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INVESTIGATION OF A CLAMSHELL ROLL-OUT EJECTION CONCEPT

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16. Abstract

The equations for the motion, forces, and couples generated by clamshells released from spinning sounding rockets in accordance with a roll-out ejection concept are presented. The application of these equations to a study of a system for the Javelin (i.e., Honest John-Nike-Nike-X248) rocket vehicle is discussed.

The roll-out ejection concept advocated requires that each deploying clamshell be pivoted about an axis at its trailing edge located in the system sectioning plane. Clamshell despinning is a consequence of this deployment since the pivotal, i.e., roll-out, rate is in opposition to the rocket vehicle spin. The energy required by the deployment is derived largely from the rotational energy of the clamshell. Thus, the rocket vehicle will not be significantly despun by this kind of clamshell deployment.

This ejection concept also permits a system design which makes it possible to limit clamshell angular motion to rotation about that one of its centroidal principal axes which is brought into parallelism with the rocket vehicle longitudinal axis. Also, by equalizing the moments of inertia about the other centroidal principal axes, the roll-out motion can be decoupled from any extraneous angular motion about these axes.

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CONTENTS

LIST OF SYMBOLS

A, B, C, D = inertial parameters (slug-ft^2).

$C_{x_1}, C_{x_2}, C_{x_3}$ = hinge-couple components about axes parallel to the x_1-, x_2-, and x_3-axes, respectively (ft-lb).

$C_{y_1}, C_{y_2}, C_{y_3}$ = hinge-couple components about axes parallel to the clamshell body-fixed y_1-, y_2-, and y_3-axes, respectively (ft-lb).

$C\psi, C\theta, C\phi$ = cosines of the Euler angles ψ, θ, and ϕ, respectively.

d_1 = clamshell hinge-axis displacement from the x_1-axis (the rocket vehicle longitudinal axis) (ft).

d_2 = clamshell center of mass (c.m.) displacement from the $x_1 x_2$-plane (the system bisection plane) before clamshell deployment (ft).

d_3 = clamshell c.m. displacement from the system base plane (ft).

d_5 = clamshell c.m. displacement from the hinge axis (ft).

d_6 = clamshell c.m. displacement from the $x_2 x_3$-plane (the rocket vehicle system transverse plane containing its barycenter) (ft).

d_7 = clamshell c.m. displacement from the x_1-axis during deployment (ft).

d_{7f} = terminal value of d_7 (ft).

$F_{x_1}, F_{x_2}, F_{x_3}$ = hinge-force components directed along axes parallel to the x_1-, x_2-, and x_3-axes, respectively (lb).

$F_{y_1}, F_{y_2}, F_{y_3}$ = hinge-force components directed along axes parallel to the clamshell body-fixed y_1-, y_2-, and y_3-axes, respectively (lb).

F_1, F_2, F_3, F_4, F_5 = inertial forces (lb).

$$\left.\begin{aligned} J_{cy_1} &= \int_m (y_2^2 + y_3^2)\, dm \\ J_{cy_2} &= \int_m (y_1^2 + y_3^2)\, dm \end{aligned}\right\}$$ significant elements of the clamshell inertia matrix defined in terms of the clamshell body-fixed y-frame (slug-ft^2).

$$\left.\begin{array}{l} J_{cy_3} = \int_m (y_1^2 + y_2^2)\,dm \\ J_{cy_5} = \int_m y_1 y_3\,dm \end{array}\right\}$$ significant elements of the clamshell inertia matrix defined in terms of the clamshell body-fixed y-frame (slug-ft^2)

J_{vx_1} = rocket vehicle (minus clamshells) spin moment of inertia (moment of inertia about the x_1-axis) (slug-ft^2).

$J_{z_1}, J_{z_2}, J_{z_3}$ = clamshell moments of inertia about the z_1-, z_2-, and z_3-axes, respectively (slug-ft^2).

K = direction cosine matrix.

$M_{y_1}, M_{y_2}, M_{y_3}$ = moments about the clamshell body-fixed y_1-, y_2-, and y_3-axes, respectively (ft-lb).

$M_{z_1}, M_{z_2}, M_{z_3}$ = moments about the clamshell body-fixed z_1-, z_2-, and z_3-axes, respectively (ft-lb).

m = clamshell mass (slugs).

$\mathbf{p}$ = position vector from the origin of the x-frame to the clamshell c.m. (ft).

R_1 = component of the position vector from an inertial frame origin to the x-frame origin directed along the rocket vehicle body-fixed x_1-axis (ft).

$S\psi, S\theta, S\phi$ = sines of the Euler angles ψ, θ, and ϕ, respectively.

t = elapsed time (s).

t_f = time at the end of the clamshell deployment phase and the beginning of the free-flight phase (s).

U, V = momental parameters (ft-lb).

W_1, W_2, W_3 = clamshell free-flight rotational rate components about the z_1-, z_2-, and z_3-axes, respectively (s^{-1}).

$\{X_j\}$ = displacement vector for the jth point on the clamshell defined in terms of the X-frame (ft).

$\{X_{cm}\}$ = clamshell c.m. displacement vector defined in terms of the inertial X-frame (ft).

$\{z_j\}$ = displacement vector for the jth point on the clamshell defined in terms of the x-frame (the clamshell centroidal principal axis frame) (ft).

α = angle between the $x_1 x_2$-plane and the plane defined by the x_1-axis and the position vector $\mathbf{p}$.

β = angle in the clamshell mass-symmetry plane between the clamshell body-fixed y-frame and the clamshell centroidal principal axis set.

γ = clamshell roll-out angle (the angle between the x_1x_2-plane and the y_1y_2-plane).

η = angle between the x_1x_2-plane and the plane containing both the clamshell hinge axis and clamshell c.m.

η_0 = initial value of η.

$\alpha_f, \gamma_f, \eta_f$ = terminal values of α, γ, and η, respectively.

ψ, θ, ϕ = Euler angles (see Figure 6).

Ω_1 = rocket vehicle spin (rotational rate of the x-frame) (s^{-1}).

Ω_{1f} = terminal value of Ω_1 (s^{-1}).

Ω_{10} = initial value of Ω_1 (s^{-1}).

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INTRODUCTION

In this report, a roll-out ejection concept for the release of clamshells from spinning sounding rockets is developed and discussed. The primary aim is to establish the desirability of this particular concept for use with sounding rockets. It will be seen that the conditions under which the clamshells are ejected impose requirements not considered in other applications. These requirements affect chiefly the manner in which the clamshells are to be ejected.

At the present time, there are two general categories of ejectable payload-protection devices. The conceptually older and structurally simpler of these devices is the one piece nose cone. A nose cone is essentially a shell of revolution with its aft end faired and attached to the top stage of the rocket vehicle. The cone is tapered to a closed fore end. The payload is situated in the space bounded by the nose cone and the rocket vehicle. The nose cone is impelled at its ejection by springs or other means in the direction in which the rocket vehicle is pointed. Obviously, this is not attempted while the rocket vehicle is thrusting–it must occur under coasting conditions. If the rocket vehicle has a control system, it may be maneuvered so that the ejected nose cone does not present a collision hazard during a subsequent thrust phase. Unfortunately, sounding rockets do not now have this maneuvering capability. Hence, the nose cone cannot be ejected safely until the sounding rocket is in its final coast phase and at an altitude where post ejection collision is not likely to occur. Thus, the performance of a sounding rocket can be impaired by its acceleration of excess mass. In the case of the Javelin (i.e., Honest John-Nike-Nike-X248) rocket vehicle, nose cone ejection is timed to occur 120 seconds after liftoff, when the vehicle is at an altitude of about 700,000 feet. At this point in the flight, any residual X248 thrust and the drag deceleration difference between the ejected nose cone and rocket vehicle are considered to be negligible. It will be seen that this particular nose cone ejection is set for a time which occurs significantly later than is possible with clamshells. It can be seen also that, in general, nose cone ejection is troublesome when the payload is long and impossible when the payload compartment is bulbous. Guides or bumpers running the length of the payload and ejection actuators with long strokes are required in the former instance to avoid nose cone hang up. The nose cone can still be a source of trouble after it has cleared the rocket vehicle. It effectively continues to precede the payload in the trajectory and may affect instrument readings by emitting particles and disturbing the environment in other ways.

Clamshell systems are like nose cones, largely in overall shape. Each clamshell may be considered to be a longitudinal section of a shell of revolution. The clamshells are held together by bands, clamps, and the like, or they are attached to skin sections which can be ruptured at ejection time. On ejection, each clamshell is projected away from the longitudinal axis of the rocket vehicle; that is, its movement characteristically has a component which soon carries the clamshell out of the path of the payload. Therefore, the ejected clamshells do not continue to be collision hazards after they have cleared the rocket vehicle and payload. Thus, the time at which clamshell ejection is set to occur may be made meaningful in that it is not necessary to wait until the drag has dropped practically to zero before ejection. In fact, a slight amount of drag will help to increase the longitudinal separation between the payload and ejected clamshells. Obviously, the application of rocket vehicle thrust can produce even greater separation.

Ejection can occur for the Javelin when it is at an altitude of about 300,000 feet. At this point in its flight, it is about halfway into its X248 thrust phase. Perturbations due to X248 ignition and separation have been damped out, and the dynamic pressure has dropped to negligibly low values despite the considerable increase in vehicle velocity. The shape of the dynamic pressure profile for the Javelin is exemplified by the curve in Figure 1. The X248 thrust phase occurs between the tick marks located at 56 and 97.9 s. In addition to permitting the recording of scientific data at lower altitudes than it was possible previously, clamshell ejection even at this point in the final boost phase will have a significant effect on the performance of the Javelin. Because about two thirds of the vehicle velocity at final burnout is due to the X248 thrust phase, the release of clamshells earlier in the flight can improve the vehicle's performance (see Figure 2).

Unfortunately, the conditions under which sounding rocket clamshells must operate have not been sufficiently considered in a number of designs. This situation may be partly due to the established success in the release of clamshells from nonspinning rocket vehicles, in which clamshells are disengaged and simply pitched out. It should be noted that in this case, the angular motion of each clamshell is restricted to rotation about that one of its centroidal principal axes normal to its mass symmetry plane. Hence, the motion of the clamshells during and after their deployment remains uncoupled and simple. This is not the case with clamshells pitched out from a spinning rocket vehicle. Instead, such an action causes each ejecting clamshell to rotate about all of its centroidal principal axes. The resulting complication greatly increases the extraneous tendencies of these clamshells and makes it difficult to design optimal constraints to control the clamshell motion during the deployment phase of ejection.

The extraneous tendencies should be reduced, if not eliminated, by essentially limiting clamshell angular motion to rotation about a single principal axis. This requires that each clamshell be rolled out since it is rolling to begin with. This can be done by pivoting it about an axis through either its leading or trailing edge in the clamshell system sectioning planes. Extraneous rotational tendencies may yet be induced in the clamshell by reaction to constraints utilized to develop the desired rolling motion. Thus, care must still be exercised in the design of roll-out clamshell ejection mechanisms.

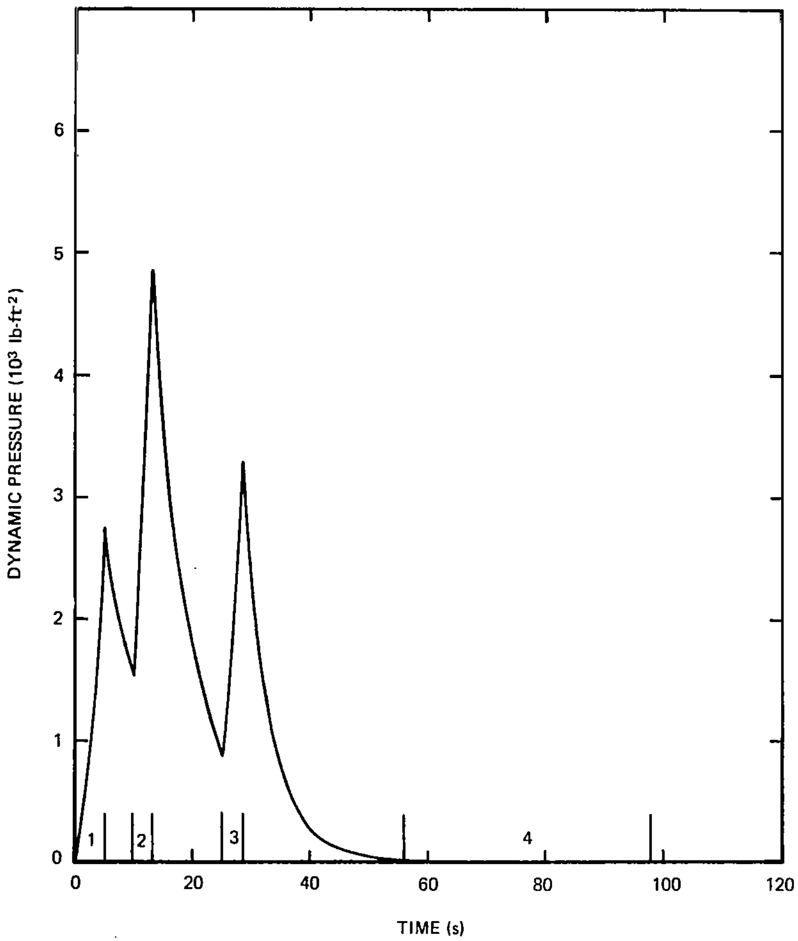

Figure 1—Dynamic pressure profile for a Javelin launched at 80° QE (quadrant elevation angle) and carrying a 120-lb gross payload.

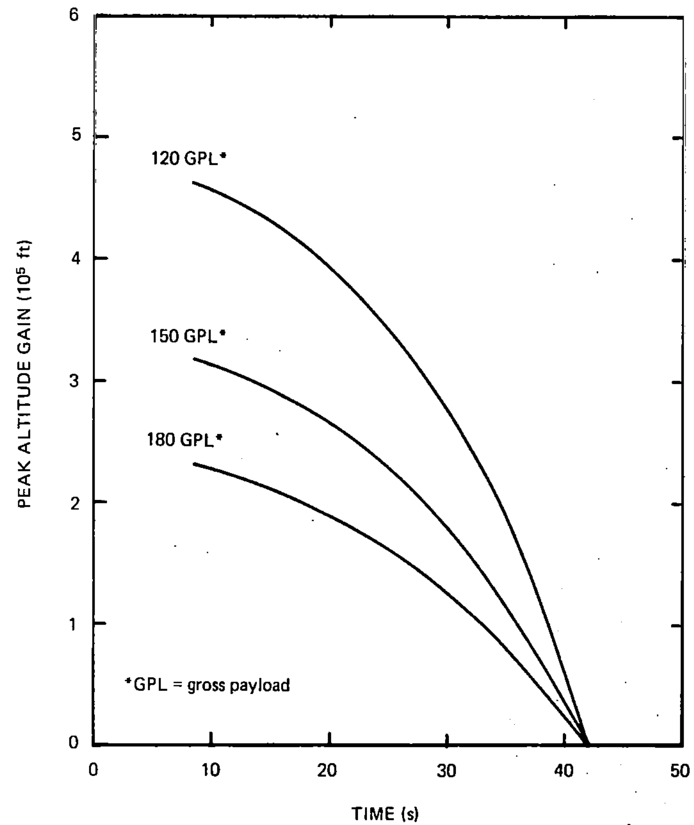

Figure 2—Effect of clamshell release time relative to X248 ignition on Javelin flight performance.

The angular momentum of a roll-out clamshell pivoted about its leading edge is increased on its deployment. This is caused by the displacement of its center of mass (c.m.) from the rocket vehicle longitudinal axis and the increase in its angular rate, which is a summation of its roll-out rate and the vehicular spin. The rocket vehicle will be despun by such clamshell deployment unless means are adopted to preclude it. This can be a troublesome endeavor since it tends to complicate the system design and increase its weight.

A clamshell pivoted about its trailing edge, on the other hand, is despun on its deployment since its pivotal, i.e., roll-out, rate is in opposition to the rocket vehicle spin. Thus, the energy for clamshell deployment can be expected to come initially from the rotational energy of the clamshell. The rocket vehicle will experience a measure of despinning after the clamshell has pivoted to a given roll-out angle. This will definitely be the case when the clamshell is totally despun, i.e., when the magnitude of the clamshell roll-out rate equals that of the rocket vehicle spin. The clamshell may be disengaged at this point in its deployment to give its free-flight motion a purely translatory character. However, in an actual flight, it may be preferable to release the clamshell earlier, i.e., at a smaller roll-out angle to reduce the extraneous torquing of the rocket vehicle during clamshell ejection. The selection of an optimum release angle is not obvious, particularly when too small an angle can result in a collision between the clamshells and the payload (this is the case with release at zero roll-out angle, i.e., instantaneous clamshell release). The effects of various system parameters must be investigated before any determination can be made with respect to this aspect or any other aspect of this problem.

ANALYTICAL ASSUMPTIONS

The following analysis is concerned with the equations for the motion, forces, and couples generated by clamshells released from spinning sounding rockets in accordance with a roll-out ejection concept. This concept requires that each ejecting clamshell be pivoted about an axis at its trailing edge in the system bisection plane so that its pivotal, i.e., roll-out, rate is in opposition to the rocket vehicle spin. Figure 3 illustrates the ejection sequence scheme viewed head-on to a rocket vehicle with a right-hand spin.

In order to facilitate resolution of the problem, it is assumed that there is a problem symmetry which permits the characterization of the system dynamics by those of a single clamshell. Thus, the

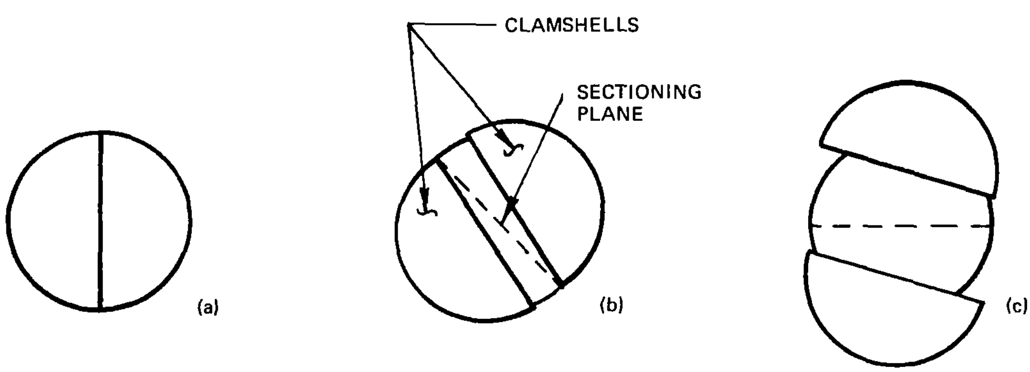

Figure 3—Trailing edge pivot type of roll-out clamshell system with right-hand vehicle spin.

clamshells are assumed to be dynamically matched, rigid bodies attached to a spinning rocket which is not coning in a significant manner when clamshell ejection is initiated. For convenience, it is assumed also that the damping and dissipative forces are negligible in comparison to the inertial forces.

Three coordinate frames are used in the analysis of the deployment phase dynamics. One of these is the x-frame, which is centered at the vehicle system barycenter and orientated so that its x_1-axis is coincident with the rocket vehicle longitudinal axis and its x_2-axis is directed in such a way that the clamshell system bisection plane is in the $x_1 x_2$-plane. The x-frame may be assumed to be a rocket vehicle body-fixed frame since the barycenter may be considered to be stationary during the time required by clamshell deployment. The clamshell body-fixed y-frame is centered at the clamshell c.m. and orientated so that its y_1-, y_2-, and y_3-axes parallel the x_1-, x_2-, and x_3-axes, respectively, of the x-frame before clamshell ejection. The clamshell is constrained during its deployment to maintain the parallelism between the x_1 and y_1 axes. The z-frame is the clamshell centroidal principal axis set. It is oriented so that its z_2-axis is normal to the clamshell mass symmetry plane and coincident with the y_2-axis of the y-frame. The clamshell may be affixed with weights to rotate the z_1- and z_3-axes and bring them into alignment with the y_1- and y_3-axes, respectively, without changing the relationship between the z_2- and y_2-axes. When this is done, the z-frame and y-frame are identical. Figure 4 illustrates the spatial relationship between the x-, y-, and z-frames.

EQUATIONS FOR THE SYSTEM ANGULAR MOTION

The equations for the angular motions of the system, derived by an application of Lagrange's equation, may be written in a form suitable for digital computer solution as follows:

$$\dot{\Omega}_1 = \frac{DU - BV}{AD - BC}$$

and

$$\ddot{\eta} = \frac{AV - CU}{AD - BC},$$

where

$$A = J_{vx_1} + 2(J_{cy_1} + md_5^2),$$

$$B = -2(J_{cy_1} + md_5^2) + 2md_5 d_1 \cos\eta,$$

$$C = B,$$

$$D = 2(J_{cy_1} + md_5^2),$$

$$U = -2(2m\Omega_1 \dot{\eta} d_5 - m\dot{\eta}^2 d_5) d_1 \sin\eta,$$

$$V = 2m\Omega_1^2 d_5 d_1 \sin\eta,$$

and

$$AD - BC = 2J_{vx_1}(J_{cy_1} + md_5^2) + 4md_1^2[J_{cy_1} + md_5^2(1 - \cos^2\eta)] \neq 0.$$

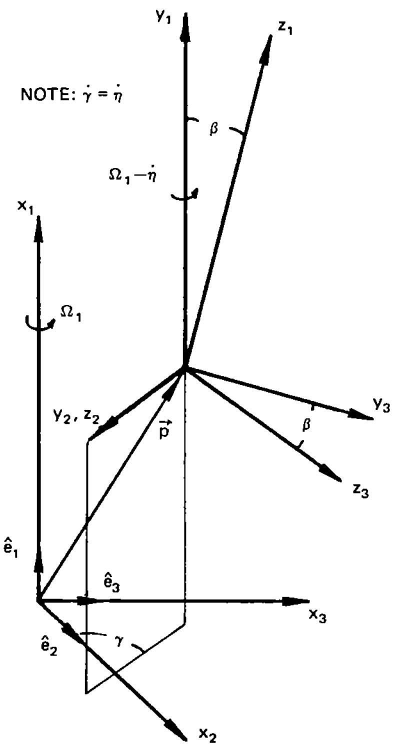

Figure 4—Coordinate frames.

EQUATIONS FOR THE HINGE FORCES

The hinge-force components are obtained by the application of Newton's Second Law to the acceleration of the clamshell c.m. This yields

$$F_{x_1} = m\ddot{R}_1 \ ,$$

$$F_{x_2} = F_1 \sin\eta + (F_2 - F_3)\cos\eta - F_4 \sin\alpha - F_5 \cos\alpha \ ,$$

and

$$F_{x_3} = F_1 \cos\eta - (F_2 - F_3)\sin\eta + F_4 \cos\alpha - F_5 \sin\alpha \ ,$$

where

$$F_1 = m\ddot{\eta} d_5 \ ,$$

$$F_2 = m\dot{\eta}^2 d_5 \ ,$$

$$F_3 = 2m\Omega_1 \dot{\eta} d_5 \ ,$$

$$F_4 = m\dot{\Omega}_1 d_7 \ ,$$

and

$$F_5 = m\Omega_1^2 d_7 \ .$$

EQUATIONS FOR THE HINGE COUPLES

From Figures 4 and 5, it can be shown that

$$C_{x_1} = C_{y_1} \ ,$$

$$C_{x_2} = C_{y_2} \cos\gamma + C_{y_3} \sin\gamma \ ,$$

$$C_{x_3} = C_{y_3} \cos\gamma - C_{y_2} \sin\gamma \ ,$$

$$F_{y_1} = F_{x_1} \ ,$$

$$F_{y_2} = F_{x_2} \cos\gamma - F_{x_3} \sin\gamma \ ,$$

and

$$F_{y_3} = F_{x_3} \cos\gamma + F_{x_2} \sin\gamma \ ,$$

where

$$C_{y_1} = M_{y_1} - F_{y_2} d_2 - F_{y_3} d_1 \ ,$$

$$C_{y_2} = M_{y_2} + F_{y_1} d_2 - F_{y_3} d_3 \ ,$$

$$C_{y_3} = M_{y_3} + F_{y_1} d_1 + F_{y_2} d_3 \ ,$$

$$M_{y_1} = M_{z_1} \cos\beta - M_{z_3} \sin\beta \ ,$$

$$M_{y_2} = M_{z_2} \ ,$$

and

$$M_{y_3} = M_{z_3} \cos\beta + M_{z_1} \sin\beta \ .$$

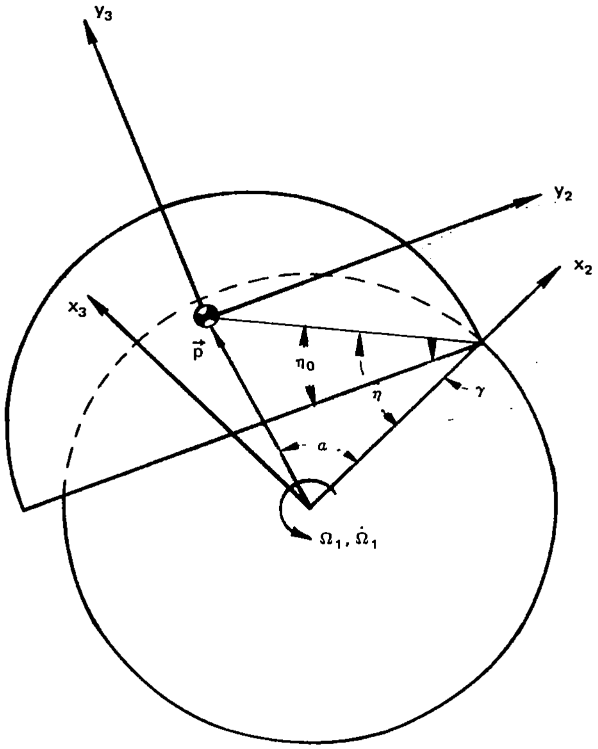

Figure 5—Deployment phase of ejection showing one ejecting clamshell.

Solution of the preceding equations requires the application of Euler's equation of motion to the problem; thus,

$$M_{z_1} = J_{z_1}(\dot{\Omega}_1 - \ddot{\eta}) \cos\beta ,$$

$$M_{z_2} = (J_{z_3} - J_{z_1})(\Omega_1 - \dot{\eta})^2 \cos\beta \sin\beta ,$$

and

$$M_{z_3} = - J_{z_3}(\dot{\Omega}_1 - \ddot{\eta}) \sin\beta ,$$

where

$$J_{z_1} = J_{cy_1} \cos^2\beta + J_{cy_3} \sin^2\beta - 2J_{cy_5} \cos\beta \sin\beta ,$$

$$J_{z_2} = J_{cy_2} ,$$

and

$$J_{z_3} = J_{cy_1} \sin^2\beta + J_{cy_3} \cos^2\beta + 2J_{cy_5} \cos\beta \sin\beta .$$

EQUATIONS FOR FREE FLIGHT

The free-flight displacements of the jth point on the clamshell may be expressed in terms of the X-frame, an inertial frame which is orientated so that its X_1-, X_2-, and X_3-axes parallel the x_1-, x_2-, and x_3-axes of the x-frame at the instant of clamshell disengagement. This inertial frame translates at the rate established by the rocket vehicle at this time; thus,

$$\{X_j\} = K\{z_j\} + \{X_{\text{c.m.}}\} ,$$

where

$$K = \begin{bmatrix} C\theta\, C\phi & -S\theta & C\theta\, S\phi \\ C\psi\, S\theta\, C\phi + S\psi\, S\phi & C\psi\, C\theta & C\psi\, S\theta\, S\phi - S\psi\, C\phi \\ S\psi\, S\theta\, C\phi - C\psi\, S\phi & S\psi\, C\theta & S\psi\, S\theta\, S\phi + C\psi\, C\phi \end{bmatrix}$$

and

$$\{X_{\text{c.m.}}\} = (t - t_f)\begin{Bmatrix} 0 \\ \dot{\eta}_f d_5 \sin\eta_f - \Omega_{1f} d_{7f} \sin\alpha_f \\ \dot{\eta}_f d_5 \cos\eta_f + \Omega_{1f} d_{7f} \cos\alpha_f \end{Bmatrix} + \begin{Bmatrix} d_6 \\ d_{7f} \cos\alpha_f \\ d_{7f} \sin\alpha_f \end{Bmatrix} .$$

The square K-matrix is a direction cosine matrix based on the Euler angle system shown in Figure 6. This angular system is a variant of a system used widely by aeronautical engineers. It is utilized to

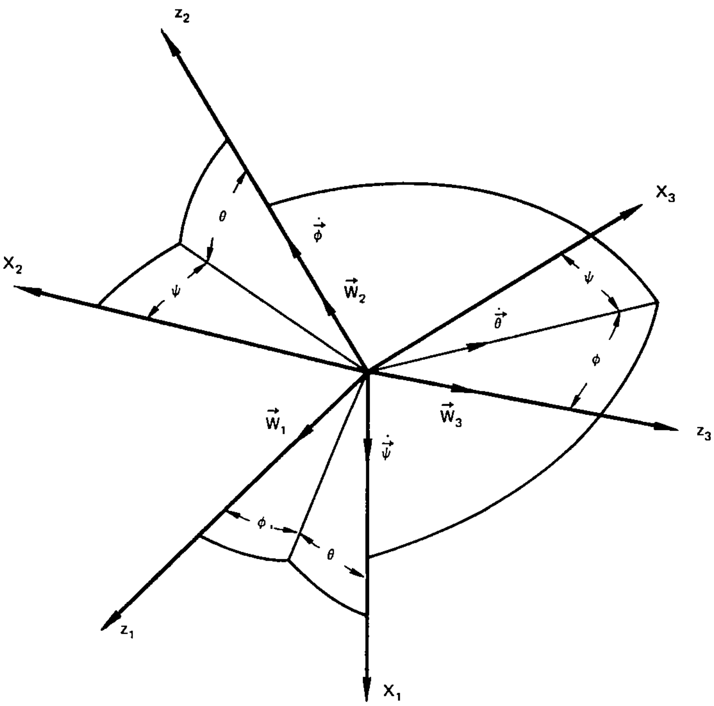

Figure 6—Euler angles and free flight coordinate systems.

simplify the determination of the initial Euler angles. From the construction in Figure 6, it can be shown that

$$\dot\psi = \frac{W_3 \sin\phi + W_1 \cos\phi}{\cos\theta},$$

$$\dot\theta = W_3 \cos\phi - W_1 \sin\phi ,$$

$$\dot\phi = W_2 + \dot\psi \sin\theta ,$$

$$\psi = \int^t \dot\psi\, dt - \gamma_f ,$$

$$\theta = \int^t \dot\theta\, dt ,$$

and

$$\phi = \int^t \dot\phi\, dt - \beta .$$

The z-frame components of the clamshell rotational rate may be obtained from Euler's equations of motion for the free flight; thus,

$$\dot{W}_1 = \frac{W_2 W_3 (J_{z_2} - J_{z_3})}{J_{z_1}} ,$$

$$\dot{W}_2 = \frac{W_3 W_1 (J_{z_3} - J_{z_1})}{J_{z_2}} ,$$

$$\dot{W}_3 = \frac{W_1 W_2 (J_{z_1} - J_{z_2})}{J_{z_3}} ,$$

$$W_1 = \int^t \dot{W}_1 \, dt + (\Omega_{1f} - \dot{\eta}_f) \cos\beta ,$$

$$W_2 = \int^t \dot{W}_2 \, dt ,$$

and

$$W_3 = \int^t \dot{W}_3 \, dt - (\Omega_{1f} - \dot{\eta}_f) \sin\beta .$$

DISCUSSION

Figures 7 through 25 illustrate the results of a study of a roll-out clamshell system for the Javelin rocket vehicle. The digital computer program and a data deck utilized in this study are listed in Appendix A. Nominal system data, if the use of unaligned clamshells for which the β-angle is not zero is assumed, are estimated to be as follows:

$$J_{vx_1} = 7.5 \text{ slug-ft}^2 ,$$

$$m = 0.4 \text{ slug} ,$$

$$J_{cy_1} = 0.1178 \text{ slug-ft}^2 ,$$

$$J_{cy_2} = 0.3466 \text{ slug-ft}^2 ,$$

$$J_{cy_3} = 0.4200 \text{ slug-ft}^2 ,$$

$$J_{cy_5} = 0.03219 \text{ slug-ft}^2 ,$$

$$d_1 = 0.8042 \text{ ft}^2 ,$$

$$d_2 = 0.4286 \text{ ft}^2 ,$$

$$d_3 = 1.456 \text{ ft}^2 ,$$

$$\Omega_{10} = 9.5 \text{ rev/s} ,$$

and

$$\ddot{R}_1 = 515 \text{ ft-s}^{-2} .$$

When the study is applied to aligned clamshells, i.e., clamshells wherein the β-angle has been zeroed, the applicable clamshell parameters are changed as follows:

$$m = 0.4592 \text{ slug} ,$$

$$J_{cy_1} = 0.1656 \text{ slug-ft}^2 ,$$

$$J_{cy_2} = 0.4654 \text{ slug-ft}^2 ,$$

$$J_{cy_3} = 0.5676 \text{ slug-ft}^2 ,$$

$$J_{cy_5} = 0.0 \text{ slug-ft}^2 ,$$

$$d_2 = 0.3733 \text{ ft} ,$$

and

$$d_3 = 1.268 \text{ ft} .$$

These changes reflect the effects of alignment brought about by the attachment of two weights to each clamshell in a manner which results in minimum clamshell mass increase.

The system motion and the hinge forces and couples generated by clamshell deployment are shown in Figures 7 through 10. There appears to be no significant difference between systems using unaligned and aligned clamshells according to these figures.

It should be noted that the rocket vehicle is subject to slight spin-up followed by negligible despinning as the clamshells deploy. The individual and the total effects are of the order of a percent of the initial vehicular spin over the range of roll-out angles considered. No violation of angular momentum conservation is represented by the rocket vehicle spin-up because each clamshell is being despun as it rolls out. The vehicular spin-up signifies that the energy taken from the rotation of the clamshells is more than sufficient for their deployment. The excess energy is not large, so the spin-up is not significant. This observation applies also to the energy deficit which results in the rocket vehicle despinning at the larger roll-out angles. Thus, no special rocket vehicle despin avoidance devices are needed for the clamshell system simulated.

Reversing the rocket vehicle spin permitted a comparative study of a roll-out system with pivot axis at the clamshell leading edge. As expected, such a system subjects the rocket vehicle to greater despinning and generates hinge forces and couples of considerably larger magnitudes than the system with trailing edge pivot. These effects, illustrated in Figures 11 and 12, are attributed to the fact that the clamshells are spun up as they roll out. It will be seen that this spin-up also raises the minimum roll-out angle at which the clamshells can be safely disengaged. Thus, a roll-out system with pivot axis located at the clamshell trailing edge is preferable to a system with pivot axis at the leading edge.

It may be inferred from Figures 8 and 10 that the hinge couples are more significant to the system designer than the hinge forces. Thus, Figures 13 through 16 are included to illustrate the effects of rocket vehicle spin and longitudinal acceleration on C_{x_2} and C_{x_3}, the hinge couples which oppose the clamshell pitching and yawing tendencies, respectively. As expected, the rocket vehicle spin at the higher levels investigated produces a decidely bad effect on C_{x_2} and C_{x_3}. On the other hand, the rocket vehicle longitudinal acceleration tends to reduce the maximum magnitude of C_{x_3} by shifting its time trace upward. No such beneficial effect is incurred for C_{x_2} despite a similar upward shifting of its time trace. Whatever the case may be, the magnitudes of C_{x_2} and C_{x_3} indicate that serious consideration should be given to reducing the rocket vehicle spin to about a half of that presently utilized. Use of a lower rocket vehicle spin can improve the X248 motor performance in addition to moderating the design requirements of the clamshell system.

The X_2X_3 projections of the near free-flight displacements of clamshells released at roll-out angles of 12.5, 15, 30, and 60 deg are shown in Figures 17 through 23. Except in Figure 19, these projections are for aligned clamshells. Since the X_1X_2 and X_1X_3 projections for these clamshells are straight lines, and therefore of little interest, they are not presented. Figure 19 shows that the near free-flight displacements of an unaligned clamshell under the conditions considered is not markedly different from that of an aligned clamshell. It is possible that conditions beyond the scope of this study could produce effects requiring further investigation.

Figures 17 and 20 show that roll-out clamshells can be released too soon. In each case, the clamshell rotational magnitude is too high for release at the roll-out angle shown. Obviously, clamshell release can take place safely at a lower roll-out angle with the trailing edge pivot type of system because the clamshells are subject to despinning and the offending parts are displaced farther away from the payload when disengagement occurs. The rotation of each clamshell will be near zero, and its free-flight motion thereby will be almost purely translatory when the clamshell is released at a roll-out angle of 60 deg. This effect occurs near 60 deg for the system under consideration at the various vehicle spin rates shown in Figure 24. Indeed, the angular motion of the system can be characterized by the reduced forms contained in Figure 25. This figure shows that the relationship between Ω_1 and $\dot{\eta}$ is constant for any given roll-out angle. The locus of points in X-space through which a given part of the clamshell passes is fixed therefore by the γ-angle at which disengagement occurs. The vehicular spin merely affects the rate at which such a given set of points in X-space is traversed. Thus, clamshells which can be released safely at 15 deg when vehicular spin is 9.5 rev/s can also be released safely at this angle at any other positive vehicular spin if the system can bear the loads imposed upon it. That is, clamshell release for the system under consideration can be programmed for roll-out angles between 15 and 60 deg. Choice of the lower angles will be influenced by the desire to reduce unbalanced torquing of the rocket vehicle during clamshell deployment. This torquing may arise from vehicular coning motion, clamshell mismatch, and the "yo-effect" caused by nonsimultaneous release of clamshells. On the other hand, release at a higher roll-out angle is desirable because it results in the ejection of clamshells with reduced rotational motion and lowered likelihood of collision with the payload.

The system angular motions are not affected by the rocket vehicle longitudinal acceleration. The system characteristics discussed in the preceding paragraph will therefore be independent of deviations in rocket vehicle thrust. Since the various acceleration levels are normally associated with different system mass properties, it was expected that the curves in the figures discussed would reflect this fact. This mass effect, however, tends to be a minor one since it involves the interchange of a relatively small amount of energy between the rocket vehicle and the deploying clamshells.

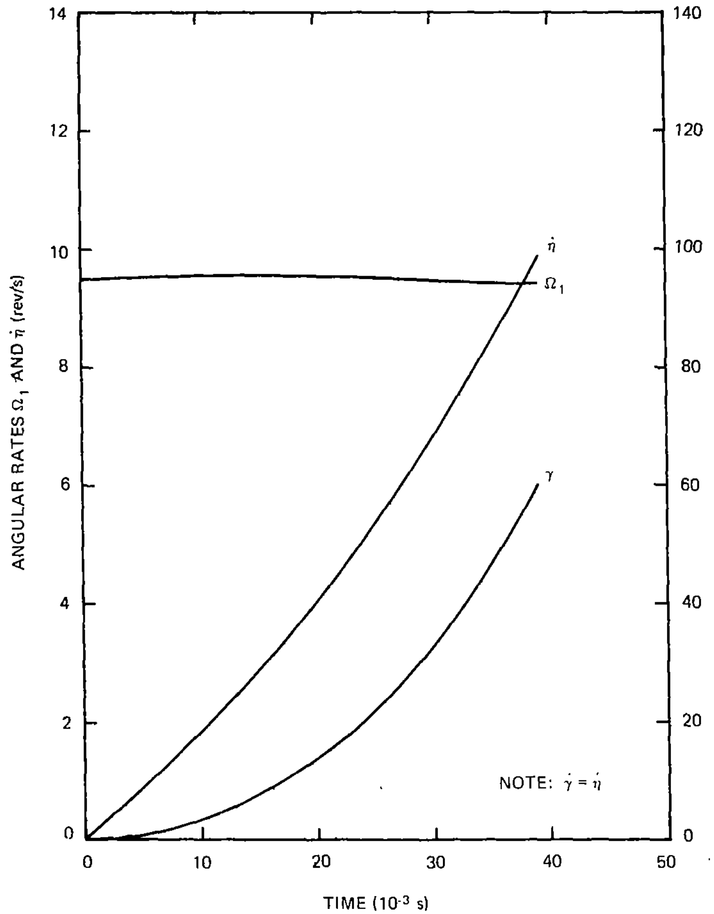

Figure 7—System motion with unaligned clamshells.

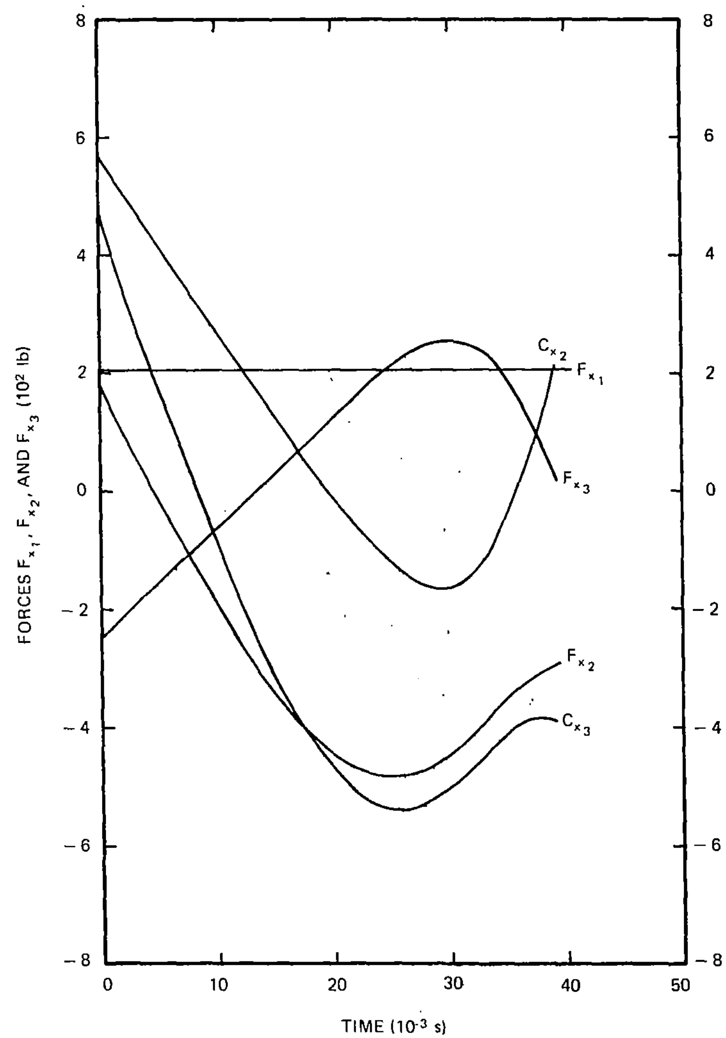

Figure 8—Forces and couples with unaligned clamshells.

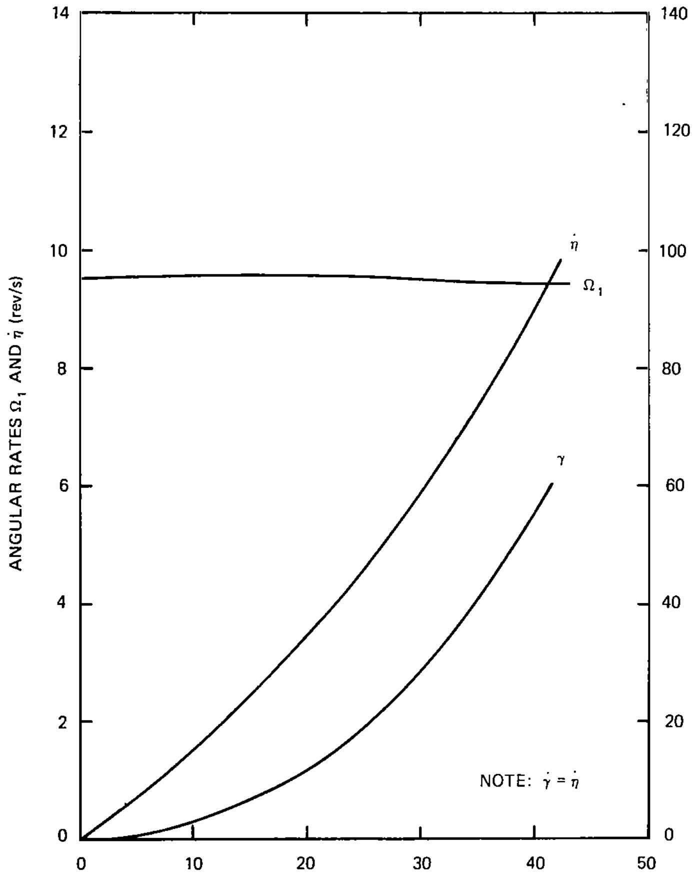

Figure 9—System motion with aligned clamshells.

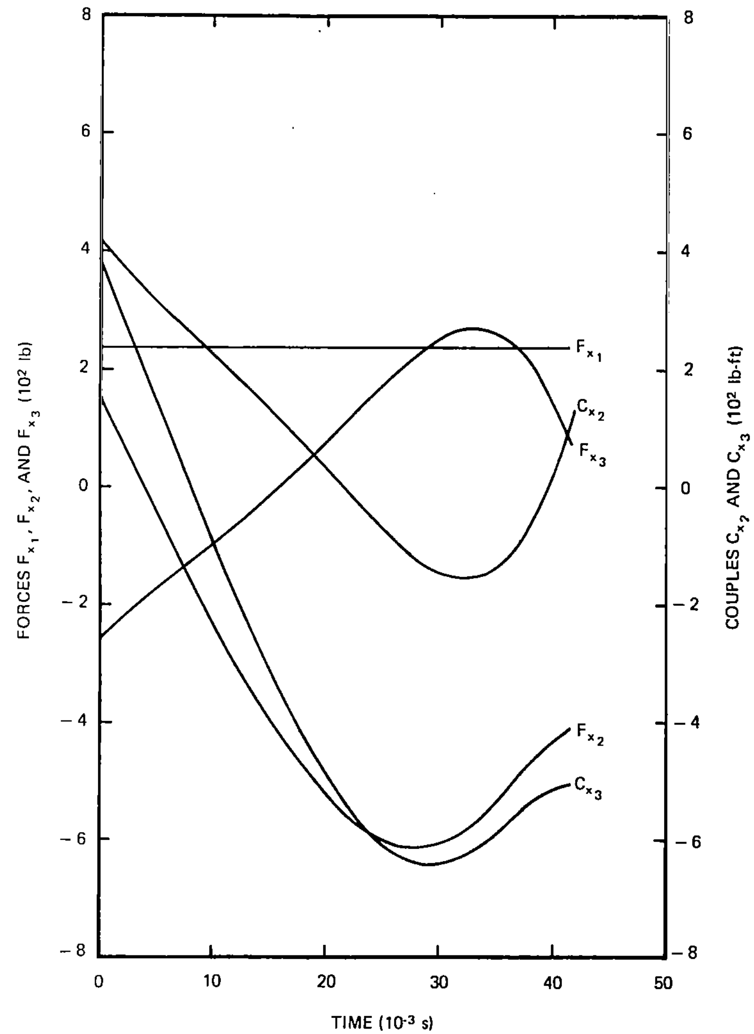

Figure 10—Forces and couples with aligned clamshells.

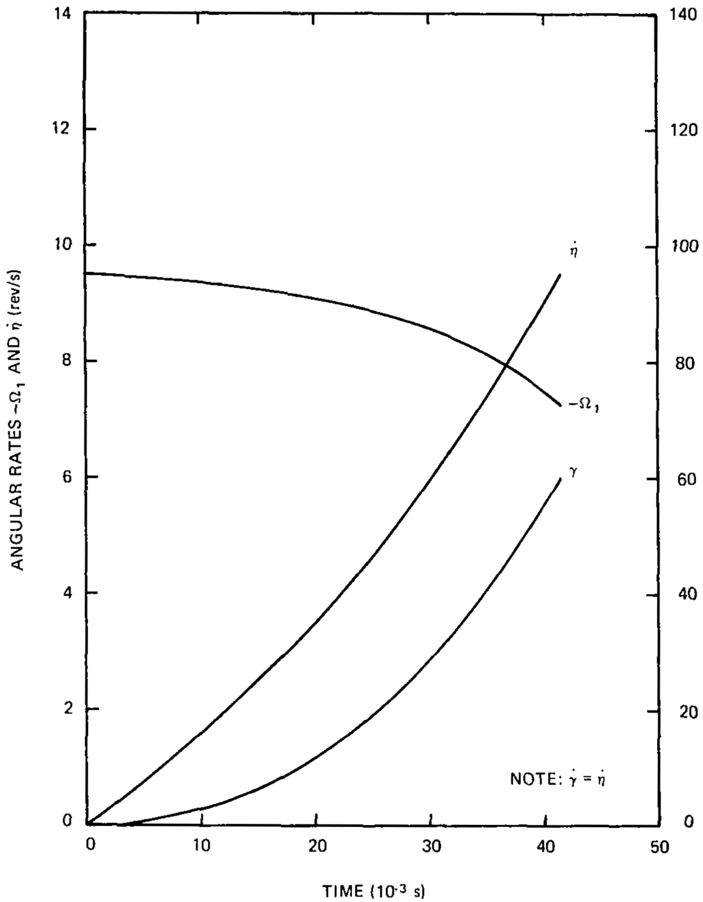

Figure 11—Effect of rocket-vehicle spin reversal on the system motion.

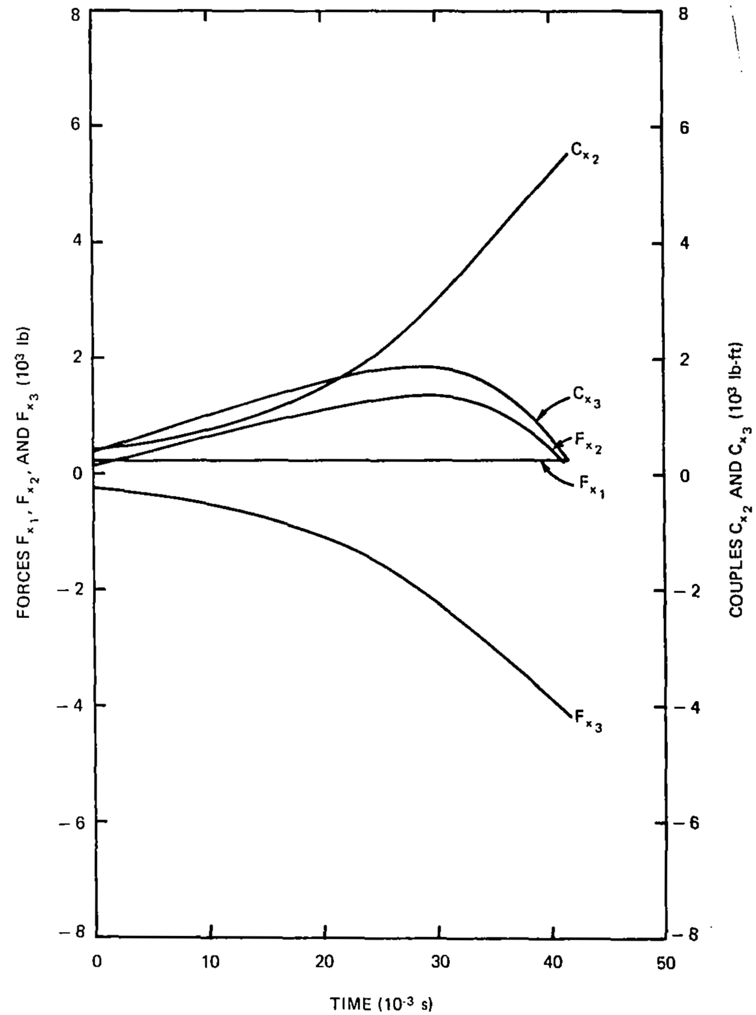

Figure 12—Effect of rocket-vehicle spin reversal on the hinge forces and couples.

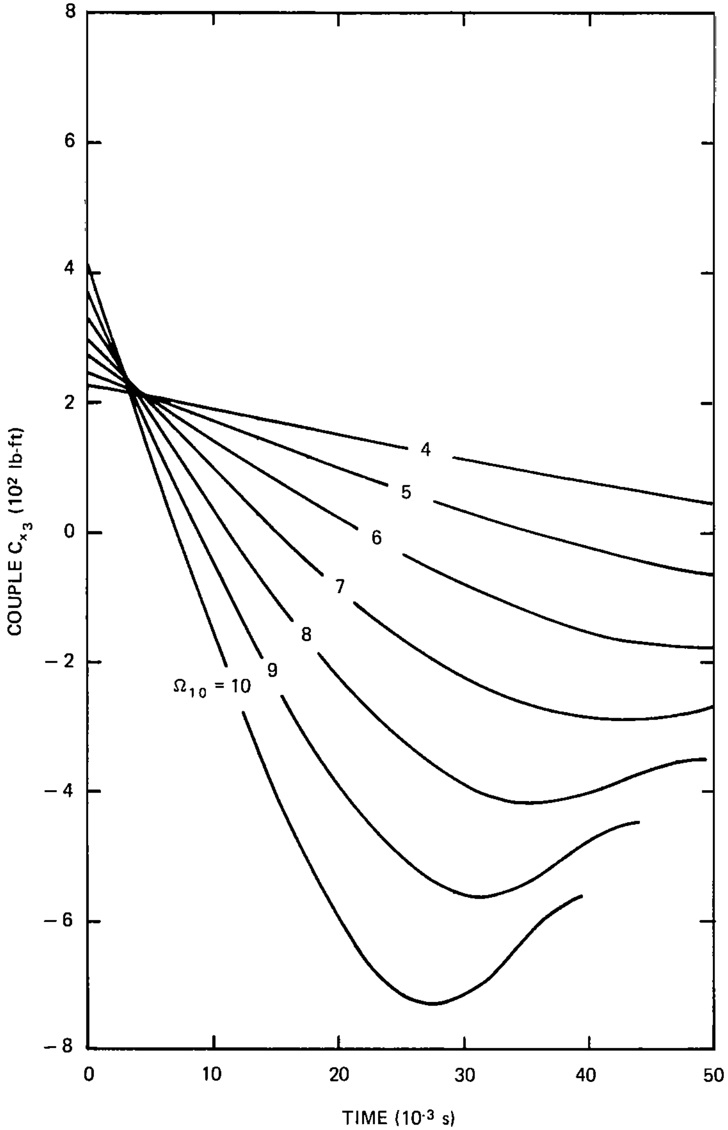

Figure 13—Effect of rocket-vehicle spin on C_{x3}.

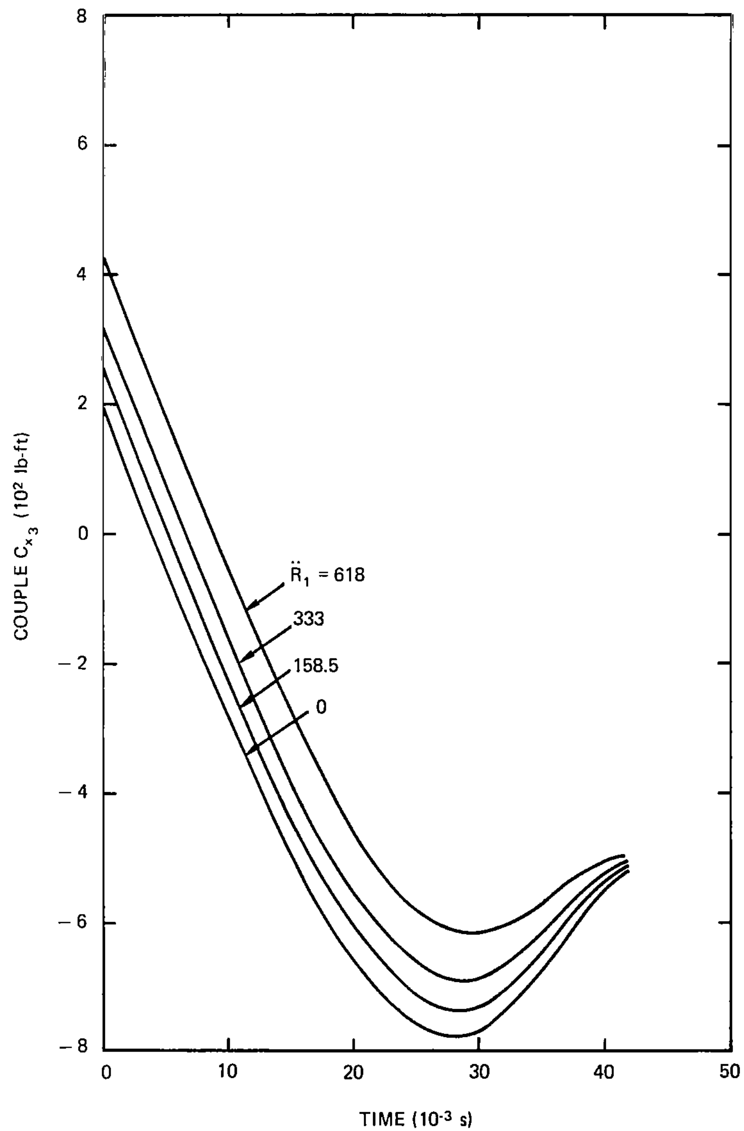

Figure 14—Effect of rocket-vehicle acceleration on C_{x3}.

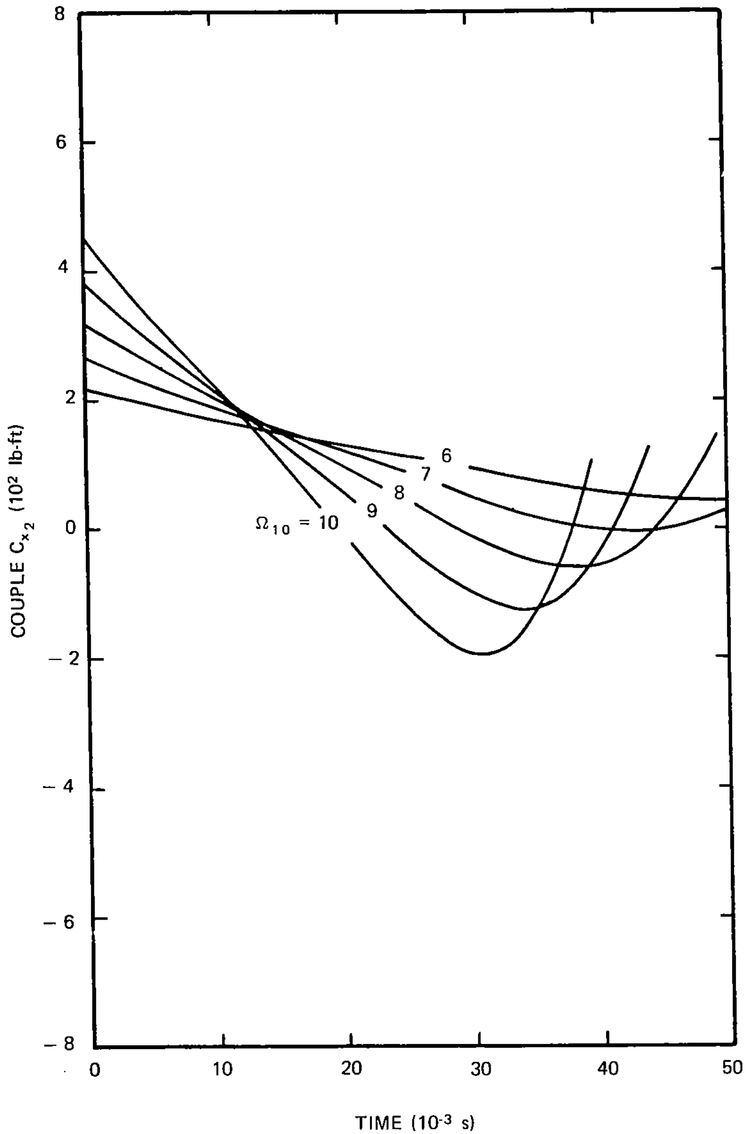

Figure 15—Effect of rocket-vehicle spin on C_{x_2}.

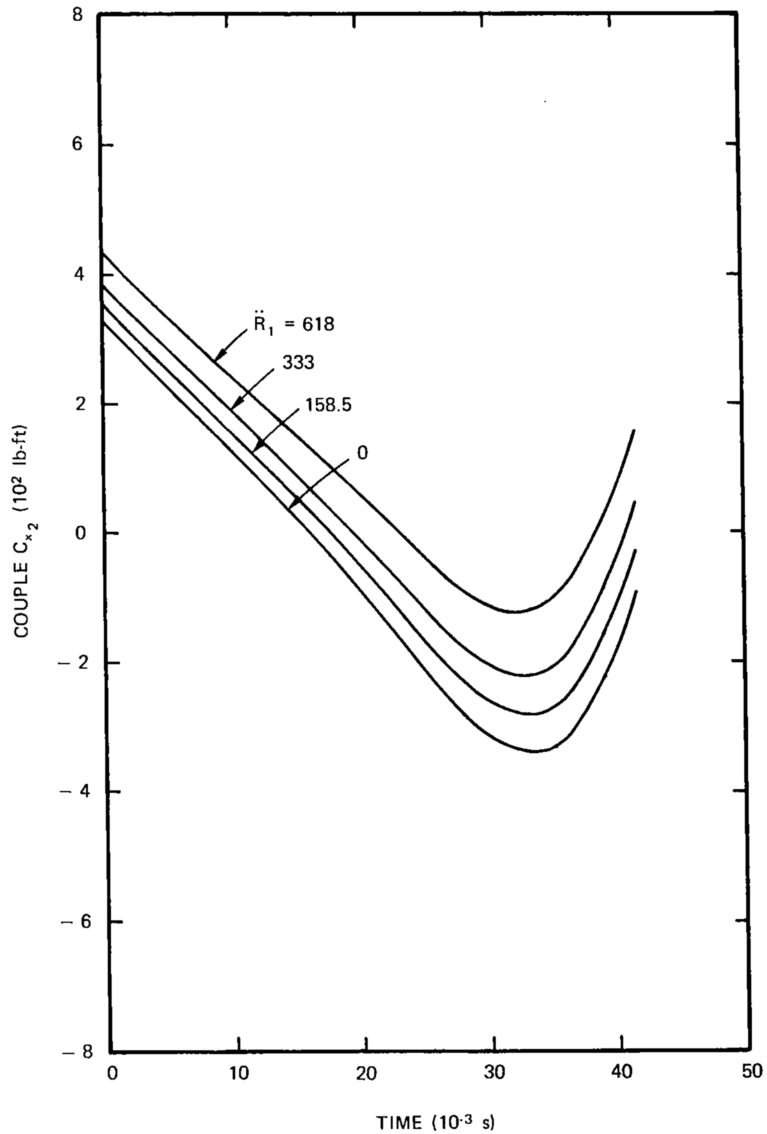

Figure 16—Effect of rocket-vehicle acceleration on C_{x_2}.

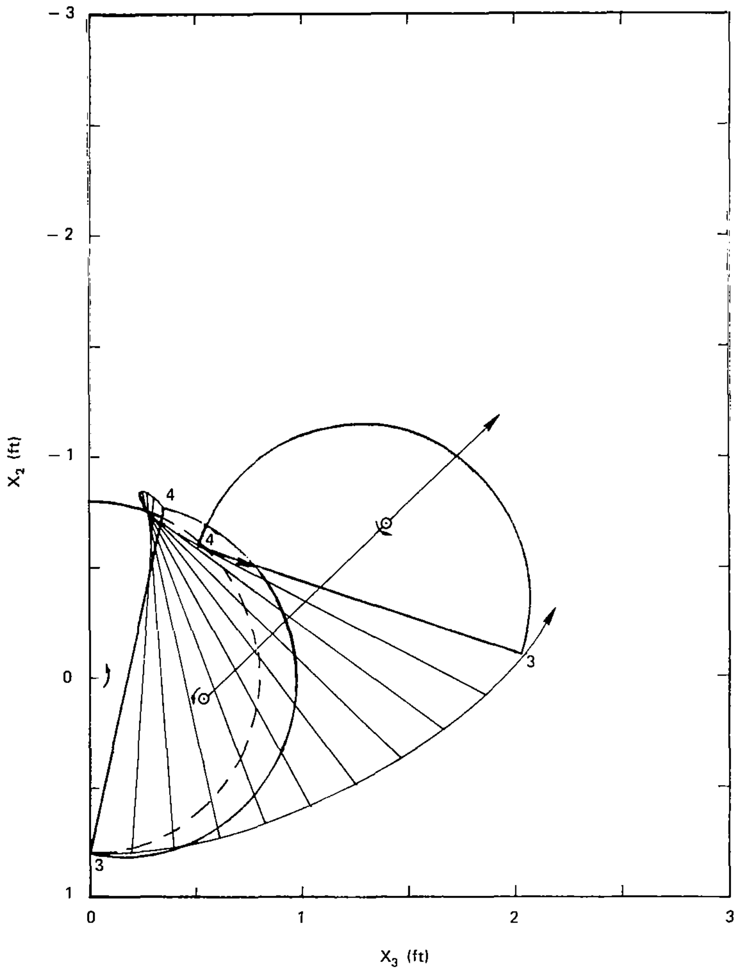

Figure 17—Near free-flight displacements of an aligned roll-out clamshell released at 12.5 deg.

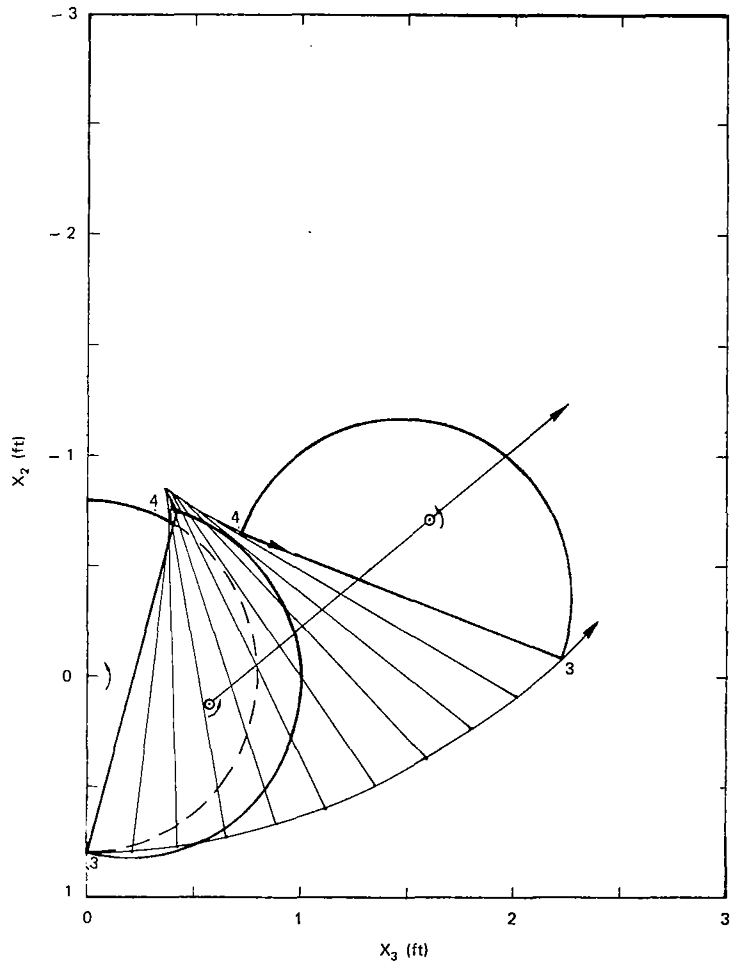

Figure 18—Near free-flight displacements of an aligned roll-out clamshell released at 15 deg.

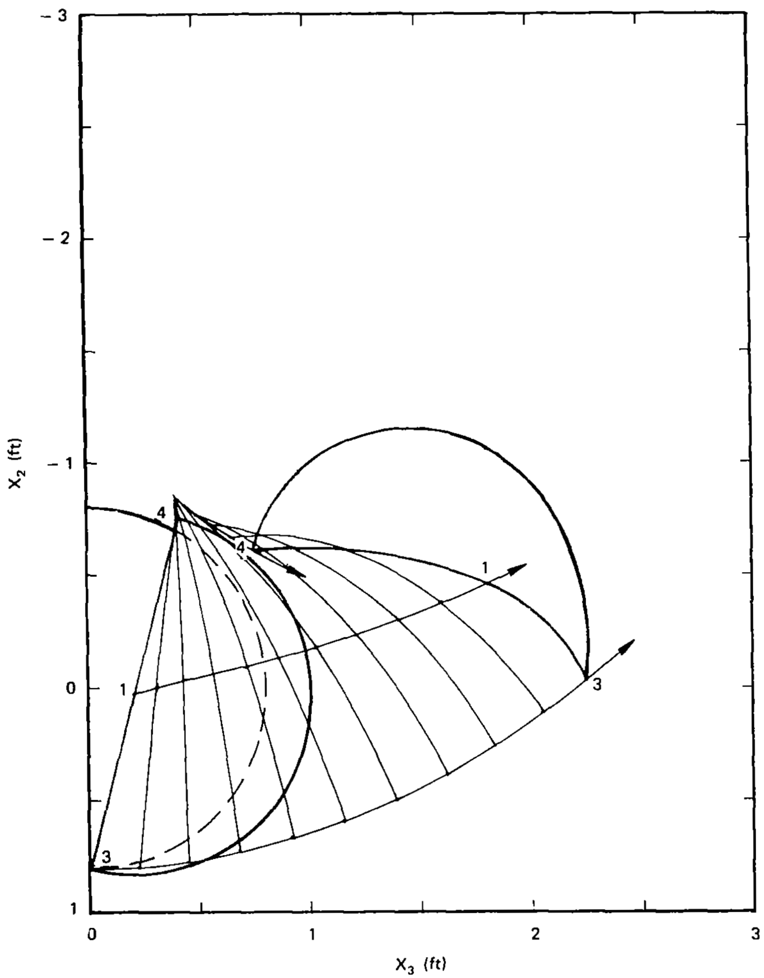

Figure 19—Near free-flight displacements of an unaligned roll-out clamshell released at 15 deg.

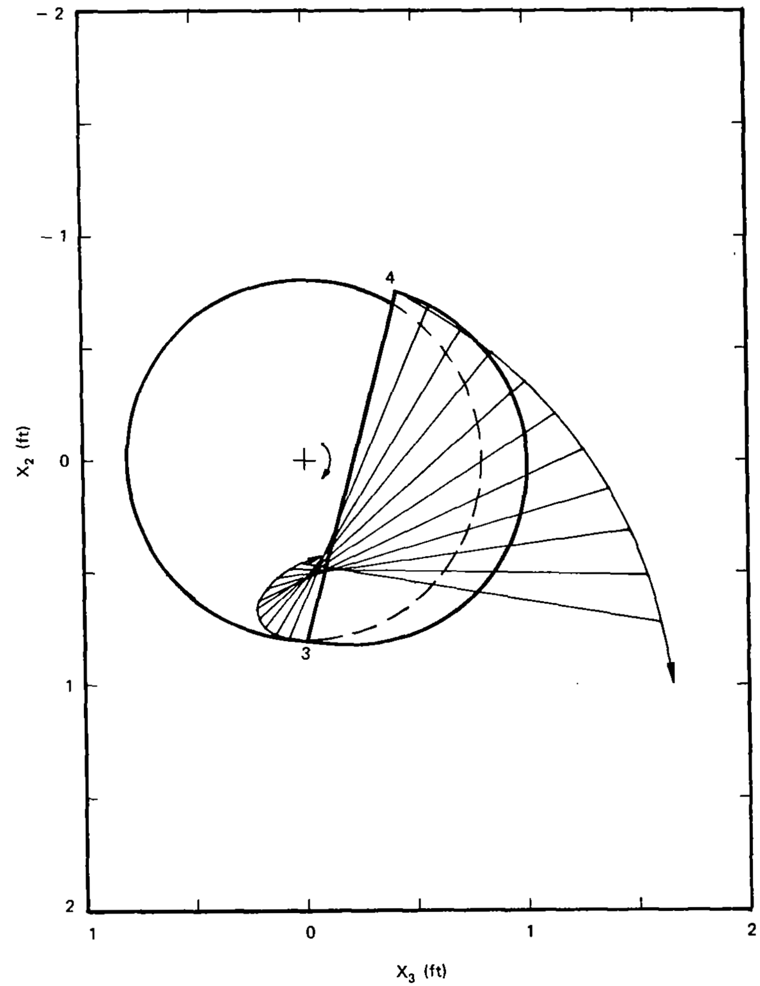

Figure 20—Effect of rocket-vehicle spin reversal on the near free-flight of an aligned clamshell released at 15 deg.

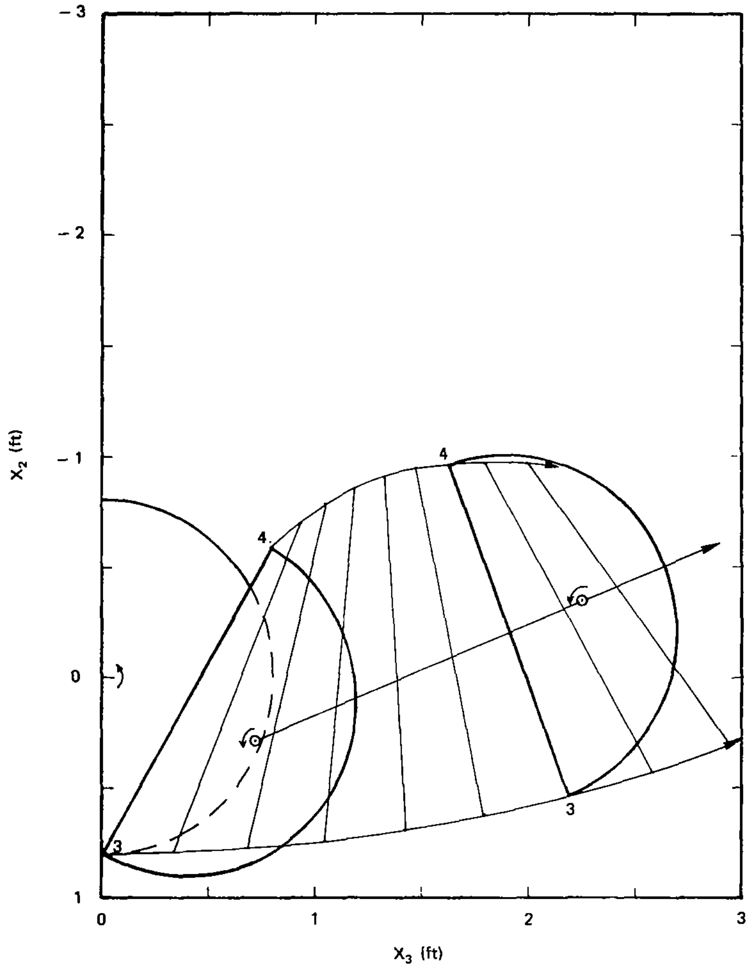

Figure 21—Near free-flight displacements of an aligned roll-out clamshell released at 30 deg.

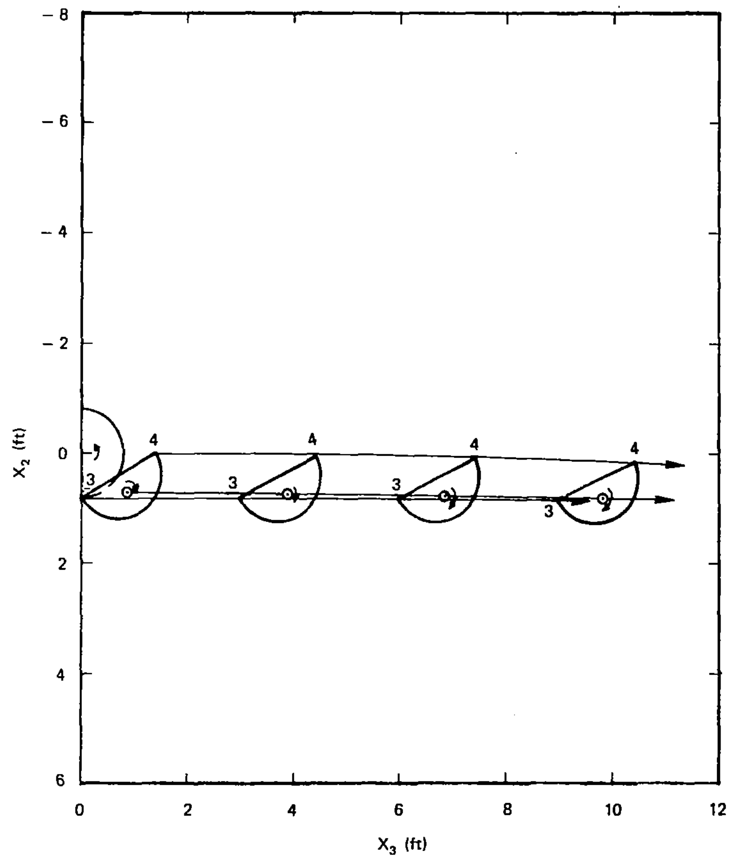

Figure 22—Near free-flight displacements of an aligned roll-out clamshell released at 60 deg.

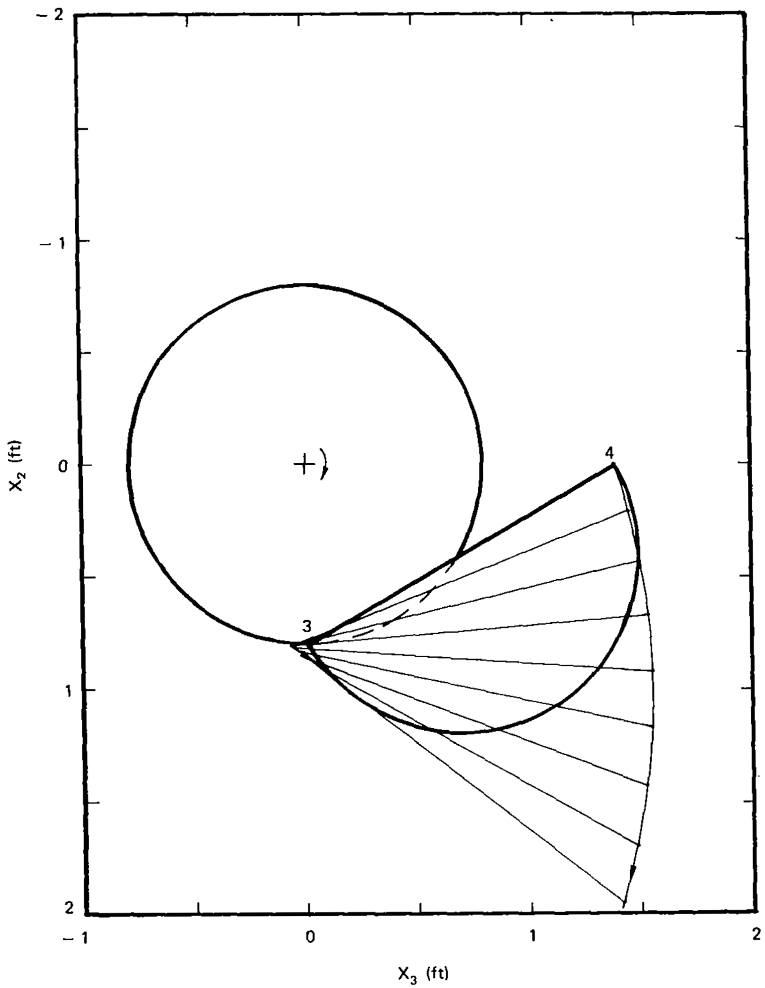

Figure 23—Effect of rocket-vehicle spin reversal on the near free-flight of an aligned clamshell released at 60 deg.

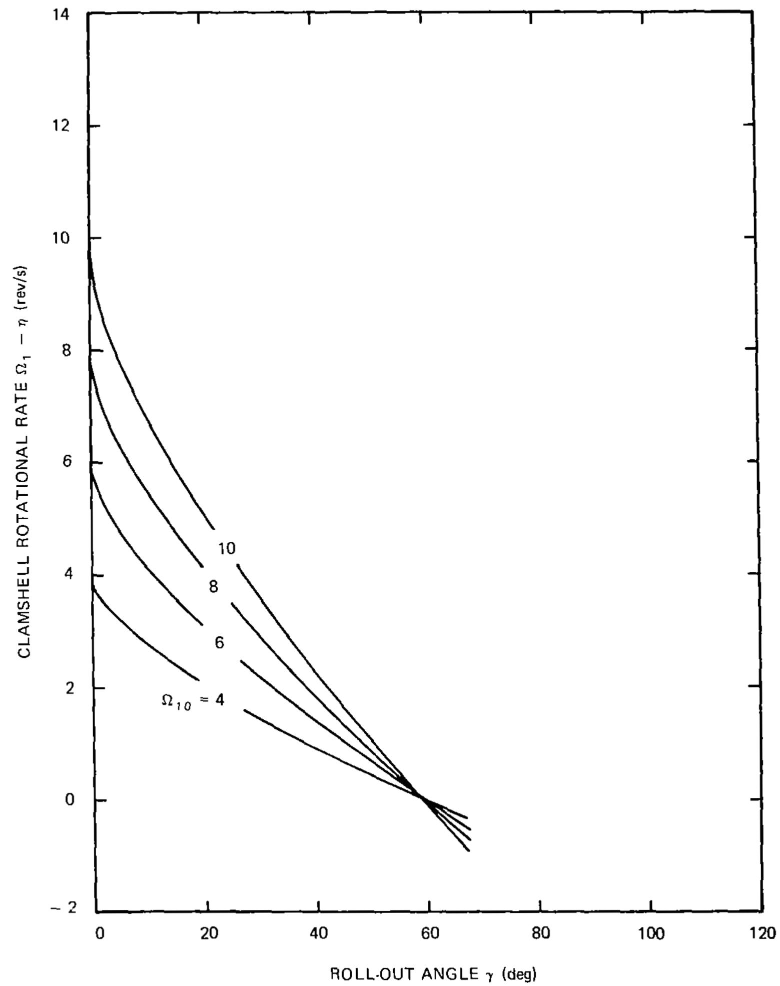

Figure 24—Clamshell rotational rate.

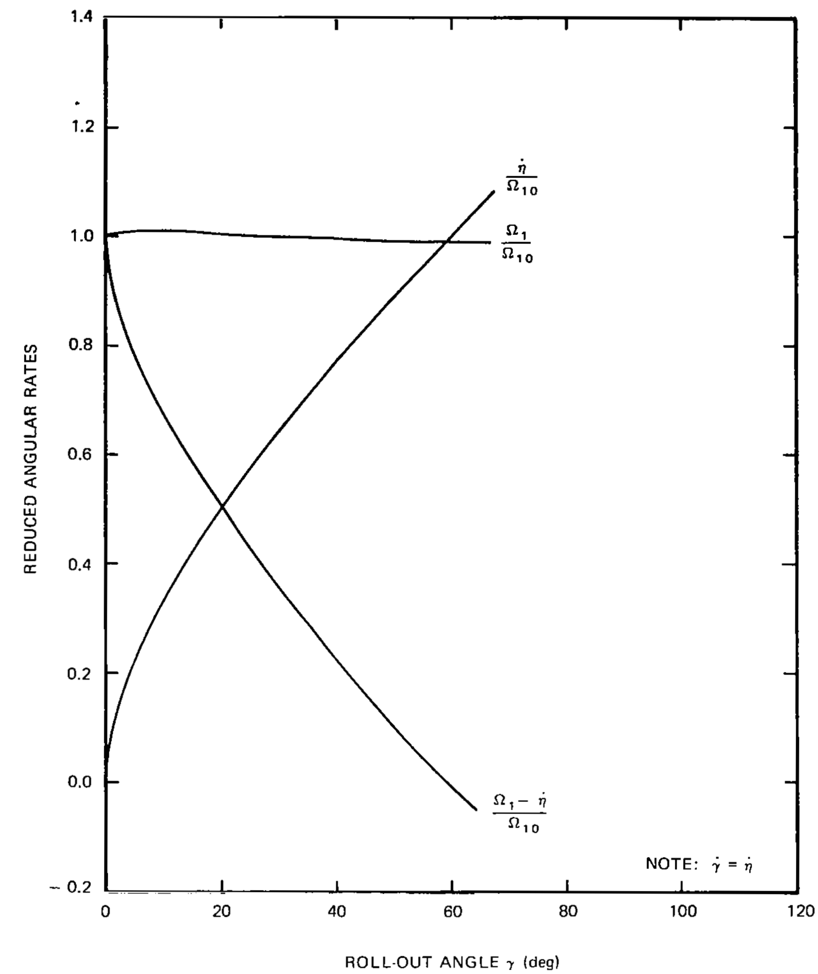

Figure 25—Angular rates for the system using aligned clamshells.

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland, December 24, 1970
311-07-12-02-51

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Appendix A

Source Listing of Program "ROC" and a Data Deck

```
// EXEC FORTRANG,PARM='NAME=ROC,DECK'
//SOURCE.SYSPUNCH DD DSN=&DECK,SYSOUT=B
//SOURCE.SYSIN DD *
C 2/21/69 - L.F.H.
C MOD. 8/21/69 - L.F.H.
C
C                   ...MAIN PROGRAM 'ROC'...
C     PROG. ROC AND ITS SUBSIDIARY SUBPROGRAMS MAY BE UTILIZED TO STUDY
C BOTH THE DEPLOYMENT AND THE FREE FLIGHT PHASES OF CLAMSHELL EJECTION.
C THE TYPE OF SYSTEM THAT CAN BE STUDIED IS BASED ON A UNIQUE CLAMSHELL
C ROLL-OUT EJECTION CONCEPT.  THE FREE FLIGHT PHASE OF A GIVEN CASE IN A
C JOB RUN MAY BE SKIPPED IF DESIRED.  THE DATA LOADING IS SET SO THAT
C THE TERMINAL CARD IN EACH LOGICAL SUBSET OF CARDS REPRESENTING A CASE
C INPUT BE PUNCHED WITH AN INTEGER OF THE FORM 'LLLKJ' AND ADJUSTED AS
C DESIRED BETWEEN COLUMNS 1 THROUGH 8, INCLUSIVE.  IF 'J' IS ZERO, THE
C FREE FLIGHT PHASE OF THE CASE IS SKIPPED.  IF 'K' IS ZERO, THE CASE IS
C THE LAST IN THE JOB RUN TO BE PROCESSED.  THE CASE NO. IS OPTIONALLY
C ENTERED BY PUNCHING UP TO THREE DIGITS IN 'LLL'; IF IT IS OMITTED, THE
C CASE NO. IS EQUAL TO THE PRECEDING CASE NO. PLUS ONE.
C                                                  L.F.H. 8/21/69.
C
  120 FORMAT( '0',39X,'...  J1 = ',I1,'  ...' )
  130 FORMAT( 80X,'RTIME = ',F8.3,' SEC.' )
C
      EXTERNAL           SET1,AUX1,DER1,AUX2,OUT1,
     X                   SET2,AUX3,DER2,AUX4,OUT2
C
      COMMON / LFH2 /    NX(47),CBLOCK(20,220)
      REAL*8             Z(250),
     1                   H,X(3),Y(8,3),
     2                   DER(8,4)
      COMMON / DATA /    Z,NEQ1,NEQ2,J1,J2,J3,J4,J5
      EQUIVALENCE
     1                   ( H,Z(44) ),( X(1),Z(61) ),( Y(1,1),Z(64) ),
     2                   ( DER(1,1),Z(91) )
C
  300 CALL STIME
      CALL LOAD( Z )
      IF( NX(20) + NX(22) .NE. 0 ) GO TO 990
      KK = NX(9) - NX(44)
      JJ = MOD( KK,10 )
      JK = MOD( KK,100 )/10
      JL = MOD( KK,100000 )/100
      IF( JL .GT. 0 ) J4 = JL
C
C              ...1ST ( DEPLOYMENT ) PHASE...
C
      CALL NIT1
      CALL RK( X,Y,DER,3,H,J1,J2,
     X   SET1,AUX1,DER1,AUX2,OUT1 )
      IF( J1 .GT. 4 ) GO TO 500
      CALL AUX1
      CALL DER1( X,Y,DER,3,1 )
      CALL AUX2
      CALL OUT1( 1 )
```

```
      IF( JJ .EQ. 0 ) GO TO 550                                          ROC00530
C                                                                        ROC00540
C                 ...2ND ( FREE FLIGHT ) PHASE...                        ROC00550
C                                                                        ROC00560
      CALL NIT2                                                          ROC00570
      CALL RK( X,Y,DER,6,H,J1,4,                                         ROC00580
     X    SET2,AUX3,DER2,AUX4,OUT2 )                                     ROC00590
      IF( J1 .GT. 4 ) GO TO 500                                          ROC00600
      CALL AUX3                                                          ROC00610
      CALL DER2( X,Y,DER,6,1 )                                           ROC00620
      CALL AUX4                                                          ROC00630
      CALL OUT2( 1 )                                                     ROC00640
      GO TO 550                                                          ROC00650
C                                                                        ROC00660
  500 WRITE( 6,120 )    J1                                               ROC00670
  550 CALL TTIME( JTIME )                                                ROC00680
      RTIME = FLOAT( JTIME*26 )/1000000.                                 ROC00690
      WRITE( 6,130 ) RTIME                                               ROC00700
      IF( JK .NE. 0 ) GO TO 300                                          ROC00710
      GO TO 999                                                          ROC00720
C                                                                        ROC00730
  990 IF( JK .EQ. 0 ) GO TO 999                                          ROC00740
      GO TO 300                                                          ROC00750
C                                                                        ROC00760
  999 STOP                                                               ROC00770
      END                                                                ROC00780
C 2/22/67 - L.F.H.                                                       LOAD0010
C MOD. 10/23/68 - L.F.H.                                                 LOAD0020
C                                                                        LOAD0030
      SUBROUTINE LOAD                                                    LOAD0040
C                                                                        LOAD0050
C                           ...PROD. VERS...                             LOAD0060
C                                                                        LOAD0070
  110 FORMAT( 20A4 )                                                     LOAD0080
  120 FORMAT( 1X,I2,5X,20A4,2X,Z8,1X,Z8,1X,Z8 )                          LOAD0090
  130 FORMAT( 15X,'...READ ERROR IN LOAD...' )                           LOAD0100
C                                                                        LOAD0110
      INTEGER*2           K3,M1                                          LOAD0120
      COMMON / LFH2 /     FWD,RD,RZ(4),                                  LOAD0130
     1                    R1,R2,R3,R4,R5,R6,R7,R8,R9,RY(3),              LOAD0140
     2                    N1,N2,N3,N4,                                   LOAD0150
     3                    CARD(20),BLANK,                                LOAD0160
     4                    R30,PSW(2),K3,M1,CBLOCK(20,220)                LOAD0170
C                                                                        LOAD0180
C   FWD IS NOT USED BY SUBP. LOAD OR SUBP. EDATA.                        LOAD0190
C   RD CONTAINS SUBP. LOAD'S SAVE AREA ADDR.                             LOAD0200
C   RZ'S ARE NOT USED BY SUBP. LOAD OR SUBP. EDATA.                      LOAD0210
C   R1 CONTAINS THE RETURN ON AN SPIE ISSUED IN SUBP. EDATA.             LOAD0220
C   R2 CONTAINS A(BUST), THE SHIFTED B-ADDR. USED IN SUBP. EDATA.        LOAD0230
C   R3 CONTAINS THE A(CURRENT LOAD POINT) ON EACH RETURN FROM SUBP.      LOAD0240
C        EDATA.                                                          LOAD0250
C   R4 CONTAINS A(LFH2), I.E., SUBP. EDATA'S SAVE AREA ADDR.             LOAD0260
C   R5 CONTAINS A(CARD), I.E., A(LFH2+88).                               LOAD0270
C   R6 CONTAINS A(CURRENT CARD CHARACTER IMAGE).                         LOAD0280
C   R7 CONTAINS A(CARD+79), I.E., A(LFH2+167).                           LOAD0290
```

```
C   R8 CONTAINS A(LOB), AN ADDR. INTERNAL TO SUBP. EDATA.
C   R9 CONTAINS A(3).
C   RY'S ARE NOT USED BY SUBP. LOAD OR SUBP. EDATA.
C   N1 IS A BRANCHING CONTROL SET BY SUBP. EDATA FOR SUBP. LOAD.
C   N2 IS A CARD COLUMN ERROR INDICATOR SET BY SUBP. EDATA.
C   N3 IS A COUNT OF CARDS 'READ' BY SUBP. LOAD AND PROC. BY SUBP. EDATA
C   N4 = 32767 IS SET BY SUBP. LOAD TO SIGNAL A 'READING' ERROR.
C   CARD(20) CONTAINS THE CHARACTERS OF THE CURRENT CARD IMAGE 'READ' BY
C        SUBP. LOAD AND PROC. BY SUBP. EDATA.
C   R30 CONTAINS A(INIT. LOAD POINT).
C   PSW CONTAINS THE O-PSW WHENEVER SUBP. EDATA IS SUBJECTED TO A PROG.
C        INTERRUPTION WHICH IS CHANNELED BY THE 'SPIE' IN SUBP. EDATA.
C   K3 = 1 IS SET BY SUBP. LOAD TO SIGNAL AN ENCOUNTER WITH AN EOF.
C   M1 = 1 IS SET BY SUBP. LOAD AFTER ALL CARDS IN A FILE HAVE BEEN
C        PROC. BY SUBP. EDATA.
C   CBLOCK IS THE AREA WHERE A BLOCK OF CARD IMAGES ARE 'READ' IN BY
C        SUBP. LOAD.  THIS BLOCK MAY CONTAIN J1 CARD IMAGES OR ALL CARD
C        IMAGES UP TO AN 'EOF', WHICHEVER IS LESS.  WHEN THE NO. OF
C        CARDS IN A FILE IS LESS THAN J1, SUBP. LOAD WILL 'READ' ALL OF
C        THE CARDS IN THE FILE AND ENCOUNTER THE 'EOF'.  IN SUCH AN
C        EVENT, SUBP. LOAD WILL SET K3 = 1 AND M1 = 0.  AFTER THE LAST
C        CARD IN THE FILE HAS BEEN PROC. BY SUBP. EDATA, SUBP. LOAD
C        SETS M1 = 1.
C
      DATA               R / 4HRR.. /,
     1                   J1 / 220 /,
     2                   K2 / 0 /
C
C   NOTE...CBLOCK(20,M) REQUIRES THAT J1 .EQ. M.
C
      N1 = 1
      N2 = 0
      N3 = 0
      N4 = 0
C
      IF( K2 .LT. 1 ) GO TO 200
      K1 = K2 + 1
      GO TO 320
C
  200 DO 300  J = 1,J1
  300 CBLOCK(1,J) = R
      K1 = 1
      K3 = 0
      M1 = 0
C
      READ( 5,110,END=600,ERR=700 ) CBLOCK
C
  320 DO 400  K = K1,J1
      IF( CBLOCK(1,K) .EQ. R ) GO TO 470
      K2 = K
C
  330 DO 350  J = 1,20
  350 CARD(J) = CBLOCK(J,K)
      N3 = N3 + 1
C
```

```
      CALL EDATA
      GO TO ( 400,450,370 ),N1
C
  370 IF( N2 .EQ. 0 ) GO TO 400
      IF( PSW(1) .NE. 0.0 ) PRINT 120, N2, CARD, PSW, R4
      IF( PSW(1) .EQ. 0.0 ) PRINT 120, N2, CARD
  400 CONTINUE
      IF( K3 .LT. 1 ) GO TO 200
C
  450 IF( K2 .LT. J1 ) GO TO 500
  470 K2 = 0
      IF( K3 .EQ. 1 ) M1 = 1
  500 RETURN
C
  600 K3 = 1
      GO TO 320
C
  700 N4 = 32767
      PRINT 130
      GO TO 500
      END
C 2/18/69 - L.F.H.
C MOD. 7/07/69 - L.F.H.
C
      SUBROUTINE NIT1
C
C               ...DATA INIT. FOR THE 1ST PHASE...
C
      REAL*8              Z(250),
     1                    TO,HO,Q(8),
     2                    D(10),JCY(6),JZ(3),
     3                    H,ETAZ,BETA,X,Y(8),
     4                    DC(5),DS(5),
     5                    TWPI,CRTD,CDTR,PID2,PID4
      COMMON / DATA /     Z,NEQ1,NEQ2,J1,J2,J3,J4,J5
      EQUIVALENCE
     1                    ( TO,Z(1) ),( HO,Z(2) ),( Q(1),Z(3) ),
     2                    ( D(1),Z(11) ),( JCY(1),Z(22) ),( JZ(1),Z(28) ),
     3                    ( H,Z(44) ),( ETAZ,Z(46) ),( BETA,Z(47) ),
     4                    ( X,Z(61) ),( Y(1),Z(64) ),
     5                    ( DC(1),Z(131) ),( DS(1),Z(136) )
C
      COMMON / CONS /     TWPI,CRTD,CDTR,PID2,PID4
C
      X = TO
      H = HO
      ETAZ = DATAN( D(2)/D(1) )
      Q(3) = ETAZ*CRTD
      Y(1) = Q(1)*TWPI
      Y(2) = Q(2)*TWPI
      Y(3) = ETAZ
      D(5) = DSQRT( D(1)**2 + D(2)**2 )
C
C               ...SET UP BETA AND THE PRIN. M. OF INERTIAS...
C
```

```
      IF( JCY(1) .EQ. JCY(3) ) GO TO 300                                INIT0350
      BETA = 0.5D0*DATAN( 2.0D0*JCY(5)/( JCY(3) - JCY(1) ) )            INIT0360
      IF( BETA .GT. PID4 ) BETA = BETA - PID2                           INIT0370
      IF( BETA + PID4 .LT. 0.0D0 ) BETA = BETA + PID2                   INIT0380
      GO TO 310                                                         INIT0390
  300 BETA = 0.0D0                                                      INIT0400
  310 DC(4) = DCOS( BETA )                                              INIT0410
      DS(4) = DSIN( BETA )                                              INIT0420
      JZ(1) = JCY(1)*DC(4)**2 + JCY(3)*DS(4)**2                         INIT0430
     1                        - 2.0D0*JCY(5)*DC(4)*DS(4)                INIT0440
      JZ(2) = JCY(2)                                                    INIT0450
      JZ(3) = JCY(1)*DS(4)**2 + JCY(3)*DC(4)**2                         INIT0460
     1                        + 2.0D0*JCY(5)*DC(4)*DS(4)                INIT0470
C                                                                       INIT0480
  990 RETURN                                                            INIT0490
      END                                                               INIT0500
C 2/14/69 - L.F.H.                                                      RK000010
C MOD. 8/22/69 - L.F.H.                                                 RK000020
C                                                                       RK000030
      SUBROUTINE RK( /X/,/Y/,/DER/,/NEQ/,/H/,/J1/,/JF/,                 RK000040
     1    SETH,AUX1,DERIV,AUX2,OUT )                                    RK000050
C                                                                       RK000060
C                   ...RUNGE-KUTTA 4TH ORDER INTEGRATOR...              RK000070
C   FIXED STEP INTEGRATION EXCEPT FOR THE TERMINAL PROCEDURE.           RK000080
C                                                                       RK000090
C   X - INDEPENDENT VARIABLE.                                           RK000100
C   Y'S - DEPENDENT VARIABLES.                                          RK000110
C   DER'S - DERIVATIVES OF THE Y'S.                                     RK000120
C   NEQ - NO. OF DERIVATIVE EQUATIONS.                                  RK000130
C   H - INTEGRATION STEP SIZE.                                          RK000140
C   J1 - BRANCHING PARAMETER SET BY SUBP. SETH FOR SUBP. RK.            RK000150
C   JF - OUTPUT PRINT FREQUENCY.                                        RK000160
C                                                                       RK000170
C   SUBP. SETH - ADJUSTS H DURING THE TERMINAL INTEGRATION PROCESS AND  RK000180
C SETS J1 = 1,2,3,4, OR 5 DEPENDING ON WHETHER H IS LEFT UNCHANGED OR   RK000190
C ADJUSTED WITHOUT THE NEED TO RESET X(1) AND Y(K,1), THE INTEGRATION   RK000200
C PROCESS IS TO BE ENDED, H IS CHANGED AND THE PRECEDING INTEGRATION    RK000210
C STEP IS TO BE REPEATED WITH THE NEWER H-VALUE AND THE RESETTED X AND  RK000220
C Y-VALUES, H MUST BE CHANGED BEYOND THE MAX. ALLOWED NO. OF TIMES, OR  RK000230
C AN ABNORMAL END OF THE INTEGRATION PROCESS IS REQUIRED,RESPECTIVELY.  RK000240
C SUBP. SETH DEPENDS ON J1=0 WHENEVER SUBP. RK IS CALLED.               RK000250
C   SUBP. AUX1 - COMPUTES, I.E. UPDATES, THE REQ'D DATA FOR SUBP. DERIV.RK000260
C   SUBP. DERIV - COMPUTES THE DERIV'S OF THE Y'S AT THE SUBSTEP POINTS.RK000270
C   SUBP. AUX2 - COMPUTES, I.E. UPDATES, THE ADDITIONAL DATA FOR OUTPUT.RK000280
C   SUBP. OUT - IS THE OUTPUT SUBPROGRAM.                               RK000290
C                                                                       RK000300
C                                                                       RK000310
      REAL*8              X(3),Y(NEQ,3),DER(NEQ,4),H,                   RK000320
     1                    CHH,HD6                                       RK000330
C                                                                       RK000340
      J1 = 0                                                            RK000350
      JN = 0                                                            RK000360
C                                                                       RK000370
  400 X(2) = X(1)                                                       RK000380
      DO 410  K = 1,NEQ                                                 RK000390
```

```
  410 Y(K,2) = Y(K,1)
      IF( J1 .NE. 3 ) GO TO 415
      IF( JN .GT. 1 .AND. MOD( JN-1,JF ) .NE. 0 ) JN = JN - 1
C
  415 CALL SETH( X,Y,DER,NEQ,H,J1 )
      GO TO ( 420,990,400,500,500 ),J1
  420 CONTINUE
C
      CALL AUX1
      CALL DERIV( X,Y,DER,NEQ,1 )
      IF( MOD( JN,JF ) .NE. 0 ) GO TO 425
      CALL AUX2
      CALL OUT( JN )
  425 CONTINUE
C
      CHH = 0.5D0*H
C
      DO 440  J = 2,4
      IF( J .EQ. 4 ) CHH = H
      X(1) = X(2) + CHH
      DO 430  K = 1,NEQ
  430 Y(K,1) = Y(K,2) + CHH*DER(K,J-1)
      CALL AUX1
      CALL DERIV( X,Y,DER,NEQ,J )
  440 CONTINUE
C
      HD6 = H/6.0D0
      X(3) = X(2)
      DO 470  K = 1,NEQ
      Y(K,3) = Y(K,2)
      Y(K,1) = DER(K,1) + 2.0D0*( DER(K,2) + DER(K,3) ) + DER(K,4)
  470 Y(K,1) = Y(K,2) + HD6*Y(K,1)
C
      JN = JN + 1
      GO TO 400
C
  500 CONTINUE
C
  990 RETURN
      END
C 2/14/69 - L.F.H.
C MOD. 8/22/69 - L.F.H.
C
      SUBROUTINE SET1( /X/,/Y/,/DER/,/NEQ/,/H/,/J1/ )
C
C               ...TERMINAL H CONTROLLER FOR THE 1ST PHASE...
C   X(1) AND Y(K,1) ARE RESET WHEN AN INTEG. STEP IS TO BE REPEATED.
C
      REAL*8              Z(250),
     X                    YT,YEPS,
     X                    ETAZ,DER(NEQ,4),
     X                    H,X(NEQ),Y(NEQ,3),
     X                    GAMD,TWPI,CRTD,CDTR,PID2,PID4
      COMMON / DATA /     Z,KKK(7)
      EQUIVALENCE
```

```
     X                    ( YT,Z(42) ),( YEPS,Z(43) ),
     X                    ( ETAZ,Z(46) ),( J3,KKK(5) )
C
      COMMON / CONS /   TWPI,CRTD,CDTR,PID2,PID4
C
      IF( J1 .EQ. 0 ) JC = 0
C
C              ...CHECK FOR TERMINAL CONDITIONS...
C
      GAMD = ( Y(3,1) - ETAZ )*CRTD
      IF( GAMD .LT. 0.0D0 ) GO TO 500
      IF( DABS( ( GAMD - YT )/YT ) .LE. YEPS ) GO TO 200
      IF( GAMD .GT. YT ) GO TO 300
      IF( J1 .EQ. 0 ) GO TO 100
      IF( Y(2,1) .LE. 0.0D0 .AND. DER(2,1) .LE. 0.0D0 ) GO TU 500
C
C              ...SET J1 AS REQUIRED...
C
  100 J1 = 1
      GO TO 990
C
  200 J1 = 2
      GO TO 990
C
  300 JC = JC + 1
      IF( JC .GT. J3 ) GO TO 400
      IF( J1 .EQ. 0 ) GO TO 500
      H = 0.5D0*H
      X(1) = X(3)
      DO 330  K = 1,NEQ
  330 Y(K,1) = Y(K,3)
      J1 = 3
      GO TO 990
C
  400 J1 = 4
      GO TO 990
C
  500 J1 = 5
  990 RETURN
      END
C 2/14/69 - L.F.H.
C MOD. 7/07/69 - L.F.H.
C
      SUBROUTINE AUX1
C
C              ...DATA UPDATER FOR THE 1ST PHASE DERIV. SUBP...
C
      REAL*8              Z(250),
     1                    D(10),M,JCY(6),
     2                    JVX1,GAM,ETAZ,Y(8),
     3                    DC(5),DS(5),
     4                    F(6),F23,
     5                    QOM,QET,
     6                    A,B,C,DD,U,V
      COMMON / DATA /     Z,NEQ1,NEQ2,J1,J2,J3,J4,J5
```

```
      EQUIVALENCE
     1                   ( D(1),Z(11) ),( M,Z(21) ),( JCY(1),Z(22) ),
     2                   ( JVX1,Z(31) ),( GAM,Z(32) ),( ETAZ,Z(46) ),
     3                   ( Y(1),Z(64) ),
     4                   ( DC(1),Z(131) ),( DS(1),Z(136) ),
     5                   ( F(1),Z(141) ),( F23,Z(147) )
      COMMON / DBX1 /    A,B,C,DD,U,V
C
C
      DC(1) = DCOS( Y(3) )
      DS(1) = DSIN( Y(3) )
C
      GAM = Y(3) - ETAZ
      DC(2) = DCOS( GAM )
      DS(2) = DSIN( GAM )
C
      D(7) = DSQRT( D(1)**2 + D(5)**2 - 2.0D0*D(5)*D(1)*DC(1) )
C
      F(2) = M*( Y(2)**2 )*D(5)
      F(3) = 2.0D0*M*Y(1)*Y(2)*D(5)
      F23 = F(2) - F(3)
      CALL FF6
C
      DD = 2.0D0*( JCY(1) + M*( D(5)**2 ) )
      A = JVX1 + 2.0D0*( JCY(1) + M*( D(7)**2 ) )
      B = - DD + 2.0D0*M*D(5)*D(1)*DC(1)
      C = B
C
      QOM = 0.0D0
      QET = F(6)*D(1)
      U = QOM + 2.0D0*F23*D(1)*DS(1)
      V = QET + 2.0D0*M*( Y(1)**2 )*D(5)*D(1)*DS(1)
C
  990 RETURN
      END
C 2/14/69 - L.F.H.
C
      SUBROUTINE DER1( X,Y,DER,NEQ,J )
C
C              ...DERIV. EQ'S. FOR THE 1ST PHASE...
C
      REAL*8             X,Y(NEQ),DER(NEQ,4),
     1                   A,B,C,D,U,V,DET
C
      COMMON / DBX1 /    A,B,C,D,U,V
C
      DET = A*D - B*C
C
      DER(1,J) = ( D*U - B*V )/DET
      DER(2,J) = ( A*V - C*U )/DET
      DER(3,J) = Y(2)
C
  990 RETURN
      END
C 2/14/69 - L.F.H.
```

```
C MOD. 7/07/69 - L.F.H.
C
      SUBROUTINE AUX2
C
C              ...DATA UPDATER FOR THE 1ST PHASE OUTPUT...
C
      REAL*8                Z(250),
     1                      D(10),M,JZ(3),
     2                      AX1,Y(8),DER(8),
     3                      DC(5),DS(5),
     4                      F(6),F23,
     5                      FX(3),FY(3),
     6                      MZ(3),MY(3),
     7                      CY(3),CX(3),
     8                      GAM,GAMD,TWPI,CRTD,CDTR,PID2,PID4,ZZZ
      COMMON / DATA /       Z,NEQ1,NEQ2,J1,J2,J3,J4,J5
      EQUIVALENCE
     1                      ( D(1),Z(11) ),( M,Z(21) ),( JZ(1),Z(28) ),
     2                      ( AX1,Z(45) ),( Y(1),Z(64) ),( DER(1),Z(91) ),
     3                      ( DC(1),Z(131) ),( DS(1),Z(136) ),
     3                      ( F(1),Z(141) ),( F23,Z(147) ),
     4                      ( FX(1),Z(151) ),( FY(1),Z(154) ),
     5                      ( MZ(1),Z(161) ),( MY(1),Z(164) ),
     6                      ( CY(1),Z(171) ),( CX(1),Z(174) ),
     7                      ( GAM,Z(32) ),( GAMD,Z(33) )
      COMMON / CONS /       TWPI,CRTD,CDTR,PID2,PID4
C
      F(1) = M*DER(2)*D(5)
      F(4) = M*DER(1)*D(7)
      F(5) = M*( Y(1)**2 )*D(7)
C
      DC(3) = ( D(1) - D(5)*DC(1) )/D(7)
      DS(3) = D(5)*DS(1)/D(7)
C
      CALL FAX1
      FX(1) = M*AX1
      FX(2) = F(1)*DS(1) + F23*DC(1) - F(4)*DS(3)
     1                         - F(5)*DC(3) - F(6)*DS(2)
      FX(3) = F(1)*DC(1) - F23*DS(1) + F(4)*DC(3)
     1                         - F(5)*DS(3) - F(6)*DC(2)
C
      FY(1) = FX(1)
      FY(2) = FX(2)*DC(2) - FX(3)*DS(2)
      FY(3) = FX(3)*DC(2) + FX(2)*DS(2)
C
      ZZZ = DER(1) - DER(2)
      MZ(1) = JZ(1)*ZZZ*DC(4)
      MZ(2) = ( JZ(3) - JZ(1) )*( ( Y(1) - Y(2) )**2 )*DC(4)*DS(4)
      MZ(3) = - JZ(3)*ZZZ*DS(4)
C
      MY(1) = MZ(1)*DC(4) - MZ(3)*DS(4)
      MY(2) = MZ(2)
      MY(3) = MZ(3)*DC(4) + MZ(1)*DS(4)
C
      CY(1) = MY(1) - FY(2)*D(2) - FY(3)*D(1)
```

```
      CY(2) = MY(2) + FY(1)*D(2) - FY(3)*D(3) + F(6)*D(4)
      CY(3) = MY(3) + FY(1)*D(1) + FY(2)*D(3)
C
      CX(1) = CY(1)
      CX(2) = CY(2)*DC(2) + CY(3)*DS(2)
      CX(3) = CY(3)*DC(2) - CY(2)*DS(2)
C
      GAMD = GAM*CRTD
C
  990 RETURN
      END
C 2/18/69 - L.F.H.
C
      SUBROUTINE FAX1
C
C               ...DUMMY LONGIT. ACCELERATION SUBP...
C
      RETURN
      END
C 2/18/69 - L.F.H.
C MOD. 7/07/69 - L.F.H.
C
      SUBROUTINE FF6
C
      REAL*8            Z(250),
     X                  F(6)
      COMMON / DATA /   Z,NEQ1,NEQ2,J1,J2,J3,J4,J5
      EQUIVALENCE
     X                  ( F(1),Z(141) )
C
  300 F(6) = 0.0D0
C
  990 RETURN
      END
C 3/26/69 - L.F.H.
C MOD. 9/24/69 - L.F.H.
C
      SUBROUTINE OUT1( JJ )
C
C               ...OUTPUT SUBP. FOR THE 1ST PHASE...
C
  110 FORMAT( '1' / '0',39X,'...BASE DATA...' / 1X
     X   / 5X,'T0 - INITIAL TIME ( SEC ).'
     X   / 5X,'H0 - INITIAL INTEGRATOR TIME STEP SIZE ( SEC ).'
     X   / 5X,'Q(1)...Q(3) - INITIAL OMEGA, ETA-DOT, AND ETA '
     X        '( RPS, RPS, DEG ).'
     X   / 5X,'D(1)...D(8) - CLAMSHELL GEOMETRIC PARAMETERS ( FT ).'
     X   / 5X,'M - CLAMSHELL MASS ( SLUG ).'
     X   / 5X,'JCY(1)...JCY(6) - CLAMSHELL Y-FRAME '
     X        'MOMENTS AND PRODUCTS OF INERTIA ( SLUG*FT**2 ).'
     X   / 5X,'JZ(1)...JZ(3) - CLAMSHELL Z-FRAME I.E. PRINCIPAL '
     X        'MOMENTS OF INERTIA ( SLUG*FT**2 ).'
     X   / 5X,'JVX1 - CENTRAL BODY ROLL MOMENT OF INERTIA '
     X        '( SLUG*FT**2 ).'
     X   / 5X,'YT - TERMINAL GAMMA ( DEG ).'
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     X    / 5X,'YEPS - TERMINAL GAMMA CONVERGFNCE CTITERION ( DEG ).'
     X    / 5X,'AX1 - SYSTFM X1 ACCELERATION ( FT/SEC**2 ).' )
 115 FORMAT( '1' / '0',39X,'...BASF DATA...' )
 120 FORMAT( '0CASE NO. ',I3,5X,10A8 / 1X
     X    / 6X,'T0,H0,Q(J)...',1P5D12.4
     X    / 12X,'D(J)...',1P8D12.4
     X    / 8X,'M,JCY(J)...',1P7D12.4
     X    / 6X,'JZ(J),JVX1...',1P4D12.4
     X    / 5X,'YT,YEPS,AX1...',1P3D12.4 )
 130 FORMAT( '1' / '0CASE NO. ',I3,5X,10A8
     X    / 38X,'1ST PHASE OUTPUT' / 1X
     X    / 5X,'T - ELAPSED TIME ( SEC ).'
     X    / 5X,'GAMD - CLAMSHELL ROLL-OUT ANGLE ( DEG ).'
     X    / 5X,'Y(3) - CLAMSHELL ETA-ANGLE ( DEG ).'
     X    / 5X,'Y(2) - CLAMSHELL ROLL-OUT RATE ( RPS ).'
     X    / 5X,'Y(1) - SYSTEM ROLL RATE ( RPS ).'
     X    / 5X,'DER(2) - CLAMSHELL ROLL-OUT ACCELERATION ( RAD/SEC**2 ).'
     X    / 5X,'DER(1) - SYSTFM ROLL ACCELERATION ( RAD/SEC**2 ).'
     X    / 5X,'F(J) - INERTIAL AND APPLIED FORCES ( LB ).'
     X    / 5X,'FX(J) - X-FRAME HINGE FORCE COMPONENTS ( LB ).'
     X    / 5X,'CX(J) - X-FRAME HINGE COUPLE COMPONENTS ( FT-LB ).'
     X    / '0' / 55X,'...'
     X    / '0',15X,'T',9X,'GAMD',8X,'Y(3)',
     X         8X,'Y(2)',8X,'Y(1)',7X,'DER(2)',6X,'DER(1)'
     X    / '0',25X,'F(1)',8X,'F(2)',8X,'F(3)',
     X         8X,'F(4)',8X,'F(5)',8X,'F(6)'
     X    / '0',25X,'FX(1)',7X,'FX(2)',7X,'FX(3)',
     X         7X,'CX(1)',7X,'CX(2)',7X,'CX(3)' )
 140 FORMAT( '1' / '0CASE NO. ',I3,5X,10A8
     X    / 38X,'1ST PHASE OUTPUT' )
 150 FORMAT( 1X / 10X,1P7D12.4 / ( 22X,1P6D12.4 ) )
C
C
      REAL*8              Z(250),
     X                    T0,H0,Q(3),D(8),M,JCY(6),
     X                    JZ(3),JVX1,GAMD,
     X                    YT,YEPS,AX1,
     X                    X,Y(3),DER(3),F(6),FX(3),CX(3),
     X                    TITLE(10)
      REAL*8              YY(3)
      REAL*8              TWPI,CRTD,CDTR,PID2,PID4
      COMMON / CONS /     TWPI,CRTD,CDTR,PID2,PID4
      COMMON / DATA /     Z,NEQ1,NEQ2,J1,J2,J3,J4,J5
      EQUIVALENCE
     X                    ( T0,Z(1) ),( H0,Z(2) ),( Q(1),Z(3) ),
     X                    ( D(1),Z(11) ),( M,Z(21) ),( JCY(1),Z(22) ),
     X                    ( JZ(1),Z(28) ),( JVX1,Z(31) ),( GAMD,Z(33) ),
     X                    ( YT,Z(42) ),( YEPS,Z(43) ),( AX1,Z(45) ),
     X                    ( X,Z(61) ),( Y(1),Z(64) ),( DER(1),Z(91) ),
     X                    ( F(1),Z(141) ),
     X                    ( FX(1),Z(151) ),( CX(1),Z(174) ),
     X                    ( TITLE(1),Z(241) )
C
      DATA                JK/ 0 /, NCASE/ 0 /
C
```

```
      IF( JJ .NE. 0 ) GO TO 400
      IF( NCASE .NE. J4 ) GO TO 230
      NCASE = J4 + 1
      J4 = NCASE
      GO TO 240
  230 NCASE = J4
  240 IF( JK .EQ. 0 ) WRITE( 6,110 )
  250 IF( JK .NE. 0 ) WRITE( 6,115 )
C
      WRITE( 6,120 )    NCASE,TITLE,
     X                  TO,HO,Q,
     X                  D,
     X                  M,JCY,
     X                  JZ,JVX1,
     X                  YT,YEPS,AX1
  300 JK = 255
C
      WRITE( 6,130 )    NCASE,TITLE
      JL = 20
C
  400 IF( MOD( JL,56 ) .NE. 0 ) GO TO 500
      WRITE( 6,140 )    NCASE ,TITLE
      JL = 0
C
  500 YY(1) = Y(1)/TWPI
      YY(2) = Y(2)/TWPI
      YY(3) = Y(3)*CRTD
      WRITE( 6,150 )
     X                  X,GAMD,YY(3),YY(2),YY(1),DER(2),DER(1),
     X                  F,
     X                  FX,CX
      JL = JL + 4
C
  990 RETURN
      END
C 2/26/69 - L.F.H.
C MOD. 9/03/69 - L.F.H.
C
      SUBROUTINE NIT2
C
C               ...DATA INIT. FOR THE 2ND PHASE...
C
      REAL*8            Z(250),
     X                  D(10),
     X                  GAM,XT,
     X                  H,BETA,
     X                  XF,
     X                  X,Y(8),W(8),
     X                  DC(5),DS(5),
     X                  D7CA,D7SA,
     X                  DXCM(3),P(3,4),
     X                  D8M3,D1M2,Y1M2,ZZZ,
     X                  TWPI,CRTD,CDTR,PID2,PID4
      COMMON / DATA /   Z,NEQ1,NEQ2,J1,J2,J3,J4,J5
      EQUIVALENCE
```

```
     X                    ( D(1),Z(11) ),
     X                    ( GAM,Z(32) ),( XT,Z(41) ),
     X                    ( H,Z(44) ),( BETA,Z(47) ),
     X                    ( XF,Z(51) ),
     X                    ( X,Z(61) ),( Y(1),W(1),Z(64) ),
     X                    ( DC(1),Z(131) ),( DS(1),Z(136) ),
     X                    ( D7CA,Z(141) ),( D7SA,Z(142) ),
     X                    ( DXCM(1),Z(151) ),( P(1,1),Z(161 ) )
C
      COMMON / CONS /    TWPI,CRTD,CDTR,PID2,PID4
C
      EQUIVALENCE        ( D8M3,D1M2,Y1M2,ZZZ )
C
      XF = X
C
C             ...BODY POINT DISPLACEMENTS IN THE Z-FRAME...
C
      D8M3 = D(8) - D(3)
      P(1,1) = D8M3*DC(4) - D(2)*DS(4)
      P(2,1) = 0.0D0
      P(3,1) = - D(2)*DC(4) - D8M3*DS(4)
      D1M2 = D(1) - D(2)
      P(1,2) = - D(3)*DC(4) + D1M2*DS(4)
      P(2,2) = 0.0D0
      P(3,2) = D1M2*DC(4) + D(3)*DS(4)
      P(1,3) = - D(3)*DC(4) - D(2)*DS(4)
      P(2,3) = D(1)
      P(3,3) = - D(2)*DC(4) + D(3)*DS(4)
      P(1,4) = P(1,3)
      P(2,4) = - D(1)
      P(3,4) = P(3,3)
C
C             ...BODY C.M. DISPLACEMENT RATES...
C
      D7CA = D(7)*DC(3)
      D7SA = D(7)*DS(3)
      DXCM(2) = Y(2)*D(5)*DS(1) - Y(1)*D7SA
      DXCM(3) = Y(2)*D(5)*DC(1) + Y(1)*D7CA
C
C             ...INIT. BODY FIXED Z-FRAME ANGULAR RATES...
C
      Y1M2 = Y(1) - Y(2)
      W(1) = Y1M2*DC(4)
      W(2) = 0.0D0
      W(3) = - Y1M2*DS(4)
C
C             ...INIT. EULERIAN ANGLES...
C SEE NOTES IN SUBP. DER2 AND SUBP. AUX4 ON ROTATIONAL TRANSFORMATION.
C
      W(4) = - GAM
      W(5) = 0.0D0
      W(6) = - BETA
C
C             ...SET UP TIME STOP AND 'H'...
C
```

```
      ZZZ = DABS( YIM2 )
      IF( ZZZ .LT. PID4 ) ZZZ = PID4
      ZZZ = PID2/ZZZ
      XT = X + ZZZ
      H = ZZZ/128.0D0
C
  990 RETURN
      END
C 2/27/69 - L.F.H.
C MOD. 8/20/69 - L.F.H.
C
      SUBROUTINE SET2( T,W,DER,NEQ,H,J1 )
C
C               ...TERMINAL H CONTROLLER FOR THE 2ND PHASE...
C
      REAL*8             Z(250),
     X                   TT,H,
     X                   T(NEQ),W(NEQ,3),DER(NEQ,4),
     X                   H1,H2
      COMMON / DATA /    Z,KKK(6),J5
      EQUIVALENCE
     X                   ( TT,Z(41) )
C
      IF( J1 .EQ. 0 ) JC = 0
C
      IF( J1 .EQ. 3 ) GO TO 255
      IF( J5 .EQ. 0 ) GO TO 250
      J5 = 0
      CALL SPIE( 0 )
      JC = JC + 1
      IF( JC .GE. 5 ) GO TO 500
      H1 = H
      H = 2.0D0*H
      T(1) = T(3)
      DO 200  K = 1,NEQ
  200 W(K,1) = W(K,3)
      J1 = 3
C
  230 IF( T(1) .EQ. TT ) GO TO 300
      IF( T(1) + H .LE. TT ) GO TO 990
      H2 = TT - T(1)
      JC = 0
      IF( J1 .EQ. 3 .AND. H1 .EQ. H2 ) GO TO 500
      H = H2
      GO TO 990
C
  250 IF( JC .EQ. 0 ) GO TO 255
      H = H*( 0.5D0**JC )
      JC = 0
  255 J1 = 1
      GO TO 230
C
  300 J1 = 2
      GO TO 990
C
```

```
  500 J1 = 5
  990 RETURN
      END
C 2/26/69 - L.F.H.
C MOD. 7/07/69 - L.F.H.
C
      SUBROUTINE AUX3
C
C              ...DATA UPDATER FOR THE 2ND PHASE DERIV. SUBP...
C
      REAL*8               Z(250),
     1                     W(8),
     2                     DC(5),DS(5)
      COMMON / DATA /      Z,NEQ1,NEQ2,J1,J2,J3,J4,J5
      EQUIVALENCE
     1                     ( W(1),Z(64) ),
     2                     ( DC(1),Z(131) ),( DS(1),Z(136) )
C
C              ...COSINES AND SINES OF THE EULERIAN ANGLES...
C
      DO 300  J = 1,3
      DC(J) = DCOS( W(J+3) )
  300 DS(J) = DSIN( W(J+3) )
C
C              ...CHECK THE COSINE OF THE 2-ANGLE...
C
      IF( DC(2) .NE. 0.0D0 ) GO TO 990
      CALL SPIE( 1 )
      J5 = 255
C
  990 RETURN
      END
C 2/24/69 - L.F.H.
C MOD. 7/07/69 - L.F.H.
C
      SUBROUTINE DER2( T,W,DER,NEQ,J )
C
C              ...DERIV. EQ'S. FOR THE 2ND PHASE...
C
      REAL*8               T,W(NEQ),DER(NEQ,4)
      REAL*8               Z(250),
     1                     JZ(3),DC(5),DS(5)
      COMMON / DATA /      Z,NEQ1,NEQ2,J1,J2,J3,J4,J5
      EQUIVALENCE
     1                     ( JZ(1),Z(28) ),( DC(1),Z(131) ),
     2                     ( DS(1),Z(136) )
C
C              ...EULER'S EQ'S. OF MOTION FOR FREE FLIGHT...
C
      DER(1,J) = W(2)*W(3)*( JZ(2) - JZ(3) )/JZ(1)
      DER(2,J) = W(3)*W(1)*( JZ(3) - JZ(1) )/JZ(2)
      DER(3,J) = W(1)*W(2)*( JZ(1) - JZ(2) )/JZ(3)
C
C              ...DERIV. EQ'S. FOR EULERIAN ANGLES...
C      THE ROTATIONAL TRANSFORMATION FROM THE INERTIAL FRAME TO THE
```

```
C BODY FIXED PRINCIPAL AXIS FRAME AT THE BODY C.M. INVOLVES THREE
C SUCCESSIVE ROTATIONS: A ROTATION ABOUT THE 1-AXIS THROUGH THE 1-ANGLE,
C A ROTATION ABOUT THE 1ST INTERMEDIATE 3-AXIS THROUGH THE 2-ANGLE, AND
C A ROTATION ABOUT THE 2ND INTERMEDIATE 2-AXIS THROUGH THE 3-ANGLE.
C
      DER(4,J) = ( W(3)*DS(3) + W(1)*DC(3) )/DC(2)
      DER(5,J) = W(3)*DC(3) - W(1)*DS(3)
      DER(6,J) = W(2) + DER(4,J)*DS(2)
C
  990 RETURN
      END
C 2/24/69 - L.F.H.
C MOD. 9/03/69 - L.F.H.
C
      SUBROUTINE AUX4
C
C              ...DATA UPDATER FOR THE 2ND PHASE OUTPUT...
C
      REAL*8             Z(250),
     X                   TF,TD,
     X                   T,W(8),
     X                   DC(5),DS(5),
     X                   D7CA,D7SA,
     X                   DXCM(3),XCM(3),
     X                   P(3,4),X(3,4),
     X                   A(3,3)
      COMMON / DATA /    Z,NEQ1,NEQ2,J1,J2,J3,J4,J5
      EQUIVALENCE
     X                   ( TF,Z(51) ),
     X                   ( T,Z(61) ),( W(1),Z(64) ),
     X                   ( DC(1),Z(131) ),( DS(1),Z(136) ),
     X                   ( D7CA,Z(141) ),( D7SA,Z(142) ),
     X                   ( DXCM(1),Z(151) ),( XCM(1),Z(154) ),
     X                   ( P(1,1),Z(161) ),( X(1,1),Z(201) )
C
C              ...BODY C.M. DISPLACEMENTS...
C
      XCM(1) = 0.0D0
      TD = T - TF
      XCM(2) = DXCM(2)*TD + D7CA
      XCM(3) = DXCM(3)*TD + D7SA
C
C     THE ROTATIONAL TRANSFORMATION FROM THE INERTIAL FRAME TO THE
C BODY FIXED PRINCIPAL AXIS FRAME AT THE BODY C.M. INVOLVES THREE
C SUCCESSIVE ROTATIONS: A ROTATION ABOUT THE 1-AXIS THROUGH THE 1-ANGLE,
C A ROTATION ABOUT THE 1ST INTERMEDIATE 3-AXIS THROUGH THE 2-ANGLE, AND
C A ROTATION ABOUT THE 2ND INTERMEDIATE 2-AXIS THROUGH THE 3-ANGLE.
C     THE FOLLOWING ELEMENTS ARE COMPONENTS OF THE INVERSE OF THE TRANS-
C FORMATION MATRIX FOR ROTATING THE INERTIAL FRAME INTO THE BODY FIXED
C PRINCIPAL AXIS FRAME AT THE C.M. OF THE BODY.
C
      A(1,1) = DC(2)*DC(3)
      A(1,2) = - DS(2)
      A(1,3) = DC(2)*DS(3)
      A(2,1) = DS(1)*DS(3) + DC(1)*DS(2)*DC(3)
```

```
      A(2,2) = DC(1)*DC(2)
      A(2,3) = - DS(1)*DC(3) + DC(1)*DS(2)*DS(3)
      A(3,1) = - DC(1)*DS(3) + DS(1)*DS(2)*DC(3)
      A(3,2) = DS(1)*DC(2)
      A(3,3) = DC(1)*DC(3) + DS(1)*DS(2)*DS(3)
C
C              ...BODY POINT DISPLACEMENTS...
C
      DO 500  J = 1,4
      DO 500  K = 1,3
      X(K,J) = XCM(K)
      DO 500  L = 1,3
  500 X(K,J) = X(K,J) + A(K,L)*P(L,J)
C
  990 RETURN
      END
C 3/26/69 - L.F.H.
C MOD. 9/03/69 - L.F.H.
C
      SUBROUTINE OUT2( JJ )
C
C              ...OUTPUT SUBP. FOR THE 2ND PHASE...
C
  130 FORMAT( '1' / 'OCASE NO. ',I3,5X,10A8
     X   / 38X,'2ND PHASE OUTPUT' / 1X
     X   / 5X,'T - ELAPSED TIME ( SEC ).'
     X   / 5X,'XCM,YCM,ZCM - C.M. FREE FLIGHT DISPLACEMENT ( FT ).'
     X   / 5X,'X(J),Y(J),Z(J) - J-TH POINT FREE FLIGHT DISPLACEMENTS '
     X     '( FT ).'
     X   / '0' / 55X,'...'
     X   / '0',14X,'T',10X,'XCM',9X,'YCM',9X,'ZCM',
     X     9X,'X(1)',8X,'Y(1)',8X,'Z(1)'
     X   / '0',25X,'X(2)',8X,'Y(2)',8X,'Z(2)',
     X     8X,'X(3)',8X,'Y(3)',8X,'Z(3)'
     X   / '0',25X,'X(4)',8X,'Y(4)',8X,'Z(4)' )
  140 FORMAT( '1' / 'OCASE NO. ',I3,5X,10A8
     X   / 38X,'2ND PHASE OUTPUT' )
  150 FORMAT( '0',9X,1P7D12.4 / ( 22X,1P6D12.4 ) )
C
      REAL*8            Z(250),
     X                  T,
     X                  XCM(3),X(3,4),
     X                  TITLE(10)
      COMMON / DATA /   Z,NEQ1,NEQ2,J1,J2,J3,J4,J5
      EQUIVALENCE
     X                  ( T,Z(61) ),
     X                  ( XCM(1),Z(154) ),( X(1,1),Z(201) ),
     X                  ( TITLE(1),Z(241) ),
     X                  ( NCASE,J4 )
C
      IF( JJ .NE. 0 ) GO TO 400
      WRITE( 6,130 )    NCASE,TITLE
      JL = 16
C
  400 IF( MOD( JL,56 ) .NE. 0 ) GO TO 500
```

```
      WRITE( 6,140 )    NCASE,TITLE                                     2OUT0400
      JL = 0                                                            2OUT0410
C                                                                       2OUT0420
  500 WRITE( 6,150 )    T,XCM,X                                         2OUT0430
      JL = JL + 4                                                       2OUT0440
C                                                                       2OUT0450
  990 RETURN                                                            2OUT0460
      END                                                               2OUT0470
/*
// EXEC ASSEMBLR,PARM='LOAD,DECK'
//SOURCE.SYSPUNCH DD DSN=&DECK,SYSOUT=B
//SOURCE.SYSIN DD *
EDAT     TITLE 'EDATA-ENTRY AND INITIALIZATION SECTS.'                  EDAT0010
         PRINT DATA                                                     EDAT0020
* 2/22/67 - L.F.H.                                                      EDAT0030
* MOD. 5/15/70 - L.F.H.                                                 EDAT0040
         SPACE 1                                                        EDAT0050
*     SUBP. EDATA PROCESSES DATA CARDS 'READ' BY SUBP. LOAD AND STORES  EDAT0060
* THE PROCESSED DATA ITEMS AS DIRECTED.  CHARACTER, FULL AND DOUBLE     EDAT0070
* WORD DECIMAL ( WHICH INCL. FULL WORD INTEGER AS WELL AS SHORT AND     EDAT0080
* LONG REAL ), HALF WORD DECIMAL INTEGER, AND FULL WORD HEXADECIMAL     EDAT0090
* DATA ARE PROCESSED.                                                   EDAT0100
*     SUBP. EDATA IS MOST EFFICIENT WHEN DIRECTED TOWARD THE LOADING OF EDAT0110
* BLOCKS OF STORAGE SUCH AS A COMMON AREA OR A LARGE ARRAY CONTAINING   EDAT0120
* THE VARIOUS TYPES OF DATA REQUIRED BY A PROCESSING PROGRAM SINCE IT   EDAT0130
* TENDS TO LOAD THE PROCESSED DATA ITEMS INTO SEQUENTIALLY HIGHER AND   EDAT0140
* HIGHER LOCATIONS.  IT MAY BE DIRECTED TO SCATTER LOAD ONLY THE RE-    EDAT0150
* QUIRED DATA ITEMS, I.E., ALL OF THE STORAGE BLOCK NEED NOT BE LOADED. EDAT0160
* THE CURRENT LOAD POINT MAY BE SHIFTED AS REQ'D TO SKIP OVER SECTIONS  EDAT0170
* OF STORAGE AT ANY TIME.  THIS SHIFT IS COMPUTED RELATIVE TO THE       EDAT0180
* INITIAL LOAD POINT.                                                   EDAT0190
*     CHARACTER DATA ARE STORED WITHOUT CHANGE BYTE-BY-BYTE; HENCE, THE EDAT0200
* CURRENT LOAD POINT CAN BE SHIFTED OFF A HALF WORD AS WELL AS A FULL   EDAT0210
* WORD AND DOUBLE WORD BOUNDARY.  IT IS ADVISABLE TO USE THE INITIAL    EDAT0220
* LOAD POINT RESET AND SHIFT FEATURE OF SUBP. EDATA FOLLOWING THE LOAD- EDAT0230
* ING OF CHARACTER DATA.                                                EDAT0240
*     THE LOAD POINT FOR THE FULL AND DOUBLE WORD DECIMAL DATA AS WELL  EDAT0250
* AS THE HEXADECIMAL AND HALF WORD DECIMAL INTEGER DATA MUST BE AT THE  EDAT0260
* APPROPRIATE BYTE BOUNDARIES.                                          EDAT0270
*     SUBP. EDATA PROCESSES ITS OWN PROGRAM INTERRUPTS.  IT SAVES THE   EDAT0280
* ADDRESS OF 'THE NEXT INSTRUCTION' AND THE OLD PSW AND RESETS THE NEXT EDAT0290
* INSTRUCTION ADDRESS BEFORE RETURNING CONTROL TO THE CONTROL PROGRAM.  EDAT0300
* THE CARD ERROR COLUMN NUMBER, THE CARD IMAGE, AND THE OLD PSW ARE     EDAT0310
* PRINTED BY SUBP. LOAD.                                                EDAT0320
*     SUBP. EDATA CAN DETECT CERTAIN PROCESSING ERRORS AND GENERATE THE EDAT0330
* CARD COLUMN NUMBER AT WHICH THE ERROR WAS DETECTED.  THE LOADING OF   EDAT0340
* ALL SUBSEQUENT DATA IS SUSPENDED, AS IT IS WHEN A PROG. INTERRUPT IS  EDAT0350
* PROCESSED.  HOWEVER, SUBSEQUENT DATA CARDS ARE CHECKED FOR ERRORS     EDAT0360
* UNTIL A RETURN TO THE CALLER OF SUBP. LOAD IS EXECUTED.  ONLY ONE     EDAT0370
* ERROR PER CARD CAN BE DETECTED AND PROCESSED.  DATA ITEMS ON A GIVEN  EDAT0380
* CARD WHICH FOLLOW A DETECTED ERROR CANNOT BE CHECKED. SUBP. LOAD      EDAT0390
* PRINTS THE CARD ERROR COLUMN NUMBER AND THE CARD IMAGE IN SUCH CASES. EDAT0400
*     FOR DETAILS ON SUBP. LOAD AND SUBP. EDATA, CALL L.F.HATAKEYAMA,   EDAT0410
* NASA-GSFC, CODE 721, X4047.                                           EDAT0420
         SPACE 1                                                        EDAT0430
```

```
EDATA    CSECT
         SPACE 1
A        EQU   10
B        EQU   11
C        EQU   12
D        EQU   13
E        EQU   14
F        EQU   15
         EJECT
*                 * * *
         ENTRY BUST
         USING *,F
         B     A100
         DC    CL6'5EDATA'
A100     STM   E,C,12(D)                SAVE THE R'S.
         L     B,4(D)                   GET THE PREV. SAVE AREA ADDR...
         L     A,24(B)                  ...& THE PARM. LIST ADDR.
         L     4,=A(LFH2)               SET UP THE CURRENT SAVE AREA...
         ST    D,4(4)                   ...
         ST    4,8(D)                   ...
         LR    D,4                      ...
         SPACE 1
         LA    F,BUST-EDATA(F)          SHIFT THE BASE ADDRESS...
         USING BUST,F                   ...
         B     A210
*                       * * * * * * * * * *
BUST     B     A200
         DC    CL6'5BUST '
A200     NI    A212+1,X'0F'             DISABLE THE BR. AT A212.
         SPACE 1
A210     LR    2,F                      SHIFT BASE REGISTERS...
         USING BUST,2                   ...
         DROP  F                        ...
         SPACE 1
A212     BC    15,A300                **
         SPACE 1
         MVC   176(8,4),4(1)            SET UP THE O-PSW.
         MVC   9(3,1),=AL3(C110)        MOD. THE O-PSW NEXT INSTR. ADDR.
         OI    A212+1,X'F0'             ENABLE THE BR. AT A212.
         BCR   15,E                     RETURN TO THE CONTOL PROG.
*                       * * * * * * * * * *
A300     SPIE  BUST,((1,15))            SPEC. A NEW P.I.E.
         SPACE 1
         STM   1,2,24(4)                SAVE R1 & R2.
         CLC   82(2,4),=H'1'            CHECK THE CARD COUNT.
         BH    A400                     ...BR. OUT IF NOT THE 1ST CARD.
         L     3,0(A)                   GET THE INIT. LOAD POINT ADDR...
         ST    3,172(4)                 ...STASH IT FOR FUTURE REF.
         LA    5,88(4)                  LOAD R5 WITH A(CARD).
         LA    7,79(5)                  SET UP R7 WITH A(CARD+79)...
         LA    8,LOB                    ...R8 WITH A(LOB)
         LA    9,3                      ...& R9 WITH 3.
         STM   1,9,24(4)                SAVE R1 - R9.
         EJECT
A400     LM    1,9,24(4)                RESET R1 - R9.
```

```
         LR    6,5                   RESET & SAVE R6...           EDAT0990
         ST    6,44(4)               ...                          EDAT1000
         XC    176(8,4),176(4)       CLEAR THE 'PSW' CELLS.       EDAT1010
         XC    CL8,CL8               ZERO LOP & HOLD.             EDAT1020
         LA    A,8                   SET UP RA, RB, RE, & RF...   EDAT1030
         LA    B,A402                ...                          EDAT1040
         LM    E,F,LOP               ...                          EDAT1050
         OI    A408+1,X'F0'          ENABLE THE BR. AT A408.      EDAT1060
         SPACE 1                                                  EDAT1070
A402     CLI   0(6),C' '             COMPUTE THE LOADING OFFSET...EDAT1080
         BE    A407                  ...                          EDAT1090
         NI    A408+1,X'0F'          DISABLE THE BR. AT A408.     EDAT1100
         LA    B,A404                ...RESET RB.                 EDAT1110
A404     CLI   0(6),C'0'             ...                          EDAT1120
         BL    A405                  ...                          EDAT1130
         CLI   0(6),C'9'             ...                          EDAT1140
         BH    C110                  ...                          EDAT1150
         MVN   0(1,8),0(6)           ...                          EDAT1160
         M     E,=F'10'              ...                          EDAT1170
         A     F,HOLD                ...                          EDAT1180
         B     A407                                               EDAT1190
A405     LA    B,A406                ...RESET RB.                 EDAT1200
A406     CLI   0(6),C' '             ...                          EDAT1210
         BNE   C110                  ...                          EDAT1220
A407     LA    6,1(6)                ...                          EDAT1230
         BCTR  A,B                                                EDAT1240
         SPACE 1                                                  EDAT1250
         CLI   0(6),C' '             CHECK THE COL. 9 CHAR.       EDAT1260
         BNE   C110                                               EDAT1270
         SPACE 1                                                  EDAT1280
A408     B     A409                **                             EDAT1290
         A     F,172(4)              SET UP THE CURRENT LOAD POINT... EDAT1300
         LR    3,F                   ...                          EDAT1310
         ST    3,32(4)               ...                          EDAT1320
         SPACE 1                                                  EDAT1330
A409     SR    A,A                   SET UP RA, RB, RE, RF,...    EDAT1340
         LA    B,S100                ...                          EDAT1350
         LA    E,4                   ...                          EDAT1360
         LA    F,24                  ...                          EDAT1370
         LA    6,1(6)                CHECK THE CARD COL. 10 CHAR... EDAT1380
A410     CLC   0(1,6),0(B)           ...                          EDAT1390
         BE    A500(A)               BR. IF .EQ. AN ALLOWED CHAR. EDAT1400
         LA    B,1(B)                INCR. RB.                    EDAT1410
         BXLE  A,E,A410              LOOP...                      EDAT1420
         B     C110                                               EDAT1430
         SPACE 1                                                  EDAT1440
A500     B     BLNK                  BR. OUT AS REQ'D...          EDAT1450
         B     CC                    ...                          EDAT1460
         B     DD                    ...                          EDAT1470
         B     HH                    ...                          EDAT1480
         B     RRR                   ...                          EDAT1490
         B     XX                    ...                          EDAT1500
         TITLE 'EDATA-C DATA, BLANK AND RETURN PROC. SECTIONS'    EDAT1510
         SPACE 1                                                  EDAT1520
*                 * * *                                           EDAT1530
```

```
         SPACE 1
CC       OI    C102+1,X'F0'            ENABLE THE BR'S AT C102...
         OI    C300+1,X'F0'            ...& C300.
         SPACE 1
C100     LA    6,1(6)                  INCR., SAVE, & CHECK R6...
         ST    6,44(4)                 ...
         CR    6,7                     ...
         BH    BLNK                    BR. OUT IF PAST CARD END.
         CLI   0(6),X'7D'              LOOK FOR THE ' MARK...
         BE    C300                    ...BR. OUT WHEN FOUND.
         SPACE 1
C102     BC    15,C100               **
         SPACE 1
C103     C     9,72(4)                 CHECK FOR PRECEDING ERRORS...
         BE    C100                    ...BR. TO AVOID DATA LOADING.
         MVC   0(1,3),0(6)             MOVE A CHARACTER.
         LA    3,1(3)                  INCR. R3.
         B     C100
         SPACE 1
C110     SR    6,5                     SET UP TROUBLE INDIC...
         LA    6,1(6)                  ...
         ST    6,76(4)                 ...
         MVI   75(4),3                 INDIC. TROUBLE.
         B     RR
         SPACE 1
C300     BC    15,C400               **
         SPACE 1
         CLC   0(2,6),=X'7D7D'         CHECK FOR THE '' MARK.
         BNE   BLNK                    BR. OUT IF NOT A '' MARK.
         LA    6,1(6)                  INCR. R6.
         ST    6,44(4)                 SAVE R6.
         B     C103
         SPACE 1
C400     NI    C102+1,X'0F'            DISABLE THE BR. AT C102.
         NI    C300+1,X'0F'            DISABLE THE BR. AT C300.
         B     C100
         SPACE 1
*                  * * *
         SPACE 1
BLNK     MVI   79(4),0                 INDIC. NO ERROR.
         ST    3,32(4)                 SAVE THE CURRENT LOAD POINT.
         SPACE 1
RR       L     1,24(4)                 RESET R1...
         SPIE  MF=(E,(1))              ...TO RESET THE OLD P.I.E.
         L     D,4(4)                  RESET RD...
         LM    E,C,12(D)               ...AND RESTORE THE OTHER R'S.
         MVI   12(D),X'FF'
         BCR   15,E
         SPACE 1
RRR      MVI   75(4),2                 INDIC. RETURN.
         B     RR
         TITLE 'EDATA-D DATA PROC. SECTION'
         SPACE 1
*                  * * *
         SPACE 1
```

```
DD       SR    A,A                      SET UP RA & RB...                   EDAT2090
         SR    B,B                      ...                                 EDAT2100
         XC    CL16,CL16                ZERO HOP, LOP, HOLD, & EXP.         EDAT2110
         MVC   TCW,=X'4EDFFFFF'         SET UP TCW.                         EDAT2120
         SPACE 2                                                            EDAT2130
D200     LA    6,1(6)                   INCR., SAVE, & CHECK R6...          EDAT2140
         ST    6,44(4)                  ...                                 EDAT2150
         CR    6,7                      ...                                 EDAT2160
         BH    D810                     ...BR. OUT IF PAST CARD END.        EDAT2170
         SPACE 1                                                            EDAT2180
         CLI   0(6),C'0'                CHECK FOR NUMERICS...               EDAT2190
         BL    D500                     ...BR. OUT IF .LT. 0.               EDAT2200
         CLI   0(6),C'9'                ...                                 EDAT2210
         BH    C110                     ...BR. TO TROUBLE IF .GT. 9.        EDAT2220
         MVN   0(1,8),0(6)              MOVE THE NUMERIC TO 'HOLD'.         EDAT2230
         LA    A,1(A)                   INCR. THE DIGIT COUNT.              EDAT2240
         SPACE 1                                                            EDAT2250
         TM    TC1,X'80'         (0,0)                                      EDAT2260
         BO    D220                                                         EDAT2270
         CH    A,=H'8'                  CHECK THE DIGIT COUNT...            EDAT2280
         BL    D220                     ...BR. AROUND IF .LT. 8.            EDAT2290
         OI    TC1,X'80'                DISCONT. THE DIGIT COUNT CHECK.     EDAT2300
         NI    TC3,X'EF'                ALLOW LONG REAL STORAGE.            EDAT2310
         NI    TC2,X'FD'                FORBID AN E IN A LONG REAL.         EDAT2320
         SPACE 1                                                            EDAT2330
D220     TM    TC1,X'40'         (1,1)                                      EDAT2340
         BO    D300                                                         EDAT2350
         LA    B,1(B)                   INCR. THE FRACT. DIGIT COUNT.       EDAT2360
         SPACE 2                                                            EDAT2370
D300     TM    TC1,X'20'         (2,0)                                      EDAT2380
         BO    D400                                                         EDAT2390
         L     E,LOP                    BUILD UP THE LONG PRIMITIVE...      EDAT2400
D310     LR    F,E                      ...                                 EDAT2410
         M     E,=F'10'                 ...                                 EDAT2420
         A     F,HOLD                   ...                                 EDAT2430
         TM    TC1,X'10'         (3,0)                                      EDAT2440
         BO    D330                                                         EDAT2450
         ST    F,LOP                    ...                                 EDAT2460
         NI    LOP,X'03'                ...                                 EDAT2470
         SR    E,E                      ...                                 EDAT2480
         SLDL  E,6                      ...                                 EDAT2490
         ST    E,HOLD                   ...                                 EDAT2500
         L     E,HOP                    ...                                 EDAT2510
         OI    TC1,X'10'                ...'OR' BIT 3.                      EDAT2520
         B     D310                                                         EDAT2530
         EJECT                                                              EDAT2540
D330     ST    F,HOP                    ...                                 EDAT2550
         NI    TC1,X'EF'                ...ZERO BIT 3.                      EDAT2560
         B     D200                                                         EDAT2570
         SPACE 2                                                            EDAT2580
D400     CH    A,=H'2'                  CHECK THE DIGIT COUNT...            EDAT2590
         BH    C110                     ...BR. TO TROUBLE IF .GT. 2.        EDAT2600
         L     F,EXP                    BUILD UP THE EXPONENT...            EDAT2610
         M     E,=F'10'                 ...                                 EDAT2620
         A     F,HOLD                   ...                                 EDAT2630
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         ST    F,EXP                     ...                              EDAT2640
         B     D200                                                       EDAT2650
         SPACE 2                                                          EDAT2660
D500     CLI   0(6),C','                 CHECK FOR A COMMA...             EDAT2670
         BE    D600                      ...BR. OUT IF COMMA.             EDAT2680
         SPACE 1                                                          EDAT2690
         SR    1,1                                                        EDAT2700
         LA    C,S200                    SET UP RC, RE, & RF...           EDAT2710
         LA    E,4                       ...                              EDAT2720
         LA    F,20                      ...                              EDAT2730
D510     CLC   0(1,6),0(C)               CHECK FOR OTHER CHARS...         EDAT2740
         BE    D700(1)                   ...BR. OUT AS REQ'D.             EDAT2750
         LA    C,1(C)                    INCR. RC.                        EDAT2760
         BXLE  1,E,D510                  LOOP...                          EDAT2770
         B     C110                      ...OR BR. TO TROUBLE.            EDAT2780
         SPACE 2                                                          EDAT2790
D600     TM    TC1,X'08'         (4,1)                                    EDAT2800
         BO    INT                                                        EDAT2810
         SPACE 1                                                          EDAT2820
         TM    TC1,X'04'         (5,1)                                    EDAT2830
         BO    D620                                                       EDAT2840
         SPACE 1                                                          EDAT2850
         A     B,EXP                     COMP. THE SCALING FACTOR...      EDAT2860
D610     NI    TC3,X'BF'                 ...ENABLE DOWNSCALING.           EDAT2870
         SPACE 1                                                          EDAT2880
D611     SLL   B,3                       ...                              EDAT2890
         ST    B,EXP                     ...                              EDAT2900
         B     FLT                                                        EDAT2910
         SPACE 1                                                          EDAT2920
D620     S     B,EXP                     ...                              EDAT2930
         BM    D630                      ...                              EDAT2940
         B     D610                      ...                              EDAT2950
         SPACE 1                                                          EDAT2960
D630     LPR   B,B                       ...                              EDAT2970
         B     D611                                                       EDAT2980
         SPACE 2                                                          EDAT2990
D700     B     D810                      BLANK.                           EDAT3000
         B     D820                      .                                EDAT3010
         B     D830                      +                                EDAT3020
         B     D840                      -                                EDAT3030
         B     D850                      D                                EDAT3040
         B     D860                      E                                EDAT3050
         EJECT                                                            EDAT3060
D810     NI    TC3,X'7F'                 ZERO BIT 16.                     EDAT3070
         B     D600                                                       EDAT3080
         SPACE 1                                                          EDAT3090
D820     TM    TC1,X'02'         (6,1)                                    EDAT3100
         BO    D821                                                       EDAT3110
         B     C110                                                       EDAT3120
D821     NI    TC1,X'BD'                 ALLOW FRACT. DIGIT COUNTING...  *EDAT3130
                                         ...FORBID 2 .'S IN THE P-PART.   EDAT3140
         NI    TC2,X'6F'                 FORBID + AFTER THE DEC. PT...   *EDAT3150
                                         ...ALSO, - AFTER THE DEC. PT.    EDAT3160
D825     NI    TC1,X'E7'                 ALLOW FLOATING.                  EDAT3170
         B     D200                                                       EDAT3180
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         SPACE 1                                                      EDAT3190
D830     TM    TC1,X'01'          (7,0)                               EDAT3200
         BO    D834                                                   EDAT3210
         TM    TC2,X'80'          (8,1)                               EDAT3220
         BO    D832                                                   EDAT3230
         B     C110                                                   EDAT3240
D832     NI    TC2,X'6F'               FORBID TWO +'S IN THE P-PART... *EDAT3250
                                       ...ALSO, + & - IN THE P-PART.   EDAT3260
D833     CH    A,=H'0'                 CHECK THE DIGIT COUNT...        EDAT3270
         BH    C110                    ...BR. TO TROUBLE IF .NE. 0.    EDAT3280
         B     D200                                                   EDAT3290
         SPACE 1                                                      EDAT3300
D834     TM    TC2,X'40'          (9,1)                               EDAT3310
         BO    D835                                                   EDAT3320
         B     C110                                                   EDAT3330
D835     NI    TC2,X'B7'               FORBID TWO +'S IN THE E-PART... *EDAT3340
                                       ...ALSO, + & - IN THE E-PART.   EDAT3350
         B     D833                                                   EDAT3360
         SPACE 1                                                      EDAT3370
D840     TM    TC2,X'20'          (10,0)                              EDAT3380
         BO    D843                                                   EDAT3390
         TM    TC2,X'10'          (11,1)                              EDAT3400
         BO    D842                                                   EDAT3410
         B     C110                                                   EDAT3420
D842     NI    TC2,X'6F'               FORBID - & + IN THE P-PART...  *EDAT3430
                                       ...ALSO, TWO -'S IN THE P-PART. EDAT3440
         NI    TC2,X'FE'               ALLOW NEG. INTEGER.             EDAT3450
         NI    TC3,X'DF'               ALLOW NEG. REAL.                EDAT3460
         B     D833                                                   EDAT3470
         SPACE 1                                                      EDAT3480
D843     TM    TC2,X'08'          (12,1)                              EDAT3490
         BO    D844                                                   EDAT3500
         B     C110                                                   EDAT3510
D844     NI    TC1,X'FB'               ALLOW NEG. EXP.                 EDAT3520
         NI    TC2,X'B7'               FORBID - & + IN THE E-PART...  *EDAT3530
                                       ...ALSO, TWO -'S IN THE E-PART. EDAT3540
         B     D833                                                   EDAT3550
         EJECT                                                        EDAT3560
D850     TM    TC2,X'04'          (13,1)                              EDAT3570
         BO    D851                                                   EDAT3580
         B     C110                                                   EDAT3590
D851     NI    TC2,X'F9'               FORBID TWO D'S IN AN ITEM...   *EDAT3600
                                       ...AND D & E IN AN ITEM.        EDAT3610
         NI    TC3,X'EF'               ALLOW LONG REAL STORAGE.        EDAT3620
D852     OI    TC1,X'60'               STOP THE FRACT. DIGIT COUNT... *EDAT3630
                                       ...AND ALLOW EXP. COMP.         EDAT3640
         OI    TC1,X'01'               SET UP EXP. SIGN CHECKS...      EDAT3650
         OI    TC2,X'20'               ...                             EDAT3660
         NI    TC1,X'FD'               FORBID . IN E-PART.             EDAT3670
         SR    A,A                     ZERO RA.                        EDAT3680
         B     D825                                                   EDAT3690
         SPACE 1                                                      EDAT3700
D860     TM    TC2,X'02'          (14,1)                              EDAT3710
         BO    D861                                                   EDAT3720
         B     C110                                                   EDAT3730
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D861     NI    TC2,X'F9'                FORBID TWO F'S IN AN ITEM...     *EDAT3740
                                        ...AND E & D IN AN ITEM.          EDAT3750
         B     D852                                                       EDAT3760
         SPACE 1                                                          EDAT3770
INT      LM    E,F,HUP                  LOAD THE LONG PRIMITIVE...        EDAT3780
         CH    E,=H'31'                 ...& CHECK THE H-ORDER PART.      EDAT3790
         BH    C110                     ...BR. TO TROUBLE IF TOO LARGE.   EDAT3800
         SLL   F,6                      LINK UP THE PARTS...              EDAT3810
         SRDL  E,6                      ...& R-SHIFT IT ALL INTO RF.      EDAT3820
         TM    TC2,X'01'         (15,1)                                   EDAT3830
         BO    IN20                                                       EDAT3840
         LNR   F,F                      MAKE THE RESULT NEG., IF REQ'D.   EDAT3850
IN20     C     9,72(4)                  CHECK FOR PRECEDING ERRORS...     EDAT3860
         BE    IN30                     ...BR. TO AVOID DATA LOADING.     EDAT3870
         ST    F,0(3)                   STASH THE INTEGER WHERE REQ'D.    EDAT3880
         LA    3,4(3)                   INCR. R3.                         EDAT3890
         SPACE 1                                                          EDAT3900
IN30     TM    TC3,X'80'         (16,1)                                   EDAT3910
         BO    DD                                                         EDAT3920
         B     BLNK                                                       EDAT3930
         SPACE 1                                                          EDAT3940
FLT      LD    2,=D'0.0'                FLOAT THE LONG PRIMITIVE...       EDAT3950
         LM    A,B,HOP                  ...                               EDAT3960
         LTR   E,A                      ...                               EDAT3970
         BZ    FL50                     ...                               EDAT3980
         SR    F,F                      ...                               EDAT3990
         SRDL  E,10                     ...                               EDAT4000
         STM   E,F,HUP                  ...                               EDAT4010
         OI    HOP,X'4F'                ...                               EDAT4020
         AD    2,DWD                    ...                               EDAT4030
FL50     LTR   B,B                      ...                               EDAT4040
         BZ    RL10                     ...                               EDAT4050
         SR    A,A                      ...                               EDAT4060
         STM   A,B,HOP                  ...                               EDAT4070
         OI    HOP,X'4E'                ...                               EDAT4080
         AD    2,DWD                    ...                               EDAT4090
         EJECT                                                            EDAT4100
         SPACE 2                                                          EDAT4110
RL10     LTDR  2,2                      CHECK THE FLOATED RESULT...       EDAT4120
         BZ    RL30                     ...BR. OUT TO AVOID SCALING.      EDAT4130
         L     C,EXP                    ...& SCALE AS REQ'D...            EDAT4140
         LTR   C,C                      ...                               EDAT4150
         BZ    RL20                     ...                               EDAT4160
         SPACE 1                                                          EDAT4170
         L     1,=A(LFH3)               ...                               EDAT4180
         TM    TC3,X'40'         (17,1)                                   EDAT4190
         BO    RL15                     ...                               EDAT4200
         SPACE 1                                                          EDAT4210
RL11     CH    C,=H'608'                ...                               EDAT4220
         BL    RL13                     ...                               EDAT4230
         SH    C,=H'600'                ...                               EDAT4240
         DD    2,600(1)                 ...                               EDAT4250
         B     RL11                                                       EDAT4260
RL13     DD    2,0(C,1)                 ...                               EDAT4270
         B     RL20                                                       EDAT4280
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         SPACE 1                                                        EDAT4290
RL15     CH    C,=H'600'                 ...                            EDAT4300
         BH    C110                      ...BR. TO TROUBLE IF TOO MUCH. EDAT4310
         MD    2,0(C,1)                  ...                            EDAT4320
         SPACE 1                                                        EDAT4330
RL20     TM    TC3,X'20'         (18,1)                                 EDAT4340
         BO    RL30                                                     EDAT4350
         LNDR  2,2                       MAKE IT NEG. IF REQ'D.         EDAT4360
         SPACE 1                                                        EDAT4370
RL30     TM    TC3,X'10'         (19,1)                                 EDAT4380
         BO    RL50                                                     EDAT4390
RL31     C     9,72(4)                   CHECK FOR PRECEDING ERRORS...  EDAT4400
         BE    IN30                      ...BR. TO AVOID DATA LOADING.  EDAT4410
         STD   2,0(3)                    STASH THE L-REAL WHERE REQ'D.  EDAT4420
         LA    3,8(3)                    INCR. R3.                      EDAT4430
         B     IN30                                                     EDAT4440
         SPACE 2                                                        EDAT4450
RL50     LTDR  2,2                       ROUND OUT AS REQ'D...          EDAT4460
         BZ    RL55                      ...                            EDAT4470
         STD   2,DWD                     ...                            EDAT4480
         NC    HOP,=X'FF000000'          ...                            EDAT4490
         NC    LOP,=X'80000000'          ...                            EDAT4500
         AD    2,DWD                     ...                            EDAT4510
RL55     C     9,72(4)                   CHECK FOR PRECEDING ERRORS...  EDAT4520
         BE    IN30                      ...BR. TO AVOID DATA LOADING.  EDAT4530
         STE   2,0(3)                    STORE THE S-REAL WHERE REQ'D.  EDAT4540
         LA    3,4(3)                    INCR. R3.                      EDAT4550
         B     IN30                                                     EDAT4560
         TITLE 'EDATA-H DATA PROC. SECTION'                             EDAT4570
*                   * * *                                               EDAT4580
         SPACE 1                                                        EDAT4590
HH       SR    A,A                       SET UP RA...                   EDAT4600
         XC    CL8,CL8                   ZERO LOP & HOLD.               EDAT4610
         OI    H510+1,X'F0'              ENABLE THE BR. AT H510.        EDAT4620
         SPACE 1                                                        EDAT4630
H200     LA    6,1(6)                    INCR., SAVE, & CHECK R6...     EDAT4640
         ST    6,44(4)                   ...                            EDAT4650
         CR    6,7                       ...                            EDAT4660
         BH    H600                      ...BR. OUT IF PAST CARD END.   EDAT4670
         SPACE 1                                                        EDAT4680
         CLI   0(6),C','                 CHECK THE DATA FIELD CHAR...   EDAT4690
         BL    H300                      ...BR. OUT IF .LT. 'COMMA'.    EDAT4700
         BE    H500                      ...BR. OUT IF .EQ. 'COMMA'.    EDAT4710
         CLI   0(6),C'0'                 ...                            EDAT4720
         BL    C110                      ...BR. TO TROUBLE IF .LT. 0.   EDAT4730
         CLI   0(6),C'9'                 ...                            EDAT4740
         BH    C110                      ...BR. TO TROUBLE IF .GT. 9.   EDAT4750
         MVN   0(1,8),0(6)               MOVE THE NUMERIC TO 'HOLD'.    EDAT4760
         LA    A,1(A)                    INCR. RA.                      EDAT4770
         SPACE 1                                                        EDAT4780
         L     F,LOP                     BUILD UP THE H-FORMATTED DATA... EDAT4790
         M     E,=F'10'                  ...                            EDAT4800
         A     F,HOLD                    ...                            EDAT4810
         CH    F,=H'32767'               ...                            EDAT4820
         BH    C110                      ...BR. TO TROUBLE IF .GT. 32767. EDAT4830
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         ST    F,LOP                    ...                             EDAT4840
         B     H200                                                     EDAT4850
         SPACE 1                                                        EDAT4860
H300     CLI   0(6),C' '                RECHECK THE DATA FIELD CHAR...  EDAT4870
         BE    H600                     ...BR. OUT IF BLANK.            EDAT4880
         CLI   0(6),C'+'                ...                             EDAT4890
         BE    H410                     ...BR. OUT IF PLUS SIGN.        EDAT4900
         CLI   0(6),C'-'                ...                             EDAT4910
         BE    H400                     ...BR. OUT IF MINUS SIGN.       EDAT4920
         B     C110                     ...BR. TO TROUBLE OTHERWISE.    EDAT4930
         SPACE 1                                                        EDAT4940
H400     NI    H510+1,X'0F'             DISABLE THE BR. AT H510.        EDAT4950
H410     CH    A,=H'0'                  CHECK FOR SIGN EMBEDMENT...     EDAT4960
         BH    C110                     ...BR. TO TROUBLE IF EMBEDDED.  EDAT4970
         B     H200                                                     EDAT4980
         SPACE 1                                                        EDAT4990
H500     C     9,72(4)                  CHECK FOR PRECEDING ERRORS...   EDAT5000
         BE    H530                     ...BR. TO AVOID DATA LOADING.   EDAT5010
         LH    B,LOP+2                                                  EDAT5020
H510     BC    15,H520                **                                EDAT5030
         LNR   B,B                       SET SIGN MINUS IF REQ'D.       EDAT5040
H520     STH   B,0(3)                    STORE THE H-INTEGER.           EDAT5050
         LA    3,2(3)                    INCR. R3.                      EDAT5060
H530     BC    15,HH                  **                                EDAT5070
         OI    H530+1,X'F0'              ENABLE THE BR. AT H530.        EDAT5080
         B     BLNK                                                     EDAT5090
         SPACE 1                                                        EDAT5100
H600     NI    H530+1,X'0F'              DISABLE THE BR. AT H530.       EDAT5110
         B     H500                                                     EDAT5120
         TITLE 'EDATA-X DATA PROC. SECTION'                             EDAT5130
         SPACE 1                                                        EDAT5140
*                 * * *                                                 EDAT5150
         SPACE 1                                                        EDAT5160
XX       SR    A,A                      ZERO RA...                      EDAT5170
         XC    CL8,CL8                  ZERO LOP & HOLD.                EDAT5180
         SPACE 1                                                        EDAT5190
X200     LA    6,1(6)                   INCR., SAVE, & CHECK R6...      EDAT5200
         ST    6,44(4)                  ...                             EDAT5210
         CR    6,7                      ...                             EDAT5220
         BH    X500                     ...BR. OUT IF PAST CARD END.    EDAT5230
         SPACE 1                                                        EDAT5240
         CLI   0(6),C','                CHECK THE DATA FIELD CHAR...    EDAT5250
         BE    X400                     ...BR. OUT IF COMMA.            EDAT5260
         CLI   0(6),C'0'                ...                             EDAT5270
         BL    X300                     ...BR. OUT IF .LT. 0.           EDAT5280
         CLI   0(6),C'9'                ...                             EDAT5290
         BH    C110                     ...BR. TO TROUBLE IF .GT. 9.    EDAT5300
         MVN   0(1,8),0(6)              MOVE THE NUMERIC TO 'HOLD'.     EDAT5310
         L     B,HOLD                   SET UP RB.                      EDAT5320
         SPACE 1                                                        EDAT5330
X220     LA    A,1(A)                   INCR. & CHECK R8...             EDAT5340
         CH    A,=H'8'                  ...                             EDAT5350
         BH    C110                     ...BR. TO TROUBLE IF .GT. 8.    EDAT5360
         SPACE 1                                                        EDAT5370
         L     C,LOP                    BUILD UP THE X.FORMATTED DATA... EDAT5380
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         SLL   C,4                      ...                              EDAT5390
         OR    C,B                      ...                              EDAT5400
         ST    C,LOP                    ...                              EDAT5410
         B     X200                     ...                              EDAT5420
         SPACE 1                                                         EDAT5430
X300     CLI   0(6),C' '                RECHECK THE DATA FIELD CHAR...   EDAT5440
         BE    X500                     ...BR. OUT IF BLANK.             EDAT5450
         CLI   0(6),C'A'                ...                              EDAT5460
         BL    C110                     ...BR. TO TROUBLE IF .LT. 'A'.   EDAT5470
         CLI   0(6),C'F'                ...                              EDAT5480
         BH    C110                     ...BR. TO TROUBLE IF .GT. 'F'.   EDAT5490
         MVN   0(1,8),0(6)              MOVE THE NUMERIC TO 'HOLD'.      EDAT5500
         L     B,HOLD                   PICK UP THE NUMERIC...           EDAT5510
         AH    B,=H'9'                  ...& REMOVE ITS BIAS.            EDAT5520
         B     X220                                                      EDAT5530
         SPACE 1                                                         EDAT5540
X400     C     9,72(4)                  CHECK FOR PRECEDING ERRORS...    EDAT5550
         BE    X410                     ...BR. TO AVOID DATA LOADING.    EDAT5560
         SPACE 1                                                         EDAT5570
         L     B,LOP                    STASH THE DATA WHERE REQ'D...    EDAT5580
         ST    B,0(3)                   ...                              EDAT5590
         LA    3,4(3)                   INCR. R3.                        EDAT5600
         SPACE 1                                                         EDAT5610
X410     BC    15,XX                  **                                 EDAT5620
         OI    X410+1,X'F0'             ENABLE THE BR. AT X410.          EDAT5630
         B     BLNK                                                      EDAT5640
         SPACE 1                                                         EDAT5650
X500     NI    X410+1,X'0F'             DISABLE THE BR. AT X410.         EDAT5660
         B     X400                                                      EDAT5670
         TITLE 'EDATA-ERASIBLE STORAGE AND CONSTANTS.'                   EDAT5680
         SPACE 1                                                         EDAT5690
DWD      DS    0D                                                        EDAT5700
CL16     DS    0CL16                                                     EDAT5710
HOP      DS    F                                                         EDAT5720
CL8      DS    0CL8                                                      EDAT5730
LOP      DS    F                                                         EDAT5740
HOLD     DS    0F                                                        EDAT5750
         DS    CL3                                                       EDAT5760
LOB      DS    C                                                         EDAT5770
EXP      DS    F                                                         EDAT5780
         SPACE 1                                                         EDAT5790
TCW      DS    0F                                                        EDAT5800
TC1      DS    C                                                         EDAT5810
TC2      DS    C                                                         EDAT5820
TC3      DS    C                                                         EDAT5830
TC4      DS    C                                                         EDAT5840
         SPACE 1                                                         EDAT5850
S100     DC    C' '                                                      EDAT5860
         DC    C'C'                                                      EDAT5870
         DC    C'D'                                                      EDAT5880
         DC    C'H'                                                      EDAT5890
         DC    C'R'                                                      EDAT5900
         DC    C'X'                                                      EDAT5910
         SPACE 1                                                         EDAT5920
S200     DC    C' '                                                      EDAT5930
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         DC    C'.'
         DC    C'+'
         DC    C'-'
         DC    C'D'
         DC    C'E'
         SPACE 1
         LTORG
         TITLE 'EDATA-CSECTS LFH2 AND LFH3.'
         SPACE 1
*                      * * * * * * * * *
         SPACE 1
LFH2     CSECT
FWD      DS    F                       +0
RD       DS    F                       +4
RZ       DS    4F                      +8
R1       DS    F                       +24
R2       DS    F                       +28
R3       DS    F                       +32
R4       DS    F                       +36
R5       DS    F                       +40
R6       DS    F                       +44
R7       DS    F                       +48
R8       DS    F                       +52
R9       DS    F                       +56
RY       DS    3F                      +60
N1       DS    F                       +72
N2       DS    F                       +76
N3       DS    F                       +80
N4       DS    F                       +84
CARD     DS    CL80                    +88
BLANK    DC    CL4' '
R30      DS    F                       +172
PSW      DS    2F                      +176
K3       DS    2H                      +184
CBLOCK   DS    4400F                   +188
         SPACE 1
*                      * * * * * * * * *
         SPACE 1
LFH3     CSECT
*                      TABLE OF 10**N.
*
TENS     DC    D'1.0E+0,1.0E+1,1.0E+2,1.0E+3,1.0E+4,1.0E+5'
         DC    D'1.0E+6,1.0E+7,1.0E+8,1.0E+9,1.0E+10'
         DC    D'1.0E+11,1.0E+12,1.0E+13,1.0E+14,1.0E+15'
         DC    D'1.0E+16,1.0E+17,1.0E+18,1.0E+19,1.0E+20'
         EJECT
         DC    D'1.0E+21,1.0E+22,1.0E+23,1.0E+24,1.0E+25'
         DC    D'1.0E+26,1.0E+27,1.0E+28,1.0E+29,1.0E+30'
         DC    D'1.0E+31,1.0E+32,1.0E+33,1.0E+34,1.0E+35'
         DC    D'1.0E+36,1.0E+37,1.0E+38,1.0E+39,1.0E+40'
         DC    D'1.0E+41,1.0E+42,1.0E+43,1.0E+44,1.0E+45'
         DC    D'1.0E+46,1.0E+47,1.0E+48,1.0E+49,1.0E+50'
         DC    D'1.0E+51,1.0E+52,1.0E+53,1.0E+54,1.0E+55'
         DC    D'1.0E+56,1.0E+57,1.0E+58,1.0E+59,1.0E+60'
         DC    D'1.0E+61,1.0E+62,1.0E+63,1.0E+64,1.0E+65'
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         DC    D'1.0E+66,1.0E+67,1.0E+68,1.0E+69,1.0E+70'                EDAT6490
         DC    D'1.0E+71,1.0E+72,1.0E+73,1.0E+74,1.0E+75'                EDAT6500
         END                                                             EDAT6510
/*
// EXEC ASSEMBLR,PARM='LOAD,DECK'
//SOURCE.SYSIN DD *
SPIE     TITLE '...DIAGNOSTIC SUPPRESSOR SUBPROGRAM...'                  SPIE0010
* 9/17/68 - L.F.H.                                                       SPIE0020
* MOD. 3/07/69 - L.F.H.                                                  SPIE0030
*                                                                        SPIE0040
* USAGE...CALL SPIE( LDW )                                               SPIE0050
*     WHERE LDW IS A PARAMETER CALLING FOR SETTING A NEW P.I.E. OR RE-   SPIE0060
* SETTING THE OLD P.I.E. DEPENDING ON WHETHER IT IS .GT. ZERO OR .LT.    SPIE0070
* ONE, RESPECTIVELY.  IF THE NEW P.I.E. HAS BEEN SET, IT REMAINS IN      SPIE0080
* EFFECT ON SUBSEQUENT CALLS ON SPIE WITH LDW .GT. ZERO; THE OLD P.I.E.  SPIE0090
* IS RESET IF A SUBSEQUENT CALL ON SPIE HAS LDW .LT. ONE.                SPIE0100
*                                                  ...GOOD LUCK-L.F.H.   SPIE0110
*                                                                        SPIE0120
SPIE     CSECT                                                           SPIE0130
         ENTRY YECH,R1                                                   SPIE0140
         USING *,15                                                      SPIE0150
         B     S100                                                      SPIE0160
         DC    CL6'5SPIE '                                               SPIE0170
SAREA    DS    18F                                                       SPIE0180
S100     STM   14,12,12(13)                                              SPIE0190
*                                                                        SPIE0200
         LA    12,SAREA                                                  SPIE0210
         ST    13,4(12)                                                  SPIE0220
         ST    12,8(13)                                                  SPIE0230
         LR    13,12                                                     SPIE0240
*                                                                        SPIE0250
         BALR  2,0                                                       SPIE0260
         USING *,2                                                       SPIE0270
         DROP  15                                                        SPIE0280
*                                                                        SPIE0290
         L     3,0(1)                                                    SPIE0300
         L     4,0(3)                                                    SPIE0310
         C     4,=F'1'                                                   SPIE0320
         BL    S300                                                      SPIE0330
*                                                                        SPIE0340
         L     4,FLAG                                                    SPIE0350
         C     4,=F'1'                                                   SPIE0360
         BE    S200                                                      SPIE0370
         MVC   FLAG,=F'1'                                                SPIE0380
*                                                                        SPIE0390
         SPIE  YECH,((1,15))                                             SPIE0400
         ST    1,R1                                                      SPIE0410
*                                                                        SPIE0420
S200     L     13,4(12)                                                  SPIE0430
         LM    14,12,12(13)                                              SPIE0440
         MVI   12(13),X'FF'                                              SPIE0450
YECH     BCR   15,14                                                     SPIE0460
*                                                                        SPIE0470
S300     L     4,FLAG                                                    SPIE0480
         C     4,=F'0'                                                   SPIE0490
```

```
         BE     S200                                                    SPIE0500
         L      1,R1                                                    SPIE0510
         SPIE   MF=(E,(1))                                              SPIE0520
         XC     FLAG,FLAG                                               SPIE0530
         B      S200                                                    SPIE0540
*                                                                       SPIE0550
R1       DS     F                                                       SPIE0560
FLAG     DC     F'0'                                                    SPIE0570
         LTORG                                                          SPIE0580
         END                                                            SPIE0590
/*
// EXEC ASSEMBLR,PARM='LOAD,DECK'
//SOURCE.SYSIN DD *
STIM     TITLE '...TIME INTERVAL MEASURING SUBPROGRAM...'               STIME010
* 6/14/68 - L.F.H.                                                      STIME020
* MOD. 8/30/68 - L.F.H.                                                 STIME030
*                                                                       STIME040
STIME    CSECT                                                          STIME050
         ENTRY TTIME,T1                                                 STIME060
         USING *,15                                                     STIME070
         B      S100                                                    STIME080
         DC     X'05'                                                   STIME090
         DC     CL5'STIME'                                              STIME100
S100     STM    14,12,12(13)                                            STIME110
         LA     15,TTIME-STIME(15)                                      STIME120
         USING TTIME,15                                                 STIME130
         NI     T102+1,X'0F'                                            STIME140
         MVC    T2,T1                                                   STIME150
         B      T100                                                    STIME160
*                                                                       STIME170
TTIME    STM    14,12,12(13)                                            STIME180
         L      3,0(1)                                                  STIME190
         L      4,T1                                                    STIME200
         OI     T102+1,X'F0'                                            STIME210
T100     LR     2,15                                                    STIME220
         USING TTIME,2                                                  STIME230
         DROP 15                                                        STIME240
         LA     12,SAREA                                                STIME250
         ST     13,4(12)                                                STIME260
         ST     12,8(13)                                                STIME270
         LR     13,12                                                   STIME280
T102     BC     0,T200                       **                         STIME290
*                                                                       STIME300
T103     STIMER TASK,RTN,TUINTVL=T2                                     STIME310
T105     L      13,4(12)                                                STIME320
         LM     14,12,12(13)                                            STIME330
         BCR    15,14                                                   STIME340
*                                                                       STIME350
T200     TTIMER CANCEL                                                  STIME360
         L      4,T1                                                    STIME370
         SR     4,0                                                     STIME380
         ST     0,T1                                                    STIME390
         ST     4,0(3)                                                  STIME400
         B      T105                                                    STIME410
*                                                                       STIME420
```

```
RTN      ABEND 4095,DUMP,STEP                                      STIME430
         EJECT                                                     STIME440
*                                                                  STIME450
T1       DC    F'138461538'          T-UNITS=60 MINUTES.           STIME460
T2       DS    F                                                   STIME470
SAREA    DS    18F                                                 STIME480
         END                                                       STIME490
/*
// EXEC ASSEMBLR,PARM='LOAD,DECK'
//SOURCE.SYSIN DD *
DATA     TITLE '...INITIAL DATA IN CSECTS DATA AND CONS...'        DATA0010
*                                                                  DATA0020
*   2/21/69 - L.F.H.                                               DATA0030
*   MOD. 9/03/69 - L.F.H.                                          DATA0040
*                                                                  DATA0050
DATA     CSECT                                                     DATA0060
*                                                                  DATA0070
Z        DC    240D'0.0',80C' '                                    DATA0080
*                                                                  DATA0090
*                        ...PROGRAM CONTROL PARAMETERS...          DATA0100
*                                                                  DATA0110
NEQ1     DC    F'3'          NO. OF 1ST PHASE DERIV. EQ'S.         DATA0120
NEQ2     DC    F'6'          NO. OF 2ND PHASE DERIV. EQ'S.         DATA0130
J1       DC    F'0'          BR. PARM. SET BY SUBP. SETH FOR SUBP. RK.  DATA0140
J2       DC    F'5'          1ST PHASE PRINT FREQ.                 DATA0150
J3       DC    F'5'          H ADJUST. PARM.                       DATA0160
J4       DC    F'0'          CASE NO.                              DATA0170
J5       DC    F'0'          2ND PHASE EULERIAN POLE INDICATOR.    DATA0180
*                                                                  DATA0190
*                        ...CONVERSION CONSTANTS...                DATA0200
*                                                                  DATA0210
CONS     CSECT                                                     DATA0220
TWPI     DC    D'6.283185307179586476'    2*PI                     DATA0230
CRTD     DC    D'57.29577951308232'       RADIANS TO DEGREES       DATA0240
CDTR     DC    D'1.745329251994330E-2'    DEGREES TO RADIANS       DATA0250
PID2     DC    D'1.570796326794897'       PI/2.0                   DATA0260
PID4     DC    D'.7853981633974483'       PI/4.0                   DATA0270
         END                                                       DATA0280
/*
// EXEC LINKGO
//GO.SYSUDUMP DD SYSOUT=A,SPACE=(TRK,(8))
//GO.DATA5 DD *
          ...JAVELIN ROC STUDY DATA - PART 1.1...                  JROC0010
                         ......                                    JROC0020
          NOMINAL DATA WITH RELEASE AT VARYING GAMMA ANGLES.       JROC0030
                         ......                                    JROC0040
1920     C'...JAVELIN ROC STUDY PART 1.1 - NO ALIGNMENT...'        JROC0050
8        D4.8828125D-4,9.5D0                 H0,Q1.                JROC0060
80       D.804167D0,.4286D0,1.456D0          D1,D2,D3.             JROC0070
136      D3.50333D0                          D8.                   JROC0080
160      D.4D0,.1178D0,.3466D0,.42D0         M,JCY1,JCY2,JCY3.     JROC0090
192      D0D0,.03219D0,0D0                   JCY4,JCY5,JCY6.       JROC0100
240      D7.5D0                              JVX1.                 JROC0110
328      D6D1,5D-6                           YT,YEPS.              JROC0120
352      D515D0                              AX1.                  JROC0130
```

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2012     D4                                             J2-PRINT FREQ.        JROC0140
2016     D15                                            J3-H ADJ. PARM.       JROC0150
177      R                                                                    JROC0160
2012     D32768                                         J2-PRINT FREQ.        JROC0170
328      D3D1                                           YT.                   JROC0180
77       R                                                                    JROC0190
328      D1.5D1                                         YT.                   JROC0200
77       R                                                                    JROC0210
328      D12.5D0                                        YT.                   JROC0220
77       R                                                                    JROC0230
328      D1D1                                           YT.                   JROC0240
77       R                                                                    JROC0250
                    ......                                                    JROC0260
                    ......                                                    JROC0270
          EFFECT OF CLAMSHELL DENSITY CHANGE TO 1.1 OF NOMINAL.               JROC0280
                    ......                                                    JROC0290
160      D.44D0,.1296D0,.3813D0,.462D0                  M,JCY1,JCY2,JCY3.     JROC0300
192      D0D0,.03541D0,0D0                              JCY4,JCY5,JCY6.       JROC0310
328      D6D1,5D-6                                      YT,YEPS.              JROC0320
2012     D4                                             J2-PRINT FREQ.        JROC0330
3170     R                                                                    JROC0340
2012     D32768                                         J2-PRINT FREQ.        JROC0350
328      D3D1                                           YT.                   JROC0360
70       R                                                                    JROC0370
328      D1.5D1                                         YT.                   JROC0380
70       R                                                                    JROC0390
328      D12.5D0                                        YT.                   JROC0400
70       R                                                                    JROC0410
328      D1D1                                           YT.                   JROC0420
70       R                                                                    JROC0430
                    ......                                                    JROC0440
          EFFECT OF CLAMSHELL DENSITY CHANGE TO 0.9 OF NOMINAL.               JROC0450
                    ......                                                    JROC0460
160      D.36D0,.1060D0,.3119D0,.378D0                  M,JCY1,JCY2,JCY3.     JROC0470
192      D0D0,.02897D0,0D0                              JCY4,JCY5,JCY6.       JROC0480
328      D6D1                                           YT.                   JROC0490
2012     D4                                             J2-PRINT FREQ.        JROC0500
4170     R                                                                    JROC0510
2012     D32768                                         J2-PRINT FREQ.        JROC0520
328      D3D1                                           YT.                   JROC0530
70       R                                                                    JROC0540
328      D1.5D1                                         YT.                   JROC0550
70       R                                                                    JROC0560
328      D12.5D0                                        YT.                   JROC0570
70       R                                                                    JROC0580
328      D1D1                                           YT.                   JROC0590
00       R          ...END OF JOB INPUT...                                    JROC0600
/*
                                                                                      1808 CARDS
```

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