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# A FORTRAN IV PROGRAM FOR PREDICTING THE UNCONTROLLED DYNAMIC RESPONSE CHARACTERISTICS OF A SPINNING, CABLE-CONNECTED, TWO-BODY SPACE STATION

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## ABSTRACT

This paper presents a 12-degree-of-freedom FORTRAN IV digital computer program to determine the nonlinear motion of two rigid bodies connected by massless cables and subject to external disturbances.

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## SUMMARY

This paper presents a 12-degree-of-freedom digital computer program for determining the nonlinear motion of two rigid bodies connected by massless cables and subjected to time-dependent external sinusoidal forces and torques. The equations used in the program and a sample problem are included.

## INTRODUCTION

Long-duration space missions may tax the ability of man to withstand long periods of weightlessness. Some uncertainty is presently associated with this ability. Because of this uncertainty, the study of techniques to provide an artificial gravity environment is very desirable. One of the most attractive means of achieving a high ratio of artificial gravity to spin velocity (equivalent to that of a large diameter space station) is to separate the manned vehicle from its adjacent booster stage by means of flexible cables and to spin the two bodies about their composite mass center. The problem of determining the dynamic response characteristics of this type of configuration is dealt with in this paper by means of a 12-degree-of-freedom digital computer program.

The disturbances presently allowed for in the program include time-dependent external sinusoidal forces and torques on both bodies. These disturbances can be used to determine the general dynamic characteristics of a given configuration and to determine the effect on these characteristics of altering body and cable parameters and/or cable configurations. The equations defining these external disturbances are programed in an external force subroutine distinct from the rest of the program (appendix A). Equations representing other external disturbances (gravity gradient torques, reaction control system jets, associated control equations, et cetera) may be included in the program by replacing and/or adding the appropriate punched cards in the force subroutine. Perturbations resulting from internal mass shifts and fixed internal rotating masses may be included in the program by adding the appropriate terms to Euler's dynamical equations. Instantaneous cable length and forces are calculated in a subroutine which represents cable free length as a constant. This subroutine may be easily modified to study vehicle motion during cable extension or retraction by simply representing cable free length as an arbitrary function of time and/or any of the dependent variables in the program. Appendix B provides data on the general input and output of the program.

## SYMBOLS

| | |
|---|---|
| $A_2$ | instantaneous angular velocity of body 2 about c.g.$_{comp}$, deg/sec |
| AA, BB | defined by equations (18) and (19) |
| $AF_{x,n}, AF_{y,n}, AF_{z,n}$ | components of amplitude of the impressed force acting on body n along $i_n$-, $j_n$-, and $k_n$-axis, respectively, lb (n = 1, 2) |
| $AG_{x,n}, AG_{y,n}, AG_{z,n}$ | components of amplitude of the impressed torque acting on body n about $i'_n$-, $j'_n$-, and $k'_n$-axis, respectively, in-lb (n = 1, 2) |
| a, b, c | components of translational velocity of c.g.$_2$ relative to c.g.$_{comp}$, directed parallel to the $\bar{\bar{X}}'\bar{\bar{Y}}'$ plane and perpendicular to the plane of $\theta_{RB}$, directed radially outward from c.g.$_{comp}$, and directed perpendicular to b and in the plane of $\theta_{RB}$, in/sec |
| $CD_n$ | equivalent viscous damping coefficient for cable$_n$, lb-sec/in. (n = 2, . . . , N + 1) |
| $CG_{x,n}, CG_{y,n}, CG_{z,n}$ | components of torque acting through c.g.$_n$ about $i_n$-, $j_n$-, and $k_n$-axis, respectively, because of N cables, in-lb (n = 1, 2) |
| $CG_{x',n}, CG_{y',n}, CG_{z',n}$ | components of torque acting through c.g.$_n$ about $i'_n$-, $j'_n$-, and $k'_n$-axis, respectively, because of N cables, in-lb (n = 1, 2) |
| $CK_n$ | spring constant of cable$_n$, lb/in. (n = 2, . . . , N + 1) |

| | |
|---|---|
| $CL_n$ | unstretched length of $cable_n$, in. $(n = 2, \ldots, N + 1)$ |
| $C_{f, max}$ | number of the highest stressed cable |
| $cable_n$ | cable connected to points $P_{1,n}$ and $P_{2,n}$ $(n = 2, \ldots, N + 1)$ |
| $c.g._{comp}$ | center of gravity of composite configuration |
| $c.g._n$ | center of gravity of body $n$ $(n = 1, 2)$ |
| $D$ | vector sum of $a$ and $c$, in/sec |
| $FD_n$ | total damping force in $cable_n$, lb $(n = 2, \ldots, N + 1)$ |
| $FK_n$ | total spring force in $cable_n$, lb $(n = 2, \ldots, N + 1)$ |
| $F_{c, max}$ | force on the highest stressed cable, lb |
| $F_{x,n}, F_{y,n}, F_{z,n}$ | components of impressed force acting on body $n$ along $i_n$-, $j_n$-, and $k_n$-axis, respectively, lb $(n = 1, 2)$ |
| $F_{x,1}C_n, F_{y,1}C_n, F_{z,1}C_n$ | components of force (because of $cable_n$) acting on body 1 parallel to $i_1$-, $j_1$-, and $k_1$-axis, respectively, lb $(n = 2, \ldots, N + 1)$ |
| $F_{x,2}C_n, F_{y,2}C_n, F_{z,2}C_n$ | components of force (because of $cable_n$) acting on body 2 parallel to $i_2$-, $j_2$-, and $k_2$-axis, respectively, lb $(n = 2, \ldots, N + 1)$ |
| $G_{x,n}, G_{y,n}, G_{z,n}$ | components of impressed torque acting on body $n$ about $i'_n$-, $j'_n$-, and $k'_n$-axis, respectively, in-lb $(n = 1, 2)$ |
| $G_{x,1,n}, G_{y,1,n}, G_{z,1,n}$ | components of torque acting through $c.g._1$ about $i_1$-, $j_1$-, and $k_1$-axis, respectively, because of $cable_n$, in-lb $(n = 2, \ldots, N + 1)$ |
| $G_{x,2,n}, G_{y,2,n}, G_{z,2,n}$ | components of torque acting through $c.g._2$ about $i_2$-, $j_2$-, and $k_2$-axis, respectively, because of $cable_n$, in-lb $(n = 2, \ldots, N + 1)$ |

| | |
|---|---|
| $I_{i',n}, I_{j',n}, I_{k',n}$ | body n moments of inertia about $i'_n$-, $j'_n$-, and $k'_n$-axis, respectively, lb-sec$^2$-in. (n = 1, 2) |
| $i_{RB}, j_{RB}, k_{RB}$ | orthogonal pseudorigid body axes fixed at c.g.$_{comp}$ |
| $i_n, j_n, k_n$ | arbitrary orthogonal axes body fixed at c.g.$_n$ (n = 1, 2) |
| $i'_n, j'_n, k'_n$ | principal axes of inertia for body n (n = 1, 2) |
| $\bar{i}_n, \bar{j}_n, \bar{k}_n$ | unit vectors directed parallel to and in the positive direction of the $i_n$-, $j_n$-, and $k_n$-axis, respectively (n = 1, 2) |
| $\bar{i}'_n, \bar{j}'_n, \bar{k}'_n$ | unit vectors directed parallel to and in the positive direction of the $i'_n$-, $j'_n$-, and $k'_n$-axis, respectively (n = 1, 2) |
| $KK_n, ZZ_n$ | functions defined by equations (13) and (14), (n = 1, 2) |
| $\left[\ell_n\right]$ | matrix of direction cosines for transforming vector components from the principal body axes of body n to the arbitrary body axes of body n (n = 1, 2) |
| $M_n$ | mass of body n, lb-sec$^2$/in. (n = 1, 2) |
| N | number of cables |
| $P_{1,n}, P_{2,n}$ | points on bodies 1 and 2, respectively, for which relative displacement vectors are determined (n = 1, 2, . . ., N + 1) (cable attachment points for n = 2, . . ., N + 1) |
| $\overline{P_{1,n}P_{2,n}}$ | magnitude of relative displacement vector from point $P_{1,n}$ to point $P_{2,n}$, in. (n = 1, 2, . . ., N + 1) |
| $TF_{x,n}, TF_{y,n}, TF_{z,n}$ | components of total force acting on body n along $i_n$-, $j_n$-, and $k_n$-axis, respectively, lb (n = 1, 2) |
| $TG_{x,n}, TG_{y,n}, TG_{z,n}$ | components of total moment acting through c.g.$_n$ about $i'_n$-, $j'_n$-, and $k'_n$-axis, respectively, in-lb (n = 1, 2) |
| t | time, sec |

$u''_n, v''_n, w''_n$ components of translational velocity vector of $c.g._n$ along $i_n$-, $j_n$-, and $k_n$-axis, respectively, in/sec $(n = 1, 2)$

$\overline{X}_n, \overline{Y}_n, \overline{Z}_n$ components of relative displacement vector from point $P_{1,n}$ to point $P_{2,n}$ parallel to $i_1$-, $j_1$-, and $k_1$-axis, respectively, in. $(n = 1, 2, \ldots, N + 1)$

$\overline{X}_{P,1,n}, \overline{Y}_{P,1,n}, \overline{Z}_{P,1,n}$ components of relative displacement vector from $c.g._1$ to $P_{1,n}$ along $i_1$-, $j_1$-, and $k_1$-axis, respectively, in. $(n = 1, 2, \ldots, N + 1)$

$\overline{X}_{P,2,n}, \overline{Y}_{P,2,n}, \overline{Z}_{P,2,n}$ components of relative displacement vector from $c.g._2$ to $P_{2,n}$ along $i_2$-, $j_2$-, and $k_2$-axis, respectively, in. $(n = 1, 2, \ldots, N + 1)$

$\overline{\overline{X}}, \overline{\overline{Y}}, \overline{\overline{Z}}$ inertially fixed orthogonal axes

$\overline{\overline{X}}', \overline{\overline{Y}}', \overline{\overline{Z}}'$ orthogonal axes parallel with $\overline{\overline{X}}$-, $\overline{\overline{Y}}$-, and $\overline{\overline{Z}}$-axis, respectively, with origin at $c.g._{comp}$

$\overline{\overline{X}}_{c.g.}, \overline{\overline{Y}}_{c.g.}, \overline{\overline{Z}}_{c.g.}$ components of $c.g._{comp}$ displacement vector along $\overline{\overline{X}}$-, $\overline{\overline{Y}}$-, and $\overline{\overline{Z}}$-axis, respectively, in.

$\overline{\overline{X}}'_{c.g.}, \overline{\overline{Y}}'_{c.g.}, \overline{\overline{Z}}'_{c.g.}$ components of relative displacement vector from $c.g._{comp}$ to $c.g._1$ along $\overline{\overline{X}}'$-, $\overline{\overline{Y}}'$-, and $\overline{\overline{Z}}'$-axis, respectively, in.

$\overline{\overline{X}}_n, \overline{\overline{Y}}_n, \overline{\overline{Z}}_n$ components of $c.g._n$ displacement vector along $\overline{\overline{X}}$-, $\overline{\overline{Y}}$-, and $\overline{\overline{Z}}$-axis, respectively, in.

$\alpha$ spin-plane pointing error, deg

$\alpha_{1,n}, \alpha_{2,n}, \alpha_{3,n}$ functions defined by equations (37), (38), and (39) $(n = 1, 2, \ldots, N + 1)$

$[\Gamma]$ general coordinate transformation matrix, defined by equation (1)

| | |
|---|---|
| $[\bar{\Gamma}]$ | orthogonal transformation matrix for transforming vector components from the arbitrary body axes of body 1 to the arbitrary body axes of body 2 |
| $[\Gamma_n]$ | orthogonal transformation matrix for transforming vector components from the inertially fixed axis system to the arbitrary body axes of body n (n = 1, 2) |
| $[\Gamma_R]$ | orthogonal transformation matrix for transforming vector components from the inertially fixed axis system to the pseudorigid body axis system |
| $[\Gamma_{R,n}]$ | orthogonal transformation matrix for transforming vector components from the pseudorigid body axis system to the arbitrary body axes of body n (n = 1, 2) |
| $\gamma$ | angle between a and D, deg |
| $\psi, \theta, \phi$ | general Euler angles |
| $\bar{\psi}, \bar{\theta}, \bar{\phi}$ | Euler angles defining angular orientation of arbitrary body-fixed axes $i_2$, $j_2$, and $k_2$ with respect to arbitrary body-fixed axes $i_1$, $j_1$, and $k_1$, deg |
| $\psi_{RB}, \theta_{RB}, \phi_{RB} (\phi=0)$ | Euler angles defining angular orientation of pseudorigid body axes $i_{RB}$, $j_{RB}$, and $k_{RB}$ with respect to axes $\bar{\bar{X}}'$, $\bar{\bar{Y}}'$, and $\bar{\bar{Z}}'$, deg |
| $\psi_n, \theta_n, \phi_n$ | Euler angles defining angular orientation of arbitrary body-fixed axes $i_n$, $j_n$, and $k_n$ with respect to inertially fixed axes $\bar{\bar{X}}$, $\bar{\bar{Y}}$, and $\bar{\bar{Z}}$, deg (n = 1, 2) |
| $\psi_{s,n}, \theta_{s,n}, \phi_{s,n}$ | Euler angles defining angular orientation of arbitrary body-fixed axes $i_n$, $j_n$, and $k_n$ with respect to pseudorigid body axes $i_{RB}$, $j_{RB}$, and $k_{RB}$, deg (n = 1, 2) |
| $\Omega_{x,n}, \Omega_{y,n}, \Omega_{z,n}$ | body n angular velocity components about $i_n$-, $j_n$-, and $k_n$-axis, respectively, deg/sec (n = 1, 2) |
| $\Omega'_{x,n}, \Omega'_{y,n}, \Omega'_{z,n}$ | body n angular velocity components about $i'_n$-, $j'_n$-, and $k'_n$-axis, respectively, deg/sec (n = 1, 2) |
| $\Omega_{x,1L}, \Omega_{y,1L}, \Omega_{z,1L}$ | functions defined by equation (33) |

$\omega_{F,n}$ frequency of the impressed force acting on body n, rad/sec (n = 1, 2)

$\omega_{T,n}$ frequency of the impressed torque acting on body n, rad/sec (n = 1, 2)

Subscripts:

m defines matrix row

p defines matrix column

A dot over a symbol indicates differentiation with respect to t.

## ANALYSIS

### Axes Systems and General Vehicle Orientation

The general body orientation of the spacecraft is shown in figure 1. Each body has two body-fixed orthogonal axes systems having origins at the body center of gravity. One of the systems must be coincident with the body principal axes. The rotational equations of motion for each body are written with respect to this system and thus will reduce to Euler's dynamical equations. Angular orientation of the other axes system within the body is completely arbitrary; however, the system is usually located coincident with geometrically symmetric axes, if such axes exist. This arbitrary system is angularly located in an inertial frame by a set of Euler angles defined in figure 2. The translational equations of motion for each body are written with respect to this arbitrary system. The arbitrary systems in the two bodies are angularly related to each other by a set of relative Euler angles which reduce to pitch, yaw, and roll for small angles (fig. 3). The two axes systems within a given body are related by a set of direction cosines.

Composite body motion is broken up into pseudorigid body motion and flexible body motion. The pseudorigid body is defined as a straight line connecting the two body centers of gravity. This pseudorigid body has a body-fixed orthogonal axes system with its origin at the composite center of gravity. An auxiliary set of reference axes $\overline{\overline{X}}'$, $\overline{\overline{Y}}'$, and $\overline{\overline{Z}}'$ (parallel to the fixed inertial axes and located at the composite center of gravity) is used to angularly orient the pseudorigid body in inertial space. Pseudorigid body orientation is shown in figure 4. Note that the $i_{RB}$ axis is coincident with the pseudorigid body and directed toward body 2 and that the $j_{RB}$ axis is restricted to the $\overline{\overline{X}}'\overline{\overline{Y}}'$ plane (a line can have no roll displacement). The angles $\psi_{RB}$ and $\theta_{RB}$ define pseudorigid body inertial angular response, and the coordinates $\overline{\overline{X}}_{c.g.}$, $\overline{\overline{Y}}_{c.g.}$, and $\overline{\overline{Z}}_{c.g.}$ define pseudorigid body inertial translational response. The flexible cables connecting the two bodies will superimpose structural oscillations on the pseudorigid body motion. The structural response of each body is measured by a set of Euler angles relating the respective arbitrary body axes to the pseudorigid body axes (fig. 5) and by monitoring the instantaneous length of the pseudorigid body $\overline{P_{1,1}P_{2,1}}$. The program will also calculate the instantaneous angular velocity of body 2 about the composite center of gravity (fig. 6).

A number of coordinate transformations are required by the program. To simplify the description of many of these transformations, the following general matrix will be required.

$$[\Gamma] = \begin{bmatrix} \Gamma_{11} & \Gamma_{12} & \Gamma_{13} \\ \Gamma_{21} & \Gamma_{22} & \Gamma_{23} \\ \Gamma_{31} & \Gamma_{32} & \Gamma_{33} \end{bmatrix} = \begin{bmatrix} \cos\theta\cos\psi & \cos\theta\sin\psi & -\sin\theta \\ -\sin\psi\cos\phi + \sin\phi\sin\theta\cos\psi & \cos\phi\cos\psi + \sin\phi\sin\theta\sin\psi & \sin\phi\cos\theta \\ \sin\psi\sin\phi + \cos\phi\sin\theta\cos\psi & -\sin\phi\cos\psi + \cos\phi\sin\theta\sin\psi & \cos\phi\cos\theta \end{bmatrix} \tag{1}$$

The principal body axes are related to the arbitrary body axes (for a given body) as follows

$$\begin{Bmatrix} i_n \\ j_n \\ k_n \end{Bmatrix} = \begin{bmatrix} \ell_n \end{bmatrix} \begin{Bmatrix} i'_n \\ j'_n \\ k'_n \end{Bmatrix} \tag{2}$$

where $n = 1, 2$ and $\begin{bmatrix} \ell_n \end{bmatrix}$ is given by

$$\begin{bmatrix} \ell_n \end{bmatrix} = \begin{bmatrix} \bar{i}_n \cdot \bar{i}'_n & \bar{i}_n \cdot \bar{j}'_n & \bar{i}_n \cdot \bar{k}'_n \\ \bar{j}_n \cdot \bar{i}'_n & \bar{j}_n \cdot \bar{j}'_n & \bar{j}_n \cdot \bar{k}'_n \\ \bar{k}_n \cdot \bar{i}'_n & \bar{k}_n \cdot \bar{j}'_n & \bar{k}_n \cdot \bar{k}'_n \end{bmatrix} \tag{3}$$

The inertial axes are related to the arbitrary body axes (for a given body) as follows

$$\begin{Bmatrix} i_n \\ j_n \\ k_n \end{Bmatrix} = \left[\Gamma_n\right] \begin{Bmatrix} \bar{\bar{X}} \\ \bar{\bar{Y}} \\ \bar{\bar{Z}} \end{Bmatrix} \tag{4}$$

where $n = 1, 2$ and $\left[\Gamma_n\right]$ is given by equation (1) after the following substitutions are made: $[\Gamma] = \left[\Gamma_n\right]$, $\Gamma_{mp} = \Gamma_{mp, n}$, $\psi = \psi_n$, $\theta = \theta_n$, and $\phi = \phi_n$ where $m = 1, 2, 3$ and $p = 1, 2, 3$. The arbitrary body axes of body 1 are related to the arbitrary body axes of body 2 as follows

$$\begin{Bmatrix} i_2 \\ j_2 \\ k_2 \end{Bmatrix} = [\bar{\Gamma}] \begin{Bmatrix} i_1 \\ j_1 \\ k_1 \end{Bmatrix} \tag{5}$$

where $[\bar{\Gamma}]$ is given by equation (1) after the following substitutions are made: $[\Gamma] = [\bar{\Gamma}]$, $\Gamma_{mp} = \bar{\Gamma}_{mp}$, $\theta = \bar{\theta}$, $\psi = \bar{\psi}$, and $\phi = \bar{\phi}$ where $m = 1, 2, 3$ and $p = 1, 2, 3$. The inertial axes are angularly related to the pseudorigid body axes as follows

$$\begin{Bmatrix} i_{RB} \\ j_{RB} \\ k_{RB} \end{Bmatrix} = \left[\Gamma_R\right] \begin{Bmatrix} \bar{\bar{X}} \\ \bar{\bar{Y}} \\ \bar{\bar{Z}} \end{Bmatrix} \tag{6}$$

where $\left[\Gamma_R\right]$ is given by equation (1) after the following substitutions are made: $[\Gamma] = \left[\Gamma_R\right]$, $\Gamma_{mp} = \Gamma_{R, mp}$, $\theta = \theta_{RB}$, $\psi = \psi_{RB}$, and $\phi = 0.0$ where $m = 1, 2, 3$ and $p = 1, 2, 3$. The Euler angles in equation (6) are derived quantities obtained from the following equations.

$$\psi_{RB} = \tan^{-1}\left(\frac{\overline{\overline{Y}}_2 - \overline{\overline{Y}}_{c.g.}}{\overline{\overline{X}}_2 - \overline{\overline{X}}_{c.g.}}\right) \tag{7}$$

$$\theta_{RB} = \tan^{-1}\left(\frac{\overline{\overline{Z}}_{c.g.} - \overline{\overline{Z}}_2}{\sqrt{\left(\overline{\overline{X}}_2 - \overline{\overline{X}}_{c.g.}\right)^2 + \left(\overline{\overline{Y}}_2 - \overline{\overline{Y}}_{c.g.}\right)^2}}\right) \tag{8}$$

The pseudorigid body axes are related to the arbitrary body axes (for a given body) as follows

$$\begin{Bmatrix} i_n \\ j_n \\ k_n \end{Bmatrix} = \left[\Gamma_{R,n}\right] \begin{Bmatrix} i_{RB} \\ j_{RB} \\ k_{RB} \end{Bmatrix} \tag{9}$$

where $n = 1, 2$ and $\left[\Gamma_{R,n}\right]$ is given by equation (1) after the following substitutions are made: $[\Gamma] = \left[\Gamma_{R,n}\right]$, $\Gamma_{mp} = \Gamma_{mp,R,n}$, $\theta = \theta_{s,n}$, $\psi = \psi_{s,n}$, and $\phi = \phi_{s,n}$ where $m = 1, 2, 3$ and $p = 1, 2, 3$. By comparing equations (4) and (6) to equation (9), the structural Euler angles can be obtained as follows

$$\psi_{s,n} = \tan^{-1}\left(\frac{\Gamma_{11,n}\Gamma_{R,21} + \Gamma_{12,n}\Gamma_{R,22}}{\Gamma_{11,n}\Gamma_{R,11} + \Gamma_{12,n}\Gamma_{R,12} + \Gamma_{13,n}\Gamma_{R,13}}\right) \tag{10}$$

$$\phi_{s,n} = \tan^{-1}\left(\frac{KK_n}{ZZ_n}\right) \tag{11}$$

$$\theta_{s,n} = \tan^{-1}\left(\frac{-\Gamma_{11,n}\Gamma_{R,13} - \Gamma_{12,n}\Gamma_{R,32} - \Gamma_{13,n}\Gamma_{R,33}}{\sqrt{KK_n^{\,2} + ZZ_n^{\,2}}}\right) \tag{12}$$

where $KK_n$ and $ZZ_n$ are given by

$$KK_n = \Gamma_{21,n}\Gamma_{R,31} + \Gamma_{22,n}\Gamma_{R,32} + \Gamma_{23,n}\Gamma_{R,33} \tag{13}$$

and

$$ZZ_n = \Gamma_{31,n}\Gamma_{R,31} + \Gamma_{32,n}\Gamma_{R,32} + \Gamma_{33,n}\Gamma_{R,33} \tag{14}$$

The instantaneous spin-plane variables (fig. 6) are derived quantities obtained from the following equations

$$\gamma = \tan^{-1}\left(\frac{BB}{AA}\right) \tag{15}$$

$$\alpha = \cos^{-1}\left(\cos\theta_{RB}\cos\gamma\right) \tag{16}$$

and

$$|A_2| = \frac{\sqrt{BB^2 + AA^2}}{\overline{P_{1,1}P_{2,1}} - \sqrt{\left(\bar{\bar{X}}'_{c.g.}\right)^2 + \left(\bar{\bar{Y}}'_{c.g.}\right)^2 + \left(\bar{\bar{Z}}'_{c.g.}\right)^2}} \tag{17}$$

where AA and BB are given by

$$AA = \left(\dot{\bar{\bar{Y}}}_2 - \dot{\bar{\bar{Y}}}_{c.g.}\right)\cos\psi_{RB} - \left(\dot{\bar{\bar{X}}}_2 - \dot{\bar{\bar{X}}}_{c.g.}\right)\sin\psi_{RB} \tag{18}$$

and

$$BB = -\left[\left(\dot{\bar{\bar{Y}}}_2 - \dot{\bar{\bar{Y}}}_{c.g.}\right)\sin\psi_{RB} + \left(\dot{\bar{\bar{X}}}_2 - \dot{\bar{\bar{X}}}_{c.g.}\right)\cos\psi_{RB}\right]\sin\theta_{RB} - \left(\dot{\bar{\bar{Z}}}_2 - \dot{\bar{\bar{Z}}}_{c.g.}\right)\cos\theta_{RB} \tag{19}$$

## Equations of Motion

The equations used in the program place no restrictions (within the limitations imposed by cable interference) on either angular or translational displacement of the two rigid bodies relative to an inertial frame and to each other. The bodies may also have completely general geometrical and inertial properties.

The rotational equations of motion used in the program are

$$I_{i',n}\dot{\Omega}'_{x,n} - \Omega'_{y,n}\Omega'_{z,n}\left(I_{j',n} - I_{k',n}\right) = TG_{x,n} \tag{20}$$

$$I_{j',n}\dot{\Omega}'_{y,n} - \Omega'_{x,n}\Omega'_{z,n}\left(I_{k',n} - I_{i',n}\right) = TG_{y,n} \tag{21}$$

and

$$I_{k',n}\dot{\Omega}'_{z,n} - \Omega'_{x,n}\Omega'_{y,n}\left(I_{i',n} - I_{j',n}\right) = TG_{z,n} \tag{22}$$

where $n = 1, 2$. Integration of these equations yields $\Omega'_{x,n}$, $\Omega'_{y,n}$, and $\Omega'_{z,n}$. Equations (20), (21), and (22) may be modified to include the effects of internal mass shifts (for example, crew movements) and fixed internal rotating masses. Body n angular velocity components about the arbitrary body axes can be obtained from

$$\begin{Bmatrix} \Omega_{x,n} \\ \Omega_{y,n} \\ \Omega_{z,n} \end{Bmatrix} = \left[\ell_n\right] \begin{Bmatrix} \Omega'_{x,n} \\ \Omega'_{y,n} \\ \Omega'_{z,n} \end{Bmatrix} \tag{23}$$

where n = 1, 2. The translational equations of motion for body n are

$$M_n \dot{u}''_n + M_n\left(\Omega_{y,n} w''_n - \Omega_{z,n} v''_n\right) = TF_{x,n} \tag{24}$$

$$M_n \dot{v}''_n + M_n\left(\Omega_{z,n} u''_n - \Omega_{x,n} w''_n\right) = TF_{y,n} \tag{25}$$

and

$$M_n \dot{w}''_n + M_n\left(\Omega_{x,n} v''_n - \Omega_{y,n} u''_n\right) = TF_{z,n} \tag{26}$$

where n = 1, 2. Integration of these equations yields $u''_n$, $v''_n$, and $w''_n$. The time rates of change of the inertial Euler angles for body n are given by

$$\dot{\theta}_n = \Omega_{y,n} \cos \phi_n - \Omega_{z,n} \sin \phi_n \tag{27}$$

$$\dot{\phi}_n = \Omega_{x,n} + \tan \theta_n\left(\Omega_{y,n} \sin \phi_n + \Omega_{z,n} \cos \phi_n\right) \tag{28}$$

and

$$\dot{\psi}_n = \frac{\Omega_{y,n} \sin \phi_n + \Omega_{z,n} \cos \phi_n}{\cos \theta_n} \tag{29}$$

where n = 1, 2. Integration of these equations results in the Euler angles shown in figure 2. The time rates of change of the relative Euler angles are given by

$$\dot{\bar{\theta}} = \left(\Omega_{y,2} - \Omega_{y,1L}\right)\cos \bar{\Phi} - \left(\Omega_{z,2} - \Omega_{z,1L}\right)\sin \bar{\Phi} \tag{30}$$

$$\dot{\bar{\Phi}} = \left(\Omega_{x,2} - \Omega_{x,1L}\right) + \tan \bar{\theta}\left[\left(\Omega_{y,2} - \Omega_{y,1L}\right)\sin \bar{\Phi} + \left(\Omega_{z,2} - \Omega_{z,1L}\right)\cos \bar{\Phi}\right] \tag{31}$$

and

$$\dot{\overline{\psi}} = \frac{\left[\left(\Omega_{y,2} - \Omega_{y,1L}\right)\sin\overline{\phi} + \left(\Omega_{z,2} - \Omega_{z,1L}\right)\cos\overline{\phi}\right]}{\cos\overline{\theta}} \tag{32}$$

where

$$\begin{Bmatrix} \Omega_{x,1L} \\ \Omega_{y,1L} \\ \Omega_{z,1L} \end{Bmatrix} = [\overline{\Gamma}] \begin{Bmatrix} \Omega_{x,1} \\ \Omega_{y,1} \\ \Omega_{z,1} \end{Bmatrix} \tag{33}$$

Integration of equations (30), (31), and (32) yields the relative Euler angles. The components (in the arbitrary axis system of body 1) of the time rate of change of $\overline{P_{1,n}P_{2,n}}$ are

$$\begin{aligned} \dot{\overline{X}}_n = {} & \overline{Y}_n\Omega_{z,1} - \overline{Z}_n\Omega_{y,1} - u_1'' - \overline{Z}_{P,1,n}\Omega_{y,1} + \overline{Y}_{P,1,n}\Omega_{z,1} \\ & + \overline{\Gamma}_{11}\alpha_{1,n} + \overline{\Gamma}_{21}\alpha_{2,n} + \overline{\Gamma}_{31}\alpha_{3,n} \end{aligned} \tag{34}$$

$$\begin{aligned} \dot{\overline{Y}}_n = {} & \overline{Z}_n\Omega_{x,1} - \overline{X}_n\Omega_{z,1} - v_1'' - \overline{X}_{P,1,n}\Omega_{z,1} + \overline{Z}_{P,1,n}\Omega_{x,1} \\ & + \overline{\Gamma}_{12}\alpha_{1,n} + \overline{\Gamma}_{22}\alpha_{2,n} + \overline{\Gamma}_{32}\alpha_{3,n} \end{aligned} \tag{35}$$

and

$$\begin{aligned} \dot{\overline{Z}}_n = {} & \overline{X}_n\Omega_{y,1} - \overline{Y}_n\Omega_{x,1} - w_1'' - \overline{Y}_{P,1,n}\Omega_{x,1} + \overline{X}_{P,1,n}\Omega_{y,1} \\ & + \overline{\Gamma}_{13}\alpha_{1,n} + \overline{\Gamma}_{23}\alpha_{2,n} + \overline{\Gamma}_{33}\alpha_{3,n} \end{aligned} \tag{36}$$

where $n = 1, 2, \ldots, N + 1$ and where

$$\alpha_{1,n} = u_2'' + \overline{Z}_{P,2,n}\Omega_{y,2} - \overline{Y}_{P,2,n}\Omega_{z,2} \tag{37}$$

$$\alpha_{2,n} = v_2'' + \overline{X}_{P,2,n}\Omega_{z,2} - \overline{Z}_{P,2,n}\Omega_{x,2} \tag{38}$$

and

$$\alpha_{3,n} = w_2'' + \overline{Y}_{P,2,n}\Omega_{x,2} - \overline{X}_{P,2,n}\Omega_{y,2} \tag{39}$$

Integration of equations (34), (35), and (36) yields the components of the relative displacement vector from point $P_{1,n}$ to point $P_{2,n}$.

## Force Equations

The total force acting on each body is made up of forces caused by the elongation of the interconnecting cables and forces caused by external sinusoidal forcing functions acting on the respective body. The cables are considered to be perfectly elastic tension members. The cable spring force is given by

$$FK_n = CK_n\left(\overline{P_{1,n}P_{2,n}} - CL_n\right) \tag{40}$$

where $n = 2, \ldots, N + 1$. When $\overline{P_{1,n}P_{2,n}}$ is less than $CL_n$, $\text{cable}_n$ is slack and $FK_n$ is set equal to zero by the program. Energy absorption per cycle because of damping may be approximated by an equivalent viscous damping term provided in the equations of cable force. This damping force is given by

$$FD_n = CD_n \frac{\overline{X}_n\dot{\overline{X}}_n + \overline{Y}_n\dot{\overline{Y}}_n + \overline{Z}_n\dot{\overline{Z}}_n}{\overline{P_{1,n}P_{2,n}}} \tag{41}$$

where $n = 2, \ldots, N + 1$.

Note that the equilibrium position of a given rotating system may be determined by inputting nonzero values for $CD_n$ and zeros for all the forcing function amplitudes and then allowing the program to run until all structural oscillations damp out. The forces $FD_n$ and $FK_n$ are directed along $\text{cable}_n$ and are signed in the arbitrary axes of body 1. The components of force, caused by $\text{cable}_n$ acting on body 1 at $P_{1,n}$, are then given by

$$F_{x,1}C_n = \left(FK_n + FD_n\right)\frac{\overline{X}_n}{\overline{P_{1,n}P_{2,n}}} \tag{42}$$

$$F_{y,1}C_n = \left(FK_n + FD_n\right)\frac{\overline{Y}_n}{\overline{P_{1,n}P_{2,n}}} \tag{43}$$

and

$$F_{z,1}C_n = \left(FK_n + FD_n\right)\frac{\overline{Z}_n}{\overline{P_{1,n}P_{2,n}}} \tag{44}$$

where $n = 2, \ldots, N+1$. The cable force acting on body 2 will be equal and opposite to the cable force acting on body 1. The components of force (in the arbitrary axis system of body 2), caused by $\text{cable}_n$ acting on body 2 at $P_{2,n}$, are given by

$$\begin{Bmatrix} F_{x,2}C_n \\ F_{y,2}C_n \\ F_{z,2}C_n \end{Bmatrix} = -[\overline{\Gamma}]\begin{Bmatrix} F_{x,1}C_n \\ F_{y,1}C_n \\ F_{z,1}C_n \end{Bmatrix} \tag{45}$$

where $n = 2, \ldots, N+1$. The components of torque (in the arbitrary axis system of body 1) acting through $\text{c.g.}_1$, caused by $\text{cable}_n$ acting at $P_{1,n}$, are given by

$$G_{x,1,n} = \overline{Y}_{P,1,n}\left(F_{z,1}C_n\right) - \overline{Z}_{P,1,n}\left(F_{y,1}C_n\right) \tag{46}$$

$$G_{y,1,n} = \overline{Z}_{P,1,n}\left(F_{x,1}C_n\right) - \overline{X}_{P,1,n}\left(F_{z,1}C_n\right) \tag{47}$$

and

$$G_{z,1,n} = \overline{X}_{P,1,n}\left(F_{y,1}C_n\right) - \overline{Y}_{P,1,n}\left(F_{x,1}C_n\right) \tag{48}$$

where $n = 2, \ldots, N + 1$. Similarly, for body 2

$$G_{x,2,n} = \overline{Y}_{P,2,n}\left(F_{z,2}C_n\right) - \overline{Z}_{P,2,n}\left(F_{y,2}C_n\right) \tag{49}$$

$$G_{y,2,n} = \overline{Z}_{P,2,n}\left(F_{x,2}C_n\right) - \overline{X}_{P,2,n}\left(F_{z,2}C_n\right) \tag{50}$$

and

$$G_{z,2,n} = \overline{X}_{P,2,n}\left(F_{y,2}C_n\right) - \overline{Y}_{P,2,n}\left(F_{x,2}C_n\right) \tag{51}$$

where $n = 2, \ldots, N + 1$. The components of torque (in the arbitrary axis system of body 1) acting through $c.g._1$, caused by all of the cables, are given by

$$CG_{x,1} = \sum_{n=2}^{N+1} G_{x,1,n} \tag{52}$$

$$CG_{y,1} = \sum_{n=2}^{N+1} G_{y,1,n} \tag{53}$$

and

$$CG_{z,1} = \sum_{n=2}^{N+1} G_{z,1,n} \tag{54}$$

Similarly, for body 2

$$CG_{x,2} = \sum_{n=2}^{N+1} G_{x,2,n} \tag{55}$$

$$CG_{y,2} = \sum_{n=2}^{N+1} G_{y,2,n} \tag{56}$$

and

$$CG_{z,2} = \sum_{n=2}^{N+1} G_{z,2,n} \tag{57}$$

The components of torque acting through c.g.$_n$, caused by all of the cables, may now be transformed to the principal axes as follows

$$\begin{Bmatrix} CG_{x',n} \\ CG_{y',n} \\ CG_{z',n} \end{Bmatrix} = \left[\ell_n\right]' \begin{Bmatrix} CG_{x,n} \\ CG_{y,n} \\ CG_{z,n} \end{Bmatrix} \tag{58}$$

where $n = 1, 2$. The components of external sinusoidal force acting on body $n$ along the arbitrary body axes are given by

$$F_{x,n} = AF_{x,n} \sin\left(\omega_{F,n} t\right) \tag{59}$$

$$F_{y,n} = AF_{y,n} \sin\left(\omega_{F,n} t\right) \tag{60}$$

and

$$F_{z,n} = AF_{z,n} \sin\left(\omega_{F,n} t\right) \tag{61}$$

where n = 1, 2. The components of external sinusoidal torque acting on body n about the principal body axes are given by

$$G_{x,n} = AG_{x,n} \sin(\omega_{T,n} t) \tag{62}$$

$$G_{y,n} = AG_{y,n} \sin(\omega_{T,n} t) \tag{63}$$

and

$$G_{z,n} = AG_{z,n} \sin(\omega_{T,n} t) \tag{64}$$

where n = 1, 2. Any component of external force or torque may be zeroed out by inputting a zero for the amplitude of that component. The components of the total force acting on body n along the arbitrary body axes may now be obtained from

$$TF_{x,n} = F_{x,n} + \sum_{m=2}^{N+1} F_{x,n} C_m \tag{65}$$

$$TF_{y,n} = F_{y,n} + \sum_{m=2}^{N+1} F_{y,n} C_m \tag{66}$$

and

$$TF_{z,n} = F_{z,n} + \sum_{m=2}^{N+1} F_{z,n} C_m \tag{67}$$

where n = 1, 2. The components of the total moment acting on body n about the principal body axes are given by

$$TG_{x,n} = CG_{x',n} + G_{x,n} \tag{68}$$

$$TG_{y,n} = CG_{y',n} + G_{y,n} \tag{69}$$

and

$$TG_{z,n} = CG_{z',n} + G_{z,n} \tag{70}$$

where $n = 1, 2$.

## CONCLUDING REMARKS

This paper has presented the six-degree-of-freedom rigid body equations of motion for each of two bodies connected by massless cables. A basic computer program was presented for determining the dynamic response of the complete configuration subject to external sinusoidal forces and torques on both bodies. The program was written in subroutine form to facilitate the addition of equations representing other perturbations and/or control systems to the basic configuration.

Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas, May 31, 1968
908-40-01-03-72

NASA-S-68-3085

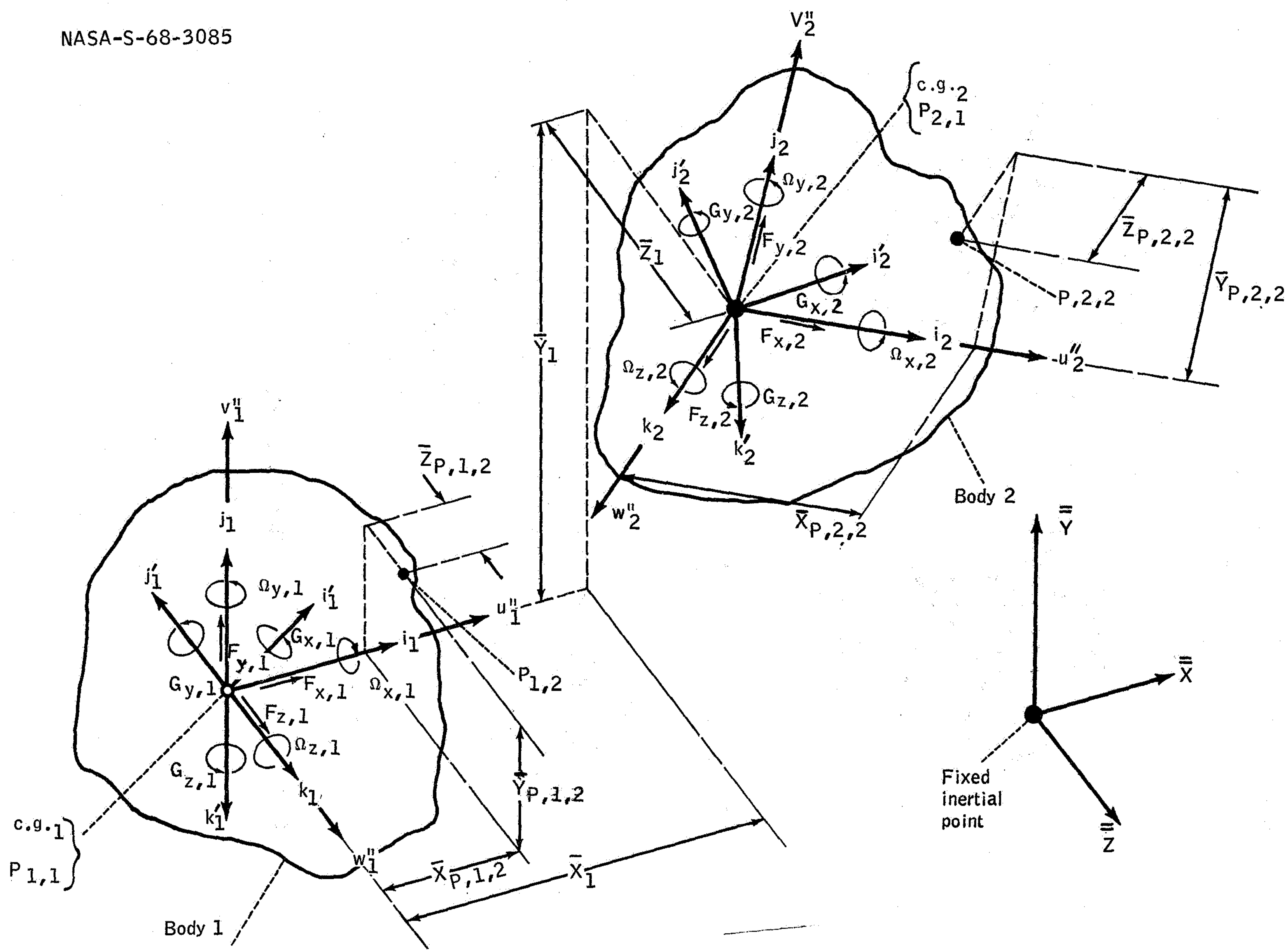


Figure 1. - General body orientation.

NASA-S-68-3083

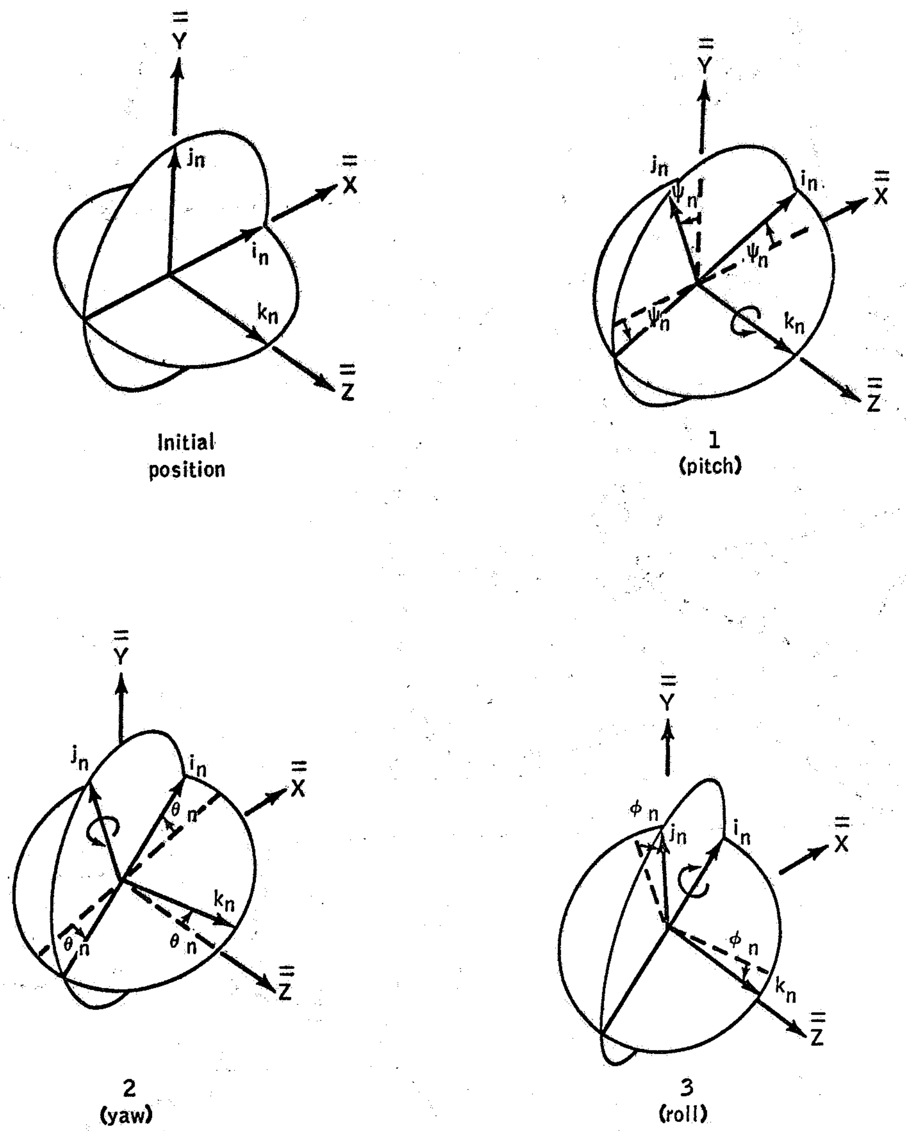


Figure 2. - Order of rotation for inertial Euler angles.

NASA-S-68-3086

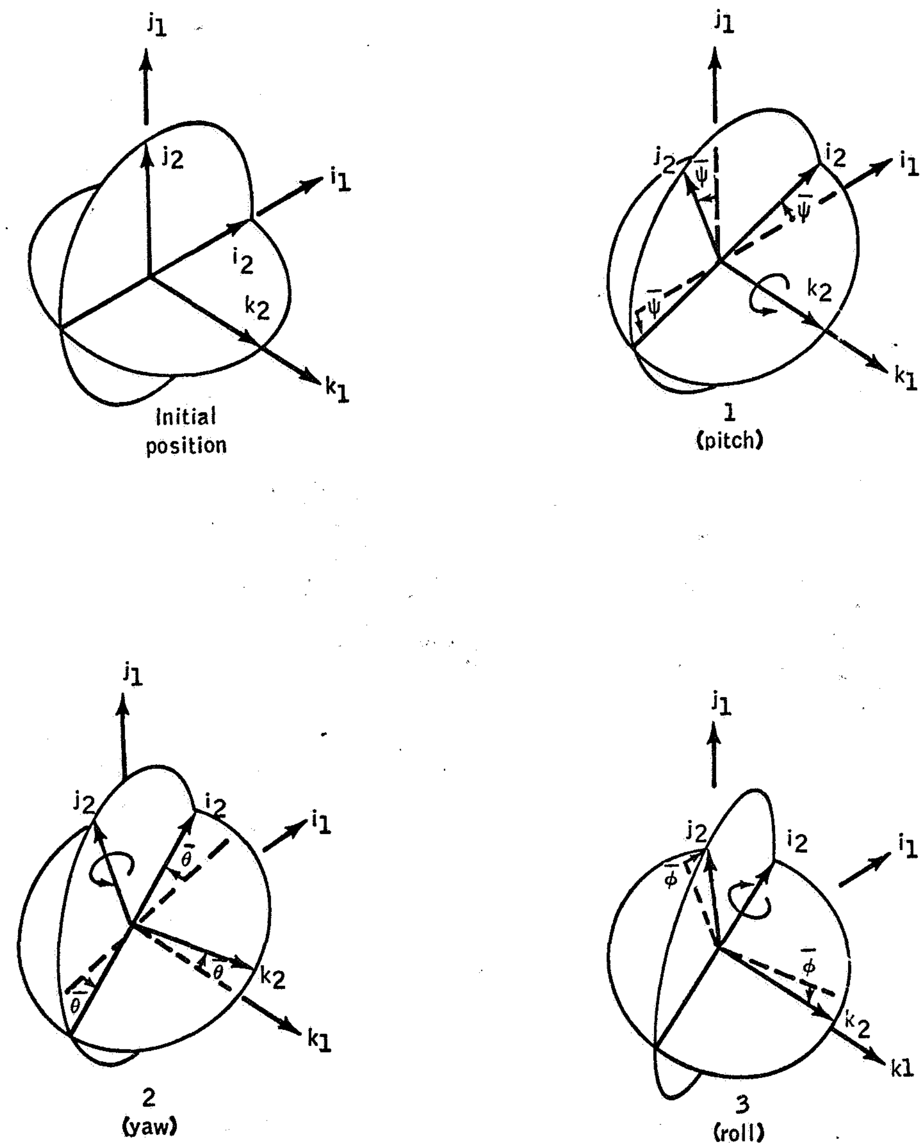


Figure 3. - Order of rotation for relative Euler angles.

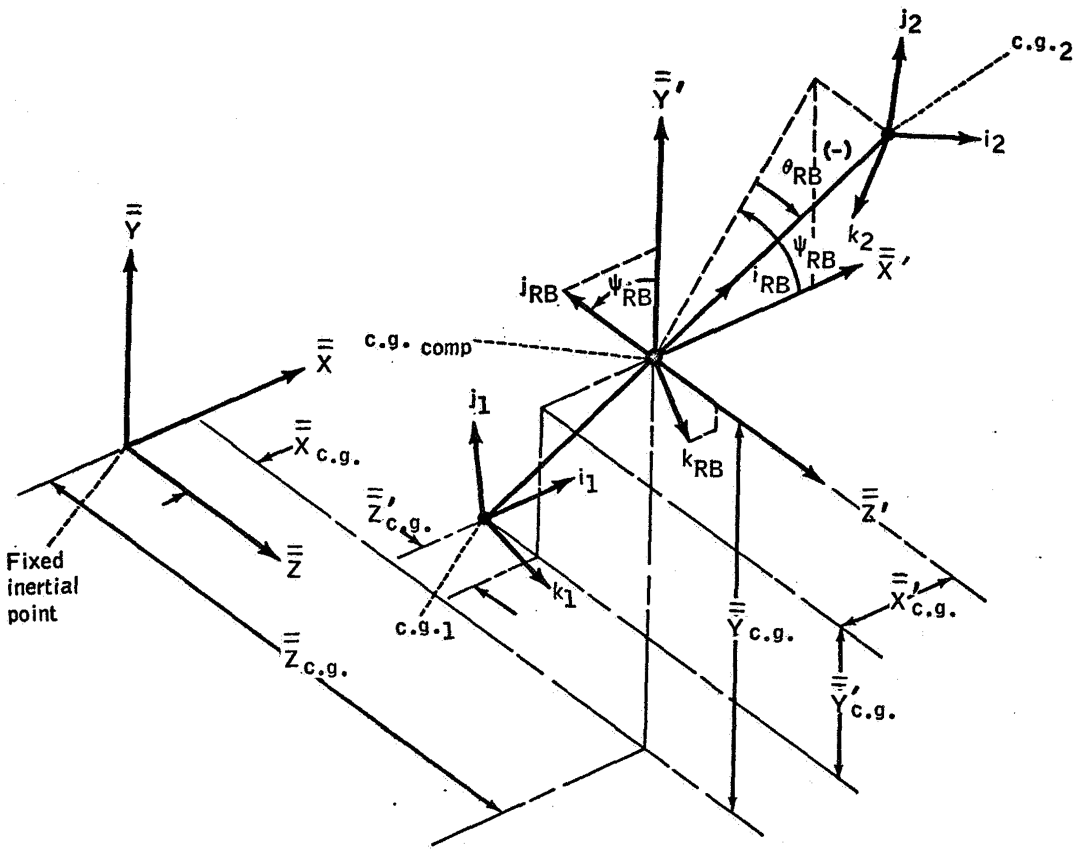


Figure 4. - Pseudorigid body orientation.

NASA-S-68-3087

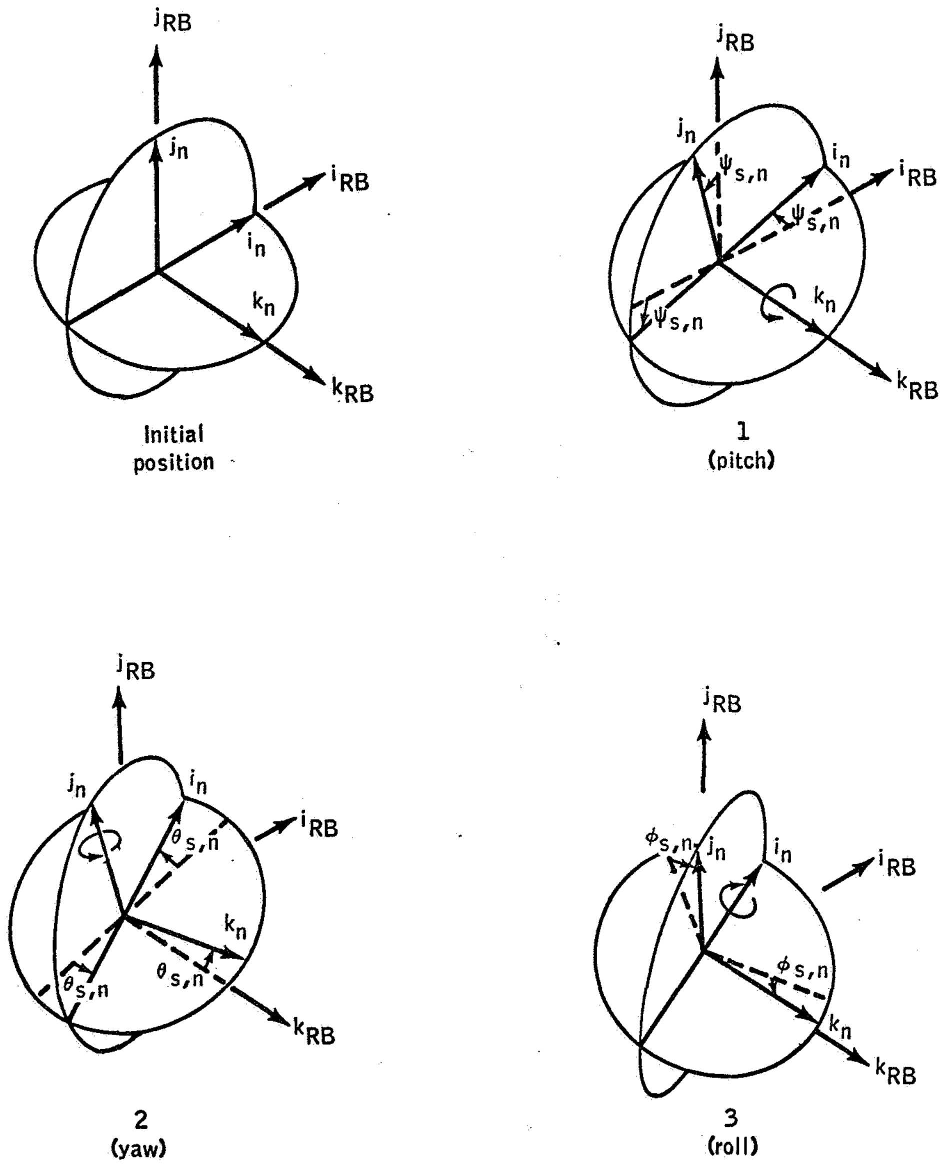


Figure 5. - Order of rotation for structural Euler angles.

NASA-S-68-3084

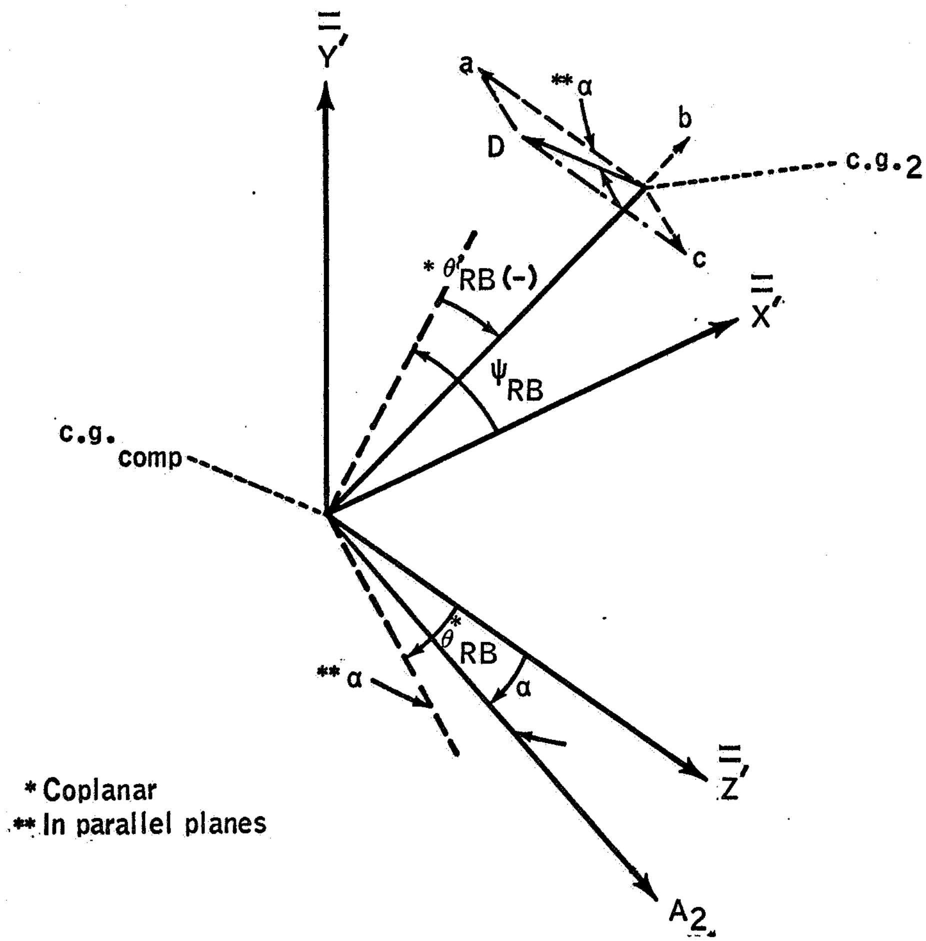


Figure 6. - Instantaneous spin-plane orientation.

# APPENDIX A

## COMPUTER PROGRAM LISTING

The FORTRAN IV source program presented in this appendix presently requires a Stromberg-Carlson (S-C) 4020 high-speed microfilm recorder for some of the output. The S-C 4020 output section[1] of the listing runs from SUBROUTINE FILM through SUBROUTINE RCLOK. The program may be modified for use on a system which does not have an S-C 4020 recorder by removing those sections of the program indicated by the applicable comment cards. If the program is modified in this manner, SUBROUTINE OUTAID should also be modified to print out those output variables which are now output in graphical form.

---

[1]This section was programed by P. H. Thornton, Landing and Docking Analysis Section, Manned Spacecraft Center.

```
C THE $ CARDS ARE SYSTEM SET-UP CARDS FOR THE MSC 7094 OPERATING SYSTEM
C AND ARE NOT PART OF THE BASIC PROGRAM.

$JOB  E02T   THOMAS       03591 ET256
$IBJOB THOMAS  GO


$IBFTC MAIN

      COMMON/FLM/OM,ON,TWM,TWN,THM,THN,FOM,FON,FIM,FIN,SIM,SIN,SEM,SEN,
     1EIM,EIN,XNIM,XNIN,TEM,TEN,ELM,ELN,TWEM,TWEN,TIEMPO,THIM,THIN,KUT,
     2ITHBOP,MOVIE,IGROP,PHI,THETA,NUM1,NUM2,NUM3,KWHICH
      COMMON VAR,KNT,KFST,L
      DIMENSION VAR(6800)
      CALL START
   10 CONTINUE
C REMOVE THE NEXT 4 CARDS IF SC-4020 NOT AVAILABLE
      CALL          FILM(OM,ON,TWM,TWN,THM,THN,FOM,FON,FIM,FIN,SIM,SIN,SEM,
     1SEN,EIM,EIN,XNIM,XNIN,TEM,TEN,ELM,ELN,TWEM,TWEN,TIEMPO,THIM,THIN,K
     2NT,ITHBOP,MOVIE,IGROP,PHI,THETA,NUM1,NUM2,NUM3,KWHICH)
      CALL CLEAN
      CALL RK
      GO TO 10
      END


C REMOVE THE FOLLOWING -$ORIGIN ACE- CARD IF SC-4020 NOT AVAILABLE
$ORIGIN       ACE
$IBFTC SRCO

      SUBROUTINE START
                DIMENSION DYDX(100),VAR(6800)
                COMMON VAR
                EQUIVALENCE (VAR(101),DYDX(1))
C               ZERO CORE AT INITIAL LOADING
                DO 20 J=1, 6800
   20           VAR(J) = 0.0
C               SET DERIVATIVE OF INDEPENDENT VARIABLE WR/T ITSELF EQUAL
C               TO ONE
                DYDX(1) = 1.0
                CALL RK
      RETURN
                END


$IBFTC SRC1

                SUBROUTINE RK
                DIMENSION Y(100),DYDX(100),Q(100),D(100),P(6200),NTEGER(1
     1          00),VAR(6800)
      COMMON    VAR, KNT, KFST
                EQUIVALENCE (VAR(1),Y(1)),(VAR(101),DYDX(1)),(VAR(201),Q(
```

```
     1           1)),(VAR(401),NTEGER(1)),(VAR(501),D(1)),(VAR(601),P(1)),
     2           (NTEGER(6),N)
C                LOAD INPUT DATA INTO COMPUTER
                 CALL INPUT
      REWIND 9
      REWIND 11
      REWIND 13
      KNT=0
      KFST=0
      P(5964)=P(5966)*0.6
      P(5965)=P(5967)*0.6
   20            CALL DYDXS
                 CALL OUTPUT
      IF(Y(1)-P(2))40,330,330
C                CALCULATE THE DELTA Y(J) AT Y(1) = 0
   40            DO 50 J = 1,N
   50            D(J) = DYDX(J)*P(1)
C                CALCULATE THE Y(J) AT T = 0
                 DO 90 J = 1,N
                 R = .5*(D(J) - Q(J))
                 Y(J) = Y(J) + R
   90            Q(J) = Q(J) + 3.0*R - .5*D(J)
C                CALCULATE DELTA Y(J) AT Y(1) = HALF STEP
                 CALL DYDXS
                 DO 120 J = 1,N
  120            D(J) = DYDX(J)*P(1)
C                CALCULATE THE Y(J) AT Y(1) = HALF STEP
                 DO 160 J = 1,N
                 R = .292893219*(D(J) - Q(J))
                 Y(J) = Y(J) + R
  160            Q(J) = Q(J) + 3.0*R - .292893219*D(J)
C                CALCULATE THE DELTA Y(J) AT Y(1) = HALF STEP (AGAIN)
                 CALL DYDXS
                 DO 190 J = 1,N
  190            D(J) = DYDX(J)*P(1)
C                CALCULATE THE Y(J) AT Y(1) = HALF STEP (AGAIN)
                 DO 230 J = 1,N
                 R = 1.70710678*(D(J) - Q(J))
                 Y(J) = Y(J) + R
  230            Q(J) = Q(J) + 3.0*R - 1.70710678*D(J)
C                CALCULATE THE DELTA Y(J) AT Y(1) = FULL STEP
                 CALL DYDXS
                 DO 260 J = 1,N
  260            D(J) = DYDX(J)*P(1)
C                CALCULATE THE Y(J) AT Y(1) = FULL STEP
                 DO 300 J = 1,N
                 R = .166666666E+00*(D(J) - 2.0*Q(J))
                 Y(J) = Y(J) + R
  300            Q(J) = Q(J) + 3.0*R - .5*D(J)
C                PROCEED TO THE NEXT INTEGRATION STEP
                 GO TO 20
  330            RETURN
                 END
```

```
$IBFTC SRC2

              SUBROUTINE INPUT
              DIMENSION Y(100),Q(100),FIRSTY(100),P(6200),NTEGER(100),V
     1        AR(6800)
              COMMON VAR
              EQUIVALENCE (VAR(1),Y(1)),(VAR(201),Q(1)),(VAR(301),
     1        FIRSTY(1)),(VAR(401),NTEGER(1)),(VAR(601),P(1))
     2        ,(NTEGER(6),N),(NTEGER(2),NP),(NTEGER(44),NPAGE)
C             SET PAGE NO. OF FIRST PAGE
              NPAGE = 1
              CALL PAGEHD
C             READ CONTROL INTEGERS INTO PROBLEM
              READ  (5,30)(NTEGER(J),J=1,8)
   30         FORMAT(8I5)
      WRITE (6,500)(NTEGER(J),J=1,8)
  500 FORMAT(1H08I5)
      NTEGER(21)=NTEGER(4) + 1
      NTEGER(24)=NTEGER(6) - 1
      NTEGER(25)=NTEGER(7)
      NTEGER(26)=NTEGER(8)
      NTEGER(6)=NTEGER(5)
C             CHECK FOR INDIVIDUAL FLOATING POINT DATA ENTRY
              IF(NP) 380,380,110
  110         DO 140 J = 1,NP
              READ  (5,130)I, (P(I))
  130         FORMAT(I5,E15.0)
      WRITE (6,150)I,P(I)
  150 FORMAT(I6,E20.8)
  140         CONTINUE
      P(1201)=1.0E36
  380         CALL INAID
C             ZERO THE Q AND SET IN IC
              DO 420 J = 1,N
              Q(J) = 0.0
              Y(J) = FIRSTY(J)
  420         CONTINUE
              RETURN
              END

$IBFTC SRC3

              SUBROUTINE PAGEHD
              DIMENSION NTEGER(100),VAR(6800)
              COMMON VAR
              EQUIVALENCE (VAR(401),NTEGER(1)),(NTEGER(44),NPAGE),
     1        (NTEGER(1),IDENT)
              WRITE (6,20)IDENT, NPAGE
   20 FORMAT(17H1  FORFUN OPTION I5,             56H
     1                            PAGE NO I5 )
```

```
      RETURN
      END

$IBFTC SRC4

      SUBROUTINE INAID
      DIMENSION  FIRSTY(100),P(6200) ,NTEGER(100),VAR(6800)
      COMMON VAR
      EQUIVALENCE (VAR(301),FIRSTY(1)),(VAR(401),NTEGER(1)),(VA
     1R(601),P(1)),(NTEGER(41),LPRINT),(NTEGER(42),NLINE),(NTEG
     2ER(43),NSKIP),(NTEGER(24),NTSKIP)
      EQUIVALENCE (P(10),DL111),(P(11),DL112),(P(12),DL113),(P(
     113),DL121),(P(14),DL122),(P(15),DL123),(P(16),DL131),(P(1
     27),DL132),(P(18),DL133),(P(26),DL211),(P(27),DL212),(P(28
     3),DL213),(P(29),DL221),(P(30),DL222),(P(31),DL223),(P(32)
     4,DL231),(P(33),DL232),(P(34),DL233)
      P(107)=DL111*P(970)+DL121*P(971)+DL131*P(972 )
      P(108)=DL112*P(970)+DL122*P(971)+DL132*P(972)
      P(109)= DL113*P(970)+DL123*P(971)+DL133*P(972)
      P(116)=DL211*P(980)+DL221*P(981)+DL231*P(982)
      P(117)=DL212*P(980)+DL222*P(981)+DL232*P(982)
      P(118)=DL213*P(980)+DL223*P(981)+DL233*P(982)
C     SET IN INITIAL CONDITIONS
      FIRSTY(2)  = P(107)/57.2957795
      FIRSTY(3)  = P(108)/57.2957795
      FIRSTY(4)  = P(109)/57.2957795
      FIRSTY(5)  = P(110)
      FIRSTY(6)  = P(111)
      FIRSTY(7)  = P(112)
      FIRSTY(8)  = P(113)/57.2957795
      FIRSTY(9)  = P(114)/57.2957795
      FIRSTY(10) = P(115)/57.2957795
      FIRSTY(11) = P(116)/57.2957795
      FIRSTY(12) = P(117)/57.2957795
      FIRSTY(13) = P(118)/57.2957795
      FIRSTY(14) = P(119)
      FIRSTY(15) = P(120)
      FIRSTY(16) = P(121)
      FIRSTY(17) = P(122)/57.2957795
      FIRSTY(18) = P(123)/57.2957795
      FIRSTY(19) = P(124)/57.2957795
  P(35)=SIN(FIRSTY(8))
  P(36)=COS(FIRSTY(8))
  P(38)=SIN(FIRSTY(17))
  P(39)=COS(FIRSTY(17))
  P(44)=SIN(FIRSTY(9))
  P(45)=COS(FIRSTY(9))
  P(46)=SIN(FIRSTY(18))
  P(47)=COS(FIRSTY(18))
  P(5976)=SIN(FIRSTY(19))
  P(5977)=SIN(FIRSTY(10))
  P(5978)=COS(FIRSTY(19))
```

```
      P(5979)=COS(FIRSTY(10))
      A2=P(39)*P(5978)
      B2=P(39)*P(5976)
      C2=-P(38)
      D2=P(46)*P(38)*P(5978)-P(5976)*P(47)
      E2=P(47)*P(5978)+P(46)*P(38)*P(5976)
      F2=P(46)*P(39)
      G2=P(5976)*P(46)+P(47)*P(38)*P(5978)
      H2=P(47)*P(38)*P(5976)-P(46)*P(5978)
      AI2=P(47)*P(39)
      A1=P(36)*P(5979)
      B1=P(36)*P(5977)
      C1=-P(35)
      D1=P(44)*P(35)*P(5979)-P(5977)*P(45)
      E1=P(45)*P(5979)+P(44)*P(35)*P(5977)
      F1=P(44)*P(36)
      G1=P(5977)*P(44)+P(45)*P(35)*P(5979)
      H1=P(45)*P(35)*P(5977)-P(44)*P(5979)
      AI1=P(45)*P(36)
      XXPR=A2*G1+B2*H1+C2*AI1
      AKKPR= D2*G1+F2*H1+F2*AI1
      ZZPR=G2*G1+H2*H1+AI2*AI1
      FIRSTY(20)=ATAN2((-XXPR),(SQRT(AKKPR**2+ZZPR**2)))
      FIRSTY(21)=ATAN2(AKKPR,ZZPR)
      FIRSTY(22)=ATAN2((A2*D1+B2*E1),(A2*A1+B2*B1+C2*C1))
      FIRSTY(23)=P(5992)
      FIRSTY(24)=P(5993)
      FIRSTY(25)=P(5994)
      FIRSTY(26)=P(5995)
      FIRSTY(27)=P(5996)
      FIRSTY(28)=P(5997)
C              SET IN CABLE INITIAL CONDITIONS
               NCABLE = NTEGER(21)
               NRESRV = NTEGER(3)
               NDO = 3*NCABLE
               DO 450 J = 1,NDO
               NPUT = J + 22 + NRESRV
  450          FIRSTY(NPUT) = P(J+139)
C              SET IN CONTROL NUMBERS FOR PRINTING
               NLINE = 53
               NSKIP = NTSKIP
               LPRINT = 0
               RETURN
               END

$IBFTC SRC5

               SUBROUTINE DYDXS
               DIMENSION Y(100),DYDX(100),P(6200),NTEGER(100),VAR(6800),
     1         X1P1(20),Y1P1(20),Z1P1(20),X2P2(20),Y2P2(20),Z2P2(20),
     2         A1(20),A2(20),A3(20),FX1I(20),FY1I(20),FZ1I(20),FX2I(20),
     3         FY2I(20),FZ2I(20),GX1(20),GY1(20),GZ1(20),GX2(20),GY2(20)
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     4          ,GZ2(20),XBR(20),YBR(20),ZBR(20),XBRD(20),YBRD(20),ZBRD(
     5          20)
                COMMON VAR
                EQUIVALENCE (VAR(1),Y(1)),(VAR(101),DYDX(1)),(VAR(401),
     1          NIEGER(1)),(VAR(601),P(1)),(Y(2),OMX1P),(DYDX(2),OMX1PD),
     2          (Y(3),OMY1P),(DYDX(3),OMY1PD),(Y(4),OMZ1P ),(Y(5),U1PP),
     3          (DYDX(5),U1PPD),(Y(6),V1PP),(DYDX(6),V1PPD),(Y(7),W1PP),
     4          (DYDX(7),W1PPD),(Y(8),THT1),(DYDX(8),THT1D),(Y(9),PHI1),
     5          (DYDX(9),PHI1D),(Y(10),PSI1),(DYDX(10),PSI1D),(Y(11),OMX2
     6          P),(DYDX(11),OMX2PD),(Y(12),OMY2P),(DYDX(12),OMY2PD),
     7          (Y(13),OMZ2P),(DYDX(13),OMZ2PD),(Y(14),U2PP),(DYDX(14),
     8          U2PPD),(Y(15),V2PP),(DYDX(15),V2PPD),(Y(16), W2PP),(DYDX
     9          (16),W2PPD),(Y(17),THT2),(DYDX(17),THT2D),(Y(18),PHI2)
                EQUIVALENCE (DYDX(18),PHI2D),(Y(19),PSI2),(DYDX(19),PSI2D
     1          ),(Y(20),THTBR),(DYDX(20),THTBRD),(Y(21),PHIBR),(DYDX(21)
     2          ,PHIBRD),(Y(22),PSIBR),(DYDX(22),PSIBRD),(P(3),CIXX1),
     3          (P(4),CIYY1),(P(5),CIZZ1),(P(6),CM1),(P(10),DL111),(P(11)
     4          ,DL112),(P(12),DL113),(P(13),DL121),(P(14),DL122),(P(15),
     5          DL123),(P(16),DL131),(P(17),DL132),(P(18),DL133),(P(19),
     6          CIXX2),(P(20),CIYY2),(P(21),CIZZ2),(P(22),CM2),(P(26),
     7          DL211),(P(27),DL212),(P(28),DL213),(P(29),DL221),(P(30),
     8          DL222),(P(31),DL223),(P(32),DL231),(P(33),DL232),(P(34),
     9          DL233),(P(35),STHT1),(P(36),CTHT1),(P(37),TTHT1)
                EQUIVALENCE (P(38),STHT2),(P(39),CTHT2),(P(40),TTHT2),
     1          (P(41),STHTBR),(P(42),CTHTBR),(P(43),TTHTBR),(P(44),SPHI1
     2          ),(P(45),CPHI1),(P(46),SPHI2),(P(47),CPHI2),(P(48),SPHIBR
     3          ),(P(49),CPHIBR),(P(50),GX1P),(P(51),GY1P),(P(52),GZ1P),(
     4          P(53),GX2P),(P(54),GY2P),(P(55),GZ2P),(P(56),OMX1),(P(57)
     5          ,OMY1),(P(58),OMZ1),(P(59),OMX2),(P(60),OMY2),(P(61),OMZ2
     6          ),(P(62),U1),(P(63),V1),(P(64),W1),(P(65),U2),(P(66),V2),
     7          (P(67),W2),(P(68),GAMB11),(P(69),GAMB12),(P(70),GAMB13),
     8          (P(71),GAMB21),(P(72),GAMB22),(P(73),GAMB23),(P(74),GAMB
     9          31),(P(75),GAMB32),(P(76),GAMB33),(P(77),SPSIBR)
                EQUIVALENCE (P(78),CPSIBR),(P(79),GX1T),(P(80),GY1T),(P(8
     1          1),GZ1T),(P(82),GX2T),(P(83),GY2T),(P(84),GZ2T),(P(85),
     2          FX1IT),(P(86),FY1IT),(P(87),FZ1IT),(P(88),FX2IT),(P(89),
     3          FY2IT),(P(90),FZ2IT),(P(91),GX1PT),(P(92),GY1PT),(P(93),
     4          GZ1PT),(P(94),GX2PT),(P(95),GY2PT),(P(96),GZ2PT),(P(97),
     5          SINPH2),(P(98),COSPH2),(P(99),COSTH2),(P(100),SINPH1),(P(
     6          101),COSPH1),(P(102),COSTH1),(P(221),X1P1(1)),(P(241),
     7          Y1P1(1)),(P(261),Z1P1(1)),(P(281),X2P2(1)),(P(301),Y2P2(1
     8          )),(P(321),Z2P2(1)),(P(341),A1(1)),(P(361),A2(1)),(P(381)
     9          ,A3(1)),(P(461),FX1I(1)),(P(481),FY1I(1))
                EQUIVALENCE (P(501),FZ1I(1)),(P(561),FZ2I(1)),(P(701),GX1
     1          (1)),(P(721),GY1(1)),(P(741),GZ1(1)),(P(761),GX2(1)),
     2          (P(781),GY2(1)),(P(801),GZ2(1)),(P(821),XBR(1)),(P(841),
     3          YBR(1)),(P(861),ZBR(1)),(P(881),XBRD(1)),(P(901),YBRD(1))
     4          ,(P(921),ZBRD(1)),(P(128),AGX1PT),(P(129),AGY1PT),(P(130)
     5          ,AGZ1PT),(P(131),AGX2PT),(P(132),AGY2PT),(P(133),AGZ2PT),
     6          (P(134),AFX1IT),(P(135),AFY1IT),(P(136),AFZ1IT),(P(137),
     7          AFX2IT),(P(138),AFY2IT),(P(139),AFZ2IT),(DYDX(4),
     8          OMZ1PD),(P(521),FX2I(1)),(P(541),FY2I(1))
      EQUIVALENCE(P(5976),SPSI2E),(P(5977),SPSI1E),(P(5978),CPSI2E),
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```
     1(P(5979),CPSI1E)
C               SET UP THE RELATIVE CONSTANT
                NCABLE = NTEGER(21)
                NRESRV = NTEGER(3)
C               SET IN X, Y, Z BAR VALUES WHICH RESULT FROM THE
C               INTEGRATION
                DO 12 J = 1,NCABLE
                JUMP1 = 3*J + 20 + NRESRV
                XBR(J) = Y(JUMP1)
                YBR(J) = Y(JUMP1 + 1)
   12           ZBR(J) = Y(JUMP1 + 2)
C               CALCULATE TRIGNOMETRIC FUNCTIONS
                STHT1 = SIN(THT1)
                CTHT1 = COS(THT1)
                TTHT1 = STHT1/CTHT1
                STHT2 = SIN(THT2)
                CTHT2 = COS(THT2)
                TTHT2 = STHT2/CTHT2
                STHTBR = SIN(THTBR)
                CTHTBR = COS(THTBR)
      CPSI1E=COS(PSI1)
      SPSI1E=SIN(PSI1)
      CPSI2E=COS(PSI2)
      SPSI2E=SIN(PSI2)
                TTHTBR = STHTBR/CTHTBR
                SPHI1 = SIN(PHI1)
                CPHI1 = COS(PHI1)
                SPHI2 = SIN(PHI2)
                CPHI2 = COS(PHI2)
                SPHIBR = SIN(PHIBR)
                CPHIBR = COS(PHIBR)
                SPSIBR = SIN(PSIBR)
                CPSIBR = COS(PSIBR)
C               CALCULATE GAMMA BAR VALUES FROM TRIG FUNCTIONS
                GAMB11 = CTHTBR*CPSIBR
                GAMB12 = CTHTBR*SPSIBR
                GAMB13 = -STHTBR
                GAMB21 = -CPHIBR*SPSIBR + SPHIBR*STHTBR*CPSIBR
                GAMB22 = CPHIBR*CPSIBR  + SPHIBR*STHTBR*SPSIBR
                GAMB23 = SPHIBR*CTHTBR
                GAMB31 = SPHIBR*SPSIBR  + CPHIBR*STHTBR*CPSIBR
                GAMB32 = -SPHIBR*CPSIBR + CPHIBR*STHTBR*SPSIBR
                GAMB33 = CPHIBR*CTHTBR
C               TRANSFORM PRINCIPAL AXIS ANGULAR VELOCITIES INTO SYMMETRY
C               AXIS COMPONENTS
                OMX1 = DL111*OMX1P + DL112*OMY1P + DL113*OMZ1P
                OMY1 = DL121*OMX1P + DL122*OMY1P + DL123*OMZ1P
                OMZ1 = DL131*OMX1P + DL132*OMY1P + DL133*OMZ1P
                OMX2 = DL211*OMX2P + DL212*OMY2P + DL213*OMZ2P
                OMY2 = DL221*OMX2P + DL222*OMY2P + DL223*OMZ2P
                OMZ2 = DL231*OMX2P + DL232*OMY2P + DL233*OMZ2P
      U1 = U1PP
      V1 = V1PP
      W1 = W1PP
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      U2 = U2PP
      V2 = V2PP
      W2 = W2PP
      OMX1PP=OMX1*GAMB11+OMY1*GAMB12-OMZ1*STHTBR
      OMY1PP=OMX1*GAMB21+OMY1*GAMB22+OMZ1*GAMB23
      OMZ1PP=OMX1*GAMB31+OMY1*GAMB32+OMZ1*GAMB33
C               CALCULATE THETA, PHI, PSI BAR DERIVATIVES
      THTBRD=CPHIBR*(OMY2-OMY1PP)-SPHIBR*(OMZ2-OMZ1PP)
      PHIBRD=OMX2-OMX1PP+TTHTBR*SPHIBR*(OMY2-OMY1PP)+TTHTBR*CPHIBR*
     1(OMZ2-OMZ1PP)
      PSIBRD=SPHIBR*(OMY2-OMY1PP)/CTHTBR+CPHIBR*(OMZ2-OMZ1PP)/CTHTBR
C               CALCULATE THT, PHI, PSI DERIVATIVES
                THT1D = CPHI1*OMY1 - SPHI1*OMZ1
                PHI1D = OMX1 + TTHT1*(SPHI1*OMY1 + CPHI1*OMZ1)
                PSI1D = (SPHI1*OMY1 + CPHI1*OMZ1)/CTHT1
                THT2D = CPHI2*OMY2 - SPHI2*OMZ2
                PHI2D = OMX2 + TTHT2*(SPHI2*OMY2 + CPHI2*OMZ2)
                PSI2D = (SPHI2*OMY2 + CPHI2*OMZ2)/CTHT2
C               NOW CALCULATE THE ALPHA VALUES
                DO 620 J = 1,NCABLE
                A1(J) = U2 + Z2P2(J)*OMY2 - Y2P2(J)*OMZ2
                A2(J) = V2 + X2P2(J)*OMZ2 - Z2P2(J)*OMX2
                A3(J) = W2 + Y2P2(J)*OMX2 - X2P2(J)*OMY2
C               THEN CALCULATE X, Y, Z BAR DERIVATIVES FOR EACH
C               ATTACHMENT POINT
                XBRD(J) = YBR(J)*OMZ1 - ZBR(J)*OMY1 - U1
     1          - Z1P1(J)*OMY1 + Y1P1(J)*OMZ1
     2          +GAMB11*A1(J)+GAMB21*A2(J)+GAMB31*A3(J)
                YBRD(J) = ZBR(J)*OMX1 - XBR(J)*OMZ1 - V1
     1          - X1P1(J)*OMZ1 + Z1P1(J)*OMX1
     2          + GAMB12*A1(J) + GAMB22*A2(J) + GAMB32*A3(J)
  620           ZBRD(J) = XBR(J)*OMY1 - YBR(J)*OMX1 - W1
     1          - Y1P1(J)*OMX1 + X1P1(J)*OMY1
     2          + GAMB13*A1(J) + GAMB23*A2(J) + GAMB33*A3(J)
C      TRANSFER TO THE CABLE FORCE SUBROUTINE
       CALL CABFOR
C               TRANSFORM SYMMETRY AXIS FORCES IN BODY 1 INTO SYMMETRY
C               AXIS FORCES IN BODY 2
                DO 790 J = 1,NCABLE
                FX2I(J) = - GAMB11*FX1I(J) - GAMB12*FY1I(J)
     1          - GAMB13*FZ1I(J)
                FY2I(J) = - GAMB21*FX1I(J) - GAMB22*FY1I(J)
     1          - GAMB23*FZ1I(J)
                FZ2I(J) = - GAMB31*FX1I(J) - GAMB32*FY1I(J)
     1          - GAMB33*FZ1I(J)
C               CALCULATE SYMMETRY AXIS MOMENTS ON BOTH BODIES
      GX1(J) = Y1P1 (J)*FZ1I(J) - Z1P1 (J)*FY1I(J)
      GY1(J)= Z1P1 (J)*FX1I(J) - X1P1 (J)*FZ1I(J)
      GZ1(J)= X1P1 (J)*FY1I(J) - Y1P1 (J)*FX1I(J)
      GX2(J)= Y2P2 (J)*FZ2I(J) - Z2P2 (J)*FY2I(J)
      GY2(J)= Z2P2 (J)*FX2I(J) - X2P2 (J)*FZ2I(J)
  790 GZ2(J) = X2P2 (J)*FY2I(J) - Y2P2 (J)*FX2I(J)
C               NOW SUM THE SYMMETRY AXIS COMPONENTS OF MOMENT
                GX1T = 0.0
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              GY1T = 0.0
              GZ1T = 0.0
              GX2T = 0.0
              GY2T = 0.0
              GZ2T = 0.0
              DO 920 J = 1,NCABLE
              GX1T = GX1T + GX1(J)
              GY1T = GY1T + GY1(J)
              GZ1T = GZ1T + GZ1(J)
              GX2T = GX2T + GX2(J)
              GY2T = GY2T + GY2(J)
  920         GZ2T = GZ2T + GZ2(J)
C             NEXT, SUM THE SYMMETRY AXIS COMPONENTS OF FORCE
              FX11T = 0.0
              FY11T = 0.0
              FZ11T = 0.0
              FX21T = 0.0
              FY21T = 0.0
              FZ21T = 0.0
              DO 1050 J = 1,NCABLE
              FX11T = FX1IT + FX1I(J)
              FY11T = FY1IT + FY1I(J)
              FZ11T = FZ1IT + FZ1I(J)
              FX21T = FX2IT + FX2I(J)
              FY21T = FY2IT + FY2I(J)
 1050         FZ21T = FZ2IT + FZ2I(J)
C             TRANSFORM SYMMETRY AXIS COMPONENTS OF TOTAL MOMENT INTO
C             PRINCIPAL AXIS COMPONENTS
              GX1PT = DL111*GX1T + DL121*GY1T + DL131*GZ1T
              GY1PT = DL112*GX1T + DL122*GY1T + DL132*GZ1T
              GZ1PT = DL113*GX1T + DL123*GY1T + DL133*GZ1T
              GX2PT = DL211*GX2T + DL221*GY2T + DL231*GZ2T
              GY2PT = DL212*GX2T + DL222*GY2T + DL232*GZ2T
              GZ2PT = DL213*GX2T + DL223*GY2T + DL233*GZ2T
C      CALL FORCING FUNCTION SUBROUTINE
       CALL FORFUN
C             CALCULATE THE ANGULAR VELOCITY DERIVATIVES
              OMX1PD = (GX1PT + OMY1P*OMZ1P*(CIYY1-CIZZ1))/CIXX1
     1        + AGX1PT/CIXX1
              OMY1PD = (GY1PT + OMX1P*OMZ1P*(CIZZ1-CIXX1))/CIYY1
     1        + AGY1PT/CIYY1
              OMZ1PD = (GZ1PT + OMX1P*OMY1P*(CIXX1-CIYY1))/CIZZ1
     1        + AGZ1PT/CIZZ1
              OMX2PD = (GX2PT + OMY2P*OMZ2P*(CIYY2-CIZZ2))/CIXX2
     1        + AGX2PT/CIXX2
              OMY2PD = (GY2PT + OMX2P*OMZ2P*(CIZZ2-CIXX2))/CIYY2
     1        + AGY2PT/CIYY2
              OMZ2PD = (GZ2PT + OMX2P*OMY2P*(CIXX2-CIYY2))/CIZZ2
     1        + AGZ2PT/CIZZ2
C             CALCULATE BODY AXIS VELOCITY RATES
              U1PPD = - OMY1*W1PP + OMZ1*V1PP + FX1IT/CM1
     1        + AFX1IT/CM1
              V1PPD = - OMZ1*U1PP + OMX1*W1PP + FY1IT/CM1
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     1          + AFY1IT/CM1
                W1PPD = - OMX1*V1PP + OMY1*U1PP + FZ1IT/CM1
     1          + AFZ1IT/CM1
                U2PPD = - OMY2*W2PP + OMZ2*V2PP + FX2IT/CM2
     1          + AFX2IT/CM2
                V2PPD = - OMZ2*U2PP + OMX2*W2PP + FY2IT/CM2
     1          + AFY2IT/CM2
                W2PPD = - OMX2*V2PP + OMY2*U2PP + FZ2IT/CM2
     1          + AFZ2IT/CM2
C               SET IN RATES OF CHANGE OF COORDINATES AS DYDXS
                DO 1280 J = 1,NCABLE
                JUMP2 = 3*J + 20 + NRESRV
                DYDX(JUMP2)       = XBRD(J)
                DYDX(JUMP2 + 1) = YBRD(J)
 1280           DYDX(JUMP2 + 2) = ZBRD(J)
      DYDX(23)=CTHT1*CPSI1E*U1PP+(SPHI1*STHT1*CPSI1E-SPSI1E*CPHI1)*V1P
     1P+(SPSI1E*SPHI1+CPHI1*STHT1*CPSI1E)*W1PP
      DYDX(24)=CTHT1*SPSI1E*U1PP+(CPHI1*CPSI1E+SPHI1*STHT1*SPSI1E)*V1PP
     1+(CPHI1*STHT1*SPSI1E-SPHI1*CPSI1E)*W1PP
      DYDX(25)=SPHI1*CTHT1*V1PP-STHT1*U1PP+CPHI1*CTHT1*W1PP
      DYDX(26)=CTHT2*CPSI2E*U2PP+(SPHI2*STHT2*CPSI2E-SPSI2E*CPHI2)*V2PP
     1+(SPSI2E*SPHI2+CPHI2*STHT2*CPSI2E)*W2PP
      DYDX(27)=CTHT2*SPSI2E*U2PP+(CPHI2*CPSI2E+SPHI2*STHT2*SPSI2E)*V2PP
     1+(CPHI2*STHT2*SPSI2E-SPHI2*CPSI2E)*W2PP
      DYDX(28)=SPHI2*CTHT2*V2PP-STHT2*U2PP+CPHI2*CTHT2*W2PP
                RETURN
                END


$IBFTC SRC6

                SUBROUTINE CABFOR
                DIMENSION P(6200),NTEGER(100),VAR(6800),FX1I(20),FY1I(20)
     1          ,FZ1I(20),XBR(20),ZBR(20),XBRD(20),YBRD(20),ZBRD(20),
     2          CABLE(20),SPRK(20),CDAMP(20),RP1P2(20),FORS(20),COEE(20)
     3          ,YBR(20)
                COMMON VAR
                EQUIVALENCE (VAR(401),NTEGER(1)),(VAR(601),P(1)),(P(461),
     1          FX1I(1)),(P(481),FY1I(1)),(P(501),FZ1I(1)),(P(821),XBR(1)
     2          ),(P(841),YBR(1)),(P(861),ZBR(1)),(P(881),XBRD(1)),(P(901
     3          ),YBRD(1)),(P(921),ZBRD(1)),(P(1221),SPRK(1)),(P(1241),
     4          CDAMP(1)),(P(1261),RP1P2(1)),(P(1301),FORS (1)),(P(1345),
     5          COEE(1)),(P(1201),CABLE(1))
                NCABLE = NTEGER(21)
C               COMPUTE INSTANTANEOUS CABLE LENGTH
                DO 180 J = 1,NCABLE
                RP1P2(J) = SQRT(XBR(J)**2 + YBR(J)**2 + ZBR(J)**2)
C               CHECK FOR CABLE SLACK AND ACT ACCORDINGLY
                IF(RP1P2(J) - CABLE(J))100,50,50
   50           COEE(J) = SPRK(J)*(1.0 - CABLE(J)/RP1P2(J))
     1          + CDAMP(J)*(XBR(J)*XBRD(J) + YBR(J)*YBRD(J)
     2          + ZBR(J)*ZBRD(J))/(RP1P2(J)**2)
                FX1I(J) = COEE(J)*XBR(J)
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                FY1I(J) = COEE(J)*YBR(J)
                FZ1I(J) = COEE(J)*ZBR(J)
                GO TO 130
C               IF THE CABLE IS SLACK SET FORCES TO ZERO
  100           FX1I(J) = 0.0
                FY1I(J) = 0.0
                FZ1I(J) = 0.0
  130           FORS(J) = SQRT(FX1I(J)**2 + FY1I(J)**2 + FZ1I(J)**2)
  180           CONTINUE
      P(1342)=RP1P2(1)
      FCABMX=0.0
      DO 300 J=1,NCABLE
      IF(FORS(J)-FCABMX)300,300,301
  301 FCABMX=FORS(J)
      AAA=J
  300 CONTINUE
      P(1344)=FCABMX
      P(5998)=AAA
      P(1340) = RP1P2(2)
      P(1341) = RP1P2(3)
      P(1343) = RP1P2(4)
                RETURN
                END

$IBFTC SRC7

                SUBROUTINE FORFUN
                DIMENSION Y(100),P(6200),NTEGER(100),VAR(6800)
                COMMON VAR
                EQUIVALENCE (VAR(1),Y(1)), (VAR(401),NTEGER(1)),(VAR(601)
     1          ,P(1))
                EQUIVALENCE (P(128),AGX1PT),(P(129),AGY1PT),(P(130),AGZ1P
     1          T),(P(131),AGX2PT),(P(132),AGY2PT), (P(133),AGZ2PT),(P(13
     2          4),AFX1IT),(P(138),AFY2IT),(P(139),AFZ2IT)
     3          ,(P(135),AFY1IT),(P(136),AFZ1IT),(P(137),AFX2IT)
      I=NTEGER(1)
      GO TO(101,102,103),I
  101 AGX1PT=P(5958)*SIN(P(5999)*Y(1))
      AGY1PT=P(5957)*SIN(P(5999)*Y(1))
      AGZ1PT=P(5956)*SIN(P(5999)*Y(1))
      AFX1IT=P(5948)*SIN(P(5945)*Y(1))
      AFY1IT=P(5947)*SIN(P(5945)*Y(1))
      AFZ1IT=P(5946)*SIN(P(5945)*Y(1))
      GO TO 103
  102 AGX2PT=P(5958)*SIN(P(5999)*Y(1))
      AGY2PT=P(5957)*SIN(P(5999)*Y(1))
      AGZ2PT=P(5956)*SIN(P(5999)*Y(1))
      AFX2IT=P(5948)*SIN(P(5945)*Y(1))
      AFY2IT=P(5947)*SIN(P(5945)*Y(1))
      AFZ2IT=P(5946)*SIN(P(5945)*Y(1))
  103 CONTINUE
      RETURN
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                END

$IBFTC SRC8

                SUBROUTINE OUTPUT
                DIMENSION Y(100),DYDX(100),P(6200),NTEGER(100),VAR(6800),
     1 REC(14)
      COMMON/FLM/OM,ON,TWM,TWN,THM,THN,FOM,FON,FIM,FIN,SIM,SIN,SEM,SEN,
     1EIM,EIN,XNIM,XNIN,TEM,TEN,ELM,ELN,TWEM,TWEN,TIEMPO,THIM,THIN,KUT,
     2ITHBOP,MOVIE,IGROP,PHI,THETA,NUM1,NUM2,NUM3,KWHICH
      COMMON    VAR ,KNT, KFST
                EQUIVALENCE (VAR(1),Y(1)),(VAR(101),DYDX(1)),(VAR(401),
     1          NTEGER(1)),(VAR(601),P(1)),(NTEGER(24),NTSKIP),(NTEGER(41
     2          ),LPRINT),(NTEGER(42),NLINE),(NTEGER(43),NSKIP),(NTEGER(
     3          44),NPAGE)
     4,(P(5991),YCG),(P(5990),XCG),(P(5989),ZCG),(P(5988),XBR2CG),(P(59
     587),YBR2CG),(P(5986),ZBR2CG),(P(5985),PSICAP),(P(5984),PHICAP)
      EQUIVALENCE(P(5970),EX2),(P(5969),EY2),(P(5968),EZ2)
      SQAX1=(Y(26)-Y(23))**2+(Y(28)-Y(25))**2
      BR12=SQRT(SQAX1+(Y(27)-Y(24))**2)
      CG=(P(22)*BR12)/(P(6)+P(22))
C     Y COORD.OF BODY 1CG IN INERTIAL PRIME SYSTEM
      YCG=CG*(Y(24)-Y(27))/BR12
      ALNAX=SQRT(SQAX1)
      ALAX1=SQRT(ABS(CG**2-YCG**2))
C     X COORD.OF BODY 1 CG IN INERTIAL PRIME SYSTEM
      XCG=ALAX1*(Y(23)-Y(26))/ALNAX
      CALL DVCHK (K000FX)
      GO TO (200,201),K000FX
  200 XCG=0.0
C     Z COORD.OF BODY 1 CG IN INERTIAL PRIME SYSTEM
  201 ZCG=ALAX1*(Y(25)-Y(28))/ALNAX
      CALL DVCHK (K000FX)
      GO TO (202,203),K000FX
  202 ZCG=0.0
C     X,Y,Z,COORDS.OF RIGID BODY CG IN INERTIAL SYSTEM
  203 XBR2CG=Y(23)-XCG
      YBR2CG=Y(24)-YCG
      ZBR2CG=Y(25)-ZCG
      EX2=Y(26)-XBR2CG
      EY2=Y(27)-YBR2CG
      EZ2=Y(28)-ZBR2CG
      AUXCA1=SQRT(EX2**2+EY2**2)
      PSICAP=ARTN(EY2,EX2)
      IF (PSICAP)204,205,205
  204 PSICAP=6.28318+PSICAP
  205 P(5973)=(-1.0)*EZ2/AUXCA1
      SHIPT=P(5973)
      PHICAP=ATAN(SHIPT)
      CPHICP=COS(PHICAP)
      CPSICP=COS(PSICAP)
      SPSICP=SINE(PSICAP)
      SPHICP=SINE(PHICAP)
```

```
 P(5963)=DYDX(25)+(DYDX(28)-DYDX(25))*CG/BR12
 P(5962)=DYDX(24)+(DYDX(27)-DYDX(24))*CG/BR12
 P(5961)=DYDX(23)+(DYDX(26)-DYDX(23))*CG/BR12
 YD2RCG=DYDX(27)-P(5962)
 XD2RCG=DYDX(26)-P(5961)
 ZD2RCG=DYDX(28)-P(5963)
 BLUAPE=(YD2RCG*SPSICP+XD2RCG*CPSICP)*SPHICP+ZD2RCG*CPHICP
 RESAPE=YD2RCG*CPSICP-XD2RCG*SPSICP
 P(5960)=RESAPE/AUXCA1
 P(5959)=BLUAPF
1/(CG-BR12)
 BLUAPM=-BLUAPE
 P(5950)=ARTN(BLUAPM,RESAPE)
 P(5949)=ARCOS(CPHICP*COS(P(5950)))
 P(5951)=SQRT(BLUAPM**2+RESAPE**2)/(BR12-CG)
 SMLA=CPHICP*CPSICP
 SMLB=-SPSICP
 SMLC=SPHICP*CPSICP
 SMLD=CPHICP*SPSICP
 SMLF=SPHICP*SPSICP
 SMLG=-SPHICP
 A2=P(39)*P(5978)
 B2=P(39)*P(5976)
 C2=-P(38)
 D2=P(46)*P(38)*P(5978)-P(5976)*P(47)
 E2=P(47)*P(5978)+P(46)*P(38)*P(5976)
 F2=P(46)*P(39)
 G2=P(5976)*P(46)+P(47)*P(38)*P(5978)
 H2=P(47)*P(38)*P(5976)-P(46)*P(5978)
 AI2=P(47)*P(39)
 A1=P(36)*P(5979)
 B1=P(36)*P(5977)
 C1=-P(35)
 D1=P(44)*P(35)*P(5979)-P(5977)*P(45)
 E1=P(45)*P(5979)+P(44)*P(35)*P(5977)
 F1=P(44)*P(36)
 G1=P(5977)*P(44)+P(45)*P(35)*P(5979)
 H1=P(45)*P(35)*P(5977)-P(44)*P(5979)
 AI1=P(45)*P(36)
 P(5982)=ARTN((A2*SMLB+B2*CPSICP),(A2*SMLA+B2*SMLD+C2*SMLG))
 P(5983)=ARTN((A1*SMLB+B1*CPSICP),(A1*SMLA+B1*SMLD+C1*SMLG))
 COMM11=G1*SMLC+H1*SMLF+AI1*CPHICP
 COMSM2=D2*SMLC+E2*SMLF+F2*CPHICP
 COMSM1=D1*SMLC+E1*SMLF+F1*CPHICP
 COMM22=G2*SMLC+H2*SMLF+AI2*CPHICP
 P(5975)=ARTN( COMSM2,COMM22)
 P(5974)=ARTN( COMSM1,COMM11)
 P(5980)=ARTN(((-1.0)*(A2*SMLC+B2*SMLF+C2*CPHICP)),SQRT(         COM
1SM2**2+COMM22**2))
 P(5981)=ARTN(((-1.0)*(A1*SMLC+B1*SMLF+C1*CPHICP)),SQRT(COMSM1   **2
1+COMM11**2))
 MOVIE=NTEGER(26)
 CVT=57.2958
```

```
      IF(KFST) 1,3,1
    3 OM=P(5981)
      ON=OM
      TWM=P(5974)
      TWN=TWM
      THM=P(5983)
      THN=THM
      FOM=P(5980)
      FON=FOM
      FIM=P(5975)
      FIN=FIM
      SIM=P(5982)
      SIN=SIM
      SEM=Y(20)
      SEN=Y(20)
      EIM=P(5984)
      EIN=EIM
      XNIM=P(5985)
      XNIN=XNIM
      TEM=Y(23)
      TEN=Y(23)
      ELM=Y(24)
      ELN=Y(24)
      TWEM=Y(25)
      TWEN=Y(25)
      THIM=P(1342)
      THIN=P(1342)
      KFST=1
      GO TO 66
    1 IF(P(5981)-OM)5,5,4
    4 OM=P(5981)
    5 IF(P(5981)-ON)6,7,7
    6 ON=P(5981)
    7 IF(P(5974)-TWM)9,9,8
    8 TWM=P(5974)
    9 IF(P(5974)-TWN)11,12,12
   11 TWN=P(5974)
   12 IF(P(5983)-THM)14,14,13
   13 THM=P(5983)
   14 IF(P(5983)-THN)15,16,16
   15 THN=P(5983)
   16 IF(P(5980)-FOM)18,18,17
   17 FOM=P(5980)
   18 IF(P(5980)-FON)19,21,21
   19 FON=P(5980)
   21 IF(P(5975)-FIM)23,23,22
   22 FIM=P(5975)
   23 IF(P(5975)-FIN)24,25,25
   24 FIN=P(5975)
   25 IF(P(5982)-SIM)27,27,26
   26 SIM=P(5982)
   27 IF(P(5982)-SIN)28,29,29
   28 SIN=P(5982)
```

```
29 IF(Y(20)-SEM)32,32,31
31 SEM=Y(20)
32 IF(Y(20)-SEN)33,34,34
33 SEN=Y(20)
34 IF(P(5984)-EIM)36,36,35
35 EIM=P(5984)
36 IF(P(5984)-EIN)37,38,38
37 EIN=P(5984)
38 IF(P(5985)-XNIM)41,41,39
39 XNIM=P(5985)
41 IF(P(5985)-XNIN)42,43,43
42 XNIN=P(5985)
43 IF(Y(23)-TEM)45,45,44
44 TEM=Y(23)
45 IF(Y(23)-TEN)46,47,47
46 TEN=Y(23)
47 IF(Y(24)-ELM)49,49,48
48 ELM=Y(24)
49 IF(Y(24)-ELN)51,52,52
51 ELN=Y(24)
52 IF(Y(25)-TWEM)54,54,53
53 TWEM=Y(25)
54 IF(Y(25)-TWEN)55,56,56
55 TWEN=Y(25)
56 IF(P(1342)-THIM)58,58,57
57 THIM=P(1342)
58 IF(P(1342)-THIN)59,66,66
59 THIN=P(1342)
66 CONTINUE
   KNT=KNT+1
   REC(1)=Y(1)
   REC(2)=CVT*P(5981)
   REC(3)=CVT*P(5974)
   REC(4)=CVT*P(5983)
   REC(5)=CVT*P(5980)
   REC(6)=CVT*P(5975)
   REC(7)=CVT*P(5982)
   REC(8)=CVT*Y(20)
   REC(9)=CVT*P(5984)
   REC(10)=CVT*P(5985)
   REC(11)=Y(23)
   REC(12)=Y(24)
   REC(13)=Y(25)
   REC(14)=P(1342)
   WRITE (9)(REC(I),I=1,14)
   IF(MOVIE)300,10,300
300 XI1=XCG+P(36)*P(5979)*P(5967)
   YI1=YCG+P(36)*P(5977)*P(5967)
   ZI1=ZCG-P(35)*P(5967)
   XJ1=XCG+(P(44)*P(35)*P(5979)-P(5977)*P(45))*P(5967)
   YJ1=YCG+(P(45)*P(5979)+P(44)*P(35)*P(5977))*P(5967)
   ZJ1=ZCG+P(44)*P(36)*P(5967)
   XK1=XCG+(P(5977)*P(44)+P(45)*P(35)*P(5979))*P(5967)
```

```
      YK1=YCG+(P(45)*P(35)*P(5977)-P(44)*P(5979))*P(5967)
      ZK1=ZCG+P(45)*P(36)*P(5967)
      XI2=EX2+P(39)*P(5978)*P(5967)
      YI2=EY2+P(39)*P(5976)*P(5967)
      ZI2=EZ2-P(38)*P(5967)
      XJ2=EX2+(P(46)*P(38)*P(5978)-P(5976)*P(47))*P(5967)
      YJ2=EY2+(P(47)*P(5978)+P(46)*P(38)*P(5976))*P(5967)
      ZJ2=EZ2+P(46)*P(39)*P(5967)
      XK2=EX2+(P(5976)*P(46)+P(47)*P(38)*P(5978))*P(5967)
      YK2=EY2+(P(47)*P(38)*P(5976)-P(46)*P(5978))*P(5967)
      ZK2=EZ2+P(47)*P(39)*P(5967)
      WRITE (11)P(5990),P(5991),P(5989),XI1,YI1,ZI1,XJ1,YJ1,ZJ1,XK1,YK1,
     1ZK1,P(5970),P(5969),P(5968),XI2,YI2,ZI2,XJ2,YJ2,ZJ2,XK2,YK2,ZK2,P(
     25970),P(5969),Y(1)
      X10=XCG+A1*P(5967)
      Y10=YCG+B1*P(5967)
      Z10=ZCG+C1*P(5967)
      X11=XCG-A1*P(5967)-P(5965)*(D1+ G1)
      Y11=YCG-B1*P(5967)-P(5965)*(E1+ H1)
      Z11=ZCG-C1*P(5967)-P(5965)*(F1+AI1)
      X12=XCG-A1*P(5967)-P(5965)*(G1- D1)
      Y12=YCG-B1*P(5967)-P(5965)*(H1- E1)
      Z12=ZCG-C1*P(5967)-P(5965)*(AI1-F1)
      X13=XCG+A1*P(5967)-P(5965)*(G1 -D1)
      Y13=YCG+B1*P(5967)-P(5965)*(H1 -E1)
      Z13=ZCG+C1*P(5967)-P(5965)*(AI1-F1)
      X14=XCG+A1*P(5967)-P(5965)*(G1 +D1)
      Y14=YCG+B1*P(5967)-P(5965)*(H1 +E1)
      Z14=ZCG+C1*P(5967)-P(5965)*(AI1+F1)
      X15=XCG+A1*P(5967)-P(5965)*(D1- G1)
      Y15=YCG+B1*P(5967)-P(5965)*(E1- H1)
      Z15=ZCG+C1*P(5967)-P(5965)*(F1-AI1)
      X16=XCG-A1*P(5967)-P(5965)*(D1- G1)
      Y16=YCG-B1*P(5967)-P(5965)*(E1- H1)
      Z16=ZCG-C1*P(5967)-P(5965)*(F1-AI1)
      X17=XCG-A1*P(5967)+P(5965)*(D1+ G1)
      Y17=YCG-B1*P(5967)+P(5965)*(E1+ H1)
      Z17=ZCG-C1*P(5967)+P(5965)*(F1+AI1)
      X18=XCG+A1*P(5967)+P(5965)*(D1+ G1)
      Y18=YCG+B1*P(5967)+P(5965)*(E1+ H1)
      Z18=ZCG+C1*P(5967)+P(5965)*(F1+AI1)
      X20=EX2-A2*P(5966)
      Y20=EY2-B2*P(5966)
      Z20=EZ2-C2*P(5966)
      X21=EX2+A2*P(5966)+P(5964)*(D2- G2)
      Y21=EY2+B2*P(5966)+P(5964)*(E2- H2)
      Z21=EZ2+C2*P(5966)+P(5964)*(F2-AI2)
      X22=EX2+A2*P(5966)-P(5964)*(D2+ G2)
      Y22=EY2+B2*P(5966)-P(5964)*(E2+ H2)
      Z22=EZ2+C2*P(5966)-P(5964)*(F2+AI2)
      X23=EX2-A2*P(5966)-P(5964)*(D2+ G2)
```

```
      Y23=EY2-B2*P(5966)-P(5964)*(E2+ H2)
      Z23=EZ2-C2*P(5966)-P(5964)*(F2+AI2)
      X24=EX2-A2*P(5966)-P(5964)*(G2- D2)
      Y24=EY2-B2*P(5966)-P(5964)*(H2- E2)
      Z24=EZ2-C2*P(5966)-P(5964)*(AI2-F2)
      X25=EX2-A2*P(5966)+P(5964)*(D2+ G2)
      Y25=EY2-B2*P(5966)+P(5964)*(E2+ H2)
      Z25=EZ2-C2*P(5966)+P(5964)*(F2+AI2)
      X26=EX2+A2*P(5966)+P(5964)*(D2+ G2)
      Y26=EY2+B2*P(5966)+P(5964)*(E2+ H2)
      Z26=EZ2+C2*P(5966)+P(5964)*(F2+AI2)
      X27=EX2+A2*P(5966)+P(5964)*(G2- D2)
      Y27=EY2+B2*P(5966)+P(5964)*(H2- E2)
      Z27=EZ2+C2*P(5966)+P(5964)*(AI2-F2)
      X28=EX2-A2*P(5966)+P(5964)*(G2 -D2)
      Y28=EY2-B2*P(5966)+P(5964)*(H2 -E2)
      Z28=EZ2-C2*P(5966)+P(5964)*(AI2-F2)
      WRITE (13)X10,X13,X14,X15,X18,X17,X12,X11,X16,X20,X23,X24,X25,X28,
     1X27,X22,X21,X26,Y10,Y13,Y14,Y15,Y18,Y17,Y12,Y11,Y16,Y20,Y23,  Y24,
     2Y25,Y28,Y27,Y22,Y21,Y26,Z10,Z13,Z14,Z15,Z18,Z17,Z12,Z11,Z16,  Z20,
     3Z23,Z24,Z25,Z28,Z27,Z22,Z21,Z26,P(5970),P(5969),Y(1)
   10          IF(Y(1) - P(2))20,50,50
C              DETERMINE WHETHER OR NOT PRINT ON THIS INTEGRATION STEP
   20          IF(NSKIP - NTSKIP)30,50,50
   30          NSKIP = NSKIP + 1
               GO TO 150
C              DETERMINE IF A NEW PAGE IS REQUIRED FOR PRINTING RESULTS
   50          IF(NLINE - 52)90,60,61
   60 CALL LASOUT
   61          NPAGE = NPAGE + 1
               CALL PAGEHD
               NLINE = 0
   90          CALL OUTAID
               NLINE = NLINE + LPRINT + 1
               NSKIP = 0
               IF(Y(1) - P(2))150,130,130
C     COMPLETE PRINTOUT AND GO TO FILM SUBROUTINES
  130          CALL LASOUT
      TIEMPO=Y(1)
      PHI=P(5972)
      THETA=P(5971)
      IGROP=NTEGER(25)
      ITHBOP=NTEGER(27)
      NUM1=600
      NUM3=600
      KWHICH=1
      END FILE 11
      END FILE 9
      END FILE 13
  150          RETURN
               END

$IBFTC SRC9
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```
                SUBROUTINE OUTAID
                DIMENSION Y(100),DYDX(100),P(6200),NTEGER(100),VAR(6800),
     1          XBR(20),YBR(20),ZBR(20),OUTP1(13),CABLE(20),RP1P2(20),
     2          OUTP2 (57,13),OUTP4(57,13)
      DIMENSION MGDT(20)
                COMMON VAR
                EQUIVALENCE (VAR(1),Y(1)),(VAR(101),DYDX(1)),(VAR(601),
     1          P(1)),(VAR(401),NTEGER(1)),
     2          (NTEGER(42),NLINE),(Y(8),THT1),(Y(9),PHI1),(Y(18),PHI2),
     3          (Y(17),THT2),(Y(20),THTBR),(DYDX(20),THTBRD),(Y(21),PHIB
     4          R),(DYDX(21),PHIBRD),(Y(22),PSIBR),(DYDX(22),PSIBRD),
     5          (P(58),OMZ1),(P(59),OMX2),(P(60),OMY2),(P(61),OMZ2),
     6          (P(56),OMX1),(P(57),OMY1),(P(841),YBR(1)),(P(821),XBR(1))
     7          ,(P(861)  ,ZBR(1)),(P(941),OUTP1(1)),(P(1201),CABLE(1)),
     8          (P(1261),RP1P2(1)),(P(2151),OUTP4(1)),(P(103),K),(P(1401
     9          ),OUTP2(1)),(NTEGER(21),NCABLE)
C               CALCULATE QUANTITIES TO BE PRINTED ON PAGE 1
C TO PRINT OUT THE GRAPH VARIABLES,MAKE THE FOLLOWING CHANGES IN THE OUT
C P1( ) CARDS-CHANGE THT1 TO P(5981),PHI1 TO P(5974),THT2 TO P(5980),PHI
C 2 TO P(5975),XBR(1) TO P(5983)*57.29578,YBR(1) TO P(5982)*57.29578,ZBR
C (1) TO P(5984)*57.29578
                OUTP1(1)   = Y(1)
                OUTP1(2)   = THT1 *57.2957795
          OUTP1(3)=P(5960)*57.2957795
                OUTP1(4)   = PHI1 *57.2957795
                OUTP1(5)   = THT2 *57.2957795
          OUTP1(6)=P(5959)*57.2957795
                OUTP1(7)=PHI2     *57.2957795
                OUTP1(8)   = THTBR*57.2957795
                OUTP1(9)   = PSIBR*57.2957795
                OUTP1(10)  = PHIBR*57.2957795
                OUTP1(11)  = XBR(1)
                OUTP1(12)  = YBR(1)
                OUTP1(13)  = ZBR(1)
C               WRITE COLUMN HEADINGS IF NEW PAGE
                IF(NLINE)150,150,170
  150           WRITE (6,160)
        DO 611 L=1,57
        DO 612 I=1,13
        OUTP2(L,I)=0.0
  612 CONTINUE
  611 CONTINUE
        DO 613 L=1,57
        DO 614 I=1,13
        OUTP4(L,I)=0.0
  614 CONTINUE
  613 CONTINUE
  160 FORMAT(//127H       TIME      THETA1     PSIRBD       PHI1       THETA2
     1THETRBD    PHI2       THETAB      PSIB        PHIB        XBR(1)       YBR(1)
     2  ZBR(1)/124H       SEC         DEG       DEG/SEC      DEG          DEG
     3DEG/SEC    DEG         DEG        DEG         DEG          IN            IN
     4   IN//)
```

```
C               WRITE OUT DATA ON FIRST PAGE
  170           WRITE (6,180)(OUTP1(I),I=1,13)
  180 FORMAT(3(F11.4,F9.4,F10.4),F11.4,3F9.3)
      MOUTPR=0
      DO 500 I=2,NCABLE
      IF(RP1P2(I)-CABLE(I))502,502,501
  501 MGDT(I)=0
      GO TO 500
  502 MGDT(I)=1
      MOUTPR=1
  500 CONTINUE
      IF(MOUTPR)504,504,505
  505 WRITE (6,503)
  503 FORMAT(18H SLACK CABLES ARE )
      DO 506 I=2,NCABLE
      IF( MGDT(I))506,506,507
  507 GO TO(511,512,513,514,515,516,517,518,519,520,521,522,523,524,525
     1,526,527,528,529,530),I
  511 WRITE (6,531)I
  531 FORMAT(1H+19X,I1)
      GO TO 506
  512 WRITE (6,532)I
  532 FORMAT(1H+21X,I1)
      GO TO 506
  513 WRITE (6,533)I
  533 FORMAT(1H+23X,I1)
      GO TO 506
  514 WRITE (6,534)I
  534 FORMAT(1H+25X,I1)
      GO TO 506
  515 WRITE (6,535)I
  535 FORMAT(1H+27X,I1)
      GO TO 506
  516 WRITE (6,536)I
  536 FORMAT(1H+29X,I1)
      GO TO 506
  517 WRITE (6,537)I
  537 FORMAT(1H+31X,I1)
      GO TO 506
  518 WRITE (6,538)I
  538 FORMAT(1H+33X,I1)
      GO TO 506
  519 WRITE (6,539)I
  539 FORMAT(1H+35X,I1)
      GO TO 506
  520 WRITE (6,540)I
  540 FORMAT(1H+37X,I2)
      GO TO 506
  521 WRITE (6,541)I
  541 FORMAT(1H+40X,I2)
      GO TO 506
  522 WRITE (6,542)I
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  542 FORMAT(1H+43X,I2)
      GO TO 506
  523 WRITE (6,543)I
  543 FORMAT(1H+46X,I2)
      GO TO 506
  524 WRITE (6,544)I
  544 FORMAT(1H+49X,I2)
      GO TO 506
  525 WRITE (6,545)I
  545 FORMAT(1H+52X,I2)
      GO TO 506
  526 WRITE (6,546)I
  546 FORMAT(1H+55X,I2)
      GO TO 506
  527 WRITE (6,547)I
  547 FORMAT(1H+58X,I2)
      GO TO 506
  528 WRITE (6,548)I
  548 FORMAT(1H+61X,I2)
      GO TO 506
  529 WRITE (6,549)I
  549 FORMAT(1H+64X,I2)
      GO TO 506
  530 WRITE (6,550)I
  550 FORMAT(1H+67X,I2)
  506 CONTINUE
  504 IF(MOUTPR)509,509,510
  510 NLINE=NLINE+1
C                CALCULATE DATA FOR SECOND PAGE
  509            K = NLINE + 1
                 OUTP2(K,1)   = Y(1)
      OUTP2(K,2)=P(5950)*57.2957795
      OUTP2(K,3)=P(5949)*57.2957795
                 OUTP2(K,4)   = P(5951)*57.2957795
                 OUTP2(K,5)=THTBRD*   57.2957795
                 OUTP2(K,6)=PSIBRD*   57.2957795
                 OUTP2(K,7)=PHIBRD*   57.2957795
                 OUTP2(K,8)   =P(5990)
                 OUTP2(K,9)   = P(5991)
                 OUTP2(K,10)  =P(5989)
                 OUTP2(K,11)  =P(5988)
                 OUTP2(K,12)  =P(5987)
                 OUTP2(K,13)  =P(5986)
C                CALCULATE DATA FOR THIRD PAGE
C TO PRINT OUT THE GRAPH VARIABLES,MAKE THE FOLLOWING CHANGE IN THE OUTP
C 4( ) CARDS-CHANGE P(1340) TO P(5985)*57.29578
                 OUTP4(K,1)   = Y(1)
                 OUTP4(K,2)   = OMX1*57.2957795
                 OUTP4(K,3)   = OMY1*57.2957795
                 OUTP4(K,4)   = OMZ1*57.2957795
                 OUTP4(K,5)   = OMX2*57.2957795
                 OUTP4(K,6)   = OMY2*57.2957795
                 OUTP4(K,7)   = OMZ2*57.2957795
```

```
      OUTP4(K,8)   = P(1340)
      OUTP4(K,9)   = P(1341)
      OUTP4(K,10)  = P(1342)
      OUTP4(K,11)  = P(1343)
      OUTP4(K,12)  = P(1344)
 OUTP4(K,13)=P(5998)
C     WRITE OUT PAGES 2 AND 3 IF AT END OF PAGE 1
      IF(NLINE - 52)420,410,410
  410 CALL LASOUT
  420 RETURN
      END
```

```
$IBFTC SRC10
```

```
      SUBROUTINE LASOUT
      DIMENSION P(6200),NTEGER(100), OUTP2 (57,13), OUTP4(57,13
     1),VAR(6800)
      COMMON VAR
      EQUIVALENCE(VAR(401),NTEGER(1)),(VAR(601),P(1)),
     1(NTEGER(44),NPAGE),(P(1401),OUTP2(1)),(P(2151),OUTP4(1)),
     2(P(103),K)
C     WRITE OUT PAGE 2
      NPAGE = NPAGE + 1
      CALL PAGEHD
      WRITE (6,440)
  440 FORMAT(//123H      TIME     GAMMA      ALPHA       IAVB2      THETABD     P
     1SIBD      PHIBD      XCG        YCG        ZCG       XBR2CG      YBR2CG     ZB
     2R2CG/123H        SEC      DEG        DEG       DEG/SEC     DEG/SEC    DEG/SE
     3C  DEG/SEC     INCHES    INCHES      INCHES    INCHES      INCHES     INCHES
     4//)
      DO 480 L = 1,K
      WRITE (6,470)(OUTP2(L,I),I=1,13)
  470 FORMAT(F11.3,F9.4,F9.1,F11.3,2F9.4,F9.3,F11.4,F10.4,F8.2,3F9.2)
  480 CONTINUE
C     WRITE OUT PAGE 3
      NPAGE = NPAGE + 1
      CALL PAGEHD
      WRITE (6,520)
  520 FORMAT(//127H       TIME     OMEGAX1    OMEGAY1   OMEGAZ1    OMEGAX2
     1OMEGAY2   OMEGAZ2    RP1P2(2) RP1P2(3)  RP1P2(1) RP1P2(4) FCABLEMAX
     2   CABLE/112H      SEC      DEG/SEC    DEG/SEC   DEG/SEC     DEG/SEC    D
     3EG/SEC  DEG/SEC     IN         IN        IN         IN          LB//)
      DO 560 L = 1,K
      WRITE (6,550)(OUTP4(L,I),I=1,13)
  550 FORMAT(F11.3,2(F11.3,F9.4,F9.4),5F10.3,F6.0)
  560 CONTINUE
      RETURN
      END
```

```
$IBFTC SRC11
```

```
      FUNCTION SINE(X)
      SINE=SIN(X)
      RETURN
      END

$IBFTC SRC12

      FUNCTION ARTN(X,Y)
      ARTN=ATAN2(X,Y)
      RETURN
      END

C REMOVE THE REST OF THE SOURCE DECK IF S-C4020 NOT AVAILABLE
$ORIGIN        ACE
$IBFTC SRFU

      SUBROUTINE FILM(OM,ON,TWM,TWN,THM,THN,FOM,FON,FIM,FIN,SIM,SIN,SEM,
     1SEN,EIM,EIN,XNIM,XNIN,TEM,TEN,ELM,ELN,TWEM,TWEN,TIEMPO,THIM,THIN,K
     2NT,ITHBOP,MOVIE,IGROP,PHI,THETA,NUM1,NUM2,NUM3,KWHICH)
      DIMENSION VAR(6800)
      DIMENSION REC(26),X(18),Y(18),Z(18)
      COMMON  VAR     , KNT     , KFST    , L
      CVT=57.2958
      K=1
      L=0
      REWIND 11
      REWIND 13
      IF(IGROP)41,11,41
   41 REWIND 9
      K=1
      L=L+1
      GO TO (1,2,3,4,5,6,7,8,9,10,11,12),L
    1 XL=0.0
      XR=TIEMPO
      YB=ON*CVT
      YT=OM*CVT
      CALL CART(XL,XR,YB,YT)
      CALL APRNTV(0,-12,-16,16HTHETAST1 DEGREES,12,650)
      M=L+1
      GO TO 33
    2 YB=TWN*CVT
      YT=TWM*CVT
      CALL CART(XL,XR,YB,YT)
      CALL APRNTV(0,-12,-14,14HPHIST1 DEGREES,12,650)
      M=L+1
      GO TO 33
    3 YB=THN*CVT
      YT=THM*CVT
      CALL CART(XL,XR,YB,YT)
      CALL APRNTV(0,-12,-14,14HPSIST1 DEGREES,12,650)
      M=L+1
```

```
      GO TO 33
    4 YB=FON*CVT
      YT=FOM*CVT
      CALL CART(XL,XR,YB,YT)
      CALL APRNTV(0,-12,-16,16HTHETAST2 DEGREES,12,650)
      M=L+1
      GO TO 33
    5 YB=FIN*CVT
      YT=FIM*CVT
      CALL CART(XL,XR,YB,YT)
      CALL APRNTV(0,-12,-14,14HPHIST2 DEGREES,12,650)
      M=L+1
      GO TO 33
    6 YB=SIN*CVT
      YT=SIM*CVT
      CALL CART(XL,XR,YB,YT)
      CALL APRNTV(0,-12,-14,14HPSIST2 DEGREES,12,650)
      M=L+1
      GO TO 33
    7 IF(IINDOF)90,41,90
   90 CONTINUE
      YB=SEN*CVT
      YT=SEM*CVT
      CALL CART(XL,XR,YB,YT)
      CALL APRNTV(0,-12,-14,14HTHETAB DEGREES,12,650)
      M=L+1
      GO TO 33
    8 YB=EIN*CVT
      YT=EIM*CVT
      CALL CART(XL,XR,YB,YT)
      CALL APRNTV(0,-12,-14,14HTHETRB DEGREES,12,650)
      M=L+1
      GO TO 33
    9 YB=XNIN*CVT
      YT=XNIM*CVT
      CALL CART(XL,XR,YB,YT)
      CALL APRNTV(0,-12,-14,14H PSIRB DEGREES,12,650)
      M=L+1
      GO TO 33
   10 YB=THIN
      YT=THIM
      CALL CART(XL,XR,YB,YT)
      CALL APRNTV(0,-12,-15,15HRP1P2-1- INCHES,12,650)
      M=L+4
   33 CONTINUE
      READ  (9)(REC(I),I=1,14)
      IX1=NXV(REC(1))
      IY1=NYV(REC(M))
   40 READ  (9)(REC(I),I=1,14)
      IX2=NXV(REC(1))
      IY2=NYV(REC(M))
      IF(IY2-IY1)34,36,35
   34 IDF=IY1-IY2
```

```
      GO TO 37
   35 IDF=IY2-IY1
   37 IF(IDF-3)36,38,38
   36 IF((IX2-IX1)-3)39,38,38
   38 CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
   39 CONTINUE
      K=K+1
      IF(KNT-K)41,41,40
   11 IF(MOVIE)50,12,50
   50 XTRM=0.0
      DO 60 J=1,KNT
      READ  (11)(REC(I),I=1,26),T
      DO 61 I=1,26
      IF(XTRM-ABS(REC(I)))62,61,61
   62 XTRM=ABS(REC(I))
   61 CONTINUE
   60 CONTINUE
      REWIND 11
      XL=-XTRM-XTRM/20.0
      XR=XTRM+XTRM/20.0
      YB=XL
      YT=XR
      CALL FRONT(NUM1)
      READ  (11)(REC(I),I=1,26),T
      DO 104 KLUG=1,NUM3
      CALL GRID1V(1,XL,XR,YB,YT,0.0,0.0,0,0,0,0,0,0)
      CALL AXIS(XL,XR,PHI,THETA,0)
      CALL DRAW(REC(1),PHI,THETA,1)
      READ  (13)(X(I),I=1,18),(Y(I),I=1,18),(Z(I),I=1,18)            ,RE
     1FX,REFY,T
      REWIND 13
      CALL GRAN(X(1),Y(1),Z(1),PHI,THETA,REFX,REFY)
      CALL UNDWRT(KWHICH)
      CALL RCLOK(170,900,100,180,10.0,T)
  104 CONTINUE
      REWIND 11
      REWIND 13
   52 CALL GRID1V(1,XL,XR,YB,YT,0.0,0.0,0,0,0,0,0,0)
      CALL AXIS(XL,XR,PHI,THETA,1)
      IF(KNT-K)12,51,51
   51 READ  (11)(REC(I),I=1,26),T
      CALL DRAW(REC(1),PHI,THETA,0)
      CALL RCLOK(170,900,100,180,10.0,T)
      K=K+1
      GO TO 52
   12 CONTINUE
  201 CONTINUE
      IF(MOVIE)102,102,100
  100 CONTINUE
      DO 105 KRUD=1,50
      CALL RESETV
  105 CONTINUE
      DO 101 KRUG=1,KNT
```

```
      CALL GRID1V(1,XL,XR,YB,YT,0.0,0.0,0,0,0,0,0,0)
      CALL AXIS(XL,XR,PHI,THETA,1)
      READ  (13)(X(I),I=1,18),(Y(I),I=1,18),(Z(I),I=1,18)                ,RE
     1FX,REFY,I
      CALL GRAN(X(1),Y(1),Z(1),PHI,THETA,REFX,REFY)
      CALL RCLOK(170,900,100,180,10.0,T)
  101 CONTINUE
      DO 106 KRUD=1,50
      CALL RESETV
  106 CONTINUE
  102 CONTINUE
      RETURN
      END
```

```
$IBFTC SRF1

      SUBROUTINE CART(XL,XR,YB,YT)
      COMMON  VAR     , KNT     , KFST    , L
      DIMENSION VAR(6800)
      CALL DXDYV(1,XL,XR,DX,N,I,NX,16.0,IERR)
      CALL DXDYV(2,YB,YT,DY,M,J,NY,16.0,IERR)
      CALL EDG(XL,XR,YB,YT,DX,DY,N,M,0.000001)
      IF(L-10)3,2,3
    2 NX=NX+2
      NY=NY+2
    3 NX=NX+1
      NY=NY+1
      CALL GRID1V(1,XL,XR,YB,YT,DX,DY,N,M,-N,-M,NX,NY)
      CALL PRINTV(-12,12HTIME SECONDS,400,12)
      RETURN
      END
```

```
$IBFTC SRF2

      SUBROUTINE EDG(XL,XR,YB,YT,DX,DY,I,J,C)
      DX=ABS(DX)
      DY=ABS(DY)
      IF(DX)60,45,60
   60 IF(DY)61,45,61
   61 CONTINUE
      FI=I
      FJ=J
      IF(XL)28,8,1
    1 D=DX*FI
      S=D
    2 AG=S-XL
      IF(AG)4,5,3
    3 IF(C-AG)7,6,6
    7 XL=S-D
      GO TO 5
    6 XL=S
      GO TO 5
    4 IF(C+AG)27,5,5
```

```
27 S=S+D
   GO TO 2
 8 D=DX*FI
 5 S=D
 9 AG=XR-S
   IF(AG)11,12,10
10 IF(C-AG)13,12,12
11 XR=S
12 IF(YB)22,15,14
13 S=S+D
   GO TO 9
14 D=DY*FJ
   CK=D
73 IF(YB/CK-1000.0)70,71,71
71 CK=CK+1000.0*D
   GO TO 73
70 S=CK
16 AG=S-YB
   IF(AG)19,15,17
17 IF(C-AG)18,15,15
18 YB=S-D
   GO TO 15
19 IF(C+AG)21,20,20
21 S=S+D
   GO TO 16
20 YB=S
   GO TO 15
22 D=DY*FJ
   S=-D
23 AG=YB-S
   IF(AG)24,15,25
24 IF(C+AG)26,15,15
25 YB=S
   GO TO 15
26 S=S-D
   GO TO 23
28 D=DX*FI
   S=-D
29 AG=XL-S
   IF(AG)30,33,32
30 IF(C+AG)31,32,32
31 S=S-D
   GO TO 29
32 XL=S
33 IF(XR)34,12,5
34 S=-D
35 AG=XR-S
   IF(AG)38,15,36
38 IF(C+AG)39,15,15
39 S=S-D
   GO TO 35
36 IF(C-AG)37,15,15
37 XR=S+D
15 IF(YT)46,45,40
```

```
40 D=DY*FJ
   CK=D
74 IF(YT/CK-1000.0)75,76,76
76 CK=CK+1000.0*D
   GO TO 74
75 S=CK
41 AG=YT-S
   IF(AG)44,45,42
42 IF(C-AG)43,45,45
43 S=S+D
   GO TO 41
44 YT=S
   GO TO 45
46 D=DY*FJ
   S=-D
47 AG=YT-S
   IF(AG)48,45,51
48 IF(C+AG)50,49,49
50 S=S-D
   GO TO 47
49 YT=S
   GO TO 45
51 IF(C-AG)52,45,45
52 YT=S+D
45 CONTINUE
   RETURN
   END

$IBFTC SRF3

      SUBROUTINE FRONT(NUM1)
      DIMENSION VAR(6800),P(6800)
      COMMON VAR
      EQUIVALENCE(VAR(601),P(1))
      U=386.4*P(6)
      V=386.4*P(22)
      DO 10 I=1,NUM1
      CALL RESETV
      CALL RITE2V(150,169,1023,180,2,38,-1,38HCABLE CONNECTED SPACE STAT
     1ION DYNAMICS,NLAST)
      CALL RITE2V(300,250,1023,180,1,29,-1,29HWEIGHT OF BODY 1 =
     1LB.,NLAST)
      CALL RITE2V(435,250,1023,180,1,29,-1,29HWEIGHT OF BODY 2 =
     1LB.,NLAST)
      CALL RITE2V(570,178,1023,180,1,37,-1,37HINITIAL SPIN SPEED =
     1  DEG./SEC.,NLAST)
      CALL RITE2V(705,88,1023,180,1,48,-1,48HINITIAL DISTANCE BETWEEN BO
     1DY C.G. S=          FT.,NLAST)
      CALL RITE2V(840,232,1023,180,1,31,-1,31HCABLE ELASTICITY =
     1  PSI,NLAST)
      CALL RITE2V(690,700,1023,180,1,1,-1,1H,,NLAST)
      CALL RITE2V(975,214,1023,180,1,33,-1,33HTOTAL CABLE AREA =
```

```
     1SQ. IN.,NLAST)
      CALL HEAD(3,3,18,26,300,592,1023,180,1,LX,LY,0,0,2,U)
      CALL HEAD(3,3,18,26,435,592,1023,180,1,LX,LY,0,0,2,V)
      CALL HEAD(3,3,18,26,570,556,1023,180,1,LX,LY,2,0,2,P(5955))
      CALL HEAD(3,3,18,26,705,772,1023,180,1,LX,LY,1,0,2,P(5952))
      CALL HEAD(3,3,18,26,840,574,1023,180,1,LX,LY,0,0,2,P(5954))
      CALL HEAD(3,3,18,26,975,556,1023,180,1,LX,LY,4,0,2,P(5953))
   10 CONTINUE
      RETURN
      END


$IBFTC SRF4

      SUBROUTINE HEAD(LVW,LVH,ISPACE,IROW,MX,MY,LIMIT,K,INT,LX,LY,IRT,
     1IVAR,IFIR,VAR)
      DIMENSION REC(400)
      CALL CAMRAV(35)
      CALL CHSIZV(LVW,LVH)
      EXTERNAL TABL1V
      CALL RITSTV(ISPACE,IROW,TABL1V)
      NDS=0
      LX=MX
      LY=MY
      IF(IVAR.EQ.0)GO TO 10
      NTH=1
      NTOTAL=6
      IF(IFIR.NE.0)GO TO 52
      READ(5,501)NU
      READ(5,500)(REC(J),J=1,NU)
      IFIR=1
   52 CONTINUE
  501 FORMAT(I5)
  500 FORMAT(10A6)
      DO 60 L=1,NU
      BCDTXT=REC(L)
      CALL RITE2V(LX,LY,LIMIT,K,INT,NTOTAL,NTH,BCDTXT,NLAST)
      CALL RITXYV(LX,LY)
      IF(K.EQ.0) GO TO 61
      IF(K.EQ.90) GO TO 90
      IF(K.EQ.180) GO TO 180
      IF(K.EQ.270) GO TO 270
   61 IF((LY-4*LVW   ).LT.LIMIT)GO TO 62
      GO TO 60
   90 IF((LX+4*LVW   ).GT.LIMIT)GO TO 63
      GO TO 60
  180 IF((LY+4*LVW   ).GT.LIMIT)GO TO 64
      GO TO 60
  270 IF((LX-4*LVW   ).LT.LIMIT)GO TO 65
      GO TO 60
   62 LY=MY
      LX=LX-IROW
      GO TO 60
   63 LX=MX
```

```
      LY=LY-IROW
      GO TO 60
   64 LY=MY
      LX=LX+IROW
      GO TO 60
   65 LX=MX
      LY=LY+IROW
   60 CONTINUE
      GO TO 20
   10 IF(VAR.GE.0.0) GO TO 43
      CALL RITE2V(LX,LY,LIMIT,K,INT,1,-1,1H-,NLAST)
      CALL RITXYV(LX,LY)
   43 CALL BNBCDV(VAR,CON,NDS)
      IF(NDS)44,45,46
   44 NDS=IABS(NDS)
      CALL RITE2V(LX,LY,LIMIT,K,INT,2,-1,2H0.,NLAST)
      IF(NDS.GE.IRT) GO TO 47
      DO 48 I=1,NDS
      CALL RITXYV(LX,LY)
      CALL RITE2V(LX,LY,LIMIT,K,INT,1,-1,1H0,NLAST)
   48 CONTINUE
      NTOTAL=IRT-NDS
      IF(NTOTAL.GT.6)NTOTAL=6
      CALL RITXYV(LX,LY)
      CALL RITE2V(LX,LY,LIMIT,K,INT,NTOTAL,1,CON,NLAST)
      GO TO 20
   47 DO 49 I=1,IRT
      CALL RITXYV(LX,LY)
      CALL RITE2V(LX,LY,LIMIT,K,INT,1,-1,1H0,NLAST)
   49 CONTINUE
      GO TO 20
   45 CALL RITE2V(LX,LY,LIMIT,K,INT,2,-1,2H0.,NLAST)
      CALL RITXYV(LX,LY)
      IF(IRT.GT.6)GO TO 73
      CALL RITXYV(LX,LY)
      CALL RITE2V(LX,LY,LIMIT,K,INT,IRT,1,CON,NLAST)
      GO TO 20
   73 KUT=6
      CALL RITXYV(LX,LY)
      CALL RITE2V(LX,LY,LIMIT,K,INT,KUT,1,CON,NLAST)
      GO TO 20
   46 IF(NDS.LE.6)GO TO 70
      MORE=NDS-6
      CALL RITE2V(LX,LY,LIMIT,K,INT,6,1,CON,NLAST)
      DO 71 KLU=1,MORE
      CALL RITXYV(LX,LY)
      CALL RITE2V(LX,LY,LIMIT,K,INT,1,-1,1H0,NLAST)
   71 CONTINUE
      IF(IRT.EQ.0)GO TO 20
      CALL RITXYV(LX,LY)
      CALL RITE2V(LX,LY,LIMIT,K,INT,1,-1,1H.,NLAST)
      DO 75 KLU=1,IRT
      CALL RITXYV(LX,LY)
```

```
      CALL RITE2V(LX,LY,LIMIT,K,INT,1,-1,1H0,NLAST)
   75 CONTINUE
      GO TO 20
   70 CALL RITE2V(LX,LY,LIMIT,K,INT,NDS,1,CON,NLAST)
      IF(IRT.EQ.0)GO TO 20
      IF((NDS+IRT).LE.6)GO TO 72
      KUT=6-NDS
      NTH=NDS+1
      CALL RITXYV(LX,LY)
      CALL RITE2V(LX,LY,LIMIT,K,INT,KUT,NTH,CON,NLAST)
      GO TO 20
   72 NTH=NDS+1
      CALL RITXYV(LX,LY)
      CALL RITE2V(LX,LY,LIMIT,K,INT,1,-1,1H.,NLAST)
      CALL  RITXYV(LX,LY)
      CALL RITE2V(LX,LY,LIMIT,K,INT,IRT,NTH,CON,NLAST)
   20 CALL RITXYV(LX,LY)
      RETURN
      END


$IBFTC SRF5

      SUBROUTINE AXIS(XL,XR,PHI,THETA,LBL)
      SPH=SIN(PHI)
      CPH=COS(PHI)
      STH=SIN(THETA)
      CTH=COS(THETA)
      CALL POINTV(0.0,0.0,0)
      XP=XR*CPH*STH
      YP=-XR*SPH
      IX1=NXV(XP)
      IY1=NYV(YP)
      IX2=NXV(-XP)
      IY2=NYV(-YP)
      CALL LINEV(IX1,IY1,IX2,IY2)
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX=IX1+12
      IY=IY1-12
      CALL RITE2V(IX,IY,1023,180,2,1,-1,1HX,N)
      XP=XR*SPH*STH
      YP=XR*CPH
      IX1=NXV(XP)
      IY1=NYV(YP)
      IX2=NXV(-XP)
      IY2=NYV(-YP)
      CALL LINEV(IX1,IY1,IX2,IY2)
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX=IX1+12
      IY=IY1+12
      CALL RITE2V(IX,IY,1023,180,2,1,-1,1HY,N)
      XP=-XR*CTH
```

```
      YP=0.0
      IX1=NXV(XP)
      IY1=NYV(YP)
      IX2=NXV(0.0)
      IY2=NYV(0.0)
      CALL LINEV(IX1,IY1,IX2,IY2)
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX=IX1-12
      IY=IY1
      CALL RITE2V(IX,IY,1023,180,2,1,-1,1HZ,N)
      RETURN
      END

$IBFTC SRF6

      SUBROUTINE DRAW(REC,PHI,THETA,LBL)
      DIMENSION REC(26)
      SPH=SIN(PHI)
      CPH=COS(PHI)
      STH=SIN(THETA)
      CTH=COS(THETA)
      X=REC(1)
      Y=REC(2)
      Z=REC(3)
      ARG1=X*CPH*STH+Y*SPH*STH-Z*CTH
      ARG2=-X*SPH+Y*CPH
      IX1=NXV(ARG1)
      IY1=NYV(ARG2)
      DO 10 I=1,4
      J=3*I+1
      X=REC(J)
      Y=REC(J+1)
      Z=REC(J+2)
      ARG1=X*CPH*STH+Y*SPH*STH-Z*CTH
      ARG2=-X*SPH+Y*CPH
      IX2=NXV(ARG1)
      IY2=NYV(ARG2)
      CALL LINEV(IX1,IY1,IX2,IY2)
      IF(LBL)18,19,18
   18 CALL IJK(I,IX2,IY2)
   19 CONTINUE
   10 CONTINUE
      IX1=IX2
      IY1=IY2
      DO 11 I=5,7
      J=3*I+1
      X=REC(J)
      Y=REC(J+1)
      Z=REC(J+2)
      ARG1=X*CPH*STH+Y*SPH*STH-Z*CTH
      ARG2=-X*SPH+Y*CPH
      IX2=NXV(ARG1)
```

```
      IY2=NYV(ARG2)
      CALL LINEV(IX1,IY1,IX2,IY2)
      IF(LBL)20,21,20
   20 CALL IJK(I,IX2,IY2)
   21 CONTINUE
   11 CONTINUE
      IF(LBL)25,26,25
   26 CONTINUE
      X=REC(25)
      Y=REC(26)
      CALL REFR(X,Y,SPH,CPH,STH,CTH)
   25 CONTINUE
      RETURN
      END
```

```
$IBFTC SRF7
```

```
      SUBROUTINE IJK(I,IX,IY)
      EXTERNAL  TABL1V
      EXTERNAL  TAB15V
      CALL CHSIZV(3,3)
      ILX=IX+9
      ILY=IY-6
      CALL VCHARV(180,1,ILX,ILY,42,TABL1V)
      GO TO(1,2,3,9,5,6,7,9),I
    1 IX1=ILX+12
      IY1=ILY-12
      CALL VCHARV(180,1,IX1,IY1,25,TAB15V)
    8 CALL  CHSIZV(2,2)
      IX1=IX1+6
      IY1=IY1+13
      CALL VCHARV(180,1,IX1,IY1,1,TABL1V)
      GO TO 9
    2 IX1=ILX
      IY1=ILY+12
      CALL VCHARV(180,1,IX1,IY1,33,TAB15V)
      GO TO 8
    3 IX1=ILX-12
      IY1=ILY
      CALL VCHARV(180,1,IX1,IY1,34,TAB15V)
      GO TO 8
    5 IX1=ILX+12
      IY1=ILY-12
      CALL VCHARV(180,1,IX1,IY1,25,TAB15V)
   10 CALL CHSIZV(2,2)
      IX1=IX1+6
      IY1=IY1+13
      CALL VCHARV(180,1,IX1,IY1,2,TABL1V)
      GO TO 9
    6 IX1=ILX
      IY1=ILY+2
      CALL VCHARV(180,1,IX1,IY1,33,TAB15V)
      GO TO 10
```

```
    7 IX1=ILX-12
      IY1=ILY
      CALL VCHARV(180,1,IX1,IY1,34,TAB15V)
      GO TO 10
    9 CONTINUE
      RETURN
      END
```

```
$IBFTC SRF8

      SUBROUTINE REFR(X,Y,SPH,CPH,STH,CTH)
      X1=0.0
      Y1=0.0
      SLOPE=Y/X
      SLINV=X/Y
      DX=X/20.0
      DY=Y/20.0
      X=0.0
      Y=0.0
      IF(ABS(SLOPE)-1.0)13,13,14
   13 DO 15 I=1,20
      Y=SLOPE*X
      XT=X*CPH*STH+Y*SPH*STH
      YT=-X*SPH+Y*CPH
      CALL POINTV(XT,YT,0)
      X=X+DX
   15 CONTINUE
      GO TO 16
   14 DO 17 I=1,20
      X=SLINV*Y
      XT=X*CPH*STH+Y*SPH*STH
      YT=-X*SPH+Y*CPH
      CALL POINTV(XT,YT,0)
      Y=Y+DY
   17 CONTINUE
   16 CONTINUE
      RETURN
      END
```

```
$IBFTC SRF9

      SUBROUTINE GRAN(X,Y,Z,PH,TH,REFX,REFY)
      DIMENSION X(18),Y(18),Z(18)
      SPH=SIN(PH)
      CPH=COS(PH)
      STH=SIN(TH)
      CTH=COS(TH)
      CALL PROJ(X(1),Y(1),Z(1),PH,TH,XCG1,YCG1)
      DO 10 I=2,9
      CALL PROJ(X(I),Y(I),Z(I),PH,TH,X(I-1),Y(I-1))
   10 CONTINUE
```

```
      CALL QUAD(XCG1,YCG1,IQD1)
      IQD=IQD1
      CALL PROJ(X(10),Y(10),Z(10),PH,TH,XCG2,YCG2)
      KUAL=1
      CALL QUAD(XCG2,YCG2,IQD2)
   20 CALL CASE(X(1),Y(1),X(2),Y(2),X(3),Y(3),X(4),Y(4),X(5),Y(5),X(6),
     1Y(6),X(7),Y(7),X(8),Y(8),XCG1,YCG1,XCG2,YCG2,IQD,ICASE)
      CALL BOX(X(1),Y(1),ICASE,A,B,C,D,E,F,G,H,O,P,Q,R,S,T,U,V,W,A
     1B,AC)
      IF(KUAL-1)25,21,22
   21 X1=X(1)
      Y1=Y(1)
      X2=X(2)
      Y2=Y(2)
      X3=X(3)
      Y3=Y(3)
      X4=X(4)
      Y4=Y(4)
      DO 11 I=11,18
      CALL PROJ(X(I),Y(I),Z(I),PH,TH,X(I-10),Y(I-10))
   11 CONTINUE
      KUAL=2
      IQD=IQD2
      ICASE1=ICASE
      GO TO 20
   22 ICASE2=ICASE
      CALL KABEL(XCG1,YCG1,XCG2,YCG2,X1,Y1,X2,Y2,X3,Y3,X4,Y4,X(1),Y(1),
     1X(2),Y(2),X(3),Y(3),X(4),Y(4),ICASE1,ICASE2)
   25 CONTINUE
      CALL REFR(REFX,REFY,SPH,CPH,STH,CTH)
      RETURN
      END

$IBFTC SRF10

      SUBROUTINE PROJ(X,Y,Z,PHI,THETA,TX,TY)
      TX=X*COS(PHI)*SIN(THETA)+Y*SIN(PHI)*SIN(THETA)-Z*COS(THETA)
      TY=-X*SIN(PHI)+Y*COS(PHI)
      RETURN
      END

$IBFTC SRF11

      SUBROUTINE QUAD(XRST,YRST,IQD)
      IF(XRST)200,201,201
  201 IF(YRST)203,202,202
  200 IF(YRST)204,204,205
  202 IQD=1
      GO TO 206
  203 IQD=2
```

```
      GO TO 206
204   IQD=3
      GO TO 206
205   IQD=4
206   CONTINUE
      RETURN
      END


$IBFTC SRF12

      SUBROUTINE CASE(X1,Y1,X2,Y2,X3,Y3,X4,Y4,X5,Y5,X6,Y6,X7,Y7,X8,Y8,
     1XCG1,YCG1,XCG2,YCG2,IQD,ICASE)
      R1=X1**2+Y1**2
      R2=X2**2+Y2**2
      R3=X3**2+Y3**2
      R4=X4**2+Y4**2
      RM=R1
      ITH=1
      IF(R2-RM)600,603,603
600   RM=R2
      ITH=2
603   IF(R3-RM)601,604,604
601   RM=R3
      ITH=3
604   IF(R4-RM)602,605,605
602   RM=R4
      ITH=4
605   CONTINUE
      GO TO(821,822,823,824),ITH
821   CALL SIML(XCG1,YCG1,XCG2,YCG2,X1,Y1,X2,Y2,XL1,YL1)
      RL1=(X1-X2)**2+(Y1-Y2)**2
      DL1=(X1-XL1)**2+(Y1-YL1)**2
      EL1=(X2-XL1)**2+(Y2-YL1)**2
      IF((DL1.GT.RL1).OR.(EL1.GT.RL1))GO TO 702
701   LINE=1
      GO TO 621
702   LINE=2
      GO TO 622
824   CALL SIML (XCG1,YCG1,XCG2,YCG2,X1,Y1,X4,Y4,XL2,YL2)
      RL2=(X1-X4)**2+(Y1-Y4)**2
      DL2=(X1-XL2)**2+(Y1-YL2)**2
      EL2=(X4-XL2)**2+(Y4-YL2)**2
      IF((DL2.GT.RL2).OR.(EL2.GT.RL2))GO TO 704
      GO TO 702
704   LINE=4
      GO TO 624
822   CALL SIML(XCG1,YCG1,XCG2,YCG2,X2,Y2,X3,Y3,XL3,YL3)
      RL3=(X2-X3)**2+(Y2-Y3)**2
      DL3=(X2-XL3)**2+(Y2-YL3)**2
      EL3=(X3-XL3)**2+(Y3-YL3)**2
      IF((DL3.GT.RL3).OR.(EL3.GT.RL3))GO TO 701
703   LINE=3
      GO TO 623
```

```
823 CALL SIML(XCG1,YCG1,XCG2,YCG2,X3,Y3,X4,Y4,XL4,YL4)
    RL4=(X3-X4)**2+(Y3-Y4)**2
    DL4=(X3-XL4)**2+(Y3-YL4)**2
    EL4=(X4-XL4)**2+(Y4-YL4)**2
    IF((DL4.GT.RL4).OR.(EL4.GT.RL4))GO TO 703
    GO TO 704
621 GO TO(631,631,633,633),IQD
622 GO TO(641,642,642,641),IQD
623 GO TO(651,652,652,651),IQD
624 GO TO(661,661,663,663),IQD
631 S28=(Y8-Y2)/(X8-X2)
    B28=Y2-S28*X2
    B3=Y3-S28*X3
    IF(B28.LT.B3) GO TO 671
    GO TO 670
633 S15=(Y5-Y1)/(X5-X1)
    B15=Y1-S15*X1
    B6=Y6-S15*X6
    IF(B15.LT.B6) GO TO 673
    GO TO 672
641 S48=(X8-X4)/(Y8-Y4)
    A48=X4-S48*Y4
    A3=X3-S48*Y3
    IF(A48.LT.A3) GO TO 675
    GO TO 674
642 S48=(X8-X4)/(Y8-Y4)
    A48=X4-S48*Y4
    A3=X3-S48*Y3
    IF(A48.LT.A3) GO TO 677
    GO TO 676
651 S35=(X5-X3)/(Y5-Y3)
    A35=X3-S35*Y3
    A4=X4-S35*Y4
    IF(A35.LT.A4) GO TO 678
    GO TO 679
652 S26=(X6-X2)/(Y6-Y2)
    A26=X2-S26*Y2
    A1=X1-S26*Y1
    IF(A26.LT.A1) GO TO 680
    GO TO 681
663 S46=(Y6-Y4)/(X6-X4)
    B46=Y4-S46*X4
    B1=Y1-S46*X1
    IF(B46.LT.B1) GO TO 684
    GO TO 685
661 S37=(Y7-Y3)/(X7-X3)
    B37=Y3-S37*X3
    B2=Y2-S37*X2
    IF(B37.LT.B2) GO TO 682
    GO TO 683
670 ICASE=4
    GO TO 800
671 ICASE=12
```

```
      GO TO 800
  672 ICASE=16
      GO TO 800
  673 ICASE=8
      GO TO 800
  674 ICASE=10
      GO TO 800
  675 ICASE=2
      GO TO 800
  676 ICASE=6
      GO TO 800
  677 ICASE=14
      GO TO 800
  678 ICASE=1
      GO TO 800
  679 ICASE=9
      GO TO 800
  680 ICASE=13
      GO TO 800
  681 ICASE=5
      GO TO 800
  682 ICASE=3
      GO TO 800
  683 ICASE=11
      GO TO 800
  684 ICASE=15
      GO TO 800
  685 ICASE=7
  800 CONTINUE
      RETURN
      END

$IBFTC SRF13

      SUBROUTINE SIML(XCG1,YCG1,XCG2,YCG2,XP1,YP1,XP2,YP2,X,Y)
      DXP12=XP1-XP2
      DYP12=YP1-YP2
      DXCG=XCG1-XCG2
      DYCG=YCG1-YCG2
      X=(DXP12*DYCG*XCG1-DXCG*DYP12*XP1+DXCG*DXP12*YP1-DXCG*DXP12*YCG1)/
     1(DXP12*DYCG-DYP12*DXCG)
      Y=(DYCG/DXCG)*X-(DYCG/DXCG)*XCG1+YCG1
      RETURN
      END

$IBFTC SRF14

      SUBROUTINE BOX(X,Y,ICASE,A,B,C,D,E,F,G,H,O,P,Q,R,S,T,U,V,W,AB,AC)
      DIMENSION X(18),Y(18)
      GO TO(1,2,3,4,3,6,3,1,9,10,10,1,13,4,10,4),ICASE
    1 IX1=NXV(X(1))
```

```
      IY1=NYV(Y(1))
      DO 20 I=2,6
      IX2=NXV(X(I))
      IY2=NYV(Y(I))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
   20 CONTINUE
      IX1=NXV(X(1))
      IY1=NYV(Y(1))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX2=NXV(X(4))
      IY2=NYV(Y(4))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=NXV(X(3))
      IY1=NYV(Y(3))
      IX2=NXV(X(8))
      IY2=NYV(Y(8))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=NXV(X(5))
      IY1=NYV(Y(5))
      CALL LINEV(IX1,IY1,IX2,IY2)
      GO TO 30
    2 IX1=NXV(X(4))
      IY1=NYV(Y(4))
      DO 21 I=5,8
      IX2=NXV(X(I))
      IY2=NYV(Y(I))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
   21 CONTINUE
      IX2=NXV(X(5))
      IY2=NYV(Y(5))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=NXV(X(7))
      IY1=NYV(Y(7))
      IX2=NXV(X(2))
      IY2=NYV(Y(2))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
      IX2=NXV(X(1))
      IY2=NYV(Y(1))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
      IX2=NXV(X(4))
      IY2=NYV(Y(4))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX2=NXV(X(6))
      IY2=NYV(Y(6))
      CALL LINEV(IX1,IY1,IX2,IY2)
      GO TO 30
    3 IX1=NXV(X(2))
```

```
      IY1=NYV(Y(2))
      DO 22 I=3,8
      IX2=NXV(X(I))
      IY2=NYV(Y(I))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
   22 CONTINUE
      IX2=NXV(X(5))
      IY2=NYV(Y(5))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX2=NXV(X(3))
      IY2=NYV(Y(3))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=NXV(X(7))
      IY1=NXV(Y(7))
      IX2=NXV(X(2))
      IY2=NYV(Y(2))
      CALL LINEV(IX1,IY1,IX2,IY2)
      GO TO 30
    4 IX1=NXV(X(1))
      IY1=NYV(Y(1))
      DO 23 I=2,5
      IX2=NXV(X(I))
      IY2=NYV(Y(I))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
   23 CONTINUE
      IX2=NXV(X(8))
      IY2=NYV(Y(8))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
      IX2=NXV(X(7))
      IY2=NYV(Y(7))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX2=NXV(X(3))
      IY2=NYV(Y(3))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=NXV(X(7))
      IY1=NYV(Y(7))
      IX2=NXV(X(2))
      IY2=NYV(Y(2))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=NXV(X(1))
      IY1=NXV(Y(1))
      IX2=NXV(X(4))
      IY2=NYV(Y(4))
      CALL LINEV(IX1,IY1,IX2,IY2)
      GO TO 30
    6 IX1=NXV(X(1))
      IY1=NYV(Y(1))
      DO 24 I=2,4
      IX2=NXV(X(I))
```

```
      IY2=NYV(Y(1))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
   24 CONTINUE
      IX2=NXV(X(1))
      IY2=NYV(Y(1))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
      DO 25 I=6,8
      IX2=NXV(X(I))
      IY2=NYV(Y(I))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
   25 CONTINUE
      IX2=NXV(X(3))
      IY2=NYV(Y(3))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=NXV(X(2))
      IY1=NYV(Y(2))
      IX2=NXV(X(7))
      IY2=NYV(Y(7))
      CALL LINEV(IX1,IY1,IX2,IY2)
      GO TO 30
    9 IX1=NXV(X(1))
      IY1=NYV(Y(1))
      DO 26 I=2,7
      IX2=NXV(X(I))
      IY2=NYV(Y(I))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
   26 CONTINUE
      IX2=NXV(X(2))
      IY2=NXV(Y(2))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=NXV(X(6))
      IY1=NYV(Y(6))
      IX2=NXV(X(1))
      IY2=NYV(Y(1))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=NXV(X(4))
      IY1=NYV(Y(4))
      CALL LINEV(IX1,IY1,IX2,IY2)
      GO TO 30
   10 IX1=NXV(X(3))
      IY1=NYV(Y(3))
      DO 27 I=4,8
      IX2=NXV(X(I))
      IY2=NYV(Y(I))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
```

```
      IY1=IY2
   27 CONTINUE
      IX2=NXV(X(3))
      IY2=NYV(Y(3))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX2=NXV(X(5))
      IY2=NYV(Y(5))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=NXV(X(1))
      IY1=NYV(Y(1))
      IX2=NXV(X(4))
      IY2=NYV(Y(4))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX2=NXV(X(6))
      IY2=NYV(Y(6))
      CALL LINEV(IX1,IY1,IX2,IY2)
      GO TO 30
   15 IX1=NXV(X(1))
      IY1=NYV(Y(1))
      DO 28 I=2,3
      IX2=NXV(X(I))
      IY2=NYV(Y(I))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
   28 CONTINUE
      IX2=NXV(X(8))
      IY2=NYV(Y(8))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=NXV(X(5))
      IY1=NYV(Y(5))
      CALL LINEV(IX1,IY1,IX2,IY2)
      DO 29 I=6,8
      IX2=NXV(X(I))
      IY2=NYV(Y(I))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=IX2
      IY1=IY2
   29 CONTINUE
      IX1=NXV(X(1))
      IY1=NYV(Y(1))
      IX2=NXV(X(6))
      IY2=NYV(Y(6))
      CALL LINEV(IX1,IY1,IX2,IY2)
      IX1=NXV(X(2))
      IY1=NYV(Y(2))
      IX2=NXV(X(7))
      IY2=NYV(Y(7))
   30 CONTINUE
      RETURN
      END

$IBFTC SRF15
```

```
      SUBROUTINE KABEL(XCG1,YCG1,XCG2,YCG2,X1,Y1,X2,Y2,X3,Y3,X4,Y4,X5,Y5
     1,X6,Y6,X7,Y7,X8,Y8,ICASE1,ICASE2)
      ICASE=ICASE1
      KUAL=1
      XCG=XCG1
      YCG=YCG1
   50 GO TO(1,2,3,1,5,1,3,1,1,2,3,1,5,1,3,1),ICASE
    1 IXC1=NXV(XCG)
      IYC1=NYV(YCG)
      GO TO 20
    2 CALL SIML(XCG1,YCG1,XCG2,YCG2,X1,Y1,X4,Y4,X,Y)
   30 IXC1=NXV(X)
      IYC1=NYV(Y)
      GO TO 20
    3 CALL SIML(XCG1,YCG1,XCG2,YCG2,X3,Y3,X4,Y4,X,Y)
      GO TO 30
    5 CALL SIML(XCG1,YCG1,XCG2,YCG2,X2,Y2,X3,Y3,X,Y)
      GO TO 30
   20 CONTINUE
      IF(KUAL-1)42,41,42
   41 IXC2=IXC1
      IYC2=IYC1
      XCG=XCG2
      YCG=YCG2
      KUAL=2
      ICASE=ICASE2
      X1=X5
      X2=X6
      X3=X7
      X4=X8
      Y1=Y5
      Y2=Y6
      Y3=Y7
      Y4=Y8
      GO TO 50
   42 CALL LINEV(IXC1,IYC1,IXC2,IYC2)
      RETURN
      END


$IBFTC SRF16

      SUBROUTINE UNDWRT(KWHICH)
      DIMENSION VAR(6800),P(6800)
      COMMON VAR
      EQUIVALENCE(VAR(601),P(1))
      EXTERNAL  TAB15V
      EXTERNAL  TABL1V
      V1=P(5958)/12.0
      V2=P(5957)/12.0
      V3=P(5956)/12.0
      CALL CHSIZV(3,3)
      CALL RITSTV(18,26,TABL1V)
```

```
      CALL RITE2V(823,97,1023,180,1,45,-1,45HTORQUE ABOUT     =          SI
     1N(      T)   FT.-LB.,NLAST)
      CALL RITE2V(873,97,1023,180,1,45,-1,45HTORQUE ABOUT     =          SI
     1N(      T)   FT.-LB.,NLAST)
      CALL RITE2V(923,97,1023,180,1,45,-1,45HTORQUE ABOUT     =          SI
     1N(      T)   FT.-LB.,NLAST)
      CALL VCHARV(180,1,832,325,25,TAB15V)
      CALL VCHARV(180,1,882,325,33,TAB15V)
      CALL VCHARV(180,1,932,325,34,TAB15V)
      CALL CHSIZV(2,2)
      CALL VCHARV(180,1,838,338,1,TABL1V)
      CALL VCHARV(180,1,888,338,1,TABL1V)
      CALL VCHARV(180,1,938,338,1,TABL1V)
      CALL HEAD(3,3,18,26,823,421,1023,180,1,LX,LY,0,0,2,V1)
      CALL HEAD(3,3,18,26,873,421,1023,180,1,LX,LY,0,0,2,V2)
      CALL HEAD(3,3,18,26,923,421,1023,180,1,LX,LY,0,0,2,V3)
      CALL HEAD(3,3,18,26,823,619,1023,180,1,LX,LY,2,0,2,P(5999))
      CALL HEAD(3,3,18,26,873,619,1023,180,1,LX,LY,2,0,2,P(5999))
      CALL HEAD(3,3,18,26,923,619,1023,180,1,LX,LY,2,0,2,P(5999))
      RETURN
      END

$IBFTC SRF17

      SUBROUTINE RCLOK(IX,IY,IR,K,FACTOR,T)
      EXTERNAL TABL1V
      R=IR
      PI=3.1415927
      C=2.0*PI*R
      LX=IX
      LY=IY
      IF(IR.LT.150) GO TO 13
      CALL CHSIZV(4,3)
      R1=IR-22
      GO TO 14
   13 CALL CHSIZV(2,2)
      R1=IR-16
   14 CALL RITSTV(23,26,TABL1V)
      R2=0.9*R1
      DTH=2.0*PI/10.0
      TH=0.0
      CX=IX
      CY=IY
      DO 11 I=1,10
      TH=TH+DTH
      LX=CX-R*COS(TH)
      LY=CY+R*SIN(TH)
      GO TO(1,2,3,4,5,6,7,8,9,10),I
    1 CALL RITE2V(LX,LY,1023,K   ,1,1,-1,1H1,NLAST)
      GO TO 11
    2 CALL RITE2V(LX,LY,1023,K   ,1,1,-1,1H2,NLAST)
      GO TO 11
```

```
 3 CALL RITE2V(LX,LY,1023,K   ,1,1,-1,1H3,NLAST)
   GO TO 11
 4 CALL RITE2V(LX,LY,1023,K   ,1,1,-1,1H4,NLAST)
   GO TO 11
 5 CALL RITE2V(LX,LY,1023,K   ,1,1,-1,1H5,NLAST)
   GO TO 11
 6 CALL RITE2V(LX,LY,1023,K   ,1,1,-1,1H6,NLAST)
   GO TO 11
 7 CALL RITE2V(LX,LY,1023,K   ,1,1,-1,1H7,NLAST)
   GO TO 11
 8 CALL RITE2V(LX,LY,1023,K   ,1,1,-1,1H8,NLAST)
   GO TO 11
 9 CALL RITE2V(LX,LY,1023,K   ,1,1,-1,1H9,NLAST)
   GO TO 11
10 CALL RITE2V(LX,LY,1023,K   ,1,1,-1,1H0,NLAST)
11 CONTINUE
   DTH=2.0*PI/100.0
   TH=0.0
   CALL SETMIV(0,0,0,0)
   CALL GRID1V(2,0.0,1023.0,0.0,1023.0,0.0,0.0,0,0,0,0,0,0)
   DO 12 I=1,100
   X1=CX-R1*COS(TH)
   Y1=CY+R1*SIN(TH)
   CALL POINTV(X1,Y1,0)
   TH=TH+DTH
12 CONTINUE
   DTH=2.0*PI/10.0
   TH=0.0
   DO 15 I=1,10
   X1=CX-R1*COS(TH)
   Y1=CY+R1*SIN(TH)
   CALL POINTV(X1,Y1,6)
   TH=TH+DTH
15 CONTINUE
   ANG=2.0*PI*T
   IF(K.NE.180)ANG=ANG+1.570795
   LX=CX-R1*COS(ANG)
   LY=CY+R1*SIN(ANG)
   CALL LINEV(IX,IY,LX,LY)
   CALL LINEV(IX,IY,LX,LY)
   ARG=ANG/FACTOR
   LX=CX-R2*COS(ARG)
   LY=CY+R2*SIN(ARG)
   CALL LINEV(IX,IY,LX,LY)
   CALL LINEV(IX,IY,LX,LY)
   ARG=ANG/100.0
   LX=CX-.8*R2*COS(ARG)
   LY=CY+.8*R2*SIN(ARG)
   CALL LINEV(IX,IY,LX,LY)
   CALL LINEV(IX,IY,LX,LY)
   RETURN
   END
```

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# APPENDIX B

## COMPUTER PROGRAM DATA

This appendix presents a description of program input, program output, and a sample problem.

### General Input

This section presents a description of program input, including correct format and proper ordering. Format statements are given at the beginning of the particular group of data to which the statements apply.

The following fixed-point data should be punched on a single data card in the order given. This card should be the first card in the data deck.

FORMAT (8 I 5)

A code number indicating the desired forcing function option (The integer 1 is used to force body 1, the integer 2 is used to force body 2, and the integer 3 is used to indicate no forcing function.)

Number of floating-point values to be input

6 (The number of auxiliary differential equations, such as control equations, to be integrated in the Runge-Kutta (R-K) subroutine is given in this datum location. This number is presently 6.)

N (This number must be less than or equal to 19.)

Number of differential equations to be integrated in the R-K subroutine (This number is equal to 3N + 25 + the number of auxiliary differential equations to be integrated in the R-K subroutine. This number is presently equal to 3N + 31.)

Number of integration steps desired between output printout intervals

An S-C 4020 output option code number (The integer 1 calls for nine graphs to be output. The integer 0 omits the graphs.)

An S-C 4020 output option code number (The integer 1 calls for output in the form of motion pictures. The integer 0 omits this output.)

Each line of the following data should be punched on a single data card. Data having a value of zero may be ignored. The order of these cards in the data deck is unimportant.

FORMAT (I5, E15.7)

| | | |
|---|---|---|
| 1 | Integration step size, sec | |
| 2 | Program termination time, sec | |
| 3 | $I_{i',1}$ | |
| 4 | $I_{j',1}$ | |
| 5 | $I_{k',1}$ | |
| 6 | $M_1$ | |
| 10 | $\bar{i}_1 \cdot \bar{i}'_1$ | |
| 11 | $\bar{i}_1 \cdot \bar{j}'_1$ | |
| 12 | $\bar{i}_1 \cdot \bar{k}'_1$ | |
| 13 | $\bar{j}_1 \cdot \bar{i}'_1$ | |
| 14 | $\bar{j}_1 \cdot \bar{j}'_1$ | Direction cosines for body 1 |
| 15 | $\bar{j}_1 \cdot \bar{k}'_1$ | |
| 16 | $\bar{k}_1 \cdot \bar{i}'_1$ | |
| 17 | $\bar{k}_1 \cdot \bar{j}'_1$ | |
| 18 | $\bar{k}_1 \cdot \bar{k}'_1$ | |
| 19 | $I_{i',2}$ | |
| 20 | $I_{j',2}$ | |
| 21 | $I_{k',2}$ | |
| 22 | $M_2$ | |

| | | |
|---|---|---|
| 26 | $\bar{i}_2 \cdot \bar{i}'_2$ | Direction cosines for body 2 |
| 27 | $\bar{i}_2 \cdot \bar{j}'_2$ | |
| 28 | $\bar{i}_2 \cdot \bar{k}'_2$ | |
| 29 | $\bar{j}_2 \cdot \bar{i}'_2$ | |
| 30 | $\bar{j}_2 \cdot \bar{j}'_2$ | |
| 31 | $\bar{j}_2 \cdot \bar{k}'_2$ | |
| 32 | $\bar{k}_2 \cdot \bar{i}'_2$ | |
| 33 | $\bar{k}_2 \cdot \bar{j}'_2$ | |
| 34 | $\bar{k}_2 \cdot \bar{k}'_2$ | |
| 110 | $u''_1$ | |
| 111 | $v''_1$ | |
| 112 | $w''_1$ | |
| 113 | $\theta_1$ | |
| 114 | $\phi_1$ | |
| 115 | $\psi_1$ | |
| 119 | $u''_2$ | |
| 120 | $v''_2$ | |
| 121 | $w''_2$ | |
| 122 | $\theta_2$ | |
| 123 | $\phi_2$ | |

| | |
|---|---|
| 124 | $\psi_2$ |
| 970 | $\Omega_{x,1}$ |
| 971 | $\Omega_{y,1}$ |
| 972 | $\Omega_{z,1}$ |
| 980 | $\Omega_{x,2}$ |
| 981 | $\Omega_{y,2}$ |
| 982 | $\Omega_{z,2}$ |
| 140 | $\overline{X}_1$ |
| 141 | $\overline{Y}_1$ |
| 142 | $\overline{Z}_1$ |
| 143 | $\overline{X}_2$ |
| 144 | $\overline{Y}_2$ |
| 145 | $\overline{Z}_2$ |
| ⋮ | ⋮ |
| 140 + 3N | $\overline{X}_{N+1}$ |
| 141 + 3N | $\overline{Y}_{N+1}$ |
| 142 + 3N | $\overline{Z}_{N+1}$ |
| 222 | $\overline{X}_{P,1,2}$ |
| ⋮ | ⋮ |
| 222 + N | $\overline{X}_{P,1,N+1}$ |
| 242 | $\overline{Y}_{P,1,2}$ |
| ⋮ | ⋮ |
| 241 + N | $\overline{Y}_{P,1,N+1}$ |

| | |
|---|---|
| 262 | $\bar{Z}_{P, 1, 2}$ |
| 261 + N | $\bar{Z}_{P, 1, N+1}$ |
| 282 | $\bar{X}_{P, 2, 2}$ |
| 281 + N | $\bar{X}_{P, 2, N+1}$ |
| 302 | $\bar{Y}_{P, 2, 2}$ |
| 301 + N | $\bar{Y}_{P, 2, N+1}$ |
| 322 | $\bar{Z}_{P, 2, 2}$ |
| 321 + N | $\bar{Z}_{P, 2, N+1}$ |
| 1202 | $CL_2$ |
| 1201 + N | $CL_{N+1}$ |
| 1222 | $CK_2$ |
| 1221 + N | $CK_{N+1}$ |
| 1242 | $CD_2$ |
| 1241 + N | $CD_{N+1}$ |
| 5945 | $\omega_{F, n}$ |
| 5946 | $AF_{z, n}$ |
| 5947 | $AF_{y, n}$ |
| 5948 | $AF_{x, n}$ |

| | |
|---|---|
| 5952 | Initial distance between $c.g._1$ and $c.g._2$, ft* |
| 5953 | Total cable area, sq in. * |
| 5954 | Cable elasticity, $lb/in^2$* |
| 5955 | Initial spin speed, deg/sec* |
| 5956 | $AG_{z,n}$ |
| 5957 | $AG_{y,n}$ |
| 5958 | $AG_{x,n}$ |
| 5966 | One-half of length of box representing body 2 in motion picture output, in. * |
| 5967 | Length of arbitrary body-fixed axes $i_n$, $j_n$, and $k_n$, and one-half of length of box representing body 1 in motion picture output, in. * |
| 5971 | Angle of rotation of $\bar{\bar{Z}}'$ axis out of projected plane of motion picture, rad† |
| 5972 | Angle of rotation of $\bar{\bar{X}}'$ and $\bar{\bar{Y}}'$ axes about the $\bar{\bar{Z}}'$ axis, rad† |
| 5992 | $\bar{\bar{X}}_1$ |
| 5993 | $\bar{\bar{Y}}_1$ |
| 5994 | $\bar{\bar{Z}}_1$ |
| 5995 | $\bar{\bar{X}}_2$ |
| 5996 | $\bar{\bar{Y}}_2$ |

*This input is required for motion picture output only.

†If these angles are both equal to zero, the $\bar{\bar{Y}}'\bar{\bar{Z}}'$ plane will be parallel to each frame of the motion picture.

| | |
|---|---|
| 5997 | $\bar{\bar{Z}}_2$ |
| 5999 | $\omega_{T,n}$ |

Data for the first of a series of runs to be made must include a card for all nonzero floating-point parameters as well as the card of fixed-point data. Data for succeeding runs may omit any nonzero floating-point parameters which remain unchanged from the respective preceding run but must include the card of fixed-point data.

## General Output

Table B-I relates the program output symbology to the symbols section of the paper. Time histories of the first 36 dependent variables (THETA1 to CABLE) (table B-I) will be output by the system printer for every run made. In addition to this fixed output format, two optional forms of output are available through the use of the S-C 4020 high-speed microfilm recorder. This option is controlled by two fixed-point numbers. The first of these options consists of nine graphs representing the time histories of the structural Euler angles, the pseudorigid body Euler angles, and the pseudorigid body length. The pseudorigid body Euler angles are subject to the following restrictions.

$$-\frac{\pi}{2} < \theta_{RB} < \frac{\pi}{2}$$

$$0 \leq \psi_{RB} < 2\pi$$

The restriction on $\psi_{RB}$ concerns only the output values, that is, when the value of $\psi_{RB}$ reaches $2\pi$, a value of zero will be plotted, causing a discontinuity in the graph. If the S-C 4020 output section of the program is removed, as described previously, there will be no output record of either the structural Euler angles or the pseudorigid body Euler angles. This output may be retained by modifying the SUBROUTINE OUTAID, as indicated by the applicable comment cards, and by making the following changes in the headings printed by the system printer.

| Original headings | Modified headings |
|---|---|
| THETA1 | THETAST1 |
| PHI1 | PHIST1 |
| THETA2 | THETAST2 |
| PHI2 | PHIST2 |
| XBR(1) | PSIST1 |
| YBR(1) | PSIST2 |
| ZBR(1) | THETRB |
| RP1P2(2) | PSIRB |

A second output option consists of an 8-millimeter motion picture of vehicle motion during the run. The motion picture consists of two distinct parts. The first part shows pseudorigid body and arbitrary body axes motion during the run. The second part represents complete vehicle motion. The vehicle is simulated by two rectangular parallelepipeds connected by a single cable tied to the geometrical center of the two opposing faces. The length of each body is controlled by data input. Body width and height are set by the program to 0.6 of the body length. Both parts of the movie show a dotted reference line in the $\bar{\bar{X}}'\bar{\bar{Y}}'$ plane. This line is the projection of that part of the pseudorigid body between $c.g._{comp}$ and $c.g._2$ and serves to give the viewer a qualitative idea of the magnitudes of $\psi_{RB}$ and $\theta_{RB}$. Both parts of the movie also show a three-handed clock in the upper right-hand corner. One revolution of the largest hand represents 1.0 second of vehicle motion. A revolution of the middle hand represents 10.0 seconds, and a revolution of the smallest hand represents 100.0 seconds. The S-C 4020 generates one frame for every integration step; therefore, an integration step size of 0.04167 second will result in a real-time movie. Motion picture output should be used with discretion since it greatly increases computer run time.

## Sample Problem

The vehicle configuration used for the sample problem was taken from reference 1 and is shown in figure B-1. Body 1 is manned, and body 2 is an empty booster casing. The launch weight of body 1 was approximately 19 000 pounds, which is within the Saturn C-1 payload capability. The spinning configuration of body 1 includes a small unmanned resupply vehicle and two Gemini capsules for emergency escape.

Four sample runs were made. A copy of the input data cards for the runs is given in figure B-2. The data for each run are headed by the card containing eight fixed-point values for that run. The first three runs demonstrate how the program can be used to obtain the dominant response characteristics of the vehicle for the arbitrary axes of body 1. The forcing function used for run one was

$$G_{y,1} = 1400 \sin (1.5t) \qquad \text{(B1)}$$

The pertinent output from this run is shown in figure B-3. This curve was output by the S-C 4020 and was used to obtain the point indicated on figure B-4. The forcing function used for run two was

$$G_{z,1} = 1400 \sin (0.1t) \tag{B2}$$

The pertinent output from this run is shown in figure B-5. This curve was used to obtain the indicated point on figure B-6. The forcing function used for run three was

$$G_{x,1} = 30 \sin (0.15t) \tag{B3}$$

The pertinent output from this run is shown in figure B-7. This curve was used to obtain the indicated point on figure B-8. A complete linear analysis of the uncontrolled dynamic response of the vehicle is presented in reference 1. The additional response characteristics given in reference 1 can also be determined by the program presented here. The final sample run was made to demonstrate all available output formats. The forcing functions used for this run were

$$G_{x,1} = 4000 \sin (0.25t) \tag{B4}$$

$$G_{y,1} = 1\,500\,000 \sin (0.25t) \tag{B5}$$

and

$$G_{z,1} = 1\,500\,000 \sin (0.25t) \tag{B6}$$

The first three sheets of printed output are shown in figure B-9. The nine graphs output by the S-C 4020 are shown in figure B-10. Typical S-C 4020 motion picture output is given in figure B-11. The first two frames shown in figure B-11 appear prior to the motion pictures of the actual run and provide run identification information. The last two frames in figure B-11 were taken from the two types of movies produced during the run.

The sample runs presented illustrate only one of many possible applications of the program. The nonlinear approach and the generality of the subroutine structure make the program highly adaptable to any type of motion study desired.

TABLE B-I. - OUTPUT SYMBOLS

| Program output symbols | Variables represented | Program output symbols | Variables represented |
|---|---|---|---|
| TIME | $t$ | YCG | $\bar{\bar{\bar{Y}}}'_{c.g.}$ |
| THETA1 | $\theta_1$ | ZCG | $\bar{\bar{\bar{Z}}}'_{c.g.}$ |
| PSIRBD | $\dot{\psi}_{RB}$ | XBR2CG | $\bar{\bar{X}}_{c.g.}$ |
| PHI1 | $\phi_1$ | YBR2CG | $\bar{\bar{\bar{Y}}}_{c.g.}$ |
| THETA2 | $\theta_2$ | ZBR2CG | $\bar{\bar{\bar{Z}}}_{c.g.}$ |
| THETRBD | $\dot{\theta}_{RB}$ | OMEGAX1 | $\Omega_{x,1}$ |
| PHI2 | $\phi_2$ | OMEGAY1 | $\Omega_{y,1}$ |
| THETAB | $\bar{\theta}$ | OMEGAZ1 | $\Omega_{z,1}$ |
| PSIB | $\bar{\psi}$ | OMEGAX2 | $\Omega_{x,2}$ |
| PHIB | $\bar{\phi}$ | OMEGAY2 | $\Omega_{y,2}$ |
| XBR(1) | $\bar{X}_1$ | OMEGAZ2 | $\Omega_{z,2}$ |
| YBR(1) | $\bar{Y}_1$ | RP1P2(2) | $\overline{P_{1,2}P_{2,2}}$ |
| ZBR(1) | $\bar{Z}_1$ | RP1P2(3) | $\overline{P_{1,3}P_{2,3}}$ |
| GAMMA | $\gamma$ | RP1P2(1) | $\overline{P_{1,1}P_{2,1}}$ |
| ALPHA | $\alpha$ | RP1P2(4) | $\overline{P_{1,4}P_{2,4}}$ |
| IAVB2 | $A_2$ | FCABLEMAX | $F_{c,max}$ |
| THETABD | $\dot{\bar{\theta}}$ | CABLE | $C_{f,max}$ |
| PSIBD | $\dot{\bar{\psi}}$ | THETAST1 | $\theta_{s,1}$ |
| PHIBD | $\dot{\bar{\phi}}$ | | |
| XCG | $\bar{\bar{\bar{X}}}'_{c.g.}$ | | |

TABLE B-I. - OUTPUT SYMBOLS - Concluded

| Program output symbols | Variables represented | Program output symbols | Variables represented |
|---|---|---|---|
| PHIST1 | $\phi_{s,1}$ | THETRB | $\theta_{RB}$ |
| PSIST1 | $\psi_{s,1}$ | PSIRB | $\psi_{RB}$ |
| THETAST2 | $\theta_{s,2}$ | T | t |
| PHIST2 | $\phi_{s,2}$ | X | $\overline{\overline{X}}'$ |
| PSIST2 | $\psi_{s,2}$ | Y | $\overline{\overline{Y}}'$ |
| | | Z | $\overline{\overline{Z}}'$ |

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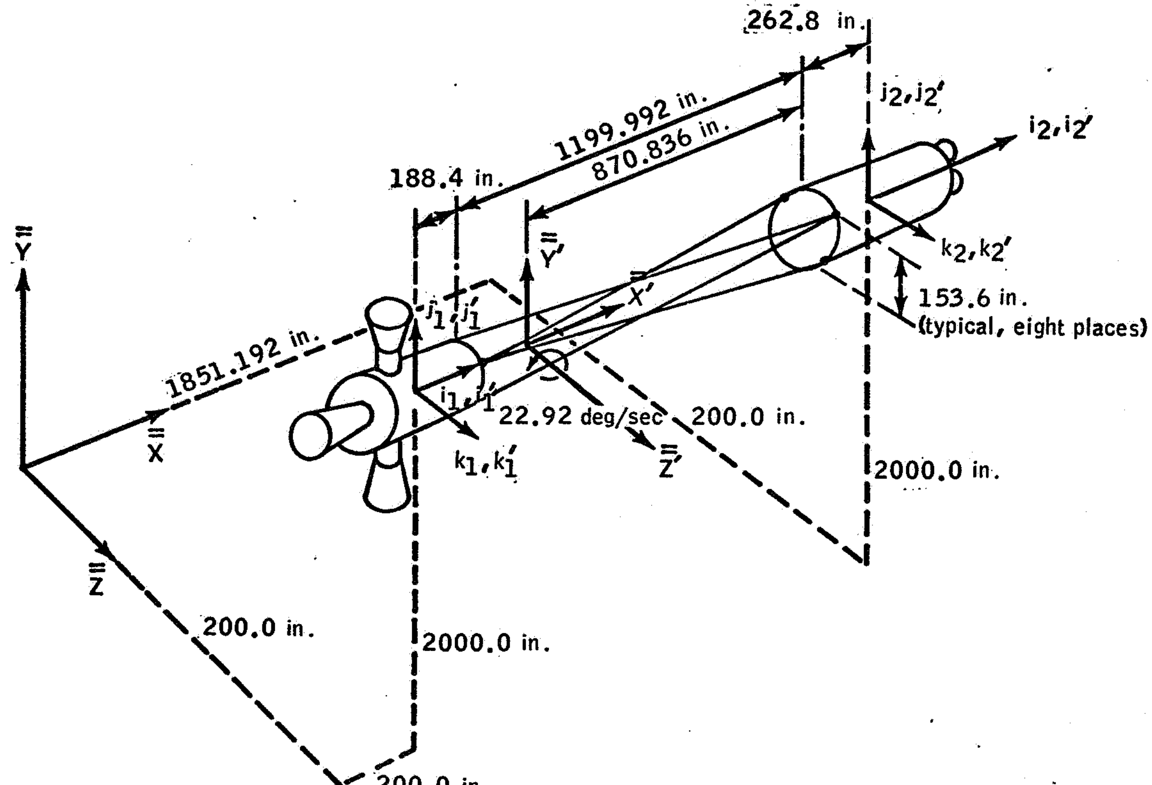



| Body parameters | | | |
|---|---|---|---|
| $M_1$ | = 101.670 lb-sec$^2$/in. | $M_2$ | = 46.417 lb-sec$^2$/in. |
| $I_{i',1}$ | = 1 236 000 lb-sec$^2$-in. | $I_{i',2}$ | = 360 000 lb-sec$^2$-in. |
| $I_{j',1}$ | = 1 086 000 lb-sec$^2$-in. | $I_{j',2}$ | = 876 000 lb-sec$^2$-in. |
| $I_{k',1}$ | = 2 076 000 lb-sec$^2$-in. | $I_{k',2}$ | = 876 000 lb-sec$^2$-in. |

Cable parameters

N = 8 (The cables are formed into four groups of two crossed cables each. Only the two foremost sets of crossed cables are shown in the figure.)

Elasticity = 14 583 333 lb/in$^2$

Area of one cable = .0189 in$^2$

Figure B-1. - Vehicle configuration for sample problem.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 109 | 6 | 8 | 55 | 1 | 1 | 0 |
| 1 | | | 5-2 | | | | |
| 2 | | | 24+0 | | | | |
| 3 | | | 1236+3 | | | | |
| 4 | | | 1086+3 | | | | |
| 5 | | | 2076+3 | | | | |
| 6 | | | 10167-2 | | | | |
| 10 | | | 1+0 | | | | |
| 14 | | | 1+0 | | | | |
| 18 | | | 1+0 | | | | |
| 19 | | | 36+4 | | | | |
| 20 | | | 876+3 | | | | |
| 21 | | | 876+3 | | | | |
| 22 | | | 46417-3 | | | | |
| 26 | | | 1+0 | | | | |
| 30 | | | 1+0 | | | | |
| 34 | | | 1+0 | | | | |
| 111 | | | -207022-3 | | | | |
| 120 | | | 453454-3 | | | | |
| 972 | | | 2292-2 | | | | |
| 982 | | | 2292-2 | | | | |
| 140 | | | 1651192-3 | | | | |
| 143 | | | 1199992-3 | | | | |
| 144 | | | 1536-1 | | | | |
| 146 | | | 1199992-3 | | | | |
| 147 | | | -1536-1 | | | | |
| 149 | | | 1199992-3 | | | | |
| 150 | | | -1536-1 | | | | |
| 152 | | | 1199992-3 | | | | |
| 153 | | | 1536-1 | | | | |
| 155 | | | 1199992-3 | | | | |
| 157 | | | -1536-1 | | | | |
| 158 | | | 1199992-3 | | | | |
| 160 | | | 1536-1 | | | | |
| 161 | | | 1199992-3 | | | | |
| 163 | | | 1536-1 | | | | |
| 164 | | | 1199992-3 | | | | |
| 166 | | | -1536-1 | | | | |
| 222 | | | 1884-1 | | | | |
| 223 | | | 1884-1 | | | | |
| 224 | | | 1884-1 | | | | |
| 225 | | | 1884-1 | | | | |
| 226 | | | 1884-1 | | | | |
| 227 | | | 1884-1 | | | | |
| 228 | | | 1884-1 | | | | |
| 229 | | | 1884-1 | | | | |
| 242 | | | -768-1 | | | | |
| 243 | | | 768-1 | | | | |
| 244 | | | 768-1 | | | | |
| 245 | | | -768-1 | | | | |
| 246 | | | -768-1 | | | | |
| 247 | | | -768-1 | | | | |
| 248 | | | 768-1 | | | | |

Figure B-2. - Input data for sample runs.

| | |
|---|---|
| 249 | 768-1 |
| 262 | 768-1 |
| 263 | 768-1 |
| 264 | -768-1 |
| 265 | -768-1 |
| 266 | 768-1 |
| 267 | -768-1 |
| 268 | -768-1 |
| 269 | 768-1 |
| 282 | -2628-1 |
| 283 | -2628-1 |
| 284 | -2628-1 |
| 285 | -2628-1 |
| 286 | -2628-1 |
| 287 | -2628-1 |
| 288 | -2628-1 |
| 289 | -2628-1 |
| 302 | 768-1 |
| 303 | -768-1 |
| 304 | -768-1 |
| 305 | 768-1 |
| 306 | -768-1 |
| 307 | -768-1 |
| 308 | 768-1 |
| 309 | 768-1 |
| 322 | 768-1 |
| 323 | 768-1 |
| 324 | -768-1 |
| 325 | -768-1 |
| 326 | -768-1 |
| 327 | 768-1 |
| 328 | 768-1 |
| 329 | -768-1 |
| 1202 | 120515-2 |
| 1203 | 120515-2 |
| 1204 | 120515-2 |
| 1205 | 120515-2 |
| 1206 | 120515-2 |
| 1207 | 120515-2 |
| 1208 | 120515-2 |
| 1209 | 120515-2 |
| 1222 | 228706-3 |
| 1223 | 228706-3 |
| 1224 | 228706-3 |
| 1225 | 228706-3 |
| 1226 | 228706-3 |
| 1227 | 228706-3 |
| 1228 | 228706-3 |
| 1229 | 228706-3 |
| 5957 | 14+2 |
| 5992 | 2+2 |
| 5993 | 2+3 |
| 5994 | 2+2 |

Figure B-2. - Continued.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5995 | | | 1851192-3 | | | | |
| 5996 | | | 2+3 | | | | |
| 5997 | | | 2+2 | | | | |
| 5999 | | | 15-1 | | | | |
| 1 | 4 | 6 | 8 | 55 | 1 | 1 | 0 |
| 2 | | | 7+1 | | | | |
| 5956 | | | 14+2 | | | | |
| 5957 | | | 0+0 | | | | |
| 5999 | | | 1-1 | | | | |
| 1 | 4 | 6 | 8 | 55 | 1 | 1 | 0 |
| 2 | | | 1+2 | | | | |
| 5956 | | | 0+0 | | | | |
| 5958 | | | 3+1 | | | | |
| 5999 | | | 15-2 | | | | |
| 1 | 13 | 6 | 8 | 55 | 1 | 1 | 1 |
| 2 | | | 25+0 | | | | |
| 5952 | | | 1376-1 | | | | |
| 5953 | | | 1512-4 | | | | |
| 5954 | | | 14583333+0 | | | | |
| 5955 | | | 2292-2 | | | | |
| 5956 | | | 15+5 | | | | |
| 5957 | | | 15+5 | | | | |
| 5958 | | | 4+3 | | | | |
| 5966 | | | 2628-1 | | | | |
| 5967 | | | 1884-1 | | | | |
| 5971 | | | 5235-4 | | | | |
| 5972 | | | 5235-4 | | | | |
| 5999 | | | 25-2 | | | | |

Figure B-2. - Concluded.

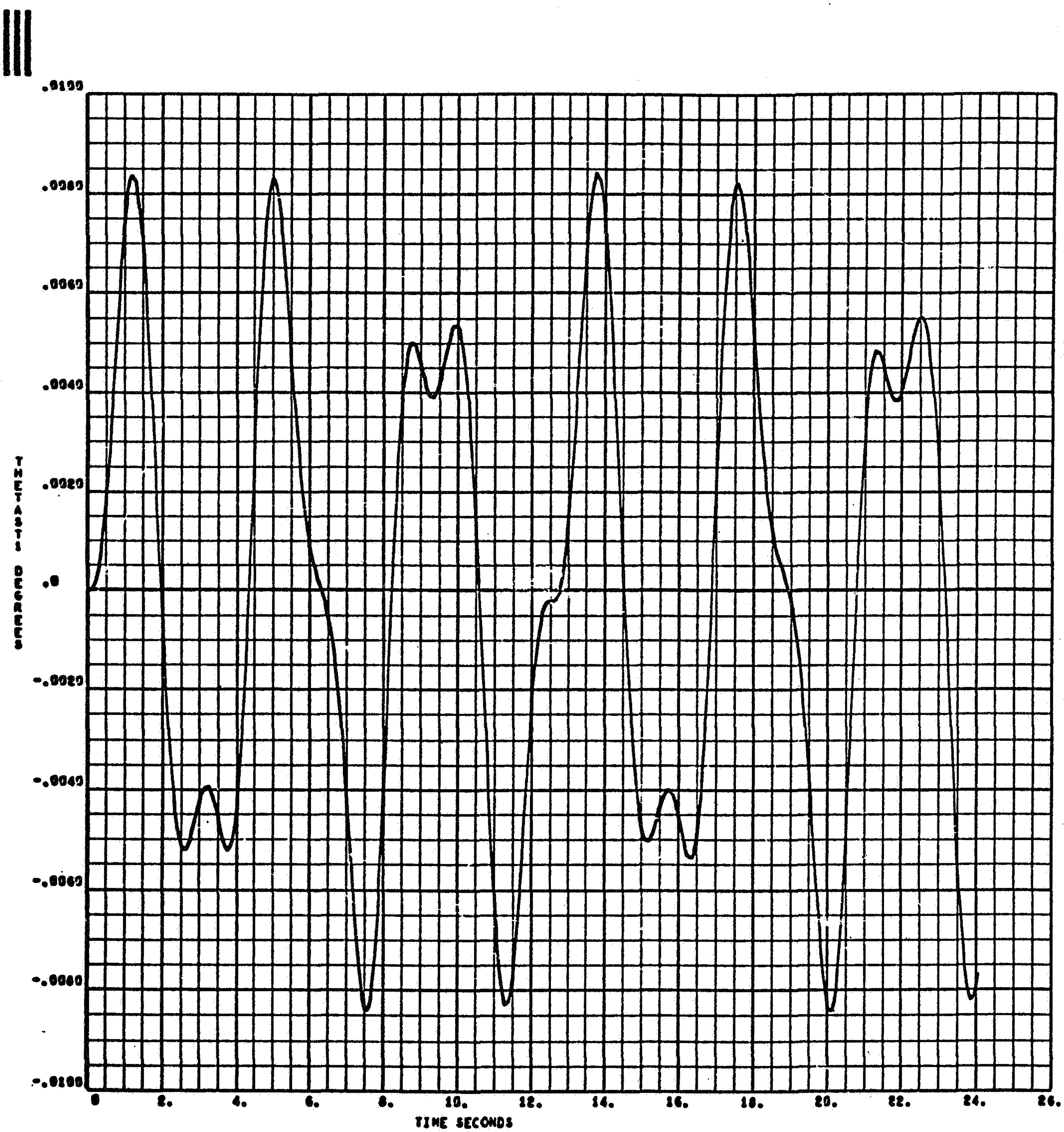



Figure B-3. - Pertinent S-C 4020 output for sample run one.

NASA-S-68-3080

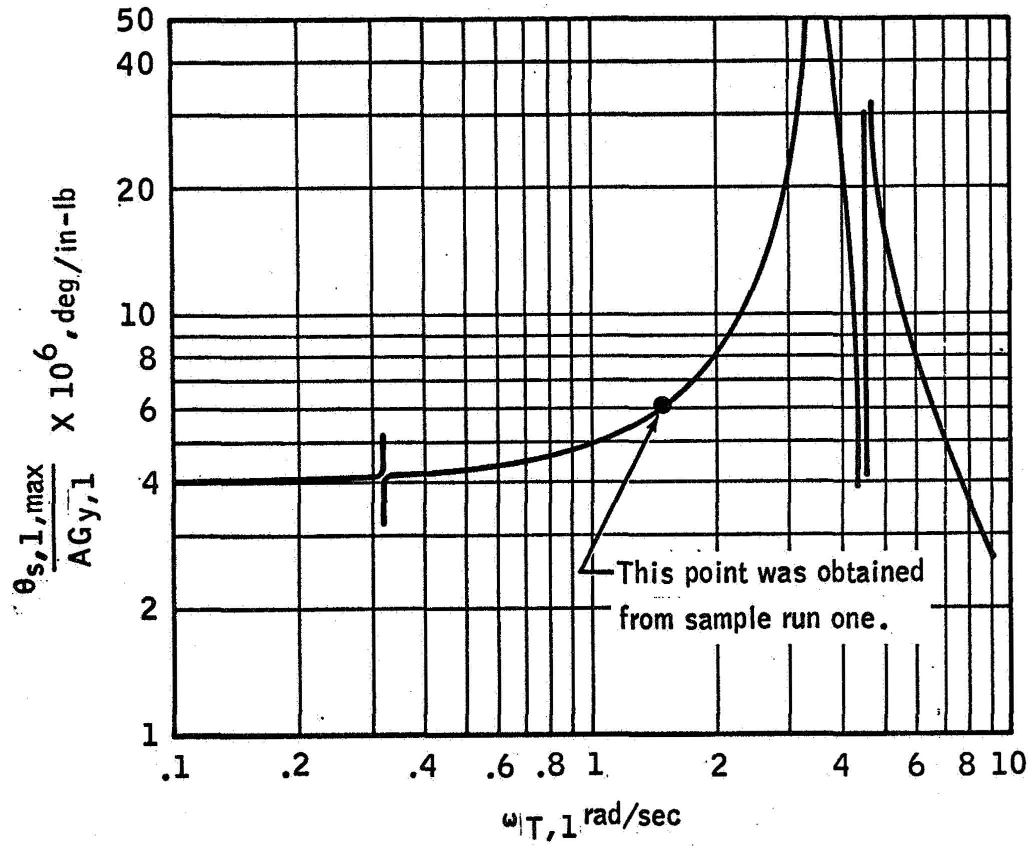



Figure B-4. - Structural yaw frequency response of the vehicle.

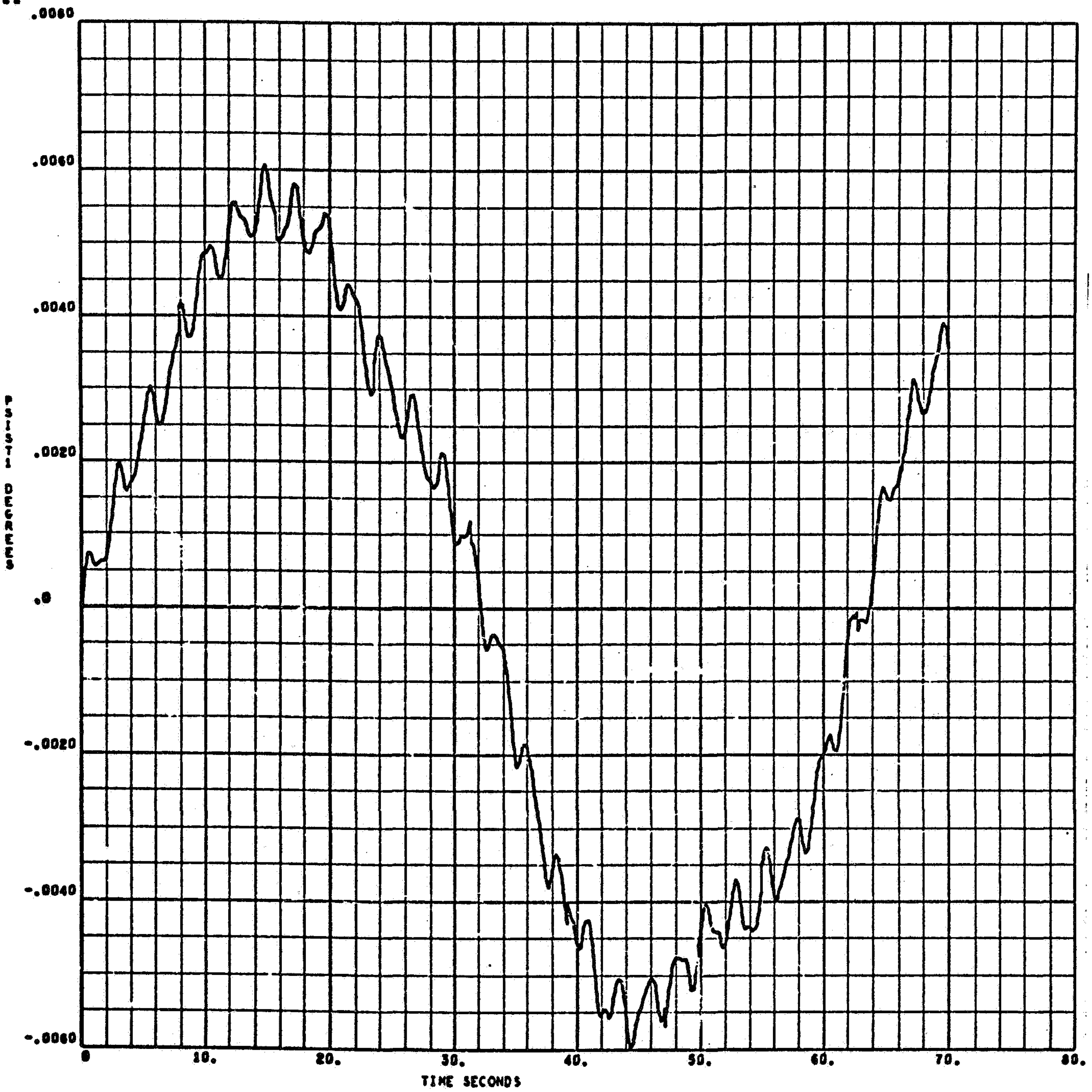



Figure B-5. - Pertinent S-C 4020 output for sample run two.

NASA-S-68-3081

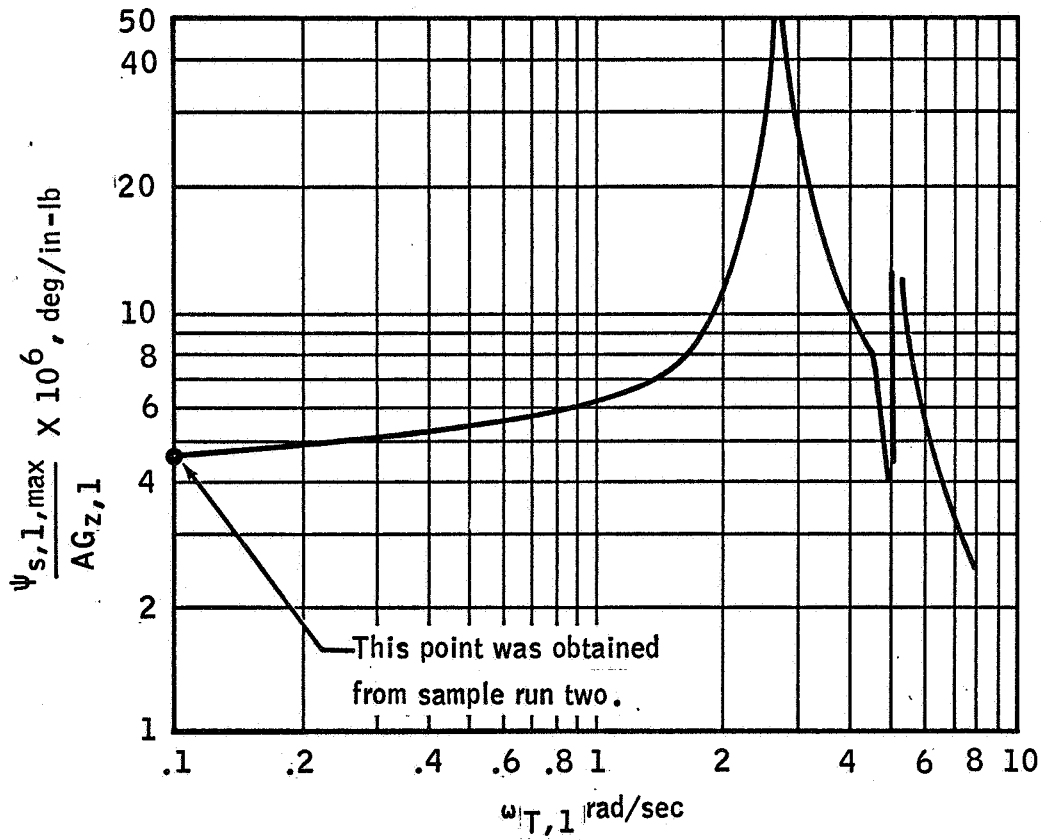



Figure B-6. - Structural pitch frequency response of the vehicle.

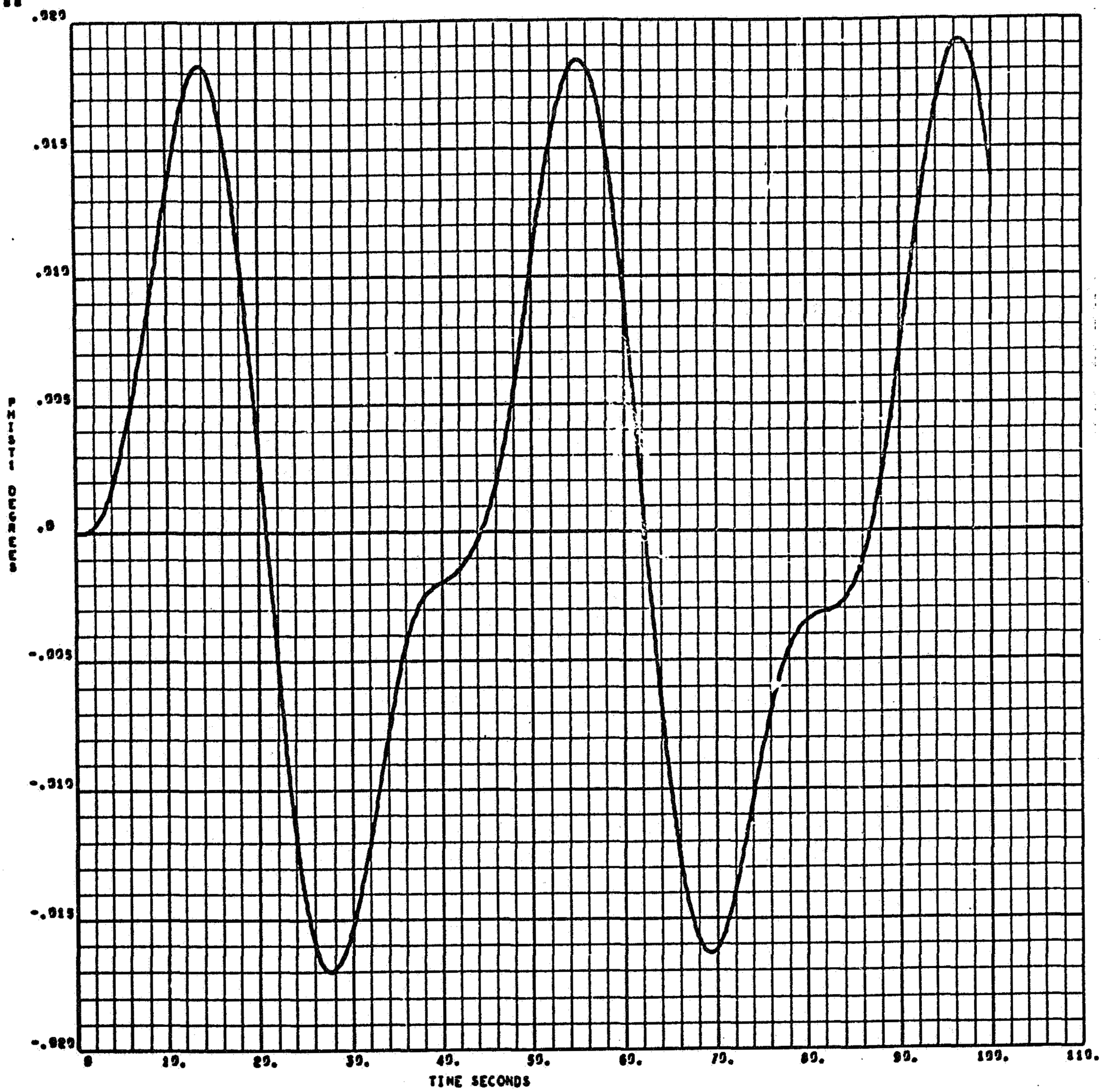



Figure B-7. - Pertinent S-C 4020 output for sample run three.

NASA-S-68-3082

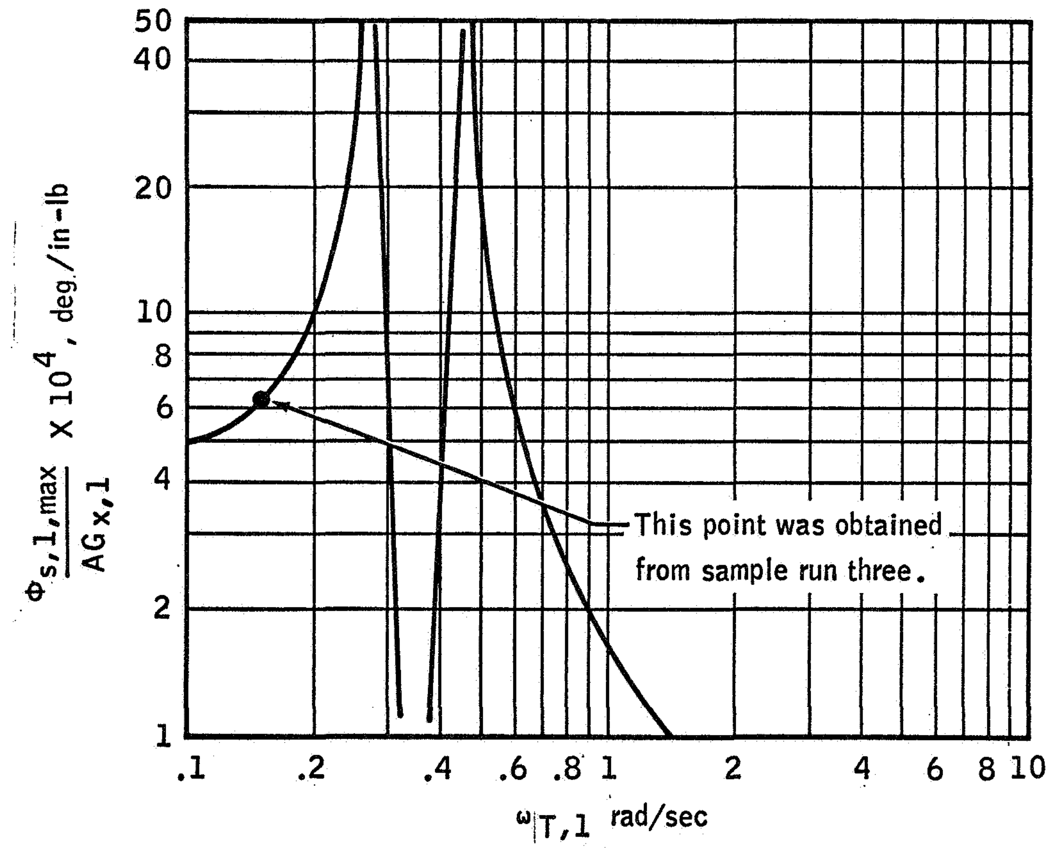



Figure B-8. - Structural roll frequency response of the vehicle.

FURFUN OPTION 1 PAGE NO 2

| TIME SEC | THETA1 DEG | PSIRBD DEG/SEC | PHI1 DEG | THETA2 DEG | THETRBD DEG/SEC | PHI2 DEG | THETAB DEG | PSIB DEG | PHIB DEG | XBR(1) IN | YBR(1) IN | ZBR(1) IN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 22.9183 | 0. | 0. | 0. | 0. | -0. | 0. | 0. | 1651.192 | 0. | 0. |
| 0.0500 | 0.0004 | 22.9183 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -0.0004 | -0.0002 | -0.0000 | 1651.192 | -0.009 | 0.012 |
| 0.1000 | 0.0033 | 22.9182 | 0.0000 | -0.0000 | 0.0000 | -0.0000 | -0.0033 | -0.0017 | -0.0000 | 1651.194 | -0.054 | 0.094 |
| 0.1500 | 0.0109 | 22.9182 | 0.0001 | -0.0001 | 0.0001 | -0.0000 | -0.0110 | -0.0056 | -0.0001 | 1651.196 | -0.174 | 0.315 |
| 0.2000 | 0.0256 | 22.9183 | 0.0002 | -0.0003 | 0.0003 | -0.0000 | -0.0259 | -0.0138 | -0.0002 | 1651.198 | -0.401 | 0.737 |
| 0.2500 | 0.0491 | 22.9185 | 0.0004 | -0.0009 | 0.0008 | -0.0000 | -0.0500 | -0.0268 | -0.0004 | 1651.200 | -0.769 | 1.415 |
| 0.3000 | 0.0832 | 22.9188 | 0.0007 | -0.0021 | 0.0015 | -0.0000 | -0.0853 | -0.0462 | -0.0007 | 1651.200 | -1.308 | 2.394 |
| 0.3500 | 0.1289 | 22.9195 | 0.0013 | -0.0045 | 0.0028 | -0.0001 | -0.1333 | -0.0731 | -0.0012 | 1651.199 | -2.043 | 3.709 |
| 0.4000 | 0.1870 | 22.9205 | 0.0021 | -0.0084 | 0.0046 | -0.0002 | -0.1954 | -0.1085 | -0.0020 | 1651.194 | -2.999 | 5.379 |
| 0.4500 | 0.2579 | 22.9219 | 0.0033 | -0.0146 | 0.0071 | -0.0004 | -0.2725 | -0.1535 | -0.0031 | 1651.183 | -4.192 | 7.415 |
| 0.5000 | 0.3415 | 22.9239 | 0.0049 | -0.0236 | 0.0105 | -0.0008 | -0.3651 | -0.2089 | -0.0044 | 1651.165 | -5.636 | 9.810 |
| 0.5500 | 0.4371 | 22.9265 | 0.0069 | -0.0362 | 0.0148 | -0.0014 | -0.4733 | -0.2757 | -0.0062 | 1651.137 | -7.341 | 12.547 |
| 0.6000 | 0.5438 | 22.9297 | 0.0096 | -0.0530 | 0.0201 | -0.0022 | -0.5968 | -0.3542 | -0.0084 | 1651.098 | -9.310 | 15.596 |
| 0.6500 | 0.6601 | 22.9338 | 0.0128 | -0.0746 | 0.0265 | -0.0034 | -0.7348 | -0.4451 | -0.0111 | 1651.045 | -11.543 | 18.918 |
| 0.7000 | 0.7846 | 22.9386 | 0.0167 | -0.1014 | 0.0340 | -0.0051 | -0.8861 | -0.5486 | -0.0143 | 1650.976 | -14.033 | 22.462 |
| 0.7500 | 0.9153 | 22.9444 | 0.0214 | -0.1335 | 0.0426 | -0.0073 | -1.0490 | -0.6646 | -0.0181 | 1650.889 | -16.772 | 26.174 |
| 0.8000 | 1.0501 | 22.9510 | 0.0268 | -0.1711 | 0.0523 | -0.0102 | -1.2215 | -0.7929 | -0.0225 | 1650.784 | -19.744 | 29.993 |
| 0.8500 | 1.1870 | 22.9587 | 0.0331 | -0.2139 | 0.0630 | -0.0138 | -1.4012 | -0.9331 | -0.0276 | 1650.658 | -22.930 | 33.856 |
| 0.9000 | 1.3237 | 22.9674 | 0.0402 | -0.2612 | 0.0746 | -0.0182 | -1.5855 | -1.0845 | -0.0334 | 1650.514 | -26.309 | 37.700 |
| 0.9500 | 1.4584 | 22.9771 | 0.0481 | -0.3123 | 0.0871 | -0.0235 | -1.7714 | -1.2461 | -0.0399 | 1650.350 | -29.856 | 41.467 |
| 1.0000 | 1.5890 | 22.9878 | 0.0568 | -0.3661 | 0.1004 | -0.0298 | -1.9559 | -1.4166 | -0.0472 | 1650.168 | -33.543 | 45.099 |
| 1.0500 | 1.7138 | 22.9996 | 0.0662 | -0.4211 | 0.1143 | -0.0370 | -2.1361 | -1.5947 | -0.0554 | 1649.970 | -37.339 | 48.548 |
| 1.1000 | 1.8315 | 23.0124 | 0.0764 | -0.4758 | 0.1287 | -0.0451 | -2.3088 | -1.7787 | -0.0645 | 1649.758 | -41.213 | 51.770 |
| SLACK CABLES | ARE | 2 | | | | | | | | | | |
| 1.1500 | 1.9413 | 23.0259 | 0.0871 | -0.5291 | 0.1435 | -0.0539 | -2.4723 | -1.9663 | -0.0743 | 1649.532 | -45.141 | 54.745 |
| SLACK CABLES | ARE | 2 6 | | | | | | | | | | |
| 1.2000 | 2.0436 | 23.0401 | 0.0984 | -0.5795 | 0.1582 | -0.0633 | -2.6254 | -2.1552 | -0.0847 | 1649.284 | -49.110 | 57.483 |
| SLACK CABLES | ARE | 2 6 | | | | | | | | | | |
| 1.2500 | 2.1395 | 23.0555 | 0.1100 | -0.6248 | 0.1727 | -0.0730 | -2.7671 | -2.3440 | -0.0954 | 1649.004 | -53.112 | 60.017 |
| SLACK CABLES | ARE | 2 6 | | | | | | | | | | |
| 1.3000 | 2.2305 | 23.0722 | 0.1221 | -0.6630 | 0.1869 | -0.0830 | -2.8968 | -2.5311 | -0.1064 | 1648.686 | -57.136 | 62.387 |
| SLACK CABLES | ARE | 2 6 | | | | | | | | | | |
| 1.3500 | 2.3183 | 23.0903 | 0.1346 | -0.6923 | 0.2009 | -0.0930 | -3.0144 | -2.7153 | -0.1175 | 1648.324 | -61.177 | 64.643 |
| SLACK CABLES | ARE | 2 6 | | | | | | | | | | |
| 1.4000 | 2.4048 | 23.1098 | 0.1474 | -0.7112 | 0.2145 | -0.1029 | -3.1204 | -2.8955 | -0.1285 | 1647.918 | -65.227 | 66.844 |
| SLACK CABLES | ARE | 2 6 | | | | | | | | | | |
| 1.4500 | 2.4922 | 23.1307 | 0.1606 | -0.7186 | 0.2279 | -0.1124 | -3.2159 | -3.0712 | -0.1391 | 1647.469 | -69.282 | 69.052 |
| SLACK CABLES | ARE | 2 6 | | | | | | | | | | |
| 1.5000 | 2.5828 | 23.1528 | 0.1741 | -0.7140 | 0.2412 | -0.1213 | -3.3025 | -3.2421 | -0.1489 | 1646.980 | -73.343 | 71.331 |
| SLACK CABLES | ARE | 2 6 | | | | | | | | | | |
| 1.5500 | 2.6788 | 23.1758 | 0.1881 | -0.6973 | 0.2545 | -0.1294 | -3.3826 | -3.4083 | -0.1578 | 1646.457 | -77.409 | 73.746 |
| SLACK CABLES | ARE | 2 6 | | | | | | | | | | |
| 1.6000 | 2.7822 | 23.1997 | 0.2026 | -0.6691 | 0.2679 | -0.1366 | -3.4586 | -3.5702 | -0.1653 | 1645.905 | -81.483 | 76.356 |
| SLACK CABLES | ARE | 2 6 | | | | | | | | | | |
| 1.6500 | 2.8949 | 23.2241 | 0.2176 | -0.6306 | 0.2816 | -0.1426 | -3.5335 | -3.7289 | -0.1713 | 1645.331 | -85.570 | 79.211 |
| SLACK CABLES | ARE | 2 6 | | | | | | | | | | |
| 1.7000 | 3.0180 | 23.2489 | 0.2334 | -0.5835 | 0.2959 | -0.1474 | -3.6104 | -3.8852 | -0.1755 | 1644.739 | -89.671 | 82.351 |
| SLACK CABLES | ARE | 2 6 | | | | | | | | | | |
| 1.7500 | 3.1527 | 23.2740 | 0.2500 | -0.5299 | 0.3110 | -0.1509 | -3.6924 | -4.0405 | -0.1778 | 1644.131 | -93.790 | 85.802 |
| SLACK CABLES | ARE | 2 6 | | | | | | | | | | |
| 1.8000 | 3.2992 | 23.2994 | 0.2675 | -0.4725 | 0.3269 | -0.1531 | -3.7825 | -4.1961 | -0.1781 | 1643.508 | -97.926 | 89.572 |
| SLACK CABLES | ARE | 2 6 | | | | | | | | | | |

Figure B-9. - Program printout for sample run four.

FORFUN OPTION 1 PAGE NO 3

| TIME SEC | GAMMA DEG | ALPHA DEG | IAVB2 DEG/SEC | THETABD DEG/SEC | PSIBD DEG/SEC | PHIBD DEG/SEC | XCG INCHES | YCG INCHES | ZCG INCHES | XBR2CG INCHES | YBR2CG INCHES | ZBR2CG INCHES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0.0 | 22.918 | 0. | 0.0000 | -0. | -517.5564 | 0. | 0. | 717.56 | 2000.00 | 200.00 |
| 0.050 | 0.0000 | 0.0 | 22.918 | -0.0247 | -0.0130 | -0.000 | -517.4530 | -10.3504 | 0. | 717.56 | 2000.00 | 200.00 |
| 0.100 | 0.0001 | 0.0 | 22.918 | -0.0981 | -0.0518 | -0.000 | -517.1430 | -20.6967 | 0.00 | 717.56 | 2000.00 | 200.00 |
| 0.150 | 0.0003 | 0.0 | 22.918 | -0.2187 | -0.1163 | -0.001 | -516.6263 | -31.0347 | 0.00 | 717.56 | 2000.00 | 200.00 |
| 0.200 | 0.0008 | 0.0 | 22.918 | -0.3834 | -0.2060 | -0.003 | -515.9030 | -41.3604 | 0.00 | 717.56 | 2000.00 | 200.00 |
| 0.250 | 0.0019 | 0.0 | 22.918 | -0.5883 | -0.3203 | -0.005 | -514.9735 | -51.6696 | 0.00 | 717.56 | 2000.00 | 200.00 |
| 0.300 | 0.0038 | 0.0 | 22.919 | -0.8284 | -0.4584 | -0.009 | -513.8378 | -61.9583 | 0.00 | 717.56 | 2000.00 | 200.00 |
| 0.350 | 0.0069 | 0.0 | 22.919 | -1.0977 | -0.6192 | -0.013 | -512.4964 | -72.2224 | 0.00 | 717.56 | 2000.00 | 200.00 |
| 0.400 | 0.0115 | 0.0 | 22.920 | -1.3894 | -0.8009 | -0.018 | -510.9497 | -82.4580 | 0.00 | 717.56 | 2000.00 | 200.00 |
| 0.450 | 0.0178 | 0.0 | 22.922 | -1.6957 | -1.0019 | -0.024 | -509.1982 | -92.6610 | 0.01 | 717.56 | 2000.00 | 200.00 |
| 0.500 | 0.0263 | 0.0 | 22.924 | -2.0085 | -1.2196 | -0.032 | -507.2425 | -102.8277 | 0.01 | 717.56 | 2000.00 | 200.00 |
| 0.550 | 0.0370 | 0.0 | 22.926 | -2.3190 | -1.4513 | -0.040 | -505.0832 | -112.9542 | 0.02 | 717.56 | 2000.00 | 200.00 |
| 0.600 | 0.0503 | 0.1 | 22.930 | -2.6184 | -1.6936 | -0.049 | -502.7212 | -123.0366 | 0.02 | 717.56 | 2000.00 | 200.00 |
| 0.650 | 0.0663 | 0.1 | 22.934 | -2.8976 | -1.9427 | -0.059 | -500.1572 | -133.0712 | 0.03 | 717.56 | 2000.00 | 200.00 |
| 0.700 | 0.0850 | 0.1 | 22.939 | -3.1480 | -2.1945 | -0.070 | -497.3921 | -143.0543 | 0.05 | 717.56 | 2000.00 | 200.00 |
| 0.750 | 0.1064 | 0.1 | 22.944 | -3.3614 | -2.4444 | -0.082 | -494.4267 | -152.9822 | 0.06 | 717.56 | 2000.00 | 200.00 |
| 0.800 | 0.1305 | 0.1 | 22.951 | -3.5305 | -2.6875 | -0.094 | -491.2619 | -162.8513 | 0.09 | 717.56 | 2000.00 | 200.00 |
| 0.850 | 0.1571 | 0.2 | 22.959 | -3.6488 | -2.9188 | -0.108 | -487.8986 | -172.6579 | 0.11 | 717.56 | 2000.00 | 200.00 |
| 0.900 | 0.1861 | 0.2 | 22.967 | -3.7114 | -3.1332 | -0.123 | -484.3377 | -182.3983 | 0.14 | 717.56 | 2000.00 | 200.00 |
| 0.950 | 0.2172 | 0.2 | 22.977 | -3.7147 | -3.3257 | -0.139 | -480.5802 | -192.0689 | 0.18 | 717.56 | 2000.00 | 200.00 |
| 1.000 | 0.2502 | 0.3 | 22.988 | -3.6571 | -3.4917 | -0.155 | -476.6272 | -201.6662 | 0.22 | 717.56 | 2000.00 | 200.00 |
| 1.050 | 0.2847 | 0.3 | 23.000 | -3.5387 | -3.6266 | -0.173 | -472.4796 | -211.1864 | 0.27 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.100 | 0.3204 | 0.3 | 23.013 | -3.3657 | -3.7248 | -0.190 | -468.1387 | -220.6261 | 0.33 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.150 | 0.3571 | 0.4 | 23.026 | -3.1694 | -3.7708 | -0.202 | -463.6049 | -229.9811 | 0.39 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.200 | 0.3935 | 0.4 | 23.041 | -2.9504 | -3.7827 | -0.211 | -458.8773 | -239.2463 | 0.46 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.250 | 0.4292 | 0.4 | 23.056 | -2.7149 | -3.7636 | -0.218 | -453.9548 | -248.4168 | 0.53 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.300 | 0.4642 | 0.5 | 23.073 | -2.4723 | -3.7167 | -0.222 | -448.8373 | -257.4876 | 0.61 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.350 | 0.4984 | 0.5 | 23.091 | -2.2335 | -3.6469 | -0.222 | -443.5254 | -266.4544 | 0.70 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.400 | 0.5318 | 0.5 | 23.111 | -2.0105 | -3.5608 | -0.216 | -438.0210 | -275.3132 | 0.79 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.450 | 0.5646 | 0.6 | 23.132 | -1.8151 | -3.4656 | -0.205 | -432.3269 | -284.0609 | 0.89 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.500 | 0.5969 | 0.6 | 23.154 | -1.6588 | -3.3692 | -0.188 | -426.4467 | -292.6949 | 1.00 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.550 | 0.6291 | 0.6 | 23.177 | -1.5511 | -3.2793 | -0.165 | -420.3844 | -301.2128 | 1.11 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.600 | 0.6616 | 0.7 | 23.201 | -1.4993 | -3.2028 | -0.136 | -414.1444 | -309.6127 | 1.23 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.650 | 0.6948 | 0.7 | 23.226 | -1.5081 | -3.1455 | -0.103 | -407.7309 | -317.8928 | 1.35 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.700 | 0.7293 | 0.7 | 23.251 | -1.5790 | -3.1118 | -0.065 | -401.1479 | -326.0512 | 1.48 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.750 | 0.7655 | 0.8 | 23.276 | -1.7109 | -3.1044 | -0.026 | -394.3987 | -334.0856 | 1.62 | 717.56 | 2000.00 | 200.00 |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.800 | 0.8039 | 0.8 | 23.302 | -1.8994 | -3.1241 | 0.014 | -387.4859 | -341.9931 | 1.76 | 717.56 | 2000.00 | 200.00 |

Figure B-9. - Continued.

FURFUN OPTION 1 PAGE NO 4

| TIME SEC | OMEGAX1 DEG/SEC | OMEGAY1 DEG/SEC | OMEGAZ1 DEG/SEC | OMEGAX2 DEG/SEC | OMEGAY2 DEG/SEC | OMEGAZ2 DEG/SEC | RP1P2(2) IN | RP1P2(3) IN | RP1P2(1) IN | RP1P2(4) IN | FCABLEMAX LB | CABLE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0. | 0. | 0. | 22.9200 | 0. | 0. | 22.9200 | 1209.783 | 1209.783 | 1651.192 | 1209.783 | 1059.488 | 2. |
| 0.050 | -0.000 | 0.0247 | 22.9329 | -0.000 | -0.0000 | 22.9199 | 1209.782 | 1209.783 | 1651.192 | 1209.784 | 1059.866 | 4. |
| 0.100 | -0.001 | 0.0977 | 22.9713 | 0.000 | -0.0005 | 22.9195 | 1209.776 | 1209.783 | 1651.194 | 1209.792 | 1061.706 | 8. |
| 0.150 | -0.003 | 0.2163 | 23.0345 | 0.000 | -0.0023 | 22.9183 | 1209.761 | 1209.782 | 1651.196 | 1209.812 | 1066.430 | 8. |
| 0.200 | -0.007 | 0.3762 | 23.1213 | 0.000 | -0.0072 | 22.9153 | 1209.730 | 1209.779 | 1651.198 | 1209.848 | 1075.139 | 8. |
| 0.250 | -0.014 | 0.5713 | 23.2299 | 0.000 | -0.0171 | 22.9096 | 1209.678 | 1209.771 | 1651.201 | 1209.904 | 1088.801 | 8. |
| 0.300 | -0.025 | 0.7944 | 23.3582 | 0.000 | -0.0343 | 22.8998 | 1209.602 | 1209.758 | 1651.203 | 1209.985 | 1108.218 | 8. |
| 0.350 | -0.039 | 1.0373 | 23.5039 | 0.000 | -0.0610 | 22.8847 | 1209.499 | 1209.738 | 1651.204 | 1210.093 | 1133.966 | 8. |
| 0.400 | -0.057 | 1.2912 | 23.6640 | 0.000 | -0.0991 | 22.8631 | 1209.364 | 1209.710 | 1651.205 | 1210.231 | 1166.402 | 8. |
| 0.450 | -0.080 | 1.5471 | 23.8357 | 0.000 | -0.1500 | 22.8339 | 1209.197 | 1209.674 | 1651.205 | 1210.400 | 1205.674 | 8. |
| 0.500 | -0.107 | 1.7961 | 24.0157 | 0.000 | -0.2146 | 22.7963 | 1208.998 | 1209.629 | 1651.204 | 1210.601 | 1251.707 | 8. |
| 0.550 | -0.138 | 2.0295 | 24.2008 | 0.000 | -0.2927 | 22.7499 | 1208.767 | 1209.574 | 1651.201 | 1210.835 | 1304.228 | 8. |
| 0.600 | -0.173 | 2.2397 | 24.3876 | 0.001 | -0.3831 | 22.6947 | 1208.504 | 1209.511 | 1651.198 | 1211.101 | 1362.765 | 8. |
| 0.650 | -0.212 | 2.4201 | 24.5729 | 0.001 | -0.4836 | 22.6312 | 1208.213 | 1209.438 | 1651.194 | 1211.396 | 1428.561 | 4. |
| 0.700 | -0.253 | 2.5653 | 24.7534 | 0.001 | -0.5909 | 22.5604 | 1207.897 | 1209.358 | 1651.188 | 1211.719 | 1502.406 | 4. |
| 0.750 | -0.297 | 2.6712 | 24.9262 | 0.002 | -0.7010 | 22.4838 | 1207.559 | 1209.270 | 1651.182 | 1212.066 | 1581.743 | 4. |
| 0.800 | -0.343 | 2.7357 | 25.0884 | 0.002 | -0.8086 | 22.4036 | 1207.203 | 1209.177 | 1651.174 | 1212.433 | 1665.640 | 4. |
| 0.850 | -0.390 | 2.7578 | 25.2374 | 0.003 | -0.9085 | 22.3221 | 1206.834 | 1209.079 | 1651.165 | 1212.815 | 1753.002 | 4. |
| 0.900 | -0.437 | 2.7384 | 25.3708 | 0.004 | -0.9947 | 22.2421 | 1206.456 | 1208.979 | 1651.154 | 1213.207 | 1842.632 | 4. |
| 0.950 | -0.483 | 2.6796 | 25.4868 | 0.006 | -1.0616 | 22.1665 | 1206.075 | 1208.879 | 1651.140 | 1213.603 | 1933.257 | 4. |
| 1.000 | -0.528 | 2.5851 | 25.5837 | 0.007 | -1.1040 | 22.0984 | 1205.695 | 1208.780 | 1651.125 | 1213.998 | 2023.576 | 4. |
| 1.050 | -0.572 | 2.4595 | 25.6601 | 0.009 | -1.1173 | 22.0409 | 1205.321 | 1208.686 | 1651.106 | 1214.386 | 2112.338 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.100 | -0.613 | 2.3101 | 25.7163 | 0.012 | -1.1005 | 22.0000 | 1204.957 | 1208.599 | 1651.085 | 1214.762 | 2198.348 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.150 | -0.653 | 2.1570 | 25.7613 | 0.021 | -1.0646 | 22.0001 | 1204.601 | 1208.520 | 1651.057 | 1215.121 | 2280.521 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.200 | -0.691 | 2.0222 | 25.8009 | 0.031 | -0.9882 | 22.0288 | 1204.243 | 1208.444 | 1651.016 | 1215.457 | 2357.170 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.250 | -0.727 | 1.9131 | 25.8356 | 0.043 | -0.8699 | 22.0837 | 1203.873 | 1208.366 | 1650.950 | 1215.759 | 2426.297 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.300 | -0.762 | 1.8360 | 25.8658 | 0.056 | -0.7129 | 22.1622 | 1203.484 | 1208.281 | 1650.855 | 1216.022 | 2486.582 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.350 | -0.796 | 1.7965 | 25.8928 | 0.069 | -0.5224 | 22.2604 | 1203.070 | 1208.187 | 1650.725 | 1216.245 | 2537.561 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.400 | -0.829 | 1.7988 | 25.9180 | 0.083 | -0.3060 | 22.3734 | 1202.631 | 1208.085 | 1650.563 | 1216.430 | 2579.699 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.450 | -0.862 | 1.8457 | 25.9428 | 0.097 | -0.0729 | 22.4955 | 1202.167 | 1207.979 | 1650.370 | 1216.581 | 2614.361 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.500 | -0.897 | 1.9378 | 25.9686 | 0.111 | 0.1664 | 22.6202 | 1201.683 | 1207.874 | 1650.154 | 1216.709 | 2643.664 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.550 | -0.932 | 2.0730 | 25.9965 | 0.123 | 0.4002 | 22.7410 | 1201.184 | 1207.774 | 1649.924 | 1216.826 | 2670.274 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.600 | -0.970 | 2.2471 | 26.0270 | 0.135 | 0.6171 | 22.8514 | 1200.679 | 1207.687 | 1649.689 | 1216.943 | 2697.110 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.650 | -1.010 | 2.4533 | 26.0601 | 0.144 | 0.8057 | 22.9455 | 1200.173 | 1207.617 | 1649.458 | 1217.074 | 2727.044 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.700 | -1.053 | 2.6828 | 26.0952 | 0.152 | 0.9557 | 23.0184 | 1199.673 | 1207.567 | 1649.239 | 1217.229 | 2762.584 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.750 | -1.100 | 2.9256 | 26.1312 | 0.157 | 1.0584 | 23.0663 | 1199.183 | 1207.537 | 1649.038 | 1217.417 | 2805.615 | 4. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 1.800 | -1.149 | 3.1707 | 26.1668 | 0.159 | 1.1069 | 23.0870 | 1198.706 | 1207.524 | 1648.857 | 1217.643 | 2892.328 | 8. |

Figure B-9. - Concluded.

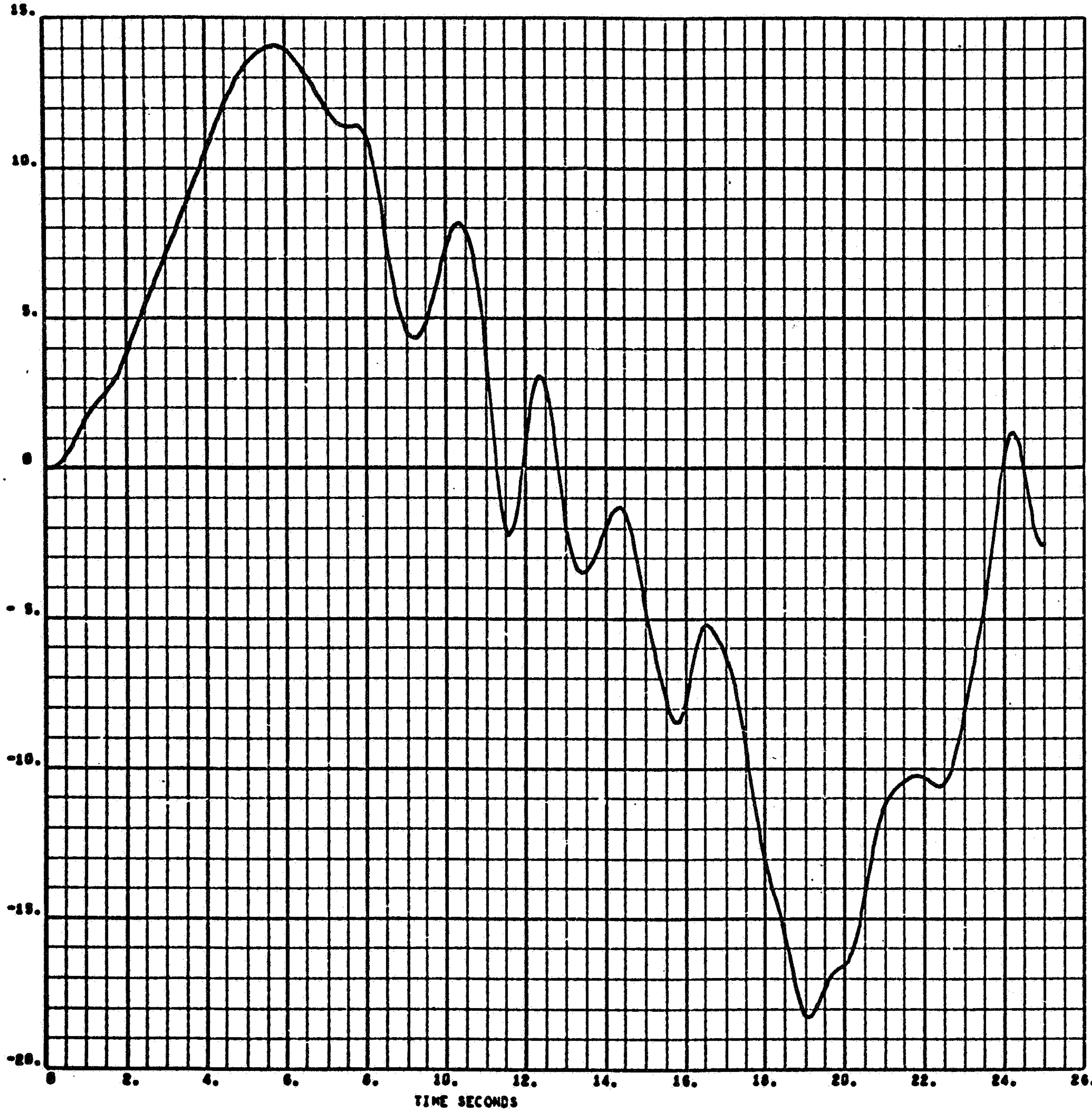



Figure B-10. - Pertinent S-C 4020 graphical output for sample run four.

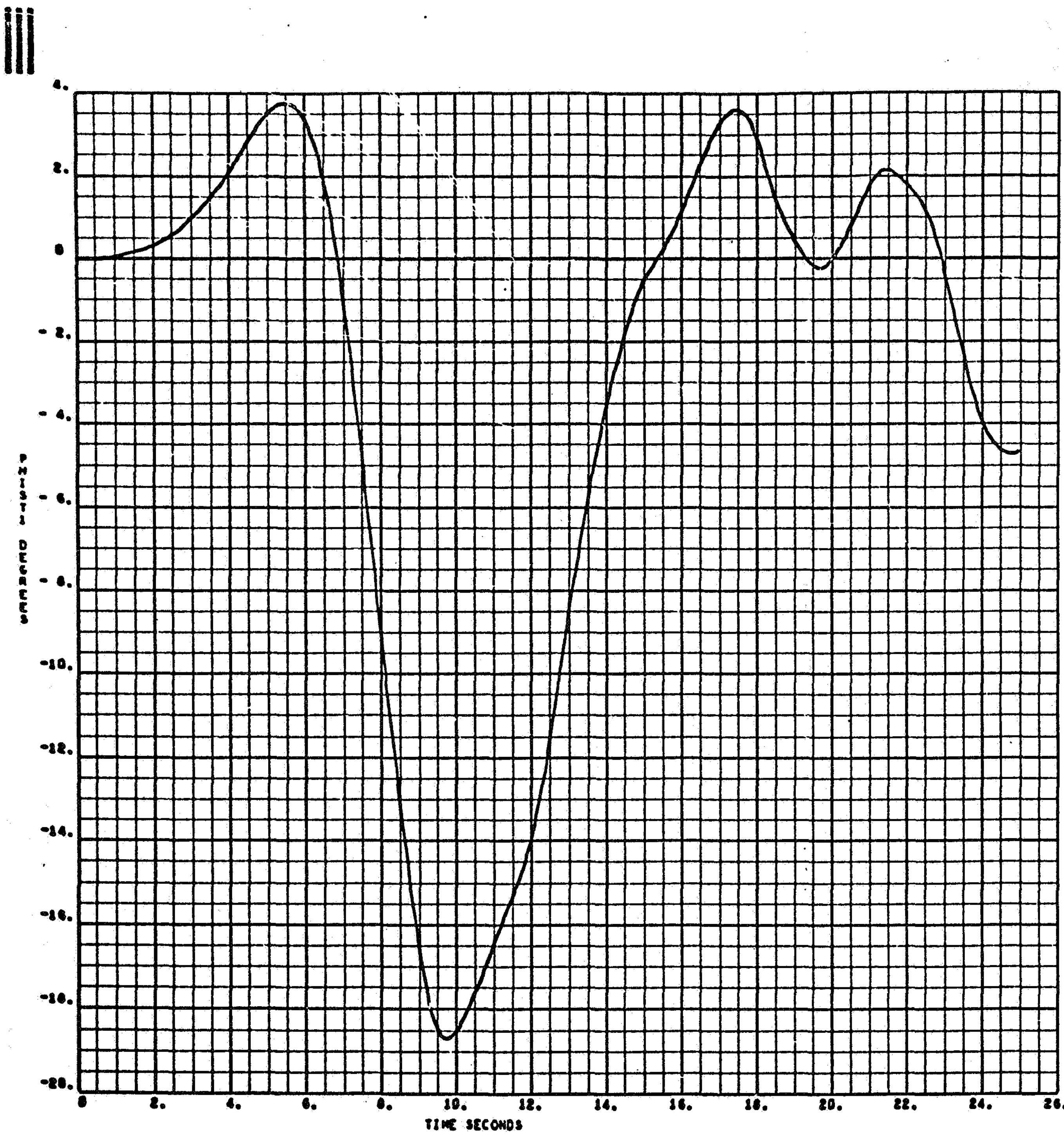



Figure B-10. - Continued.

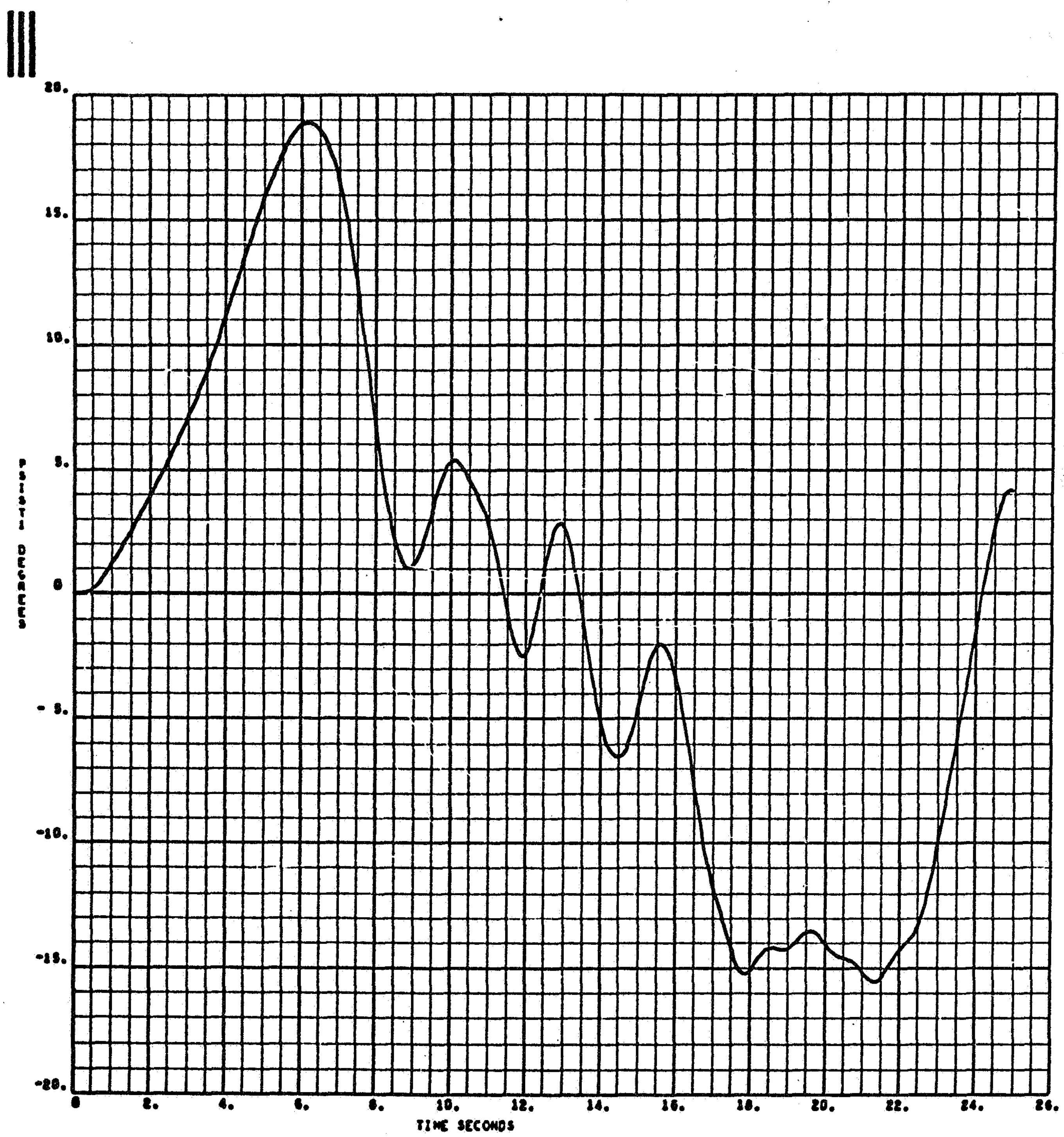



Figure B-10. - Continued.

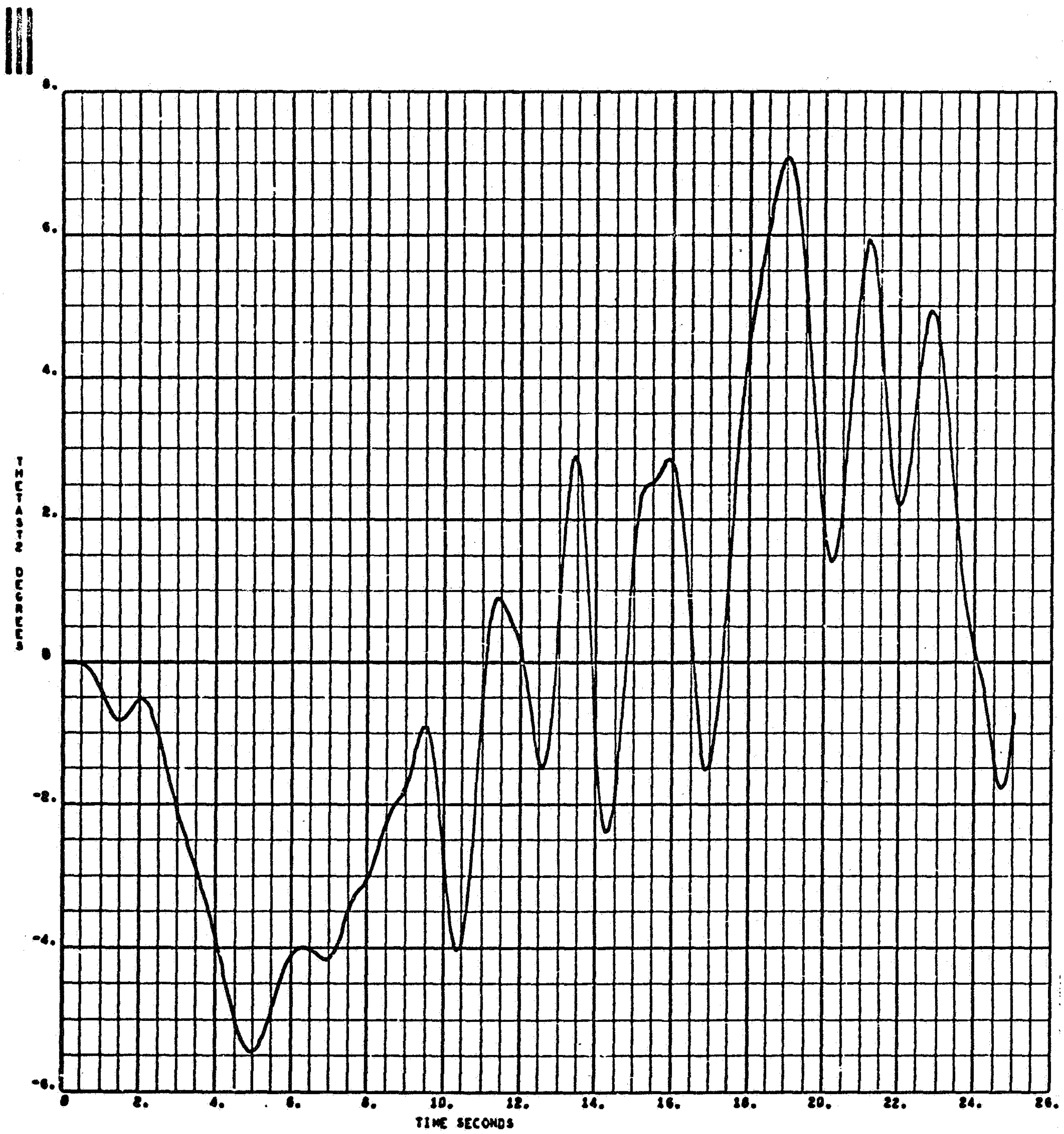



Figure B-10. - Continued.

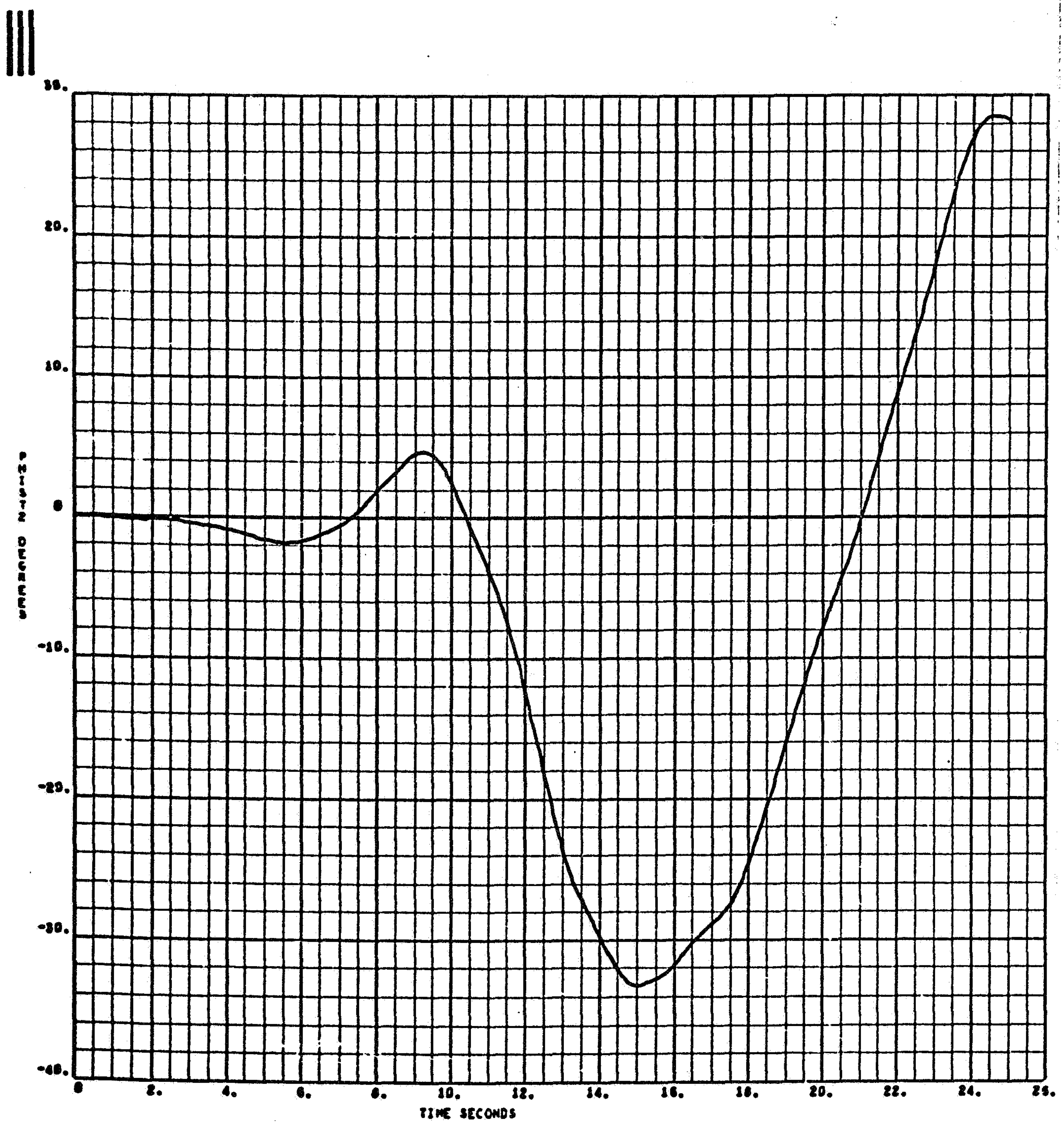



Figure B-10. - Continued.

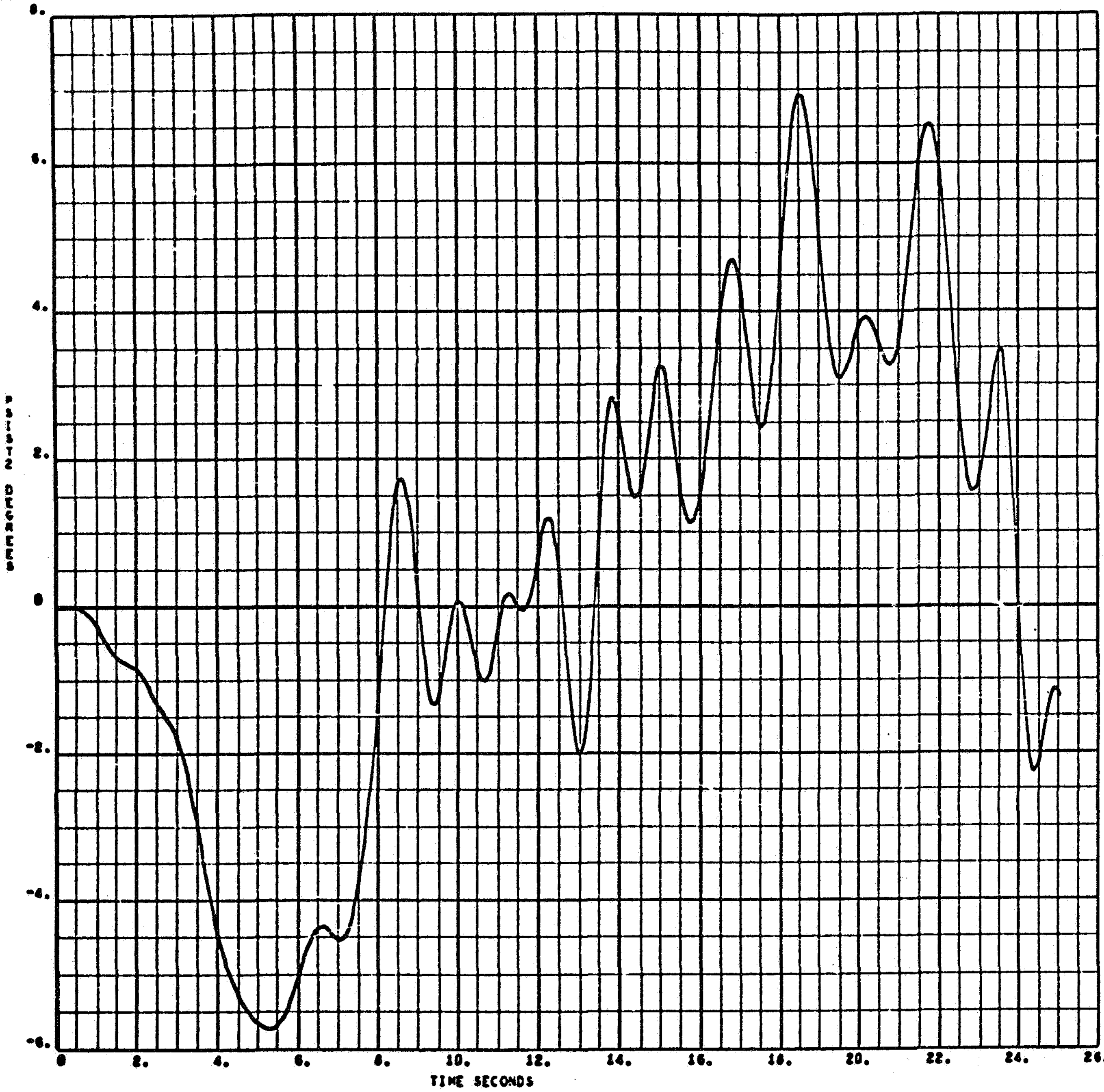



Figure B-10. - Continued.

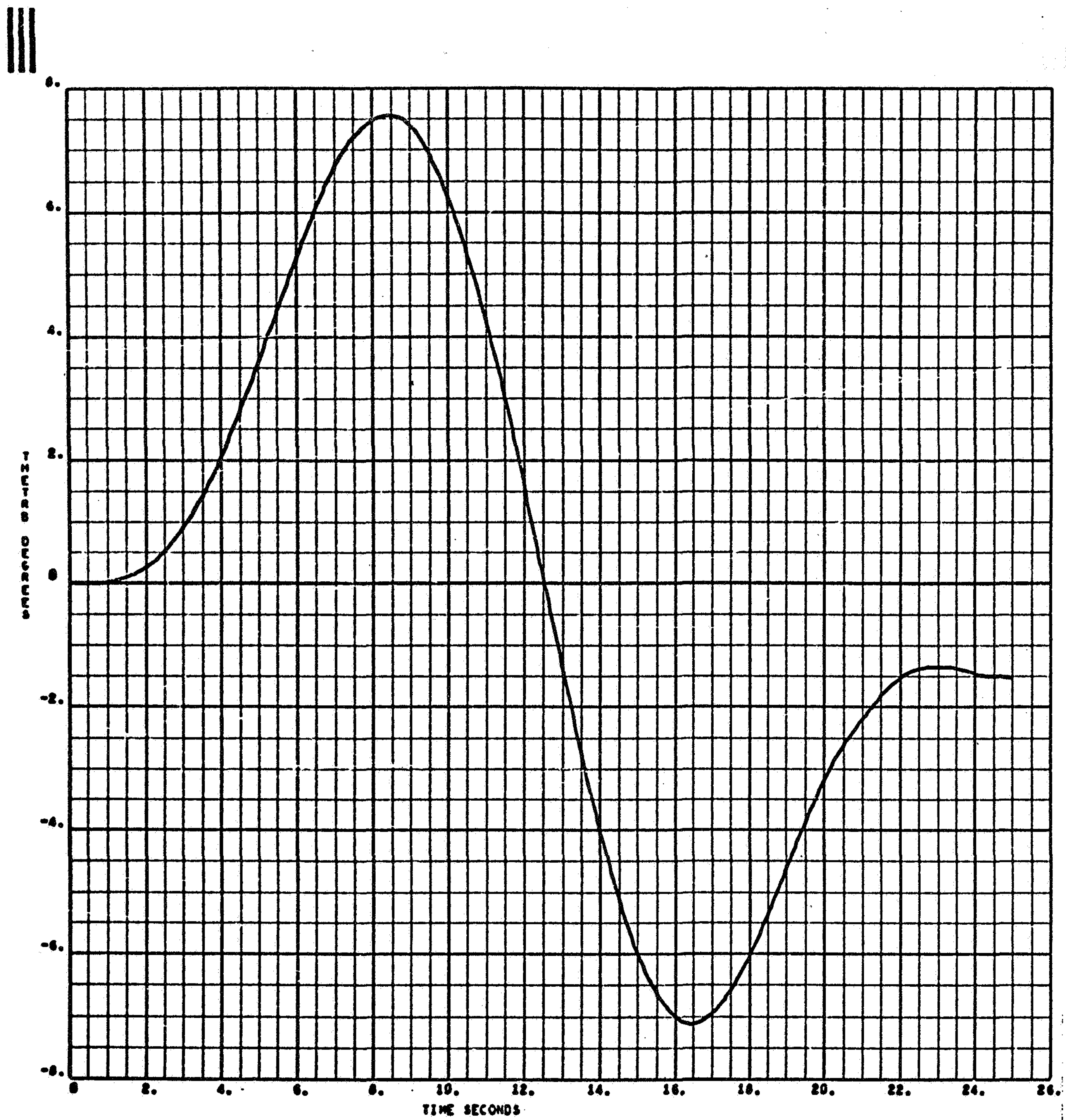



Figure B-10. - Continued.

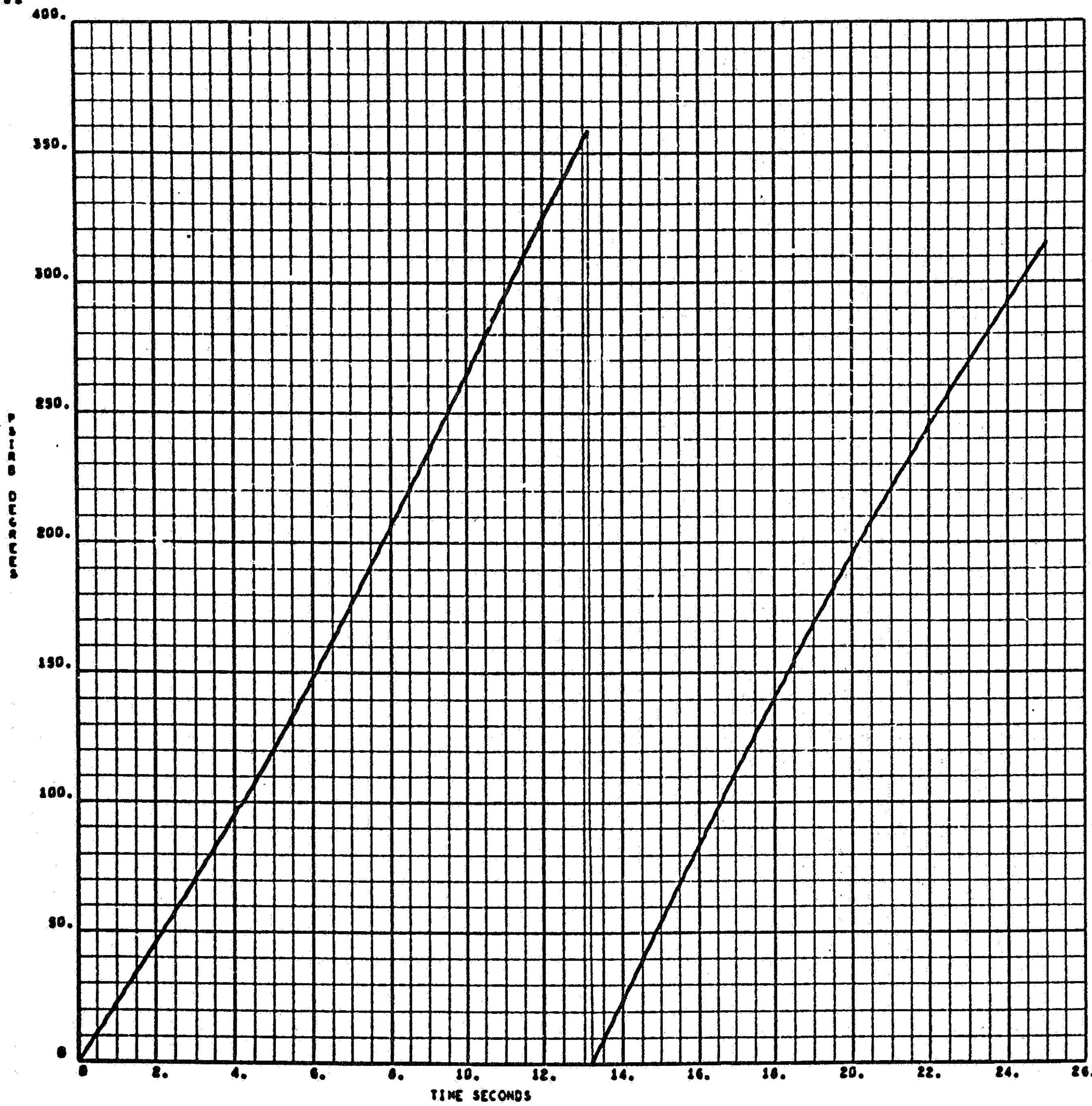



Figure B-10. - Continued.

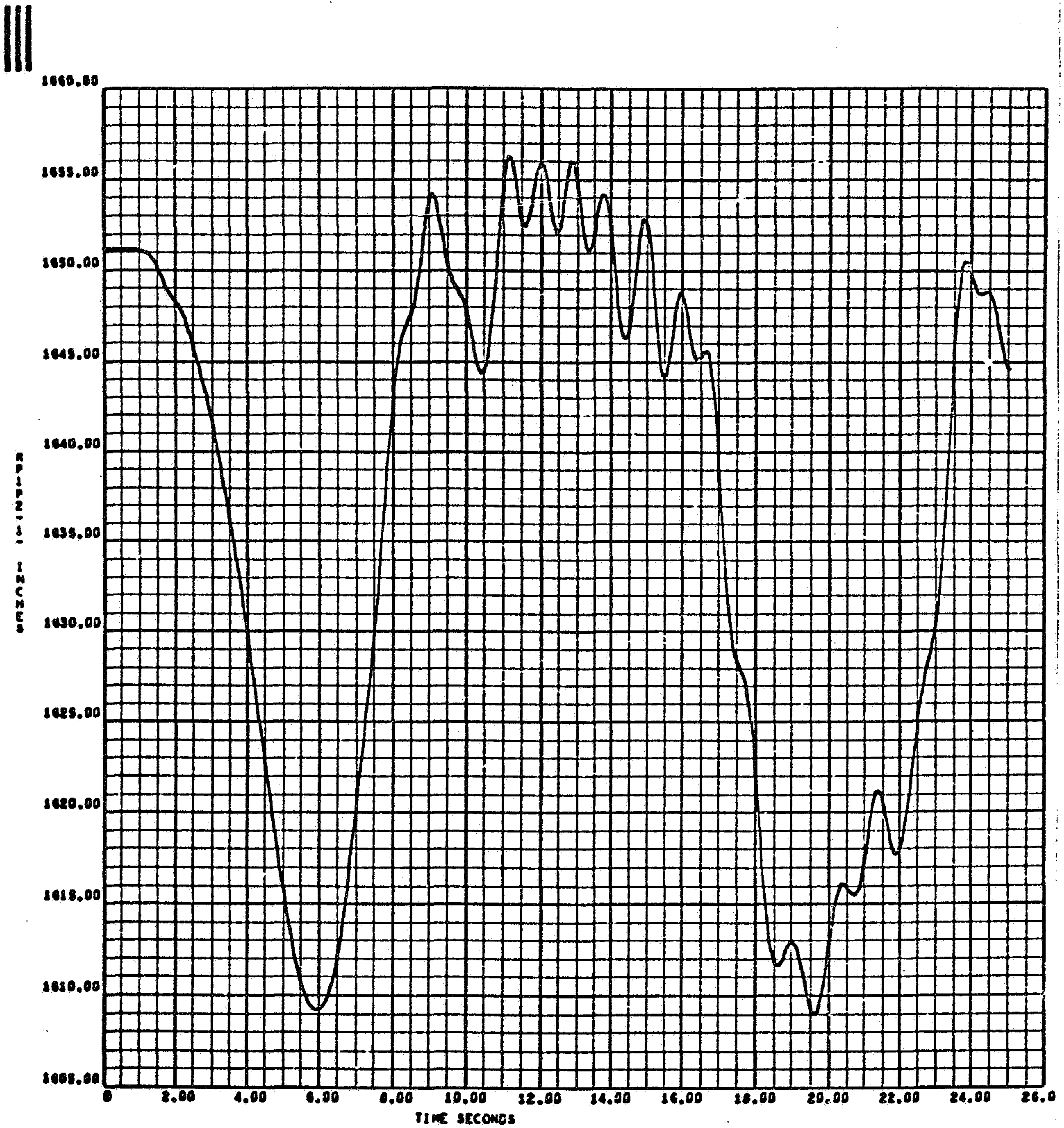



Figure B-10. - Concluded.

CABLE CONNECTED SPACE STATION DYNAMICS

WEIGHT OF BODY 1 = 39285 LB.

WEIGHT OF BODY 2 = 17935 LB.

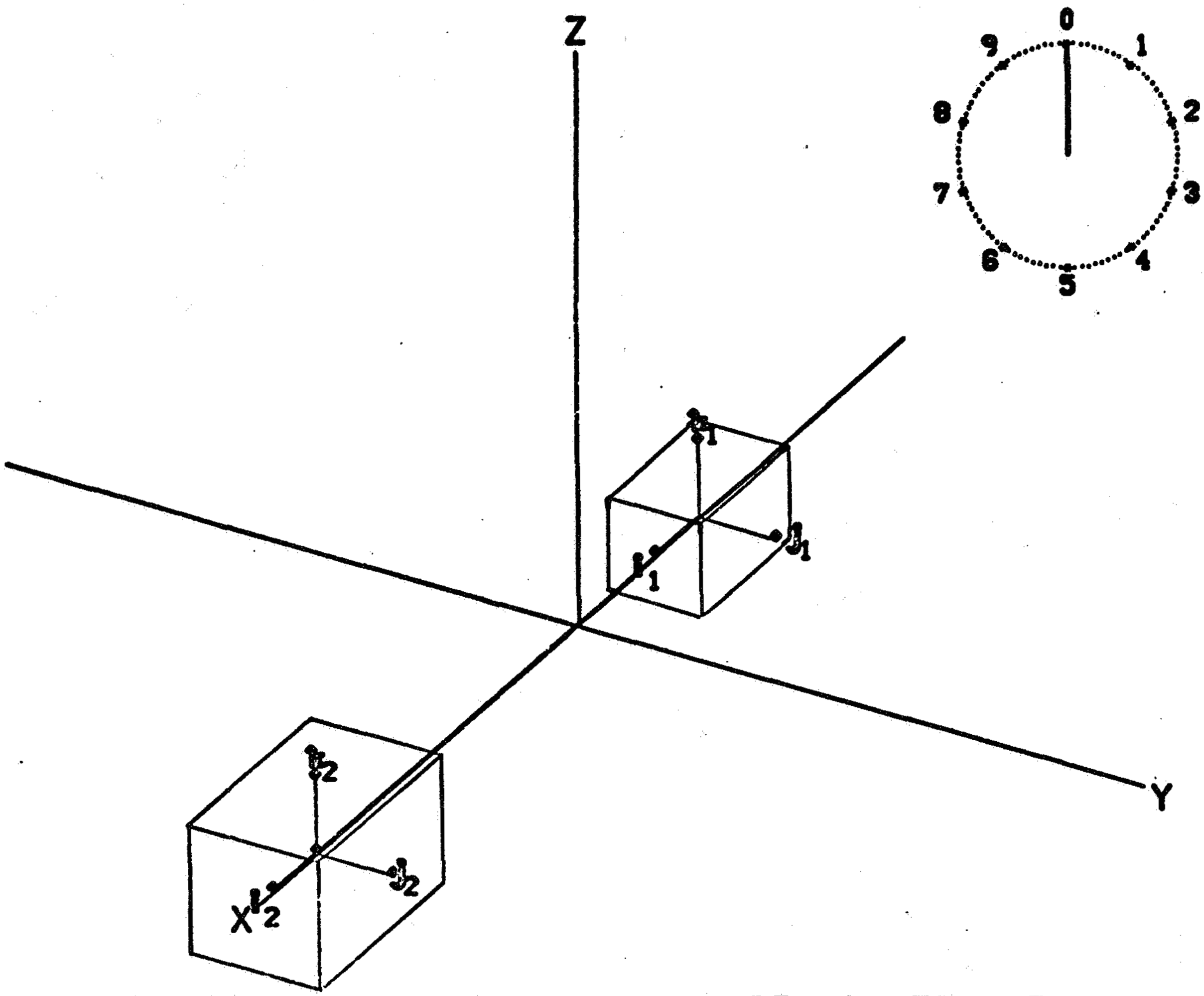
INITIAL SPIN SPEED = 22.92 DEG./SEC.

INITIAL DISTANCE BETWEEN BODY C.G.'S= 137.6 FT.

CABLE ELASTICITY = 14583300 PSI

TOTAL CABLE AREA = 0.1512 SQ. IN.

Figure B-11. - Typical S-C 4020 motion picture output for sample run four.




TORQUE ABOUT $\mathbf{i}_1$ = 333 SIN(0.25 T) FT.-LB.

TORQUE ABOUT $\mathbf{j}_1$ = 125000 SIN(0.25 T) FT.-LB.

TORQUE ABOUT $\mathbf{k}_1$ = 125000 SIN(0.25 T) FT.-LB.

Figure B-11. - Continued.

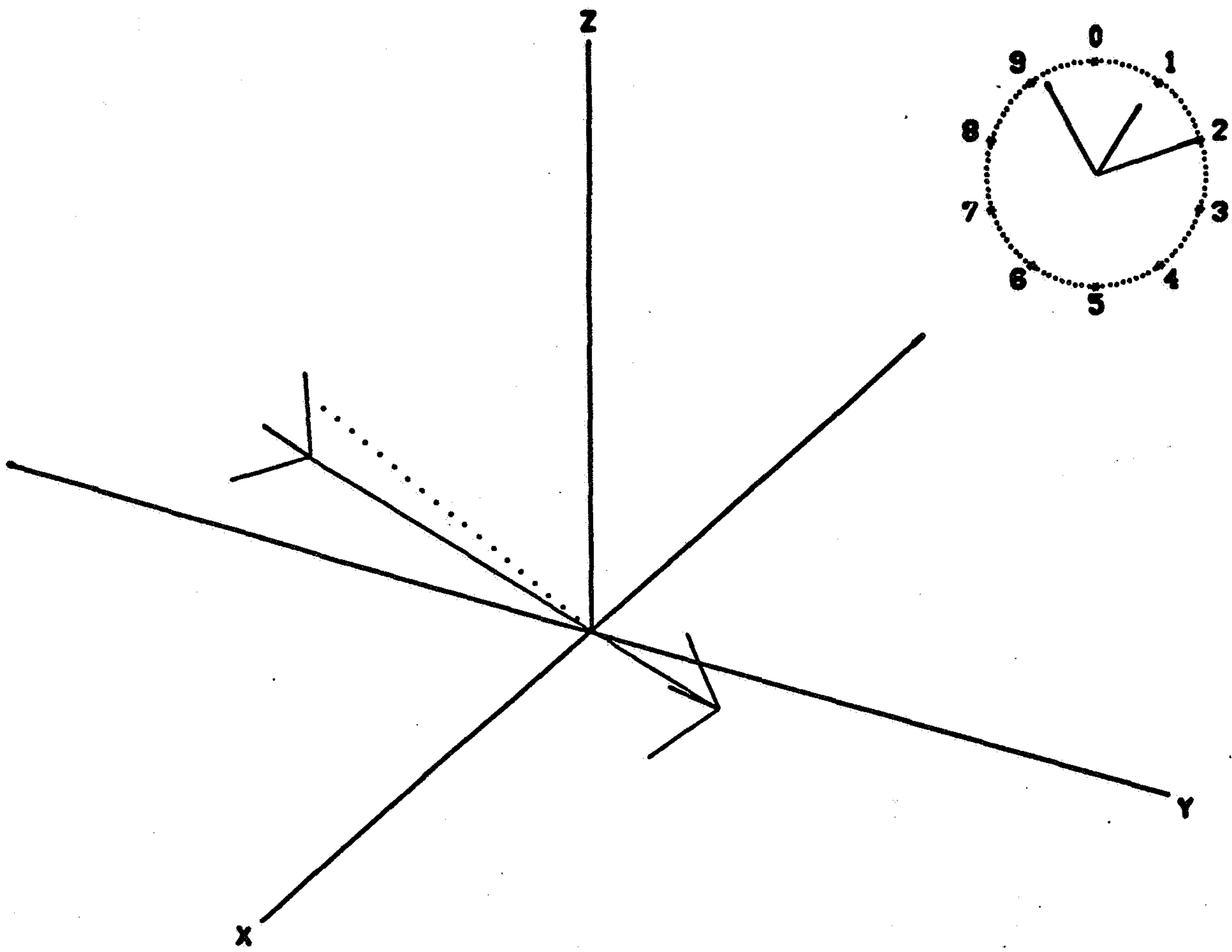



Figure B-11. - Continued.

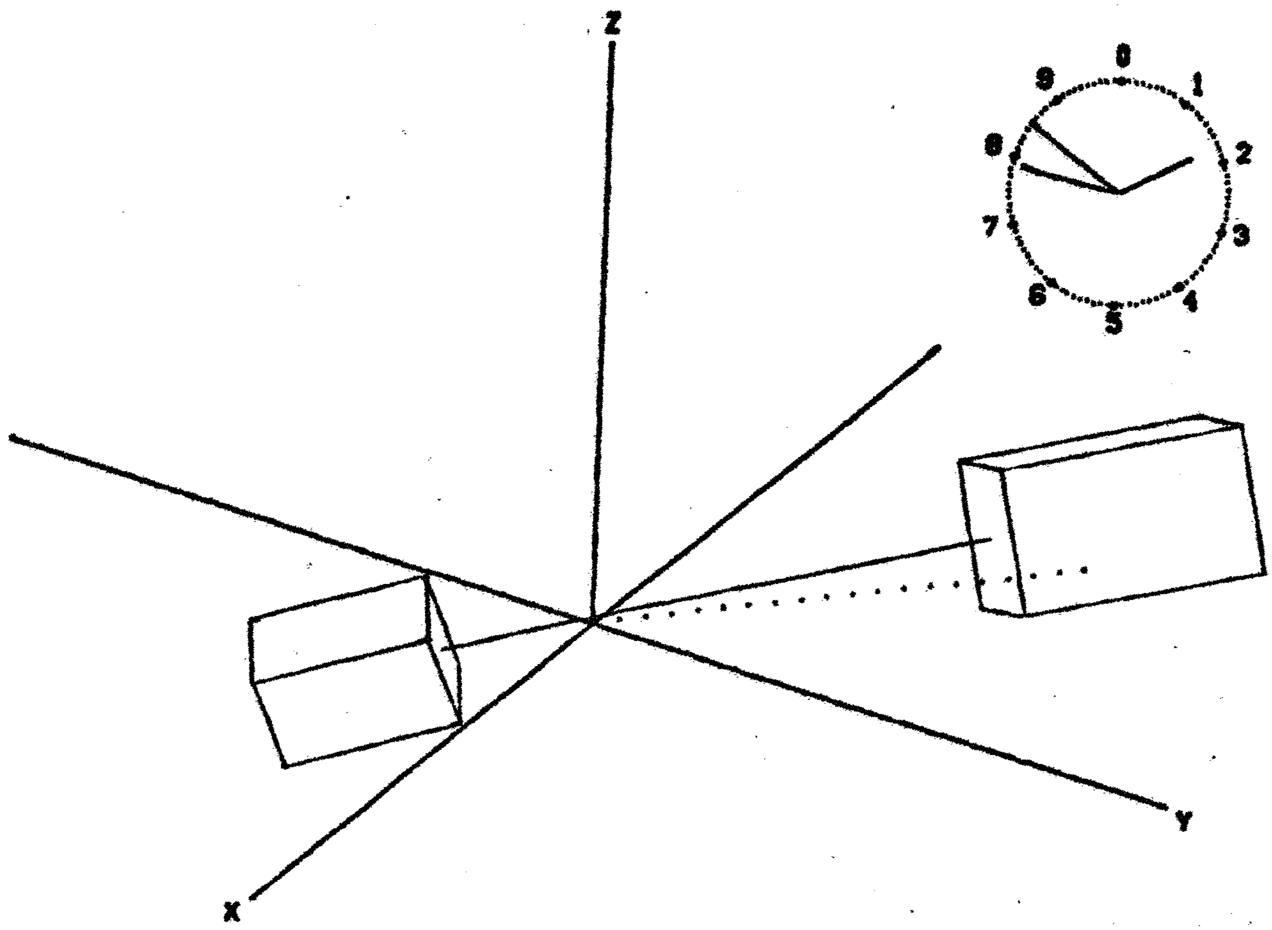



Figure B-11. - Concluded.

## REFERENCE


1. Sperry Rand Systems Group: Space Station Stabilization and Control Study. NASA-CR-66019, Dec. 1963. (Also available as Sperry Report AB-1210-0020.)