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THREE-DIMENSIONAL DYNAMICS OF SCIENTIFIC BALLOON SYSTEMS IN RESPONSE TO SUDDEN GUST LOADINGS

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SUMMARY

A mathematical model of the three-dimensional dynamics of a high-altitude scientific research balloon system perturbed from its equilibrium configuration by an arbitrary gust loading is developed. The platform is modelled as a system of four coupled pendula. The equations of motion are developed in the Lagrangian formalism assuming a small-angle approximation. Three-dimensional pendulation, torsion and precessional motion due to Coriolis forces are considered. Aerodynamic and viscous damping effects on the pendulatory and torsional motions are included.

A general model of the gust field incident upon the balloon system is also developed.

The report is concluded with a description of the digital computer simulation program and a guide to its use.

INTRODUCTION

The use of high-altitude balloon systems as stable platforms for scientific studies of the earth's atmosphere requires a knowledge of the dynamics of the system for proper data interpretation. This knowledge is especially critical in studies of the vertical distributions of atmospheric trace constituents and temperature, since data interpretation is highly sensitive to the attitude of the data-collecting instrument. It is well known that most systems remain stable at float altitude, but we need a mathematical model which can predict the attitude and motion of the system with sufficient accuracy to assure accurate interpretation and reduction of data.

In reality, the motion of a perturbed balloon system at float

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altitude is extremely complex, involving interactions between several different types of oscillation such as bounce, pendulation, rotation and precession. Further complexity may be introduced by such factors as damping (boundary layer) forces, air turbulence, cable elasticity and motion induced by the support mechanisms of the system (i.e., independent motion of a particular system element).

A number of models have been proposed to account for some of these factors. Morris and Stefan (ref. 1) have studied plane pendulation, bounce, plane torsional motion (including damping) and the atmospheric environment for a two element system (balloon and gondola). Emslie, et.al. (ref.2) have analytically and experimentally considered balloon bounce, the thermodynamics of the enclosed gas, and heat transfer between atmosphere, balloon fabric and enclosed gas. The azimuthal rotations of a balloon-gondola system have been studied in detail, both theoretically and experimentally, by Germeles, et.al. (ref.3), with particular emphasis on the aerodynamic damping and inertia of the system. Further study of the aerodynamic parameters of a rotating sphere has been done by several investigators (refs.4,5,6,7,8 and 9).

To date, there appears to have been no serious effort to develop a detailed general model defining the gross motions of a balloon system in three dimensions. This report is intended to develop such a model. Admittedly, the model will not be completely general, but as further work is done on this subject, we may expect further sophistication and generality in a three-dimensional model. The balloon system considered in this report is the NASA-Langley/AFCRL LACATE (Lower Atmosphere Composition And Temperature Experiment) system which is to be flown at 150 km altitude. The system consists of a 39 million cubic foot capacity balloon, a "load bar" containing balloon control equipment and cable reel, a gondola recovery parachute package and a research payload gondola. This system is configured as a system of four coupled pendula.

A cursory derivation of the equations of motion (EOM) for plane damped pendulation for this system was done by Hinton of NASA-Langley. This report will investigate (1) three-dimensional pendulation, (2) torsional motion, (3) aerodynamic and viscous damping effects on pendulatory and torsional motion, and (4) precessional motion due to Coriolis forces. We shall also attempt to develop a detailed general model for gust loading in three dimensions and study possible gust loading configurations. Since we are concerned primarily with the gross motions of the system, we will not investigate such factors as cable elasticity, statistical variation or turbulence in the gust field, bounce or atmospheric thermodynamics. This is done in the interest of keeping the analysis mathematically tractable.

SYMBOLS

a	balloon-to loadbar cable length = 72 feet
A_k	surface area of kth element
$[A]$	dynamic coupling coefficient matrix
$[B]$	static coupling coefficient matrix
c	parachute package-to-payload cable length = 5 feet
C_k	drag coefficient of kth element
$[D]$	damping matrix
f	loadbar-to-parachute package cable length = 1310 feet
F_{cor}	Coriolis force
g	gravitational acceleration at float altitude
h_k	length of kth cylinder
I_k	moment of inertia of kth element
J	impulsive torque
m_k	mass of kth element
m_1	m_e
m_2	$m_e + m_p$
m_3	$m_e + m_p + m_s$
m_4	$m_e + m_p + m_s + m_b$
N	torque
P_σ	linear impulse
q_k	generalized coordinate of kth element
Q_k	nonconservative force on kth element
r_b	balloon radius = 210 feet

R_k	radius of kth cylinder
t	time
T	kinetic energy
v_k	linear velocity of kth element
V	potential energy
x, y, z	Cartesian coordinates
ζ	distance from element center of mass (azimuth plane)
η_k	damping constant of kth element
θ_k	deflection angle off vertical, kth element
λ	geocentric latitude
μ	viscosity of air at float altitude
ρ	density of air at float altitude
τ_k	torsional constant of kth element
$[\tau]$	torsional coupling coefficient matrix
ϕ_k	azimuthal deflection angle, kth element
χ	angle of rotation about azimuth plane
ψ	gust axis incidence angle relative to horizontal
ω_0	rotation rate of earth
ω_k	angular velocity of kth element produced by gust

SUBSCRIPTS

1	initial value
2	final value
k	system element (b, s, p or e)
b	balloon
s	load bar
p	parachute package
e	payload package

FORMULATION OF PROBLEM

The analysis will be carried out using a spherical polar coordinate system and an idealized model of the balloon system as shown in Figure 1. The origin of this coordinate system is taken to coincide with the geometric center of the balloon. The z-axis is taken as the local vertical and is positive downward. Similar systems are set up individually for the load bar, parachute package and gondola, each with the z-axis as the local vertical and the same positive sense as the balloon z-axis. This system facilitates the definition of angular deflections for each element of the system, since, proceeding down from the balloon, the total angular deflection of the system down to the element in question is additive with respect to the balloon center. This also makes algebraic work considerably more manageable.

With regard to the system model, we make some basic idealizations. Since the moment of inertia of the balloon alone is much greater than that of any of the other system elements, the balloon is assumed to be a spherical shell with an extremely small thickness-to-radius ratio(ref.3). Elastic deformation of this shape due to gust loading will be neglected. Secondly, we idealize the load bar, parachute package and gondola as right circular cylinders; these are not necessarily their actual shapes, but they will be defined as cylinders with moments of inertia equivalent to the actual shape to simplify rigid body computations. Analysis in a Eulerian system was considered, but was deemed too difficult to attempt for the problem at hand; the Euler approach may, however, be more general and should be studied in the future.

The equations of motion are developed in the Lagrangian formalism. Since angular deflections due to gust loading are anticipated to be no greater than 0.01 radians during flight (ref.10), the small-angle approximation is invoked to simplify the mathematics somewhat. We will no consider bounce in this report; translational motion of the balloon center of mass (CM) is included while assuming the balloon CM to remain at its initial equilibrium (float) altitude. Thus, we must deal with a system having eight degrees of freedom. The θ and φ deflections and their corresponding angular velocities are found for each system element individually; obviously, moving down from the balloon toward the payload, the gross motion of the system becomes more complex due to the motions of the elements above the one under study. Pendulation (with and without damping), torsional (azimuthal) motion (with and without damping) and precessional motion will be considered separately. In this manner, we will be able to examine the character of each type of motion alone; then, when we consider various combinations of motion, we will have some means of judging the degree to which each type of motion contributes to the overall motion of the system.

The Lagrangian EOM are derived in the standard form

$$\frac{d}{dt}\frac{\partial T}{\partial \dot{q}_k} - \frac{\partial T}{\partial q_k} + \frac{\partial V}{\partial q_k} = Q_k \qquad (1)$$

where, for the problem at hand, the generalized coordinates q_k are the eight angles $\theta_b, \varphi_b, \theta_s, \varphi_s, \theta_p, \varphi_p, \theta_e$ and φ_e. The generalized nonconservative forces Q_k take into account the aerodynamic and viscous damping terms. We should note at this point that the EOM developed in the following sections are not carried to a closed form analytical solution. Solutions could be found in closed form in principle, but the algebraic work required to do so would be prohibitive. Hence, the EOM are developed to the point where they are easily integrable numerically. Terms due to separate motion types may be added together and then integrated as a whole to obtain the overall motion.

After the EOM are derived, we then address the problem of defining the gust loading model, since the gust velocity field configuration incident on the system will define the initial conditions for solution of the EOM. No attempt will be made in this report to define the stability criteria for system motions; this problem will be taken up in a future study.

DEVELOPMENT OF THE EQUATIONS OF MOTION

Pendulatory Motion

We first consider pendulation without the inclusion of damping terms. The total kinetic and potential energies are

$$T = \tfrac{1}{2} \sum_k [m_k v_k^2 + I_k(\dot{\theta}_k^2 + \dot{\varphi}_k^2)] \quad , \quad k = b,s,p \text{ and } e \qquad (2)$$

and

$$\begin{aligned} V = {} & m_s g r_b(1-\cos\theta_b)+a(1-\cos\theta_s) + \\ & m_p g r_b(1-\cos\theta_b)+a(1-\cos\theta_s)+f(1-\cos\theta_p) + \\ & m_e g r_b(1-\cos\theta_b)+a(1-\cos\theta_s)+f(1-\cos\theta_p)+c(1-\cos\theta_e) \end{aligned} \qquad (3)$$

The linear velocities v_k are first defined in a Cartesian coordinate system by their x,y,z components and then transformed to the spherical polar representation. In Cartesian coordinates

$$v_{b_i} = \alpha_i \quad , \quad v_b = v_{b_x} + v_{b_y} + v_{b_z} \tag{4}$$

$$v_{s_i} = \alpha_i + \beta_i \quad , \quad v_s = v_{s_x} + v_{s_y} + v_{s_z} \tag{5}$$

$$v_{p_i} = \alpha_i + \beta_i + \gamma_i \quad , \quad v_p = v_{p_x} + v_{p_y} + v_{p_z} \tag{6}$$

$$v_{e_i} = \alpha_i + \beta_i + \gamma_i + \delta_i \quad , \quad v_e = v_{e_x} + v_{e_y} + v_{e_z} \tag{7}$$

where i = x,y,z successively. Transformation to spherical polar coordinates is made through the variables $\alpha, \beta, \gamma, \delta$. For the balloon we have

$$\alpha_x = r_b(\dot{\theta}_b \cos\theta_b \cos\varphi_b - \dot{\varphi}_b \sin\theta_b \sin\varphi_b)$$

$$\alpha_y = r_b(\dot{\theta}_b \cos\theta_b \sin\varphi_b + \dot{\varphi}_b \sin\theta_b \cos\varphi_b) \tag{8}$$

$$\alpha_z = -r_b \dot{\theta}_b \sin\ _b$$

The transformation relations for the load bar(β), parachute package(γ) and gondola(δ) are of the same form as Equation (8), with r_b replaced by a,f,c and the angle subscripts replaced by s,p,e respectively.

With T and V now completely specified, the EOM can be developed from Equation (1). Taking the appropriate derivatives and after considerable algebraic manipulation, we obtain eight EOM corresponding to the eight degrees of freedom $\theta_b, \varphi_b, \theta_s, \varphi_s, \theta_p, \varphi_p, \theta_e$ and φ_e. We find that these EOM are represented in the format of a system of eight simultaneous linear equations, i.e.,

$$\begin{bmatrix} A_{11} & A_{12} & \cdots & A_{18} \\ A_{21} & A_{22} & \cdots & A_{28} \\ A_{31} & \cdot & & \cdot \\ A_{41} & \cdot & & \cdot \\ A_{51} & \cdot & & \cdot \\ A_{61} & \cdot & & \cdot \\ A_{71} & \cdot & & \cdot \\ A_{81} & A_{82} & & A_{88} \end{bmatrix} \begin{bmatrix} \ddot{\theta}_b \\ \ddot{\varphi}_b \\ \ddot{\theta}_s \\ \ddot{\varphi}_s \\ \ddot{\theta}_p \\ \ddot{\varphi}_p \\ \ddot{\theta}_e \\ \ddot{\varphi}_e \end{bmatrix} = \begin{bmatrix} B_1 \\ B_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ B_8 \end{bmatrix} \tag{9}$$

or in more compact matrix notation

$$[A][\ddot{q}] = [B] \qquad (10)$$

where $[A]$ is the dynamic coupling coefficient matrix containing the coefficients of all terms involving the second derivative with respect to time, and $[B]$ is the static coupling coefficient matrix containing all other terms (including damping terms). The elements of $[A]$ and $[B]$ are given in the Appendix A.

It is clear that the pendulation EOM exhibit rather strong dynamic coupling for the entire balloon system; $[B]$ indicates the presence of static coupling as well. This is not surprising, considering the complexity of the problem. Equation (10) may be solved for the desired solution matrix $[\ddot{q}]$ using the Gaussian elimination algorithm (or method of detached coefficients[11]), and the resulting equations integrated directly to obtain $[\dot{q}]$ and $[q]$. The extremely high degree of dynamic and static coupling, however, makes direct analytic closed-form solution and integration prohibitively cumbersome as far as algebraic work is concerned.

Torsional Motion

The torsional EOM derivation will be confined to motion in the azimuth plane. This is done to avoid using a Eulerian angle formalism, for the same reasons as mentioned before. This is not restrictive for our purposes; since we use a small-angle approximation, motion in the θ-direction will be small compared to the motion in the azimuth plane. When pendulation and torsion are considered together, the torsional motion may be considered superimposable onto the pendulatory motion.

The kinetic and potential energies are written[12,13]

$$T = \tfrac{1}{2}(I_b\dot{\varphi}_b^2 + I_s\dot{\varphi}_s^2 + I_p\dot{\varphi}_p^2 + I_e\dot{\varphi}_e^2)$$

$$V = \tfrac{1}{2}\tau_s(\varphi_b-\varphi_s)^2 + \tau_p(\varphi_s-\varphi_p)^2 + \tau_e(\varphi_p-\varphi_e)^2 \qquad (11)$$

where the torsion constants τ_k are defined by[1]

$$\tau_s = -m_s g R_s^2/(r_b+a) \quad ; \quad \tau_p = -m_p g R_p^2/(r_b+a+f+h_s)$$

$$\tau_e = -m_e g R_e^2/(r_b+a+f+c+h_s+h_p) \qquad (12)$$

The Lagrangian EOM for the undamped case are[12]

$$I_b\ddot{\varphi}_b + \tau_s(\varphi_b-\varphi_s) = 0$$
$$I_s\ddot{\varphi}_s - \tau_s(\varphi_b-\varphi_s) + \tau_p(\varphi_s-\varphi_p) = 0 \quad (13)$$
$$I_p\ddot{\varphi}_p - \tau_p(\varphi_s-\varphi_p) + \tau_e(\varphi_p-\varphi_e) = 0$$
$$I_e\ddot{\varphi}_e - \tau_e(\varphi_p-\varphi_e) = 0$$

In order to include viscous and aerodynamic damping effects, we define the damping constants η_k[1]

$$\eta_b = 2.5(\rho\mu)^{\frac{1}{2}} r_b^4 |\dot{\varphi}|_b^{\frac{1}{2}} \qquad \eta_s = 2.5(\rho\mu)^{\frac{1}{2}} R_s^4 |\dot{\varphi}|_s^{\frac{1}{2}}$$
$$\eta_p = 2.5(\rho\mu)^{\frac{1}{2}} R_p^4 |\dot{\varphi}|_p^{\frac{1}{2}} \qquad \eta_e = 2.5(\rho\mu)^{\frac{1}{2}} R_e^4 |\dot{\varphi}|_e^{\frac{1}{2}} \quad (14)$$

so that the EOM for the damped case are

$$I_b\ddot{\varphi}_b = -\eta_b\dot{\varphi}_b - \tau_s(\varphi_b-\varphi_s)$$
$$I_s\ddot{\varphi}_s = -\eta_s\dot{\varphi}_s + \tau_s\varphi_b - (\tau_p+\tau_s)\varphi_s + \tau_p\varphi_p$$
$$I_p\ddot{\varphi}_p = -\eta_p\dot{\varphi}_p + \tau_p\varphi_s - (\tau_p+\tau_e)\varphi_p + \tau_e\varphi_e \quad (15)$$
$$I_e\ddot{\varphi}_e = -\eta_e\dot{\varphi}_e + \tau_e(\varphi_p-\varphi_e)$$

The EOM for both the undamped and damped cases show the existence of only static coupling; hence the system of equations in both cases may be integrated directly. Note also that for each case a system of only four EOM is obtained, in keeping with our consideration of motion in the azimuth plane.

In the digital computer program, the EOM are solved in the forms given by Equations (13) and (15). Analytic solutions to these EOM may be obtained by assuming solutions of the form $\varphi_i = F_i e^{kt}$, i=b,s,p,e. For nontrivial solutions, the EOM must satisfy the condition

$$\sum_{i=1}^{8} f_i k_i = 0 \quad (16)$$

where the f_i are constant coefficients of the the k^i; this equation is of eighth degree in k and thus has eight roots. Since the $f_i > 0$, there exist no real roots > 0[13], but real roots < 0 may exist. Complex roots are also admissible and would occur in conjugate pairs. Since we require $\varphi_i \rightarrow 0$ as $t \rightarrow \infty$, the real parts of complex roots must be < 0. If we assume the existence of α complex roots of the form $k=p+iq$ and β real negative roots $u(u>0)$, we may write the solutions as

$$\varphi_i = \sum_{j=1}^{\alpha} F_{ij} e^{-p_j t} \sin(q_j t + \phi_{ij}) + \sum_{m=1}^{\beta} G_{im} e^{-u_m t} \qquad (17)$$

so that solutions can be constructed once the k_i are known, but the algebraic work would become extremely cumbersome. That sinusoidal solutions of this form do indeed exist is verified by the computer program results, which will be discussed later.

In order to superimpose torsional motion upon the pendulatory motion, we must define the analogous forms of the matrices $[A]$ and $[B]$ as defined in Equation (9). We set $A_{i1}=A_{i3}=A_{i5}=A_{i7}=0$ and $B_1=B_3=B_5=B_7=0$; also, $A_{i2}=I_b, A_{i4}=I_s, A_{i6}=I_p, A_{i8}=I_e$. B_2, B_4, B_6 and B_8 will correspond to the right hand sides of the EOM; thus, the elements B_i corresponding to torsional terms can be added to the pendulation $[B]$ by introducing a new eight-element torsional coupling coefficient matrix $[T]$, which is also a column matrix.

Inclusion of Damping Effects

Damping forces are nonconservative in nature and are included in the Q_k term of Equation (1). The work of this section is applicable to both pendulatory and torsional motion. Following the lead of Germeles, et.al.[3], we assume viscous damping on the balloon proper, and with spherical symmetry for the balloon, we have

$$\begin{aligned} Q_{b_\theta} &= 2.5(\rho\mu)^{\frac{1}{2}} r_b^3 |\dot{\theta}_b|^{\frac{1}{2}} \dot{\theta}_b \\ Q_b &= 2.5(\rho\mu)^{\frac{1}{2}} r_b^3 |\dot{\varphi}_b|^{\frac{1}{2}} \dot{\varphi}_b \end{aligned} \qquad (18)$$

Aerodynamic damping is assumed to affect the other system elements, and is derived from the definition of the aerodynamic drag coefficient. Drag on supporting cables is neglected, since the surface area of the cables is small compared to that of the other system elements. Hence

$$\begin{aligned} Q_s &= \tfrac{1}{2}\rho A_s C_s v_s^2 (r_b+a) &&= \tfrac{1}{2} A_s C_s v_s \; v_s(r_b+a) \\ Q_p &= \tfrac{1}{2}\rho A_p C_p v_p^2 (r_b+a+f) &&= \tfrac{1}{2} A_p C_p v_p \; v_p(r_b+a+f) \\ Q_e &= \tfrac{1}{2}\rho A_e C_e v_e^2 (r_b+a+f+c) &&= \tfrac{1}{2} A_e C_e v_e \; v_e(r_b+a+f+c) \end{aligned} \qquad (19)$$

To be properly added to the matrix $[B]$, Equations (19) must be separated into their θ and φ components. Transforming the v_k by the relations[14]

$$\begin{aligned} v_{s_\theta} &= r_b\dot\theta_b + a\dot\theta_s & v_{s_\varphi} &= r_b\dot\varphi_b\theta_b + a\dot\varphi_s\theta_s \\ v_{p_\theta} &= r_b\dot\theta_b + a\dot\theta_s + f\dot\theta_p & v_{p_\varphi} &= r_b\dot\varphi_b\theta_b + a\dot\varphi_s\theta_s + f\dot\varphi_p\theta_p \\ v_{e_\theta} &= r_b\dot\theta_b + a\dot\theta_s + f\dot\theta_p + c\dot\theta_e & v_{e_\varphi} &= r_b\dot\varphi_b\theta_b + a\dot\varphi_s\theta_s + f\dot\varphi_p\theta_p + c\dot\varphi_e\theta_e \end{aligned} \qquad (20)$$

we then have

$$\begin{aligned} Q_{s_\theta} &= \tfrac{1}{2}\rho A_s C_s (r_b+a)(r_b\dot\theta_b + a\dot\theta_s)^2 \\ Q_{p_\theta} &= \tfrac{1}{2}\rho A_p C_p (r_b+a+f)(r_b\dot\theta_b + a\dot\theta_s + f\dot\theta_p)^2 \\ Q_{e_\theta} &= \tfrac{1}{2}\rho A_e C_e (r_b+a+f+c)(r_b\dot\theta_b + a\dot\theta_s + f\dot\theta_p + c\dot\theta_e)^2 \end{aligned} \qquad (21)$$

and

$$\begin{aligned} Q_{s_\varphi} &= \tfrac{1}{2}\rho A_s C_s (r_b+a)(r_b\theta_b\dot\varphi_b + a\theta_s\dot\varphi_s)^2 \\ Q_{p_\varphi} &= \tfrac{1}{2}\rho A_p C_p (r_b+a+f)(r_b\theta_b\dot\varphi_b + a\theta_s\dot\varphi_s + f\theta_p\dot\varphi_p)^2 \\ Q_{e_\varphi} &= \tfrac{1}{2}\rho A_e C_e (r_b+a+f+c)(r_b\theta_b\dot\varphi_b + a\theta_s\dot\varphi_s + f\theta_p\dot\varphi_p + c\theta_e\dot\varphi_e)^2 \end{aligned} \qquad (22)$$

To properly introduce these terms into the $[B]$ matrix, we define a column damping matrix $[D]$ whose elements can be shown to be

$$\begin{aligned} D_1 &= Q_{b_\theta} S_b / m_4 r_b^2 & D_5 &= Q_{p_\theta} S_p / m_2 f^2 \\ D_2 &= Q_{b_\varphi} S_{bb} / m_4 r_b^2 \theta_b^2 & D_6 &= Q_{p_\varphi} S_{pp} / m_2 f^2 \theta_p^2 \\ D_3 &= Q_{s_\theta} S_s / m_3 a^2 & D_7 &= Q_{e_\theta} S_e / m_1 c^2 \\ D_4 &= Q_{s_\varphi} S_{ss} / m_3 a^2 \theta_s^2 & D_8 &= Q_{e_\varphi} S_{ee} / m_1 c^2 \theta_e^2 \end{aligned} \qquad (23)$$

where the S parameters are given in the Appendix. Thus, the inclusion of damping terms can be accomplished by adding the damping matrix $[D]$ to $[B]$, i.e.,

$$[B]_{damped} = [B]_{undamped} + [D] \tag{24}$$

Precessional Motion

Precessional motion in this paper is modeled after the standard Foucault pendulum analysis found in many classical mechanics texts (e.g., Marion[15], Symon[16], Becker[17], or Goldstein[18]). In this framework, we consider motion for the case where $\omega_y=0$ and $\dot{z}=0$ (which is consistent with our neglect of balloon bounce).

The Coriolis force $\vec{F}_{cor} = -2m(\vec{\omega} \times \vec{v})$, when applied through a distance $\vec{r}$, produces an amount of work $W = 2m\,\dot{\vec{r}} \cdot (\vec{\omega} \times \vec{r})$, which may also be written in the Levi-Civita density formalism as

$$W = 2m \sum_{ijk} \epsilon_{ijk}\dot{r}_i\omega_j r_k \tag{25}$$

We consider Equation (25) to be the total energy due to Coriolis forces, so that, in Cartesian coordinates, the Coriolis contribution to the Lagrangian is

$$L_{cor} = -2m[\dot{x}\omega_z y + \dot{y}(\omega_x z - \omega_z x)] \tag{26}$$

Transforming to spherical coordinates and using the small-angle approximation yields the precessional EOM[14,15]

$$\begin{aligned}\ddot{\theta}_b &= 2m_b\omega_o r_b^2[2(\xi_b-\mu_b\varphi_b)\sin\lambda + \xi_b\theta_b\cos\lambda] \\ \ddot{\varphi}_b &= 2m_b\omega_o r_b^2[-2\theta_b(\xi_b\varphi_b+\mu_b)\sin\lambda]\end{aligned} \tag{27}$$

$$\begin{aligned}\ddot{\theta}_s = {}& 2(m_b+m_s)a\omega_o\{2[(r_b\xi_b+a\xi_s)-(r_b\mu_b+a\mu_s)\varphi_s]\sin\lambda \\ & + \theta_s(r_b\xi_b+a\xi_s)\cos\lambda\}\end{aligned} \tag{28}$$

$$\ddot{\varphi}_s = 2(m_b+m_s)a\omega_o\{-2\theta_s[(r_b\xi_b+a\xi_s)\varphi_s+(r_b\mu_b+a\mu_s)]\sin\lambda\}$$

$$\begin{aligned}\ddot{\theta}_p = {}& 2(m_b+m_s+m_p)f\omega_o\{2[(r_b\xi_b+a\xi_s+f\xi_p)-(r_b\mu_b+a\mu_s+f\mu_p)\varphi_p]\sin\lambda \\ & + \theta_p(r_b\xi_b+a\xi_s+f\xi_p)\cos\lambda\}\end{aligned} \tag{29}$$

$$\ddot{\varphi}_p = 2(m_b+m_s+m_p)f\omega_o\left\{-2\theta_p\left[(r_b\xi_b+a\xi_s+f\xi_p)\varphi_p+(r_b\mu_b+a\mu_s+f\mu_p)\right]\sin\lambda\right.$$

$$\begin{aligned}\ddot{\theta}_e = 2(m_b+m_s+m_p+m_e)c\omega_o\{2[(r_b\xi_b+a\xi_s+f\xi_p+c\xi_e) \\ -(r_b\mu_b+a\mu_s+f\mu_p+c\mu_e)\varphi_e]\sin\lambda \\ +\theta_e(r_b\xi_b+a\xi_s+f\xi_p+c\xi_e)\cos\lambda\}\end{aligned}$$

$$\begin{aligned}\ddot{\varphi}_e = 2(m_b+m_s+m_p+m_e)c\omega_o\{-2\theta_e[(r_b\xi_b+a\xi_s+f\xi_p+c\xi_e)\varphi_e \\ +(r_b\mu_b+a\mu_s+f\mu_p+c\mu_e)]\sin\lambda\}\end{aligned} \qquad (30)$$

where for convenience and brevity we use the abbreviations

$$\mu_k = \dot{\theta}_k-\dot{\varphi}_k\theta_k\varphi_k \qquad \xi_k = \dot{\theta}_k\varphi_k + \dot{\varphi}_k\theta_k \qquad k=b,s,p,e$$

As with the torsional EOM, the precessional EOM exhibit only stat-coupling and may be integrated directly. They are added to the pendulation EOM in a fashion similar to that done in the torsional case; likewise, an analytic solution is possible but prohibitively cumbersome. Precessional motion is not expected to affect the motion of the system significantly; this will be discussed later.

GUST LOADING MODELING

The gust loading model may properly be considered to be the most important aspect of the problem, since the character of the gust field will determine the initial conditions(IC) for solution of the EOM. We will try to define the IC in terms of the gust velocity profile incident on the system. Statistical variation in the gust field or gust effects on supporting cables will be neglected, since they are not expected to be significant in a small-angle deflection analysis.

Gust loading is expected to occur suddenly and to last for a specified finite time interval before being "turned off". If this time interval is small compared to the time interval in which the system is in motion after being loaded, the gust model may be developed as an impulsive motion problem.[14] Denote the time of onset of the gust by t_1 and its "turn-off" time by t_2. The linear impulse is defined by

$$P_\sigma = \Delta(mv) = m(v_2 - v_1) = \int_{t_1}^{t_2} F\,dt \qquad (31)$$

and the applied torque by $N = \dot{L} = I\dot{\omega}$. Hence the impulsive torque J is

$$J = \int_{t_1}^{t_2} N\,dt = I(\omega_2 - \omega_1) = I\Delta\omega \qquad (32)$$

If the primary linear impulse P_σ is applied such that its line of action is at distance ς from the CM of the element in question, then $N = F\varsigma$ and hence

$$J = \varsigma\int_{t_1}^{t_2} F\,dt = P_\sigma \varsigma \qquad (33)$$

Equating (32) and (33), the angular velocity change produced by a linear impulse acting at distance ς from the CM is $\Delta\omega = P_\sigma \varsigma / I$. If a number n of different impulses $P_{\sigma i}$ are applied simultaneously at different distances ς_i, then, noting that the $P_{\sigma i}$ and hence also $\Delta\omega$, are now functions of ς_i as well as of time, we have in general

$$\Delta\omega(\varsigma_i) = \frac{1}{I} \sum_{i=1}^{n} P_{\sigma i}(\varsigma_i)\varsigma_i \qquad (34)$$

which gives the differential change in angular velocity produced during the time interval in which the gust acts. We are primarily interested in motion during a specified time interval after the gust loading has occurred. Since damping forces will influence the motion of the system after gust loading, then we may expect $\Delta\omega$ to be diminished by some function of time (perhaps an exponential decay type behavior) $f(t)$ for $t>0$ due to damping. The actual temporal-spatial inter-relationships are not clear at this time and will require further study. Thus, for $t > t_2$ we modify Equation (34) to read

$$\Delta\omega(\varsigma_i) = \frac{1}{I} \sum_{i=1}^{n} P_{\sigma i}(\varsigma_i)\varsigma_i f(t) \qquad (35)$$

We also note that translational motion may also suffer the effect of damping.

Spatial Character of Gust Field

Deferring for the present the question of the temporal factor, let us consider the effects of the spatial character of the gust field upon the system. Since we have assumed spherical symmetry for the balloon and cylindrical symmetry for the other system elements, on velocity field profiles that are asymmetric with respect to the element CM will yield a net rotational motion on that element. The geometry of the problem for the balloon is shown in Fig.2 for a profile whose peak is offset from the CM, and similar geometries exist for the other system elements.

For the moment, confine the analysis to a planar velocity profile parallel to the azimuth plane. Then

$$P^{k}_{\sigma i}(\varsigma_i) = m_k \left[v(\varsigma_i) - v(\varsigma_{i-1}) \right] \qquad (36)$$

and

$$\Delta\omega_k(\varsigma_i) = \frac{1}{I_k} \sum_{i=1}^{n} P^{k}_{\sigma i}(\varsigma_i)\, \varsigma_i\, f(t) \qquad (37)$$

where k = b,s,p or e. Substituting (36) into (40),

$$\Delta\omega_k(\varsigma_i) = \frac{m_k}{I_k} \sum_{i=1}^{n} \left[v(\varsigma_i) - v(\varsigma_{i-1}) \right] \varsigma_i\, f(t) \qquad (38)$$

Writing out the first few terms of (38) will show that, upon adding up all terms, we have

$$\omega_k(\varsigma_n) = \omega_k(\varsigma_o) + \frac{m_k}{I_k} \sum_{i=1}^{n} (n-i+1)\, \varsigma_i \left[v(\varsigma_i) - v(\varsigma_{i-1}) \right] f(t) \qquad (39)$$

By Fig.2, ς_o is located at the CM(also the geometric center), so that no net rotational impulse is produced at that point; only translational motion could be produced at ς_o. Thus, in all cases, $\omega(\varsigma_o)=0$ so that (39) becomes

$$\omega_k(\varsigma_n) = \frac{m_k}{I_k} \sum_{i=1}^{n} (n-i+1)\, \varsigma_i \left[v(\varsigma_i) - v(\varsigma_{i-1}) \right] f(t) \qquad (40)$$

Equation (40) thus gives the total accumulated ω out to distance $\varsigma = \varsigma_n$, but due to the symmetry of the system, this is only half of the total ω which must also include the contributions from $\zeta = 0$ to $\zeta = -\zeta_n$. Hence we must sum over 2n points and (40) now reads

$$\Omega_k = \omega_k(\pm \zeta_n) = \frac{m_k}{I_k} \sum_{i=1}^{2n} (n-i+1)\,\zeta_i \left[v(\zeta_i) - v(\zeta_{i-1})\right] f(t) \tag{41}$$

This expression provides the IC for the problem by defining the net angular velocity change in terms of incident gust velocity profile.

Two- and Three-Dimensional Gust Configurations

The analysis above assumed a planar velocity profile parallel to the azimuth plane. We might also consider planar profiles rotated about the azimuth plane, three-dimensional profiles normal to the z-axis, or more generally, planar and three-dimensional profiles incident on the system at angles off the horizontal (e.g., a gust coming up from below at some specified angle). Consider each case separately, assuming the system at rest prior to load.

We first study a planar profile rotated about the azimuth plane by an angle χ. Assume the characteristic length of the element to be h_k and the point of intersection of the profile at $\zeta = 0$ and the system element occurring at distance h_k' from the CM along the body axis. In keeping with the coordinate system definition, $h_k' > 0$ below the CM. At angle χ, the body will see a ζ different from what it saw in the azimuth plane, i.e.,

$$\zeta' = \zeta \sec \chi \tag{42}$$

This equation, however, becomes singular as $\chi \to \pm \pi/2$. But we are concerned only with the effect of the gust over h_k. Denote $\zeta > 0$ by ζ_+ and $\zeta < 0$ by ζ_-. Then from Fig.3, we find that as $\chi \to \pm \pi/2$ the body effectively sees

$$\begin{aligned} &\zeta_+' \to h_k' + \tfrac{1}{2}h_k , \quad \zeta_-' \to \tfrac{1}{2}h_k - h_k' , \quad \begin{pmatrix}90^\circ\\270^\circ\end{pmatrix} < \chi < \begin{pmatrix}180^\circ\\360^\circ\end{pmatrix} \\ &\zeta_+' \to \tfrac{1}{2}h_k - h_k' , \quad \zeta_-' \quad h_k' + \tfrac{1}{2}h_k , \quad \begin{pmatrix}0^\circ\\180^\circ\end{pmatrix} < \chi < \begin{pmatrix}90^\circ\\270^\circ\end{pmatrix} \end{aligned} \tag{43}$$

Equations (42) and (43) provide further generalization of (41), as we can now specify Ω for any planar profile rotated about the azimuth plane, observing the restrictions of Equation (43); the cases $\chi = 0$ and $\chi = \pi$ are included in this generality due to (42).

Now extend the analysis to a three-dimensional profile normal to the z-axis(Fig.4). Such a profile may consist of a series of identical parallel planar profiles "stacked" one upon another and either parallel to or rotated about the azimuth plane, or a profile whose volume shape is that of a body of revolution. The geometry for a planar stacked profile is that shown in Fig.4, and is an extension of the profile shape used in the derivation of Equation (41). For the stacked profile rotated about the azimuth plane (Fig.5), we assume that there exist a number m of planar profiles parallel to each other rotated about the azimuth plane at angle χ. For each planar the profile, the element will see a different ζ'_j and hence will experience a different net angular velocity change Ω_j. The total Ω_k produced on each element is then

$$\Omega_k^{fin} = \frac{1}{m} \sum_{j=1}^{m} \Omega_{kj} \tag{44}$$

observing the restrictions of (43), and with (42) modified to

$$\zeta'_j = \zeta_j \sec \chi \tag{45}$$

For the case of a profile whose shape is that of a body of revolution, regard the profile as a number q of planar parallel stacked profiles, each parallel to the azimuth plane(Fig.6). It is clear that the spatial character of each such profile is dependent on the distance z from the spherical coordinate system origin, i.e., we have $v(\zeta_i) \longrightarrow v(\zeta_i, z)$. The effective velocity profile then becomes

$$v(\zeta_i, z) = \frac{1}{q} \sum_{i=1}^{q} v_i(\zeta_i, z) \tag{46}$$

so that Equation (41) should now read

$$\Omega_k^q = \frac{m_k}{I_k} \sum_{i=1}^{2n} (n-i+1)\, \zeta_i \left[v(\zeta_i, z) - v(\zeta_{i+1}, z) \right] f(t) \tag{47}$$

In general, it is possible for any gust to approach the balloon system at some angle Ψ relative to the horizontal(Fig.6). For a given gust configuration, the variable under study(denoted arbitrarily here by A) will have a horizontal component $A\cos\Psi$, and a vertical component $A\sin\Psi$. These components must be taken into account and defined before proceeding with a given computation. For this study, we would be interested in the horizontal component.

We have said nothing about the definition of the velocity profile itself. For the LACATE mission, Davis[19] indicates that a gust may load the system for a time interval of 6 seconds and have a peak velocity of 4.0 knots. The time history of this load would be a step function, and the spatial shape is expected to be a $(1 - \cos^2\epsilon)$ type waveform spread over a distance of about 300 meters. Thus, we would define our velocity profile by

$$v(\zeta_i) = \begin{cases} \frac{1}{2}v_{peak}\left[1 - \cos^2 \frac{\pi}{\lambda}(-\zeta_i - \nu - \lambda)\right], & \zeta < 0 \\ \frac{1}{2}v_{peak}\left[1 - \cos^2 \frac{\pi}{\lambda}(\zeta_i - \nu - \lambda)\right], & \zeta > 0 \end{cases} \qquad (48)$$

where ν is the distance ζ at which the peak of the profile occurs and λ is the profile quarter-wavelength.

Indeed, other balloon missions may use other velocity profiles. They may also anticipate gust field configurations other than those discussed in this paper, but most of them will probably be reducible to one of the cases discussed here. As more knowledge of the nature of gust fields that occur in reality is gained, it will be possible to make this gust loading model more general and better able to describe the gust as it occurs in nature.

CONCLUSIONS

We will deal with no lengthy conclusions in this report, as it is felt that such conclusions should be backed up with more in-depth study, particularly with respect to the stability criteria for the system. Therefore, we will defer such discussion until the follow-up study on the stability criteria has been completed. Here, we will make only passing mention of certain observations that may be made from the study and computer program results.

The motion of the system is extremely complex, as we might intuitively expect. This is definitely borne out by a number of test cases run on the computer program. As we noted in the analysis section of this report, strong static and dynamic coupling between the various elements of the system is evidenced by the computer program. We also find that the contributions due to the Coriolis effect are very small indeed, as we would expect. Damping effects appear to be negligible for approximately the first three minutes in any given test case; after this time, these effects gradually begin to be more significant, although they do not appear to become an overriding or even major factor in the overall system motion. However, when we consider torsional motion alone, the damping effects do appear to become a significant part of the motion after a few minutes.

The most significant type of motion appears to be the pendulatory motion. The magnitude of this motion varies from component to component of the balloon system. The balloon exhibits, in a typically convergent set of solutions, the most pronounced degree of pendulation. This would be expected from our current model, since we have assumed that the gust is applied spatially only over the dimensions of the balloon; subsequent motion of the other system components is assumed to be induced by the motion of the balloon. We find that the balloon may take rather large excursions in both the θ and φ directions; in the same test case, the load bar made major excursions only in the φ direction, although to a lesser degree than did the parachute package. The payload made only small excursions in the θ direction; this fact is further backed up by preliminary data from the actual LACATE flight, which indicated very little motion in the payload package.

It may also be noted that for the case of simple damped pendulatory motion in a plane, the analytical results obtained in this study reduce to those obtained by Hinton[10].

Although we have been remiss in making any really concrete conclusions in this report, we feel that more accurate and meaningful conclusions can be drawn after further study into the stability question, and after LACATE flight data are available to verify the correctness of the model proposed here.

COMPUTER PROGRAM STRUCTURE AND USAGE

Program LACATE consists of the driver program LACATE and attendant subroutines GUST, DIFSUB, PEDERV, MATINV, DIFFUN, PEND, TORS, CORL, DAMP, BOSS and PLOTS. The basic program structure is shown in Figure 7 . The program has been modularized by function to facilitate its use so that only those modules that are desired for a particular run are executed. The gust model module, which provides the $\dot{\theta}_b$ and $\dot{\varphi}_b$ initial conditions, constitutes subroutine GUST. Subroutine DIFSUB is the main integrating module, and has subroutine DIFFUN as an externally defined argument. DIFFUN is used to define the derivatives of the equations of motion to be integrated. It contains logic used to call up the pendulation module PEND, the torsion module TORS, and/or the Coriolis module CORL as desired. The module PEND also has a logical flag that may be set to call the damping module DAMP if desired. A short discussion of each module follows; for more detailed information, the user should consult the program listing documentation.

Under the current program configuration, motion of the balloon simulated over a 30 second time interval requires approximately 60 seconds of CPU time to compile and execute; it requires $45K_8$ locations of core and expends 400 O/S calls, and is designed for use on the CDC 6600.

LACATE

This is the mainline program which reads all NAMELIST inputs, calls the gust module to set up initial conditions, sets up the inputs for DIFSUB, and makes the call to DIFSUB, which integrates the equations of motion. This routine also controls all printed, punched and plotted output functions.

GUST

This subroutine computes the initial conditions for the angular velocities of the balloon. It requires as inputs the following variables read from cards:

- ALPHA – the quarter wavelength of the sinusoidally shaped gust velocity profile.
- NU – the distance ζ at which the peak of the gust velocity profile occurs.
- NRB – number of ζ points to be used.

It provides as output the values TDOTB and DOTB, which are the initial conditions on $\dot{\theta}_b$ and $\dot{\varphi}_b$, respectively.

DIFSUB

This subroutine integrates the system of first order differential equations of motion. In our case, we have a "system of systems" of ordinary differential equations. It requires as inputs the data in NAMELIST /DIF1/ . The equations to be integrated are defined and set up in DIFFUN.

DIFFUN

Subroutine DIFFUN computes the scaled derivatives and sets up the equations of motion to be integrated by DIFSUB. By setting the logical flags appropriately, the user may choose any desired combination of the modules PEND, TORS and CORL. After this has been done, the total contribution from each module is added up to give a cumulative total due to the combinations before returning to DIFSUB for integration. If a module is not used, its contribution is automatically preset to zero.

PEND

Subroutine PEND sets up the pendulatory equations of motion. The damping module DAMP may be called, if desired, to add in the contributions of viscous and aerodynamic damping.

TORS

This subroutine sets up the equations of motion for plane torsional motion. This module already contains its own damping terms.

CORL

Subroutine CORL sets up the equations of motion for inclusion of the Coriolis effect on the motion of the system.

DAMP

Subroutine DAMP computes the viscous and aerodynamic damping terms to be added into the pendulation module. The damping terms are passed back to PEND via the D(I) array and added to the B(I) array in PEND.

BOSS

Subroutine BOSS is a SNOBOL 4.0 generated routine which solves a system of linear equations represented by the matrix equation $[A][\ddot{q}] = [B]$. BOSS is utilized only by subroutine PEND to solve the system of eight linear equations of motion. The algorithm employed is the method of detached coefficients, alternatively called the method of Gaussian elimination.

PLOTS

This routine calls up the Calcomp plotting routines TPPLOT and AVPLOT.

Sample inputs, outputs and a program listing are given in Appendix B.

PLOTTING ROUTINES FOR LACATE

Two post-processor plotting routines have been written to provide plots for program LACATE. These are programs TPBLOT and AVPLOT.

PROGRAM TPPLOT

This program uses the punched output of the angles θ and φ for each component of the balloon system from program LACATE to provide a plot of THETA versus PHI. A point is plotted after each pass through DIFSUB, so the user may observe the spatial motion of each component as seen from above that component. All four plots (balloon, load bar, parachute package and payload) are plotted together, with the same scaling factors, to provide a comparative view of the magnitude of each component's motion relative to the other components.

The program is written for the Calcomp plotter, and requires as inputs the punched output of the angles from DIFSUB. The number of passes through DIFSUB, and hence the number of punched cards, is denoted by the variable NB, which is set by the user. The scaling may also be reset by the user by changing the adjusted minimum AMIN and scale factor ASCF as dictated by the range of data being dealt with; this will allow the user to use as much space on the plotting paper as possible in order to obtain the best detail.

The program may be run successfully in 50 seconds, $50K_8$ core and 700 O/S calls; No. 301 Red plotting paper is recommended.

PROGRAM AVPLOT

Program AVPLOT is a Calcomp routine intended to provide plots of the solutions of the equations of motion as a function of time. It requires as inputs the punched card output from LACATE for the angular velocities as well as the angles. At this writing, however, AVPLOT has not been completely debugged and tested, and thus further discussion of it will be deferred until future updates on LACATE.

CONCLUDING REMARKS

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APPENDIX A

ELEMENTS OF THE DYNAMIC AND STATIC COUPLING COEFFICIENT MATRICES

For brevity in writing out the terms of the $[A]$ and $[B]$ matrices, we first introduce the following expressions:

$$S_b = (I_b/m_4 r_b^2 + 1)^{-1} \qquad S_{bb} = (I_b/m_4 r_b \theta_b^2 + 1)^{-1}$$

$$S_s = (I_s/m_3 a^2 + 1)^{-1} \qquad S_{ss} = (I_s/m_3 a\,\theta_s^2 + 1)^{-1}$$

$$S_p = (I_p/m_2 f^2 + 1)^{-1} \qquad S_{pp} = (I_p/m_2 f\,\theta_p^2 + 1)^{-1}$$

$$S_e = (I_e/m_1 c^2 + 1)^{-1} \qquad S_{ee} = (I_e/m_1 c\,\theta_e^2 + 1)^{-1}$$

The elements of the dynamic coupling coefficient matrix $[A]$ are then written

$$A_{12}=A_{14}=A_{21}=A_{32}=A_{34}=A_{43}=A_{56}=A_{58}=A_{65}=A_{76}=A_{78}=A_{87} = 0$$

$$A_{11}=A_{22}=A_{33}=A_{44}=A_{55}=A_{66}=A_{77}=A_{88} = 1$$

$$A_{13} = m_3 a S_b/m_4 r_b$$

$$A_{15} = m_2 f S_b/m_4 r_b$$

$$A_{16} = m_2 f\ {}_p(\varphi_b - \varphi_p)S_b/m_4 r_b$$

$$A_{17} = m_1 c S_b/m_4 r_b$$

$$A_{18} = m_1 c\,\theta_e(\varphi_b - \varphi_e)S_b/m_4 r_b$$

$$A_{23} = A_{24} = m_3 a \varphi_s S_{bb}/m_4 r_b \theta_b$$

$$A_{25} = A_{26} = m_2 f \varphi_p S_{bb}/m_4 r_b \theta_b$$

$$A_{27} = A_{28} = m_1 c \varphi_e S_{bb}/m_4 r_b \theta_b$$

$$A_{31} = r_b S_s/a$$

$$A_{35} = m_2 f S_s/m_3 a$$

$$A_{36} = m_2 f \theta_p (\varphi_s - \varphi_p) S_s / m_3 a$$

$$A_{37} = m_1 c S_s / m_3 a$$

$$A_{38} = m_1 c \theta_e (\varphi_s - \varphi_e) S_s / m_3 a$$

$$A_{41} = r_b \varphi_b S_{ss} / a \theta_s \quad = A_{42}$$

$$A_{45} = A_{46} = m_2 f \varphi_p S_{ss} / m_3 a \theta_s$$

$$A_{47} = A_{48} = m_1 c \varphi_e S_{ss} / m_3 a \theta_s$$

$$A_{51} = r_b S_p / f$$

$$A_{52} = r_b \theta_b (\varphi_p - \varphi_b) S_p / f$$

$$A_{53} = a S_p / f$$

$$A_{54} = a \theta_s (\varphi_p - \varphi_s) S_p / f$$

$$A_{57} = m_1 c S_p / m_2 f$$

$$A_{61} = A_{62} = r_b \varphi_b S_{pp} / f \theta_p$$

$$A_{63} = A_{64} = a \varphi_s S_{pp} / f \theta_p$$

$$A_{67} = A_{68} = m_1 c \varphi_e S_{pp} / m_2 f \theta_p$$

$$A_{71} = r_b S_e / c$$

$$A_{72} = r_b \theta_b (\varphi_e - \varphi_b) S_e / c$$

$$A_{73} = a S_e / c$$

$$A_{74} = a \theta_s (\varphi_e - \varphi_s) S_e / c$$

$$A_{75} = f S_e / c$$

$$A_{81} = A_{82} = r_b \varphi_b S_{ee} / c \theta_e$$

$$A_{83} = A_{84} = a\varphi_s S_{ee}/c\,\theta_e$$

$$A_{85} = A_{86} = f\varphi_p S_{ee}/c\,\theta_e$$

and the elements of the column static coupling coefficient matrix $[B]$ are written

$$\begin{aligned} B_1 = S_b\{&\dot{\varphi}_b^2\theta_b - m_3(-a\dot{\varphi}_s^2\theta_s + g\theta_b)/m_4 r_b \\ &- m_2 f[2\dot{\theta}_p\dot{\varphi}_p(\varphi_b-\varphi_p) - \dot{\varphi}_p^2\theta_p + \dot{\theta}_p^2(\theta_b-\theta_p)]/m_4 r_b \\ &- m_1 c[2\dot{\theta}_e\dot{\varphi}_e(\varphi_b-\varphi_e) - \dot{\varphi}_e^2\theta_e + \dot{\theta}_e^2(\theta_b-\theta_e)]/m_4 r_b\} \end{aligned}$$

$$B_2 = S_{bb}\{-2(m_3 a\dot{\theta}_s\dot{\varphi}_s + m_2 f\dot{\theta}_p\dot{\varphi}_p + m_1 c\dot{\theta}_e\dot{\varphi}_e)/m_4 r_b\theta_b \quad - \quad 2\dot{\theta}_b\dot{\varphi}_b/\theta_b\}$$

$$\begin{aligned} B_3 = S_s\{&\dot{\varphi}_s^2\theta_s - (-r_b\dot{\varphi}_b^2\theta_b + g\theta_s)/a \\ &- m_2 f[2\dot{\theta}_p\dot{\varphi}_p(\varphi_s-\varphi_p) - \dot{\varphi}_p^2\theta_p + \dot{\theta}_p^2(\theta_s-\theta_p)]/m_3 a \\ &- m_1 c[2\dot{\theta}_e\dot{\varphi}_e(\varphi_s-\varphi_e) - \dot{\varphi}_e^2\theta_e + \dot{\theta}_e^2(\theta_s-\theta_e)]/m_3 a\} \end{aligned}$$

$$B_4 = S_{ss}\{-2(m_3 r_b\dot{\theta}_b\dot{\varphi}_b + m_2 f\dot{\theta}_p\dot{\varphi}_p + m_1 c\dot{\theta}_e\dot{\varphi}_e)/m_3 a\theta_s \quad - \quad 2\dot{\theta}_s\dot{\varphi}_s/\theta_s\}$$

$$\begin{aligned} B_5 = S_p\{&\dot{\varphi}_p^2\theta_p - r_b[-\dot{\varphi}_b^2\theta_b + \dot{\theta}_b^2(\theta_p-\theta_b) + 2\dot{\theta}_b\dot{\varphi}_b(\varphi_p-\varphi_b)]/f \\ &- a[-\dot{\varphi}_s^2\theta_s + \dot{\theta}_s^2(\theta_p-\theta_s) + 2\dot{\theta}_s\dot{\varphi}_s(\varphi_p-\varphi_s)]/f \\ &+ m_1 c\dot{\varphi}_e^2\theta_e/m_2 f \quad + g\theta_p/f\} \end{aligned}$$

$$B_6 = S_{pp}\{-2[m_2(r_b\dot{\theta}_b\dot{\varphi}_b + a\dot{\theta}_s\dot{\varphi}_s) + m_1 c\dot{\theta}_e\dot{\varphi}_e]/m_2 f\theta_p \quad - \quad 2\dot{\theta}_p\dot{\varphi}_p/\theta_p\}$$

$$\begin{aligned} B_7 = S_e\{&\dot{\varphi}_e^2\theta_e - r_b[-\dot{\varphi}_b^2\theta_b + \dot{\theta}_b^2(\theta_e-\theta_b) + 2\dot{\theta}_b\dot{\varphi}_b(\varphi_e-\varphi_b)]/c \\ &- a[-\dot{\varphi}_s^2\theta_s + \dot{\theta}_s^2(\theta_e-\theta_s) + 2\dot{\theta}_s\dot{\varphi}_s(\varphi_e-\varphi_s)]/c \\ &- f\dot{\varphi}_p^2\theta_p/c \quad + \quad g\theta_e/c\} \end{aligned}$$

and

$$B_8 = S_{ee}\{-2(r_b\dot{\theta}_b\dot{\varphi}_b + a\dot{\theta}_s\dot{\varphi}_s + f\dot{\theta}_p\dot{\varphi}_p)/c\theta_e \quad - \quad 2\dot{\theta}_e\dot{\varphi}_e/\theta_e\}$$

APPENDIX B

SAMPLE INPUTS AND OUTPUTS AND LISTING OF PROGRAM LACATE

This appendix provides data inputs and output for a typical 30 second run, as well as a complete listing of the LACATE program.

Inputs

All inputs are made through the use of NAMELIST statements set up according to their functional use. The following tables describe these inputs in more detail; unless a value is otherwise specified, a particular variable is to be set by the user. All inputs are made in the MKS system of units.

NAMELIST	VARIABLES/CONSTANTS	FUNCTION
ANGL	THETAB, THETAS, THETAP, THETAE, PHIB, PHIS, PHIP, PHIE, TDOTS, TDOTP, TDOTE, DOTS, DOTP, DOTE, OMEGA, LAMDA	Inputs initial conditions on angles, angular velocities and Coriolis constants
CONS	MB, MS, MP, ME, RB, A1, L, P, RS, RP, RE, G, RHO, MU, N, HS, HP, HE	Inputs constants used in program
TEST	IPEND, ITORS, ICORL, IPLOTS, IDAMP	Inputs logical flags for module selection
DIF1	H, JSTART, HMIN, HMAX, EPS, MTH, MAXDER, TO, TF, PV	Initialization constants for DIFSUB
DRAG	ASCS, APCP, AECE	Constants used in aerodynamic damping computations

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Outputs

Program LACATE provides both printed and punched output. Printer output consists of the THETA and PHI angles and their corresponding angular velocities for each component of the system, i.e., the solutions of the equations of motion. These values are printed after each successful pass through DIFSUB at intervals of time determined by the step size chosen by DIFSUB. Printed output is also punched on cards to be used as inputs to the two post-processor plotting routines. Output from a typical test case follow. For each time indicated, the top line gives the values of the angles, while directly below each angle value is given its corresponding angular velocity at that time. The case shown was run for TF = 30.0 seconds. At the end of this time, DIFSUB was still providing convergent solutions and a normal termination occurs. In the case of a non-convergent solution, output would continue as in the convergent case, but when the minimum step size specified by DIFSUB is reached, program execution is halted and an error code and working storage array are dumped for diagnostic purposes. The angles have units of radians, and the angular velocities are given in radians/sec.

Also shown are representative gust model computations for the velocity profile (A) of Equation (48) in the text. Referring to Figure , we interpret this data as follows:

- I – the value of ζ, i.e., the distance outward from the center of the balloon.
- AA(I) – the velocity at station I for $\zeta < 0$.
- BB(I) – the velocity at station I for $\zeta > 0$.
- V(J) – the velocity at station I considering both $\zeta < 0$ and $\zeta > 0$, i.e., V(I)=AA(I)+BB(I). These values of V are used to compute the rotational impulse at station I due to V(I).

The computation of the net rotational impulse produced by the gust at each station I, i.e., the computation of Ω, is also shown. Note that as one proceeds from I=1 to I=150, the net impulse is accumulating. In other words, W(I) is the net change in angular velocity that has been produced by all velocity components from I=1 to I=I(current). Thus the final value of W(I) (here, W(150)) is the net change in angular velocity over the entire balloon, and it is this value that is taken as the initial condition(s) for $\dot{\theta}_b$ and/or $\dot{\varphi}_b$.

PARAMETER	VALUE	DESCRIPTION
THETAB	radians	balloon theta deflection
THETAS	radians	load bar theta deflection
THETAP	radians	parachute package theta deflection
THETAE	radians	payload theta deflection
PHIB	radians	balloon phi deflection
PHIS	radians	load bar phi deflection
PHIP	radians	parachute phi deflection
PHIE	radians	payload phi deflection
TDOTS	rad/sec	load bar angular velocity in theta direction
TDOTP	rad/sec	parachute package angular velocity, theta direction
TDOTE	rad/sec	payload angular velocity, theta direction
DOTS	rad/sec	load bar angular velocity, phi direction
DOTP	rad/sec	parachute package angular velocity, phi direction
DOTE	rad/sec	payload angular velocity, phi direction
OMEGA	$7.27 \times 10^{-5} \frac{rad}{sec}$	rotational velocity of the earth; used only in CORL
LAMDA	5.7305×10^{-1} rad	geometric latitude at Holloman Air Force Base, New Mexico; used only in CORL
MB	861.82 kg.	mass of balloon
MS	112.94 kg.	mass of load bar
MP	37.194 kg.	mass of parachute package
ME	214.095 kg.	mass of payload package
M	M(1)=214.095 kg. M(2)=251.29 M(3)=364.23 M(4)=1226.06	An array dimensioned M(4) such that: M(1)=ME M(2)=ME+MP M(3)=ME+MP+MS M(4)=ME+MP+MS+MB
RB	64.00 meters	balloon radius
A1	23.16 meters	length of cable between balloon attachment point and load bar
L	396.24 meters	length of cable between load bar and parachute package
P	3.3527 meters	length of cable between parachute package and payload package

PARAMETER	VALUE	DESCRIPTION
RS	0.6096 meters	radius of load bar cylinder
RP	0.4572 meters	radius of parachute cylinder
RE	0.9244 meters	radius of payload cylinder
G	9.656 m/sec	acceleration due to gravity at an altitude of 50 km;resettable
RHO	$1.027 \times 10^{-3} \frac{kg}{m^3}$	density of air at 50 km altitude; user resettable
MU	$1.695 \times 10^{-5} \frac{kg}{m\text{-}sec}$	viscosity of air at 50 km altitude ; user resettable
N		number of differential equations to be solved =4 for TORS =8 for PEND and CORL
HS	0.6096 meters	length of load bar
HP	0.9144 meters	length of parachute package
HE	1.8288 meters	length of payload package
IPEND		pendulation module flag =0, module not used =1, module is used
ITORS		torsion module flag
ICORL		Coriolis module flag
IPLOT		plotting module flag
IDAMP		damping module flag
H,JSTART,HMIN,HMAX,EPS, MTH,MAXDER,TO,TF,PV		refer to subroutine DIFSUB
ASCS	1.03085 m^2	product of load bar surface area and drag coefficient
APCP	1.03085 m^2	same for oarachute package
AECE	1.50503 m^2	same for payload package

```
$ANGL
 THETAB  =  0.1E-05,
 THETAS  =  0.1E-05,
 THETAP  =  0.1E-05,
 THETAE  =  0.1E-05,
 PHIB    =  0.1E-05,
 PHIS    =  0.1E-05,
 PHIP    =  0.1E-05,
 PHIE    =  0.1E-05,
 TDOTS   =  0.0,
 TDOTP   =  0.0,
 TDOTE   =  0.0,
 DOTS    =  0.0,
 DOTP    =  0.0,
 DOTE    =  0.0,
 OMEGA   =  0.727E-04,
 LAMDA   =  0.57305E+00,
$END
```

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```
 $CONS
 MB     =  0.861825566E+03,
 MS     =  0.1129445076E+03,
 MP     =  0.371945768E+02,
 ME     =  0.2140956128E+03,
 M      =  0.2140956128E+03,  0.2512901896E+03,  0.3642346972E+03,
           0.12260602572E+04,
 BB     =  0.64E+02,
 A1     =  0.23164778E+02,
 L      =  0.3962387E+03,
 P      =  0.3352789E+01,
 RS     =  0.6096E+00,
 RP     =  0.4572E+00,
 RE     =  0.9144E+00,
 G      =  0.9656084E+01,
 RHO    =  0.1027665726E-02,
 MU     =  0.169496074855E-04,
 N      =  8,
 HS     =  0.6096E+00,
 HP     =  0.9144E+00,
 HE     =  0.18288E+01,
 $END
```

```
$TEST
IPEND  =  1.
ITORS  =  0.
ICORL  =  0.
IPLOT  =  0.
IOAMP  =  0.
$END
```

```
$DIF1
H       =  0.125E-06,
JSTART  =  0,
HMIN    =  0.125E-09,
HMAX    =  0.1E+00,
EPS     =  0.125E-03,
MTH     =  0,
MAXDER  =  4,
TO      =  0.0,
TF      =  0.3E+02,
PV      =  0.5E-01,
$END
```

```
$DRAG
ASCS   = 0.103085E+01,
APCP   = 0.103085E+01,
AFCE   = 0.150503E+01,
$END
```

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	.000000	9.99968E-07	9.99968E-07	1.00000E-06	1.00000E-06	1.00000E-06	1.00000E-06	1.00000E-06	1.00000E-06
RATES		-2.59833E-04	-2.59833E-04	-5.21047E-14	-6.33756E-15	-7.22736E-20	-4.03730E-13	-3.99133E-25	-1.26514E-1[illegible]
ANGLE	.000000	9.99935E-07	9.99935E-07	1.00000E-06	1.00000E-06	1.00000E-06	1.00000E-06	1.00000E-06	1.00000E-06
RATES		-2.59833E-04	-2.59833E-04	-1.04210E-13	-1.26751E-14	-1.44549E-19	-8.07460E-13	-7.80818E-25	-2.53028E-16
ANGLE	.001250	6.75144E-07	6.75144E-07	9.99999E-07	1.00000E-06	1.00000E-06	9.99995E-07	1.00000E-06	1.00000E-06
RATES		-2.59833E-04	-2.59833E-04	-5.89555E-10	-6.33883E-11	-8.60610E-16	-4.03810E-09	-4.69607E-21	-1.26540E-12
ANGLE	.002500	3.50354E-07	3.50353E-07	9.99998E-07	1.00000E-06	1.00000E-06	9.99985E-07	1.00000E-06	1.00000E-06
RATES		-2.59833E-04	-2.59833E-04	-1.24740E-09	-1.26764E-10	-1.98675E-15	-8.07540E-09	-2.69783E-19	-2.53054E-12
ANGLE	.102500	-2.56325E-05	-2.56329E-05	9.94610E-07	9.99480E-07	1.00000E-06	9.66879E-07	1.00000E-06	9.99990E-07
RATES		-2.59670E-04	-2.59833E-04	-4.91595E-07	-5.19456E-09	-1.90635E-12	-3.30951E-07	-1.75336E-15	-1.03708E-10
ANGLE	.202500	-5.15833E-05	-5.16162E-05	8.96416E-07	9.98454E-07	1.00000E-06	9.01496E-07	1.00000E-06	9.99969E-07
RATES		-2.59349E-04	-2.59833E-04	-1.41806E-06	-1.01975E-08	-8.84399E-11	-6.53127E-07	-1.50633E-13	-2.04666E-10
ANGLE	.302500	-7.74861E-05	-7.75994E-05	6.61964E-07	9.96934E-07	9.99982E-07	8.03966E-07	1.00000E-06	9.99939E-07
RATES		-2.58872E-04	-2.59833E-04	-2.75227E-06	-1.42209E-08	-1.67685E-09	-9.74213E-07	-1.91280E-12	-3.05283E-10
ANGLE	.402500	-1.03326E-04	-1.03583E-04	2.53315E-07	9.95109E-07	9.99656E-07	6.74436E-07	1.00000E-06	9.99898E-07
RATES		-2.58239E-04	-2.59833E-04	-4.46599E-06	-1.63659E-08	-6.17865E-09	-1.29381E-06	-7.00076E-11	-4.05438E-10
ANGLE	.502500	-1.29122E-04	-1.29566E-04	-2.69482E-07	9.93319E-07	9.98885E-07	5.29037E-07	9.99991E-07	9.99852E-07
RATES		-2.57529E-04	-2.59832E-04	-6.34593E-06	-1.68339E-08	-1.33048E-08	-1.61232E-06	-8.93074E-10	-5.05288E-10
ANGLE	.602500	-1.54831E-04	-1.55549E-04	-1.01587E-06	9.91743E-07	9.96995E-07	3.51973E-07	9.99821E-07	9.99797E-07
RATES		-2.56667E-04	-2.59832E-04	-8.54979E-06	-1.37017E-08	-2.60924E-08	-1.92835E-06	-4.30062E-09	-6.04497E-10
ANGLE	.702500	-1.80447E-04	-1.81532E-04	-1.99724E-06	9.90709E-07	9.93463E-07	1.43459E-07	9.99091E-07	9.99732E-07
RATES		-2.55654E-04	-2.59832E-04	-1.10547E-05	-6.30600E-09	-4.56587E-08	-2.24123E-06	-1.22722E-08	-7.02951E-10
ANGLE	.802500	-2.05955E-04	-2.07516E-04	-3.24301E-06	9.90661E-07	9.87580E-07	-9.61496E-08	9.97237E-07	9.99656E-07
RATES		-2.54492E-04	-2.59832E-04	-1.38237E-05	6.42553E-09	-7.38229E-08	-2.55000E-06	-2.67542E-08	-8.00449E-10
ANGLE	.902500	-2.31338E-04	-2.33499E-04	-4.77702E-06	9.92207E-07	9.78359E-07	-3.66384E-07	9.93512E-07	9.99571E-07
RATES		-2.53183E-04	-2.59832E-04	-1.68113E-05	2.57745E-08	-1.12809E-07	-2.85349E-06	-5.02571E-08	-8.96738E-10
ANGLE	1.002500	-2.56584E-04	-2.59482E-04	-6.61847E-06	9.96083E-07	9.64588E-07	-6.66643E-07	9.86860E-07	9.99477E-07
RATES		-2.51730E-04	-2.59832E-04	-1.99708E-05	5.30031E-08	-1.64901E-07	-3.15019E-06	-8.59035E-08	-9.91494E-10
ANGLE	1.102500	-2.81677E-04	-2.85465E-04	-8.78212E-06	1.00314E-06	9.44838E-07	-9.96158E-07	9.75881E-07	9.99373E-07
RATES		-2.50136E-04	-2.59832E-04	-2.32526E-05	8.93818E-08	-2.32507E-07	-3.43827E-06	-1.36873E-07	-1.08428E-09
ANGLE	1.202500	-3.06604E-04	-3.11448E-04	-1.12776E-05	1.01435E-06	9.17431E-07	-1.35396E-06	9.58879E-07	9.99260E-07

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	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	1.302500	-3.31350E-04	-3.37432E-04	-1.41093E-05	1.03083E-06	8.80437E-07	-1.73883E-06	9.33870E-07	9.99138E-07
RATES		-2.46535E-04	-2.59832E-04	-2.99758E-05	1.94504E-07	-4.24289E-07	-3.97932E-06	-2.97026E-07	-1.26157E-09
ANGLE	1.402500	-3.55904E-04	-3.63415E-04	-1.72763E-05	1.05377E-06	8.31673E-07	-2.14928E-06	8.98554E-07	9.99008E-07
RATES		-2.44535E-04	-2.59832E-04	-3.33115E-05	2.65509E-07	-5.53534E-07	-4.22662E-06	-4.12214E-07	-1.34452E-09
ANGLE	1.502500	-3.80251E-04	-3.89398E-04	-2.07725E-05	1.08451E-06	7.68703E-07	-2.58348E-06	3.50354E-07	9.98870E-07
RATES		-2.42407E-04	-2.59831E-04	-3.65600E-05	3.50124E-07	-7.08349E-07	-4.45389E-06	-5.54418E-07	-1.42235E-09
ANGLE	1.602500	-4.04378E-04	-4.15381E-04	-2.45865E-05	1.12443E-06	6.88849E-07	-3.03923E-06	7.85451E-07	9.98724E-07
RATES		-2.40153E-04	-2.59831E-04	-3.96701E-05	4.49145E-07	-8.91138E-07	-4.65715E-06	-7.26001E-07	-1.49388E-09
ANGLE	1.702500	-4.28275E-04	-4.41364E-04	-2.87021E-05	1.17502E-06	5.89197E-07	-3.51391E-06	7.03803E-07	9.98571E-07
RATES		-2.37777E-04	-2.59831E-04	-4.25929E-05	5.63185E-07	-1.10417E-06	-4.83198E-06	-9.29095E-07	-1.55775E-09
ANGLE	1.802500	-4.51928E-04	-4.67347E-04	-3.30982E-05	1.23779E-06	4.66616E-07	-4.00443E-06	5.99163E-07	9.98413E-07
RATES		-2.35281E-04	-2.59831E-04	-4.52823E-05	6.92651E-07	-1.34958E-06	-4.97352E-06	-1.16560E-06	-1.61247E-09
ANGLE	1.902500	-4.75325E-04	-4.93330E-04	-3.77492E-05	1.31430E-06	3.17773E-07	-4.50719E-06	4.69108E-07	9.98249E-07
RATES		-2.32670E-04	-2.59831E-04	-4.76961E-05	8.37729E-07	-1.62920E-06	-5.07652E-06	-1.43721E-06	-1.65637E-09
ANGLE	2.002500	-4.98456E-04	-5.19313E-04	-4.26257E-05	1.40611E-06	1.39159E-07	-5.01807E-06	3.13051E-07	9.98082E-07
RATES		-2.29946E-04	-2.59831E-04	-4.97960E-05	9.98370E-07	-1.94474E-06	-5.13543E-06	-1.74548E-06	-1.68771E-09
ANGLE	2.102500	-5.21308E-04	-5.45297E-04	-4.76946E-05	1.51475E-06	-7.28870E-08	-5.53235E-06	1.18256E-07	9.97912E-07
RATES		-2.27113E-04	-2.59830E-04	-5.15488E-05	1.17428E-06	-2.29756E-06	-5.14446E-06	-2.09183E-06	-1.70463E-09
ANGLE	2.202500	-5.43873E-04	-5.71280E-04	-5.29198E-05	1.64174E-06	-3.22148E-07	-6.04476E-06	-1.10148E-07	9.97741E-07
RATES		-2.24172E-04	-2.59830E-04	-5.29268E-05	1.36493E-06	-2.68875E-06	-5.09767E-06	-2.47750E-06	-1.70520E-09
ANGLE	2.302500	-5.66137E-04	-5.97263E-04	-5.82627E-05	1.78850E-06	-6.12501E-07	-6.54939E-06	-3.79148E-07	9.97572E-07
RATES		-2.21126E-04	-2.59830E-04	-5.39079E-05	1.56952E-06	-3.11906E-06	-4.98910E-06	-2.90357E-06	-1.68750E-09
ANGLE	2.402500	-5.88092E-04	-6.23246E-04	-6.36827E-05	1.95638E-06	-9.47879E-07	-7.03979E-06	-6.92828E-07	9.97405E-07
RATES		-2.17979E-04	-2.59830E-04	-5.44764E-05	1.78703E-06	-3.58892E-06	-4.81293E-06	-3.37085E-06	-1.64959E-09
ANGLE	2.502500	-6.09728E-04	-6.49229E-04	-6.91381E-05	2.14561E-06	-1.33224E-06	-7.50889E-06	-1.05534E-06	9.97243E-07
RATES		-2.14732E-04	-2.59830E-04	-5.46227E-05	2.01621E-06	-4.09839E-06	-4.56361E-06	-3.87982E-06	-1.58961E-09
ANGLE	2.602500	-6.31034E-04	-6.75211E-04	-7.45866E-05	2.36027E-06	-1.76953E-06	-7.94913E-06	-1.47085E-06	9.97088E-07
RATES		-2.11387E-04	-2.59829E-04	-5.43440E-05	2.25559E-06	-4.64717E-06	-4.23607E-06	-4.43056E-06	-1.50584E-09
ANGLE	2.702500	-6.52003E-04	-7.01194E-04	-7.99358E-05	2.59831E-06	-2.25366E-06	-8.35245E-06	-1.94354E-06	9.96943E-07
RATES		-2.07947E-04	-2.59829E-04	-5.36442E-05	2.50347E-06	-5.23462E-06	-3.82590E-06	-5.02267E-06	-1.39670E-09
ANGLE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	2.902500	-6.92878E-04	-7.53160E-04	-9.04714E-05	3.15034E-06	-3.43753E-06	-9.01424E-06	-3.07665E-06	9.96692E-07
RATES		-2.00785E-04	-2.59829E-04	-5.10285E-05	3.01719E-06	-6.52114E-06	-2.74483E-06	-6.32675E-06	-1.09752E-09
ANGLE	3.002500	-7.12771E-04	-7.79143E-04	-9.54793E-05	3.46524E-06	-4.12453E-06	-9.25506E-06	-3.74485E-06	9.96592E-07
RATES		-1.97066E-04	-2.59828E-04	-4.91521E-05	3.27884E-06	-7.21717E-06	-2.07060E-06	-7.03532E-06	-9.05973E-10
ANGLE	3.102500	-7.32287E-04	-8.05126E-04	-1.00282E-04	3.80633E-06	-4.88278E-06	-9.42393E-06	-4.48566E-06	9.96512E-07
RATES		-1.93257E-04	-2.59828E-04	-4.69329E-05	3.54071E-06	-7.94581E-06	-1.30765E-06	-7.77851E-06	-6.86254E-11
ANGLE	3.202500	-7.51417E-04	-8.31109E-04	-1.04847E-04	4.17351E-06	-5.71543E-06	-9.51211E-06	-5.30240E-06	9.96456E-07
RATES		-1.89359E-04	-2.59828E-04	-4.44047E-05	3.80046E-06	-8.70476E-06	-4.58657E-07	-8.55355E-06	-4.38957E-10
ANGLE	3.302500	-7.70154E-04	-8.57091E-04	-1.09146E-04	4.56644E-06	-6.62537E-06	-9.51123E-06	-6.19810E-06	9.96426E-07
RATES		-1.85372E-04	-2.59828E-04	-4.16061E-05	4.05570E-06	-9.49147E-06	4.71428E-07	-9.35736E-06	-1.65390E-10
ANGLE	3.402500	-7.88487E-04	-8.83074E-04	-1.13153E-04	4.98454E-06	-7.61524E-06	-9.41353E-06	-7.17547E-06	9.96424E-07
RATES		-1.81298E-04	-2.59828E-04	-3.85800E-05	4.30405E-06	-1.03032E-05	1.47514E-06	-1.01867E-05	1.32331E-10
ANGLE	3.502500	-8.06409E-04	-9.09057E-04	-1.16848E-04	5.42702E-06	-8.68739E-06	-9.21215E-06	-8.23688E-06	9.96453E-07
RATES		-1.77136E-04	-2.59827E-04	-3.53726E-05	4.54312E-06	-1.11368E-05	2.54219E-06	-1.10382E-05	4.51186E-10
ANGLE	3.602500	-8.23910E-04	-9.35040E-04	-1.20216E-04	5.89282E-06	-9.84385E-06	-8.90141E-06	-9.38439E-06	9.96515E-07
RATES		-1.72888E-04	-2.59827E-04	-3.20332E-05	4.77062E-06	-1.19893E-05	3.65929E-06	-1.19086E-05	7.87171E-10
ANGLE	3.702500	-8.40982E-04	-9.61022E-04	-1.23246E-04	6.38068E-06	-1.10864E-05	-8.47712E-06	-1.06197E-05	9.96612E-07
RATES		-1.6[illegible]554E-04	-2.[illegible]827E-04	-2.86127E-05	4.98433E-06	-1.28574E-05	4.80989E-06	-1.27943E-05	1.13523E-09
ANGLE	3.802500	-8.57617E-04	-9.[illegible]005E-04	-1.25932E-04	6.88911E-06	-1.24163E-05	-7.93693E-06	-1.19442E-05	9.96743E-07
RATES		-1.64135E-04	-2.59827E-04	-2.51635E-05	5.18217E-06	-1.37378E-05	5.97412E-06	-1.36922E-05	1.48923E-09
ANGLE	3.902500	-8.73805E-04	-1.01299E-03	-1.28275E-04	7.41643E-06	-1.38347E-05	-7.28062E-06	-1.33589E-05	9.96910E-07
RATES		-1.59631E-04	-2.59826E-04	-2.17383E-05	5.36224E-06	-1.46270E-05	7.12873E-06	-1.45987E-05	1.84190E-09
ANGLE	4.002500	-8.89539E-04	-1.03897E-03	-1.30278E-04	7.96077E-06	-1.53423E-05	-6.51050E-06	-1.48645E-05	9.97112E-07
RATES		-1.55043E-04	-2.59826E-04	-1.83894E-05	5.52284E-06	-1.55217E-05	8.24713E-06	-1.55107E-05	2.18491E-09
ANGLE	4.102500	-9.04809E-04	-1.06495E-03	-1.31954E-04	8.52010E-06	-1.69395E-05	-5.63168E-06	-1.64615E-05	9.97347E-07
RATES		-1.50371E-04	-2.59826E-04	-1.51677E-05	5.66248E-06	-1.64186E-05	9.29965E-06	-1.64248E-05	2.50887E-09
ANGLE	4.202500	-9.19609E-04	-1.09094E-03	-1.33316E-04	9.09229E-06	-1.86263E-05	-4.65238E-06	-1.81498E-05	9.97613E-07
RATES		-1.45618E-04	-2.59826E-04	-1.21223E-05	5.77997E-06	-1.73146E-05	1.02538E-05	-1.73377E-05	2.80347E-09
ANGLE	4.302500	-9.33929E-04	-1.11692E-03	-1.34384E-04	9.67505E-06	-2.04025E-05	-3.58422E-06	-1.99291E-05	9.97907E-07
RATES		-1.40782E-04	-2.59826E-04	-9.29923E-06	5.87436E-06	-1.82065E-05	1.10747E-05	-1.82462E-05	3.05765E-09
ANGLE	4.402500	-9.47761E-04	-1.14290E-03	-1.35184E-04	1.02661E-05	-2.27675E-05	-2.44236E-06	-2.17989E-05	9.98223E-07

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	4.502500	-9.61098E-04	-1.16888E-03	-1.35744E-04	1.08629E-05	-2.42206E-05	-1.24570E-06	-2.37583E-05	9.98557E-07
RATES		-1.30873E-04	-2.59825E-04	-4.48657E-06	5.99159E-06	-1.99669E-05	1.21698E-05	-2.00373E-05	3.39770E-09
ANGLE	4.602500	-9.73932E-04	-1.19487E-03	-1.36095E-04	1.14632E-05	-2.62605E-05	-1.68807E-08	-2.58060E-05	9.98900E-07
RATES		-1.25802E-04	-2.59825E-04	-2.56896E-06	6.01400E-06	-2.08303E-05	1.23690E-05	-2.09141E-05	3.45954E-09
ANGLE	4.702500	-9.86254E-04	-1.22085E-03	-1.36273E-04	1.20645E-05	-2.83862E-05	1.21774E-06	-2.79406E-05	9.99246E-07
RATES		-1.20655E-04	-2.59825E-04	-1.01666E-06	6.01246E-06	-2.16794E-05	1.22866E-05	-2.17748E-05	3.43346E-09
ANGLE	4.802500	-9.98059E-04	-1.24683E-03	-1.36315E-04	1.26645E-05	-3.05959E-05	2.42821E-06	-3.01603E-05	9.99583E-07
RATES		-1.15436E-04	-2.59825E-04	1.47829E-07	5.98744E-06	-2.25126E-05	1.18880E-05	-2.26174E-05	3.30828E-09
ANGLE	4.902500	-1.00934E-03	-1.27281E-03	-1.36262E-04	1.32608E-05	-3.28880E-05	3.58125E-06	-3.24633E-05	9.99903E-07
RATES		-1.10147E-04	-2.59824E-04	9.08114E-07	5.93960E-06	-2.33281E-05	1.11410E-05	-2.34400E-05	3.07375E-09
ANGLE	5.002500	-1.02008E-03	-1.29880E-03	-1.36153E-04	1.38512E-05	-3.52607E-05	4.64059E-06	-3.48474E-05	1.00019E-06
RATES		-1.04790E-04	-2.59824E-04	1.25418E-06	5.86982E-06	-2.41248E-05	1.00176E-05	-2.42412E-05	2.72087E-09
ANGLE	5.102500	-1.03029E-03	-1.32478E-03	-1.36031E-04	1.44336E-05	-3.77121E-05	5.56735E-06	-3.73105E-05	1.00044E-06
RATES		-9.93677E-05	-2.59824E-04	1.18254E-06	5.77908E-06	-2.49018E-05	8.49426E-06	-2.50203E-05	2.24216E-09
ANGLE	5.202500	-1.03995E-03	-1.35076E-03	-1.35937E-04	1.50059E-05	-4.02401E-05	6.32062E-06	-3.98504E-05	1.00064E-06
RATES		-9.38847E-05	-2.59824E-04	6.96302E-07	5.66850E-06	-2.56585E-05	6.55306E-06	-2.57769E-05	1.63193E-09
ANGLE	5.302500	-1.04907E-03	-1.37674E-03	-1.35913E-04	1.55663E-05	-4.28428E-05	6.85797E-06	-4.24648E-05	1.00076E-06
RATES		-8.83440E-05	-2.59824E-04	-1.94899E-07	5.53920E-06	-2.63949E-05	4.18176E-06	-2.65109E-05	8.86404E-10
ANGLE	5.402500	-1.05762E-03	-1.40273E-03	-1.35997E-04	1.61128E-05	-4.55181E-05	7.13608E-06	-4.51514E-05	1.00081E-06
RATES		-8.27497E-05	-2.59824E-04	-1.47503E-06	5.39236E-06	-2.71108E-05	1.37450E-06	-2.72229E-05	3.89958E-12
ANGLE	5.502500	-1.06561E-03	-1.42871E-03	-1.36228E-04	1.66438E-05	-4.82639E-05	7.11137E-06	-4.79082E-05	1.00076E-06
RATES		-7.71059E-05	-2.59823E-04	-3.12195E-06	5.22911E-06	-2.78069E-05	-1.86828E-06	-2.79136E-05	-1.01518E-09
ANGLE	5.602500	-1.07304E-03	-1.45469E-03	-1.36641E-04	1.71577E-05	-5.10784E-05	6.74062E-06	-5.07331E-05	1.00060E-06
RATES		-7.14171E-05	-2.59823E-04	-5.10768E-06	5.05052E-06	-2.84837E-05	-5.53987E-06	-2.85840E-05	-2.16837E-09
ANGLE	5.702500	-1.07989E-03	-1.48067E-03	-1.37268E-04	1.76531E-05	-5.39597E-05	5.98162E-06	-5.36240E-05	1.00032E-06
RATES		-6.56879E-05	-2.59823E-04	-7.39894E-06	4.85757E-06	-2.91425E-05	-9.62763E-06	-2.92353E-05	-3.45118E-09
ANGLE	5.802500	-1.08617E-03	-1.50665E-03	-1.38137E-04	1.81285E-05	-5.69060E-05	4.79366E-06	-5.65791E-05	9.99899E-07
RATES		-5.99232E-05	-2.59823E-04	-9.95758E-06	4.65115E-06	-2.97844E-05	-1.41134E-05	-2.98689E-05	-4.85732E-09
ANGLE	5.902500	-1.09188E-03	-1.53264E-03	-1.39274E-04	1.85826E-05	-5.99156E-05	3.13812E-06	-5.95968E-05	9.99337E-07
RATES		-5.41281E-05	-2.59823E-04	-1.27412E-05	4.43203E-06	-3.04108E-05	-1.89742E-05	-3.04864E-05	-6.37880E-09
ANGLE	6.002500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	6.102500	-1.10154E-03	-1.58460E-03	-1.42426E-04	1.94221E-05	-6.61196E-05	-1.71719E-06	-6.58139E-05	9.97730E-07
RATES		-4.24678E-05	-2.59823E-04	-1.87970E-05	3.95816E-06	-3.16245E-05	-2.97085E-05	-3.16800E-05	-9.72877E-09
ANGLE	6.202500	-1.10549E-03	-1.61058E-03	-1.44467E-04	1.98052E-05	-6.93115E-05	-4.98018E-06	-6.90108E-05	9.96666E-07
RATES		-3.66133E-05	-2.59823E-04	-2.19694E-05	3.70437E-06	-3.22154E-05	-3.55179E-05	-3.22549E-05	-1.15349E-08
ANGLE	6.302500	-1.10886E-03	-1.63657E-03	-1.46827E-04	2.01624E-05	-7.25621E-05	-8.83663E-06	-7.22652E-05	9.95418E-07
RATES		-3.07500E-05	-2.59823E-04	-2.51690E-05	3.43981E-06	-3.27984E-05	-4.15758E-05	-3.28314E-05	-1.34119E-08
ANGLE	6.402500	-1.11164E-03	-1.66255E-03	-1.49505E-04	2.04926E-05	-7.58707E-05	-1.33095E-05	-7.55765E-05	9.93980E-07
RATES		-2.48832E-05	-2.59822E-04	-2.83431E-05	3.16474E-06	-3.33755E-05	-4.78456E-05	-3.33966E-05	-1.53468E-08
ANGLE	6.502500	-1.11383E-03	-1.68853E-03	-1.52497E-04	2.07948E-05	-7.92363E-05	-1.84182E-05	-7.89441E-05	9.92346E-07
RATES		-1.90186E-05	-2.59822E-04	-3.14394E-05	2.87933E-06	-3.39487E-05	-5.42902E-05	-3.39579E-05	-1.73260E-08
ANGLE	6.602500	-1.11544E-03	-1.71451E-03	-1.55792E-04	2.10580E-05	-8.26601E-05	-2.41782E-05	-8.23678E-05	9.90512E-07
RATES		-1.31616E-05	-2.59822E-04	-3.44066E-05	2.58373E-06	-3.45230E-05	-6.08728E-05	-3.45174E-05	-1.93356E-08
ANGLE	6.702500	-1.11647E-03	-1.74049E-03	-1.59374E-04	2.13111E-05	-8.61406E-05	-3.06015E-05	-8.58474E-05	9.88476E-07
RATES		-7.31759E-06	-2.59822E-04	-3.71956E-05	2.27805E-06	-3.50911E-05	-6.75569E-05	-3.50774E-05	-2.13617E-08
ANGLE	6.802500	-1.11691E-03	-1.76648E-03	-1.63224E-04	2.15231E-05	-8.95783E-05	-3.76964E-05	-8.93832E-05	9.86238E-07
RATES		-1.49176E-06	-2.59822E-04	-3.97598E-05	1.96239E-06	-3.56639E-05	-7.43071E-05	-3.56401E-05	-2.33901E-08
ANGLE	6.902500	-1.11677E-03	-1.79246E-03	-1.67317E-04	2.17030E-05	-9.32734E-05	-4.54680E-05	-9.29755E-05	9.83797E-07
RATES		4.31075E-06	-2.59822E-04	-4.20562E-05	1.63688E-06	-3.62399E-05	-8.10896E-05	-3.62074E-05	-2.54070E-08
ANGLE	7.002500	-1.11605E-03	-1.81844E-03	-1.71624E-04	2.18500E-05	-9.69263E-05	-5.39177E-05	-9.66248E-05	9.81156E-07
RATES		1.00850E-05	-2.59822E-04	-4.40457E-05	1.30163E-06	-3.68203E-05	-8.78720E-05	-3.67808E-05	-2.73985E-08
ANGLE	7.102500	-1.11475E-03	-1.84442E-03	-1.76113E-04	2.19629E-05	-1.00638E-04	-6.30440E-05	-1.00332E-04	9.78318E-07
RATES		1.58263E-05	-2.59822E-04	-4.56942E-05	9.56841E-07	-3.74064E-05	-9.46244E-05	-3.73618E-05	-2.93509E-08
ANGLE	7.202500	-1.11288E-03	-1.87041E-03	-1.80748E-04	2.20408E-05	-1.04408E-04	-7.28425E-05	-1.04097E-04	9.75287E-07
RATES		2.15301E-05	-2.59822E-04	-4.69726E-05	6.02711E-07	-3.79988E-05	-1.01319E-04	-3.79512E-05	-3.12510E-08
ANGLE	7.302500	-1.11045E-03	-1.89639E-03	-1.85491E-04	2.20829E-05	-1.08238E-04	-8.33062E-05	-1.07922E-04	9.72070E-07
RATES		2.71922E-05	-2.59822E-04	-4.78578E-05	2.39514E-07	-3.85982E-05	-1.07929E-04	-3.85497E-05	-3.30856E-08
ANGLE	7.402500	-1.10745E-03	-1.92237E-03	-1.90301E-04	2.20883E-05	-1.12128E-04	-9.44254E-05	-1.11808E-04	9.68673E-07
RATES		3.28086E-05	-2.59822E-04	-4.83324E-05	-1.32429E-07	-3.92047E-05	-1.14432E-04	-3.91573E-05	-3.48424E-08
ANGLE	7.502500	-1.10389E-03	-1.94835E-03	-1.95137E-04	2.20560E-05	-1.16079E-04	-1.06188E-04	-1.15754E-04	9.65105E-07
RATES		3.83755E-05	-2.59822E-04	-4.83855E-05	-5.12744E-07	-3.98183E-05	-1.20808E-04	-3.97738E-05	-3.65091E-08
ANGLE	7.[illegible]02500	-1.09977E-03	-1.97433E-03	-1.99958E-04	2.17853E-05	-1.20092E-04	-1.13582E-04	-1.19763E-04	9.61375E-07

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	7.702500	-1.09511E-03	-2.00032E-03	-2.04719E-04	2.18754E-05	-1.24167E-04	-1.31590E-04	-1.23835E-04	9.57494E-07
RATES		4.93478E-05	-2.59822E-04	-4.72169E-05	-1.29675E-06	-4.10644E-05	-1.33106E-04	-4.10312E-05	-3.95275E-08
ANGLE	7.802500	-1.08991E-03	-2.02630E-03	-2.09380E-04	2.17255E-05	-1.28305E-04	-1.45195E-04	-1.27970E-04	9.53475E-07
RATES		5.47471E-05	-2.59822E-04	-4.60059E-05	-1.69947E-06	-4.16950E-05	-1.38999E-04	-4.16699E-05	-4.08588E-08
ANGLE	7.902500	-1.08416E-03	-2.05228E-03	-2.13899E-04	2.15351E-05	-1.32506E-04	-1.59381E-04	-1.32169E-04	9.49328E-07
RATES		6.00851E-05	-2.59822E-04	-4.43952E-05	-2.10865E-06	-4.23289E-05	-1.44707E-04	-4.23132E-05	-4.20595E-08
ANGLE	8.002500	-1.07789E-03	-2.07826E-03	-2.18238E-04	2.13035E-05	-1.36771E-04	-1.74128E-04	-1.36433E-04	9.45069E-07
RATES		6.53595E-05	-2.59822E-04	-4.24060E-05	-2.52376E-06	-4.29644E-05	-1.50221E-04	-4.29595E-05	-4.31221E-08
ANGLE	8.102500	-1.07110E-03	-2.10425E-03	-2.22360E-04	2.10300E-05	-1.41099E-04	-1.89416E-04	-1.40761E-04	9.40710E-07
RATES		7.05682E-05	-2.59822E-04	-4.00654E-05	-2.94428E-06	-4.35993E-05	-1.55536E-04	-4.36066E-05	-4.40405E-08
ANGLE	8.202500	-1.06378E-03	-2.13023E-03	-2.26232E-04	2.07143E-05	-1.45491E-04	-2.05226E-04	-1.45154E-04	9.36268E-07
RATES		7.57005E-05	-2.59822E-04	-3.74058E-05	-3.36970E-06	-4.42313E-05	-1.60646E-04	-4.42523E-05	-4.48102E-08
ANGLE	8.302500	-1.05596E-03	-2.15621E-03	-2.29824E-04	2.03558E-05	-1.49946E-04	-2.21536E-04	-1.49612E-04	9.31756E-07
RATES		8.07819E-05	-2.59822E-04	-3.44647E-05	-3.79958E-06	-4.48579E-05	-1.65551E-04	-4.48938E-05	-4.54286E-08
ANGLE	8.402500	-1.04763E-03	-2.18219E-03	-2.33109E-04	1.99542E-05	-1.54462E-04	-2.38326E-04	-1.54133E-04	9.27189E-07
RATES		8.57841E-05	-2.59822E-04	-3.12838E-05	-4.23349E-06	-4.54764E-05	-1.70250E-04	-4.55284E-05	-4.58953E-08
ANGLE	8.502500	-1.03880E-03	-2.20817E-03	-2.36066E-04	1.95089E-05	-1.59041E-04	-2.55575E-04	-1.58717E-04	9.22584E-07
RATES		9.07150E-05	-2.59822E-04	-2.79082E-05	-4.67110E-06	-4.60836E-05	-1.74744E-04	-4.61530E-05	-4.62116E-08
ANGLE	8.602500	-1.02949E-03	-2.23416E-03	-2.38679E-04	1.90197E-05	-1.63679E-04	-2.73264E-04	-1.63363E-04	9.17955E-07
RATES		9.55736E-05	-2.59822E-04	-2.43863E-05	-5.11213E-06	-4.66767E-05	-1.79037E-04	-4.67642E-05	-4.63824E-08
ANGLE	8.702500	-1.01969E-03	-2.26014E-03	-2.40934E-04	1.84863E-05	-1.68375E-04	-2.91373E-04	-1.68069E-04	9.13315E-07
RATES		1.00359E-04	-2.59822E-04	-2.07686E-05	-5.55641E-06	-4.72522E-05	-1.83133E-04	-4.73585E-05	-4.64140E-08
ANGLE	8.802500	-1.00942E-03	-2.28612E-03	-2.42825E-04	1.79083E-05	-1.73128E-04	-3.09881E-04	-1.72834E-04	9.08679E-07
RATES		1.05071E-04	-2.59822E-04	-1.71068E-05	-6.00383E-06	-4.78071E-05	-1.87037E-04	-4.79325E-05	-4.63162E-08
ANGLE	8.902500	-9.98682E-04	-2.31210E-03	-2.44351E-04	1.72854E-05	-1.77936E-04	-3.28770E-04	-1.77655E-04	9.04059E-07
RATES		1.09708E-04	-2.59822E-04	-1.34533E-05	-6.45440E-06	-4.83380E-05	-1.90756E-04	-4.84823E-05	-4.61016E-08
ANGLE	9.002500	-9.87483E-04	-2.33809E-03	-2.45514E-04	1.66172E-05	-1.82795E-04	-3.48023E-04	-1.82530E-04	8.99465E-07
RATES		1.14270E-04	-2.59822E-04	-9.86032E-06	-6.90819E-06	-4.88416E-05	-1.94298E-04	-4.90045E-05	-4.57862E-08
ANGLE	9.102500	-9.75831E-04	-2.36407E-03	-2.46323E-04	1.59036E-05	-1.87703E-04	-3.67620E-04	-1.87455E-04	8.94907E-07
RATES		1.18757E-04	-2.59823E-04	-6.37901E-06	-7.36538E-06	-4.93148E-05	-1.97669E-04	-4.94955E-05	-4.53886E-08
ANGLE	9.202500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	7.702500	-1.09511E-03	-2.00032E-03	-2.04719E-04	2.18754E-05	-1.24167E-04	-1.31590E-04	-1.23835E-04	9.57494E-07
RATES		4.93478E-05	-2.59822E-04	-4.72169E-05	-1.29675E-06	-4.10644E-05	-1.33106E-04	-4.10312E-05	-3.95275E-08
ANGLE	7.802500	-1.08991E-03	-2.02630E-03	-2.09380E-04	2.17255E-05	-1.28305E-04	-1.45195E-04	-1.27970E-04	9.53475E-07
RATES		5.47471E-05	-2.59822E-04	-4.60059E-05	-1.69947E-06	-4.16950E-05	-1.38999E-04	-4.16699E-05	-4.08588E-08
ANGLE	7.902500	-1.08415E-03	-2.05228E-03	-2.13899E-04	2.15351E-05	-1.32506E-04	-1.59381E-04	-1.32169E-04	9.49328E-07
RATES		6.00851E-05	-2.59822E-04	-4.43952E-05	-2.10865E-06	-4.23289E-05	-1.44707E-04	-4.23132E-05	-4.20595E-08
ANGLE	8.002500	-1.07789E-03	-2.07826E-03	-2.18238E-04	2.13035E-05	-1.36771E-04	-1.74128E-04	-1.36433E-04	9.45069E-07
RATES		6.53595E-05	-2.59822E-04	-4.24360E-05	-2.52376E-06	-4.29644E-05	-1.50221E-04	-4.29595E-05	-4.31221E-08
ANGLE	8.102500	-1.07110E-03	-2.10425E-03	-2.22360E-04	2.10300E-05	-1.41099E-04	-1.89416E-04	-1.40761E-04	9.40710E-07
RATES		7.05682E-05	-2.59822E-04	-4.00654E-05	-2.94428E-06	-4.35993E-05	-1.55536E-04	-4.36066E-05	-4.40405E-08
ANGLE	8.202500	-1.06378E-03	-2.13023E-03	-2.26232E-04	2.07143E-05	-1.45491E-04	-2.05226E-04	-1.45154E-04	9.36268E-07
RATES		7.57095E-05	-2.59822E-04	-3.74058E-05	-3.36970E-06	-4.42313E-05	-1.60646E-04	-4.42523E-05	-4.48102E-08
ANGLE	8.302500	-1.05596E-03	-2.15621E-03	-2.29824E-04	2.03558E-05	-1.49946E-04	-2.21536E-04	-1.49612E-04	9.31756E-07
RATES		8.07819E-05	-2.59822E-04	-3.44647E-05	-3.79958E-06	-4.48579E-05	-1.65551E-04	-4.48938E-05	-4.54286E-08
ANGLE	8.402500	-1.04763E-03	-2.18219E-03	-2.33109E-04	1.99542E-05	-1.54462E-04	-2.38326E-04	-1.54133E-04	9.27189E-07
RATES		8.57841E-05	-2.59822E-04	-3.12838E-05	-4.23349E-06	-4.54764E-05	-1.70250E-04	-4.55284E-05	-4.58953E-08
ANGLE	8.502500	-1.03880E-03	-2.20817E-03	-2.36066E-04	1.95089E-05	-1.59041E-04	-2.55575E-04	-1.58717E-04	9.22584E-07
RATES		9.07150E-05	-2.59822E-04	-2.79082E-05	-4.67110E-06	-4.60836E-05	-1.74744E-04	-4.61530E-05	-4.62116E-08
ANGLE	8.602500	-1.02949E-03	-2.23416E-03	-2.38679E-04	1.90197E-05	-1.63679E-04	-2.73264E-04	-1.63363E-04	9.17955E-07
RATES		9.55736E-05	-2.59822E-04	-2.43863E-05	-5.11213E-06	-4.66767E-05	-1.79037E-04	-4.67642E-05	-4.63824E-08
ANGLE	8.702500	-1.01969E-03	-2.26014E-03	-2.40934E-04	1.84863E-05	-1.68375E-04	-2.91373E-04	-1.68069E-04	9.13315E-07
RATES		1.00359E-04	-2.59822E-04	-2.07686E-05	-5.55641E-06	-4.72522E-05	-1.83133E-04	-4.73585E-05	-4.64140E-08
ANGLE	8.802500	-1.00942E-03	-2.28612E-03	-2.42825E-04	1.79083E-05	-1.73128E-04	-3.09881E-04	-1.72834E-04	9.08679E-07
RATES		1.05071E-04	-2.59822E-04	-1.71068E-05	-6.00383E-06	-4.78071E-05	-1.87037E-04	-4.79325E-05	-4.63162E-08
ANGLE	8.902500	-9.98682E-04	-2.31210E-03	-2.44351E-04	1.72854E-05	-1.77936E-04	-3.28770E-04	-1.77655E-04	9.04059E-07
RATES		1.09708E-04	-2.59822E-04	-1.34533E-05	-6.45440E-06	-4.83380E-05	-1.90756E-04	-4.84823E-05	-4.61016E-08
ANGLE	9.002500	-9.87483E-04	-2.33809E-03	-2.45514E-04	1.66172E-05	-1.82795E-04	-3.48023E-04	-1.82530E-04	8.99465E-07
RATES		1.14270E-04	-2.59822E-04	-9.86032E-06	-6.90819E-06	-4.88416E-05	-1.94298E-04	-4.90045E-05	-4.57862E-08
ANGLE	9.102500	-9.75831E-04	-2.36407E-03	-2.46323E-04	1.59036E-05	-1.87703E-04	-3.67620E-04	-1.87455E-04	8.94907E-07
RATES		1.18757E-04	-2.59823E-04	-6.37901E-06	-7.36538E-06	-4.93148E-05	-1.97669E-04	-4.94955E-05	-4.53886E-08
ANGLE	9.202500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	9.302500	-9.51202E-04	-2.41603E-03	-2.46940E-04	1.43382E-05	-1.97652E-04	-4.07787E-04	-1.97444E-04	8.85925E-07
RATES		1.27500E-04	-2.59823E-04	5.41878E-08	-8.29105E-06	-5.01578E-05	-2.03933E-04	-5.03704E-05	-4.44385E-08
ANGLE	9.402500	-9.38239E-04	-2.44201E-03	-2.46790E-04	1.34856E-05	-2.02686E-04	-4.28326E-04	-2.02500E-04	8.81508E-07
RATES		1.31756E-04	-2.59823E-04	2.91611E-06	-8.76023E-06	-5.05219E-05	-2.06844E-04	-5.07483E-05	-4.39391E-08
ANGLE	9.502500	-9.24854E-04	-2.46800E-03	-2.46367E-04	1.25859E-05	-2.07755E-04	-4.49149E-04	-2.07591E-04	8.77139E-07
RATES		1.35933E-04	-2.59823E-04	5.48784E-06	-9.23421E-06	-5.08444E-05	-2.09618E-04	-5.10829E-05	-4.34639E-08
ANGLE	9.602500	-9.11056E-04	-2.49398E-03	-2.45705E-04	1.16386E-05	-2.12853E-04	-4.70242E-04	-2.12714E-04	8.72815E-07
RATES		1.40030E-04	-2.59823E-04	7.73475E-06	-9.71345E-06	-5.11229E-05	-2.12264E-04	-5.13720E-05	-4.30465E-08
ANGLE	9.702500	-8.96852E-04	-2.51996E-03	-2.44835E-04	1.06430E-05	-2.17977E-04	-4.91594E-04	-2.17864E-04	8.68529E-07
RATES		1.44047E-04	-2.59823E-04	9.62734E-06	-1.01985E-05	-5.13557E-05	-2.14789E-04	-5.16134E-05	-4.27226E-08
ANGLE	9.802500	-8.82251E-04	-2.54594E-03	-2.43795E-04	9.59860E-06	-2.23122E-04	-5.13194E-04	-2.23035E-04	8.64268E-07
RATES		1.47982E-04	-2.59823E-04	1.11418E-05	-1.06897E-05	-5.15409E-05	-2.17203E-04	-5.18056E-05	-4.25303E-08
ANGLE	9.902500	-8.67260E-04	-2.57193E-03	-2.42624E-04	8.50475E-06	-2.28283E-04	-5.35029E-04	-2.28222E-04	8.60018E-07
RATES		1.51833E-04	-2.59823E-04	1.22602E-05	-1.11878E-05	-5.16773E-05	-2.19511E-04	-5.19472E-05	-4.25089E-08
ANGLE	10.002500	-8.51888E-04	-2.59791E-03	-2.41362E-04	7.36072E-06	-2.33455E-04	-5.57090E-04	-2.33422E-04	8.55760E-07
RATES		1.55599E-04	-2.59823E-04	1.29711E-05	-1.16932E-05	-5.17638E-05	-2.21720E-04	-5.20372E-05	-4.26990E-08
ANGLE	10.102500	-8.36144E-04	-2.62389E-03	-2.40050E-04	6.16578E-06	-2.38634E-04	-5.79368E-04	-2.38627E-04	8.51470E-07
RATES		1.59278E-04	-2.59824E-04	1.32694E-05	-1.22063E-05	-5.18000E-05	-2.23837E-04	-5.20749E-05	-4.31419E-08
ANGLE	10.202500	-8.20037E-04	-2.64987E-03	-2.38729E-04	4.91910E-06	-2.43813E-04	-6.01853E-04	-2.43834E-04	8.47121E-07
RATES		1.62868E-04	-2.59824E-04	1.31565E-05	-1.27277E-05	-5.17855E-05	-2.25867E-04	-5.20602E-05	-4.38789E-08
ANGLE	10.302500	-8.03575E-04	-2.67586E-03	-2.37439E-04	3.61984E-06	-2.48988E-04	-6.24536E-04	-2.49037E-04	8.42681E-07
RATES		1.66367E-04	-2.59824E-04	1.26404E-05	-1.32578E-05	-5.17204E-05	-2.27814E-04	-5.19929E-05	-4.49508E-08
ANGLE	10.402500	-7.86768E-04	-2.70184E-03	-2.36221E-04	2.26712E-06	-2.54154E-04	-6.47411E-04	-2.54230E-04	8.38116E-07
RATES		1.69771E-04	-2.59824E-04	1.17353E-05	-1.37971E-05	-5.16053E-05	-2.29684E-04	-5.18736E-05	-4.63976E-08
ANGLE	10.502500	-7.69625E-04	-2.72782E-03	-2.35112E-04	8.59992E-07	-2.59307E-04	-6.70469E-04	-2.59409E-04	8.33385E-07
RATES		1.73080E-04	-2.59824E-04	1.04620E-05	-1.43458E-05	-5.14408E-05	-2.31478E-04	-5.17030E-05	-4.82576E-08
ANGLE	10.602500	-7.52157E-04	-2.75380E-03	-2.34148E-04	-6.02507E-07	-2.64440E-04	-6.93703E-04	-2.64568E-04	8.28446E-07
RATES		1.76289E-04	-2.59824E-04	8.84657E-06	-1.49045E-05	-5.12281E-05	-2.33200E-04	-5.14823E-05	-5.05672E-08
ANGLE	10.702500	-7.34372E-04	-2.77979E-03	-2.33361E-04	-2.12138E-06	-2.69550E-04	-7.17105E-04	-2.69703E-04	8.23251E-07
RATES		1.79396E-04	-2.59824E-04	6.92094E-06	-1.54734E-05	-5.09687E-05	-2.34853E-04	-5.12130E-05	-5.33602E-08
ANGLE	10.802500	-7.16283E-04	-2.80577E-03	-2.32781E-04	-3.69767E-06	-2.74631E-04	-7.40570E-04	-2.74808E-04	8.17751E-07

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	10.902500	-6.97898E-04	-2.83175E-03	-2.32433E-04	-5.33244E-06	-2.79680E-04	-7.54389E-04	-2.79880E-04	8.11893E-07
RATES		1.85291E-04	-2.59825E-04	2.29017E-06	-1.66428E-05	-5.03165E-05	-2.37953E-04	-5.05367E-05	-6.05159E-08
ANGLE	11.002500	-6.79230E-04	-2.85773E-03	-2.32337E-04	-7.02676E-06	-2.84692E-04	-7.88257E-04	-2.84913E-04	8.05622E-07
RATES		1.88073E-04	-2.59825E-04	-3.29137E-07	-1.72439E-05	-4.99279E-05	-2.39402E-04	-5.01342E-05	-6.49292E-08
ANGLE	11.102500	-6.60289E-04	-2.88372E-03	-2.32510E-04	-8.78176E-06	-2.89664E-04	-8.12266E-04	-2.89904E-04	7.98880E-07
RATES		1.90740E-04	-2.59825E-04	-3.08837E-06	-1.78561E-05	-4.95007E-05	-2.40783E-04	-4.96923E-05	-6.99292E-08
ANGLE	11.202500	-6.41087E-04	-2.90970E-03	-2.32964E-04	-1.05995E-05	-2.94591E-04	-8.36410E-04	-2.94849E-04	7.91608E-07
RATES		1.93289E-04	-2.59825E-04	-5.93747E-06	-1.84796E-05	-4.90374E-05	-2.42096E-04	-4.92138E-05	-7.55297E-08
ANGLE	11.302500	-6.21637E-04	-2.93568E-03	-2.33705E-04	-1.24782E-05	-2.99469E-04	-8.60682E-04	-2.99745E-04	7.83745E-07
RATES		1.95716E-04	-2.59825E-04	-8.82494E-06	-1.91144E-05	-4.85404E-05	-2.43340E-04	-4.87016E-05	-8.17433E-08
ANGLE	11.402500	-6.01950E-04	-2.96166E-03	-2.34733E-04	-1.44220E-05	-3.04297E-04	-8.85075E-04	-3.04588E-04	7.75229E-07
RATES		1.98018E-04	-2.59825E-04	-1.16986E-05	-1.97606E-05	-4.80125E-05	-2.44513E-04	-4.81586E-05	-8.85782E-08
ANGLE	11.502500	-5.82039E-04	-2.98765E-03	-2.36046E-04	-1.64309E-05	-3.09070E-04	-9.09581E-04	-3.09375E-04	7.65999E-07
RATES		2.00193E-04	-2.59825E-04	-1.45063E-05	-2.04180E-05	-4.74564E-05	-2.45613E-04	-4.75876E-05	-9.60389E-08
ANGLE	11.602500	-5.61918E-04	-3.01363E-03	-2.37634E-04	-1.85062E-05	-3.13787E-04	-9.34194E-04	-3.14104E-04	7.55990E-07
RATES		2.02236E-04	-2.59826E-04	-1.71972E-05	-2.10866E-05	-4.68745E-05	-2.46639E-04	-4.69914E-05	-1.04126E-07
ANGLE	11.702500	-5.41598E-04	-3.03961E-03	-2.39482E-04	-2.06488E-05	-3.18444E-04	-9.58906E-04	-3.18772E-04	7.45142E-07
RATES		2.04146E-04	-2.59826E-04	-1.97217E-05	-2.17661E-05	-4.62695E-05	-2.47588E-04	-4.63729E-05	-1.12839E-07
ANGLE	11.802500	-5.21095E-04	-3.06559E-03	-2.41572E-04	-2.28599E-05	-3.23039E-04	-9.83708E-04	-3.23377E-04	7.33391E-07
RATES		2.05919E-04	-2.59826E-04	-2.20331E-05	-2.24563E-05	-4.56438E-05	-2.48459E-04	-4.57345E-05	-1.22173E-07
ANGLE	11.902500	-5.00421E-04	-3.09158E-03	-2.43881E-04	-2.51406E-05	-3.27571E-04	-1.00859E-03	-3.27918E-04	7.20676E-07
RATES		2.07554E-04	-2.59826E-04	-2.40879E-05	-2.31567E-05	-4.49996E-05	-2.49248E-04	-4.50787E-05	-1.32124E-07
ANGLE	12.002500	-4.79591E-04	-3.11756E-03	-2.46379E-04	-2.74918E-05	-3.32038E-04	-1.03355E-03	-3.32392E-04	7.06935E-07
RATES		2.09047E-04	-2.59826E-04	-2.58465E-05	-2.38670E-05	-4.43391E-05	-2.49955E-04	-4.44077E-05	-1.42683E-07
ANGLE	12.102500	-4.58619E-04	-3.14354E-03	-2.49037E-04	-2.99145E-05	-3.36438E-04	-1.05858E-03	-3.36798E-04	6.92109E-07
RATES		2 10397E-04	-2.59826E-04	-2.72738E-05	-2.45866E-05	-4.36641E-05	-2.50575E-04	-4.37235E-05	-1.53847E-07
ANGLE	12.202500	-4.37519E-04	-3.16952E-03	-2.51819E-04	-3.24096E-05	-3.40770E-04	-1.08366E-03	-3.41136E-04	6.76136E-07
RATES		2.11602E-04	-2.59826E-04	-2.83399E-05	-2.53149E-05	-4.29762E-05	-2.51109E-04	-4.30278E-05	-1.65608E-07
ANGLE	12.302500	-4.16306E-04	-3.19551E-03	-2.54589E-04	-3.49780E-05	-3.45033E-04	-1.10880E-03	-3.45403E-04	6.58957E-07
RATES		2.12661E-04	-2.59827E-04	-2.90205E-05	-2.60514E-05	-4.22769E-05	-2.51554E-04	-4.23222E-05	-1.77964E-07
ANGLE	12.402500	-3.94996E-04	-3.22140E-03	-2.57605E-04	[illegible]	[illegible]	[illegible]	-3.49400E-04	[illegible]

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	12.502500	-3.73598E-04	-3.24747E-03	-2.60529E-04	-4.03374E-05	-3.53346E-04	-1.15917E-03	-3.53724E-04	6.20744E-07
RATES		2.14336E-04	-2.59827E-04	-2.91576E-05	-2.75461E-05	-4.08478E-05	-2.52169E-04	-4.08855E-05	-2.04462E-07
ANGLE	12.602500	-3.52134E-04	-3.27345E-03	-2.63417E-04	-4.31299E-05	-3.57394E-04	-1.18440E-03	-3.57776E-04	5.99591E-07
RATES		2.14951E-04	-2.59827E-04	-2.85962E-05	-2.83032E-05	-4.01192E-05	-2.52339E-04	-4.01560E-05	-2.18614E-07
ANGLE	12.702500	-3.30616E-04	-3.29944E-03	-2.66227E-04	-4.59984E-05	-3.61369E-04	-1.20964E-03	-3.61755E-04	5.76991E-07
RATES		2.15417E-04	-2.59827E-04	-2.76138E-05	-2.90659E-05	-3.93815E-05	-2.52414E-04	-3.94192E-05	-2.33385E-07
ANGLE	12.802500	-3.09058E-04	-3.32542E-03	-2.68918E-04	-4.89434E-05	-3.65270E-04	-1.23488E-03	-3.65660E-04	5.52883E-07
RATES		2.15736E-04	-2.59827E-04	-2.62177E-05	-2.98338E-05	-3.86346E-05	-2.52396E-04	-3.86752E-05	-2.48794E-07
ANGLE	12.902500	-2.87476E-04	-3.35140E-03	-2.71450E-04	-5.19654E-05	-3.69095E-04	-1.26011E-03	-3.69490E-04	5.27202E-07
RATES		2.15907E-04	-2.59827E-04	-2.44215E-05	-3.06064E-05	-3.78779E-05	-2.52285E-04	-3.79232E-05	-2.64868E-07
ANGLE	13.002500	-2.65884E-04	-3.37738E-03	-2.73782E-04	-5.50650E-05	-3.72845E-04	-1.28533E-03	-3.73244E-04	4.99878E-07
RATES		2.15932E-04	-2.59827E-04	-2.22452E-05	-3.13837E-05	-3.71105E-05	-2.52080E-04	-3.71625E-05	-2.81640E-07
ANGLE	13.102500	-2.44297E-04	-3.40337E-03	-2.75879E-04	-5.82424E-05	-3.76517E-04	-1.31052E-03	-3.76922E-04	4.70841E-07
RATES		2.15811E-04	-2.59827E-04	-1.97145E-05	-3.21653E-05	-3.63315E-05	-2.51784E-04	-3.63916E-05	-2.99153E-07
ANGLE	13.202500	-2.22729E-04	-3.42935E-03	-2.77706E-04	-6.14982E-05	-3.80111E-04	-1.33568E-03	-3.80522E-04	4.40313E-07
RATES		2.15547E-04	-2.59827E-04	-1.68606E-05	-3.29514E-05	-3.55394E-05	-2.51396E-04	-3.56091E-05	-3.17456E-07
ANGLE	13.302500	-2.01195E-04	-3.45533E-03	-2.79233E-04	-6.48329E-05	-3.83624E-04	-1.36080E-03	-3.84043E-04	4.07312E-07
RATES		2.15141E-04	-2.59827E-04	-1.37197E-05	-3.37421E-05	-3.47326E-05	-2.50920E-04	-3.48132E-05	-3.36610E-07
ANGLE	13.402500	-1.79708E-04	-3.48132E-03	-2.80434E-04	-6.82469E-05	-3.87056E-04	-1.38586E-03	-3.87484E-04	3.72651E-07
RATES		2.14596E-04	-2.59828E-04	-1.03326E-05	-3.45380E-05	-3.39094E-05	-2.50356E-04	-3.40017E-05	-3.56680E-07
ANGLE	13.502500	-1.58283E-04	-3.50730E-03	-2.81285E-04	-7.17407E-05	-3.90405E-04	-1.41087E-03	-3.90843E-04	3.35934E-07
RATES		2.13914E-04	-2.59828E-04	-6.74351E-06	-3.53394E-05	-3.30677E-05	-2.49707E-04	-3.31724E-05	-3.77740E-07
ANGLE	13.602500	-1.36932E-04	-3.53328E-03	-2.81770E-04	-7.53150E-05	-3.93669E-04	-1.43580E-03	-3.94118E-04	2.97057E-07
RATES		2.13097E-04	-2.59828E-04	-3.00002E-06	-3.61471E-05	-3.22054E-05	-2.48975E-04	-3.23230E-05	-3.99874E-07
ANGLE	13.702500	-1.15670E-04	-3.55926E-03	-2.81875E-04	-7.89704E-05	-3.96846E-04	-1.46066E-03	-3.97307E-04	2.55910E-07
RATES		2.12149E-04	-2.59828E-04	8.48019E-07	-3.69619E-05	-3.13202E-05	-2.48164E-04	-3.14511E-05	-4.23169E-07
ANGLE	13.802500	-9.45092E-05	-3.58525E-03	-2.81593E-04	-8.27077E-05	-3.99932E-04	-1.48543E-03	-4.00407E-04	2.12370E-07
RATES		2.11072E-04	-2.59828E-04	4.74919E-06	-3.77848E-05	-3.04099E-05	-2.47277E-04	-3.05540E-05	-4.47719E-07
ANGLE	13.902500	-7.34623E-05	-3.61123E-03	-2.80920E-04	-8.65278E-05	-4.02926E-04	-1.51011E-03	-4.03416E-04	1.66308E-07
RATES		2.09869E-04	-2.59828E-04	8.65129E-06	-3.86168E-05	-2.94721E-05	-2.46315E-04	-2.96293E-05	-4.73625E-07
ANGLE	14.002500	-5.25419E-05	-3.63721E-03	-2.79860E-04	-9.04315E-05	-4.05625E-04	-1.53469E-03	-4.05332E-04	1.17582E-07

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	12.502500	-3.73598E-04	-3.24747E-03	-2.60529E-04	-4.03374E-05	-3.53346E-04	-1.15917E-03	-3.53724E-04	6.20744E-07
RATES		2.14336E-04	-2.59827E-04	-2.91576E-05	-2.75461E-05	-4.08478E-05	-2.52169E-04	-4.08855E-05	-2.04462E-07
ANGLE	12.602500	-3.52134E-04	-3.27345E-03	-2.63417E-04	-4.31299E-05	-3.57394E-04	-1.18440E-03	-3.57776E-04	5.99591E-07
RATES		2.14951E-04	-2.59827E-04	-2.85962E-05	-2.83032E-05	-4.01192E-05	-2.52339E-04	-4.01560E-05	-2.18614E-07
ANGLE	12.702500	-3.30616E-04	-3.29944E-03	-2.66227E-04	-4.59934E-05	-3.61369E-04	-1.20964E-03	-3.61755E-04	5.76991E-07
RATES		2.15417E-04	-2.59827E-04	-2.76138E-05	-2.90659E-05	-3.93815E-05	-2.52414E-04	-3.94192E-05	-2.33385E-07
ANGLE	12.802500	-3.09058E-04	-3.32542E-03	-2.68918E-04	-4.89434E-05	-3.65270E-04	-1.23498E-03	-3.65660E-04	5.52883E-07
RATES		2.15736E-04	-2.59827E-04	-2.62177E-05	-2.98338E-05	-3.86346E-05	-2.52396E-04	-3.86752E-05	-2.48794E-07
ANGLE	12.902500	-2.87476E-04	-3.35140E-03	-2.71450E-04	-5.19654E-05	-3.69095E-04	-1.26011E-03	-3.69490E-04	5.27202E-07
RATES		2.15907E-04	-2.59827E-04	-2.44215E-05	-3.06064E-05	-3.78779E-05	-2.52285E-04	-3.79232E-05	-2.64868E-07
ANGLE	13.002500	-2.65884E-04	-3.37738E-03	-2.73782E-04	-5.50650E-05	-3.72845E-04	-1.28533E-03	-3.73244E-04	4.99878E-07
RATES		2.15932E-04	-2.59827E-04	-2.22452E-05	-3.13837E-05	-3.71105E-05	-2.52080E-04	-3.71625E-05	-2.81640E-07
ANGLE	13.102500	-2.44297E-04	-3.40337E-03	-2.75879E-04	-5.82424E-05	-3.76517E-04	-1.31052E-03	-3.76922E-04	4.70841E-07
RATES		2.15811E-04	-2.59827E-04	-1.97145E-05	-3.21653E-05	-3.63315E-05	-2.51784E-04	-3.63916E-05	-2.99153E-07
ANGLE	13.202500	-2.22729E-04	-3.42935E-03	-2.77706E-04	-6.14982E-05	-3.80111E-04	-1.33568E-03	-3.80522E-04	4.40313E-07
RATES		2.15547E-04	-2.59827E-04	-1.68606E-05	-3.29514E-05	-3.55394E-05	-2.51396E-04	-3.56091E-05	-3.17456E-07
ANGLE	13.302500	-2.01195E-04	-3.45533E-03	-2.79233E-04	-6.48329E-05	-3.83624E-04	-1.36080E-03	-3.84043E-04	4.07312E-07
RATES		2.15141E-04	-2.59827E-04	-1.37197E-05	-3.37421E-05	-3.47326E-05	-2.50920E-04	-3.48132E-05	-3.36610E-07
ANGLE	13.402500	-1.79708E-04	-3.48132E-03	-2.80434E-04	-6.82469E-05	-3.87056E-04	-1.38586E-03	-3.87484E-04	3.72651E-07
RATES		2.14596E-04	-2.59828E-04	-1.03326E-05	-3.45380E-05	-3.39094E-05	-2.50356E-04	-3.40017E-05	-3.56680E-07
ANGLE	13.502500	-1.58283E-04	-3.50730E-03	-2.81285E-04	-7.17407E-05	-3.90405E-04	-1.41087E-03	-3.90843E-04	3.35934E-07
RATES		2.13914E-04	-2.59828E-04	-6.74351E-06	-3.53394E-05	-3.30677E-05	-2.49707E-04	-3.31724E-05	-3.77740E-07
ANGLE	13.602500	-1.36932E-04	-3.53328E-03	-2.81770E-04	-7.53150E-05	-3.93669E-04	-1.43580E-03	-3.94118E-04	2.97057E-07
RATES		2.13097E-04	-2.59828E-04	-3.00002E-06	-3.61471E-05	-3.22054E-05	-2.48975E-04	-3.23230E-05	-3.99874E-07
ANGLE	13.702500	-1.15670E-04	-3.55926E-03	-2.81875E-04	-7.89704E-05	-3.96846E-04	-1.46066E-03	-3.97307E-04	2.55910E-07
RATES		2.12149E-04	-2.59828E-04	8.48019E-07	-3.69619E-05	-3.13202E-05	-2.48164E-04	-3.[illegible]4511E-05	-4.23169E-07
ANGLE	13.802500	-9.45092E-05	-3.58525E-03	-2.81593E-04	-8.27077E-05	-3.99932E-04	-1.48543E-03	-4.00407E-04	2.12370E-07
RATES		2.11072E-04	-2.59828E-04	4.74919E-06	-3.77848E-05	-3.04099E-05	-2.47277E-04	-3.05540E-05	-4.47719E-07
ANGLE	13.902500	-7.34623E-05	-3.61123E-03	-2.80920E-04	-8.65278E-05	-4.02926E-04	-1.51011E-03	-4.03416E-04	1.66308E-07
RATES		2.09869E-04	-2.59828E-04	8.65129E-06	-3.86168E-05	-2.94721E-05	-2.46315E-04	-2.96293E 05	-4.73625E-07
ANGLE	14.002500	-5.25419E-05	-3.63721E-03	-2.79860E-04	-9.04315E-05	-4.05625E-04	-1.53469E-03	-4.05332E-04	1.17582E-07

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	14.102500	-3.17600E-05	-3.66320E-03	-2.78420E-04	-9.44200E-05	-4.08626E-04	-1.55916E-03	-4.09150E-04	6.60424E-08
RATES		2.07098E-04	-2.59828E-04	1.62505E-05	-4.03122E-05	-2.75050E-05	-2.44185E-04	-2.76871E-05	-5.29911E-07
ANGLE	14.202500	-1.11285E-05	-3.68918E-03	-2.76612E-04	-9.84944E-05	-4.11325E-04	-1.58357E-03	-4.11867E-04	1.15270E-08
RATES		2.05536E-04	-2.59828E-04	1.98467E-05	-4.11776E-05	-2.64713E-05	-2.43022E-04	-2.66649E-05	-5.60502E-07
ANGLE	14.302500	9.34125E-06	-3.71516E-03	-2.74455E-04	-1.02656E-04	-4.13919E-04	-1.60776E-03	-4.14481E-04	-4.61360E-08
RATES		2.03862E-04	-2.59828E-04	2.32434E-05	-4.20560E-05	-2.54015E-05	-2.41799E-04	-2.56057E-05	-5.92861E-07
ANGLE	14.402500	2.96380E-05	-3.74114E-03	-2.71971E-04	-1.06906E-04	-4.16403E-04	-1.63188E-03	-4.16987E-04	-1.07129E-07
RATES		2.02077E-04	-2.59828E-04	2.63967E-05	-4.29482E-05	-2.42937E-05	-2.40518E-04	-2.45074E-05	-6.27090E-07
ANGLE	14.502500	4.97509E-05	-3.76713E-03	-2.69186E-04	-1.11246E-04	-4.18776E-04	-1.65586E-03	-4.19381E-04	-1.71642E-07
RATES		2.00185E-04	-2.59828E-04	2.92662E-05	-4.38549E-05	-2.31465E-05	-2.39183E-04	-2.33682E-05	-6.63284E-07
ANGLE	14.602500	6.96695E-05	-3.79311E-03	-2.66130E-04	-1.15678E-04	-4.21031E-04	-1.67971E-03	-4.21659E-04	-2.39879E-07
RATES		1.98189E-04	-2.59828E-04	3.18163E-05	-4.47765E-05	-2.19584E-05	-2.37796E-04	-2.21867E-05	-7.01531E-07
ANGLE	14.702500	8.93833E-05	-3.81909E-03	-2.62837E-04	-1.20232E-04	-4.23165E-04	-1.70342E-03	-4.23816E-04	-3.12047E-07
RATES		1.96091E-04	-2.59828E-04	3.40163E-05	-4.57131E-05	-2.07284E-05	-2.36360E-04	-2.09615E-05	-7.41912E-07
ANGLE	14.802500	1.08882E-04	-3.84507E-03	-2.59343E-04	-1.24821E-04	-4.25174E-04	-1.72698E-03	-4.25849E-04	-3.88364E-07
RATES		1.93895E-04	-2.59828E-04	3.58408E-05	-4.66648E-05	-1.94557E-05	-2.34877E-04	-1.96917E-05	-7.84496E-07
ANGLE	14.902500	1.28157E-04	-3.87106E-03	-2.55686E-04	-1.29536E-04	-4.27054E-04	-1.75039E-03	-4.27752E-04	-4.69353E-07
RATES		1.91601E-04	-2.59828E-04	3.72706E-05	-4.76314E-05	-1.81400E-05	-2.33349E-04	-1.83769E-05	-8.29340E-07
ANGLE	15.002500	1.47198E-04	-3.89704E-03	-2.51907E-04	-1.34348E-04	-4.28800E-04	-1.77365E-03	-4.29522E-04	-5.54342E-07
RATES		1.89214E-04	-2.59828E-04	3.82925E-05	-4.86124E-05	-1.67812E-05	-2.31777E-04	-1.70169E-05	-8.76489E-07
ANGLE	15.102500	1.65995E-04	-3.92302E-03	-2.48047E-04	-1.39259E-04	-4.30408E-04	-1.79674E-03	-4.31153E-04	-6.44464E-07
RATES		1.86735E-04	-2.59828E-04	3.88998E-05	-4.96071E-05	-1.53794E-05	-2.30163E-04	-1.56118E-05	-9.25970E-07
ANGLE	15.202500	1.84540E-04	-3.94901E-03	-2.44148E-04	-1.44270E-04	-4.31874E-04	-1.81968E-03	-4.32642E-04	-7.39651E-07
RATES		1.84166E-04	-2.59827E-04	3.90922E-05	-5.06146E-05	-1.39355E-05	-2.28508E-04	-1.41624E-05	-9.77796E-07
ANGLE	15.302500	2.02824E-04	-3.97499E-03	-2.40250E-04	-1.49333E-04	-4.33193E-04	-1.84244E-03	-4.33984E-04	-8.40140E-07
RATES		1.81508E-04	-2.59827E-04	3.88759E-05	-5.16340E-05	-1.24502E-05	-2.26811E-04	-1.26697E-05	-1.03197E-06
ANGLE	15.402500	2.20837E-04	-4.00097E-03	-2.36393E-04	-1.54598E-04	-4.34362E-04	-1.86504E-03	-4.35174E-04	-9.46162E-07
RATES		1.78763E-04	-2.59827E-04	3.82636E-05	-5.26640E-05	-1.09250E-05	-2.25073E-04	-1.11351E-05	-1.08846E-06
ANGLE	15.502500	2.38572E-04	-4.02695E-03	-2.32617E-04	-1.59916E-04	-4.35376E-04	-1.88746E-03	-4.36208E-04	-1.05795E-06
RATES		1.75932E-04	-2.59827E-04	3.72741E-05	-5.37033E-05	-9.36159E-06	-2.23293E-04	-9.56049E-06	-1.14722E-06
ANGLE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	15.702500	2.73171E-04	-4.07892E-03	-2.25450E-04	-1.70867E-04	-4.35927E-04	-1.93175E-03	-4.37796E-04	-1.29970E-06
RATES		1.70018E-04	-2.59827E-04	3.42675E-05	-5.59040E-05	-6.12813E-06	-2.19603E-04	-6.29986E-06	-1.27134E-06
ANGLE	15.802500	2.90019E-04	-4.10490E-03	-2.22123E-04	-1.76500E-04	-4.37456E-04	-1.95361E-03	-4.38342E-04	-1.43010E-06
RATES		1.66936E-04	-2.59827E-04	3.23160E-05	-5.68624E-05	-4.46299E-06	-2.17688E-04	-4.61906E-06	-1.33651E-06
ANGLE	15.902500	3.06554E-04	-4.13088E-03	-2.19033E-04	-1.82240E-04	-4.37818E-04	-1.97528E-03	-4.38718E-04	-1.56711E-06
RATES		1.63773E-04	-2.59827E-04	3.01170E-05	-5.79241E-05	-2.76924E-06	-2.15725E-04	-2.90851E-06	-1.40362E-06
ANGLE	16.002500	3.22769E-04	-4.15687E-03	-2.16114E-04	-1.88085E-04	-4.38008E-04	-1.99676E-03	-4.38922E-04	-1.71093E-06
RATES		1.60527E-04	-2.59827E-04	2.77141E-05	-5.89876E-05	-1.04992E-06	-2.13710E-04	-1.17143E-06	-1.47254E-06
ANGLE	16.102500	3.38655E-04	-4.18285E-03	-2.13472E-04	-1.94037E-04	-4.38026E-04	-2.01802E-03	-4.38951E-04	-1.86172E-06
RATES		1.57201E-04	-2.59826E-04	2.51541E-05	-6.00513E-05	6.91761E-07	-2.11640E-04	5.88807E-07	-1.54312E-06
ANGLE	16.202500	3.54205E-04	-4.20883E-03	-2.11093E-04	-2.00096E-04	-4.37869E-04	-2.03908E-03	-4.38803E-04	-2.01964E-06
RATES		1.53794E-04	-2.59826E-04	2.24859E-05	-6.11137E-05	2.45240E-06	-2.09512E-04	2.36865E-06	-1.61521E-06
ANGLE	16.302500	3.69410E-04	-4.23482E-03	-2.08983E-04	-2.06260E-04	-4.37535E-04	-2.05992E-03	-4.38476E-04	-2.18484E-06
RATES		1.50307E-04	-2.59826E-04	1.97605E-05	-6.21732E-05	4.22873E-06	-2.07320E-04	4.16443E-06	-1.68864E-06
ANGLE	16.402500	3.84262E-04	-4.26080E-03	-2.07146E-04	-2.12530E-04	-4.37022E-04	-2.08054E-03	-4.37969E-04	-2.35745E-06
RATES		1.46740E-04	-2.59826E-04	1.70294E-05	-6.32283E-05	6.01708E-06	-2.05062E-04	5.97244E-06	-1.76323E-06
ANGLE	16.502500	3.98754E-04	-4.28678E-03	-2.05580E-04	-2.18906E-04	-4.36330E-04	-2.10093E-03	-4.37281E-04	-2.53756E-06
RATES		1.43094E-04	-2.59826E-04	1.43444E-05	-6.42776E-05	7.81398E-06	-2.02731E-04	7.73891E-06	-1.83861E-06
ANGLE	16.602500	4.12877E-04	-4.31276E-03	-2.04278E-04	-2.25336E-04	-4.35459E-04	-2.12109E-03	-4.36411E-04	-2.72527E-06
RATES		1.39370E-04	-2.59826E-04	1.17563E-05	-6.53194E-05	9.61595E-06	-2.00324E-04	9.61012E-06	-1.91518E-06
ANGLE	16.702500	4.26624E-04	-4.33875E-03	-2.03227E-04	-2.31969E-04	-4.34407E-04	-2.14099E-03	-4.35358E-04	-2.92064E-06
RATES		1.35568E-04	-2.59825E-04	9.31464E-06	-6.63523E-05	1.14196E-05	-1.97835E-04	1.14324E-05	-1.99216E-06
ANGLE	16.802500	4.39987E-04	-4.36473E-03	-2.02410E-04	-2.38656E-04	-4.33175E-04	-2.16065E-03	-4.34124E-04	-3.12374E-06
RATES		1.31688E-04	-2.59825E-04	7.06635E-06	-6.73747E-05	1.32216E-05	-1.95259E-04	1.32521E-05	-2.06955E-06
ANGLE	16.902500	4.52958E-04	-4.39071E-03	-2.01806E-04	-2.45444E-04	-4.31762E-04	-2.18004E-03	-4.32708E-04	-3.33450E-06
RATES		1.27733E-04	-2.59825E-04	5.05543E-06	-6.83850E-05	1.50188E-05	-1.92569E-04	1.50660E-05	-2.14718E-06
ANGLE	17.002500	4.65530E-04	-4.41669E-03	-2.01389E-04	-2.52332E-04	-4.30171E-04	-2.19916E-03	-4.31111E-04	-3.55319E-06
RATES		1.23703E-04	-2.59825E-04	3.32209E-06	-6.93817E-05	1.68083E-05	-1.89820E-04	1.68709E-05	-2.22486E-06
ANGLE	17.102500	4.77695E-04	-4.44268E-03	-2.01130E-04	-2.59319E-04	-4.28401E-04	-2.21800E-03	-4.29334E-04	-3.77957E-06
RATES		1.19600E-04	-2.59825E-04	1.90215E-06	-7.03632E-05	1.85672E-05	-1.86946E-04	1.86637E-05	-2.30241E-06
ANGLE	17.202500	4.89446E-04	-4.468[illegible]-03	-2.0[illegible]-04	-2.66[illegible]-04	-4.26454E-04	-2.23655E-03	-4.27378E-04	-4.01[illegible]

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	17.302500	5.00776E-04	-4.49464E-03	-2.00949E-04	-2.73584E-04	-4.24331E-04	-2.25479E-03	-4.25246E-04	-4.25549E-06
RATES		1.11180E-04	-2.59824E-04	1.20535E-07	-7.22742E-05	2.21041E-05	-1.80856E-04	2.22032E-05	-2.45649E-06
ANGLE	17.402500	5.11679E-04	-4.52062E-03	-2.00953E-04	-2.80858E-04	-4.22034E-04	-2.27271E-03	-4.22939E-04	-4.50496E-06
RATES		1.06868E-04	-2.59824E-04	-1.96112E-07	-7.32005E-05	2.38379E-05	-1.77628E-04	2.39455E-05	-2.53273E-06
ANGLE	17.502500	5.22146E-04	-4.54661E-03	-2.00969E-04	-2.88223E-04	-4.19564E-04	-2.29031E-03	-4.20458E-04	-4.76202E-06
RATES		1.02490E-04	-2.59824E-04	-1.09995E-07	-7.41053E-05	2.55530E-05	-1.74268E-04	2.56673E-05	-2.60826E-06
ANGLE	17.602500	5.32173E-04	-4.57259E-03	-2.00956E-04	-2.95678E-04	-4.16924E-04	-2.30756E-03	-4.17806E-04	-5.02659E-06
RATES		9.80500E-05	-2.59824E-04	3.85987E-07	-7.49873E-05	2.72481E-05	-1.70769E-04	2.73672E-05	-2.68297E-06
ANGLE	17.702500	5.41753E-04	-4.59857E-03	-2.00872E-04	-3.03220E-04	-4.14115E-04	-2.32445E-03	-4.14985E-04	-5.29858E-06
RATES		9.35503E-05	-2.59823E-04	1.29247E-06	-7.58452E-05	2.89224E-05	-1.67124E-04	2.90444E-05	-2.75677E-06
ANGLE	17.802500	5.50880E-04	-4.62455E-03	-2.00677E-04	-3.10846E-04	-4.11140E-04	-2.34098E-03	-4.11998E-04	-5.57790E-06
RATES		8.89944E-05	-2.59823E-04	2.60360E-06	-7.66778E-05	3.05753E-05	-1.63326E-04	3.06983E-05	-2.82957E-06
ANGLE	17.902500	5.59549E-04	-4.65053E-03	-2.00331E-04	-3.18554E-04	-4.08001E-04	-2.35711E-03	-4.08847E-04	-5.86445E-06
RATES		8.43860E-05	-2.59823E-04	4.30716E-06	-7.74843E-05	3.22064E-05	-1.59367E-04	3.23287E-05	-2.90131E-06
ANGLE	18.002500	5.67755E-04	-4.67652E-03	-1.99795E-04	-3.26342E-04	-4.04700E-04	-2.37284E-03	-4.05534E-04	-6.15811E-06
RATES		7.97287E-05	-2.59823E-04	6.38470E-06	-7.82640E-05	3.38158E-05	-1.55238E-04	3.39357E-05	-2.97195E-06
ANGLE	18.102500	5.75492E-04	-4.70250E-03	-1.99034E-04	-3.34206E-04	-4.01239E-04	-2.38815E-03	-4.02061E-04	-6.45878E-06
RATES		7.50268E-05	-2.59823E-04	8.81188E-06	-7.90163E-05	3.54039E-05	-1.50931E-04	3.55198E-05	-3.04145E-06
ANGLE	18.202500	5.82757E-04	-4.72848E-03	-1.98014E-04	-3.42144E-04	-3.97620E-04	-2.40302E-03	-3.98431E-04	-6.76635E-06
RATES		7.02846E-05	-2.59822E-04	1.15588E-05	-7.97411E-05	3.69714E-05	-1.46437E-04	3.70818E-05	-3.10980E-06
ANGLE	18.302500	5.89547E-04	-4.75446E-03	-1.96705E-04	-3.50153E-04	-3.93845E-04	-2.41743E-03	-3.94646E-04	-7.08069E-06
RATES		6.55067E-05	-2.59822E-04	1.45905E-05	-8.04384E-05	3.85192E-05	-1.41746E-04	3.86227E-05	-3.17698E-06
ANGLE	18.402500	5.95857E-04	-4.78045E-03	-1.95080E-04	-3.58230E-04	-3.89918E-04	-2.43136E-03	-3.90707E-04	-7.40169E-06
RATES		6.06978E-05	-2.59822E-04	1.78676E-05	-8.11084E-05	4.00483E-05	-1.36848E-04	4.01438E-05	-3.24301E-06
ANGLE	18.502500	6.01685E-04	-4.80643E-03	-1.93117E-04	-3.66373E-04	-3.85837E-04	-2.44479E-03	-3.86618E-04	-7.72923E-06
RATES		5.58628E-05	-2.59822E-04	2.13466E-05	-8.17517E-05	4.15603E-05	-1.31731E-04	4.16467E-05	-3.30790E-06
ANGLE	18.602500	6.07028E-04	-4.83241E-03	-1.90799E-04	-3.74579E-04	-3.81607E-04	-2.45770E-03	-3.82379E-04	-8.06321E-06
RATES		5.10069E-05	-2.59821E-04	2.49800E-05	-8.23689E-05	4.30565E-05	-1.26384E-04	4.31330E-05	-3.37168E-06
ANGLE	18.702500	6.11885E-04	-4.85839E-03	-1.88111E-04	-3.82845E-04	-3.77227E-04	-2.47006E-03	-3.77992E-04	-8.40351E-06
RATES		4.61351E-05	-2.59821E-04	2.87214E-05	-8.29610E-05	4.45388E-05	-1.20793E-04	4.46047E-05	-3.43436E-06
ANGLE	18.802500	6.16254E-04	-4.88437E-03	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	18.902500	6.20134E-04	-4.91036E-03	-1.81602E-04	-3.99550E-04	-3.68026E-04	-2.49303E-03	-3.68780E-04	-9.10265E-06
RATES		3.63651E-05	-2.59821E-04	3.63164E-05	-8.40734E-05	4.74681E-05	-1.08820E-04	4.75124E-05	-3.55660E-06
ANGLE	19.002500	6.23525E-04	-4.93634E-03	-1.77780E-04	-4.07983E-04	-3.63207E-04	-2.50359E-03	-3.63957E-04	-9.46129E-06
RATES		3.14774E-05	-2.59821E-04	4.00671E-05	-8.45960E-05	4.89189E-05	-1.02405E-04	4.89524E-05	-3.61622E-06
ANGLE	19.102500	6.26430E-04	-4.96232E-03	-1.73589E-04	-4.16468E-04	-3.58243E-04	-2.51350E-03	-3.58990E-04	-9.82585E-06
RATES		2.65950E-05	-2.59820E-04	4.37180E-05	-8.50976E-05	5.03628E-05	-9.56785E-05	5.03860E-05	-3.67488E-06
ANGLE	19.202500	6.28845E-04	-4.98830E-03	-1.69039E-04	-4.25002E-04	-3.53134E-04	-2.52272E-03	-3.53880E-04	-1.01962E-05
RATES		2.17231E-05	-2.59820E-04	4.72193E-05	-8.55792E-05	5.18015E-05	-8.86193E-05	5.18151E-05	-3.73260E-06
ANGLE	19.302500	6.30774E-04	-5.01428E-03	-1.64150E-04	-4.33583E-04	-3.47883E-04	-2.53121E-03	-3.48623E-04	-1.05723E-05
RATES		1.68667E-05	-2.59820E-04	5.05232E-05	-8.60416E-05	5.32366E-05	-8.12029E-05	5.32415E-05	-3.78939E-06
ANGLE	19.402500	6.32219E-04	-5.04027E-03	-1.58942E-04	-4.42209E-04	-3.42487E-04	-2.53894E-03	-3.43232E-04	-1.09541E-05
RATES		1.20308E-05	-2.59820E-04	5.35852E-05	-8.64855E-05	5.46696E-05	-7.34020E-05	5.46669E-05	-3.84527E-06
ANGLE	19.502500	6.33181E-04	-5.06625E-03	-1.53443E-04	-4.50879E-04	-3.36949E-04	-2.54587E-03	-3.[illegible]7694E-04	-1.13413E-05
RATES		7.22024E-06	-2.59820E-04	5.63643E-05	-8.69114E-05	5.61017E-05	-6.51863E-05	5.60928E-05	-3.90022E-06
ANGLE	19.602500	6.33664E-04	-5.09223E-03	-1.47681E-04	-4.59590E-04	-3.31257E-04	-2.55196E-03	-3.32014E-04	-1.17341E-05
RATES		2.43962E-06	-2.59819E-04	5.88239E-05	-8.73197E-05	5.75340E-05	-5.65212E-05	5.75202E-05	-3.95424E-06
ANGLE	19.702500	6.33671E-04	-5.11821E-03	-1.41692E-04	-4.68342E-04	-3.25442E-04	-2.55715E-03	-3.26190E-04	-1.21321E-05
RATES		-2.30665E-06	-2.59819E-04	6.09321E-05	-8.77103E-05	5.89673E-05	-4.73681E-05	5.89501E-05	-4.00729E-06
ANGLE	19.802500	6.33204E-04	-5.14419E-03	-1.35511E-04	-4.77131E-04	-3.19474E-04	-2.56141E-03	-3.20224E-04	-1.25355E-05
RATES		-7.01441E-06	-2.59819E-04	6.26626E-05	-8.80831E-05	6.04020E-05	-3.76832E-05	6.03832E-05	-4.05933E-06
ANGLE	19.902500	6.32269E-04	-5.17018E-03	-1.29177E-04	-4.85958E-04	-3.13362E-04	-2.56467E-03	-3.14114E-04	-1.29439E-05
RATES		-1.16797E-05	-2.59819E-04	6.39947E-05	-8.84378E-05	6.18384E-05	-2.74168E-05	6.18198E-05	-4.11030E-06
ANGLE	20.002500	6.30870E-04	-5.19616E-03	-1.22731E-04	-4.94818E-04	-3.07106E-04	-2.56687E-03	-3.07860E-04	-1.33575E-05
RATES		-1.62990E-05	-2.59819E-04	6.49139E-05	-8.87740E-05	6.32763E-05	-1.65128E-05	6.32597E-05	-4.16013E-06
ANGLE	20.102500	6.29012E-04	-5.22214E-03	-1.16214E-04	-5.03711E-04	-3.00706E-04	-2.56794E-03	-3.01461E-04	-1.37759E-05
RATES		-2.08687E-05	-2.59818E-04	6.54119E-05	-8.90909E-05	6.47155E-05	-4.90731E-06	6.47027E-05	-4.20873E-06
ANGLE	20.202500	6.26699E-04	-5.24812E-03	-1.09669E-04	-5.12635E-04	-2.94163E-04	-2.56782E-03	-2.94919E-04	-1.41992E-05
RATES		-2.53859E-05	-2.59818E-04	6.54871E-05	-8.93879E-05	6.61552E-05	7.47242E-06	6.61479E-05	-4.25301E-06
ANGLE	20.302500	6.23937E-04	-5.27410E-03	-1.03138E-04	-5.21598E-04	-2.87475E-04	-2.56641E-03	-2.88232E-04	-1.46271E-05
RATES		-2.98478E-05	-2.59818E-04	6.51439E-05	-8.96641E-05	6.75942E-05	2.07094E-05	6.75944E-05	-4.30184E-06
ANGLE	20.402500	6.20732E-04	-5.30009E-03	-9.64615E-05	-5.30567E-04	-2.80644E-04	-2.56363E-03	-2.81400E-04	-1.50595E-05
RATES		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	20.502500	6.17089E-04	-5.32607E-03	-9.02800E-05	-5.39571E-04	-2.73669E-04	-2.55939E-03	-2.74423E-04	-1.54962E-05
RATES		-3.85958E-05	-2.59818E-04	6.32535E-05	-9.01518E-05	7.04645E-05	5.01480E-05	7.04850E-05	-4.38868E-06
ANGLE	20.602500	6.13016E-04	-5.35205E-03	-8.40311E-05	-5.48597E-04	-2.66551E-04	-2.55356E-03	-2.67303E-04	-1.59371E-05
RATES		-4.28777E-05	-2.59818E-04	6.17467E-05	-9.03619E-05	7.18920E-05	6.65832E-05	7.19252E-05	-4.42940E-06
ANGLE	20.702500	6.08517E-04	-5.37803E-03	-7.79501E-05	-5.57642E-04	-2.59291E-04	-2.54602E-03	-2.60039E-04	-1.63820E-05
RATES		-4.70959E-05	-2.59818E-04	5.99020E-05	-9.05490E-05	7.33116E-05	8.43475E-05	7.33589E-05	-4.46811E-06
ANGLE	20.802500	6.03600E-04	-5.40401E-03	-7.20691E-05	-5.66705E-04	-2.51889E-04	-2.53661E-03	-2.52631E-04	-1.68307E-05
RATES		-5.12490E-05	-2.59817E-04	5.77534E-05	-9.07127E-05	7.47206E-05	1.03607E-04	7.47833E-05	-4.50467E-06
ANGLE	20.902500	5.98270E-04	-5.42999E-03	-6.64163E-05	-5.75783E-04	-2.44347E-04	-2.52523E-03	-2.45082E-04	-1.72828E-05
RATES		-5.53356E-05	-2.59817E-04	5.53393E-05	-9.08530E-05	7.61162E-05	1.24553E-04	7.61957E-05	-4.53889E-06
ANGLE	21.002500	5.92536E-04	-5.45598E-03	-6.10164E-05	-5.84875E-04	-2.36666E-04	-2.51164E-03	-2.37393E-04	-1.77383E-05
RATES		-5.93548E-05	-2.59817E-04	5.27023E-05	-9.09700E-05	7.74956E-05	1.47409E-04	7.75926E-05	-4.57061E-06
ANGLE	21.102500	5.86403E-04	-5.48196E-03	-5.58892E-05	-5.93976E-04	-2.28849E-04	-2.49566E-03	-2.29564E-04	-1.81968E-05
RATES		-6.33057E-05	-2.59817E-04	4.98831E-05	-9.10640E-05	7.88555E-05	1.72435E-04	7.89709E-05	-4.59965E-06
ANGLE	21.202500	5.79878E-04	-5.50794E-03	-5.10499E-05	-6.03086E-04	-2.20896E-04	-2.47706E-03	-2.21599E-04	-1.86581E-05
RATES		-6.71877E-05	-2.59817E-04	4.69451E-05	-9.11356E-05	8.01928E-05	1.99932E-04	8.03270E-05	-4.62583E-06
ANGLE	21.302500	5.72969E-04	-5.53392E-03	-4.65090E-05	-6.12202E-04	-2.12811E-04	-2.45557E-03	-2.13500E-04	-1.91219E-05
RATES		-7.10001E-05	-2.59817E-04	4.39234E-05	-9.11852E-05	8.15041E-05	2.30256E-04	8.16573E-05	-4.64896E-06
ANGLE	21.402500	5.65681E-04	-5.55990E-03	-4.22717E-05	-6.21322E-04	-2.04596E-04	-2.43089E-03	-2.05269E-04	-1.95878E-05
RATES		-7.47425E-05	-2.59817E-04	4.08745E-05	-9.12137E-05	8.27860E-05	2.63824E-04	8.29582E-05	-4.66886E-06
ANGLE	21.502500	5.58024E-04	-5.58588E-03	-3.83380E-05	-6.30444E-04	-1.96255E-04	-2.40266E-03	-1.96909E-04	-2.00555E-05
RATES		-7.84145E-05	-2.59817E-04	3.78497E-05	-9.12216E-05	8.40352E-05	3.01127E-04	8.42261E-05	-4.68532E-06
ANGLE	21.602500	5.50002E-04	-5.61187E-03	-3.47031E-05	-6.39565E-04	-1.87791E-04	-2.37050E-03	-1.88425E-04	-2.05247E-05
RATES		-8.20155E-05	-2.59817E-04	3.49001E-05	-9.12099E-05	8.52484E-05	3.42743E-04	8.54574E-05	-4.69815E-06
ANGLE	21.702500	5.41624E-04	-5.63785E-03	-3.13568E-05	-6.48685E-04	-1.79207E-04	-2.33393E-03	-1.79820E-04	-2.09950E-05
RATES		-8.55453E-05	-2.59817E-04	3.20752E-05	-9.11791E-05	8.64222E-05	3.89360E-04	8.66487E-05	-4.70710E-06
ANGLE	21.802500	5.32896E-04	-5.66383E-03	-2.82843E-05	-6.57800E-04	-1.70508E-04	-2.29241E-03	-1.71097E-04	-2.14659E-05
RATES		-8.90034E-05	-2.59817E-04	2.94225E-05	-9.11298E-05	8.75537E-05	4.41788E-04	8.77966E-05	-4.71195E-06
ANGLE	21.902500	5.23827E-04	-5.68981E-03	-2.54630E-05	-6.66910E-04	-1.61698E-04	-2.24529E-03	-1.62262E-04	-2.19371E-05
RATES		-9.23392E-05	-2.59817E-04	2.69857E-05	-9.10625E-05	8.86399E-05	5.01013E-04	8.88981E-05	-4.71242E-06
ANGLE	22.002500	5.14422E-04	-5.71570E-03	-2.28753E-05	-6.76012E-04	-1.52783E-04	-2.19184E-03	-1.53320E-04	-2.24062E-05

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	22.102500	5.04689E-04	-5.74177E-03	-2.04927E-05	-6.85105E-04	-1.43765E-04	-2.13131E-03	-1.44274E-04	-2.28786E-05
RATES		-9.89418E-05	-2.59817E-04	2.29146E-05	-9.08743E-05	9.06660E-05	6.44443E-04	9.09508E-05	-4.69806E-06
ANGLE	22.202500	4.94636E-04	-5.76776E-03	-1.82816E-05	-6.94186E-04	-1.34651E-04	-2.05260E-03	-1.35132E-04	-2.33478E-05
RATES		-1.02107E-04	-2.59817E-04	2.13524E-05	-9.07536E-05	9.16010E-05	7.31575E-04	9.18967E-05	-4.68429E-06
ANGLE	22.302500	4.84270E-04	-5.79374E-03	-1.62084E-05	-7.03255E-04	-1.25446E-04	-1.98455E-03	-1.25897E-04	-2.38152E-05
RATES		-1.05197E-04	-2.59817E-04	2.01438E-05	-9.06149E-05	9.24812E-05	8.31345E-04	9.27861E-05	-4.66371E-06
ANGLE	22.402500	4.73599E-04	-5.81972E-03	-1.42392E-05	-7.12309E-04	-1.16157E-04	-1.89583E-03	-1.16576E-04	-2.42803E-05
RATES		-1.08210E-04	-2.59817E-04	1.93107E-05	-9.04582E-05	9.33051E-05	9.45802E-04	9.36172E-05	-4.63673E-06
ANGLE	22.502500	4.62631E-04	-5.84570E-03	-1.23332E-05	-7.21346E-04	-1.06787E-04	-1.79483E-03	-1.07176E-04	-2.47424E-05
RATES		-1.11146E-04	-2.59817E-04	1.88679E-05	-9.02844E-05	9.40712E-05	1.07724E-03	9.43886E-05	-4.60275E-06
ANGLE	22.602500	4.51373E-04	-5.87168E-03	-1.04517E-05	-7.30365E-04	-9.73444E-05	-1.67973E-03	-9.77006E-05	-2.52006E-05
RATES		-1.14002E-04	-2.59817E-04	1.88240E-05	-9.00953E-05	9.47787E-05	1.22801E-03	9.50994E-05	-4.56118E-06
ANGLE	22.702500	4.39833E-04	-5.89766E-03	-8.55450E-06	-7.39364E-04	-8.78336E-05	-1.54849E-03	-8.81577E-05	-2.56543E-05
RATES		-1.16778E-04	-2.59818E-04	1.91816E-05	-8.98954E-05	9.54270E-05	1.40035E-03	9.57490E-05	-4.51151E-06
ANGLE	22.802500	4.28020E-04	-5.92365E-03	-6.60173E-06	-7.48344E-04	-7.82610E-05	-1.39886E-03	-7.85529E-05	-2.61026E-05
RATES		-1.19470E-04	-2.59818E-04	1.99366E-05	-8.96937E-05	9.60159E-05	1.59585E-03	9.63371E-05	-4.45339E-06
ANGLE	22.902500	4.15943E-04	-5.94963E-03	-4.55101E-06	-7.57304E-04	-6.85329E-05	-1.22833E-03	-6.88929E-05	-2.65446E-05
RATES		-1.22077E-04	-2.59818E-04	2.10771E-05	-8.95082E-05	9.65454E-05	1.81465E-03	9.68639E-05	-4.38698E-06
ANGLE	23.002500	4.03609E-04	-5.97561E-03	-2.36769E-06	-7.66248E-04	-5.89549E-05	-1.03488E-03	-5.91832E-05	-2.69797E-05
RATES		-1.24597E-04	-2.59819E-04	2.25869E-05	-8.93656E-05	9.70162E-05	2.05426E-03	9.73300E-05	-4.31321E-06
ANGLE	23.102500	3.91028E-04	-6.00159E-03	-1.60349E-08	-7.75181E-04	-4.92326E-05	-8.16741E-04	-4.94299E-05	-2.74070E-05
RATES		-1.27026E-04	-2.59819E-04	2.44434E-05	-8.93088E-05	9.74290E-05	2.30819E-03	9.77363E-05	-4.23432E-06
ANGLE	23.202500	3.78208E-04	-6.02757E-03	2.53719E-06	-7.84117E-04	-3.94719E-05	-5.73090E-04	-3.96389E-05	-2.78264E-05
RATES		-1.29364E-04	-2.59820E-04	2.66184E-05	-8.93394E-05	9.77849E-05	2.56429E-03	9.80842E-05	-4.15426E-06
ANGLE	23.302500	3.65160E-04	-6.05356E-03	5.32212E-06	-7.93072E-04	-2.96784E-05	-3.[illegible]660E-04	-2.98159E-05	-2.82381E-05
RATES		-1.31606E-04	-2.59821E-04	2.90789E-05	-8.97162E-05	9.80854E-05	2.80394E-03	9.83750E-05	-4.07907E-06
ANGLE	23.402500	3.51892E-04	-6.07954E-03	8.36541E-06	-8.02075E-04	-1.99575E-05	-1.43040E-05	-1.99666E-05	-2.86429E-05
RATES		-1.33750E-04	-2.59821E-04	3.17369E-05	-9.03457E-05	9.83320E-05	3.00316E-03	9.86108E-05	-4.01638E-06
ANGLE	23.502500	3.38414E-04	-6.10552E-03	1.16873E-05	-8.11156E-04	-1.00140E-05	2.93539E-04	-1.00958E-05	-2.90421E-05
RATES		-1.35793E-04	-2.59822E-04	3.47061E-05	-9.15539E-05	9.85264E-05	3.13988E-03	9.87932E 05	-3.97325E-06
ANGLE	23.602500	3.24736E-04	-6.13150E-03	1.53105E-05	-8.20360E-04	-1.53670E-07	6.10772E-04	-2.07430E-07	[illegible]

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	23.702500	3.10871E-04	-6.15749E-03	1.92475E-05	-8.29728E-04	9.71870E-06	9.28181E-04	9.68765E-06	-2.98347E-05
RATES		-1.39565E-04	-2.59824E-04	4.09747E-05	-9.46356E-05	9.87683E-05	3.14401E-03	9.90085E-05	-3.97161E-06
ANGLE	23.802500	2.96827E-04	-6.18347E-03	2.35070E-05	-8.39296E-04	1.95985E-05	1.23669E-03	1.95908E-05	-3.02337E-05
RATES		-1.41287E-04	-2.59825E-04	4.42267E-05	-9.67922E-05	9.88204E-05	3.01138E-03	9.90464E-05	-4.01315E-06
ANGLE	23.902500	2.82617E-04	-6.20945E-03	2.80930E-05	-8.49092E-04	2.94814E-05	1.52829E-03	2.94955E-05	-3.06380E-05
RATES		-1.42876E-04	-2.59825E-04	4.74885E-05	-9.91328E-05	9.88298E-05	2.81087E-03	9.90413E-05	-4.07600E-06
ANGLE	24.002500	2.68252E-04	-6.23543E-03	3.30034E-05	-8.59124E-04	3.93631E-05	1.79755E-03	3.93977E-05	-3.10493E-05
RATES		-1.44389E-04	-2.59826E-04	5.07079E-05	-1.01512E-04	9.87993E-05	2.56994E-03	9.89960E-05	-4.15147E-06
ANGLE	24.102500	2.53743E-04	-6.26142E-03	3.82315E-05	-8.69392E-04	4.92400E-05	2.04173E-03	4.92935E-05	-3.14684E-05
RATES		-1.45764E-04	-2.59826E-04	5.38332E-05	-1.03814E-04	9.87312E-05	2.31329E-03	9.89134E-05	-4.23170E-06
ANGLE	24.202500	2.39103E-04	-6.28740E-03	4.37653E-05	-8.79882E-04	5.91082E-05	2.26027E-03	5.91792E-05	-3.18956E-05
RATES		-1.47016E-04	-2.59827E-04	5.68140E-05	-1.05958E-04	9.86281E-05	2.05987E-03	9.87961E-05	-4.31064E-06
ANGLE	24.302500	2.24344E-04	-6.31338E-03	4.95879E-05	-8.90577E-04	6.89645E-05	2.45418E-03	6.90516E-05	-3.23304E-05
RATES		-1.48145E-04	-2.59827E-04	5.96023E-05	-1.07901E-04	9.84924E-05	1.82191E-03	9.86468E-05	-4.38434E-06
ANGLE	24.402500	2.09478E-04	-6.33936E-03	5.56778E-05	-9.01455E-04	7.88057E-05	2.62536E-03	7.89076E-05	-3.27722E-05
RATES		-1.49146E-04	-2.59827E-04	6.21527E-05	-1.09626E-04	9.83263E-05	1.60584E-03	9.84682E-05	-4.45068E-06
ANGLE	24.502500	1.94519E-04	-6.36535E-03	6.20091E-05	-9.12495E-04	8.85288E-05	2.77614E-03	8.87443E-05	-3.32203E-05
RATES		-1.50019E-04	-2.59827E-04	6.44235E-05	-1.11136E-04	9.81320E-05	1.41392E-03	9.82625E-05	-4.50885E-06
ANGLE	24.602500	1.79479E-04	-6.39133E-03	6.85520E-05	-9.23676E-04	9.84312E-05	2.90893E-03	9.85593E-05	-3.36737E-05
RATES		-1.50762E-04	-2.59827E-04	6.63773E-05	-1.12443E-04	9.79114E-05	1.24583E-03	9.80320E-05	-4.55886E-06
ANGLE	24.702500	1.64371E-04	-6.41731E-03	7.52729E-05	-9.34977E-04	1.08210E-04	3.02604E-03	1.08350E-04	-3.41318E-05
RATES		-1.51372E-04	-2.59828E-04	6.79812E-05	-1.13562E-04	9.76662E-05	1.09987E-03	9.77786E-05	-4.60116E-06
ANGLE	24.802500	1.49209E-04	-6.44329E-03	8.21356E-05	-9.46382E-04	1.17964E-04	3.12956E-03	1.18114E-04	-3.45937E-05
RATES		-1.51848E-04	-2.59828E-04	6.92078E-05	-1.14512E-04	9.73978E-05	9.73718E-04	9.75037E-05	-4.63639E-06
ANGLE	24.902500	1.34006E-04	-6.46928E-03	8.91011E-05	-9.57875E-04	1.27689E-04	3.22133E-03	1.27850E-04	-3.50589E-05
RATES		-1.52189E-04	-2.59828E-04	7.00355E-05	-1.15307E-04	9.71074E-05	8.64928E-04	9.72086E-05	-4.66525E-06
ANGLE	25.002500	1.18776E-04	-6.49526E-03	9.61287E-05	-9.69439E-04	1.37384E-04	3.30300E-03	1.37555E-04	-3.55266E-05
RATES		-1.52395E-04	-2.59828E-04	7.04484E-05	-1.15962E-04	9.67958E-05	7.71114E-04	9.68942E-05	-4.68842E-06
ANGLE	25.102500	1.03531E-04	-6.52124E-03	1.03176E-04	-9.81063E-04	1.47048E-04	3.37594E-03	1.47228E-04	-3.59964E-05
RATES		-1.52465E-04	-2.59828E-04	7.04369E-05	-1.16489E-04	9.64636E-05	6.90157E-04	9.65610E-05	-4.70648E-06
ANGLE	25.202500	8.82870E-05	-6.54723E-03	1.10201E-04	-9.92734E-04	1.56677E-04	3.44136E-03	1.56867E-04	-3.64678E-05

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	25.302500	7.30560E-05	-6.57321E-03	1.17161E-04	-1.00444E-03	1.66269E-04	3.50026E-03	1.66470E-04	-3.69402E-05
RATES		-1.52198E-04	-2.59828E-04	6.91360E-05	-1.17193E-04	9.57381E-05	5.59568E-04	9.58387E-05	-4.72925E-06
ANGLE	25.402500	5.78519E-05	-6.59919E-03	1.24014E-04	-1.01617E-03	1.75823E-04	3.55351E-03	1.76034E-04	-3.74135E-05
RATES		-1.51862E-04	-2.59828E-04	6.78598E-05	-1.17383E-04	9.53444E-05	5.06953E-04	9.54489E-05	-4.73471E-06
ANGLE	25.502500	4.26881E-05	-6.62517E-03	1.30720E-04	-1.02791E-03	1.85337E-04	3.60185E-03	1.85559E-04	-3.78871E-05
RATES		-1.51392E-04	-2.59828E-04	6.61861E-05	-1.17470E-04	9.49291E-05	4.61174E-04	9.50392E-05	-4.73660E-06
ANGLE	25.[illegible]02500	2.75780E-05	-6.65116E-03	1.37239E-04	-1.03966E-03	1.94809E-04	3.64591E-03	1.95041E-04	-3.83607E-05
RATES		-1.50789E-04	-2.59828E-04	6.41370E-05	-1.17459E-04	9.44914E-05	4.21255E-04	9.46084E-05	-4.73510E-06
ANGLE	25.702500	1.25348E-05	-6.67714E-03	1.43535E-04	-1.05140E-03	2.04235E-04	3.68425E-03	2.04480E-04	-3.88340E-05
RATES		-1.50055E-04	-2.59828E-04	6.17404E-05	-1.17350E-04	9.40300E-05	3.8[illegible]477E-04	9.41553E-05	-4.73035E-06
ANGLE	25.802500	-2.42865E-06	-6.70312E-03	1.49576E-04	-1.06313E-03	2.13614E-04	3.72332E-03	2.13872E-04	-3.93067E-05
RATES		-1.49192E-04	-2.59828E-04	5.90295E-05	-1.17144E-04	9.35434E-05	3.55848E-04	9.36782E-05	-4.72242E-06
ANGLE	25.902500	-1.72994E-05	-6.72910E-03	1.55332E-04	-1.07483E-03	2.22943E-04	3.75753E-03	2.23214E-04	-3.97784E-05
RATES		-1.48202E-04	-2.59828E-04	5.60423E-05	-1.16841E-04	9.30298E-05	3.29086E-04	9.31753E-05	-4.71132E-06
ANGLE	26.002500	-3.20649E-05	-6.75509E-03	1.60777E-04	-1.08649E-03	2.32219E-04	3.78923E-03	2.32506E-04	-4.02488E-05
RATES		-1.47087E-04	-2.59828E-04	5.28206E-05	-1.16442E-04	9.24873E-05	3.05601E-04	9.26446E-05	-4.69703E-06
ANGLE	26.102500	-4.67128E-05	-6.78107E-03	1.65890E-04	-1.09811E-03	2.41439E-04	3.81873E-03	2.41742E-04	-4.07177E-05
RATES		-1.45851E-04	-2.59828E-04	4.94101E-05	-1.15945E-04	9.19139E-05	2.84977E-04	9.20838E-05	-4.67948E-06
ANGLE	26.202500	-6.12311E-05	-6.80705E-03	1.70654E-04	-1.10968E-03	2.50600E-04	3.84630E-03	2.50921E-04	-4.11846E-05
RATES		-1.44496E-04	-2.59828E-04	4.58590E-05	-1.15350E-04	9.13073E-05	2.66862E-04	9.14906E-05	-4.65857E-06
ANGLE	26.302500	-7.56080E-05	-6.83304E-03	1.75059E-04	-1.12118E-03	2.59699E-04	3.87217E-03	2.60039E-04	-4.16493E-05
RATES		-1.43024E-04	-2.59828E-04	4.22177E-05	-1.14656E-04	9.06652E-05	2.50955E-04	9.08622E-05	-4.63417E-06
ANGLE	26.402500	-8.98322E-05	-6.85902E-03	1.79097E-04	-1.13261E-03	2.68732E-04	3.89655E-03	2.69092E-04	-4.21113E-05
RATES		-1.41439E-04	-2.59828E-04	3.85376E-05	-1.13860E-04	8.[illegible]853E-05	2.37001E-04	9.01962E-05	-4.60610E-06
ANGLE	26.502500	-1.03892E-04	-6.88500E-03	1.82767E-04	-1.14395E-03	2.[illegible]7695E-04	3.91962E-03	2.78077E-04	-4.25704E-05
RATES		-1.39745E-04	-2.59828E-04	3.48707E-05	-1.12964E-04	8.[illegible]2653E-05	2.24779E-04	8.94898E-05	-4.57419E-06
ANGLE	26.602500	-1.17778E-04	-6.91098E-03	1.86073E-04	-1.15519E-03	2.86584E-04	3.94155E-03	2.86983E-04	-4.30260E-05
RATES		-1.37945E-04	-2.59828E-04	3.12686E-05	-1.11965E-04	8.85029E-05	2.14103E-04	8.87405E-05	-4.53823E-06
ANGLE	26.702500	-1.31478E-04	-6.93697E-03	1.89025E-04	-1.16634E-03	2.95394E-04	3.96249E-03	2.95824E-04	-4.34779E-05
RATES		-1.36041E-04	-2.59828E-04	2.77816E-05	-1.10863E-04	8.76958E-05	2.04810E-04	8.79458E-05	-4.49790E-06
ANGLE	26.[illegible]02500	-1.44983E-04	-6.96295E-03	1.91638E-04	-1.17736E-03	3.04121E-04	3.98255E-03	3.04577E-04	-4.392[illegible]E-05

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	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	26.902500	-1.58282E-04	-6.98893E-03	1.93924E-04	-1.18826E-03	3.12761E-04	4.00187E-03	3.13243E-04	-4.43684E-05
RATES		-1.31936E-04	-2.59828E-04	2.13440E-05	-1.08347E-04	8.59395E-05	1.89829E-04	8.62107E-05	-4.40374E-06
ANGLE	27.002500	-1.71367E-04	-7.01492E-03	1.95913E-04	-1.19903E-03	3.21308E-04	4.02055E-03	3.21817E-04	-4.48061E-05
RATES		-1.29742E-04	-2.59828E-04	1.84813E-05	-1.06933E-04	8.49867E-05	1.83915E-04	8.52664E-05	-4.34926E-06
ANGLE	27.102500	-1.84227E-04	-7.04090E-03	1.97631E-04	-1.20965E-03	3.29756E-04	4.03868E-03	3.30294E-04	-4.52380E-05
RATES		-1.27458E-04	-2.59828E-04	1.59081E-05	-1.05415E-04	8.39820E-05	1.78924E-04	8.42685E-05	-4.28954E-06
ANGLE	27.202500	-1.96855E-04	-7.06688E-03	1.99106E-04	-1.22011E-03	3.38102E-04	4.05636E-03	3.38669E-04	-4.56638E-05
RATES		-1.25086E-04	-2.59828E-04	1.36579E-05	-1.03794E-04	8.29243E-05	1.74775E-04	8.32159E-05	-4.22436E-06
ANGLE	27.302500	-2.09242E-04	-7.09286E-03	2.00375E-04	-1.23040E-03	3.46339E-04	4.07366E-03	3.46935E-04	-4.60827E-05
RATES		-1.22630E-04	-2.59828E-04	1.17588E-05	-1.02070E-04	8.18126E-05	1.71398E-04	8.21074E-05	-4.15349E-06
ANGLE	27.402500	-2.21379E-04	-7.11885E-03	2.01471E-04	-1.24052E-03	3.54463E-04	4.09066E-03	3.55088E-04	-4.64943E-05
RATES		-1.20091E-04	-2.59828E-04	1.02335E-05	-1.00243E-04	8.05462E-05	1.68729E-04	8.09426E-05	-4.07674E-06
ANGLE	27.502500	-2.33258E-04	-7.14483E-03	2.02435E-04	-1.25045E-03	3.62467E-04	4.10743E-03	3.63122E-04	-4.68979E-05
RATES		-1.17474E-04	-2.59828E-04	9.09829E-06	-9.83143E-05	7.94249E-05	1.66715E-04	7.97211E-05	-3.99391E-06
ANGLE	27.602500	-2.44871E-04	-7.17081E-03	2.03305E-04	-1.26018E-03	3.70346E-04	4.12403E-03	3.71031E-04	-4.72929E-05
RATES		-1.14778E-04	-2.59828E-04	8.36355E-06	-9.62850E-05	7.81488E-05	1.65305E-04	7.84429E-05	-3.90486E-06
ANGLE	27.702500	-2.56210E-04	-7.19679E-03	2.04125E-04	-1.26970E-03	3.78094E-04	4.14051E-03	3.78808E-04	-4.76786E-05
RATES		-1.12008E-04	-2.59828E-04	8.03367E-06	-9.41556E-05	7.68184E-05	1.64452E-04	7.71084E-05	-3.80942E-06
ANGLE	27.802500	-2.67269E-04	-7.22278E-03	2.04932E-04	-1.27901E-03	3.85707E-04	4.15694E-03	3.86449E-04	-4.80544E-05
RATES		-1.09165E-04	-2.59828E-04	8.10595E-06	-9.19267E-05	7.54343E-05	1.64121E-04	7.57184E-05	-3.70751E-06
ANGLE	27.902500	-2.78039E-04	-7.24876E-03	2.05766E-04	-1.28808E-03	3.93178E-04	4.17337E-03	3.93949E-04	-4.84197E-05
RATES		-1.06250E-04	-2.59827E-04	8.57044E-06	-8.95988E-05	7.39977E-05	1.64276E-04	7.42740E-05	-3.59905E-06
ANGLE	28.002500	-2.88515E-04	-7.27474E-03	2.06666E-04	-1.29692E-03	4.00504E-04	4.18982E-03	4.01302E-04	-4.87739E-05
RATES		-1.03266E-04	-2.59827E-04	9.41082E-06	-8.71722E-05	7.25101E-05	1.64887E-04	7.27768E-05	-3.48403E-06
ANGLE	28.102500	-2.98689E-04	-7.30073E-03	2.07668E-04	-1.30551E-03	4.07678E-04	4.20637E-03	4.08502E-04	-4.91162E-05
RATES		-1.00212E-04	-2.59827E-04	1.06056E-05	-8.46467E-05	7.09735E-05	1.65923E-04	7.12286E-05	-3.36243E-06
ANGLE	28.202500	-3.08554E-04	-7.32671E-03	2.08306E-04	-1.31384E-03	4.14696E-04	4.22303E-03	4.15545E-04	-4.94461E-05
RATES		-9.70908E-05	-2.59827E-04	1.21277E-05	-8.20223E-05	6.93898E-05	1.67361E-04	6.96316E-05	-3.23430E-06
ANGLE	28.302500	-3.18104E-04	-7.35269E-03	2.10112E-04	-1.32191E-03	4.21553E-04	4.23986E-03	4.22425E-04	-4.97628E-05
RATES		-9.39029E-05	-2.59827E-04	1.39446E-05	-7.92982E-05	6.77616E-05	1.69174E-04	6.79884E-05	-3.09972E-06
ANGLE	28.402500	-3.27331E-04	-7.37867E-03	2.11612E-04	-1.32970E-03	4.28246E-04	4.25689E-03	4.29140E-04	-5.00657E-05

	TIME	THETAB	PHIB	THETAS	PHIS	THETAP	PHIP	THETAE	PHIE
ANGLE	28.502500	-3.36230E-04	-7.40466E-03	2.13330E-04	-1.33720E-03	4.34769E-04	4.27415E-03	4.35684E-04	-5.03542E-05
RATES		-8.73304E-05	-2.59827E-04	1.83104E-05	-7.35473E-05	6.43823E-05	1.73847E-04	6.45750E-05	-2.81165E-06
ANGLE	28.602500	-3.44794E-04	-7.43064E-03	2.15287E-04	-1.34440E-03	4.41120E-04	4.29167E-03	4.42053E-04	-5.06277E-05
RATES		-8.39471E-05	-2.59828E-04	2.07730E-05	-7.05176E-05	6.26374E-05	1.76668E-04	6.28113E-05	-2.65850E-06
ANGLE	28.702500	-3.53016E-04	-7.45662E-03	2.17496E-04	-1.35130E-03	4.47295E-04	4.30950E-03	4.48244E-04	-5.08856E-05
RATES		-8.04999E-05	-2.59828E-04	2.33597E-05	-6.73829E-05	6.08598E-05	1.79790E-04	6.10144E-05	-2.49955E-06
ANGLE	28.802500	-3.60891E-04	-7.48260E-03	2.19967E-04	-1.35788E-03	4.53290E-04	4.32765E-03	4.54254E-04	-5.11273E-05
RATES		-7.69894E-05	-2.59828E-04	2.60207E-05	-6.41411E-05	5.90530E-05	1.83197E-04	5.91879E-05	-2.33503E-06
ANGLE	28.902500	-3.68411E-04	-7.50859E-03	2.22706E-04	-1.36412E-03	4.59104E-04	4.34615E-03	4.60080E-04	-5.13523E-05
RATES		-7.34160E-05	-2.59828E-04	2.87052E-05	-6.07900E-05	5.72205E-05	1.86876E-04	5.73355E-05	-2.16521E-06
ANGLE	29.002500	-3.75571E-04	-7.53457E-03	2.25712E-04	-1.37003E-03	4.64733E-04	4.36504E-03	4.65719E-04	-5.15601E-05
RATES		-6.97804E-05	-2.59828E-04	3.13618E-05	-5.73273E-05	5.53658E-05	1.90813E-04	5.54611E-05	-1.99039E-06
ANGLE	29.102500	-3.82364E-04	-7.56055E-03	2.28979E-04	-1.37558E-03	4.70176E-04	4.38433E-03	4.71171E-04	-5.17501E-05
RATES		-6.60830E-05	-2.59828E-04	3.39393E-05	-5.37508E-05	5.34925E-05	1.94998E-04	5.35685E-05	-1.81086E-06
ANGLE	29.202500	-3.88784E-04	-7.58654E-03	2.32498E-04	-1.38077E-03	4.75430E-04	4.40405E-03	4.76432E-04	-5.19220E-05
RATES		-6.23247E-05	-2.59828E-04	3.63878E-05	-5.00581E-05	5.16038E-05	1.99420E-04	5.16612E-05	-1.62695E-06
ANGLE	29.302500	-3.94826E-04	-7.61252E-03	2.36253E-04	-1.38559E-03	4.80496E-04	4.42423E-03	4.81502E-04	-5.20753E-05
RATES		-5.85062E-05	-2.59828E-04	3.86594E-05	-4.62472E-05	4.97033E-05	2.04069E-04	4.97428E-05	-1.43897E-06
ANGLE	29.402500	-4.00483E-04	-7.63850E-03	2.40224E-04	-1.39002E-03	4.85370E-04	4.44488E-03	4.86380E-04	-5.22096E-05
RATES		-5.46284E-05	-2.59828E-04	4.07087E-05	-4.23162E-05	4.77942E-05	2.08937E-04	4.78168E-05	-1.24726E-06
ANGLE	29.502500	-4.05749E-04	-7.66448E-03	2.44386E-04	-1.39404E-03	4.90054E-04	4.46602E-03	4.91065E-04	-5.23245E-05
RATES		-5.06925E-05	-2.59828E-04	4.24938E-05	-3.82634E-05	4.58795E-05	2.14017E-04	4.58863E-05	-1.05213E-06
ANGLE	29.602500	-4.10618E-04	-7.69047E-03	2.48711E-04	-1.39766E-03	4.94546E-04	4.48769E-03	4.95557E-04	-5.24198E-05
RATES		-4.66998E-05	-2.59828E-04	4.39766E-05	-3.40876E-05	4.39621E-05	2.19301E-04	4.39544E-05	-8.53916E-07
ANGLE	29.702500	-4.15086E-04	-7.71645E-03	2.53168E-04	-1.40086E-03	4.98846E-04	4.50989E-03	4.99855E-04	-5.24951E-05
RATES		-4.26519E-05	-2.59828E-04	4.51240E-05	-2.97878E-05	4.20447E-05	2.24785E-04	4.20239E-05	-6.52912E-07
ANGLE	29.802500	-4.19146E-04	-7.74243E-03	2.57721E-04	-1.40361E-03	5.02955E-04	4.53266E-03	5.03961E-04	-5.25502E-05
RATES		-3.85505E-05	-2.59828E-04	4.59078E-05	-2.53638E-05	4.01297E-05	2.30464E-04	4.00971E-05	-4.49408E-07
ANGLE	29.902500	-4.22793E-04	-7.76842E-03	2.62333E-04	-1.40592E-03	5.06872E-04	4.55600E-03	5.07875E-04	-5.25849E-05
RATES		-3.43976E-05	-2.59828E-04	4.63055E-05	-2.08157E-05	3.82191E-05	2.36333E-04	3.81765E 05	-2.43671E-07
ANGLE	30.002500	-4.26023E-04	-7.79440E-03	2.66964E-04	-1.40777E-03	5.10599E-04	4.57993E-03	5.11597E-04	-5.25988E-05

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GUST VELOCITY PROFILE

I	AA	BB	V
1	1.263839711387192E+00	1.263839711387192E+00	2.527679422774384E+00
2	1.242809741255677E+00	1.284766628714550E+00	2.527576369970220E+00
3	1.221685942803028E+00	1.305581313957177E+00	2.527267256760197E+00
4	1.200477581668785E+00	1.326274637063563E+00	2.526752218732341E+00
5	1.179193960584534E+00	1.346837521215754E+00	2.526031481800288E+00
6	1.157844415293631E+00	1.367260946811029E+00	2.525105362104654E+00
7	1.136438310455986E+00	1.387535955417974E+00	2.523974265873960E+00
8	1.114985035540641E+00	1.407653653706184E+00	2.522638689246818E+00
9	1.093494000706940E+00	1.427605217346958E+00	2.521099218053891E+00
10	1.071974632677204E+00	1.447381894884217E+00	2.519356527561413E+00
11	1.050436370601552E+00	1.466975011572941E+00	2.517411382174487E+00
12	1.028888601917826E+00	1.486375973184458E+00	2.515264635102284E+00
13	1.007340956207351E+00	1.505576269775936E+00	2.512917227983280E+00
14	9.958027110493950E-01	1.524567479423389E+00	2.510370190472784E+00
15	9.642833678751259E-01	1.543341271915587E+00	2.507624639790706E+00
16	9.427923678238876E-01	1.561889412408199E+00	2.504681780232076E+00
17	9.213391376026223E-01	1.580203755035691E+00	2.501542902639306E+00
18	8.999330873511866E-01	1.598276296460179E+00	2.498209383831366E+00
19	8.785836065145674E-01	1.616099079494951E+00	2.494682686009511E+00
20	8.573300597245191E-01	1.633664296381809E+00	2.490964356106318E+00
21	8.360917826916854E-01	1.650964242420024E+00	2.487056021111698E+00
22	8.149680781108870E-01	1.667991329246036E+00	2.482959407356915E+00
23	7.939382115803610E-01	1.684738088181652E+00	2.478676299762213E+00
24	7.730114075378225E-01	1.701197173511211E+00	2.474208581049027E+00
25	7.521968452140193E-01	1.717361365701493E+00	2.469558210915508E+00
26	7.315036546066800E-01	1.733223574570644E+00	2.464727229177313E+00
27	7.109409124755075E-01	1.748776842397056E+00	2.459717754872557E+00
28	6.905176383610403E-01	1.764014346971514E+00	2.454531935332551E+00
29	6.702427906281478E-01	1.778929404589654E+00	2.449172195217798E+00
30	6.501252625367862E-01	1.793515472983664E+00	2.443640735520447E+00
31	6.301738783408624E-01	1.807766154191938E+00	2.437940032532794E+00
32	6.103973894178836E-01	1.821675197365494E+00	2.432072536783377E+00
33	5.908044704300153E-01	1.835236501509748E+00	2.426040971939756E+00
34	5.714037155193274E-01	1.848444118160085E+00	2.419847833680009E+00
35	5.522036345378680E-01	1.861292253994037E+00	2.413495888531898E+00
36	5.332126493151605E-01	1.873775273306434E+00	2.406987922681594E+00
37	5.144390899638935E-01	1.885887700787460E+00	2.400326790751294E+00
38	4.958911912262298E-01	1.897624223321095E+00	2.393515414547323E+00
39	4.775770888615583E-01	1.908979692916787E+00	2.386556781778339E+00
40	4.595043160780930E-01	1.919949128666893E+00	2.379453944744981E+00
41	4.416823000089938E-01	1.930527718991861E+00	2.372210019000846E+00
42	4.241173582354598E-01	1.940710823750642E+00	2.364828181986098E+00
43	4.068176953574518E-01	1.950493976276057E+00	2.357311671633497E+00

ORIGINAL PAGE IS
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46	3.565856607691806E-01	1.977401696492365E+00	2.333987357261535E+00
47	3.404217826503313E-01	1.985543909840963E+00	2.325965692491295E+00
48	3.245598952443256E-01	1.993266505590910E+00	2.317826400835230E+00
49	3.090069561317978E-01	2.000566096340634E+00	2.309573052472430E+00
50	2.937697873777374E-01	2.007439480233401E+00	2.301209267511129E+00
51	2.786550725392422E-01	2.013883642361776E+00	2.292738714901006E+00
52	2.642693537337468E-01	2.019875756090037E+00	2.284165109823775E+00
53	2.500190287695219E-01	2.025473184294086E+00	2.275492213063600E+00
54	2.361103483392943E-01	2.030613480518113E+00	2.266723828857394E+00
55	2.225494132765277E-01	2.035314390047773E+00	2.257863033326288E+00
56	2.093421718893378E-01	2.035738503899131E+00	2.248916022788464E+00
57	1.964944173314116E-01	2.043389994723171E+00	2.239884412054577E+00
58	1.840117850808554E-01	2.045761147625219E+00	2.230772932706074E+00
59	1.718997504583628E-01	2.049665330899307E+00	2.221585531357658E+00
60	1.601636262274422E-01	2.052162761676669E+00	2.212326337904099E+00
61	1.488085602641593E-01	2.054190853488535E+00	2.202999413752693E+00
62	1.378395332990161E-01	2.055769216742632E+00	2.193608750041649E+00
63	1.272613567322818E-01	2.056897159113461E+00	2.184158515845733E+00
64	1.170786705234952E-01	2.057574185845660E+00	2.174652856369363E+00
65	1.072959411562735E-01	2.057799999722218E+00	2.165095941128484E+00
66	9.791745967908394E-02	2.057574502442463E+00	2.155491962121545E+00
67	8.894733982313596E-02	2.056397792167746E+00	2.145845131990862E+00
68	8.038951619783319E-02	2.055770165976952E+00	2.136159682174778E+00
69	7.224774256503785E-02	2.054192118486498E+00	2.126439861051523E+00
70	6.452559019242621E-02	2.052164341883426E+00	2.116689932075843E+00
71	5.722644628711304E-02	2.049687725621709E+00	2.106914171903812E+00
72	5.035351250981512E-02	2.046763356032187E+00	2.097116868541988E+00
73	4.390980357054941E-02	2.043392515846008E+00	2.087302319416551E+00
74	3.789814590622131E-02	2.039576683632036E+00	2.077474829538218E+00
75	3.232117644093035E-02	2.035317533148131E+00	2.067638709589048E+00
76	2.718134142922302E-02	2.030616932607273E+00	2.057798274036486E+00
77	2.248089538315556E-02	2.025476943857853E+00	2.047957839241008E+00
78	1.822190008336644E-02	2.019899821479342E+00	2.038121721562703E+00
79	1.440622367468158E-02	2.013888011773384E+00	2.028294235468053E+00
80	1.103553984671607E-02	2.007444151790722E+00	2.018479591637424E+00
81	8.111327099718568E-03	2.000571067974562E+00	2.008682395074274E+00
82	5.634860096025342E-03	1.993271775120725E+00	1.998906643216749E+00
83	3.607249097510867E-03	1.985549474955263E+00	1.989156724052769E+00
84	2.029359489012880E-03	1.977407554750080E+00	1.979436914239088E+00
85	9.018913883247319E-04	1.968849585837205E+00	1.969751477225529E+00
86	2.753393425129769E-04	1.959879322042170E+00	1.960104661384676E+00
87	1.110579709973078E-10	1.950500698037573E+00	1.950500698148630E+00
88	2.259725356635626E-04	1.940717827617092E+00	1.940943800152752E+00
89	9.031574968895902E-04	1.930535001891094E+00	1.931438159387980E+00
90	2.031257957636368E-03	1.919956687434373E+00	1.921987945362005E+00
91	3.609779093444607E-03	1.908987524175986E+00	1.912597303270424E+00
92	5.638028509537707E-03	1.897632323668958E+00	1.903270352178495E+00
93	8.115116544533174E-03	1.885896066609815E+00	1.894011183214346E+00
[illegible]	[illegible]	[illegible]	[illegible]

97	2.248718158386798E-02	1.835245891699415E+00	1.857733073278276E+00
98	2.718824560755906E-02	1.821684833605090E+00	1.848873079212645E+00
99	3.232869556847495E-02	1.807776032259675E+00	1.840104727828148E+00
100	3.790627668483570E-02	1.793525588546657E+00	1.831431865231487E+00
101	4.391854243376003E-02	1.778939753210871E+00	1.822858295644629E+00
102	5.036285562447351E-02	1.764024924111688E+00	1.814387779736158E+00
103	5.723638955498922E-02	1.748787643416676E+00	1.806024032971663E+00
104	6.453612925206587E-02	1.733234594732011E+00	1.797770723984073E+00
105	7.225887279361931E-02	1.717372600170759E+00	1.789631472964388E+00
106	8.040123271327237E-02	1.701208617360564E+00	1.781609850073835E+00
107	8.895963748613367E-02	1.684749736391623E+00	1.773709373877750E+00
108	9.793033309548127E-02	1.668003176706890E+00	1.765933509802366E+00
109	1.073093846793083E-01	1.650976283935272E+00	1.758285668514576E+00
110	1.170926782563924E-01	1.633676552669596E+00	1.750769204925987E+00
111	1.272759225307372E-01	1.616111493190665E+00	1.743387415721401E+00
112	1.378546507739760E-01	1.598288883138718E+00	1.736143538912692E+00
113	1.488242227845475E-01	1.580216529133935E+00	1.729043751918482E+00
114	1.601798269231560E-01	1.561902343347342E+00	1.722082170270497E+00
115	1.719164822231756E-01	1.543354364023685E+00	1.715270846246860E+00
116	1.840290405756635E-01	1.524580726957765E+00	1.708609767533424E+00
117	1.965121889873203E-01	1.505589666925786E+00	1.702101855913106E+00
118	2.093604519110936E-01	1.486389514073288E+00	1.695749965984316E+00
119	2.225681936478505E-01	1.466988690261267E+00	1.689556883909113E+00
120	2.361296208184838E-01	1.447395705372057E+00	1.683525326190548E+00
121	2.500387849049606E-01	1.427619153576586E+00	1.677657938481545E+00
122	2.642895848597266E-01	1.407667709564642E+00	1.671957294424367E+00
123	2.788757697816600E-01	1.387550124739903E+00	1.666425894521559E+00
124	2.937909416580808E-01	1.367275225381235E+00	1.661066165039315E+00
125	3.090265581710202E-01	1.346851898772066E+00	1.655880456943081E+00
126	3.245619355670587E-01	1.326289109299445E+00	1.650871044866493E+00
127	3.404442515888721E-01	1.305595874524634E+00	1.646040126113505E+00
128	3.566085484679107E-01	1.284781271226770E+00	1.641389819694680E+00
129	3.730677359761110E-01	1.263854429421492E+00	1.636922165397600E+00
130	3.898145945361424E-01	1.242824528356174E+00	1.632639122892314E+00
131	4.068417783879497E-01	1.221700792483610E+00	1.628542570871559E+00
132	4.241418188110568E-01	1.200492487415836E+00	1.624634306226888E+00
133	4.417071274004343E-01	1.179208915859896E+00	1.620916043260330E+00
134	4.595299993952047E-01	1.157859413537373E+00	1.617389412932575E+00
135	4.776026170580465E-01	1.136453345039379E+00	1.614055962147425E+00
136	4.959170531045398E-01	1.115000099968924E+00	1.610917153073459E+00
137	5.144652741800968E-01	1.093509088322364E+00	1.607974362502461E+00
138	5.332391443839377E-01	1.071989736861788E+00	1.605228881245722E+00
139	5.522304286375572E-01	1.050451484730097E+00	1.602681913567650E+00
140	5.714307972970047E-01	1.028903779360716E+00	1.600334576657723E+00
141	5.908318278066638E-01	1.007356072333565E+00	1.598187930140225E+00
142	6.104250103935982E-01	9.858178152293320E-01	1.596242825622930E+00
143	6.302017508001150E-01	9.642984554835863E-01	1.594500206283598E+00
144	6.501533742537333E-01	9.428374322428870E-01	1.592960806496620E+00
145	6.702711292726096E-01	9.213541722243919E-01	1.591625301496403E+00

148	7.315325990784700E-01	8.573149654530461E-01	1.588847564531513E+00
149	7.522259663489272E-01	8.361066323514557E-01	588332598700373E+00
150	7.730406925622901E-01	8.149828651882913E-01	1.588023557750581E+00
151	7.939676476489517E-01	7.939529295893024E-01	1.587920577238251E+00

GUST ROTATIONAL IMPULSE

	W
1	-3.773906402486371E-08
2	-2.641403408967097E-07
3	-8.299780179851085E-07
4	-1.885745008296455E-06
5	-3.581520818174075E-06
6	-6.066839684444256E-06
7	-9.490559065544746E-06
8	-1.400072857607459E-05
9	-1.974445944727746E-05
10	-2.686779460447930E-05
11	-3.551557944123443E-05
12	-4.583133338216874E-05
13	-5.795712231153154E-05
14	-7.203343196086030E-05
15	-8.819904232930907E-05
16	-1.065909032303049E-04
17	-1.273440110371830E-04
18	-1.505912867183525E-04
19	-1.764634552342270E-04
20	-2.050889263862238E-04
21	-2.365936771859464E-04
22	-2.711011358346692E-04
23	-3.087320673788446E-04
24	-3.496044611304705E-04
25	-3.938334199152134E-04
26	-4.415310512349176E-04
27	-4.928063604073378E-04
28	-5.477651457636880E-04
29	-6.065098959674962E-04
30	-6.691396895330201E-04
31	-7.357500966003669E-04
32	-8.064330830490560E-04
33	-8.812769169986266E-04
34	-9.603660777763331E-04
35	-1.043781167412348E-03
36	-1.131593824696586E-03
37	-1.223891641913465E-03
38	-1.320728084255290E-03
39	-1.422172412002223E-03
40	-1.528284605519820E-03
41	-1.639120293119183E-03
42	-1.754730681843279E-03
43	-1.875162491215901E-03

ORIGINAL PAGE IS
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46	-2.265785019396852E-03
47	-2.405877807910656E-03
48	-2.550956197100496E-03
49	-2.701038762360677E-03
50	-2.856139214816519E-03
51	-3.016266360423986E-03
52	-3.181424062399962E-03
53	-3.351611207027247E-03
54	-3.526821672852343E-03
55	-3.707044303313881E-03
56	-3.892262882817382E-03
57	-4.082456116288352E-03
58	-4.277597612214162E-03
59	-4.477655869206343E-03
60	-4.682594266087831E-03
61	-4.892371055531336E-03
62	-5.106939361249008E-03
63	-5.326247178758126E-03
64	-5.550237379716216E-03
65	-5.778847719847213E-03
66	-6.012010850446725E-03
67	-6.249654333483429E-03
68	-6.491700660283234E-03
69	-6.738067273804438E-03
70	-6.988665944924888E-03
71	-7.243406049708967E-03
72	-7.502188106727314E-03
73	-7.764910309285278E-03
74	-8.031465317673403E-03
75	-8.301740952356751E-03
76	-8.575620241098092E-03
77	-8.852981469575638E-03
78	-9.133698235462839E-03
79	-9.417639505953423E-03
80	-9.704669678701927E-03
81	-9.994648646155124E-03
82	-1.028743186323750E-02
83	-1.058287041836525E-02
84	-1.088081110774719E-02
85	-1.118109651294946E-02
86	-1.148356508166282E-02
87	-1.178805121165843E-02
88	-1.209438533786689E-02
89	-1.240239402255133E-02
90	-1.271190004851896E-02
91	-1.302272251532760E-02
92	-1.333467693843615E-02
93	-1.364757535124389E-02
94	-1.39[illegible]E-02

97	-1.490475364589096E-02
98	-1.521941813161382E-02
99	-1.553385174870464E-02
100	-1.584762524431705E-02
101	-1.616112679708392E-02
102	-1.647354214253494E-02
103	-1.678485470078261E-02
104	-1.709484570641506E-02
105	-1.740329434051224E-02
106	-1.770997786472539E-02
107	-1.801467175732763E-02
108	-1.831714985118060E-02
109	-1.861718447351557E-02
110	-1.891454658746983E-02
111	-1.920900593528474E-02
112	-1.950033118309413E-02
113	-1.978829006720872E-02
114	-2.007264954182830E-02
115	-2.035317592807517E-02
116	-2.062963506428983E-02
117	-2.090179245747636E-02
118	-2.116941343582635E-02
119	-2.143226330222370E-02
120	-2.169010748865441E-02
121	-2.194271171140283E-02
122	-2.218984212698227E-02
123	-2.243126548867025E-02
124	-2.266674930358714E-02
125	-2.289606199019822E-02
126	-2.311897303617372E-02
127	-2.333525315648277E-02
128	-2.354467445165842E-02
129	-2.374701056610484E-02
130	-2.394203684638974E-02
131	-2.412953049938726E-02
132	-2.430927075021205E-02
133	-2.448103899981824E-02
134	-2.464461898219494E-02
135	-2.479979692103240E-02
136	-2.494636168579889E-02
137	-2.508410494709268E-02
138	-2.521282133121394E-02
139	-2.533230857387129E-02
140	-2.544236767261876E-02
141	-2.554280303892920E-02
142	-2.563342264812263E-02
143	-2.571403818872997E-02
144	-2.578446521022593E-02
145	-2.584452326731397E-02

148	-2.596074237586188E-02
149	-2.597760532807880E-02
150	-2.598326221657343E-02

```
      PROGRAM LACATE(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,PUNCH)
C
C                                                                *
C****                                                            *
C                                                                *
C                                                                *
C*                                                                *
C*                                                                *
C*****************************************************************
C*                                                                *
C* PURPOSE                                                        *
C*                                                                *
C*    PROGRAM LACATE INTEGRATES THE LAGRANGIAN EQUATIONS OF MOTION *
C*    FOR THE NASA-LRC/AFCRL LACATE BALLOON SYSTEM IN RESPONSE TO  *
C*    A SUDDEN WIND GUST. THE PENDULATION MOTION IS HANDLED IN THREE *
C*    DIMENSIONS BY SUBROUTINE PEND. TORSIONAL MOTION IS CONSIDERED *
C*    IN TWO DIMENSIONS BY SUBROUTINE TORS. SUBROUTINE CORL TAKES  *
C*    INTO ACCOUNT CORIOLIS FORCE EFFECTS IN TWO DIMENSIONS. THE   *
C*    GUST LOADING MODEL DESIRED BY THE USER IS CHOSEN THROUGH USE *
C*    OF SUBROUTINE GUST. THE SMALL ANGLE APPROXIMATION FOR THE    *
C*    EQUATIONS OF MOTION IS EMPLOYED THROUGHOUT. SUBROUTINE PLOTS *
C*    PROVIDES PLOTS OF THE SOLUTIONS TO THE EQUATIONS OF MOTION   *
C*    (ANGULAR VELOCITIES AND ANGLES). DAMPING MAY ALSO BE INCLUDED. *
C*                                                                *
C* PROPRIETARY                                                    *
C*                                                                *
C*    NONE                                                        *
C*                                                                *
C* USE                                                            *
C*                                                                *
C*    CALL LACATE                                                 *
C*                                                                *
C* PARAMETERS                                                     *
C*                                                                *
C*    NONE                                                        *
C*                                                                *
C* REQUIRED ROUTINES                                              *
C*                                                                *
C*    GUST,DIFSUB,DIFFUN,PEND,TORS,CORL                           *
C*                                                                *
C* AUTHOR/IMPLEMENTOR                                             *
C*                                                                *
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
C*     D.R.DORSEY,JR                                                     *
C*     COMPUTER SCIENCES CORPORATION  -                                  *
C*     NASA/LANGLEY RESEARCH CENTER PROGRAM OFFICE                       *
C*                                                                       *
C* DATE RELEASED                                                         *
C*                                                                       *
C*     SEPTEMBER 14,1973                                                 *
C*                                                                       *
C* LATEST REVISION                                                       *
C*                                                                       *
C*     SEPTEMBER 14,1973                                                 *
C*                                                                       *
C************************************************************************
C
C      ****************************************************************
C
C
C
C                      BBBBBBBBBBBBBBB
C                     B              B
C                    B                B         ---L A C A T E---
C                   B                  B
C                  B                    B
C                 B                      B  .......BALLOON
C                B                        B
C                B                        B     RADIUS =  64.008 M
C                B                        B     WEIGHT = 861.825 KG
C                B                        B     VOLUME = 39M  CUFT
C                 B                      B
C                  B                    B
C                   B                  B      ...HELIUM FILLED
C                    B                B       ...RADAR REFLECTOR
C                     B              B        ...AFCRL PARACHUTE
C                      B            B
C                       B          B
C                        B        B
C                         B      B
C                          B    B
C                           B  B
C                            BB
C                             B
C                             A
C                             A
```

```
C                A
C                A
C                A              A = 23.1648 M
C                A
C                A
C       ---------XXXXX---------
C       *        X   X         * ...........LOAD BAR
C       *        X   X         *
C       *        X   X         *        RADIUS =    0.6096 M
C                X   X                  LENGTH =    2.1336 M
C                XXXXX                  WEIGHT = 112.9445 KG
C                  L
C                  L
C                  L
C                  L                    ...FLIGHT CONTROL
C                  L                       ELECTRONICS
C                  L                    ...DIPOLE ANTENNAS
C                  L                    ...REEL-DOWN
C                  L
C                  L
C                  L
C                  L
C                  L                       L = 396.24 M
C                  L
C                  L
C                  L
C                  L
C                HHHHH
C               H     H ................PARACHUTE PACKAGE
C               H     H
C               H     H                 RADIUS =    0.4572 M
C               H     H                 LENGTH =    1.5240 M
C                HHHHH                  WEIGHT =   37.1946 KG
C                  P
C                  P                     ...AFCRL ELECTRONICS 2
C                  P                     ...GONDOLA PARACHUTE
C                  P
C                  P                       P = 3.3528 M
C                  P
C                SSSSS  ................PAYLOAD PACKAGE
C                S   S
C                SSSSS                  RADIUS =    0.9144 M
C                 RRR                   LENGTH =    1.8288 M
```

```
C                                  R R                      WEIGHT = 214.0956 KG
C                                  RRR
C                               CCCCCCCCC                 ...RADIOMETER (NASA)
C                               C       C                 ...INSTRUMENTATION
C                               CCCCCCCCC                 ...CRUSH PAD
C                                 C   C
C                                  CCC
C
C
C
C    ************************************************************
C
C
C                   O                     ** L A C A T E **
C                  /
C                 /I
C                / I                            FOUR
C           RB  /  I                            COUPLED
C              /   I                            PENDULUM
C             /*  *I    THETAB,PHIB             CONFIGURATION
C            /  ** I
C           /      I                            DEFINITION OF ANGLES
C          X       I                              AND LENGTHS
C          +
C          I+
C          I +  A1
C          I  +         THETAS,PHIS
C          I   +
C          I*   *+
C          I **   +
C          I       +
C          I        +
C                    Y
C                   /
C                  /I
C           L     / I
C                /  I
C               /   I
C              /*  *I
C             /  ** I   THETAP,PHIP
C            /      I
C           /       I
```

```
              C        Z          I
              C        +
              C        I+
              C        I +
              C        I  +  P
              C        I   +
              C        I*   *+          THETAE,PHIE
              C        I **    +
              C        I        +
              C        I         +
              C        I          O
              C
              C
              C*****************************************************************
              C
  000003            COMMON / CONST / MB,MS,MP,ME,M,RB,A1,L,P,RS,RP,RE,G,RHO,MU,N,
                    *                HS,HP,HE
  000003            COMMON/ CORIO / OMEGA,LAMDA
  000003            COMMON/ DAMPC / ASCS,APCP,AECE,D(8),IDAMP
  000003            COMMON/ GUSTA / TDOIB,DOTB
  000003            COMMON/ TESTC/ IPEND,ITORS,ICURL
  000003            REAL MB,MS,MP,ME,M,L,MU,LAMDA
  000003            DIMENSION Y(128),DY(16),WK(480)
  000003            DIMENSION M(4)
              C*****************************************************************
  000003            NAMELIST/ ANGL/ THETAB,THETAS,THETAP,THETAE,PHIB,PHIS,PHIP,PHIE,
                   1                TDOTS,TDOTP,TDOTE,DOTS,DOTP,DOTE,
                   2                OMEGA,LAMDA
  000003            NAMELIST/ CONS/ MB,MS,MP,ME,M,RB,A1,L,P,RS,RP,RE,G,RHO,MU,N,
                    *               HS,HP,HE
  000003            NAMELIST/ TEST/ IPEND,ITORS,ICORL,IPLOT,IDAMP
  000003            NAMELIST/ DIF1/ H,JSTART,HMIN,HMAX,EPS,MTH,MAXDER,TO,TF,PV
  000003            NAMELIST/ DRAG/ ASCS,APCP,AECE
              C*****************************************************************
              C
              C---  READ NAMELIST INPUTS
              C
  000003            READ(5,ANGL)
  000006            READ(5,CONS)
  000011            READ(5,TEST)
  000014            READ(5,DIF1)
  000017            READ(5,DRAG)
              C
```

```
          C---  WRITE NAMELIST INPUTS
          C
000022          WRITE(6.ANGL)
000025          WRITE(6.CONS)
000030          WRITE(6.TEST)
000033          WRITE(6.DIF1)
000036          WRITE(6.DRAG)
          C
          C---  CHOOSE DESIRED GUST MODEL AND SET UP INITIAL CONDITIONS FOR
          C---  BALLOON VELOCITIES
          C
000041          CALL GUST
          C
          C      INITIALIZE THE VALUES FOR DIFSUB
          C
000042          T=T0
000043          N1=N*2
000045          LNCNT=17
          C
          C      SET Y VALUES AS INPUTS FOR DIFSUB
          C
000046          Y(1)=THETAB
000047          Y(2)=PHIB
000051          Y(3)=THETAS
000052          Y(4)=PHIS
000054          Y(5)=THETAP
000055          Y(6)=PHIP
000057          Y(7)=THETAE
000060          Y(8)=PHIE
000062          Y(9)=TDOTB
000063          Y(10)=DOTB
000065          Y(11)=TDOTS
000066          Y(12)=DOTS
000070          Y(13)=TDOTP
000071          Y(14)=DOTP
000073          Y(15)=TDOTE
000074          Y(16)=DOTE
          C
          C
          C      INTEGRATE EQUATIONS OF MOTION
          C
000076       20 CALL DIFSUB(N1.T.H.Y.HK.JSTART.HMIN.HMAX.EPS.MTH.MAXDER.IERR)
          C
```

```
              C      CHECK IF THE STEP WAS SUCCESSFUL
              C
  000112             IF(IERR.EQ.1) GO TO 50
              C
              C      PRINT THE FOLLOWING IF THE STEP WAS UNSUCCESSFUL.
              C
  000114             WRITE(6,30) IERR
  000122          30 FORMAT(1H0//5X,5HIERR=,I2///2X,3HWK=)
  000122             WRITE(6,40) (WK(I),I=1,112)
  000134          40 FORMAT(1H0,5X,4E29.15)
  000134             RETURN
              C
              C      IF THE STEP WAS SUCCESSFUL THEN WRITE THE FOLLOWING
              C
  000136          50 IF(LNCNT.LT.16) GO TO 60
  000141             WRITE(6,55)
  000144          55 FORMAT(1H1,11X,4HTIME,9X,6HTHETAB,9X,4HPHIB,9X,6HTHETAS,9X,4HPHIS,
                    1       9X,6HTHETAP,9X,4HPHIP,9X,6HTHETAE,9X,4HPHIE/)
  000144             LNCNT=0
  000145          60 WRITE(6,65) T,(Y(I),I=1,N1)
  000162          65 FORMAT(6H ANGLE,F11.6,3X,8(2X,E12.5)/6H RATES,14X,8(2X,E12.5)/)
  000162             PUNCH 68 ,T,(Y(I),I=1,8)
  000176             PUNCH 68,T,(Y(I),I=9,16)
  000212          68 FORMAT(1X,F7.3,8E9.2)
  000212             LNCNT=LNCNT+1
              C
              C      CHECK IF THE TIME LIMIT HAS BEEN EXCEEDED
              C
  000214             IF(T.LT.TF) GO TO 20
  000216             WRITE(6,70) H,JSTART,IERR
  000230          70 FORMAT(///,5X,E25.15,2(10X,I2))
              C
              C---   SET UP PLOTS IF DESIRED
              C
  000230             IF(IPLOT.EQ.1) CALL PLOTS
              C
              C
              C
  000233             RETURN
              C
              C
  000235             END
```

```
      SUBROUTINE GUST
C
C*********************************************************************
C*                                                                   *
C* PURPOSE                                                           *
C*                                                                   *
C*    SUBROUTINE GUST COMPUTES THE ANGULAR ACCELERATION PRODUCED ON  *
C*    THE BALLOON BY A GIVEN GUST VELOCITY PROFILE. THE VELOCITY     *
C*    PROFILE MAY BE CHOSEN BY THE USER FROM SUBROUTINE GUST.  THE   *
C*    FINAL VALUE OF THE W ARRAY IS TAKEN AS THE INITIAL CONDITION   *
C*    ON ANGULAR VELOCITY FOR THE BALLOON.                           *
C*    THE ROUTINE ALSO DEFINES THE EQUATION FOR THE GUST             *
C*    VELOCITY PROFILE. THE ARRAY AA RETURNS THE VELOCITIES FOR      *
C*    -RB.LE.X.LE.0..WHILE ARRAY BB CONTAINS VELOCITIES FOR THE      *
C*    RANGE 0.LE.X.LE.+RB.                                           *
C*                                                                   *
C* PROPRIETARY                                                       *
C*                                                                   *
C*    NONE                                                           *
C*                                                                   *
C* USE                                                               *
C*                                                                   *
C*    CALL GUST                                                      *
C*                                                                   *
C* PARAMETERS                                                        *
C*                                                                   *
C*    NONE                                                           *
C*                                                                   *
C* REQUIRED ROUTINES                                                 *
C*                                                                   *
C*    NONE                                                           *
C*                                                                   *
C* AUTHOR/IMPLEMENTOR                                                *
C*                                                                   *
C*    D.R.DORSEY,JR - B.SEAY                                         *
C*                                                                   *
C* DATE RELEASED                                                     *
C*                                                                   *
C*    SEPTEMBER 14,1973                                              *
C*                                                                   *
C* LATEST REVISION                                                   *
C*                                                                   *
```

```
        C*     SEPTEMBER 14,1973                                                  *
        C*                                                                        *
        C*************************************************************************
        C
        C
        C
        C*************************************************************************
        C
        C
        C*-*-
        C
        C
        C*************************************************************************
        C
        C
        C
000002         COMMON/ GUSTA / TDOTB,DOTB
000002         DIMENSION AA(151),BB(151),V(151),W(151)
        C
        C      **********************************************************
        C
        C      DEFINE THE GUST VELOCITY PROFILE
        C
000002         READ(5,7) ALPHA,NU,NRB
000014       7 FORMAT(5X,F5.1,2I5)
000014         PI=3.1416
000015         PIA=PI/ALPHA
000017         RB=64.0
000020         ZNU=FLOAT(NU)
000021         ZNUA=-(ZNU+ALPHA)
000023         VM=2.0578
000025         VM2=0.5*VM
000026         J=NRB+1
000031         WRITE(6,10)
000034      10 FORMAT(1H1,30X,21HGUST VELOCITY PROFILE,//)
        C
        C      DEFINE CENTERLINE VELOCITY(CORRESPONDS TO X=0)
        C
000034         AA(1)=VM2*(1.0-COS(PIA*ZNUA))
000042         BB(1)=AA(1)
000044         V(1)=AA(1)+BB(1)
000046         WRITE(6,20) AA(1),BB(1),V(1)
000057      20 FORMAT(5X,1H1,23X,2HAA,34X,2HBB,36X,1HV//4X,3H  1,3(12X,E24.15))
```

```
          C
          C     DEFINE THE OFF-CENTERLINE VELOCITIES
          C
 000057         DO 40 I=2.J
 000061         ZN=FLOAT(I-1)
 000063         AA(I)=VM2*(1.0-COS(PIA*(-ZN+ZNUA)))
 000074         BB(I)=VM2*(1.0-COS(PIA*(ZN+ZNUA)))
 000104         V(I)=AA(I)+BB(I)
 000106         WRITE(6.30) I.AA(I).BB(I).V(I)
 000122      30 FORMAT(4X.I3.3(12X.E24.15))
 000122      40 CONTINUE
          C
          C     COMPUTE THE ANGULAR VELOCITIES
          C
 000125         WRITE(6.50)
 000130      50 FORMAT(1H1.30X.23HGUST ROTATIONAL IMPULSE.//)
 000130         W(1)=1.5/(RB*RB)*(V(2)-V(1))
 000134         WRITE(6.60) W(1)
 000142      60 FORMAT(28X.1HW//4X.3H  1.12X.E24.15)
 000142         DO 80 K=2.NRB
 000144         ZN=FLOAT(K)
 000145         W(K)=W(K-1)+1.5/(RB*RB)*ZN*(V(K+1)-V(K))
 000155         WRITE(6.70) K.W(K)
 000165      70 FORMAT(4X.I3.12X.E24.15)
 000165      80 CONTINUE
          C
 000170         TOOTB=0.01*W(150)
 000172         DOTB =0.01*W(150)
          C
 000173         RETURN
 000174         END
```

```
      SUBROUTINE DIFSUB(N,T,H,Y,WK,JSTART,HMIN,HMAX,EPS,MTH,MAXDER,IERR)
C***********************************************************************
C*
C* PURPOSE
C*
C*    SUBROUTINE DIFSUB INTEGRATES A SYSTEM OF N FIRST ORDER ORDINARY
C*    DIFFERENTIAL EQUATIONS OVER ONE STEP OF LENGTH H AT EACH CALL.
C*    H CAN BE SPECIFIED BY THE USER FOR ANY OR ALL STEPS, BUT, IT MAY
C*    BE INCREASED OR DECREASED BY DIFSUB WITHIN THE RANGE HMIN TO HMAX
C*    THE STEP ADJUSTMENT IS USED TO ACHIEVE AS LARGE A STEP AS
C*    POSSIBLE, WHILE NOT COMMITTING A SINGLE STEP ERROR WHICH IS
C*    LARGER THAN EPS IN THE L-2 NORM. THE USER SPECIFIED PARAMETER MTH
C*    INDICATES WHETHER THE SYSTEM IS TO BE SOLVED BY NON-STIFF OR
C*    STIFF METHODS.
C*
C* PROPRIETARY
C*
C*    NONE.
C*
C* USE
C*
C*    CALL DIFSUB(N,T,H,Y,WK,JSTART,HMIN,HMAX,EPS,MTH,MAXDER,IERR)
C*
C* PARAMETERS
C*
C*    N------THE NUMBER OF FIRST ORDER DIFFERENTIAL EQUATIONS.
C*
C*    T------THE INDEPENDENT VARIABLE.
C*
C*    H------ON INPUT, THE STEP LENGTH TO BE ATTEMPTED ON THIS STEP.
C*           ON OUTPUT, THE STEP LENGTH DIFSUB RECOMMENDS FOR THE NEXT
C*           STEP. DIFSUB WILL USE ITS RECOMMENDED STEP LENGTH UNLESS
C*           THE USER MODIFIES IT.
C*
C*           H MAY BE ADJUSTED UP AS FAR AS HMAX OR DOWN AS FAR AS HMIN
C*           BY DIFSUB IN ORDER TO ACHIEVE AN ECONOMICAL INTEGRATION.
C*           HOWEVER, IF THE USER SPECIFIES AN H VALUE, IT WILL BE USED
C*           PROVIDED SUCH AN H DOES NOT CAUSE A SINGLE STEP ERROR
C*           GREATER THAN EPS. THE USER IS REQUIRED TO SUPPLY H ONLY ON
C*           THE FIRST CALL. TO SAVE COMPUTER TIME, THE USER IS ADVISED
C*           TO USE A SMALL STEP (SAY .125E-06) FOR THE FIRST CALL.
C*           AFTER THE FIRST CALL THE STEP LENGTH WILL BE INCREASED BY
```

```
C*          DIFSUB.
C*
C*     Y------AN ARRAY OF 8*N LOCATIONS CONTAINING THE DEPENDENT
C*            VARIABLES AND THEIR SCALED DERIVATIVES. Y(N*(J-1)+I)
C*            CONTAINS J-TH DERIVATIVE OF Y(I) SCALED BY
C*            H**J/FACTORIAL(J). WHERE H IS THE CURRENT STEP SIZE. ONLY
C*            Y(I),I=1,N MUST BE PROVIDED BY THE CALLING PROGRAM ON THE
C*            FIRST CALL (INITIAL VALUES). DERIVATIVES ARE CALCULATED BY
C*            DIFSUB BY NUMERICAL DIFFERENCING AND DO NOT NEED TO BE
C*            PROVIDED BY THE USER. IF IT IS DESIRED TO INTERPOLATE TO
C*            NON-MESH POINTS, THESE VALUES CAN BE USED. IF THE CURRENT
C*            STEP SIZE IS H AND THE VALUE AT T+E IS NEEDED, FORM S=E/H
C*            AND COMPUTE
C*
C*                                 NO
C*                       Y(I)(T+E)=SUM Y(N*(J-1)+I)*S**J
C*                                 J=0
C*
C*            WHENEVER DIFSUB IS CALLED WITH JSTART=0, Y(I),I=N+1,8*N
C*            IS SET TO 0.
C*
C*     WK-----A WORK STORAGE ARRAY OF DIMENSION N*(N+14). THE USER NEED
C*            ONLY DIMENSION THE ARRAY CORRECTLY. THE ARRAY IS ZERO
C*            FILLED OR INITIALIZED AND USED BY DIFSUB. THE USER SHOULD
C*            NOT PUT ANYTHING INTO THE ARRAY. THE ARRAY IS USED TO
C*            HOLD THE FOLLOWING
C*
C*            WK(1)-WK(8*N)
C*                THE Y ARRAY VALUES ARE SAVED IN THE EVENT THAT A STEP
C*                MUST BE REPEATED.
C*
C*            WK(8*N+1)-WK(9*N)
C*                HOLDS CORRECTION TERMS IN THE CORRECTOR LOOP.
C*
C*            WK(9*N+1)-WK(10*N)
C*                HOLDS SUMS OF ALL CORRECTION TERMS IN THE PREVIOUS
C*                STEP AFTER THE SUMS HAVE BEEN ACCUMULATED IN
C*                WK(13*N+I),I=1,N FOR THE CURRENT STEP. THIS ENABLES
C*                THE BACKWARDS DIFFERENCE OF WK(13*N+I) TO BE FORMED
C*                AND USED TO ESTIMATE THE STEP SIZE FOR ONE ORDER
C*                HIGHER THAN CURRENT.
C*
C*            WK(10*N+1)-WK(11*N)
```

```
C*                HOLDS THE DERIVATIVES OF Y(I) WITH RESPECT TO T WHEN *
C*                THEY ARE COMPUTED BY DIFFUN.                         *
C*                                                                     *
C*          WK(11*N+1)-WK(12*N)                                        *
C*                HOLDS THE DERIVATIVES OF Y(I) WITH RESPECT TO T      *
C*                DURING JACOBIAN EVALUATION.                          *
C*                                                                     *
C*          WK(12*N+1)-WK(13*N)                                        *
C*                HOLDS THE MAXIMUM ABSOLUTE VALUE OF Y(I) UP TO AND   *
C*                INCLUDING THE PRESENT STEP.                          *
C*                                                                     *
C*          WK(13*N+1)-WK(14*N)                                        *
C*                HOLDS THE SINGLE STEP ERROR ESTIMATES                *
C*                WK(13*N+I)=Y(N*(K-1)+I)*H**K/(FACTORIAL(K-1)*A(K))   *
C*                WHERE K IS THE HIGHEST DERIVATIVE AVAILABLE.         *
C*                                                                     *
C*          WK(14*N+1)-WK(14*N+N**2)                                   *
C*                USED FOR STIFF METHODS(MTH=1,2) TO HOLD JACOBIAN BY  *
C*                COLUMNS. WK(N*(13+J)+I)=(D/DY(J))DY(I)  ,I=1,N J=1,N *
C*                                                                     *
C*    JSTART-AN INPUT/OUTPUT CODE USED AS FOLLOWS                      *
C*                                                                     *
C*          INPUT                                                      *
C*                                                                     *
C*          =-1   REPEAT THE LAST STEP WITH A NEW H.                   *
C*                                                                     *
C*          =0    PERFORM THE FIRST STEP. THE FIRST CALL MUST BE DONE  *
C*                WITH THIS VALUE TO PERMIT PROPER INITIALIZATION.     *
C*                                                                     *
C*          =+1   TAKE A NEW STEP CONTINUING FROM THE LAST.            *
C*                                                                     *
C*          OUTPUT                                                     *
C*                                                                     *
C*          =NQ   THE CURRENT ORDER OF THE INTEGRATION METHOD ON RETURN*
C*                ALSO, THE MAXIMUM DERIVATIVE AVAILABLE.              *
C*                                                                     *
C*    HMIN---THE MINIMUM STEP SIZE THAT WILL BE USED FOR THE           *
C*          INTEGRATION. NOTE THAT ON STARTING HMIN MUST BE MUCH       *
C*          SMALLER (SAY .125E-09) THAN THE AVERAGE H EXPECTED SINCE   *
C*          A FIRST ORDER METHOD IS USED INITIALLY.                    *
C*                                                                     *
C*    HMAX---THE MAXIMUM STEP SIZE THE USER WILL ALLOW.                *
C*                                                                     *
```

```
C*     EPS----THE ERROR TEST CONSTANT. SINGLE STEP ERROR ESTIMATES
C*            WK(N*13+I) DIVIDED BY WK(N*12+I) MUST BE LESS THAN EPS IN
C*            THE EUCLIDEAN NORM. STEP AND/OR ORDER IS ADJUSTED TO
C*            ACHIEVE THIS ERROR BOUND.
C*
C*     MTH----THE METHOD INDICATOR.
C*
C*            =0   AN ADAMS PREDICTOR-CORRECTOR FOR NON-STIFF SYSTEMS.
C*
C*            =1   A MULTI-STEP METHOD FOR STIFF SYSTEMS. IT WILL ALSO
C*                 WORK FOR NON-STIFF SYSTEMS. A USER SUPPLIED ROUTINE
C*                 PEDERV IS REQUIRED TO CALCULATE THE PARTIAL
C*                 DERIVATIVES (D/DY(J))DY(I), THAT IS, THE JACOBIAN.
C*                 ANOTHER USER SUPPLIED ROUTINE MATINV IS REQUIRED TO
C*                 INVERT THE JACOBIAN.
C*
C*            =2   THE SAME AS MTH=1 EXCEPT THAT THE PARTIAL DERIVATIVES
C*                 ARE CALCULATED IN DIFSUB BY NUMERICAL DIFFERENCING
C*                 AND HENCE PEDERV IS NOT CALLED. HOWEVER A DUMMY
C*                 SUBROUTINE NAMED PEDERV SHOULD BE SUPPLIED. MATINV IS
C*                 STILL NECESSARY TO INVERT THE JACOBIAN.
C*
C*     MAXDER-THE MAXIMUM ORDER INTEGRATION THE USER WISHES TO BE USED.
C*            FOR NON-STIFF METHODS(MTH=0) IT MUST SATISFY
C*            1.GE.MAXDER.LE.7 AND FOR STIFF METHODS(MTH=1,2) IT MUST
C*            SATISFY 1.GE.MAXDER.LE.6.
C*
C*     IERR---A COMPLETION CODE WITH THE FOLLOWING MEANINGS
C*
C*            =+1  THE STEP WAS SUCCESSFUL. ALL REQUIREMENTS WERE MET.
C*
C*            =-1  THE STEP WAS TAKEN WITH H=HMIN; BUT, THE REQUESTED
C*                 ERROR, EPS, WAS NOT ACHIEVED.
C*
C*            =-2  THE MAXIMUM ORDER SPECIFIED, MAXDER, WAS TOO LARGE.
C*                 OBSERVE THE CONSTRAINTS IN THE DEFINITION OF MAXDER.
C*
C*            =-3  CORRECTOR CONVERGENCE COULD NOT BE ACHIEVED FOR
C*                 H.GT.HMIN.
C*
C*            =-4  THE REQUESTED ERROR IS SMALLER THAN CAN BE HANDLED
C*                 FOR THE CONSTRAINTS PLACED ON THE PARAMETERS. EXAMINE
C*                 THE PARAMETERS TO DETERMINE IF SOME MAY BE RELAXED
```

```
C*                  AND TRY AGAIN.
C*
C*    NOTE:  THE FOLLOWING POINTS SHOULD BE KEPT IN MIND WHEN CHOOSING
C*           THE PARAMETERS.
C*
C*           HIGHER ORDER INTEGRATIONS (MAXDER) AND SMALL STEP SIZES
C*           (H) REQUIRE MORE CALCULATIONS AND HENCE MORE TIME, BUT
C*           THEY RESULT IN BETTER ACCURACY.
C*
C*           SMALL ERROR TOLERANCES (EPS) REQUIRE HIGHER ORDER
C*           INTEGRATIONS AND/OR SMALLER STEP SIZE.
C*
C*           THE USER SHOULD NOT ATTEMPT TO CHOOSE THE BEST STEP SIZE
C*           OR RESTRICT THE ORDER TO ATTEMPT AN OPTIMAL COMBINATION.
C*           AS MUCH AS POSSIBLE, SUCH DECISIONS SHOULD BE LEFT TO
C*           DIFSUB. DIFSUB BASES ITS DECISIONS ON PRECISE CALCULATIONS
C*           AND OPTIMIZES STEP SIZE AND ORDER TO ACHIEVE THE ERROR
C*           TOLERANCE WITH ECONOMICAL CALCULATIONS.
C*
C*           PROBLEM NECESSITY MAY REQUIRE SOME PARAMETERS TO BE
C*           CONSTRAINED; THOSE NOT CONSTRAINED SHOULD BE FREE TO VARY
C*           AS MUCH AS POSSIBLE TO PERMIT DIFSUB TO OPTIMIZE THEM.
C*
C* REQUIRED ROUTINES
C*
C*    ALL OF THE FOLLOWING REQUIRED ROUTINES MUST BE SUPPLIED BY THE
C*    USER EVEN IF ONLY AS DUMMY SUBROUTINES.
C*
C*    SUBROUTINE DIFFUN(T,Y,DY)
C*
C*           T--INDEPENDENT VARIABLE
C*
C*           Y--ARRAY OF DEPENDENT VARIABLES AND SCALED DERIVATIVES.
C*              THIS ARRAY IS THE SAME AS THE Y ARRAY FOR DIFSUB AND IS
C*              DIMENSIONED THE SAME.
C*
C*           DY-ARRAY OF DIMENSION N WHICH HOLDS THE DERIVATIVES OF
C*              Y(I),I=1,N WITH RESPECT TO T.
C*
C*           DIFFUN MUST ALWAYS BE SUPPLIED. IT COMPUTES THE DERIVATIVE
C*           OF Y(I) WITH RESPECT TO T, RETURNS IT IN DY(I) TO DIFSUB.
C*
C*    SUBROUTINE MATINV(PW,N,J)
```

```
C*
C*          PW--ARRAY CONTAINING THE JACOBIAN PASSED FROM DIFSUB.
C*             DIMENSIONED PW(N,N)
C*
C*          N--THE SIZE OF THE SYSTEM.
C*
C*          J--RETURN CODE
C*
C*          =1    IF INVERSION OF PW SUCCESSFUL (DET(PW).NE.0).
C*
C*          =-1   IF INVERSION OF PW UNSUCCESSFUL (DET(PW).EQ.0).
C*
C*          MATINV MUST BE PROVIDED FOR STIFF METHODS(MTH=1,2) WHILE
C*          ONLY A DUMMY SUBROUTINE IS NECESSARY FOR NON-STIFF METHODS
C*          (MTH=0). MATINV INVERTS THE JACOBIAN AND RETURNS THE
C*          INVERSE IN PW TO DIFSUB.
C*
C*    SUBROUTINE PEDERV(T,Y,PW,N)
C*
C*          T--INDEPENDENT VARIABLE.
C*
C*          Y--ARRAY OF DEPENDENT VARIABLES AND FIRST SEVEN
C*             DERIVATIVES. THIS ARRAY IS THE SAME AS THE Y ARRAY FOR
C*             DIFSUB AND IS DIMENSIONED THE SAME.
C*
C*          PW-ARRAY DIMENSIONED N**2 CONTAINING THE JACOBIAN BY
C*             COLUMNS. PW(N**2).
C*
C*          N--THE SIZE OF THE SYSTEM.
C*
C*          PEDERV MUST BE PROVIDED FOR STIFF METHODS(MTH=1,2) WHILE
C*          ONLY A DUMMY SUBROUTINE IS REQUIRED FOR NON-STIFF METHODS
C*          (MTH=0). PEDERV COMPUTES THE PARTIAL DERIVATIVES OF DY(I)
C*          I=1,N AND STORES THEM BY COLUMNS IN THE PW ARRAY.
C*          PW(N*(J-1)+I)=(D/DY(J))DY(I) I=1,N , J=1,N
C*
C* AUTHOR/IMPLEMENTER
C*
C*    S.BAUDENDISTEL/G.W.HAIGLER
C*
C* LANGUAGE
C*
C*    FORTRAN
```

```
      C*
      C* DATE RELEASED
      C*
      C*    MAY 25, 1973
      C*
      C* LATEST REVISION
      C*
      C*    MAY 25, 1973
      C*
      C***********************************************************************
      C
00017       DIMENSION Y(1),WK(1),A(8),PERTST(42)
      C
      C***********************************************************************
      C* THE COEFFICIENTS IN PERTST ARE USED IN SELECTING THE STEP AND
      C* ORDER, THEREFORE ONLY ABOUT ONE PERCENT ACCURACY IS NEEDED.
      C***********************************************************************
      C*
      C***********************************************************************
      C* THIS ROW IS USED TO CALCULATE E FOR STIFF SYSTEMS
      C*
00017       DATA PERTST /2.0,4.5,7.333,10.42,13.7,17.15,1.0,
      C***********************************************************************
      C* THIS ROW IS USED TO CALCULATE E FOR NON-STIFF STYSTEMS
      C*
           1          2.0,12.0,24.0,37.89,53.33,70.08,87.97,
      C***********************************************************************
      C* THIS ROW IS USED TO CALCULATE EUP FOR STIFF SYSTEMS
      C*
           2          3.0,6.0,9.167,12.5,15.98,1.0,1.0,
      C***********************************************************************
      C* THIS ROW IS USED TO CALCUALTE EUP FOR NON-STIFF SYSTEMS
      C*
           3          12.0,24.0,37.89,53.33,70.08,87.97,1.0,
      C***********************************************************************
      C* THIS ROW IS USED TO CALCULATE EDWN FOR STIFF SYSTEMS
      C*
           4          1.,1.,0.5,0.1667,0.04133,0.008267,1.0,
      C***********************************************************************
      C* THIS ROW IS USED TO CALCULATE EDWN FOR NON-STIFF SYSTEMS
      C*
           5          1.0,1.0,2.0,1.0,.3157,.07407,.0139/
      C***********************************************************************
```

```
000017          DATA A(2) / -1.0 /
000017          IRET=1
000017          IERR=+1
000020          IF(JSTART.LE.0)GOTO 25
        C*************************************************************************
        C* BEGIN BY SAVING INFORMATION FOR POSSIBLE RESTARTS AND CHANGING       *
        C* H BY THE FACTOR R IF THE CALLER HAS CHANGED H.  ALL VARIABLES        *
        C* DEPENDENT ON H MUST ALSO BE CHANGED.                                 *
        C* HNEW IS THE STEP SIZE THAT WAS USED ON THE LAST CALL.                *
        C*************************************************************************
000022        5 NN=N*K
000025          DO 10 I=1,NN
000026       10 WK(I)=Y(I)
000033          HOLD=HNEW
000034          IF(H.EQ.HOLD)GOTO 20
000036       15 RACUM=H/HOLD
000037          IRET1=1
000041          GOTO 415
000041       20 NQOLD=NQ
000042          TOLD=T
000043          RACUM=1.
000045          IF(JSTART.GT.0)GOTO 170
000047          GOTO 55
000047       25 IF(JSTART.EQ.-1)GOTO 50
        C*************************************************************************
        C* ON THE FIRST AND ANY SUBSEQUENT CALL WITH JSTART=0, THE ORDER IS     *
        C* SET TO 1 AND THE INITIAL DERIVATIVES ARE CALCULATED.  ARRAY ACCESS   *
        C* CONSTANTS ARE CALCULATED AND ARRAYS Y,WK ARE ZEROED OR INITIALIZED   *
        C*************************************************************************
000051          NQ=1
000051          N8=N*8
000053          N9=N8+N
000054          N10=N9+N
000055          N11=N10+N
000056          N12=N11+N
000057          N13=N12+N
000060          N14=N13+N
000061          N10P1=N10+1
000063          N11P1=N11+1
000065          N14P1=N14+1
000066          NN=N*(N+14)
000071          DO 30 I=1,NN
000073       30 WK(I)=0.
```

```
000077          NN=N+1
000100          DO 35 I=NN,N8
000101       35 Y(I)=0.
000105          DO 40 I=1,N
000106       40 WK(N12+I)=AMAX1(1.,ABS(Y(I)))
000111          CALL DIFFUN(T,Y,WK(N10P1))
000125          DO 45 I=1,N
000132       45 Y(N+I)=WK(N10+I)*H
000141          HNEW=H
000141          K=2
000143          GOTO 5
        C*********************************************************************
        C* REPEAT LAST STEP BY RESTORING SAVED INFORMATION.                  *
        C*********************************************************************
000143       50 IF(NQ.EQ.NQOLD)JSTART=1
000146          T=TOLD
000147          NQ=NQOLD
000150          K=NQ+1
000152          GOTO 15
        C*********************************************************************
        C* SET THE COEFFICIENTS THAT DETERMINE THE ORDER AND THE METHOD      *
        C* TYPE.  CHECK FOR EXCESSIVE ORDER.  THE LAST TWO STATEMENTS OF     *
        C* THIS SECTION  SET IWEVAL .GT.0 IF THE JACOBIAN IS TO BE RE-       *
        C* EVALUATED BECAUSE OF THE ORDER CHANGE, AND THEN REPEAT THE        *
        C* INTEGRATION STEP IF IT HAS NOT YET BEEN DONE (IRET=1) OR SKIP TO A *
        C* FINAL SCALING BEFORE EXIT IF IT HAS BEEN COMPLETED (IRET=2).      *
        C*********************************************************************
000153       55 IF(MTH.EQ.0)GOTO 70
000155          IF(NQ-2)130,135,60
000157       60 IF(NQ-4)140,145,65
000162       65 IF(NQ-6)150,155,90
000165       70 IF(NQ-2)95,100,75
000170       75 IF(NQ-4)105,110,80
000173       80 IF(NQ-6)115,120,85
000176       85 IF(NQ.EQ.7)GOTO 125
000200       90 IERR=-2
000202          RETURN
        C*********************************************************************
        C* THE FOLLOWING COEFFICIENTS SHOULD BE DEFINED TO THE MAXIMUM       *
        C* ACCURACY PERMITTED BY THE MACHINE.  THEY ARE, IN THE ORDER USED.. *
        C*                                                                   *
        C* THE FOLLOWING ARE FOR NON-STIFF METHODS                           *
        C*                                                                   *
```

```
        C* -1
        C* -1/2.-1/2
        C* -5/12.-3/4.-1/6
        C* -3/8.-11/12.-1/3.-1/24
        C* -251/720.-25/24.-35/72.-5/48.-1/120
        C* -95/288.-137/120.-5/8.-17/96.-1/40.-1/720
        C* -19087/60480.-49/40.-203/270.-49/192.-7/144.-7/1440.-1/5040
        C*
        C* THE FOLLOWING ARE FOR STIFF METHODS
        C*
        C* -1
        C*.-2/3.-1/3
        C* -6/11.-6/11.-1/11
        C* -12/25.-7/10.-1/5.-1/50
        C* -120/274.-225/274.-85/274.-15/274.-1/274
        C* -180/441.-58/63.-15/36.-25/252.-3/252.-1/1764
        C*************************************************************************
000202     95 A(1) = -1.0
000204        GOTO 160
000204    100 A(1) = -0.500000000
000205        A(3) = -0.500000000
000207        GOTO 160
000207    105 A(1) = -0.41666666666666667
000210        A(3) = -0.750000000
000212        A(4) = -0.16666666666666667
000214        GOTO 160
000214    110 A(1) = -0.375000000
000215        A(3) = -0.91666666666666667
000217        A(4) = -0.333333333333333
000220        A(5) = -0.041666666666666667
000222        GOTO 160
000223    115 A(1) = -0.34861111111111111
000224        A(3) = -1.0416666666666667
000226        A(4) = -0.48611111111111111
000227        A(5) = -0.10416666666666667
000231        A(6) = -0.0083333333333333333
000233        GOTO 160
000233    120 A(1) = -0.32986111111111111
000234        A(3) = -1.1416666666666667
000236        A(4) = -0.625000000
000237        A(5) = -0.17708333333333333
000241        A(6) = -0.0250000000
000242        A(7) = -0.0013888888888888889
```

```
000244            GOTO 160
000245        125 A(1) = -0.3155919312169312
000246            A(3) = -1.235000000
000250            A(4) = -0.7518518518518519
000251            A(5) = -0.2552083333333333
000253            A(6) = -0.04861111111111111
000254            A(7) = -0.004861111111111111
000256            A(8) = -0.0001984126984126984
000260            GOTO 160
000260        130 A(1) = -1.000000000
000262            GOTO 160
000262        135 A(1) = -0.6666666666666667
000263            A(3) = -0.3333333333333333
000265            GOTO 160
000266        140 A(1) = -0.5454545454545455
000267            A(3) = A(1)
000271            A(4) = -0.09090909090909091
000273            GOTO 160
000273        145 A(1) = -0.480000000
000274            A(3) = -0.700000000
000276            A(4) = -0.200000000
000277            A(5) = -0.020000000
000301            GOTO 160
000302        150 A(1) = -0.437956204379562
000303            A(3) = -0.8211678832116788
000305            A(4) = -0.3102189781021898
000306            A(5) = -0.05474452554744526
000310            A(6) = -0.0036496350364963504
000312            GOTO 160
000312        155 A(1) = -0.4081632653061225
000313            A(3) = -0.9206349206349206
000315            A(4) = -0.4166666666666667
000316            A(5) = -0.0992063492063492
000320            A(6) = -0.0119047619047619
000321            A(7) = -0.000566893424036282
000323        160 K=NQ+1
000325            IDOUB=K
          C*****************************************************************
          C* MTYP=1 FOR STIFF METHODS AND MTYP=2 FOR NON-STIFF METHODS     *
          C*****************************************************************
000326            MTYP=1
000327            IF(MTH.EQ.0)MTYP=2
000332            EDWN=NQ
```

```
000333         ENO1=.5/EDWN
000335         ENO2=.5/(EDWN+1.)
000341         ENO3=.5/(EDWN+2.)
000344         L=7*(MTYP-1)+NQ
         C*********************************************************************
         C* E IS A COMPARISON FOR ERRORS OF THE CURRENT ORDER NQ. EUP IS        *
         C* TO TEST FOR INCREASING THE ORDER, EDWN FOR DECREASING THE ORDER.    *
         C*********************************************************************
000347         E=(PERTST(L)*EPS)**2
000353         EUP=(PERTST(L+14)*EPS)**2
000355         EDWN=(PERTST(L+28)*EPS)**2
000357         IF(EDWN.EQ.0.)GOTO 430
000360         BND=EPS*ENO3/N
000363     165 IWEVAL=MTH
000364         IF(IRET.GT.1)GOTO 380
         C*********************************************************************
         C* THIS SECTION COMPUTES THE PREDICTED VALUES BY EFFECTIVELY          *
         C* MULTIPLYING THE SAVED INFORMATION BY THE PASCAL TRIANGLE MATRIX    *
         C*********************************************************************
000370     170 T=T+H
000371         L=N*(K-1)
000375         DO 175 J=2,K
000376         NN=L
000400         DO 175 J1=J,K
000401         NN=NN-N
000403         DO 175 I=1,N
000404         NT=NN+I
000405     175 Y(NT)=Y(NT)+Y(NT+N)
         C*********************************************************************
         C* UP TO 3 CORRECTOR ITERATIONS ARE TAKEN.  CONVERGENCE IS TESTED BY  *
         C* REQUIRING CHANGES TO BE LESS THAN BND WHICH IS DEPENDENT ON THE    *
         C* ERROR TEST CONSTANT.  THE SUM OF THE CORRECTIONS IS ACCUMULATED IN *
         C* THE ARRAY WK(N13+I).  IT IS EQUAL TO THE K-TH DERIVATIVE OF Y      *
         C* MULTIPLIED BY H**K/(FACTORIAL(K-1)*A(K)), AND IS PROPORTIONAL TO   *
         C* THE ACTUAL ERRORS TO THE LOWEST POWER OF H PRESENT.  (H**K)        *
         C*********************************************************************
000420         DO 180 I=1,N
000422     180 WK(N13+I)=0.
000427         DO 260 L=1,3
000430         CALL DIFFUN(T,Y,WK(N10P1))
         C*********************************************************************
         C* IF THERE HAS BEEN A CHANGE OF ORDER OR THERE HAS BEEN TROUBLE      *
         C* WITH CONVERGENCE, THE JACOBIAN IS RE-EVALUATED PRIOR TO STARTING   *
```

```
            C* THE CORRECTOR ITERATION IN THE CASE OF STIFF METHODS. IWEVAL IS
            C* THEN SET TO -1 AS AN INDICATOR THAT IT HAS BEEN DONE.
            C*******************************************************************
000434            IF(IWEVAL.LT.1)GOTO 220
000442            IF(MTH.EQ.2)GOTO 200
000445            CALL PEDERV(T,Y,WK(N14P1),N)
000452            R=A(1)*H
000457            NN=N*N
000461            DO 185 I=1,NN
000463        185 WK(N14+I)=WK(N14+I)*R
            C*******************************************************************
            C* ADD THE IDENTITY MATRIX TO THE JACOBIAN AND INVERT
            C*******************************************************************
000471        190 NN=N13
000472            J1=N+1
000474            DO 195 I=1,N
000476            NN=NN+J1
000500        195 WK(NN)=1.+WK(NN)
000505            IWEVAL=-1
000506            CALL MATINV(WK(N14P1),N,J1)
000514            IF(J1.GT.0)GOTO 220
000522            GOTO 265
            C*******************************************************************
            C* EVALUATE THE JACOBIAN BY NUMERICAL DIFFERENCING. R IS THE CHANGE
            C* MADE TO THE ELEMENT OF Y. IT IS EPS RELATIVE TO Y WITH A MINIMUM OF
            C* EPS**2
            C*******************************************************************
000522        200 DO 205 I=1,N
000524        205 WK(N8+I)=Y(I)
000532            J1=N13
000533            DO 215 J=1,N
000535            R=EPS*AMAX1(EPS,ABS(WK(N8+J)))
000544            Y(J)=Y(J)+R
000547            D=A(1)*H/R
000551            CALL DIFFUN(T,Y,WK(N11P1))
000556            J1=J1+N
000563            DO 210 I=1,N
000565            NN=J1+I
000566        210 WK(NN)=(WK(N11+I)-WK(N10+I))*D
000602        215 Y(J)=WK(N8+J)
000610            GOTO 190
000610        220 IF(MTH.NE.0)GOTO 230
000612            DO 225 I=1,N
```

```
000613      225 WK(N8+I)=Y(N+I)-WK(N10+I)*H
000625          GOTO 250
000625      230 DO 235 I=1,N
000627      235 WK(N11+I)=Y(N+I)-WK(N10+I)*H
000641          DO 245 I=1,N
000642          D=0.
000643          NN=N13+I
000645          DO 240 J=1,N
000646          NN=NN+N
000647      240 D=D+WK(NN)*WK(N11+J)
000657      245 WK(N8+I)=D
000664      250 NT=N
            C*********************************************************************
            C* CORRECT AND SEE IF ALL CHANGES ARE LESS THAN BND RELATIVE TO      *
            C* WK(N12+I). IF SO, THE CORRECTOR IS SAID TO HAVE CONVERGED.        *
            C*********************************************************************
000665          DO 255 I=1,N
000667          Y(I)=Y(I)+A(1)*WK(N8+I)
000674          Y(N+I)=Y(N+I)-WK(N8+I)
000701          WK(N13+I)=WK(N13+I)+WK(N8+I)
000705          IF(ABS(WK(N8+I)).LE.BND*WK(N12+I))NT=NT-1
000714      255 CONTINUE
000722          IF(NT.LE.0)GOTO 285
000723      260 CONTINUE
            C*********************************************************************
            C* THE CORRECTOR ITERATION FAILED TO CONVERGE IN 3 TRIES. VARIOUS    *
            C* POSSIBILITIES ARE CHECKED FOR. IF H IS ALREADY HMIN AND THIS IS   *
            C* EITHER ADAMS METHOD OR THE STIFF METHOD IN WHICH THE JACOBIAN HAS *
            C* ALREADY BEEN RE-EVALUATED, A NO CONVERGENCE EXIT IS TAKEN.        *
            C* OTHERWISE THE JACOBIAN IS RE-EVALUATED AND/OR THE STEP IS REDUCED *
            C* TO TRY AND GET CONVERGENCE.                                       *
            C*********************************************************************
000725      265 T=TOLD
000726          IF(H.LE.HMIN*1.00001.AND.(IWEVAL-MTYP).LT.-1)GOTO 270
000743          IF(MTH.EQ.0.OR.IWEVAL.NE.0)RACUM=RACUM*.25
000752          IWEVAL=MTH
000753          IRET1=2
000755          GOTO 415
000755      270 IERR=-3
000757      275 NN=N*K
000762          DO 280 I=1,NN
000763      280 Y(I)=WK(I)
000770          H=HOLD
```

```
000771         NQ=NQOLD
000772         JSTART=NQ
000773         RETURN
          C***********************************************************************
          C* THE CORRECTOR CONVERGED AND CONTROL IS PASSED TO STATEMENT 300     *
          C* IF THE ERROR TEST IS O.K..  AND TO 310 OTHERWISE.                  *
          C* IF THE STEP IS O.K. IT IS ACCEPTED. IF IDOUB HAS BEEN REDUCED      *
          C* TO ONE.  A TEST IS MADE TO SEE IF THE STEP CAN BE INCREASED        *
          C* AT THE CURRENT ORDER OR BY GOING TO ONE HIGHER OR ONE LOWER.       *
          C* SUCH A CHANGE IS ONLY MADE IF THE STEP CAN BE INCREASED BY AT      *
          C* LEAST 1.1.  IF NO CHANGE IS POSSIBLE IDOUB IS SET TO 10 TO         *
          C* PREVENT FUTHER TESTING FOR 10 STEPS.                               *
          C* IF A CHANGE IS POSSIBLE, IT IS MADE AND IDOUB IS SET TO            *
          C* NQ + 1     TO PREVENT FURTHER TESING FOR THAT NUMBER OF STEPS.     *
          C* IF THE ERROR WAS TOO LARGE, THE OPTIMUM STEP SIZE FOR THIS OR      *
          C* LOWER ORDER IS COMPUTED, AND THE STEP RETRIED.  IF IT SHOULD       *
          C* FAIL TWICE MORE IT IS AN INDICATION THAT THE DERIVATIVES THAT      *
          C* HAVE ACCUMULATED IN THE Y ARRAY HAVE ERRORS OF THE WRONG ORDER     *
          C* SO THE FIRST DERIVATIVES ARE RECOMPUTED AND THE ORDER IS SET TO 1. *
          C***********************************************************************
000774     285 D=0.
000775         DO 290 I=1,N
000777     290 D=D+(WK(N13+I)/WK(N12+I))**2
001010         IWEVAL=0
001010         IF(D.GT.E)GOTO 310
001014         IF(K.LT.3)GOTO 300
          C***********************************************************************
          C* COMPLETE THE CORRECTION OF THE HIGHER ORDER DERIVATIVES AFTER A    *
          C* SUCCESFUL STEP.                                                    *
          C***********************************************************************
001016         L=N
001017         DO 295 J=3,K
001020         L=L+N
001022         DO 295 I=1,N
001023         NN=L+I
001024     295 Y(NN)=Y(NN)+A(J)*WK(N13+I)
001037     300 IERR=+1
001040         HNEW=H
001041         IF(IDOUB.LE.1)GOTO 315
001044         IDOUB=IDOUB-1
001045         IF(IDOUB.GT.1)GOTO 390
001050         DO 305 I=1,N
001051     305 WK(N9+I)=WK(N13+I)
```

```
001060        GOTO 390
              C**********************************************************************
              C* REDUCE THE FAILURE FLAG COUNT TO CHECK FOR MULTIPLE FAILURES.      *
              C* RESTORE T TO ITS ORIGINAL VALUE AND TRY AGAIN UNLESS THERE HAVE    *
              C* THREE FAILURES.  IN THAT CASE THE DERVATIVES ARE ASSUMED TO HAVE   *
              C* ACCUMULATED ERRORS SO A RESTART FROM THE CURRENT VALUES OF Y IS    *
              C* TRIED.                                                             *
              C**********************************************************************
001060    310 IERR=IERR-2
001062        IF(H.LE.HMIN*1.00001)GOTO 410
001066        T=TOLD
001067        IF(IERR.LE.-5)GOTO 400
              C**********************************************************************
              C* PR1, PR2, AND PR3  WILL CONTAIN THE AMOUNTS BY WHICH THE STEP SIZE *
              C* SHOULD BE DIVIDED AT ORDER ONE LOWER, AT THIS ORDER, AND AT ORDER  *
              C* ONE HIGHER RESPECTIVELY.                                           *
              C**********************************************************************
001071    315 PR2=(D/E)**ENQ2*1.2
001076        PR3=1.E+20
001100        IF(NQ.GE.MAXDER.OR.IERR.LE.-1)GOTO 325
001112        D=0.
001113        DO 320 I=1,N
001114    320 D=D+((WK(N13+I)-WK(N9+I))/WK(N12+I))**2
001130        PR3=(D/EUP)**ENQ3*1.4
001135    325 PR1=1.E+20
001136        IF(NQ.LE.1)GOTO 335
001141        D=0.
001142        NN=N*(K-1)
001145        DO 330 I=1,N
001146        NN=NN+1
001150    330 D=D+(Y(NN)/WK(N12+I))**2
001157        PR1=(D/EDWN)**ENQ1*1.3
001164    335 CONTINUE
001164        IF(PR2.LE.PR3)GOTO 365
001167        IF(PR3.LT.PR1)GOTO 370
001171    340 R=1./AMAX1(PR1,1.E-04)
001176        NEWQ=NQ-1
001200    345 IDOUB=10
001201        IF(IERR.EQ.1.AND.R.LT.1.1)GOTO 390
001213        IF(NEWQ.LE.NQ)GOTO 355
              C**********************************************************************
              C* COMPUTE ONE ADDITIONAL SCALED DERIVATIVE IF ORDER IS INCREASED.    *
              C**********************************************************************
```

```
001215          NN=NEWQ*N
001217          DO 350 I=1,N
001221          NN=NN+1
001223      350 Y(NN)=WK(N13+I)*A(K)/K
001233      355 K=NEWQ+1
001235          IF(IER*R.EQ.1)GOTO 375
001237          RACUM=RACUM*R
001240          IRETI=3
001241          GOTO 415
001242      360 IF(NEWQ.EQ.NQ)GOTO 170
001244          NQ=NEWQ
001245          GOTO 55
001245      365 IF(PR2.GT.PR1)GOTO 340
001251          NEWQ=NQ
001251          R=1./AMAX1(PR2,1.E-04)
001256          GOTO 345
001257      370 R=1./AMAX1(PR3,1.E-04)
001264          NEWQ=NQ+1
001266          GOTO 345
001267      375 IRET=2
001270          R=AMIN1(R,HMAX/ABS(H))
001275          H=H*R
001276          HNEW=H
001276          IF(NQ.EQ.NEWQ)GOTO 380
001301          NQ=NEWQ
001301          GOTO 55
001302      380 R1=1.
001303          L=0
001305          DO 385 J=2,K
001306          R1=R1*R
001310          L=L+N
001311          DO 385 I=1,N
001313          NN=L+I
001314      385 Y(NN)=Y(NN)*R1
001323          IDOUB=K
001324      390 DO 395 I=1,N
001326      395 WK(N12+I)=AMAX1(WK(N12+I),ABS(Y(I)))
001340          JSTART=NQ
001341          RETURN
001342      400 IF(NQ.EQ.1)GOTO 430
001344          CALL DIFFUN(T,Y,WK(N1OP1))
001351          R=H/HOLD
001357          DO 405 I=1,N
```

```
001360            Y(I)=WK(I)
001363            NN=N+I
001363            WK(NN)=HOLD*WK(N10+I)
001370       405  Y(NN)=WK(NN)*R
001376            NO=1
001376            IERR=+1
001400            GOTO 55
001401       410  IERR=-1
001402            HNEW=H
001403            JSTART=NO
001405            RETURN
          C**********************************************************************
          C* THIS SECTION SCALES ALL VARIABLES CONNECTED WITH H AND RETURNS      *
          C* TO THE ENTERING SECTION.                                            *
          C**********************************************************************
001406       415  RACUM=AMAX1(ABS(HMIN/HOLD),RACUM)
001414            RACUM=AMIN1(RACUM,ABS(HMAX/HOLD))
001421            RI=1.
001422            L=0
001423            DO 420 J=2,K
001424            L=L+N
001425            RI=RI*RACUM
001427            DO 420 I=1,N
001431            NN=L+I
001432       420  Y(NN)=WK(NN)*RI
001442            H=HOLD*RACUM
001444            DO 425 I=1,N
001445       425  Y(I)=WK(I)
001452            IDOUB=K
001453            IF(IRET1-2)20,170,360
001456       430  IERR=-4
001460            GOTO 275
001460            END
```

```
              SUBROUTINE PEDERV(T,Y,PW,N)
        C
        C THIS IS A DUMMY SUBROUTINE TO SATISFY THE LOADER.
        C A DUMMY SUBROUTINE IS EMPLOYED WHEN NON-STIFF (MTH=0) METHODS ARE DESIRED.
        C
000007        RETURN
000010        END
```

```
      SUBROUTINE MATINV(PW,N,J)
C
C     THIS IS A DUMMY SUBROUTINE TO SATISFY THE LOADER.
C     A DUMMY SUBROUTINE IS EMPLOYED WHEN NON-STIFF (MTH=0) METHODS ARE DESIRED.
C
000006      RETURN
000007      END
```

```
      SUBROUTINE DIFFUN(T,Y,DY)
C
C*****************************************************************
C*                                                               *
C* PURPOSE                                                       *
C*                                                               *
C*    SUBROUTINE DIFFUN IS USED TO COMPUTE THE SCALED DERIVATIVES  *
C*    USED BY DIFSUB. FLAGS MAY BE SET BY THE USER TO CHOOSE THE   *
C*    DERIVATIVES FOR PENDULATION,TORSION,AND CORIOLIS EFFECTS IN  *
C*    ANY COMBINATION DESIRED. THE INDIVIDUAL CONTRIBUTIONS ARE THEN *
C*    SUMMED TO OBTAIN A TOTAL COMPOSITE VALUE TO BE USED IN DIFSUB. *
C*                                                               *
C* PROPRIETARY                                                   *
C*                                                               *
C*    NONE                                                       *
C*                                                               *
C* USE                                                           *
C*                                                               *
C*    CALL DIFFUN(T,Y,DY)                                        *
C*                                                               *
C* PARAMETERS                                                    *
C*                                                               *
C*    T---TIME                                                   *
C*                                                               *
C*    Y---ARRAY OF DEPENDENT VARIABLES AND THEIR SCALED DERIVATIVES *
C*                                                               *
C*    DY--ARRAY OF THE DERIVATIVES OF Y                          *
C*                                                               *
C* REQUIRED ROUTINES                                             *
C*                                                               *
C*    PEND,TORS,CORL,DAMP                                        *
C*                                                               *
C* AUTHOR/IMPLEMENTOR                                            *
C*                                                               *
C*    D.R.DORSEY,JR - B.SEAY                                     *
C*                                                               *
C* DATE RELEASED                                                 *
C*                                                               *
C*    SEPTEMBER 14,1973                                          *
C*                                                               *
C* LATEST REVISION                                               *
C*                                                               *
```

C-2

```
        C*     SEPTEMBER 14,1973                                               *
        C*                                                                     *
        C***********************************************************************
        C
        C          I--- = 0  .  OFF FLAG
        C          I--- = 1  .  ON  FLAG
        C
        C***********************************************************************
        C
000006         COMMON/ TESTC/ IPEND,ITORS,ICORL
000006         DIMENSION Y(128),DY(16)
000006         DIMENSION DYP(16),DYT(16),DYC(16)
        C
        C***********************************************************************
        C
000006         DO 10 I=1,16
000007         DYP(I)=0.0
000010         DYT(I)=0.0
000011         DYC(I)=0.0
000012      10 CONTINUE
        C
        C
        C---   PENDULATION MODULE
        C
000014         IF(IPEND.EQ.0) GO TO 30
000015         CALL PEND(T,Y,DYP)
        C
        C---   TORSION MODULE
        C
000016      30 IF(ITORS.EQ.0) GO TO 60
000021         CALL TORS(T,Y,DYT)
        C
        C---   CORIOLIS MODULE
        C
000023      60 IF(ICORL.EQ.0) GO TO 90
000026         CALL CORL(T,Y,DYC)
000030      90 CONTINUE
        C
        C---   SUM UP CONTRIBUTIONS TO GET TOTAL DY - IF A MODULE WAS NOT
        C---   USED,ITS CONTRIBUTION HAS BEEN PRESET TO ZERO.
        C
000030         DO 100 I=1,16
000034     100 DY(I)=DYP(I)+DYT(I)+DYC(I)
```

000042 RETURN
000043 END

ORIGINAL PAGE IS
OF POOR QUALITY

```
      SUBROUTINE PEND(T,Y,DY)
C
C*************************************************************************
C*                                                                       *
C* PURPOSE                                                               *
C*                                                                       *
C*    SUBROUTINE PEND INTEGRATES THE DYNAMICALLY COUPLED LAGRANGIAN      *
C*    EQUATIONS OF MOTION FOR THE PENDULATORY MOTION, USING THE          *
C*    METHOD OF DETACHED COEFFICIENTS (SUBROUTINE BOSS) TO DECOUPLE      *
C*    THE EQUATIONS BEFORE INTEGRATION. VISCOUS DAMPING MAY BE           *
C*    INCLUDED, IF DESIRED.                                              *
C*                                                                       *
C* PROPRIETARY                                                           *
C*                                                                       *
C*    NONE                                                               *
C*                                                                       *
C* USE                                                                   *
C*                                                                       *
C*    CALL PEND(T,Y,DY)                                                  *
C*                                                                       *
C* PARAMETERS                                                            *
C*                                                                       *
C*    T---TIME                                                           *
C*                                                                       *
C*    Y---ARRAY OF DEPENDENT VARIABLES AND SCALED DERIVATIVES            *
C*                                                                       *
C*    DY--ARRAY OF DERIVATIVES OF Y WITH RESPECT TO T                    *
C*                                                                       *
C* REQUIRED ROUTINES                                                     *
C*                                                                       *
C*    DAMP                                                               *
C*                                                                       *
C* AUTHOR/IMPLEMENTOR                                                    *
C*                                                                       *
C*    D.K.DORSEY,JR. - B.SEAY                                            *
C*                                                                       *
C* DATE RELEASED                                                         *
C*                                                                       *
C*    SEPTEMBER 14,1973                                                  *
C*                                                                       *
C* LATEST REVISION                                                       *
C*                                                                       *
```

```
      C*     SEPTEMBER 14,1973                                                *
      C*                                                                      *
      C***********************************************************************
      C
      C
      C
      C***********************************************************************
      C
      C                                                                  *
      C*-*-                                                           *  *
      C                                                                  *
      C
      C***********************************************************************
      C
      C
      C
000006         COMMON / CONST / MB,MS,MP,ME,M,RB,A1,L,P,RS,RP,RC,G,RHO,MU,N,
             *                  HS,HP,HE
000006         COMMON/ DAMPC / ASCS,APCP,AECE,D(8),IDAMP
000006         COMMON / SBSPE / SB,SS,SP,SE,SB1,SS1,SP1,SE1
000006         DIMENSION Y(128),M(4),DY(16),A(8,8),B(8),C(8,9),Q(8)
000006         REAL MB,MS,MP,ME,M,L,MU
      C
      C***********************************************************************
      C
      C
      C      COMPUTE THE THETA*S AND PHI*S
      C
000006         THETAB=Y(1)
000007         PHIB=Y(2)
000010         THETAS=Y(3)
000012         PHIS=Y(4)
000013         THETAP=Y(5)
000015         PHIP=Y(6)
000016         THETAE=Y(7)
000020         PHIE=Y(8)
000021         TDOTB=Y(9)
000023         DDTB=Y(10)
000024         TDOTS=Y(11)
000026         DDTS=Y(12)
000027         TDOTP=Y(13)
000031         DDTP=Y(14)
000032         TDOTE=Y(15)
```

```
000034        DATE=Y(16)
         C
         C
         C*********************************************************************
         C
         C        DRVROUTINE DIFPEN
         C
         C*********************************************************************
         C*                                                                   *
         C* PURPOSE                                                           *
         C*                                                                   *
         C*       DRVROUTINE DIFPEN DEFINES THE DERIVATIVES FOR PEND TO BE USED    *
         C*       IN DIFSUB.                                                  *
         C*                                                                   *
         C   THIS PROGRAM COMPUTES THE DERIVATIVES OF Y(I) I=1.16 WITH RESPECT TO
         C   T PLACES THE RESULTS IN DY(I) I=1.16 AND RETURNS TO DIFSUB
         C
         C        INITIALIZE VALUES FOR DIFFUN
         C
000035        XIB=39.369134*RB*RB
000037        XIS=3.86755*RS*RS
000041        XIP=1.2743*RP*RP
000043        XIE=7.329*RE*RE
         C
000045        Z1=XIB/(M(4)*RB*RB)
000050        Z2=XIS/(M(3)*A1*A1)
000053        Z3=XIP/(M(2)*L*L)
000056        Z4=XIE/(M(1)*P*P)
         C
000061        SB=1./(Z1+1.)
000064        SS=1./(Z2+1.)
000066        SP=1./(Z3+1.)
000071        SE=1./(Z4+1.)
         C
000073        Z1=Z1/(THETAB*THETAB)
000075        Z2=Z2/(THETAS*THETAS)
000077        Z3=Z3/(THETAP*THETAP)
000100        Z4=Z4/(THETAE*THETAE)
         C
000102        SB1=1./(Z1+1.)
000105        SS1=1./(Z2+1.)
000107        SP1=1./(Z3+1.)
000112        SE1=1./(Z4+1.)
```

```
      C
      C
      C     FORM THE A MATRIX
      C
000114      DO 10 I=1,N
000116   10 A(I,I)=1.0
000124      A(1,2)=A(1,4)=A(2,1)=A(3,2)=A(3,4)=A(4,3)=A(5,6)=A(5,8)=A(6,5)=
           1A(7,6)=A(7,8)=A(8,7)=0.0
      C
      C     SET UP THE INITIAL VALUES
      C
000162      C1=SB/(M(4)*RB)
000165      D1=M(3)*A1
000167      E1=M(2)*L
000171      F1=M(1)*P
000173      G1=RB*THETAB
000175      H1=A1*THETAS
000177      H2=RB*PHIB
000201      A(1,3)=D1*C1
000203      A(1,5)=E1*C1
000204      A(1,6)=E1*THETAP*(PHIB-PHIP)*C1
000211      A(1,7)=F1*C1
000212      A(1,8)=F1*THETAE*(PHIB-PHIE)*C1
      C
      C     RESET  C1
      C
000217      C1=SB1/(M(4)*G1)
000222      A(2,3)=D1*PHIS*C1
000224      A(2,4)=D1*THETAS*C1
000226      A(2,5)=E1*PHIP*C1
000230      A(2,6)=E1*THETAP*C1
000232      A(2,7)=F1*PHIE*C1
000234      A(2,8)=F1*THETAE*C1
      C
      C     RESET C1
      C
000236      C1=SS/A1
000240      A(3,1)=RB*C1
000242      C1=C1/M(3)
000244      A(3,5)=E1*C1
000245      A(3,6)=E1*THETAP*(PHIS-PHIP)*C1
000252      A(3,7)=F1*C1
000253      A(3,8)=F1*THETAE*(PHIS-PHIE)*C1
```

```
        C
000334        C1=SE/P
000336        A(7,1)=RB*C1
000337        A(7,2)=G1*(PHIE-PHIB)*C1
000342        A(7,4)=H1*(PHIE-PHIS)*C1
000346        A(7,3)=A1*C1
000347        A(7,5)=L*C1
        C
        C     RESET C1
        C
000351        C1=SE1/(P*THETAE)
000354        A(8,1)=H2*C1
000355        A(8,2)=G1*C1
000357        A(8,3)=A1*PHIS*C1
000361        A(8,4)=H1*C1
000362        A(8,5)=L*PHIP*C1
000365        A(8,6)=L*THETAP*C1
        C
        C     FORM THE B-MATRIX
        C
        C
        C     SET UP INITIAL CONDITIONS
        C
000367        PDB2TB=DOTB*DOTB*THETAB
000371        PDS2TS=DOTS*DOTS*THETAS
000373        PDP2TP=DOTP*DOTP*THETAP
000375        PDE2TE=DOTE*DOTE*THETAE
        C
000377        PDBTDB=DOTB*TDOTB
000401        PDSTDS=DOTS*TDOTS
000403        PDPTDP=DOTP*TDOTP
000405        PDETDE=DOTE*TDOTE
        C
000407        PBMPP=PHIB-PHIP
000411        PBMPE=PHIB-PHIE
000413        PSMPP=PHIS-PHIP
000414        PSMPE=PHIS-PHIE
        C
000416        TBMTP=THETAB-THETAP
000420        TBMTE=THETAB-THETAE
000422        TSMTP=THETAS-THETAP
000423        TSMTE=THETAS-THETAE
        C
```

```
      C
      C      RESET C1
      C
000260       C1=SS1/H1
000262       A(4,1)=H2*C1
000263       A(4,2)=G1*C1
      C
      C      RESET C1
      C
000265       C1=C1/M(3)
000267       A(4,5)=E1*PHIP*C1
000271       A(4,6)=E1*THETAP*C1
000273       A(4,7)=F1*PHIE*C1
000275       A(4,8)=F1*THETAE*C1
      C
      C      RESET C1
      C
000277       C1=SP/L
000301       A(5,1)=RB*C1
000302       A(5,2)=G1*(PHIP-PHIB)*C1
000305       A(5,3)=A1*C1
000307       A(5,4)=H1*(PHIP-PHIS)*C1
      C
      C      RESET C1
      C
000312       C1=C1/M(2)
000313       A(5,7)=F1*C1
      C
      C      RESET C1
      C
000315       C1=SP1/(L*THETAP)
000320       A(6,1)=H2*C1
000321       A(6,2)=G1*C1
000323       A(6,3)=A1*PHIS*C1
000325       A(6,4)=H1*C1
      C
      C      RESET C1
      C
000326       C1=C1/M(2)
000330       A(6,7)=F1*PHIE*C1
000332       A(6,8)=F1*THETAE*C1
      C
             [illegible] C1
```

```
000425        R1=1./(M(4)*RB)
000430        R2=M(2)*L
000432        R3=M(1)*P
000434        R4=M(3)*A1
       C
       C      R1, Q1, AND W1 WILL VARY WHEN NECESSARY
       C
       C      COMPUTE THE B-MATRIX
       C
000436        B(1)=SB*(PDB2TB-R1*(M(3)*(-A1*PDS2TS+G*THETAB)
             1     +R2*(TDOTP*(2.*DOTP*PBMPP+TDOTP*TBMTP)-PDP2TP)
             2     +R3*(TDOTE*(2.*DOTE*PBMPE+TDOTE*TBMTE)-PDE2TE)))
       C
000466        Q1=-2./THETAB
       C
000470        B(2)=Q1*SB1*(R1*(R4*PDSTDS+R2*PDPTDP+R3*PDETDE)+PDBTDB)
       C
000501        R1=1./A1
000503        W1=1./M(3)
       C
000505        B(3)=SS*(PDS2TS-R1*((-RB*PDB2TB+G*THETAS)
             1     +W1*(R2*(TDOTP*(2.*DOTP*PSMPP+TDOTP*TSMTP)-PDP2TP)
             2     +R3*(TDOTE*(2.*DOTE*PSMPE+TDOTE*TSMTE)-PDE2TE))))
       C
000535        Q1=(Q1*THETAB)/THETAS
000540        R1=R1*W1
       C
000541        B(4)=Q1*SS1*(R1*(M(3)*RB*PDBTDB+R2*PDPTDP+R3*PDETDE)+PDSTDS)
       C
000553        R1=1./L
000555        W1=1./M(2)
       C
000557        B(5)=SP*(PDP2TP-R1*(RB*(TDOTB*(2.*DOTB*(-PBMPP)+TDOTB*(-TBMTP))-
             1            PDB2TB)
             2     +A1*(TDOTS*(2.*DOTS*(-PSMPP)+TDOTS*(-TSMTP))-PDS2TS)
             3     +G*THETAP-R3*W1*PDE2TE))
       C
000612        Q1=(Q1*THETAS)/THETAP
000614        R1=R1*W1
       C
000616        B(6)=Q1*SP1*(R1*(M(2)*(RB*PDBTDB+A1*PDSTDS)+R3*PDETDE)+PDPTDP)
       C
000630        R1=1./P
```

```
      C
000631      B(7)=SE*(PDE2TE-R1*(RB*(TDOTB*(2.*DOTB*(-PBMPE)+TDOTB*(-TBMTE))-
           1      PDB2TB)
           2    +A1*(TDOTS*(2.*DOTS*(-PSMPE)+TDOTS*(-TSMTE))-PDS2TS)
           3    -L*PDP2TP+G*THETAE))
      C
000663      Q1=(Q1*THETAP)/THETAE
      C
000665      B(8)=Q1*SE1*(R1*(RB*PDBTDB+A1*PDSTDS+L*PDPTDP)+PDETDE)
      C
      C     ADD IN DAMPING CONTRIBUTION
      C
000676      IF(IDAMP.EQ.0) GO TO 30
000677      CALL DAMP(Y)
000701      DO 20 K=1,8
000705   20 B(K)=B(K)+D(K)
      C
000711   30 CONTINUE
      C
      C     FORM THE C-MATRIX
      C
000711      DO 40 I=1,8
000713      C(I,9)=B(I)
000715      DO 40 J=1,8
000716   40 C(I,J)=A(I,J)
000730      CALL BOSS(C,N,O)
      C
      C     THE DERIVATIVES ARE FORMED AS FOLLOWS
      C
000732      DO 50 I=1,8
000736      DY(I)=Y(I+8)
000741      DY(I+8)=D(I)
000742   50 CONTINUE
      C
      C
000744      RETURN
000745      END
```

```
      SUBROUTINE TORS(T,Y,DY)
C
C*********************************************************************
C*                                                                   *
C* PURPOSE                                                           *
C*                                                                   *
C*    SUBROUTINE TORS INTEGRATES THE TORSIONAL EQUATIONS OF MOTION.  *
C*    DAMPING IS ALREADY INCLUDED. THESE EQUATIONS HAVE ONLY STATIC  *
C*    COUPLING AND CAN BE INTEGRATED DIRECTLY BY DIFSUB.             *
C*                                                                   *
C* PROPRIETARY                                                       *
C*                                                                   *
C*    NONE                                                           *
C*                                                                   *
C* USE                                                               *
C*                                                                   *
C*    CALL TORS(T,Y,DY)                                              *
C*                                                                   *
C* PARAMETERS                                                        *
C*                                                                   *
C*    T---TIME                                                       *
C*                                                                   *
C*    Y---ARRAY OF DEPENDENT VARIABLES AND SCALED DERIVATIVES        *
C*                                                                   *
C*    DY--ARRAY OF DERIVATIVES OF Y WITH RESPECT TO T                *
C*                                                                   *
C* REQUIRED ROUTINES                                                 *
C*                                                                   *
C*    NONE                                                           *
C*                                                                   *
C* AUTHOR/IMPLEMENTOR                                                *
C*                                                                   *
C*    D.R.DORSEY,JR - B.SEAY                                         *
C*                                                                   *
C* DATE RELEASED                                                     *
C*                                                                   *
C*    SEPTEMBER 14,1973                                              *
C*                                                                   *
C* LATEST REVISION                                                   *
C*                                                                   *
C*    SEPTEMBER 14,1973                                              *
C*                                                                   *
```

```
      C*************************************************************************
      C
      C
      C
      C*************************************************************************
      C
      C
      C*-*-
      C
      C
      C*************************************************************************
      C
      C
      C
000006      COMMON / CONST / MB,MS,MP,ME,M,RB,A1,L,P,RS,RP,RE,G,RHO,MU,N,
           *                 HS,HP,HE
000006      REAL MB,MS,MP,ME,M,L,MU
000006      DIMENSION Y(64),M(4),DY(16)
      C
      C*************************************************************************
      C
000006      Q=RB+A1
000007      TAUS=MS*G*RS*RS/Q
000013      Q=Q+L+HS
000016      TAUP=MP*G*RP*RP/Q
000022      Q=Q+P+HP
000024      TAUE=ME*G*RE*RE/Q
      C
      C
000030      QN=2.5*SQRT(RHO*MU)
000035      ETAB=QN*RB**4*SQRT(ABS(Y(10)))
000047      ETAS=QN*RS**4*SQRT(ABS(Y(12)))
000057      ETAP=QN*RP**4*SQRT(ABS(Y(14)))
000067      ETAE=QN*RE**4*SQRT(ABS(Y(16)))
      C
000077      AIB=2.*MB*RB*RB/3.
000103      AIS=0.5*MS*RS*RS
000106      AIP=0.5*MP*RP*RP
000110      AIE=0.5*ME*RE*RE
      C
      C     DBVROUTINE DIFTOR
      C
      C*************************************************************************
```

```
      C*                                                                    *
      C* PURPOSE                                                            *
      C*                                                                    *
      C*    DRVROUTINE DIFTOR DEFINES THE DERIVATIVES FOR TORS TO BE USED   *
      C*    IN DIFSUB.                                                      *
      C*                                                                    *
      C*                                                                    *
      C**********************************************************************
      C
      C
      C
      C     THE DERIVATIVES ARE COMPUTED AS FOLLOWS
      C
      C
000113      DY(1) =0.0
000114      DY(2) =Y(10)
000115      DY(3) =0.0
000116      DY(4) =Y(12)
000120      DY(5) =0.0
000121      DY(6) =Y(14)
000122      DY(7) =0.0
000123      DY(8) =Y(16)
000125      DY(9) =0.0
000126      DY(10)=1./AIB*(-ETAB*Y(10)-TAUS*(Y(2)-Y(4)))
000134      DY(11)=0.0
000135      DY(12)=1./AIS*(-ETAS*Y(12)+TAUS*(Y(2)-Y(4))-TAUP*(Y(4)-Y(6)))
000150      DY(13)=0.0
000151      DY(14)=1./AIP*(-ETAP*Y(14)+TAUP*(Y(4)-Y(6))-TAUE*(Y(6)-Y(8)))
000164      DY(15)=0.0
000165      DY(16)=1./AIE*(-ETAE*Y(16)+TAUE*(Y(6)-Y(8)))
      C
      C
000175      RETURN
000175      END
```

```
      SUBROUTINE CORL(T,Y,DY)
C
C***********************************************************************
C*                                                                     *
C* PURPOSE                                                             *
C*                                                                     *
C*    SUBROUTINE CORL INTEGRATES THE 2-D EQUATIONS OF MOTION FOR THE   *
C*    CORIOLIS EFFECT. THE EQUATIONS HAVE ONLY STATIC COUPLING AND     *
C*    CAN BE INTEGRATED DIRECTLY BY DIFSUB. NO DAMPING IS INCLUDED.    *
C*                                                                     *
C* PROPIETARY                                                          *
C*                                                                     *
C*    NONE                                                             *
C*                                                                     *
C* USE                                                                 *
C*                                                                     *
C*    CALL CORL(T,Y,DY)                                                *
C*                                                                     *
C* PARAMETERS                                                          *
C*                                                                     *
C*    T---TIME                                                         *
C*                                                                     *
C*    Y---ARRAY OF DEPENDENT VARIABLES AND SCALED DERIVATIVES          *
C*                                                                     *
C*    DY--ARRAY OF DERIVATIVES OF Y WITH RESPECT TO T                  *
C*                                                                     *
C* REQUIRED ROUTINES                                                   *
C*                                                                     *
C*    NONE                                                             *
C*                                                                     *
C* AUTHOR/IMPLEMENTOR                                                  *
C*                                                                     *
C*    D.R.DORSEY,JR - B.SEAY                                           *
C*                                                                     *
C* DATE RELEASED                                                       *
C*                                                                     *
C*    SEPTEMBER 14,1973                                                *
C*                                                                     *
C* LATEST REVISION                                                     *
C*                                                                     *
C*    SEPTEMBER 14,1973                                                *
C*                                                                     *
```

```
              C*********************************************************************
              C
              C
              C
              C*********************************************************************
              C
              C                                                                *
              C*-*-                                                            *
              C                                                                *
              C
              C     ***************************************************************
              C
              C
              C
 000006             COMMON/ CORIO / OMEGA,LAMDA
 000006             COMMCN / CONST / MB,MS,MP,ME,M,RB,AI,L,P,RS,RP,RE,G,RHO,MU,N,
                   *                 HS,HP,HE
 000006             DIMENSION Y(128),M(4),DY(16)
 000006             REAL MB,MS,MP,ME,M,L,MU,LAMDA
 000006             REAL MUB,MUS,MUP,MUE
              C
              C*********************************************************************
              C
              C
              C     SET UP XI≠S AND MU≠S
              C
 000006             XIB=Y(9)*Y(2)+Y(10)*Y(1)
 000011             XIS=Y(11)*Y(4)+Y(12)*Y(3)
 000016             XIP=Y(13)*Y(6)+Y(14)*Y(5)
 000022             XIE=Y(15)*Y(8)+Y(16)*Y(7)
 000027             MUB=Y(9)-Y(10)*Y(1)*Y(2)
 000033             MUS=Y(11)-Y(12)*Y(3)*Y(4)
 000040             MUP=Y(13)-Y(14)*Y(5)*Y(6)
 000044             MUE=Y(15)-Y(16)*Y(7)*Y(8)
              C
              C     SET UP INITIAL VALUES
              C
 000051             T1=2.*MB*OMEGA*RB*RB
 000055             SLAM=2.*SIN(LAMDA)
 000060             CLAM=COS(LAMDA)
              C
              C
              C     DRVROUTINE DIFCOR
```

```
          C
          C**************************************************************************
          C*                                                                       *
          C* PURPOSE                                                               *
          C*                                                                       *
          C*     DRVROUTINE DIFCOR DEFINES THE DERIVATIVES FOR CORL TO BE USED     *
          C*     IN DIFSUB.                                                        *
          C*                                                                       *
          C
          C  THIS PROGRAM COMPUTES THE DERIVATIVES OF Y(I) I=1,16 WITH RESPECT TO
          C  T. PLACES THE RESULTS IN DY(I) I=1,16 AND RETURNS TO DIFSUB
          C
          C      SET UP THE FIRST DERIVATIVES
          C
000063           DO 10 I=1,8
000066           DY(I)=Y(I+8)
000070        10 CONTINUE
          C
000072           DY(9) =T1*(SLAM*(XIB-MUB*Y(2))+CLAM*XIB*Y(1))
000102           DY(10)=T1*(-SLAM*(XIB*Y(2)+MUB)*Y(1))
          C
          C      RESET THE INITIAL VALUES
          C
000107           T1=2.*(MB+MS)*OMEGA
000113           T2=T1*A1
000114           XI1=RB*XIB+A1*XIS
000120           XMU1=RB*MUB+A1*MUS
          C
          C      COMPUTE MORE DERIVATIVES
          C
000123           DY(11)=T2*(SLAM*(XI1-XMU1*Y(4))+CLAM*XI1*Y(3))
000133           DY(12)=T2*(-SLAM*(XI1*Y(4)+XMU1)*Y(3))
          C
          C      RESET VALUES
          C
000141           T1=T1+2.*MP*OMEGA
000144           T2=T1*L
000146           XI1=XI1+L*XIP
000151           XMU1=XMU1+L*MUP
          C
          C      COMPUTE FURTHER DY≠S
          C
000154           DY(13)=T2*(SLAM*(XI1-XMU1*Y(6))+CLAM*XI1*Y(5))
```

```
000164          DY(14)=T2*(-SLAM*(XI1*Y(6)+XMU1)*Y(5))
          C
          C     RESET LAST INITIAL VALUES
          C
000172          T1=T1+2.*ME*OMEGA
000175          T2=T1*P
000177          XI1=XI1+P*XIE
000202          XMU1=XMU1+P*MUE
          C
          C     COMPUTE LAST SET OF DERIVATIVES
          C
000205          DY(15)=T2*(SLAM*(XI1-XMU1*Y(6))+CLAM*XI1*Y(7))
000215          DY(16)=T2*(-SLAM*(XI1*Y(8)+XMU1)*Y(7))
          C
          C
000223          RETURN
000224          END
```

```
      SUBROUTINE DAMP(Y)
C
C*******************************************************************
C*                                                                 *
C* PURPOSE                                                         *
C*                                                                 *
C*    SUBROUTINE DAMP DEFINES THE VISCOUS/AERODYNAMIC DAMPING EFFECTS *
C*    THAT MAY BE INCLUDED IN SUBROUTINE PEND. THE DAMPING VALUES    *
C*    ARE RETURNED TO PEND THROUGH THE ARRAY D(1)-D(8).              *
C*                                                                 *
C* PROPRIETARY                                                     *
C*                                                                 *
C*    NONE                                                         *
C*                                                                 *
C* USE                                                             *
C*                                                                 *
C*    CALL DAMP(Y)                                                 *
C*                                                                 *
C* PARAMETERS                                                      *
C*                                                                 *
C*    Y---ARRAY OF DEPENDENT VARIABLES AND SCALED DERIVATIVES      *
C*                                                                 *
C* REQUIRED ROUTINES                                               *
C*                                                                 *
C*    NONE                                                         *
C*                                                                 *
C* AUTHOR/IMPLEMENTOR                                              *
C*                                                                 *
C*    D.R.DORSEY,JR - B.SEAY                                       *
C*                                                                 *
C* DATE RELEASED                                                   *
C*                                                                 *
C*    SEPTEMBER 14,1973                                            *
C*                                                                 *
C* LATEST REVISION                                                 *
C*                                                                 *
C*    SEPTEMBER 14,1973                                            *
C*                                                                 *
C*******************************************************************
C
C
C
```

```
       C*****************************************************************
       C                                                                *
       C*-*-                                                            *
       C*-*-                                                            *
       C*-*-                                                            *
       C*-*-                                                            *
       C                                                                *
       C*****************************************************************
       C
       C
       C
000003        COMMON / CONST / MB,MS,MP,ME,M,RB,A1,L,P,RS,RP,RE,G,RHO,MU,N,
             *                 HS,HP,HE
000003        COMMON/ DAMPC / ASCS,APCP,AECE,D(8),IDAMP
000003        COMMON / SBSPE / SB,SS,SP,SE,SB1,SS1,SP1,SE1
000003        REAL MB,MS,MP,ME,M,L,MU
000003        DIMENSION M(4),Y(128)
       C
       C*****************************************************************
       C
       C      INITIALIZE VALUES FOR B-MATRIX
       C
000003        RHOM=2.5*SQRT(RHO*MU)
000010        ATDOTB=ABS(Y(9))
000013        SATDB=SQRT(ATDOTB)
000015        D(1)=RHOM*RB*RB*SATDB*Y(9)/M(4)*SB
       C
000024        ADOTB=ABS(Y(10))
000026        SADB=SQRT(ADOTB)
000030        D(2)=RHOM*RB*RB*SADB*Y(10)/(M(4)*Y(1)*Y(1))*SB1
       C
000040        RAC=0.5*RHO*ASCS
000042        Z1=RB+A1
000044        XI1=RB*Y(9)+A1*Y(11)
000050        AXI1=ABS(XI1)
000051        XI2=AXI1*XI1
000053        D(3)=RAC*Z1*XI2/(M(3)*A1*A1)*SS
       C
000060        YI1=RB*Y(1)*Y(10)+A1*Y(3)*Y(12)
000065        AYI1=ABS(YI1)
000067        YI2=AYI1*YI1
000071        D(4)=RAC*Z1*YI2/(M(3)*A1*A1*Y(3)*Y(3))*SS1
       C
```

```
000100      RAC=0.5*RHO*APCP
000102      Z1=Z1+L
000104      XI1=XI1+L*Y(13)
000107      AXI1=ABS(XI1)
000110      XI2=AXI1*XI2
000112      D(5)=RAC*Z1*XI2/(M(2)*L*L)*SP
      C
000117      YI1=YI1+L*Y(14)*Y(5)
000123      AYI1=ABS(YI1)
000124      YI2=AYI1*YI1
000125      D(6)=RAC*Z1*YI2/(M(2)*L*L*Y(5)*Y(5))*SP1
      C
000134      RAC=0.5*RHO*AECE
000136      Z1=Z1+P
000140      XI1=XI1+P*Y(15)
000143      AXI1=ABS(XI1)
000144      XI2=AXI1*XI1
000146      D(7)=RAC*Z1*XI2/(M(1)*P*P)*SE
      C
000153      YI1=YI1+P*Y(16)*Y(7)
000157      AYI1=ABS(YI1)
000160      YI2=AYI1*YI1
000161      D(8)=RAC*Z1*YI2/(M(1)*L*L*Y(7)*Y(7))*SE1
      C
000170      RETURN
000171      END
```

```
      SUBROUTINE BOSS(A,N,D)                                            BOSS0001
C
C***********************************************************************
C*                                                                     *
C* PURPOSE                                                             *
C*                                                                     *
C*    SUBROUTINE BOSS EMPLOYS THE METHOD OF DETACHED COEFFICIENTS TO   *
C*    SOLVE A SYSTEM OF REAL LINEAR EQUATIONS REPRESENTED BY THE MATRIX*
C*    EQUATION  AX=B , WHERE A IS A SQUARE MATRIX OF COEFFICIENTS, X IS*
C*    THE SOLUTION VECTOR, AND B IS THE RHS CONSTANT VECTOR.           *
C*                                                                     *
C* PROPRIETARY                                                         *
C*                                                                     *
C*    NONE                                                             *
C*                                                                     *
C* USE                                                                 *
C*                                                                     *
C*    CALL BOSS(A,N,D)                                                 *
C*                                                                     *
C* PARAMETERS                                                          *
C*                                                                     *
C*    A   AN AUGMENTED INPUT MATRIX CONTAINING THE LHS MATRIX OF       *
C*        COEFFICIENTS IN THE FIRST N COLUMNS AND THE RHS CONSTANT     *
C*        VECTOR IN THE (N+1)-ST COLUMN. THIS MATRIX MUST BE           *
C*        DIMENSIONED AT LEAST (N,N+1) IN THE CALLING PROGRAM.         *
C*                                                                     *
C*    N   THE NUMBER OF ROWS IN THE A MATRIX.                          *
C*                                                                     *
C*    D   THE SOLUTION VECTOR. THIS VECTOR MUST BE DIMENSIONED AT      *
C*        LEAST N IN THE CALLING PROGRAM.                              *
C*                                                                     *
C* REQUIRED ROUTINES                                                   *
C*                                                                     *
C*    NONE                                                             *
C*                                                                     *
C* AUTHOR/IMPLEMENTOR                                                  *
C*                                                                     *
C*   V.C.TAYLOR                                                        *
C*                                                                     *
C* DATE RELEASED                                                       *
C*                                                                     *
C*   JUNE 14, 1973                                                     *
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      C*                                                                        *
      C* LATEST REVISION                                                        *
      C*                                                                        *
      C*   JUNE 14, 1973                                                        *
      C*                                                                        *
      C**************************************************************************
      C
      C
000006         DIMENSION A(N,1),D(N)                                            BOSS0002
000006         B12=A(1,2)/A(1,1)                                                BOSS0003
000012         B13=A(1,3)/A(1,1)                                                BOSS0004
000015         B14=A(1,4)/A(1,1)                                                BOSS0005
000021         B15=A(1,5)/A(1,1)                                                BOSS0006
000024         B16=A(1,6)/A(1,1)                                                BOSS0007
000030         B17=A(1,7)/A(1,1)                                                BOSS0008
000033         B18=A(1,8)/A(1,1)                                                BOSS0009
000037         B19=A(1,9)/A(1,1)                                                BOSS0010
000042         B22=(A(2,2)-A(2,1)*B12)                                          BOSS0011
000051         B23=(A(2,3)-A(2,1)*B13)                                          BOSS0012
000061         B24=(A(2,4)-A(2,1)*B14)                                          BOSS0013
000070         B25=(A(2,5)-A(2,1)*B15)                                          BOSS0014
000100         B26=(A(2,6)-A(2,1)*B16)                                          BOSS0015
000107         B27=(A(2,7)-A(2,1)*B17)                                          BOSS0016
000117         B28=(A(2,8)-A(2,1)*B18)                                          BOSS0017
000126         B29=(A(2,9)-A(2,1)*B19)                                          BOSS0018
000136         B32=(A(3,2)-A(3,1)*B12)                                          BOSS0019
000145         B33=(A(3,3)-A(3,1)*B13)                                          BOSS0020
000155         B34=(A(3,4)-A(3,1)*B14)                                          BOSS0021
000164         B35=(A(3,5)-A(3,1)*B15)                                          BOSS0022
000174         B36=(A(3,6)-A(3,1)*B16)                                          BOSS0023
000203         B37=(A(3,7)-A(3,1)*B17)                                          BOSS0024
000213         B38=(A(3,8)-A(3,1)*B18)                                          BOSS0025
000222         B39=(A(3,9)-A(3,1)*B19)                                          BOSS0026
000232         B42=(A(4,2)-A(4,1)*B12)                                          BOSS0027
000241         B43=(A(4,3)-A(4,1)*B13)                                          BOSS0028
000251         B44=(A(4,4)-A(4,1)*B14)                                          BOSS0029
000260         B45=(A(4,5)-A(4,1)*B15)                                          BOSS0030
000270         B46=(A(4,6)-A(4,1)*B16)                                          BOSS0031
000277         B47=(A(4,7)-A(4,1)*B17)                                          BOSS0032
000307         B48=(A(4,8)-A(4,1)*B18)                                          BOSS0033
000316         B49=(A(4,9)-A(4,1)*B19)                                          BOSS0034
000326         B52=(A(5,2)-A(5,1)*B12)                                          BOSS0035
000335         B53=(A(5,3)-A(5,1)*B13)                                          BOSS0036
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000345      B54=(A(5,4)-A(5,1)*B14)                                   BOSS0037
000354      B55=(A(5,5)-A(5,1)*B15)                                   BOSS0038
000364      B56=(A(5,6)-A(5,1)*B16)                                   BOSS0039
000373      B57=(A(5,7)-A(5,1)*B17)                                   BOSS0040
000403      B58=(A(5,8)-A(5,1)*B18)                                   BOSS0041
000412      B59=(A(5,9)-A(5,1)*B19)                                   BOSS0042
000422      B62=(A(6,2)-A(6,1)*B12)                                   BOSS0043
000431      B63=(A(6,3)-A(6,1)*B13)                                   BOSS0044
000441      B64=(A(6,4)-A(6,1)*B14)                                   BOSS0045
000450      B65=(A(6,5)-A(6,1)*B15)                                   BOSS0046
000460      B66=(A(6,6)-A(6,1)*B16)                                   BOSS0047
000467      B67=(A(6,7)-A(6,1)*B17)                                   BOSS0048
000477      B68=(A(6,8)-A(6,1)*B18)                                   BOSS0049
000506      B69=(A(6,9)-A(6,1)*B19)                                   BOSS0050
000516      B72=(A(7,2)-A(7,1)*B12)                                   BOSS0051
000525      B73=(A(7,3)-A(7,1)*B13)                                   BOSS0052
000535      B74=(A(7,4)-A(7,1)*B14)                                   BOSS0053
000544      B75=(A(7,5)-A(7,1)*B15)                                   BOSS0054
000554      B76=(A(7,6)-A(7,1)*B16)                                   BOSS0055
000563      B77=(A(7,7)-A(7,1)*B17)                                   BOSS0056
000573      B78=(A(7,8)-A(7,1)*B18)                                   BOSS0057
000602      B79=(A(7,9)-A(7,1)*B19)                                   BOSS0058
000612      B82=(A(8,2)-A(8,1)*B12)                                   BOSS0059
000621      B83=(A(8,3)-A(8,1)*B13)                                   BOSS0060
000631      B84=(A(8,4)-A(8,1)*B14)                                   BOSS0061
000640      B85=(A(8,5)-A(8,1)*B15)                                   BOSS0062
000650      B86=(A(8,6)-A(8,1)*B16)                                   BOSS0063
000657      B87=(A(8,7)-A(8,1)*B17)                                   BOSS0064
000667      B88=(A(8,8)-A(8,1)*B18)                                   BOSS0065
000676      B89=(A(8,9)-A(8,1)*B19)                                   BOSS0066
000706      C23=B23/B22                                               BOSS0067
000710      C24=B24/B22                                               BOSS0068
000711      C25=B25/B22                                               BOSS0069
000713      C26=B26/B22                                               BOSS0070
000714      C27=B27/B22                                               BOSS0071
000716      C28=B28/B22                                               BOSS0072
000720      C29=B29/B22                                               BOSS0073
000721      C13=(B13-B12*C23)                                         BOSS0074
000724      C14=(B14-B12*C24)                                         BOSS0075
000727      C15=(B15-B12*C25)                                         BOSS0076
000732      C16=(B16-B12*C26)                                         BOSS0077
000735      C17=(B17-B12*C27)                                         BOSS0078
000740      C18=(B18-B12*C28)                                         BOSS0079
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000743      C19=(B19-B12*C29)                                   BOSS0080
000746      C33=(B33-B32*C23)                                   BOSS0081
000751      C34=(B34-B32*C24)                                   BOSS0082
000754      C35=(B35-B32*C25)                                   BOSS0083
000757      C36=(B36-B32*C26)                                   BOSS0084
000762      C37=(B37-B32*C27)                                   BOSS0085
000765      C38=(B38-B32*C28)                                   BOSS0086
000770      C39=(B39-B32*C29)                                   BOSS0087
000773      C43=(B43-B42*C23)                                   BOSS0088
000776      C44=(B44-B42*C24)                                   BOSS0089
001001      C45=(B45-B42*C25)                                   BOSS0090
001004      C46=(B46-B42*C26)                                   BOSS0091
001007      C47=(B47-B42*C27)                                   BOSS0092
001012      C48=(B48-B42*C28)                                   BOSS0093
001015      C49=(B49-B42*C29)                                   BOSS0094
001020      C53=(B53-B52*C23)                                   BOSS0095
001023      C54=(B54-B52*C24)                                   BOSS0096
001026      C55=(B55-B52*C25)                                   BOSS0097
001031      C56=(B56-B52*C26)                                   BOSS0098
001034      C57=(B57-B52*C27)                                   BOSS0099
001037      C58=(B58-B52*C28)                                   BOSS0100
001042      C59=(B59-B52*C29)                                   BOSS0101
001045      C63=(B63-B62*C23)                                   BOSS0102
001050      C64=(B64-B62*C24)                                   BOSS0103
001053      C65=(B65-B62*C25)                                   BOSS0104
001056      C66=(B66-B62*C26)                                   BOSS0105
001061      C67=(B67-B62*C27)                                   BOSS0106
001064      C68=(B68-B62*C28)                                   BOSS0107
001067      C69=(B69-B62*C29)                                   BOSS0108
001072      C73=(B73-B72*C23)                                   BOSS0109
001075      C74=(B74-B72*C24)                                   BOSS0110
001100      C75=(B75-B72*C25)                                   BOSS0111
001103      C76=(B76-B72*C26)                                   BOSS0112
001106      C77=(B77-B72*C27)                                   BOSS0113
001111      C78=(B78-B72*C28)                                   BOSS0114
001114      C79=(B79-B72*C29)                                   BOSS0115
001117      C83=(B83-B82*C23)                                   BOSS0116
001122      C84=(B84-B82*C24)                                   BOSS0117
001125      C85=(B85-B82*C25)                                   BOSS0118
001130      C86=(B86-B82*C26)                                   BOSS0119
001133      C87=(B87-B82*C27)                                   BOSS0120
001136      C88=(B88-B82*C28)                                   BOSS0121
001141      C89=(B89-B82*C29)                                   BOSS0122
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001144      D34=C34/C33                                    BOSS0123
001146      D35=C35/C33                                    BOSS0124
001150      D36=C36/C33                                    BOSS0125
001151      D37=C37/C33                                    BOSS0126
001153      D38=C38/C33                                    BOSS0127
001154      D39=C39/C33                                    BOSS0128
001156      D14=(C14-C13*D34)                              BOSS0129
001161      D15=(C15-C13*D35)                              BOSS0130
001164      D16=(C16-C13*D36)                              BOSS0131
001167      D17=(C17-C13*D37)                              BOSS0132
001172      D18=(C18-C13*D38)                              BOSS0133
001175      D19=(C19-C13*D39)                              BOSS0134
001200      D24=(C24-C23*D34)                              BOSS0135
001203      D25=(C25-C23*D35)                              BOSS0136
001206      D26=(C26-C23*D36)                              BOSS0137
001211      D27=(C27-C23*D37)                              BOSS0138
001214      D28=(C28-C23*D38)                              BOSS0139
001217      D29=(C29-C23*D39)                              BOSS0140
001222      D44=(C44-C43*D34)                              BOSS0141
001225      D45=(C45-C43*D35)                              BOSS0142
001230      D46=(C46-C43*D36)                              BOSS0143
001233      D47=(C47-C43*D37)                              BOSS0144
001236      D48=(C48-C43*D38)                              BOSS0145
001241      D49=(C49-C43*D39)                              BOSS0146
001244      D54=(C54-C53*D34)                              BOSS0147
001247      D55=(C55-C53*D35)                              BOSS0148
001252      D56=(C56-C53*D36)                              BOSS0149
001255      D57=(C57-C53*D37)                              BOSS0150
001260      D58=(C58-C53*D38)                              BOSS0151
001263      D59=(C59-C53*D39)                              BOSS0152
001266      D64=(C64-C63*D34)                              BOSS0153
001271      D65=(C65-C63*D35)                              BOSS0154
001274      D66=(C66-C63*D36)                              BOSS0155
001277      D67=(C67-C63*D37)                              BOSS0156
001302      D68=(C68-C63*D38)                              BOSS0157
001305      D69=(C69-C63*D39)                              BOSS0158
001310      D74=(C74-C73*D34)                              BOSS0159
001313      D75=(C75-C73*D35)                              BOSS0160
001316      D76=(C76-C73*D36)                              BOSS0161
001321      D77=(C77-C73*D37)                              BOSS0162
001324      D78=(C78-C73*D38)                              BOSS0163
001327      D79=(C79-C73*D39)                              BOSS0164
001332      D84=(C84-C83*D34)                              BOSS0165
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001335      D85=(C85-C83*D35)                          BOSS0166
001340      D86=(C86-C83*D36)                          BOSS0167
001343      D87=(C87-C83*D37)                          BOSS0168
001346      D88=(C88-C83*D38)                          BOSS0169
001351      D89=(C89-C83*D39)                          BOSS0170
001354      E45=D45/D44                                BOSS0171
001356      E46=D46/D44                                BOSS0172
001360      E47=D47/D44                                BOSS0173
001361      E48=D48/D44                                BOSS0174
001363      E49=D49/D44                                BOSS0175
001364      E15=(D15-D14*E45)                          BOSS0176
001367      E16=(D16-D14*E46)                          BOSS0177
001372      E17=(D17-D14*E47)                          BOSS0178
001375      E18=(D18-D14*E48)                          BOSS0179
001400      E19=(D19-D14*E49)                          BOSS0180
001403      E25=(D25-D24*E45)                          BOSS0181
001406      E26=(D26-D24*E46)                          BOSS0182
001411      E27=(D27-D24*E47)                          BOSS0183
001414      E28=(D28-D24*E48)                          BOSS0184
001417      E29=(D29-D24*E49)                          BOSS0185
001422      E35=(D35-D34*E45)                          BOSS0186
001425      E36=(D36-D34*E46)                          BOSS0187
001430      E37=(D37-D34*E47)                          BOSS0188
001433      E38=(D38-D34*E48)                          BOSS0189
001436      E39=(D39-D34*E49)                          BOSS0190
001441      E55=(D55-D54*E45)                          BOSS0191
001444      E56=(D56-D54*E46)                          BOSS0192
001447      E57=(D57-D54*E47)                          BOSS0193
001452      E58=(D58-D54*E48)                          BOSS0194
001455      E59=(D59-D54*E49)                          BOSS0195
001460      E65=(D65-D64*E45)                          BOSS0196
001463      E66=(D66-D64*E46)                          BOSS0197
001466      E67=(D67-D64*E47)                          BOSS0198
001471      E68=(D68-D64*E48)                          BOSS0199
001474      E69=(D69-D64*E49)                          BOSS0200
001477      E75=(D75-D74*E45)                          BOSS0201
001502      E76=(D76-D74*E46)                          BOSS0202
001505      E77=(D77-D74*E47)                          BOSS0203
001510      E78=(D78-D74*E48)                          BOSS0204
001513      E79=(D79-D74*E49)                          BOSS0205
001516      E85=(D85-D84*E45)                          BOSS0206
001521      E86=(D86-D84*E46)                          BOSS0207
001524      E87=(D87-D84*E47)                          BOSS0208
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001527      E88=(D88-D84*E48)                                   BOSS0209
001532      E89=(D89-D84*E49)                                   BOSS0210
001535      F56=E56/E55                                         BOSS0211
001537      F57=E57/E55                                         BOSS0212
001541      F58=E58/E55                                         BOSS0213
001542      F59=E59/E55                                         BOSS0214
001544      F16=(E16-E15*F56)                                   BOSS0215
001547      F17=(E17-E15*F57)                                   BOSS0216
001552      F18=(E18-E15*F58)                                   BOSS0217
001555      F19=(E19-E15*F59)                                   BOSS0218
001560      F26=(E26-E25*F56)                                   BOSS0219
001563      F27=(E27-E25*F57)                                   BOSS0220
001566      F28=(E28-E25*F58)                                   BOSS0221
001571      F29=(E29-E25*F59)                                   BOSS0222
001574      F36=(E36-E35*F56)                                   BOSS0223
001577      F37=(E37-E35*F57)                                   BOSS0224
001602      F38=(E38-E35*F58)                                   BOSS0225
001605      F39=(E39-E35*F59)                                   BOSS0226
001610      F46=(E46-E45*F56)                                   BOSS0227
001613      F47=(E47-E45*F57)                                   BOSS0228
001616      F48=(E48-E45*F58)                                   BOSS0229
001621      F49=(E49-E45*F59)                                   BOSS0230
001624      F66=(E66-E65*F56)                                   BOSS0231
001627      F67=(E67-E65*F57)                                   BOSS0232
001632      F68=(E68-E65*F58)                                   BOSS0233
001635      F69=(E69-E65*F59)                                   BOSS0234
001640      F76=(E76-E75*F56)                                   BOSS0235
001643      F77=(E77-E75*F57)                                   BOSS0236
001646      F78=(E78-E75*F58)                                   BOSS0237
001651      F79=(E79-E75*F59)                                   BOSS0238
001654      F86=(E86-E85*F56)                                   BOSS0239
001657      F87=(E87-E85*F57)                                   BOSS0240
001662      F88=(E88-E85*F58)                                   BOSS0241
001665      F89=(E89-E85*E59/E55)                               BOSS0242
001670      G67=F67/F66                                         BOSS0243
001672      G68=F68/F66                                         BOSS0244
001674      G69=F69/F66                                         BOSS0245
001675      G17=(F17-F16*G67)                                   BOSS0246
001700      G18=(F18-F16*G68)                                   BOSS0247
001703      G19=(F19-F16*G69)                                   BOSS0248
001706      G27=(F27-F26*G67)                                   BOSS0249
001711      G28=(F28-F26*G68)                                   BOSS0250
001714      G29=(F29-F26*G69)                                   BOSS0251
```

```
001717      G37=(F37-F36*G67)                    BOSS0252
001722      G38=(F38-F36*G68)                    BOSS0253
001725      G39=(F39-F36*G69)                    BOSS0254
001727      G47=(F47-F46*G67)                    BOSS0255
001732      G48=(F48-F46*G68)                    BOSS0256
001735      G49=(F49-F46*G69)                    BOSS0257
001740      G57=(F57-F56*G67)                    BOSS0258
001743      G58=(F58-F56*G68)                    BOSS0259
001746      G59=(F59-F56*G69)                    BOSS0260
001750      G77=(F77-F76*G67)                    BOSS0261
001753      G78=(F78-F76*G68)                    BOSS0262
001756      G79=(F79-F76*G69)                    BOSS0263
001761      G87=(F87-F86*G67)                    BOSS0264
001764      G88=(F88-F86*G68)                    BOSS0265
001767      G89=(F89-F86*G69)                    BOSS0266
001771      H78=G78/G77                          BOSS0267
001773      H79=G79/G77                          BOSS0268
001775      H18=(G18-G17*H78)                    BOSS0269
002000      H19=(G19-G17*H79)                    BOSS0270
002003      H28=(G28-G27*H78)                    BOSS0271
002006      H29=(G29-G27*H79)                    BOSS0272
002010      H38=(G38-G37*H78)                    BOSS0273
002013      H39=(G39-G37*H79)                    BOSS0274
002016      H48=(G48-G47*H78)                    BOSS0275
002021      H49=(G49-G47*H79)                    BOSS0276
002023      H58=(G58-G57*H78)                    BOSS0277
002026      H59=(G59-G57*H79)                    BOSS0278
002031      H68=(G68-G67*H78)                    BOSS0279
002034      H69=(G69-G67*H79)                    BOSS0280
002036      H88=(G88-G87*H78)                    BOSS0281
002041      H89=(G89-G87*H79)                    BOSS0282
002044      D89=H89/H88                          BOSS0283
002046      D(1)  =(H19-H18*D89)                 BOSS0284
002051      D(2)  =(H29-H28*D89)                 BOSS0285
002054      D(3)  =(H39-H38*D89)                 BOSS0286
002060      D(4)  =(H49-H48*D89)                 BOSS0287
002063      D(5)  =(H59-H58*D89)                 BOSS0288
002067      D(6)  =(H69-H68*D89)                 BOSS0289
002072      D(7)  =(H79-H78*D89)                 BOSS0290
002076      D(8)  =D89                           BOSS0291
002077      RETURN                               BOSS0292
002077      END                                  BOSS0293
```

```
      C
      C***************************************************************************
      C
000002        RETURN
000003        END
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      SUBROUTINE PLOTS
C
C*********************************************************************
C*                                                                   *
C* PURPOSE                                                           *
C*                                                                   *
C*    SUBROUTINE PLOTS GIVES PLOTS OF THE SOLUTIONS OF THE EQUATIONS *
C*    OF MOTION.I.E.,PLOTS OF THE ANGLES AND ANGULAR VELOCITIES AS A *
C*    FUNCTION OF TIME. PLOTS OF THETA VS PHI ARE ALSO PROVIDED.     *
C*                                                                   *
C* PROPRIETARY                                                       *
C*                                                                   *
C*    NONE                                                           *
C*                                                                   *
C* USE                                                               *
C*                                                                   *
C*    CALL PLOTS                                                     *
C*                                                                   *
C* PARAMETERS                                                        *
C*                                                                   *
C*    NONE .                                                         *
C*                                                                   *
C* AUTHOR/IMPLEMENTOR                                                *
C*                                                                   *
C*    D.R.DORSEY,JR - B.SEAY                                         *
C*                                                                   *
C* DATE RELEASED                                                     *
C*                                                                   *
C*    SEPTEMBER 14,1973                                              *
C*                                                                   *
C* LATEST REVISION                                                   *
C*                                                                   *
C*    SEPTEMBER 14,1973                                              *
C*                                                                   *
C*********************************************************************
C
C     THIS IS A DUMMY SUBROUTINE TO SATISFY THE LOADER.
C     IT HAS BEEN DECIDED THAT THE PLOTTING ROUTINES FOR PROGRAM
C     LACATE CAN BEST BE HANDLED AS POSTPROCESSOR ROUTINES RUN
C     SEPARATELY FROM LACATE. FOR PLOTS OF THE SOLUTIONS OF THE
C     EQUATIONS OF MOTION,REFER TO PROGRAM AVPLOT. FOR THE TWO-
C     DIMENSIONAL THETA-PHI PLOTS,REFER TO PROGRAM TPPLOT.
```

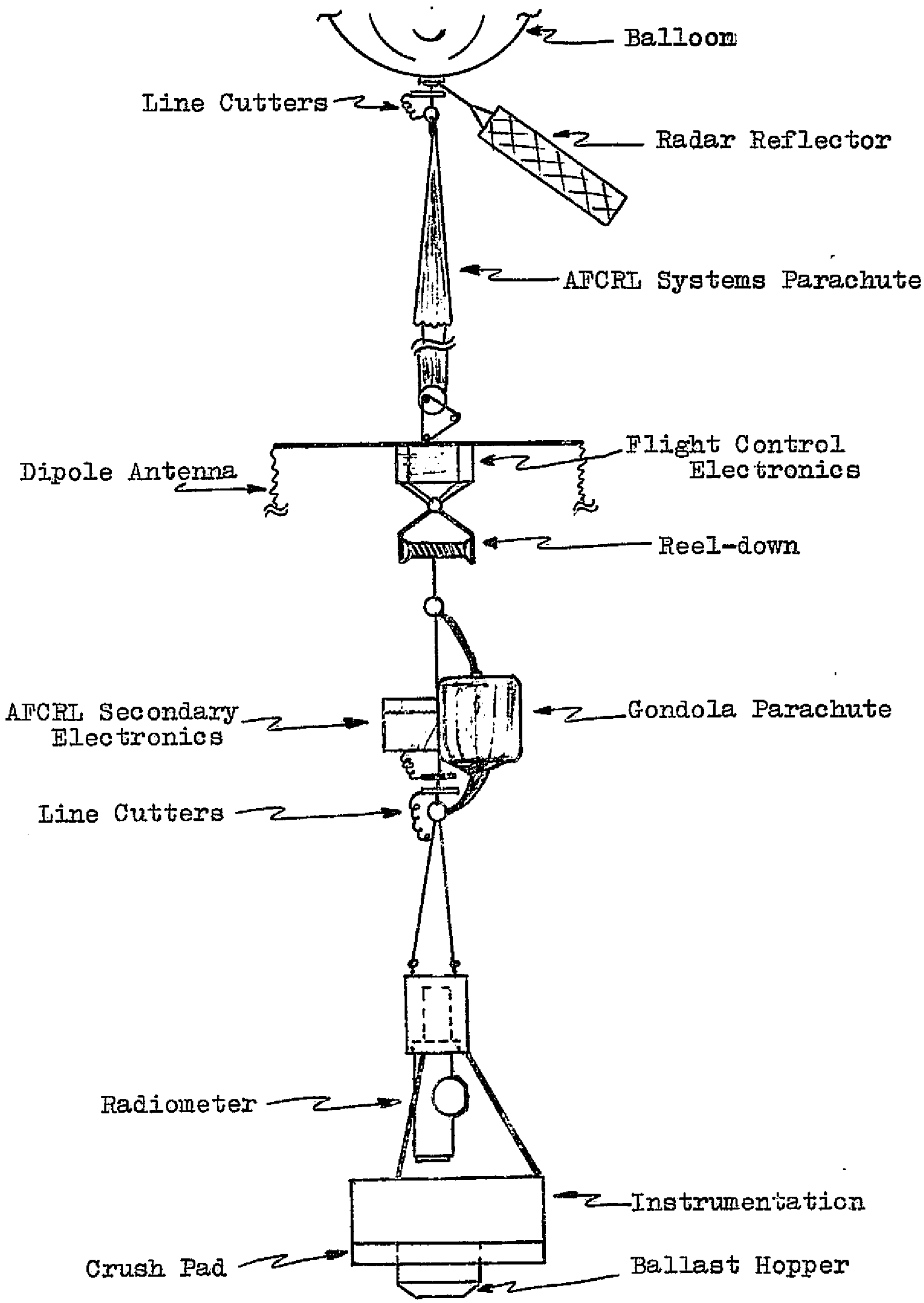

Figure 1a. LACATE Balloon System - General Structure

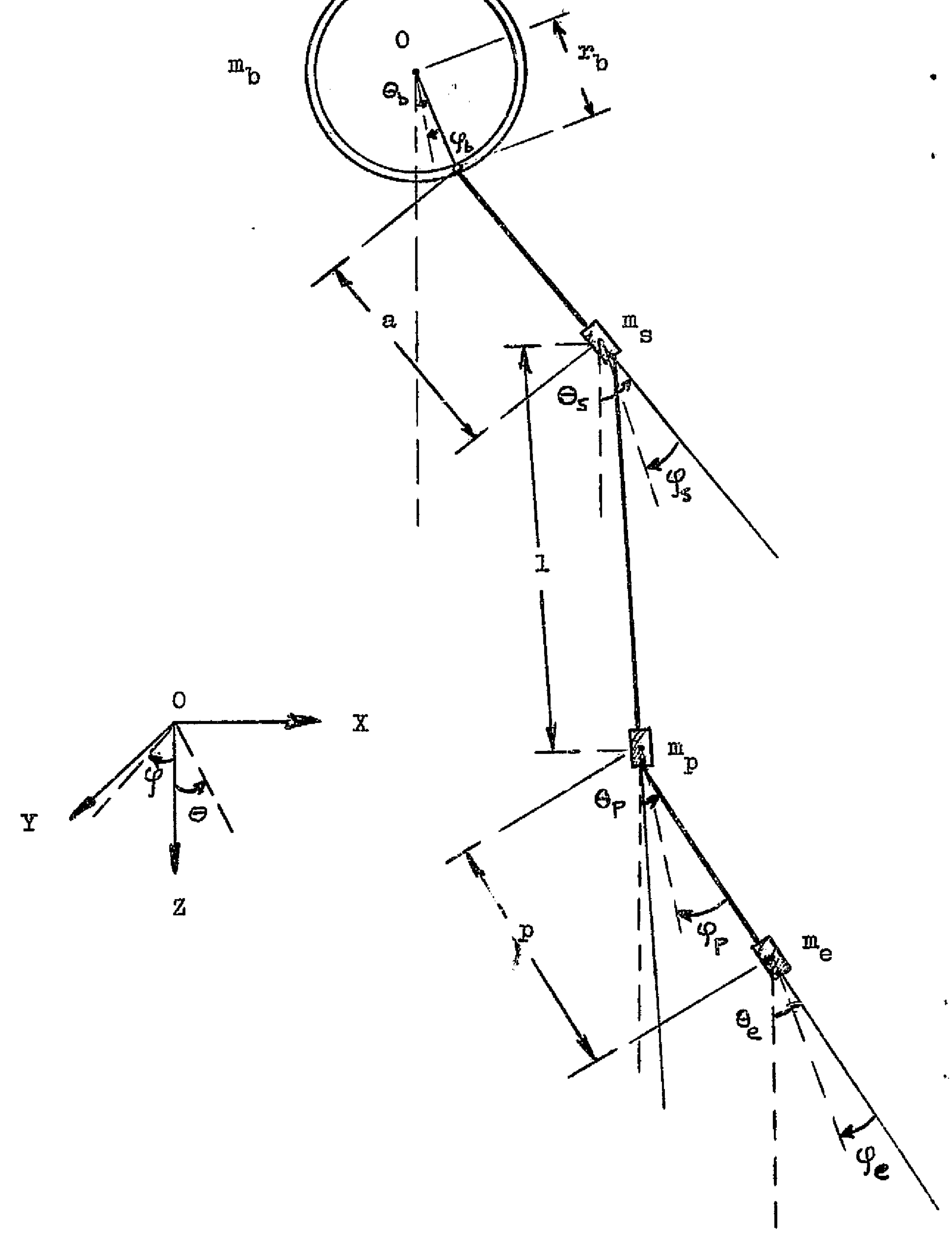

Figure 1b. LACATE Balloon Idealized Model

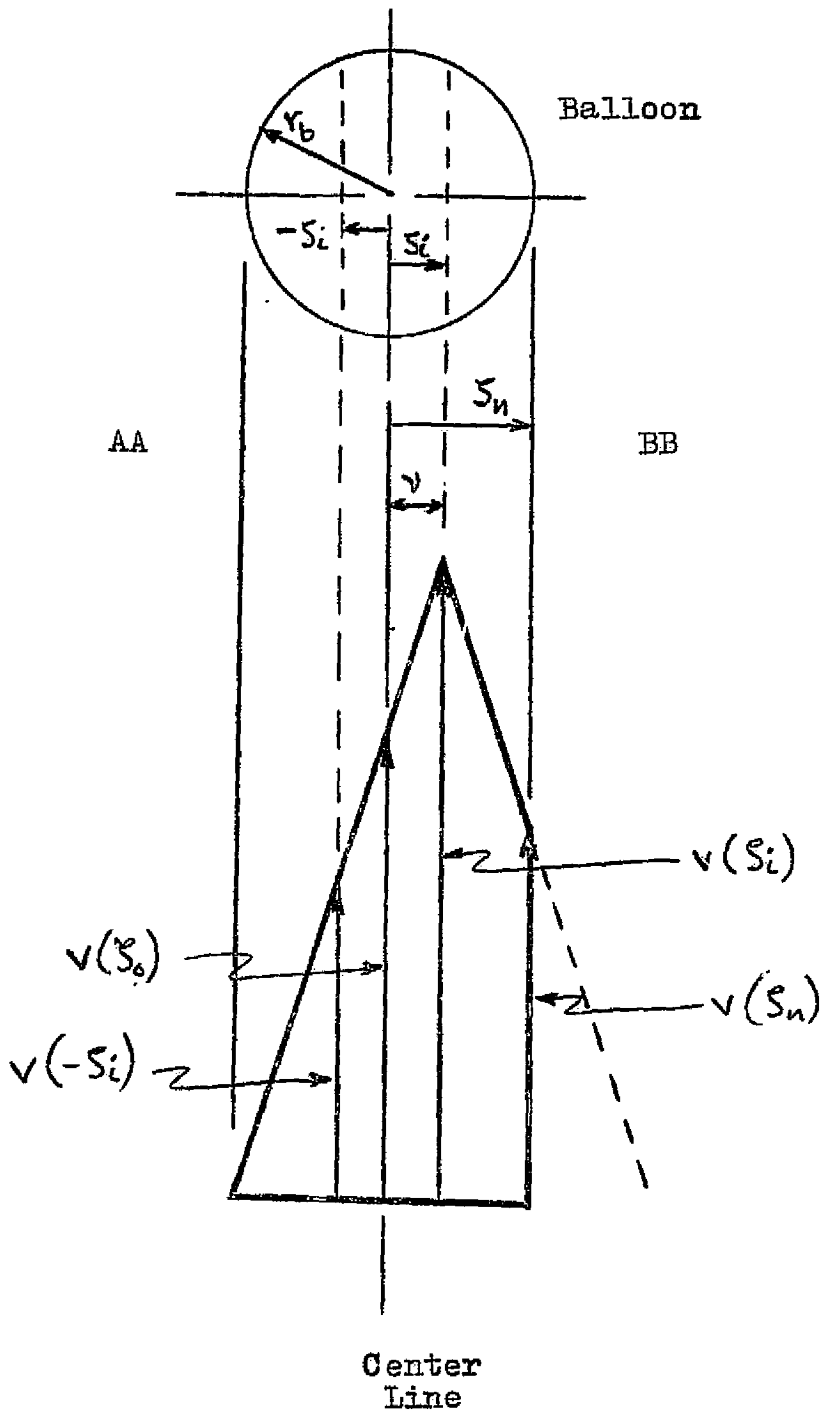

Figure 2. Geometry Definitions For Gust Model

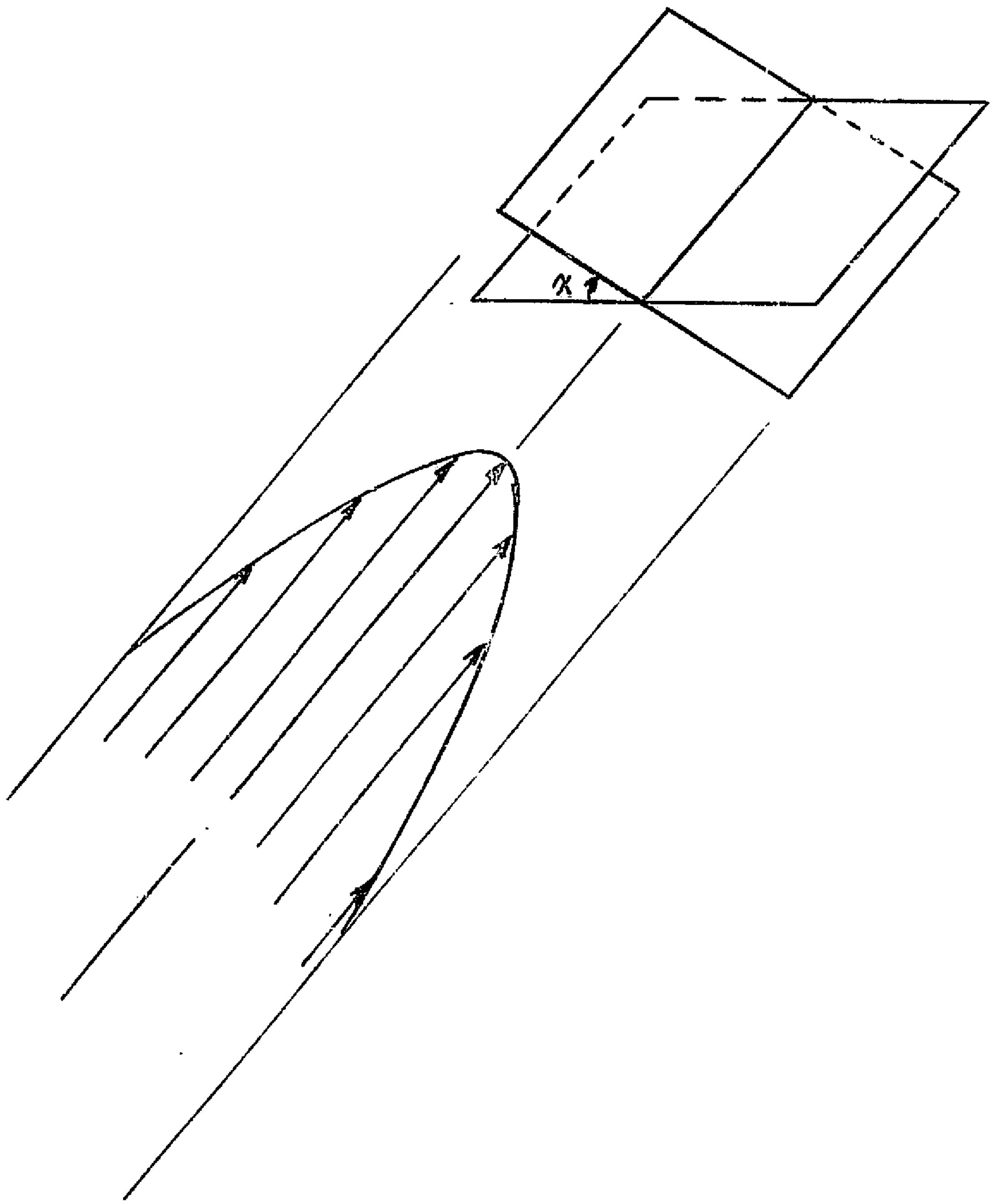

Figure 3. Planar Gust Profile Rotated about Azimuth Plane

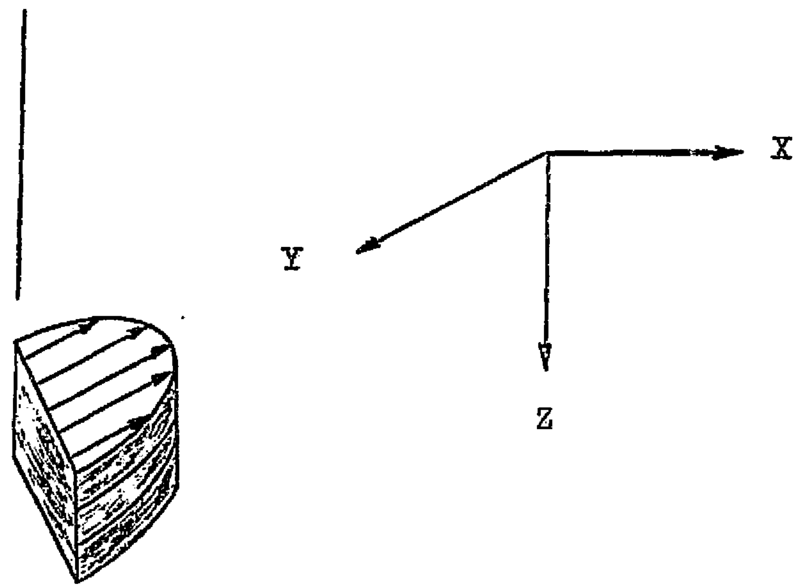

Figure 4. Planar Stacked Gust Profile Parallel to Azimuth Plane

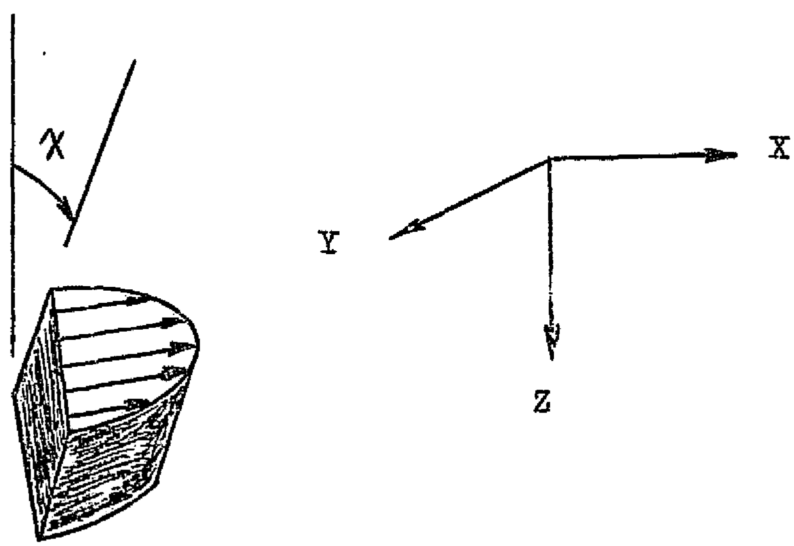

Figure 5. Planar Stacked Gust Profile Rotated about Azimuth Plane

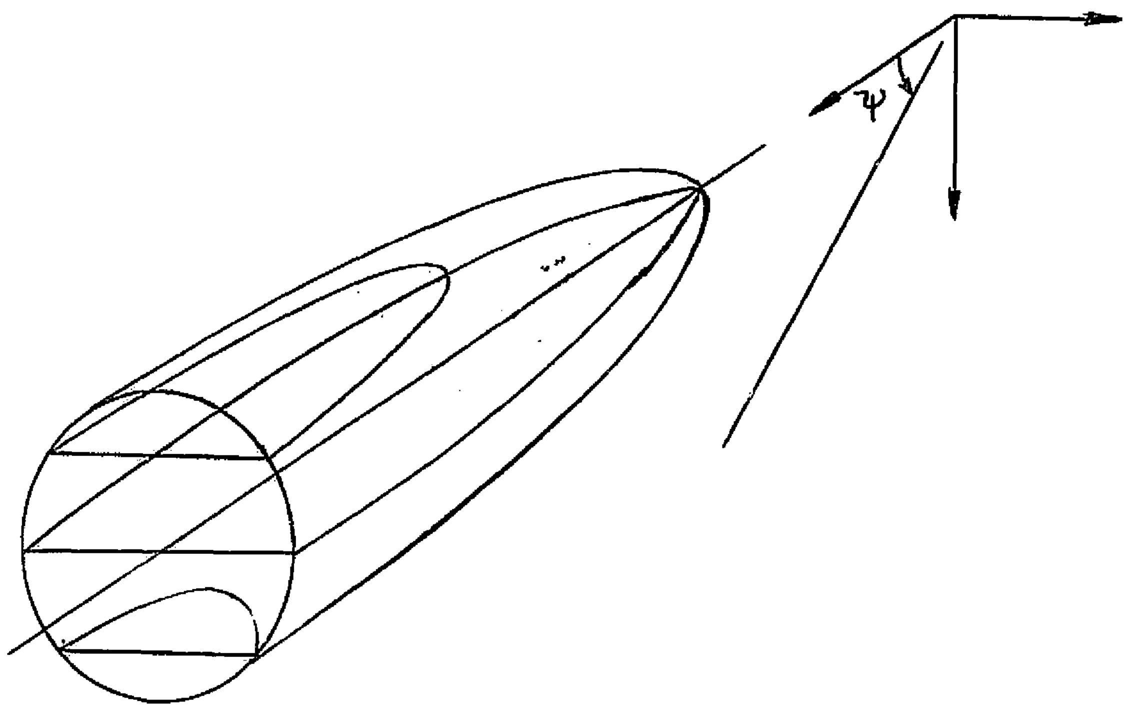

Figure 6. General Three-Dimensional Gust Profile
In Form of a Body of Revolution

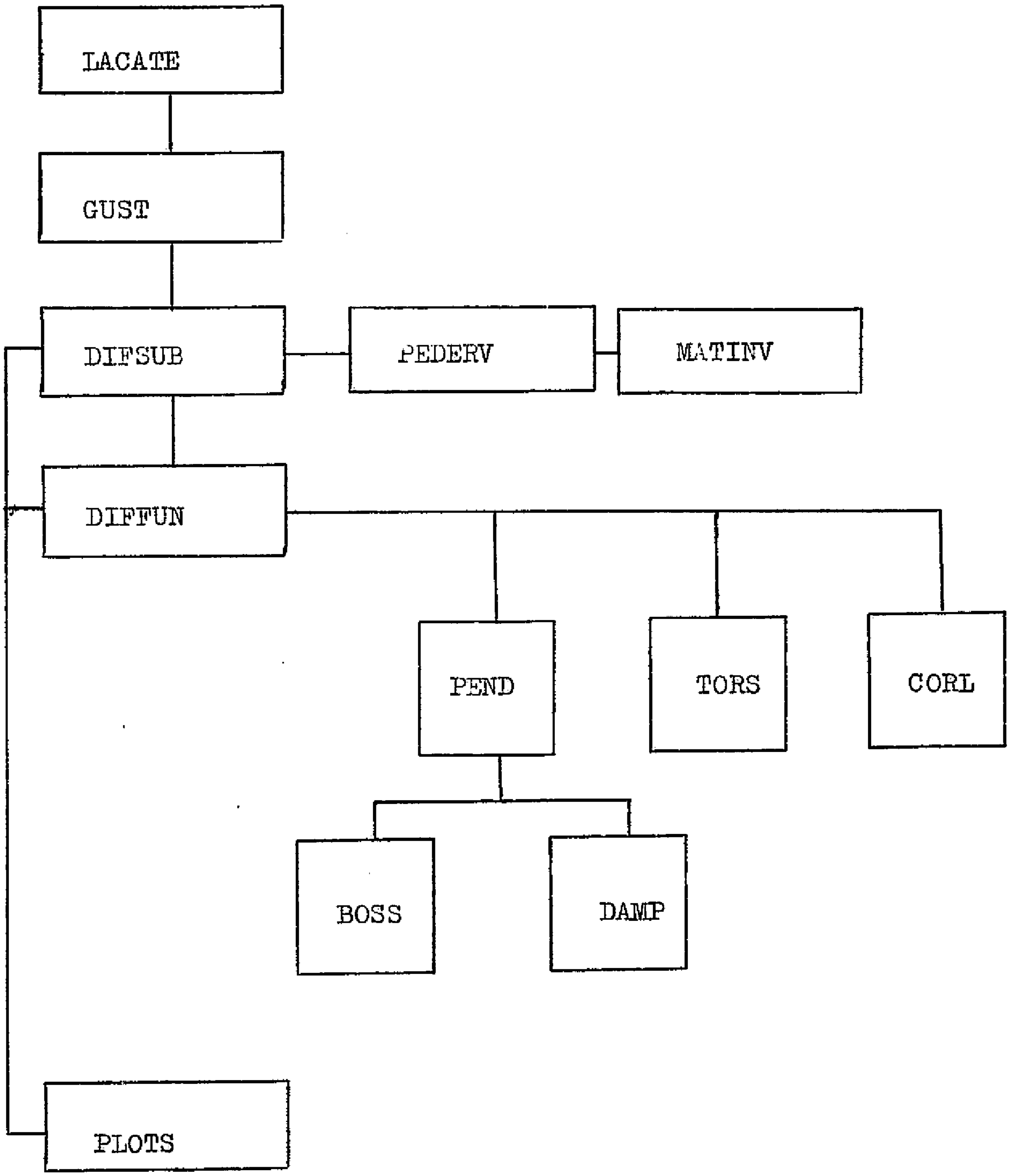

Figure 7. LACATE Program Structure