,15)/0.,-.025,-.0625,-.095,-.125,10*-.15/
      DATA (ZCAA(I),I=1,15)/.75,1.25,1.75,2.35,2.35,2.0,1.5,0.85,0.22,
     *-.25,-.25,.5,.22,-.15,-.75/
      DATA (ZCNA(I),I=1,15)/0.0,.5,1.5,3.1,5.4,7.4,8.2,6.4,6.,6.,6.,6.,
     *7.6,7.6,3.,2/
      DATA (ZCMA(I),I=1,15)/0.0,1.8,3.,3.3,4.7,6.7,8.0,6.0,1.7,-2.5,
     *-5.8,-8.2,-10.,-10.,-5./
      DATA (ZCAA(I),I=16,30)/1.35,1.5,1.9,2.5,2.45,2.0,1.5,.9,.35,-.1,
```

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     *-.3,.4,.25,-.1,-.75/
      DATA (ZCNA(I),I=16,30)/0.0,0.5,1.6,3.7,6.,8.,9.4,10.2,10.8,11.2,
     *11.0,10.4,9.8,8.4,4.0/
      DATA (ZCMA(I),I=16,30)/0.0,1.6,2.8,3.0,3.6,6.8,8.2,4.0,-2.8,-7.0,
     *-10.7,-12.4,-13.0,-11.8,-4.7/
      DATA (ZCNA(I),I=31,45)/0.,.7,2.,4.1,7.5,10.7,13.,14.25,15.8,16.,
     *15.6,14.7,14.4,11.5,4.5/
      DATA (ZCMA(I),I=31,45)/0.,.8,2.3,3.4,5.7,7.3,7.8,5.3,0.,-6.,-11.7
     *,-17.,-20.7,-19.1,-8./
      DATA (ZCAA(I),I=31,45)/1.25,1.7,2.,2.2,2.,1.65,1.05,.25,-.45,-.6,-
     *.5,-.25,-.25,-.45,-.9/
      DATA (   WD(I),I = 1,41)/58.3,56.7,55.1,53.6,52.1,50.8,49.5,48.2,
     146.8,45.2,43.4,41.1,38.8,36.6,34.5,32.4,31.2,29.1,26.6,24.0,19.5,
     213.5,5.81,-2.4,-1.7,-21.5,-25.2,-27.,-28.7,-30.5,-32.3,-34.1,-36.,
     3-38.,-40.,-41.7,-43.5,-45.8,-48.1,-50.4,-0.0/
      DATA (FCNA3(I),I=1,15)/15*0./
      DATA (FCMA3(I),I=1,15)/15*0./
      DATA (FCAA3(I),I=1,15)/15*0./
      DATA (Z(I),I=1,41)/-35000.,-3900.,-3800.,-3700.,-3600.,-3500.0,
     1-3400.0,-3300.0,-3200.0,-3100.0,-3000.0,-2900.0,-2800.0,-2700.0,
     2-2600.0,-2500.0,-2400.0,-2300.0,-2200.0,-2100.0,-2000.0,-1900.0,
     3-1800.0,-1700.0,-1600.0,-1500.0,-1400.0,-1300.0,-1200.0,-1100.0,
     4-1000.0,-900.0,-800.0,-700.0,-600.0,-500.0,-400.0,-300.0,-200.0,
     5-100.0,0.0/
      DATA (TIMX(I),I=1,9)/0.0,0.2,4.2,4.4,5.0,6.0,7.0,8.0,40.0/
      DATA (PERAL2(I),I=1,12)/0.,.217,.385,.525,.685,1.,0.,5.,10.,15.,
     *25.,40./
      DATA (ZCAA2(I),I=1,12)/6*0.,.119,.14,.135,.13,.117,.085/
      DATA (ZCNA2(I),I=1,12)/6*0.,0.,.03,.055,.085,.175,.24/
      DATA (ZCMA2(I),I=1,12)/6*0.,  0.,-.035,-.065,-.1,-.2,-.28/
      DATA (ZCAA2(I),I=13,24)/.212,.225,.225,.223,.21,.16,.289,.3,.325,
     *.325,.3,.2/
      DATA (ZCNA2(I),I=13,24)/0.,.03,.071,.115,.2,.27,.0,.028,.064,.11,
     *.185,.27/
      DATA (ZCMA2(I),I=13,24)/0.,-.04,-.08,-.13,-.23,-.31,0.,-.033,-.075
     *,-.13,-.22,-.31/
      DATA (ZCAA2(I),I=25,36)/.377,.385,.415,.415,.39,.32,.55,.55,.55,.5
     *4,.50,.41/
      DATA (ZCNA2(I),I=25,36)/0.,.02,.052,.095,.175,.275,.0,.01,.032,.09
     *,.17,.28/
      DATA (ZCMA2(I),I=25,36)/0.,-.02,-.06,-.115,-.2,-.295,0.,-.013,-.03
     *7,-.091,-.175,-.28/
      DO 609 I=1,18                                                  M0000440
      J=1                                                            M0000450
      FC(I,J)=0.0
  609 CONTINUE                                                       M0000480
      NM=0
      AA0=1.3302117E-02
      AA1=-8.8502064E-05
      AA2=-4.2143056E-09
      AA3=5.9517557E-13
      AA4=-3.9744789E-17
      AA5=7.8771273E-22
      TPR=0.0
      READ 3,(N,N1,N2)
      READ  1,(RAPP,RETR,ZMRP1,ZMRP2,NPARA)
      PRINT 1,(RAPP,RETR,ZMRP1,ZMRP2,NPARA)
```

```
      READ 1,(DT,DELP)
      PRINT 1,(DT,DELP)
      READ 1,(X1,Y1,Z1,U1,V1,W1)
      READ 1,(X2,Y2,Z2,U2,V2,W2)
      READ 1,(X3,Y3,Z3,U3,V3,W3)
      READ 1,(P1,Q1,R1,THI1,PHI1,PSI1)
      READ 1,(P2,Q2,R2,THI2,PHI2,PSI2)
      P1=P1/57.3
      Q1=Q1/57.3
      R1=R1/57.3
      P2=P2/57.3
      Q2=Q2/57.3
      R2=R2/57.3
      THI1=THI1*0.01744
      THI2=THI2*0.01744
      PHI1=PHI1*0.01744
      PHI2=PHI2*0.01744
      PSI1=PSI1*0.01744
      PSI2=PSI2*0.01744
      READ 1,(P3,Q3,R3,THI3,PHI3,PSI3)
      READ 1,(XIX1,XIY1,XIZ1,S1,YL,XM1)
      READ 1,(XIX2D,XIY2D,XIZ2 ,ST2,YPL,XXW2)
      READ 1,(XIX3,XIY3,XIZ3,S3,YPL3,XXW3)
      READ 1,(XLX1,XLY1,XLZ1,XLAX1,XLAY1,XLAZ1)
      READ 1,(XLX2,XLY2,XLZ2,XLBX1,XLBY1,XLBZ1)
      READ 1,(XM21T,XM22T,XM23T,XM31,XM32,XM33)
      READ 1,(G,RALPH)
      PRINT 3,(N,N1,N2)
      PRINT 1,(X1,Y1,Z1,U1,V1,W1)
      PRINT 1,(X2,Y2,Z2,U2,V2,W2)
      PRINT 1,(X3,Y3,Z3,U3,V3,W3)
      PRINT 1,(P1,Q1,R1,THI1,PHI1,PSI1)
      PRINT 1,(P2,Q2,R2,THI2,PHI2,PSI2)
      PRINT 1,(P3,Q3,R3,THI3,PHI3,PSI3)
      PRINT 1,(XIX1,XIY1,XIZ1,S1,YL,XM1)
      PRINT 1,(XIX2D,XIY2D,XIZ2 ,ST2,YPL,XXW2)
      PRINT 1,(XIX3,XIY3,XIZ3,S3,YPL3,XXW3)
      PRINT 1,(XLX1,XLY1,XLZ1,XLAX1,XLAY1,XLAZ1)
      PRINT 1,(XLX2,XLY2,XLZ2,XLBX1,XLBY1,XLBZ1)
      PRINT 1,(XM21T,XM22T,XM23T,XM31,XM32,XM33)
      PRINT 1,(G)
    3 FORMAT (3I2)
    2 FORMAT (5E15.6)                                    M0001030
    1 FORMAT (6E12.6)
      XMAAL(1)= .4
      XMAAL(2) = .6
      XMAAL(3) = .9
      DO 550 I = 4,18
  550 XMAAL(I) = AL(I-3)
      NAZ(1) = 3
      NAZ(2) = 15
      NSZ(1) = -1
      NSZ(2) = -1
      KAPP = .245
      PORO=15.0
      PORO=16.2
      KOV1 = 1.
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```
228            KOV2 = 1.
229            KOV3 = 1.
230            X2PR = X2
231            Y2PR = Y2
232            Z2PR = Z2
233            ITT1 = 0
234            ITT2 = 0
235            NAZ2(1) = 6
236            NAZ2(2) = 6
237            NSZ2(1) = -1
238            NSZ2(2) = -1
239            SS0 = .1
240            SS0=0.0
241            SS0=.01
242            SS1 = .7
243            SS1=0.75
244            SS1=1.0
245            SS1=0.8
246            SS2 = 1.
247            TT1 = 4.
248            TT1=8.0
249            TT1=12.0
250            TT2 = 20.
251            SDTOT = .55*ST2
252            TEMPD = .65 * PORO * YPL
253            CP1=0.0
254            CP2=0.0
255            CP3=0.0
256            CP4=0.0
257            CP5=0.0
258            CP6=0.0
259            DO 744 I=1,8
260            CP1=CP1+DCOSX(I)
261            CP2=CP2+DCOSY(I)
262            CP3=CP3+DCOSZ(I)
263            CP4=CP4+(LCY(I)*DCOSZ(I)-LCZ(I)*DCOSY(I))
264            CP5=CP5+(LCZ(I)*DCOSX(I)-LCX(I)*DCOSZ(I))
265            CP6=CP6+(LCX(I)*DCOSY(I)-LCY(I)*DCOSX(I))
266        744 CONTINUE
267            Q11=SIN(PHI1/2.)*COS(PSI1/2.)*COS(THI1/2.)-SIN(PSI1/2.)*SIN(THI1/2M0001050
268           *.)*COS(PHI1/2.)                                                  M0001060
269            Q12=SIN(PHI2/2.)*COS(PSI2/2.)*COS(THI2/2.)-SIN(PSI2/2.)*SIN(THI2/2M0001070
270           *.)*COS(PHI2/2.)                                                  M0001080
271            Q13=SIN(PHI3/2.)*COS(PSI3/2.)*COS(THI3/2.)-SIN(PSI3/2.)*SIN(THI3/2M0001090
272           *.)*COS(PHI3/2.)                                                  M0001100
273            Q21=SIN(THI1/2.)*COS(PSI1/2.)*COS(PHI1/2.)+SIN(PSI1/2.)*SIN(PHI1/2M0001110
274           *.)*COS(THI1/2.)                                                  M0001120
275            Q22=SIN(THI2/2.)*COS(PSI2/2.)*COS(PHI2/2.)+SIN(PSI2/2.)*SIN(PHI2/2M0001130
276           *.)*COS(THI2/2.)                                                  M0001140
277            Q23=SIN(THI3/2.)*COS(PSI3/2.)*COS(PHI3/2.)+SIN(PSI3/2.)*SIN(PHI3/2M0001150
278           *.)*COS(THI3/2.)                                                  M0001160
279            Q31=SIN(PSI1/2.)*COS(THI1/2.)*COS(PHI1/2.)-SIN(THI1/2.)*SIN(PHI1/2M0001170
280           *.)*COS(PSI1/2.)                                                  M0001180
281            Q32=SIN(PSI2/2.)*COS(THI2/2.)*COS(PHI2/2.)-SIN(THI2/2.)*SIN(PHI2/2M0001190
282           *.)*COS(PSI2/2.)                                                  M0001200
283            Q33=SIN(PSI3/2.)*COS(THI3/2.)*COS(PHI3/2.)-SIN(THI3/2.)*SIN(PHI3/2M0001210
284           *.)*COS(PSI3/2.)                                                  M0001220
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285            Q41=COS(PSI1/2.)*COS(THI1/2.)*COS(PHI1/2.)+SIN(PSI1/2.)*SIN(THI1/2M0001230
286           *.)*SIN(PHI1/2.)                                                  M0001240
287            Q42=COS(PSI2/2.)*COS(THI2/2.)*COS(PHI2/2.)+SIN(PSI2/2.)*SIN(THI2/2M0001250
288           *.)*SIN(PHI2/2.)                                                  M0001260
289            Q43=COS(PSI3/2.)*COS(THI3/2.)*COS(PHI3/2.)+SIN(PSI3/2.)*SIN(THI3/2M0001270
290           *.)*SIN(PHI3/2.)                                                  M0001280
291            NEQ=30                                                           M0001290
292            NSQ=0                                                            M0001300
293            T=0.0                                                            M0001320
294            II=1                                                             M0001330
295            TIME = 0.                                                        M0001340
296            DELT=DT
297            DO 78 I=1,3                                                      M0001360
298            DO 78 J=1,3                                                      M0001370
299            E3(I,J)=0.0                                                      M0001380
300         78 CONTINUE                                                         M0001390
301            E3(1,1)=1.0                                                      M0001400
302            E3(2,2)=1.0                                                      M0001410
303            E3(3,3)=1.0                                                      M0001420
304            XL1(1,1)=0.0                                                     M0001430
305            XL1(1,2)=-XLZ1                                                   M0001440
306            XL1(1,3)=XLY1                                                    M0001450
307            XL1(2,1)=XLZ1                                                    M0001460
308            XL1(2,2)=0.0                                                     M0001470
309            XL1(2,3)=-XLX1                                                   M0001480
310            XL1(3,1)=-XLY1                                                   M0001490
311            XL1(3,2)=XLX1                                                    M0001500
312            XL1(3,3)=0.0                                                     M0001510
313            XL2(1,1)=0.0                                                     M0001520
314            XL2(1,2)=-XLZ2                                                   M0001530
315            XL2(1,3)=XLY2                                                    M0001540
316            XL2(2,1)=XLZ2                                                    M0001550
317            XL2(2,2)=0.0                                                     M0001560
318            XL2(2,3)=-XLX2                                                   M0001570
319            XL2(3,1)=-XLY2                                                   M0001580
320            XL2(3,2)=XLX2                                                    M0001590
321            XL2(3,3)=0.0                                                     M0001600
322            XLA1(1,1)=0.0                                                    M0001610
323            XLA1(1,2) = -XLAZ1                                               M0001620
324            XLA1(1,3)=XLAY1                                                  M0001630
325            XLA1(2,1)=XLAZ1                                                  M0001640
326            XLA1(2,2)=0.0                                                    M0001650
327            XLA1(2,3)=-XLAX1                                                 M0001660
328            XLA1(3,1)=-XLAY1                                                 M0001670
329            XLA1(3,2)=XLAX1                                                  M0001680
330            XLA1(3,3)=0.0                                                    M0001690
331            XLB1(1,1)=0.0                                                    M0001700
332            XLB1(1,2) = -XLBZ1                                               M0001710
333            XLB1(1,3)=XLBY1                                                  M0001720
334            XLB1(2,1)=XLBZ1                                                  M0001730
335            XLB1(2,2)=0.0                                                    M0001740
336            XLB1(2,3)=-XLBX1                                                 M0001750
337            XLB1(3,1)=-XLBY1                                                 M0001760
338            XLB1(3,2)=XLBX1                                                  M0001770
339            XLB1(3,3)=0.0                                                    M0001780
340         7605 CONTINUE                                                       M0001790
341            XG1(1,1)=0.0                                                     M0001800
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342          XG1(2,1)=0.0                                              M0001810
343          XG1(3,1)=XM1*G                                            M0001820
344          XG2(1,1)=0.0                                              M0001830
345          XG2(2,1)=0.0                                              M0001840
346          XG2(3,1) = XXW2                                           M0001850
347          XG3(1,1)=0.0                                              M0001860
348          XG3(2,1)=0.0                                              M0001870
349          XG3(3,1) = XXW3                                           M0001880
350          DO 93 I=1,3                                               M0001890
351          DO 93 J=1,3                                               M0001900
352          B13(I,J)=-E3(I,J)                                         M0001910
353          B14(I,J)=xLA1(I,J)                                        M0001920
354          B15(I,J)=0.0                                              M0001930
355          B16(I,J)=0.0                                              M0001940
356          B23(I,J)=0.0                                              M0001950
357          B24(I,J)=0.0                                              M0001960
358          B25(I,J)=-E3(I,J)                                         M0001970
359          B26(I,J)=-xLB1(I,J)                                       M000198
360          BD13(I,J)=0.0                                             M0001990
361          BD14(I,J)=0.0                                             M0002000
362          BD15(I,J)=0.0                                             M0002010
363          BD16(I,J)=0.0                                             M0002020
364          BD23(I,J)=0.0                                             M0002030
365          BD24(I,J)=0.0                                             M0002040
366          BD25(I,J)=0.0                                             M0002050
367          BD26(I,J)=0.0                                             M0002060
368       93 CONTINUE                                                  M0002070
369          DO 7 I=1,3                                                M0002080
370          DO 7 J=7,9                                                M0002090
371          B(I,J)=B13(I,J-6)                                         M0002100
372          BD(I,J)=BD13(I,J-6)                                       M0002110
373        7 CONTINUE                                                  M0002120
374          DO 8 I=1,3                                                M0002130
375          DO 8 J=10,12                                              M0002140
376          B(I,J)=B14(I,J-9)                                         M0002150
377          BD(I,J)=BD14(I,J-9)                                       M0002160
378        8 CONTINUE                                                  M0002170
379          DO 9 I=1,3                                                M0002180
380          DO 9 J=13,15                                              M0002190
381          B(I,J)=B15(I,J-12)                                        M0002200
382          BD(I,J)=BD15(I,J-12)                                      M0002210
383        9 CONTINUE                                                  M0002220
384          DO 10 I=1,3                                               M0002230
385          DO 10 J=16,18                                             M0002240
386          B(I,J)=B16(I,J-15)                                        M0002250
387       10 CONTINUE                                                  M0002270
388          DO 13 I=4,6                                               M0002280
389          DO 13 J=7,9                                               M0002290
390          B(I,J)=B23(I-3,J-6)                                       M0002300
391          BD(I,J)=BD23(I-3,J-6)                                     M0002310
392       13 CONTINUE                                                  M0002320
393          DO 14 I=4,6                                               M0002330
394          DO 14 J=10,12                                             M0002340
395          B(I,J)=B24(I-3,J-9)                                       M0002350
396          BD(I,J)=BD24(I-3,J-9)                                     M0002360
397       14 CONTINUE                                                  M0002370
398          DO 15 I=4,6                                               M0002380
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399          DO 15 J=13,15                                          M0002390
400          B(I,J)=B25(I-3,J-12)                                   M0002400
401          BD(I,J)=BD25(I-3,J-12)                                 M0002410
402       15 CONTINUE                                               M0002420
403          DO 16 I=4,6                                            M0002430
404          DO 16 J=16,18                                          M0002440
405          B(I,J)=-B26(I-3,J-15)                                  M0002450
406          BD(I,J)=BD26(I-3,J-15)                                 M0002460
407       16 CONTINUE                                               M0002470
408          DO 39 I=1,18                                           M0002480
409          DO 39 J=1,18                                           M0002490
410          M(I,J)=0.                                              M0002500
411       39 CONTINUE                                               M0002510
412          M(1,1)=XM1                                             M0002520
413          M(2,2)=XM1                                             M0002530
414          M(3,3)=XM1                                             M0002540
415          M(4,4)=XIX1                                            M0002550
416          M(5,5)=XIY1                                            M0002560
417          M(6,6)=XIZ1                                            M0002570
418          M(13,13)=XM31                                          M0002640
419          M(14,14)=XM32                                          M0002650
420          M(15,15)=XM33                                          M0002660
421          M(16,16)=XIX3                                          M0002670
422          M(17,17)=XIY3                                          M0002680
423          M(18,18)=XIZ3                                          M0002690
424          DO 53 I=1,18                                           M0002700
425          DO 53 J=1,18                                           M0002710
426          MI(I,J)=0.                                             M0002720
427       53 CONTINUE                                               M0002730
428          MI(1,1)=1.0/XM1                                        M0002740
429          MI(2,2)=1.0/XM1                                        M0002750
430          MI(3,3)=1.0/XM1                                        M0002760
431          MI(4,4)=1.0/XIX1                                       M0002770
432          MI(5,5)=1.0/XIY1                                       M0002780
433          MI(6,6)=1.0/XIZ1                                       M0002790
434          MI(13,13)=1.0/XM31                                     M0002860
435          MI(14,14)=1.0/XM32                                     M0002870
436          MI(15,15)=1.0/XM33                                     M0002880
437          MI(16,16)=1.0/XIX3                                     M0002890
438          MI(17,17)=1.0/XIY3                                     M0002900
439          MI(18,18)=1.0/XIZ3                                     M0002910
440          DO 51 I=1,3                                            M0002920
441          DO 51 J=1,3                                            M0002930
442          M1(I,J)=0.0                                            M0002940
443          M2(I,J)=0.0                                            M0002950
444          M3(I,J)=0.0                                            M0002960
445       51 CONTINUE                                               M0002970
446          M1(1,1)=XM1                                            M0002980
447          M1(2,2)=XM1                                            M0002990
448          M1(3,3)=XM1                                            M0003000
449          M3(1,1)=XM31                                           M0003040
450          M3(2,2)=XM32                                           M0003050
451          M3(3,3)=XM33                                           M0003060
452          DO 27 I=1,3                                            M0003070
453          DO 27 J=1,3                                            M0003080
454          XI1(I,J)=0.0                                           M0003090
455          XI2(I,J)=0.0
```

```
456          XI3(I,J)=0.0                                                    M0003110
457       27 CONTINUE                                                        M0003120
458          XI1(1,1)=XIX1                                                   M0003130
459          XI1(2,2)=XIY1                                                   M0003140
460          XI1(3,3)=XIZ1                                                   M0003150
461          XI3(1,1)=XIX3                                                   M0003190
462          XI3(2,2)=XIY3                                                   M0003200
463          XI3(3,3)=XIZ3                                                   M0003210
464          FG(4,1)=0.0                                                     M0003220
465          FG(5,1)=0.0                                                     M0003230
466          FG(6,1)=0.0                                                     M0003240
467          FG(10,1)=0.0                                                    M0003250
468          FG(11,1)=0.0                                                    M0003260
469          FG(12,1)=0.0                                                    M0003270
470          FG(16,1)=0.0                                                    M0003280
471          FG(17,1)=0.0                                                    M0003290
472          FG(18,1)=0.0                                                    M0003300
473      300 IND=4                                                           M0003310
474          GO TO 4                                                         M0003320
475      200 IND=1                                                           M0003330
476      500 CONTINUE                                                        M0003340
477          CALL RUNGE(IND,TIME,DELT,39,0)                                  M0003350
478        4 QD11=-(-R1*Q21+Q1*Q31-P1*Q41)*0.5                               M0003360
479          ZZ=-Z1*0.3048
480          RHO=(1.16790729*EXP(AA0+ZZ*(AA1+ZZ*(AA2+ZZ*(AA3+ZZ*(AA4+ZZ*(AA5)))
481         1)))))*0.00194
482          DELD1 = TEMPD * (SQRT(SS1) - SQRT(SS0)) * KOV1
483          DELD2 = TEMPD * (SQRT(SS2) - SQRT(SS1)) * KOV2
484          DELD3 = TEMPD * ( 1 - SQRT(SS2))        * KOV3
485          DEL1SQ = DELD1 * DELD1
486          DEL2SQ = DELD2 * DELD2
487          DEL3SQ = DELD3 * DELD3
488          IF (TIME.GE.TT1)  GO TO 5007
489          XYZPRM = (X2 - X2PR)**2 + (Y2 - Y2PR)**2 + (Z2 - Z2PR)**2
490          PER = SS0 + (SS1 - SS0)*XYZPRM/DEL1SQ
491          SDDOT = (2.*W2*SDTOT*(SS1-SS0)*SQRT(XYZPRM))/DEL1SQ
492          IF (PER.LE.SS1) GO TO 7020
493          PER=SS1
494          SDDOT = 0.
495          GO TO  7020
496      5007 IF (SS1.EQ.1) GO TO 7020
497          IF (TIME.GE.TT2) GO TO 1070
498          IF (ITT1.EQ.1) GO TO 6007
499          X2PR = X2
500          Y2PR = Y2
501          Z2PR = Z2
502          ITT1 = 1
503      6007 CONTINUE
504          XYZPRM = (X2 - X2PR)**2 + (Y2 - Y2PR)**2 + (Z2 - Z2PR)**2
505          PER = SS1 + (SS2 - SS1)*XYZPRM/DEL2SQ
506          SDDOT = (2.*W2*SDTOT*(SS2-SS1)*SQRT(XYZPRM))/DEL2SQ
507          IF (PER.LE.SS2) GO TO 7020
508          PER=SS2
509          SDDOT = 0.
510          GO TO 7020
511      1070 IF (SS2.EQ.1) GO TO 7020
512          IF (ITT2.EQ.1) GO TO 1170
```

```
      X2PR = X2                                                                 
      Y2PR = Y2                                                                 
      Z2PR = Z2                                                                 
      ITT2 = 1                                                                  
 1170 CONTINUE                                                                  
      XYZPRM = (X2 - X2PR)**2 + (Y2 - Y2PR)**2 + (Z2 - Z2PR)**2                 
      PER = SS2 + (1. - SS2 )*XYZPRM/DEL3SQ                                     
      SDDOT = (2.*U2*SDTOT*(1.-SS2)*SQRT(XYZPRM))/DEL3SQ                        
      IF (PER.LE.1.0) GO TO 7020                                                
      PER=1.0                                                                   
      SDDOT = 0.                                                                
 7020 CONTINUE                                                                  
 9905 S2=PER*ST2                                                                
      SDRAG = PER*SDTOT                                                         
      RALPHA=RALPH+YPL*(-0.22*PER+0.22)                                         
      ZMAPP=RHO*SDRAG*SQRT(SDRAG)*KAPP/SQRT(NP*RA)                              
      XMAPP = (-.8*PER + 1.2)*ZMAPP                                             
      YMAPP = XMAPP                                                             
      MZDOT = 1.5*RHO*SDDOT*SQRT(SDRAG)*KAPP                                    
      XM21=XMAPP+(XXW2/G)                                                       
      XM22=YMAPP+(XXW2/G)                                                       
      XM23=ZMAPP+(XXW2/G)                                                       
      XIX2=XIX2D+YMAPP*RAPP*RAPP                                                
      XIY2=XIY2D+XMAPP*RAPP*RAPP                                                
      M(7,7)=XM21                                                  M0002580     
      M(8,8)=XM22                                                  M0002590     
      M(9,9)=XM23                                                  M0002600     
      M(10,10)=XIX2                                                M0002610     
      M(11,11)=XIY2                                                M0002620     
      M(12,12)=XIZ2                                                M0002630     
      MI(7,7)=1.0/XM21                                             M0002800     
      MI(8,8)=1.0/XM22                                             M0002810     
      MI(9,9)=1.0/XM23                                             M0002820     
      MI(10,10)=1.0/XIX2                                           M0002830     
      MI(11,11)=1.0/XIY2                                           M0002840     
      MI(12,12)=1.0/XIZ2                                           M0002850     
      M2(1,1)=XM21                                                 M0003010     
      M2(2,2)=XM22                                                 M0003020     
      M2(3,3)=XM23                                                 M0003030     
      XI2(1,1)=XIX2                                                M0003160     
      XI2(2,2)=XIY2                                                M0003170     
      XI2(3,3)=XIZ2                                                M0003180     
      QD12=-(-R2*Q22+Q2*Q32-P2*Q42)*0.5                            M0003370     
      QD13=-(-R3*Q23+Q3*Q33-P3*Q43)*0.5                            M0003380     
      QD13=0.0                                                                  
      QD21=-(R1*Q11-P1*Q31-Q1*Q41)*0.5                             M0003390     
      QD22=-(R2*Q12-P2*Q32-Q2*Q42)*0.5                              M000340     
      QD23=-(R3*Q13-P3*Q33-Q3*Q43)*0.5                              M000341     
      QD23=0.0                                                                  
      QD31=-(-Q1*Q11+P1*Q21-R1*Q41)*0.5                            M0003420     
      QD32=-(-Q2*Q12+P2*Q22-R2*Q42)*0.5                            M0003430     
      QD33=-(-Q3*Q13+P3*Q23-R3*Q43)*0.5                            M0003440     
      QD33=0.0                                                                  
      QD41=-(P1*Q11+Q1*Q21+R1*Q31)*0.5                             M0003450     
      QD42=-(P2*Q12+Q2*Q22+R2*Q32)*0.5                             M0003460     
      QD43=-(P3*Q13+Q3*Q23+R3*Q33)*0.5                             M0003470     
      QD43=0.0                                                                  
```

```
570       7001 CONTINUE                                                    M0003480
571            G1(1,1)=Q11**2 -Q21**2 -Q31**2 +Q41**2                      M0003490
572            G1(1,2)=2.D*(Q11*Q21+Q31*Q41)                               M0003500
573            G1(1,3)=2.D*(Q11*Q31-Q21*Q41)                               M0003510
574            G1(2,1)=2.D*(Q11*Q21-Q31*Q41)                               M0003520
575            G1(2,2)=-Q11**2 +Q21**2 -Q31**2 +Q41**2                     M0003530
576            G1(2,3)=2.D*(Q21*Q31+Q11*Q41)                               M0003540
577            G1(3,1)=2.D*(Q11*Q31+Q21*Q41)                               M0003550
578            G1(3,2)=2.D*(Q21*Q31-Q11*Q41)                               M0003560
579            G1(3,3)=-Q11**2 -Q21**2 +Q31**2 +Q41**2                     M0003570
580       7002 CONTINUE                                                    M0003580
581            G2(1,1) = Q12**2 - Q22**2 - Q32**2 + Q42**2                 M0003590
582            G2(1,2)=2.D*(Q12*Q22+Q32*Q42)                               M0003600
583            G2(1,3)=2.D*(Q12*Q32-Q22*Q42)                               M0003610
584            G2(2,1)=2.D*(Q12*Q22-Q32*Q42)                               M0003620
585            G2(2,2)=-Q12**2 +Q22**2 -Q32**2 +Q42**2                     M0003630
586            G2(2,3)=2.D*(Q22*Q32+Q12*Q42)                               M0003640
587            G2(3,1)=2.D*(Q12*Q32+Q22*Q42)                               M0003650
588            G2(3,2)=2.D*(Q22*Q32-Q12*Q42)                               M0003660
589            G2(3,3)=-Q12**2 -Q22**2 +Q32**2 +Q42**2                     M0003670
590       7003 CONTINUE                                                    M0003680
591            G3(1,1)=Q13**2 -Q23**2 -Q33**2 +Q43**2                      M0003690
592            G3(1,2)=2.D*(Q13*Q23+Q33*Q43)                               M0003700
593            G3(1,3)=2.D*(Q13*Q33-Q23*Q43)                               M0003710
594            G3(2,1)=2.D*(Q13*Q23-Q33*Q43)                               M0003720
595            G3(2,2)=-Q13**2 +Q23**2 -Q33**2 +Q43**2                     M0003730
596            G3(2,3)=2.D*(Q23*Q33+Q13*Q43)                               M0003740
597            G3(3,1)=2.D*(Q13*Q33+Q23*Q43)                               M0003750
598            G3(3,2)=2.D*(Q23*Q33-Q13*Q43)                               M0003760
599            G3(3,3)=-Q13**2 -Q23**2 +Q33**2 +Q43**2                     M0003770
600       7004 CONTINUE                                                    M0003780
601            CALL MTXMPY(G2,G1,G12,3,-3,3)                               M0003790
602            CALL MTXMPY(G3,G1,G13,3,-3,3)                               M0003800
603            DO 94 I=1,3                                                 M0003810
604            DO 94 J=1,3                                                 M0003820
605            B11(I,J)=G12(I,J)                                           M0003830
606            B21(I,J)=G13(I,J)                                           M0003840
607         94 CONTINUE                                                    M0003850
608            DO 89 I=1,3                                                 M0003860
609            DO 89 J=1,3                                                 M0003870
610            G12(I,J)=-G12(I,J)                                          M0003880
611            G13(I,J)=-G13(I,J)                                          M0003890
612         89 CONTINUE                                                    M0003900
613            CALL MTXMPY(G12,XL1,B12,3,3,3)                              M0003910
614            CALL MTXMPY(G13,XL2,B22,3,3,3)                              M0003920
615            DO 95 I=1,3                                                 M0003930
616            DO 95 J=1,3                                                 M0003940
617            G12(I,J)=-G12(I,J)                                          M0003950
618            G13(I,J)=-G13(I,J)                                          M0003960
619         95 CONTINUE                                                    M0003970
620            XOM1(1,1)=0.0                                               M0003980
621            XOM1(1,2)=-R1                                               M0003990
622            XOM1(1,3)=Q1                                                M0004000
623            XOM1(2,1)=R1                                                M0004010
624            XOM1(2,2)=0.0                                               M0004020
625            XOM1(2,3)=-P1                                               M0004030
626            XOM1(3,1)=-Q1                                               M0004040
```

```
      XOM1(3,2)=P1                                                    M0004050
      XOM1(3,3)=0.0                                                   M0004060
      XOM2(1,1)=0.0                                                   M0004070
      XOM2(1,2)=-R2                                                   M0004080
      XOM2(1,3)=Q2                                                    M0004090
      XOM2(2,1)=R2                                                    M0004100
      XOM2(2,2)=0.0                                                   M0004110
      XOM2(2,3)=-P2                                                   M0004120
      XOM2(3,1)=-Q2                                                   M0004130
      XOM2(3,2)=P2                                                    M0004140
      XOM2(3,3)=0.0                                                   M0004150
      XOM3(1,1)=0.0                                                   M0004160
      XOM3(1,2)=-R3                                                   M0004170
      XOM3(1,3)=Q3                                                    M0004180
      XOM3(2,1)=R3                                                    M0004190
      XOM3(2,2)=0.0                                                   M0004200
      XOM3(2,3)=-P3                                                   M0004210
      XOM3(3,1)=-Q3                                                   M0004220
      XOM3(3,2)=P3                                                    M0004230
      XOM3(3,3)=0.0                                                   M0004240
      DO 88 I=1,3                                                     M0004250
      DO 88 J=1,3                                                     M0004260
      XOM2(I,J)=-XOM2(I,J)                                            M0004270
      XOM3(I,J)=-XOM3(I,J)                                            M0004280
   88 CONTINUE                                                        M0004290
      CALL MTXMPY(XOM2,G12,AA,3,3,3)                                  M0004300
      CALL MTXMPY(G12,XOM1,BB,3,3,3)                                  M0004310
      DO 81 I=1,3                                                     M0004320
      DO 81 J=1,3                                                     M0004330
      BD11(I,J)=AA(I,J)+BB(I,J)                                       M0004340
   81 CONTINUE                                                        M0004350
      CALL MTXMPY(XOM3,G13,AA,3,3,3)                                  M0004360
      CALL MTXMPY(G13,XOM1,BB,3,3,3)                                  M0004370
      DO 87 I=1,3                                                     M0004380
      DO 87 J=1,3                                                     M0004390
      BD21(I,J)=AA(I,J)+BB(I,J)                                       M0004400
   87 CONTINUE                                                        M0004410
      DO 82 I=1,3                                                     M0004420
      DO 82 J=1,3                                                     M0004430
      BD11(I,J)=-BD11(I,J)                                            M0004440
      BD21(I,J)=-BD21(I,J)                                            M0004450
   82 CONTINUE                                                        M0004460
      CALL MTXMPY(BD11,XL1,BD12,3,3,3)                                M0004470
      CALL MTXMPY(BD21,XL2,BD22,3,3,3)                                M0004480
      DO 80 I=1,3                                                     M0004490
      DO 80 J=1,3                                                     M0004500
      XOM2(I,J)=-XOM2(I,J)                                            M0004510
      XOM3(I,J)=-XOM3(I,J)                                            M0004520
      BD11(I,J)=-BD11(I,J)                                            M0004530
      BD21(I,J)=-BD21(I,J)                                            M0004540
   80 CONTINUE                                                        M0004550
      DO 5 I=1,3
      DO 5 J=1,3
      B(I,J)=B11(I,J)                                                 M0004580
      BD(I,J)=BD11(I,J)                                               M0004590
    5 CONTINUE                                                        M0004600
      DO 6 I=1,3                                                      M0004610
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      DO 6 J=4,6                                                    M0004620
      B(I,J)=B12(I,J-3)                                             M0004630
      BD(I,J)=BD12(I,J-3)                                           M0004640
    6 CONTINUE                                                      M0004650
      DO 11 I=4,6                                                   M0004660
      DO 11 J=1,3                                                   M0004670
      B(I,J)=B21(I-3,J)                                             M0004680
      BD(I,J)=BD21(I-3,J)                                           M0004690
   11 CONTINUE                                                      M0004700
      DO 12 I=4,6                                                   M0004710
      DO 12 J=4,6                                                   M0004720
      B(I,J)=B22(I-3,J-3)                                           M0004730
      BD(I,J)=BD22(I-3,J-3)                                         M0004740
   12 CONTINUE                                                      M0004750
      XV1(1,1)=0.0                                                  M0004760
      XV1(1,2)=-W1                                                  M0004770
      XV1(1,3)=V1                                                   M0004780
      XV1(2,1)=W1                                                   M0004790
      XV1(2,2)=0.0                                                  M0004800
      XV1(2,3)=-U1                                                  M0004810
      XV1(3,1)=-V1                                                  M0004820
      XV1(3,2)=U1                                                   M0004830
      XV1(3,3)=0.0                                                  M0004840
      XV2(1,1)=0.0                                                  M0004850
      XV2(1,2)=-W2                                                  M0004860
      XV2(1,3)=V2                                                   M0004870
      XV2(2,1)=W2                                                   M0004880
      XV2(2,2)=0.0                                                  M0004890
      XV2(2,3)=-U2                                                  M0004900
      XV2(3,1)=-V2                                                  M0004910
      XV2(3,2)=U2                                                   M0004920
      XV2(3,3)=0.0                                                  M0004930
      XV3(1,1)=0.0                                                  M0004940
      XV3(1,2)=-W3                                                  M0004950
      XV3(1,3)=V3                                                   M0004960
      XV3(2,1)=W3                                                   M0004970
      XV3(2,2)=0.0                                                  M0004980
      XV3(2,3)=-U3                                                  M0004990
      XV3(3,1)=-V3                                                  M0005000
      XV3(3,2)=U3                                                   M0005010
      XV3(3,3)=0.0                                                  M0005020
      DO 83 I=1,3                                                   M0005050
      DO 83 J=1,3                                                   M0005060
      XOM1(I,J) = -XOM1(I,J)                                        M0005070
   83 CONTINUE                                                      M0005080
      CALL MTXMPY(M1,XOM1,AA,3,3,3)
      CALL MTXMPY(AA,V1M,F1I,3,3,1)                                 M0005040
      CALL MTXMPY(XOM1,X11,AA,3,3,3)                                M0005090
      CALL MTXMPY(AA,XOM11,XL1I,3,3,1)                              M0005100
      DO 37 I=1,3                                                   M0005110
      DO 37 J=1,3                                                   M0005120
      XOM1(I,J) = -XOM1(I,J)                                        M0005130
      XOM2(I,J)=-XOM2(I,J)
   37 CONTINUE                                                      M0005140
      CALL MTXMPY(M2,XOM2,AA,3,3,3)
      CALL MTXMPY(AA,V2M,F2I,3,3,1)                                 M0005160
      CALL MTXMPY(XOM2,X12,AA,3,3,3)                                M0005210
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```
      CALL MTXMPY(AA,XOM21,XL2I,3,3,1)                                  M0005220
      F2I(1,1)=F2I(1,1)+XMAPP*RAPP*(XOMD(11,1)+P2*R2)
      F2I(2,1)=F2I(2,1)+YMAPP*RAPP*(-XOMD(10,1)+Q2*R2)
      F2I(3,1)=F2I(3,1)+ZMAPP*RAPP*(-P2*P2-Q2*Q2)
      XL2I(1,1)=XL2I(1,1)+YMAPP*RAPP*(-XOMD(8,1)-U2*R2+W2*P2)
      XL2I(2,1)=XL2I(2,1)+XMAPP*RAPP*(+XOMD(7,1)+W2*Q2-V2*R2)
      DO 28 I=1,3                                                       M0005230
      DO 28 J=1,3                                                       M0005240
      XOM2(I,J)=-XOM2(I,J)                                              M0005250
      XOM3(I,J)=-XOM3(I,J)                                              M0005310
   28 CONTINUE                                                          M0005260
      CALL MTXMPY(M3,XOM3,AA,3,3,3)
      CALL MTXMPY(AA,V3M,F3I,3,3,1)                                     M0005280
      CALL MTXMPY(XOM3,X13,AA,3,3,3)                                    M0005330
      CALL MTXMPY(AA,XOM31,XL3I,3,3,1)                                  M0005340
      DO 25 I=1,3                                                       M0005350
      DO 25 J=1,3                                                       M0005360
      XOM3(I,J)=-XOM3(I,J)                                              M0005370
   25 CONTINUE                                                          M0005380
      CALL MTXMPY(G1,XG1,FG1,3,3,1)                                     M0005390
      CALL MTXMPY(G2,XG2,FG2,3,3,1)                                     M0005400
      CALL MTXMPY(G3,XG3,FG3,3,3,1)                                     M0005410
 7008 CONTINUE                                                          M0005420
      CALL TBL(Z,WD,Z1,N1,UWD1)                                         M0005430
      CALL TBL(Z,WD,Z2,N1,UWD2)                                         M0005440
C     NEXT 2 CARDS ZERO OUT THE WINDS
      UWD1=0.0
      UWD2=0.0
      WWD1=0.0                                                          M0005450
      WWD2=0.0                                                          M0005460
      WWD3=0.0                                                          M0005470
      VWD1=UWD1                                                         M0005480
      VWD3=UWD2                                                         M0005510
      WIN1(1,1)=UWD1                                                    M0005520
      WIN1(2,1)=VWD1                                                    M0005530
      WIN1(3,1)=WWD1                                                    M0005540
 7009 CONTINUE                                                          M0005550
      CALL MTXMPY(G1,WIN1,WIN1,3,3,1)                                   M0005560
      UWD1=WIN1(1,1)                                                    M0005570
      VWD1=WIN1(2,1)                                                    M0005580
      WWD1=WIN1(3,1)                                                    M0005590
      WIN2(1,1)=UWD2                                                    M0005600
      WIN2(2,1)=VWD2                                                    M0005610
      WIN2(3,1)=WWD2                                                    M0005620
 7010 CONTINUE                                                          M0005630
      CALL MTXMPY(G2,WIN2,WIN2,3,3,1)                                   M0005640
      UWD2=WIN2(1,1)                                                    M0005650
      VWD2=WIN2(2,1)                                                    M0005660
      WWD2=WIN2(3,1)                                                    M0005670
      WIN3(1,1)=UWD3                                                    M0005680
      WIN3(2,1)=VWD3                                                    M0005690
      WIN3(3,1)=WWD3                                                    M0005700
 7011 CONTINUE                                                          M0005710
      CALL MTXMPY(G3,WIN3,WIN3,3,3,1)                                   M0005720
      UWD3=WIN3(1,1)                                                    M0005730
      VWD3=WIN3(2,1)                                                    M0005740
      WWD3=WIN3(3,1)                                                    M0005750
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      7012 CONTINUE                                                    M0005760
           UH1=U1-UWD1                                                 M0005770
           UH2=U2-UWD2-RALPHA*Q2
           UH3=U3-UWD3                                                 M0005790
           VH1=V1-VWD1                                                 M0005800
           VH2=V2-VWD2+RALPHA*P2
           VH3=V3-VWD3
           WH1=W1-WWD1                                                 M0005830
           WH2=W2-WWD2                                                 M0005840
           WH3=W3-WWD3                                                 M0005850
           V11=(UH1*UH1+VH1*VH1+WH1*WH1)**0.5                          M0005860
           V21=(UH2*UH2+VH2*VH2+WH2*WH2)**0.5                          M0005870
           V31=(UH3*UH3+VH3*VH3+WH3*WH3)**0.5                          M0005880
           VSOUND=0.0037*Z1+1138.0
           MACH1=V11/VSOUND
           AL1=ARCOS(WH1/V11)*57.3
           AL2=ARCOS(WH2/V21)*57.3
           AL3=ARCOS(WH3/V31)*57.3
      7013 CONTINUE                                                    M0005950
           CALL TBLND(-1,3,ZCNA,XMAAL,NAZ,ZXA,NSZ,CNA1)
           CALL TBLND(-1,3,ZCMA,XMAAL,NAZ,ZXA,NSZ,CMA1)
           CALL TBLND(-1,3,ZCAA,XMAAL,NAZ,ZXA,NSZ,CAA1)
           CMA1=CMA1+CNA1*(ZMRP1/YL)
           CALL TBLND(-1,3,ZCNA2,PERAL2,NAZ2,ZXA2,NSZ2,CNA2)
           CALL TBLND(-1,3,ZCMA2,PERAL2,NAZ2,ZXA2,NSZ2,CMA2)
           CALL TBLND(-1,3,ZCAA2,PERAL2,NAZ2,ZXA2,NSZ2,CAA2)
           CMA2=CMA2+CNA2*(ZMRP2/YPL)
           CALL TBL(AL,FCNA3,AL3,N,CNA3)
           CALL TBL(AL,FCAA3,AL3,N,CAA3)
           CALL TBL(AL,FCMA3,AL3,N,CMA3)
      7014 CONTINUE                                                    M0006200
           QA1 = 0.5*RHO*V11*V11*S1                                    M0006210
           QBAR1=QA1/S1
           QA2=0.5*RHO*V21*V21*ST2
           QBAR2=QA2/ST2
           QA3=0.5*RHO*V31*V31*S3
           UVG1=(UH1*UH1+VH1*VH1)**0.5
           UVG2=(UH2*UH2+VH2*VH2)**0.5
           UVG3=(UH3*UH3+VH3*VH3)**0.5
           FX1=-QA1*CNA1*(UH1/UVG1)
           FX2=-QA2*CNA2*(UH2/UVG2)
           FX3=-QA3*CNA3*(UH3/UVG3)
           FY1=-QA1*CNA1*(VH1/UVG1)
           FY2=-QA2*CNA2*(VH2/UVG2)
           FY3=-QA3*CNA3*(VH3/UVG3)
           FZ1=-QA1*CAA1
           FZ2=-QA2*CAA2-MZDOT*W2
           FZ3=-QA3*CAA3
           YL1=QA1*YL*CMA1*(VH1/UVG1)
           YL2=QA2*YPL*CMA2*(VH2/UVG2)
           YL3=QA3*YPL3*CMA3*(VH3/UVG3)
           YM1=-QA1*YL*CMA1*(UH1/UVG1)
           YM2=-QA2*YPL*CMA2*(UH2/UVG2)
           YM3=-QA3*YPL3*CMA3*(UH3/UVG3)
           YN1=0.0
           YN2=0.0
           YN3=0.0
```

```
      7016 CONTINUE                                                    M0006430
           CALL MTXMPY(B,MI,AIA,6,18,18)                               M0006440
           CALL MTXMPY(AIA,B,K,6,-18,6)                                M0006450
           DO 501 I=1,6                                                M0006460
           DO 501 J=1,6                                                M0006470
           KINV(I,J)=0.0                                               M0006480
       501 CONTINUE                                                    M0006490
           KINV(1,1)=1.0                                               M0006500
           KINV(2,2)=1.0                                               M0006510
           KINV(3,3)=1.0                                               M0006520
           KINV(4,4)=1.0                                               M0006530
           KINV(5,5)=1.0                                               M0006540
           KINV(6,6)=1.0                                               M0006550
           CALL LINSYS(K,6,6,DET,KINV,6)                               M0006560
           DO 701 I=1,6                                                M0006570
           DO 701 J=1,18                                               M0006580
           B(I,J)=-B(I,J)                                              M0006590
       701 CONTINUE                                                    M0006600
           CALL MTXMPY(B,KINV,BIB,-18,6,6)                             M0006610
           DO 703 I=1,6                                                M0006620
           DO 703 J=1,18                                               M0006630
           B(I,J)=-B(I,J)                                              M0006640
       703 CONTINUE                                                    M0006650
           CALL MTXMPY(BIB,BD,T2,18,6,18)                              M0006660
           CALL MTXMPY(BIB,AIA,T1,18,6,18)                             M0006670
           CALL TBL(TIMX,THR,TIME,N2,THR1)
           FC(1,1)=THR1*CP1*RETR
           FC(2,1)=THR1*CP2*RETR
           FC(3,1)=THR1*CP3*RETR
           FC(4,1)=THR1*CP4*RETR
           FC(5,1)=THR1*CP5*RETR
           FC(6,1)=THR1*CP6*RETR
           DO 502 I=1,18                                               M0006680
           J=1                                                         M0006690
           FS(I,J)=FI(I,J)+FA(I,J)+FG(I,J)+FC(I,J)                     M0006700
       502 CONTINUE                                                    M0006710
           CALL MTXMPY(T1,FS,FR1,18,18,1)                              M0006720
           CALL MTXMPY(T2,XOM,FR2,18,18,1)                             M0006730
           DO 503 I=1,18                                               M0006740
           J=1                                                         M0006750
           FR(I,J)=FR1(I,J)+FR2(I,J)                                   M0006760
       503 CONTINUE                                                    M0006770
           DO 504 I=1,18                                               M0006780
           J=1                                                         M0006790
           FS1(I,J)=FI(I,J)+FR(I,J)+FA(I,J)+FG(I,J)+FC(I,J)            M0006800
       504 CONTINUE                                                    M0006810
           CALL MTXMPY(MI,FS1,XOMD,18,18,1)                            M0006820
      C    THE NEXT 3 CARDS ZERO OUT XOMD FOR THE 2ND PARACHUTE
           XOMD(13,1)=0.0
           XOMD(14,1)=0.0
           XOMD(15,1)=0.0
           CALL MTXMPY(AIA,KINV,BB1,-18,6,6)
           CALL MTXMPY(BB1,B,CC1,18,6,18)
           CALL MTXMPY(CC1,XOM,XOMC,18,18,1)
           DO 9019 I=1,18
           J=1
           XOM(I,J)=XOM(I,J)-XOMC(I,J)
```

```
912       9019 CONTINUE
913            T = TIME                                                  M000683
914            DO 3001 I=1,18
915            DO 3001 J=1,18                                            M0006870
916            XOMT(I,J)=0.0                                             M0006880
917       3001 CONTINUE                                                  M0006890
918            DO 3002 I=1,3                                             M0006900
919            DO 3002 J=1,3                                             M0006910
920            XOMT(I,J)=G1(J,I)                                         M0006920
921            XOMT(I+6,J+6)=G2(J,I)                                     M0006930
922            XOMT(I+12,J+12)=G3(J,I)                                   M0006940
923       3002 CONTINUE                                                  M0006950
924            CALL MTXMPY(XOMT,XOM,XOMF,18,18,1)                        M0006960
925            X1D=XOMF(1 ,1)
926            Y1D=XOMF(2 ,1)
927            Z1D=XOMF(3 ,1)
928            X2D=XOMF(7 ,1)
929            Y2D=XOMF(8 ,1)
930            Z2D=XOMF(9 ,1)
931            X3D=XOMF(13,1)
932            Y3D=XOMF(14,1)
933            Z3D=XOMF(15,1)
934            IND=IND+1                                                 M000684
935            IF(IND-4)500,500,600                                      M0006850
936        600 CONTINUE
937            DIRC=ARCOS(G1(3,3))*57.3
938            SSS1=(1-(G1(1,3)*G1(1,3)))**0.5
939            SSS2=(1-(G2(1,3)*G2(1,3)))**0.5
940            SSS3=(1-(G3(1,3)*G3(1,3)))**0.5
941            THI1=XTAN2(-G1(1,3),SSS1)
942            THI2=XTAN2(-G2(1,3),SSS2)
943            THI3=XTAN2(-G3(1,3),SSS3)
944            PHI1=XTAN2(G1(2,3),G1(3,3))
945            PHI2=XTAN2(G2(2,3),G2(3,3))
946            PHI3=XTAN2(G3(2,3),G3(3,3))
947            PSI1=XTAN2(G1(1,2),G1(1,1))
948            PSI2=XTAN2(G2(1,2),G2(1,1))
949            PSI3=XTAN2(G3(1,2),G3(1,1))
950            IF(T-TPR)4006,7006,7006
951       7006 PRINT 1000,T                                              M0007180
952            TPR=TPR+DELP
953       1000 FORMAT (1H0,4HTIME,3X,E15.6)                              M0007190
954            PRINT 6666,DIRC
955       6666 FORMAT (1H,4HDIRC,3X,E15.6)
956            PRINT 9898,(CMA1,CNA1,CAA1)
957            PRINT 9899,(CMA2,CNA2,CAA2)
958       9898 FORMAT (1H,4HCMA1,3X,E15.6,2X,4HCNA1,3X,E15.6,2X,4HCAA1,3X,E15.6)
959       9899 FORMAT (1H,4HCMA2,3X,E15.6,2X,4HCNA2,3X,E15.6,2X,4HCAA2,3X,E15.6)
960            PRINT 7050                                                M0007200
961       7050 FORMAT (T8,2HFA,T25,2HFI,T40,2HFG,T55,2HFR,T70,4HDOMG,T85 ,3HOMG, M0007210
962           1T100,2HFC,//)
963            PRINT 7051, (FA(I,1),FI(I,1),FG(I,1),FR(I,1),XOMD(I,1),XOM(I,1), M0007230
964           1FC(I,1),I=1,18)
965       7051 FORMAT (7E15.8)                                           M0007250
966            PRINT 1001,(X1,Y1,Z1,THI1,PHI1,PSI1)
967       1001 FORMAT (1H ,                                              M0007270
968           1         2HX1,3X,E15.6,2X,2HY1,3X,E15.6,2X,2HZ1,3X,E15.6/2X,4HTHI1,M0007280
```

```
      13X,E15.6,2X,4HPHI1,3X,E15.6,2X,4HPSI1,3X,E15.6)                    M0007290
      PRINT 1002,(U1,V1,W1,P1,Q1,R1)                                      M0007300
 1002 FORMAT (1H ,                                                        M0007310
     1        2HU1,3X,E15.6,2X,2HV1,3X,E15.6,2X,2HW1,3X,E15.6/2X,2HP1,3X M0007320
     1,E15.6,2X,2HQ1,3X,E15.6,2X,2HR1,3X,E15.6)                          M0007330
      PRINT 1003,(AL1)
 1003 FORMAT (1H ,                                                        M0007350
     1        3HAL1,3X,E15.6)
      PRINT 6001,(X2,Y2,Z2,THI2,PHI2,PSI2)
 6001 FORMAT (1H ,                                                        M0007390
     1        2HX2,3X,E15.6,2X,2HY2,3X,E15.6,2X,2HZ2,3X,E15.6/2X,4HTHI2, M0007400
     113X,E15.6,2X,4HPHI2,3X,E15.6,2X,4HPSI2,3X,E15.6)                   M0007410
      PRINT 6002,(U2,V2,W2,P2,Q2,R2)                                      M0007420
 6002 FORMAT (1H ,                                                        M0007430
     1        2HU2,3X,E15.6,2X,2HV2,3X,E15.6,2X,2HW2,3X,E15.6/2X,2HP2,3X M0007440
     1,E15.6,2X,2HQ2,3X,E15.6,2X,2HR2,3X,E15.6)                          M0007450
      PRINT 6003,(AL2)
 6003 FORMAT (1H ,                                                        M0007470
     1        3HAL2,3X,E15.6)
      PRINT 1010,(RHO,QBAR2,QBAR1)
 1010 FORMAT (1H,3HRHO,3X,E15.6,2X,5HQBAR2,3X,E15.6,2X,5HQBAR1,3X,E15.6)
      HXB=XIX1*P1
      HYB=XIY1*Q1
      HZB=XIZ1*R1
      HXI=G1(1,1)*HXB+G1(2,1)*HYB+G1(3,1)*HZB
      HYI=G1(1,2)*HXB+G1(2,2)*HYB+G1(3,2)*HZB
      HZI=G1(1,3)*HXB+G1(2,3)*HYB+G1(3,3)*HZB
      TAM=SQRT(HXI*HXI+HYI*HYI+HZI*HZI)
      PRINT 9304,(TAM,HXI,HYI,HZI)
 9304 FORMAT (1H,3HTAM,3X,E15.6,2X,3HHXI,3X,E15.6,2X,3HHYI,3X,E15.6,2X,
     113HHZI,3X,E15.6)
 6169 FORMAT (6E12.6)
 1111 FORMAT (1H,2HS2,3X,E15.6)
      PRINT 1111,S2
      NM=NM+1
      PTIME(NM)=TIME
      PZ1(NM)=Z1
      PFR7(NM)=FR(7,1)
      PFR8(NM)=FR(8,1)
      PFR9(NM)=FR(9,1)
      PS2(NM)=S2
      PQBAR1(NM)=QBAR1
      PQBAR2(NM)=QBAR2
      PP1(NM)=P1*57.3
      PQ1(NM)=Q1*57.3
      PR1(NM)=R1*57.3
      PZ2(NM)=Z2
      PDX1(NM)=XOMF(1,1)
      PDY1(NM)=XOMF(2,1)
      PDZ1(NM)=XOMF(3,1)
      PAL1(NM)=AL1
      PAL2(NM)=AL2
      IF(TIME-20.0)4006,9001,9001
 4006 II=II+1                                                             M0007510
      GO TO 200                                                           M0007520
 9001 CONTINUE
      CALL IDENT (9,9HCUT PAPER)
```

```
1026            CALL QUIK3V (-1,35,TIMEL,Z1L,-NM,PTIME,PZ1)
1027            CALL QUIK3V (-1,35,TIMEL,PFRL7,-NM,PTIME,PFR7)
1028            CALL QUIK3V (-1,35,TIMEL,PFRL8,-NM,PTIME,PFR8)
1029            CALL QUIK3V (-1,35,TIMEL,PFRL9,-NM,PTIME,PFR9)
1030            CALL QUIK3V (-1,35,TIMEL,PS2L ,-NM,PTIME,PS2)
1031            CALL QUIK3V (-1,35,TIMEL,PQBA1L,-NM,PTIME,PQBAR1)
1032            CALL QUIK3V (-1,35,TIMEL,PQBA2L,-NM,PTIME,PQBAR2)
1033            CALL QUIK3V (-1,35,TIMEL,PZ2L,-NM,PTIME,PZ2)
1034            CALL QUIK3V (-1,35,TIMEL,PP1L,-NM,PTIME,PP1)
1035            CALL QUIK3V (-1,35,TIMEL,PQ1L,-NM,PTIME,PQ1)
1036            CALL QUIK3V (-1,35,TIMEL,PR1L,-NM,PTIME,PR1)
1037            CALL QUIK3V (-1,35,TIMEL,PDX1L,-NM,PTIME,PDX1)
1038            CALL QUIK3V (-1,35,TIMEL,PDY1L,-NM,PTIME,PDY1)
1039            CALL QUIK3V (-1,35,TIMEL,PDZ1L,-NM,PTIME,PDZ1)
1040            CALL QUIK3V (-1,35,TIMEL,PAL1L,-NM,PTIME,PAL1)
1041            CALL QUIK3V (-1,35,TIMEL,PAL2L,-NM,PTIME,PAL2)
1042            CALL ENDJOB
1043            CALL EXIT
1044         9101 CONTINUE
1045            END                                              M0007540

@HDG,P      RUNGE

@PRT,S    RUNGE
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MURPHYBIN206*TPF$(0).RUNGE

```
      SUBROUTINE RUNGE (KUTTA,TIME,DT,NVAR,NDVAR)
C  KUTTA IS A CONTROL INTEGER
C  TIME IS TIME OF INTEGRATION
C  DT IS THE TIME INCREMENT
C  NVAR = NUMBER OF VARIABLES TO BE INTEGRATED ONCE
C  NDVAR= NUMBER OF VARIABLES TO BE INTEGRATED TWICE
      DIMENSION C1( 60),C2( 60),C3( 60),C4( 60),CD1( 60),CD2( 60),
     1 CD3( 60),CD4( 60),SX( 60),SXD( 60)
      COMMON/FUNI/ X( 60)
      COMMON/FIRT/ XD( 60)
      COMMON/SECD/XDD(30)
      GO TO (1,2,3,4),KUTTA
    1 DO 10 I=1,NVAR
      SX(I) = X(I)
      C1(I) = XD(I)*DT
   10 X(I)  = SX(I)+0.5*C1(I)
      IF(NDVAR.EQ.0)GO TO 50
      DO 100 I=1,NDVAR
      SXD(I) = XD(I)
      CD1(I) = XDD(I)*DT
  100 XD(I) = SXD(I)+0.5*CD1(I)
   50 CONTINUE
      TIME = TIME + 0.5*DT
      RETURN
    2 DO 20 I=1,NVAR
      C2(I) = XD(I)*DT
   20 X(I) = SX(I)+0.5*C2(I)
      IF(NDVAR.EQ.0)GO TO 51
      DO 200 I=1,NDVAR
      CD2(I) = XDD(I)*DT
  200 XD(I) = SXD(I)+0.5*CD2(I)
   51 CONTINUE
      RETURN
    3 DO 30 I=1,NVAR
      C3(I) = XD(I)*DT
   30 X(I) = SX(I)+C3(I)
      IF(NDVAR.EQ.0)GO TO 52
      DO 300 I=1,NDVAR
      CD3(I) = XDD(I)*DT
  300 XD(I) = SXD(I)+CD3(I)
   52 CONTINUE
      TIME = TIME+0.5*DT
      RETURN
    4 DO 40 I=1,NVAR
      C4(I) = XD(I)*DT
   40 X(I) = SX(I)+(C1(I)+C4(I)+2.*(C2(I)+C3(I)))/6.0
      IF(NDVAR.EQ.0)GO TO 53
      DO 400 I=1,NDVAR
      CD4(I) = XDD(I)*DT
  400 XD(I) = SXD(I)+(CD1(I)+CD4(I)+2.0*(CD2(I)+CD3(I)))/6.0
   53 CONTINUE
      RETURN
      END
```


@HDG,P TPL

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TBL

@PRT,S TBL
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```
MURPHYBIN206*TPFS(0).TBL
     1          SUBROUTINE TBL(X,Y,X1,N,Y1)
     2      C   THE DATA MUST BE  IN ASCENDING ORDER
     3          DIMENSION X(1),Y(1)
     4          DO 93 I=1,N
     5          IF(X(I)-X1)93,95,91
     6       91 DX=X1-X(I-1)
     7          DX1=X(I)-X(I-1)
     8          DY=Y(I)-Y(I-1)
     9          Y1=Y(I-1)+DY*(DX/DX1)
    10          GO TO 94
    11       95 Y1=Y(I)
    12          GO TO 94
    13       93 CONTINUE
    14       94 CONTINUE
    15          RETURN
    16          END

@HD6,P    TBLND

@PRT,S    TBLND
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TBLND                                                                DATE  040379   PAGE      1

MURPHYBIN206*TPF$(U).TBLND
      1            SUBROUTINE TBLND(NEXTR,ND,Z,X,NA,XA,NS,ANS)
      2      C                                                                    TBLND010
      3      C  N-DIMENSIONAL TABLE LOOK-UP ROUTINE                 03/20/73     TBLND020
      4      C                                                                    TBLND030
      5      C                                                                    TBLND060
      6      C                                                                    TBLND070
      7      C                                                                    TBLND080
      8      C     NEXTR      EXTRAPOLATION CONTROL (INTEGER)                     TBLND090
      9      C                  IF ZERO, NO EXTRAPOLATION (RUN TERMINATED)        TBLND100
     10      C                  IF POSITIVE, EXTRAPOLATION OCCURS                 TBLND110
     11      C                  IF NEGATIVE, NO EXTRAPOLATION (RUN CONTINUED)     TBLND120
     12      C     ND         TABLE LOOK-UP DIMENSION, LIMITED TO 6 (INTEGER)     TBLND130
     13      C                (ONE GREATER THAN NUMBER OF INDEPENDENT PARAMETERS) TBLND140
     14      C                  IF POSITIVE, INDEPENDENT VECTOR INDICES ARE FOUND TBLND150
     15      C                  IF NEGATIVE, SAVED VALUES OF INDEPENDENT VECTOR   TBLND160
     16      C                    INDICES ARE USED                                TBLND170
     17      C     Z          TABLE OF DEPENDENT PARAMETERS (REAL ARRAY)          TBLND180
     18      C     X          TABLE OF INDEPENDENT VECTORS (REAL ARRAY)           TBLND190
     19      C                (EACH VECTOR MUST BE IN ASCENDING ORDER)            TBLND200
     20      C                  EXAMPLE OF X AND Z TABLES:                        TBLND210
     21      C                     X-TABLE                Z-TABLE                TBLND220
     22      C                       A1          C1,...,C4 FOR B1 FOR A1         TBLND230
     23      C                       A2             @      @  B2  @  @          TBLND240
     24      C                       B1             @      @  B3  @  @          TBLND250
     25      C                       B2             @      @  B1  @  A2         TBLND260
     26      C                       B3             @      @  B2  @  @          TBLND270
     27      C                       C1             @      @  B3  @  @          TBLND280
     28      C                       C2                                         TBLND290
     29      C                       C3                                         TBLND300
     30      C                       C4                                         TBLND310
     31      C     NA         LENGTH OF EACH INDEPENDENT VECTOR (INTEGER ARRAY)   TBLND320
     32      C                  EXAMPLE:  NA(3) > 2, 3, 4                         TBLND330
     33      C     XA         INDEPENDENT PARAMETERS (REAL ARRAY)                 TBLND340
     34      C     NS         SAVED VALUES OF INDEPENDENT VECTOR INDICES (INTEGERS) TBLND350
     35      C                (SHOULD BE INITIALLY SET TO -1 SO THAT INDEPENDENT  TBLND360
     36      C                  VECTORS ARE TESTED FOR ASCENDING ORDER)           TBLND370
     37      C                                                                    TBLND380
     38      C                                                                    TBLND390
     39      C     ERROR CONDITIONS:  (IF AN ERROR OCCURS, A MESSAGE IS PRINTED   TBLND400
     40      C                         AND THE RUN IS TERMINATED).                TBLND410
     41      C        1.  AT LEAST ONE OF THE INDEPENDENT VECTORS IS NOT IN       TBLND420
     42      C            ASCENDING ORDER.                                        TBLND430
     43      C        2.  WITH NEXTR SET TO ZERO, AT LEAST ONE OF THE INDEPENDENT TBLND440
     44      C            PARAMETERS IS OUT OF RANGE OF THE INDEPENDENT VECTORS.  TBLND450
     45      C        3.  TABLE LOOK-UP DIMENSION, ND, IS GREATER THAN 6.         TBLND460
     46      C                                                                    TBLND470
     47      C                                                                    TBLND480
     48            DIMENSION  Z(1), X(1), NA(1), XA(1), NS(1),                     0490
     49           *           RATIO(5), NGROUP(5), ITOT(5), WJ(32)                0500
     50      C                                                                    TBLND510
     51      C                                                                    TBLND560
     52      C                                                                    TBLND600
     53      C                                                                    TBLND610
     54          1 IF (ND .LT. 0)  GO TO 60                                       0620
     55            IF(ND .LT. 7)  GO TO 10                                        0630
     56          2 WRITE (6,902)                                                  0640
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      4 WRITE (6,904)                                                    0650
        STOP                                                             0660
C                                                                        TBLN0670
   10 L1 = 1                                                             0680
      LF = ND - 1                                                        0690
      DO 39  I=1,LF                                                      0700
      L2 = L1 + NA(I) - 1                                                0710
      IF (NS(I) .GT. -1) GO TO 20                                        0720
      NS(I) = 0                                                          0730
      JF = L2 - 1                                                        0740
      DO 12  J=L1,JF                                                     0750
      IF (X(J) .LT. X(J+1))  GO TO 12                                    0760
   11 WRITE (6,902)                                                      0770
      WRITE (6,911)  I, J                                                0780
      GO TO 90                                                           0790
   12 CONTINUE                                                           0800
C                                                                        TBLN0810
   20 IF (NS(I) .LT. L1  .OR.  NS(I) .GT. L2)  NS(I) = L1 - 1            0820
      IF (XA(I) .GT. X(L1)  .AND.  XA(I) .LT. X(L2))  GO TO 22           0830
      IF (XA(I) .GE. X(L2))  NS(I) = L2                                  0840
      IF (XA(I) .LE. X(L1))  NS(I) = L1 - 1                              0850
   21 IF (NEXTR)  33,30,32                                               0860
   22 IF (NS(I) .EQ. L2)  NS(I) = L2 - 1                                 0870
      L = NS(I)                                                          0880
      LL = 1                                                             0890
      IF (L .LT. L1)  GO TO 26                                           0900
      IF (XA(I) .LE. X(L))  LL = -1                                      0910
   24 IF (XA(I) .GT. X(L)  .AND.  XA(I) .LE. X(L+1)) GO TO 33            0920
   26 L = L + LL                                                         0930
      NS(I) = L                                                          0940
      IF (L .GE. L1  .AND.  L .LT. L2)  GO TO 24                         0950
      GO TO 21                                                           0960
   30 WRITE (6,902)                                                      0970
      WRITE (6,930)  I                                                   0980
      GO TO 90                                                           0990
   32 IF (NS(I) .GE. L2)  NS(I) = L2 - 1                                 1000
      IF (NS(I) .LT. L1)  NS(I) = L1                                     1010
C                                                                        TBLN1020
   33 KA = NS(I)                                                         1030
      KB = NS(I) + 1                                                     1040
      IF (NS(I) .LT. L1)  KA = L1                                        1050
      IF (NS(I) .EQ. L2)  KB = L2                                        1060
      IF (X(KA) .EQ. X(KB))  GO TO 35                                    1070
   34 RATIO(I) = (XA(I) - X(KA)) / (X(KB) - X(KA))                       1080
      GO TO 37                                                           1090
   35 RATIO(I) = 0.0                                                     1100
      NS(I) = KA                                                         1110
   37 L1 = L2 + 1                                                        1120
   39 CONTINUE                                                           1130
C                                                                        TBLN1140
   40 NGROUP(1) = NS(1)                                                  1150
      NSUM = NA(1)                                                       1160
   42 DO 44  I=2,LF                                                      1170
      NGROUP(I) = NS(I) - NSUM                                           1180
      NSUM = NSUM + NA(I)                                                1190
   44 CONTINUE                                                           1200
      ITOT(LF) = 1                                                       1210
```

```
      C                                                                 TBLN1220
   50 DO 52  I=2,LF                                                     1230
      J=LF-I+1
      ITOT(J) = ITOT(J+1) * NA(J+1)                                     1250
   52 CONTINUE                                                          1260
      C                                                                 TBLN1270
   60 KF = 2**LF                                                        1280
      MW = -2                                                           1290
   61 DO 69  I=1,KF,2                                                   1300
      IFIRST = 1                                                        1310
      MW = MW + 2                                                       1320
   62 DO 67  J=1,LF
      MM = 2**(J-1)                                                     1340
      MMM = MM
      MWM = MW
      CALL BIN(MMM,0,36,0,MWM,1)
      IF(MMM.EQ.0) GO TO 65
      IMON = NGROUP(J) + 1                                              1360
      GO TO 66                                                          1370
   65 IMON = NGROUP(J)                                                  1380
   66 IFIRST = IFIRST + (IMON-1)*ITOT(J)                                1390
   67 CONTINUE                                                          1400
      ISEC = IFIRST + ITOT(1)                                           1410
      WJ(I) = Z(IFIRST)                                                 1420
      WJ(I+1) = Z(ISEC)                                                 1430
   69 CONTINUE                                                          1440
      C                                                                 TBLN1450
   70 DO 79  I=1,LF                                                     1460
      KF = KF/2                                                         1470
   71 DO 77  J=1,KF                                                     1480
      WJ(J) = WJ(2*J-1)                                                 1490
      IF (RATIO(I) .EQ. 0.0) GO TO 77                                   1500
      WJ(J) = WJ(J) + (WJ(2*J) - WJ(2*J-1)) * RATIO(I)                  1510
   77 CONTINUE                                                          1520
   79 CONTINUE                                                          1530
      C                                                                 TBLN1540
   80 ANS   = WJ(1)
      RETURN                                                            1560
      C                                                                 TBLN1570
   90 CONTINUE
      RETURN                                                            1600
      C                                                                 TBLN1610
  902 FORMAT (1H1/10X,'ERROR OCCURRED IN TBLND ROUTINE'/1H )            1620
  904 FORMAT (10X,'DIMENSION OF TABLE EXCEEDS 6  (M = ',I2,')')         1630
  911 FORMAT (10X,'INDEPENDENT VECTOR NO. ',I2,' IS NOT IN ASCENDING ORD 1640
     *ER AT INDEX NO.',I3)                                              1650
  930 FORMAT (10X,'INDEPENDENT PARAMETER NO. ',I2,' IS OUT OF RANGE OR T 1660
     *HE CORRESPONDING VECTOR (K = 0)')                                 1670
10000 CONTINUE
      END                                                               1680

@HDG,P     XTAN2

@PRT,S     XTAN2
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```

```
MURPHYBIN206*TPFS(L).XTAN2
      1            FUNCTION XTAN2(A,B)
      2            IF(B .EQ. 0.0) GO TO 100
      3            XTAN2=ATAN2(A,B)*57.3
      4            RETURN
      5        100 IF(A)10,16,15
      6         10 XTAN2=-90.0
      7            RETURN
      8         16 XTAN2=0.0
      9            RETURN
     10         15 XTAN2=90.0
     11            RETURN
     12            END

@FIN
```

APPROVAL

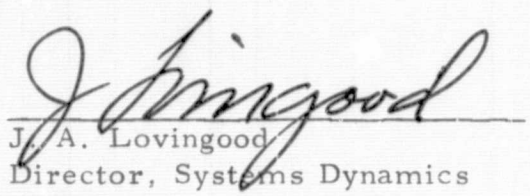
COMPUTER PROGRAM DEVELOPMENT AND USER'S MANUAL FOR PROGRAM PARACH

by

Hughlen I. Murphree

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.



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