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GEOMETRICAL DESCRIPTION FOR A PROPOSED AEROASSIST FLIGHT EXPERIMENT VEHICLE

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SUMMARY

One geometry currently under consideration for the Aeroassist Flight Experiment (AFE) vehicle is composed of several segments of simple general conics: an ellipsoidal nose tangent to an elliptical cone and a base skirt with the base plane raked relative to the body axis. An analytic representation for the body coordinates and first and second partial derivatives of this configuration has been developed. Equations are given which define the body radius and partial derivatives for a prescribed axial and circumferential position on the vehicle. The results for a sample case are tabulated and presented graphically.

INTRODUCTION

To further exploit the opportunities in near and far space, a new family of vehicles, known as aeroassist vehicles, have been proposed. A review of several aeroassist vehicle concepts is given by Walberg in reference 1. These vehicles will typically operate in the upper reaches of the atmosphere at velocities higher than those usually encountered by other reentry vehicles and utilize their aerodynamic characteristics to assist in carrying out orbital maneuvers associated with their mission.

One vehicle of this class that is of current interest is an aeroassist orbital transfer vehicle (AOTV) which will be used to transfer payload from low to high-Earth orbit and back. In returning from high to low-earth orbit, this vehicle will use the upper atmosphere to assist its retro rockets in reducing the vehicle speed to the Earth orbital velocity. This will decrease the amount of propellant required for this maneuver. It has been determined from previous studies[2] that a vehicle with L/D in the range of at least 0.2-0.4 is required to carry out this mission effectively. Vehicles that exhibit this range of L/D fall into the class of very blunt bodies such as 60 deg.-70 deg. sphere cones or other simple blunt shapes.

In order to better understand the flow field, pressures, loads, aerodynamics, and heating on vehicles of this class under flight conditions, an Aeroassist Flight Experiment (AFE) has been proposed by research organizations within the National Aeronautics and Space Administration. Although numerous body shapes have been considered, a configuration proposed by the Johnson Space Center[3] appears to be a leading candidate for the flight experiment. This configuration is a blunted, elliptic cone raked off at the base. This forebody is fitted with a skirt type afterbody having a generous corner radius to reduce the heating in the region of the forebody-afterbody juncture.

The purpose of the present paper is to provide a description of the "raked, elliptic cone" geometry proposed for the aeroassist flight experiment vehicle (AFE). Numerical flow field methods as well as structural analysis codes require a geometry subprogram which can provide body coordinates, slopes, and radii of curvature for the vehicle in question. These slopes and radii of curvature require first and second partial derivatives of the geometry. In the present paper, a piece-wise analytic description is presented for the proposed AFE vehicle in a cylindrical coordinate system, along with a listing of FORTRAN subroutines which will provide body coordinates and first and second partial derivatives for the body geometry.

SYMBOLS

a	Ellipsoid principle axis in x-direction
b	Ellipsoid principle axis in y-direction
c	Ellipsoid principle axis in z-direction
ℓ_{base}	Length of base plane in the plane of symmetry
R	Radius of circular arc for skirt
r	Radial distance from x-axis
x	Axial distance from vertex of elliptical cone
$\bar{x}$	Axial distance from nose of body
y	Vertical direction (normal to x-z plane)
z	Direction normal to x-y plane
δ	Rake angle
ε	Cone ellipticity ratio $\tan\theta_{xz}/\tan\theta_{xy}$
ε_b	Ellipsoid ellipticity in x-y plane, b/a
ϕ	Circumferential angle: ϕ = 90 deg., upper symmetry plane ϕ = 0 deg., planform plane ϕ = -90 deg., lower symmetry plane
τ	Angular extent of circular arc for ϕ = 90 deg. plane
θ	Half angle of elliptical cone in meridional plane

Subscripts:

b	Rearmost point of reference circle
c	Plane of tangency between ellipsoid and elliptical cone, foremost point of raked circle
E	Ellipsoid
m	Intersection of meridional cut with circle plane

m_2 Intersection of meridional cut with base plane

max The aftmost coordinate of the body

N Foremost point of body

R Intersection of circle plane with x-z plane

R_2 Intersection of base plane with x-z plane

xy Symmetry plane

xz Planform plane

O Center of ellipsoid

Os Center for circular arc

DESCRIPTION

One geometry currently under consideration for the Aeroassist Flight Experiment (AFE) vehicle is composed of several segments of simple general conics. Consider first an elliptical cone (see Figure 1) whose axis is the x-axis in a Cartesian x-y-z coordinate system. The apex of this cone lies at the origin of this coordinate system. The half-angle of this cone in a given meridional (ϕ = constant) plane is defined to be θ. In particular, the half-angle of this cone in the x-y plane is defined to be θ_{xy}, while its half-angle in the x-z plane is defined to be θ_{xz}. From these two angles, the cone ellipticity ratio ($\varepsilon = \tan\theta_{xy}/\tan\theta_{xz}$) is determined.

Now define a reference plane as one which is normal to the x-y plane and raked at an angle δ with the x-axis. The definition of the angle δ is constrained by the requirement that the intersection of the reference

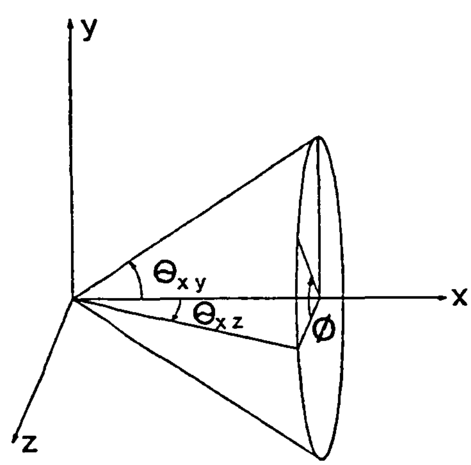

FIGURE 1: Elliptical Cone

plane with the elliptical cone forms a circle in the reference plane (see Figure 2). The diameter of this circle is taken to be unity so that the body coordinates can be readily non-dimensionalized by this diameter. The axial location of the intersection of this reference plane with the x-axis is defined to be x_R. The axial coordinate of the circle in a given meridional (ϕ = constant) plane is defined to be $x_m(\phi)$. In particular, the foremost axial coordinate of this circle (ϕ = 90 deg.) is defined to be x_m(90 deg.) = x_c, while its rearmost axial coordinate (ϕ = -90 deg.) is defined to be x_m(-90 deg.) = x_b.

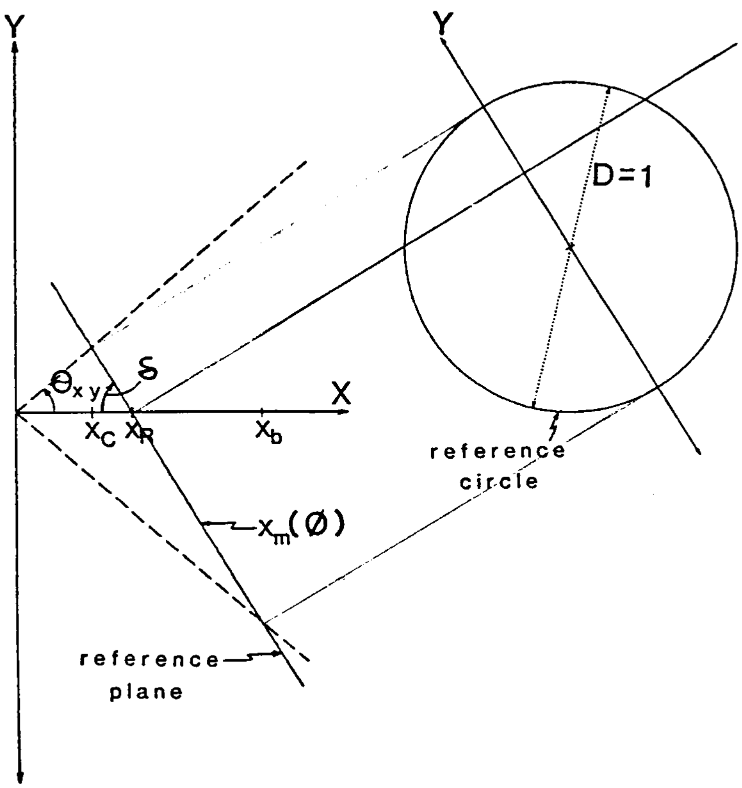

FIGURE 2: Reference Circle

The nose region of the pointed elliptical cone forward of the axial position x_c is replaced by a portion of an ellipsoid which is tangent to the elliptical cone in every meridional plane at $x = x_c$ (see Figure 3). The center of the ellipsoid is defined to be $(x_o,0,0)$. The shape of this ellipsoid (that is, the principle axes a,b,c) is therefore determined by its ellipticity in the x-y plane (ε_b), along with the shape of the original cone. The foremost axial coordinate of this ellipsoid (the nose of the body) is defined to be x_N.

The region of the elliptic cone between $x = x_c$ and the reference circle is a function of ϕ. For example, at ϕ = 90 deg., this region does not exist, while for ϕ = -90 deg., the axial extent of the region is $x_b - x_c$. For this portion of the geometry, part of the original elliptical cone defines the body surface.

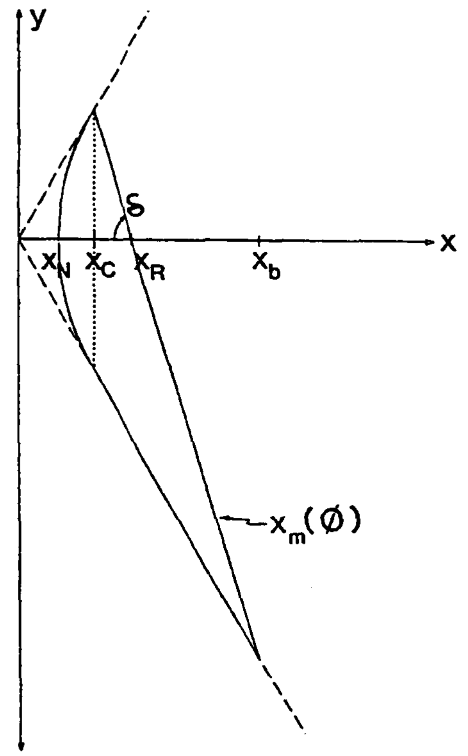

FIGURE 3: Ellipsoidal Nose

In each ϕ = constant plane, a circular arc of radius R is fit tangent to the elliptical cone at the reference circle, forming a skirt. The center of rotation of this arc (x_{os}, r_{os}) is a function of ϕ. The rear of the body is defined by a base plane which is parallel to the reference plane (see Figure 4). The angular extent (τ) of the circular arc in the ϕ = 90 deg. plane defines the distance between the reference plane and this base plane. Note that this resulting base plane is not a circle. The axial location of the intersection of this base plane with the x-z plane is defined to be x_{R2}, while the axial coordinate of the base (which is a function of ϕ) is defined for a given meridional cut to be $x_{m2}(\phi)$.

This geometry can be completely defined analytically simply by specifying $\theta_{xy}, \delta, R, \varepsilon_b$, and τ. Then the radius $r(x,\phi)$ in a cylindrical coordinate system, along with the first partial derivatives (r_x, r_ϕ) and second partial derivatives $(r_{xx}, r_{\phi\phi}, r_{x\phi})$, can be calculated for any position (x,ϕ) on the body.

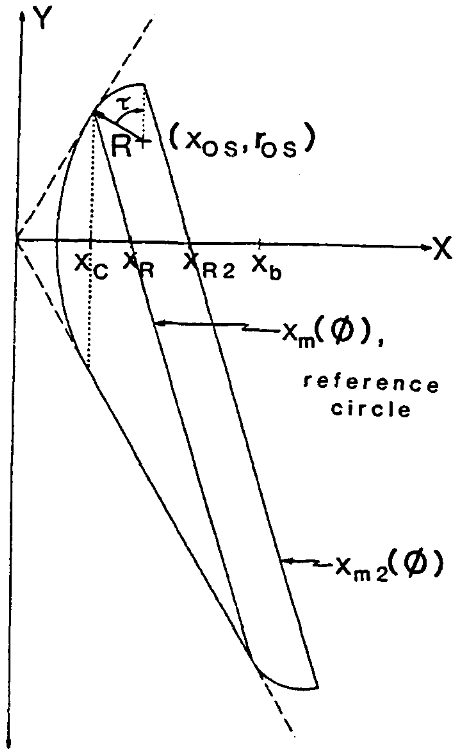

FIGURE 4: Complete Geometry

ANALYSIS

Several parameters are constant for the entire body, and thus may be calculated once at the beginning of the analysis. From the geometry of the intersection of the reference plane with the elliptical cone being a circle, it follows that

$$\cos^2 \delta = \cos^2 \theta_{xy} - \cot^2 \theta_{xz} \sin^2 \theta_{xy}$$

so that

$$\cot^2 \theta_{xz} = \frac{\cos^2 \theta_{xy} - \cos^2 \delta}{\sin^2 \theta_{xy}}$$

or

$$\sin^2 \theta_{xy} \cot^2 \theta_{xz} = \cos^2 \theta_{xy} - \cos^2 \delta$$

Thus,

$$\cos^2 \delta = 1 - \sin^2 \theta_{xy} - \cot^2 \theta_{xz} \sin^2 \theta_{xy}$$

so that

$$\sin^2 \theta_{xy} = \frac{1 - \cos^2 \delta}{1 + \cot^2 \theta_{xz}} = \frac{\sin^2 \delta \tan^2 \theta_{xz}}{1 + \tan^2 \theta_{xz}} = \sin^2 \theta_{xz} \sin^2 \delta$$

Therefore,

$$\sin \theta_{xz} = \frac{\sin \theta_{xy}}{\sin \delta} \tag{1}$$

Now define the cone ellipticity ratio to be

$$\varepsilon = \frac{\tan \theta_{xy}}{\tan \theta_{xz}} \tag{2}$$

The equation for the ellipsoid is

$$\left[\frac{x - x_o}{a}\right]^2 + \left[\frac{y}{b}\right]^2 + \left[\frac{z}{c}\right]^2 = 1 \tag{3}$$

where $(x_o,0,0)$ is the center of the ellipsoid. For $z = 0$, the ellipse in the x-y plane is

$$\left[\frac{x - x_o}{a}\right]^2 + \left[\frac{y}{b}\right]^2 = 1 \tag{4}$$

Differentiate equation (4) with respect to x to obtain

$$\left(\frac{\partial y}{\partial x}\right)_E = - \left[\frac{x - x_o}{y}\right] \frac{b^2}{a^2} \tag{5}$$

The slope of the elliptical cone in this plane is

$$\left(\frac{\partial y}{\partial x}\right)_c = \tan \theta_{xy} \tag{6}$$

In the tangency plane ($x = x_c$, $y = r_c$)

$$\left(\frac{\partial y}{\partial x}\right)_E = \left(\frac{\partial y}{\partial x}\right)_c$$

so that

$$\tan \theta_{xy} = \frac{-(x_c - x_o)}{x_c \tan \theta_{xy}} \frac{b^2}{a^2} \tag{7}$$

Thus,

$$x_c = \frac{x_o\, b^2/a^2}{\tan^2 \theta_{xy} + b^2/a^2} \tag{8}$$

In an analogous manner, for $y = 0$, the ellipse in the x-z plane is

$$\left[\frac{x - x_o}{a}\right]^2 + \left[\frac{z}{c}\right]^2 = 1$$

so that

$$\frac{\partial z}{\partial x} = \tan \theta_{xz} = -\left[\frac{x_c - x_o}{x_c \tan \theta_{xz}}\right] \frac{c^2}{a^2}$$

and

$$x_c = \frac{x_o\, c^2/a^2}{\tan^2 \theta_{xz} + c^2/a^2} \tag{9}$$

Equations (8) and (9) yield

$$c = b \frac{\tan \theta_{xz}}{\tan \theta_{xy}} = \frac{b}{\varepsilon} \tag{10}$$

and by definition

$$a = b/\varepsilon_b \tag{11}$$

Rearranging (7)

$$x_c - x_o = - \frac{x_c \tan^2 \theta_{xy}}{b^2/a^2} \tag{12}$$

From the geometry of the elliptical cone

$$y_c = x_c \tan \theta_{xy} \tag{13}$$

Substitute equations (12) and (13) into (4) to obtain

$$\frac{a^2 x_c^2 \tan^4 \theta_{xy}}{b^4} + \frac{x_c^2 \tan^2 \theta_{xy}}{b^2} = 1$$

Divide by the 2nd term and the result is

$$\frac{a^2}{b^2} \tan^2 \theta_{xy} + 1 = \frac{b^2}{x_c^2 \tan^2 \theta_{xy}}$$

so that

$$b = x_c \tan \theta_{xy} \left[\frac{a^2}{b^2} \tan^2 \theta_{xy} + 1\right]^{1/2} \tag{14}$$

From the geometry

$$\tan \delta = \frac{y_c}{x_R - x_c} = \frac{x_c \tan \theta_{xy}}{x_R - x_c}$$

and

$$\tan \delta = \frac{-y_b}{x_b - x_R} = \frac{x_b \tan \theta_{xy}}{x_b - x_R}$$

so that

$$x_c = \frac{x_R \tan \delta}{\tan \delta + \tan \theta_{xy}} \tag{15a}$$

and

$$x_b = \frac{x_R \tan \delta}{\tan \delta - \tan \theta_{xy}} \tag{15b}$$

Also from the geometry (for a reference circle of unit diameter)

$$y_c - y_b = -(x_c - x_b)\tan \theta_{xy} = \sin \delta \tag{16}$$

Substitute equations (15a) and (15b) into (16) to obtain

$$\frac{-x_R \tan \delta}{\tan \delta + \tan \theta_{xy}} + \frac{x_R \tan \delta}{\tan \delta - \tan \theta_{xy}} = \frac{\sin \delta}{\tan \theta_{xy}}$$

Thus,

$$x_R = \frac{\cos \delta}{2 \tan \theta_{xy} \tan \delta} (\tan^2 \delta - \tan^2 \theta_{xy})$$

$$= \frac{\sin \delta}{2 \tan \theta_{xy}} \left[1 - \frac{\tan^2 \theta_{xy}}{\tan^2 \delta} \right]$$

Substitute this expression into (15a) to obtain

$$x_c = \frac{\cos\,\delta}{2\,\tan\,\theta_{xy}}\,(\tan\,\delta\,-\,\tan\,\theta_{xy}) = \frac{\sin\,\delta\,-\,\cos\,\delta\,\tan\,\theta_{xy}}{2\,\tan\,\theta_{xy}}$$

Rearrange equation (12) to obtain

$$x_o = \frac{x_c\,(\tan^2\,\theta_{xy} + b^2/a^2)}{b^2/a^2} = x_c\left(1 + \tan^2\,\theta_{xy}/\varepsilon_b^2\right) \tag{17}$$

Now solve equation (14) for $\left(1 + \frac{\tan^2\,\theta_{xy}}{\varepsilon_b^2}\right)$ and substitute into equation (17) to obtain

$$x_o = \frac{b^2}{x_c\,\tan^2\,\theta_{xy}}$$

From the geometry

$$x_N = x_o - a$$

and

$$x_{R2} = x_R + \frac{R}{\sin\,\delta}\left[\cos\,(\tau - \theta_{xy} - \delta) - \cos\,(\theta_{xy} + \delta)\right]$$

The equations above are used to calculate θ_{xz}, ε, a, b, c, x_o, x_N, x_c, x_R, and x_{R2} from the input parameters θ_{xy}, δ, R, ε_b, and τ. The remaining parameters are dependent on the two independent body coordinates (x,ϕ). For purposes of analysis, the body is treated in three sections: the ellipsoidal nose, elliptical cone, and skirt. Two options are available for the afterbody. One option is to model the actual geometry so that the skirt curves back to the base plane. Another option is to replace the actual afterbody with a cylindrical afterbody extension. This extension begins at $x = x_{os}(\phi)$ so that it is tangent to the skirt. The equations for this afterbody extension are presented in this report, in addition to the equations for the actual afterbody.

Section I: Ellipsoidal Nose

Region: $x_N \leq x \leq x_C$

Let $y = r \sin \phi$ and $z = r \cos \phi$. Substitute these expressions into equation (3) to obtain

$$\left[\frac{x - x_o}{a}\right]^2 + r^2 \left[\frac{\sin^2 \phi}{b^2} + \frac{\cos^2 \phi}{c^2}\right] = 1$$

so that

$$r = \left\{\frac{1 - \left[\frac{x - x_o}{a}\right]^2}{\left[\frac{\sin^2 \phi}{b^2} + \frac{\cos^2 \phi}{c^2}\right]}\right\}^{1/2} \qquad (18)$$

Differentiate equation (18) with respect to x to obtain

$$\frac{\partial r}{\partial x} = \frac{\frac{x_o - x}{a^2}}{r\left[\frac{\sin^2 \phi}{b^2} + \frac{\cos^2 \phi}{c^2}\right]} \qquad (19)$$

Now differentiate equation (18) with respect to ϕ to obtain

$$\frac{\partial r}{\partial \phi} = \frac{r \sin \phi \cos \phi \left[\frac{1}{c^2} - \frac{1}{b^2}\right]}{\left[\frac{\sin^2 \phi}{b^2} + \frac{\cos^2 \phi}{c^2}\right]} \qquad (20)$$

Differentiate equation (19) with respect to x to obtain

$$\frac{\partial^2 r}{\partial x^2} = \frac{-\left\{\frac{1}{a^2} + \left[\frac{\sin^2 \phi}{b^2} + \frac{\cos^2 \phi}{c^2}\right]\left[\frac{\partial r}{\partial x}\right]^2\right\}}{r\left[\frac{\sin^2 \phi}{b^2} + \frac{\cos^2 \phi}{c^2}\right]}$$

Differentiate equation (20) with respect to x to obtain

$$\frac{\partial^2 r}{\partial x \partial \phi} = \frac{\left[\frac{1}{c^2} - \frac{1}{b^2}\right]\frac{\partial r}{\partial x} \sin (2\phi)}{2\left[\frac{\sin^2 \phi}{b^2} + \frac{\cos^2 \phi}{c^2}\right]}$$

Now differentiate equation (20) with respect to ϕ to obtain

$$\frac{\partial^2 r}{\partial \phi^2} = \frac{\left[\frac{1}{c^2} - \frac{1}{b^2}\right]\left[r \cos (2\phi) + \frac{3}{2}\frac{\partial r}{\partial \phi} \sin (2\phi)\right]}{\left[\frac{\sin^2 \phi}{b^2} + \frac{\cos^2 \phi}{c^2}\right]}$$

Section II: Elliptical Cone

Region: $x_c < x \leq x_m$

From the geometry

$$\cot^2 \theta = \cos^2 \phi \cot^2 \theta_{xz} + \sin^2 \phi \cot^2 \theta_{xy}$$

or

$$\cot^2 \theta = \cot^2 \theta_{xy} \left[\sin^2 \phi + \varepsilon^2 \cos^2 \phi\right] \tag{21}$$

so that

$$\tan \theta = \frac{\tan \theta_{xy}}{\left[\sin^2 \phi + \varepsilon^2 \cos^2 \phi\right]^{1/2}}$$

Differentiate equation (21) with respect to ϕ to obtain

$$\frac{d\theta}{d\phi} = \frac{\sin^3 \theta}{\cos \theta} \frac{\cos \phi \sin \phi \left[\varepsilon^2 - 1\right]}{\tan^2 \theta_{xy}} \tag{22}$$

Also from the geometry

$$x_m = \frac{x_R \tan \delta \cot \theta}{\sin \phi + \tan \delta \cot \theta} = \frac{x_R \sin \delta}{\sin \phi \cos \delta \tan \theta + \sin \delta} \tag{23}$$

and

$$r = \frac{x}{\left[\sin^2 \phi \cot^2 \theta_{xy} + \cos^2 \phi \cot^2 \theta_{xz}\right]^{1/2}} = x \tan \theta \tag{24}$$

Differentiate equation (24) with respect to x to obtain

$$\frac{\partial r}{\partial x} = \tan \theta \tag{25}$$

Now differentiate equation (24) with respect to ϕ to obtain

$$\frac{\partial r}{\partial \phi} = \frac{r^3}{x^2} \sin \phi \cos \phi \left[\cot^2 \theta_{xz} - \cot^2 \theta_{xy}\right]$$

$$= \frac{x \sin^3 \theta \sin \phi \cos \phi (\varepsilon^2 - 1)}{\cos^3 \theta \tan^2 \theta_{xy}} = \frac{x}{\cos^2 \theta} \frac{d\theta}{d\phi} \tag{26}$$

Differentiate equation (25) with respect to x to obtain

$$\frac{\partial^2 r}{\partial x^2} = 0$$

Now differentiate equation (25) with respect to ϕ to obtain

$$\frac{\partial^2 r}{\partial x \partial \phi} = \sec^2 \theta \frac{d\theta}{d\phi}$$

Differentiate equation (26) with respect to ϕ to obtain

$$\frac{\partial^2 r}{\partial \phi^2} = \frac{x}{\cos^2 \theta} \left[2 \tan \theta \left(\frac{d\theta}{d\phi} \right)^2 + \frac{d^2\theta}{d\phi^2} \right]$$

Differentiate equation (22) with respect to ϕ to obtain

$$\frac{d^2\theta}{d\phi^2} = \tan \theta \left[\frac{d\theta}{d\phi} \right]^2$$

$$+ \frac{(\varepsilon^2 - 1)\sin^2 \theta}{2 \cos \theta \tan^2 \theta_{xy}} \left[2\sin \theta \cos (2\phi) + 3\cos \theta \sin (2\phi) \frac{d\theta}{d\phi} \right]$$

Section III: Circular Arc Skirt

Region: $x_m < x \leqslant x_{m2}$, for base plane option

$x_m < x \leqslant x_{os}$, for cylindrical afterbody option

The equation of the circular arc is

$$(x - x_{os})^2 + (r - r_{os})^2 = R^2$$

where: (x_{os}, r_{os}) is the center of the circle;
R is the radius, an input parameter

Rearrange this equation to obtain

$$r = r_{os} + \left[R^2 - (x - x_{os})^2\right]^{1/2} \tag{27}$$

Differentiate equation (27) with respect to x to obtain

$$\frac{\partial r}{\partial x} = -\frac{x - x_{os}}{r - r_{os}} \tag{28}$$

Now differentiate equation (27) with respect to ϕ to obtain

$$\frac{\partial r}{\partial \phi} = \frac{\partial r_{os}}{\partial \phi} - \frac{\partial r}{\partial x}\frac{\partial x_{os}}{\partial \phi} \tag{29}$$

From the geometry

$$r_{os} = x_m \tan\theta - R\cos\theta$$

and (30)

$$x_{os} = x_m + R\sin\theta$$

Differentiate equation (30) with respect to x to obtain

$$\frac{\partial r_{os}}{\partial x} = 0 \qquad \text{and} \qquad \frac{\partial x_{os}}{\partial x} = 0$$

Since these partial derivatives with respect to x are equal to zero, the partial derivatives with respect to ϕ are actually total derivatives. Thus, differentiating (30) with respect to ϕ gives

$$\frac{dr_{os}}{d\phi} = \frac{dx_m}{d\phi}\tan\theta + \frac{d\theta}{d\phi}\left[\frac{x_m}{\cos^2\theta} + R\sin\theta\right] \tag{31a}$$

$$\frac{dx_{os}}{d\phi} = \frac{dx_m}{d\phi} + R\frac{d\theta}{d\phi}\cos\theta \tag{31b}$$

Differentiate equation (23) with respect to ϕ to obtain

$$\frac{dx_m}{d\phi} = \frac{-x_m^2}{x_R} \frac{\cos \delta}{\sin \delta} \left[\tan \theta \cos \phi + \frac{d\theta}{d\phi} \frac{\sin \phi}{\cos^2 \theta}\right] \tag{32}$$

Differentiate equation (28) again with respect to x to obtain

$$\frac{\partial^2 r}{\partial x^2} = \frac{1 + \left[\frac{\partial r}{\partial x}\right]^2}{r_{os} - r}$$

Now differentiate equation (28) with respect to ϕ to obtain

$$\frac{\partial^2 r}{\partial x \partial \phi} = \frac{\frac{dx_{os}}{d\phi} - \frac{\partial r}{\partial x}\left[\frac{\partial r}{\partial \phi} - \frac{dr_{os}}{d\phi}\right]}{r - r_{os}}$$

Differentiate equation (29) with respect to ϕ to obtain

$$\frac{\partial^2 r}{\partial \phi^2} = \frac{d^2 r_{os}}{d\phi^2} - \left[\frac{\partial r}{\partial x} \frac{d^2 x_{os}}{d\phi^2} + \frac{dx_{os}}{d\phi} \frac{\partial^2 r}{\partial x \partial \phi}\right]$$

Differentiate equation (31a) with respect to ϕ to obtain

$$\frac{d^2 r_{os}}{d\phi^2} = \frac{d^2 x_m}{d\phi^2} \tan \theta + \frac{d^2\theta}{d\phi^2}\left[R \sin \theta + \frac{x_m}{\cos^2 \theta}\right]$$

$$+ \left[R \cos \theta + 2x_m \frac{\tan \theta}{\cos^2 \theta}\right]\left(\frac{d\theta}{d\phi}\right)^2 + 2 \frac{dx_m}{d\phi} \frac{d\theta}{d\phi} \sec^2 \theta$$

and equation (31b) with respect to ϕ to obtain

$$\frac{d^2 x_{os}}{d\phi^2} = \frac{d^2 x_m}{d\phi^2} + R\left[\frac{d^2\theta}{d\phi^2}\cos\theta - \left(\frac{d\theta}{d\phi}\right)^2 \sin\theta\right]$$

Differentiate equation (32) with respect to ϕ to obtain

$$\frac{d^2 x_m}{d\phi^2} = \frac{2}{x_m}\left[\frac{dx_m}{d\phi}\right]^2 - \frac{x_m^2 \cos\delta}{x_R \sin\delta \cos^2\theta}\left\{2\,\frac{d\theta}{d\phi}\cos\phi\right.$$

$$\left. + \sin\phi\left[2\left(\frac{d\theta}{d\phi}\right)^2 \tan\theta + \frac{d^2\theta}{d\phi^2} - \sin\theta\cos\theta\right]\right\}$$

If the base plane option is exercised, the end of the circular arc skirt region is defined by

$$x_{m2} = x_{os} + \frac{\sin\delta\ V - W}{V} \tag{33}$$

where

$$U = \sin\delta(x_{r2} - x_{os}) - r_{os}\cos\delta\sin\phi$$

$$V = \sin^2\delta + \cos^2\delta\ \sin^2\phi$$

$$W = S[(U\sin\delta)^2 - V(U^2 - R^2\sin^2\phi\cos^2\delta)]^{1/2}$$

$$S = \mathrm{sign}\ (\phi)$$

Applying equations (33) and (27) at ϕ = 90 deg. and ϕ = – 90 deg. yields an expression for the length of the base plane in the plane of symmetry.

$$\ell_{base} = [\{x_m(\phi=90) - x_m(\phi=-90)\}^2 + \{r(\phi=90) + r(\phi=-90)\}^2]^{1/2}$$

Section IV: Cylindrical Afterbody Option

Region: $x > x_{os}$

Note: The equations for the base plane option are located in the Appendix.

For the cylindrical afterbody

$$r = r_{os} + R \tag{34}$$

Differentiate equation (34) with respect to x to obtain

$$\frac{\partial r}{\partial x} = 0 \tag{35}$$

Differentiate equation (34) with respect to ϕ to obtain

$$\frac{\partial r}{\partial \phi} = [x_m \sec^2 \theta + R \sin \theta]\frac{d\theta}{d\phi} + \tan \theta \frac{dx_m}{d\phi} \tag{36}$$

Differentiate equation (35) again with respect to x to obtain

$$\frac{\partial^2 r}{\partial x^2} = 0$$

Differentiate equation (36) with respect to x to obtain

$$\frac{\partial^2 r}{\partial x \partial \phi} = 0$$

Differentiate equation (36) again with respect to ϕ to obtain

$$\frac{\partial^2 r}{\partial \phi^2} = \tan \theta \frac{d^2 x_m}{d\phi^2} + 2 \frac{dx_m}{d\phi}\frac{d\theta}{d\phi} \sec^2 \theta + (x_m \sec^2 \theta + R\sin \theta)\frac{d^2\theta}{d\phi^2}$$

$$+ (2x_m \tan \theta \sec^2 \theta + R \cos \theta)\left(\frac{d\theta}{d\phi}\right)^2$$

RESULTS AND DISCUSSION

As a sample case, values for the body coordinates, first derivtives, and second derivatives are calculated at discrete locations over the range of $-90 \leq \phi \leq 90$ deg. and $x_N \leq x \leq x_{m2}(\phi)$. For this case, the base plane option is exercised in conjunction with the following values: $\tau = \theta_{xy} = 60$ deg., $\delta = 73$ deg., $R = 0.1$, and $\varepsilon_b = 1$. The results are tabulated in Tables 1 through 5 (for $\phi = 90, -90, 45, -45$, and 0 degrees, respectively), immediately following the concluding remarks. Figures 5, 6, 7, 8, and 9 illustrate the body shape, and axial distribution of first and second derivatives, for these same ϕ values. These figures are located after the Tables.

CONCLUDING REMARKS

A piecewise analytic representation for a "raked elliptic cone" geometry proposed for the Aeroassist Flight Experiment (AFE) vehicle has been developed. These expressions define the body coordinates and first and second partial derivatives for any prescribed axial and circumferential position on the vehicle.

APPENDIX: Base Plane Option

Region: $x_{m2} < x < x_{R2}, \quad \phi > 0$

$x = x_{R2} \quad , \quad \phi = 0$

$x_{R2} < x < x_{m2}, \quad \phi < 0$

From the geometry

$$r = \frac{\tan \delta}{\sin \phi} (x_{R2} - x) \tag{A-1}$$

Differentiate equation (A-1) with respect to x to obtain

$$\frac{\partial r}{\partial x} = - \frac{\tan \delta}{\sin \phi} \tag{A-2}$$

Differentiate equation (A-1) with respect to ϕ to obtain

$$\frac{\partial r}{\partial \phi} = - (x_{R2} - x) \tan \delta \frac{\cos \phi}{\sin^2 \phi} = - r \cot \phi \tag{A-3}$$

Differentiate equation (A-2) again with respect to x to obtain

$$\frac{\partial^2 r}{\partial x^2} = 0$$

Differentiate equation (A-3) with respect to x to obtain

$$\frac{\partial^2 r}{\partial x \partial \phi} = - \frac{\partial r}{\partial x} \cot \phi$$

Now differentiate equation (A-3) again with respect to ϕ to obtain

$$\frac{\partial^2 r}{\partial \phi^2} = r \csc^2 \phi - \frac{\partial r}{\partial \phi} \cot \phi$$

For $\phi < 0$, r is double valued. One surface is defined by the Base Plane equations, while the other is within either the Elliptical Cone or the Circular Arc Skirt region. The maximum axial distance on the body is $x = x_{m2}$ for $\phi = -90$ degrees.

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REFERENCES

1. Walberg, G. D., "A Survey of Aeroassisted Orbit Transfer," Journal of Spacecraft and Rockets, Vol. 22, No. 1, January-February 1985, pp. 3-18.

2. Talley, T. A., White, N. W., and Naftel, J. C., "Impact of Atmospheric Uncertainties and Viscous Interaction Effects on the Performance of Aeroassisted Orbital Transfer Vehicles," Thermal Design of Aeroassisted Orbital Transfer Vehicles; Progress in Astronautics and Aeronautics, Vol. 96, edited by H. F. Nelson, AIAA, New York, 1985, pp. 198-229.

3. Roberts, B. B., "Systems Analysis and Technology Development for the NASA Orbit Transfer Vehicle," AIAA Paper No. 85-0965, June 1985.

TABLE 1. Body Coordinates and Partial Derivatives for Sample Case (ϕ = 90 deg.)

Phi = 90. deg

X	R	Rx	Rphi	Rxx	Rxp	Rpp
.06960	0.00000	0.17000E+39	0.00000	-.17000E+39	0.0000	0.0000
.07107	0.03632	12.345	0.00000	-4223.2	0.0000	0.0124
.07254	0.05133	8.7080	0.00000	-1496.8	0.0000	0.0176
.07401	0.06281	7.0925	0.00000	-816.76	0.0000	0.0215
.07548	0.07247	6.1270	0.00000	-531.81	0.0000	0.0248
.07694	0.08096	5.4665	0.00000	-381.47	0.0000	0.0277
.07841	0.08861	4.9778	0.00000	-290.91	0.0000	0.0303
.07988	0.09563	4.5970	0.00000	-231.43	0.0000	0.0327
.08135	0.10215	4.2893	0.00000	-189.89	0.0000	0.0349
.08282	0.10826	4.0337	0.00000	-159.54	0.0000	0.0370
.08429	0.11402	3.8170	0.00000	-136.55	0.0000	0.0390
.08576	0.11949	3.6301	0.00000	-118.66	0.0000	0.0409
.08723	0.12469	3.4667	0.00000	-104.40	0.0000	0.0426
.08869	0.12968	3.3221	0.00000	-92.819	0.0000	0.0443
.09016	0.13446	3.1930	0.00000	-83.262	0.0000	0.0460
.09163	0.13906	3.0768	0.00000	-75.265	0.0000	0.0475
.09310	0.14350	2.9713	0.00000	-68.492	0.0000	0.0491
.09457	0.14780	2.8751	0.00000	-62.696	0.0000	0.0505
.09604	0.15195	2.7868	0.00000	-57.690	0.0000	0.0520
.09751	0.15599	2.7053	0.00000	-53.330	0.0000	0.0533
.09898	0.15990	2.6299	0.00000	-49.506	0.0000	0.0547
.10044	0.16371	2.5597	0.00000	-46.129	0.0000	0.0560
.10191	0.16743	2.4942	0.00000	-43.129	0.0000	0.0572
.10338	0.17104	2.4328	0.00000	-40.450	0.0000	0.0585
.10485	0.17457	2.3752	0.00000	-38.045	0.0000	0.0597
.10632	0.17802	2.3210	0.00000	-35.877	0.0000	0.0609
.10779	0.18139	2.2697	0.00000	-33.913	0.0000	0.0620
.10926	0.18469	2.2212	0.00000	-32.129	0.0000	0.0632
.11073	0.18792	2.1753	0.00000	-30.501	0.0000	0.0643
.11219	0.19108	2.1316	0.00000	-29.012	0.0000	0.0653
.11366	0.19418	2.0900	0.00000	-27.644	0.0000	0.0664
.11513	0.19722	2.0503	0.00000	-26.385	0.0000	0.0674
.11660	0.20021	2.0124	0.00000	-25.223	0.0000	0.0685
.11807	0.20314	1.9762	0.00000	-24.148	0.0000	0.0695
.11954	0.20601	1.9415	0.00000	-23.150	0.0000	0.0704
.12101	0.20884	1.9081	0.00000	-22.223	0.0000	0.0714
.12248	0.21162	1.8761	0.00000	-21.359	0.0000	0.0724
.12394	0.21435	1.8454	0.00000	-20.552	0.0000	0.0733
.12541	0.21704	1.8157	0.00000	-19.798	0.0000	0.0742
.12688	0.21969	1.7872	0.00000	-19.091	0.0000	0.0751
.12835	0.22229	1.7596	0.00000	-18.428	0.0000	0.0760
.12982	0.22485	1.7330	0.00000	-17.804	0.0000	0.0769
.13129	0.22732	1.6266	0.00000	-69.616	0.0000	0.0808
.13276	0.22964	1.5308	0.00000	-61.136	0.0000	0.0844
.13423	0.23183	1.4462	0.00000	-54.357	0.0000	0.0875
.13570	0.23389	1.3706	0.00000	-48.835	0.0000	0.0903
.13716	0.23585	1.3023	0.00000	-44.266	0.0000	0.0928
.13863	0.23772	1.2402	0.00000	-40.433	0.0000	0.0951
.14010	0.23950	1.1832	0.00000	-37.181	0.0000	0.0972
.14157	0.24120	1.1307	0.00000	-34.394	0.0000	0.0992
.14304	0.24282	1.0820	0.00000	-31.983	0.0000	0.1010

TABLE 1. (Continued)

X	R	Rx	Rphi	Rxx	Rxp	Rpp
.14451	0.24438	1.0366	0.00000	-29.881	0.0000	0.1026
.14598	0.24587	0.99411	0.00000	-28.035	0.0000	0.1042
.14745	0.24730	0.95415	0.00000	-26.405	0.0000	0.1057
.14891	0.24867	0.91645	0.00000	-24.957	0.0000	0.1071
.15038	0.24999	0.88076	0.00000	-23.663	0.0000	0.1084
.15185	0.25126	0.84688	0.00000	-22.503	0.0000	0.1097
.15332	0.25248	0.81461	0.00000	-21.457	0.0000	0.1109
.15479	0.25366	0.78380	0.00000	-20.511	0.0000	0.1120
.15626	0.25479	0.75431	0.00000	-19.653	0.0000	0.1131
.15773	0.25587	0.72603	0.00000	-18.872	0.0000	0.1141
.15920	0.25692	0.69884	0.00000	-18.158	0.0000	0.1151
.16066	0.25793	0.67266	0.00000	-17.505	0.0000	0.1161
.16213	0.25890	0.64739	0.00000	-16.905	0.0000	0.1170
.16360	0.25983	0.62297	0.00000	-16.354	0.0000	0.1179
.16507	0.26073	0.59933	0.00000	-15.846	0.0000	0.1188
.16654	0.26159	0.57640	0.00000	-15.377	0.0000	0.1197
.16801	0.26242	0.55414	0.00000	-14.943	0.0000	0.1205
.16948	0.26322	0.53249	0.00000	-14.542	0.0000	0.1213
.17095	0.26398	0.51141	0.00000	-14.169	0.0000	0.1221
.17241	0.26472	0.49086	0.00000	-13.824	0.0000	0.1228
.17388	0.26543	0.47079	0.00000	-13.503	0.0000	0.1236
.17535	0.26610	0.45118	0.00000	-13.204	0.0000	0.1243
.17682	0.26675	0.43199	0.00000	-12.926	0.0000	0.1250
.17829	0.26737	0.41320	0.00000	-12.667	0.0000	0.1257
.17976	0.26797	0.39477	0.00000	-12.427	0.0000	0.1264
.18123	0.26853	0.37669	0.00000	-12.202	0.0000	0.1271
.18270	0.26907	0.35892	0.00000	-11.993	0.0000	0.1277
.18416	0.26959	0.34145	0.00000	-11.799	0.0000	0.1284
.18563	0.27008	0.32425	0.00000	-11.618	0.0000	0.1290
.18710	0.27054	0.30732	0.00000	-11.450	0.0000	0.1296
.18857	0.27098	0.29061	0.00000	-11.293	0.0000	0.1302
.19004	0.27139	0.27414	0.00000	-11.148	0.0000	0.1308
.19151	0.27178	0.25786	0.00000	-11.014	0.0000	0.1315
.19298	0.27215	0.24178	0.00000	-10.890	0.0000	0.1320
.19445	0.27249	0.22587	0.00000	-10.775	0.0000	0.1326
.19592	0.27281	0.21012	0.00000	-10.670	0.0000	0.1332
.19738	0.27311	0.19452	0.00000	-10.573	0.0000	0.1338
.19885	0.27339	0.17906	0.00000	-10.485	0.0000	0.1344
.20032	0.27364	0.16372	0.00000	-10.405	0.0000	0.1349
.20179	0.27387	0.14849	0.00000	-10.333	0.0000	0.1355
.20326	0.27407	0.13336	0.00000	-10.268	0.0000	0.1361
.20473	0.27426	0.11832	0.00000	-10.211	0.0000	0.1366
.20620	0.27442	0.10336	0.00000	-10.161	0.0000	0.1372
.20767	0.27456	0.88472E-01	0.00000	-10.118	0.0000	0.1377
.20913	0.27468	0.73639E-01	0.00000	-10.081	0.0000	0.1383
.21060	0.27478	0.58854E-01	0.00000	-10.052	0.0000	0.1388
.21207	0.27485	0.44107E-01	0.00000	-10.029	0.0000	0.1394
.21354	0.27491	0.29389E-01	0.00000	-10.013	0.0000	0.1399
.21501	0.27494	0.14690E-01	0.00000	-10.003	0.0000	0.1404
.21648	0.27495	0.10431E-05	0.00000	-10.000	0.0000	0.1410

TABLE 2. Body Coordinates and Partial Derivatives for Samples Case (ϕ = - 90 deg.)

Phi = -90. deg

X	R	Rx	Rphi	Rxx	Rxp	Rpp
.06960	0.00000	0.17000E+39	0.00000	-.17000E+39	0.0000	0.0000
.07428	0.06476	6.8752	0.00000	-745.36	0.0000	0.0221
.07897	0.09134	4.8230	0.00000	-265.61	0.0000	0.0312
.08365	0.11157	3.9063	0.00000	-145.73	0.0000	0.0382
.08834	0.12849	3.3555	0.00000	-95.409	0.0000	0.0439
.09302	0.14328	2.9766	0.00000	-68.817	0.0000	0.0490
.09771	0.15653	2.6946	0.00000	-52.774	0.0000	0.0535
.10239	0.16862	2.4737	0.00000	-42.219	0.0000	0.0577
.10708	0.17977	2.2941	0.00000	-34.838	0.0000	0.0615
.11176	0.19016	2.1442	0.00000	-29.435	0.0000	0.0650
.11645	0.19990	2.0163	0.00000	-25.340	0.0000	0.0684
.12113	0.20908	1.9053	0.00000	-22.146	0.0000	0.0715
.12582	0.21777	1.8078	0.00000	-19.599	0.0000	0.0745
.13050	0.22604	1.7321	0.00000	0.00000E+00	0.0000	0.0773
.13519	0.23415	1.7321	0.00000	0.00000E+00	0.0000	0.0801
.13987	0.24227	1.7321	0.00000	0.00000E+00	0.0000	0.0828
.14456	0.25038	1.7321	0.00000	0.00000E+00	0.0000	0.0856
.14924	0.25850	1.7321	0.00000	0.00000E+00	0.0000	0.0884
.15393	0.26661	1.7321	0.00000	0.00000E+00	0.0000	0.0912
.15861	0.27473	1.7321	0.00000	0.00000E+00	0.0000	0.0939
.16330	0.28284	1.7321	0.00000	0.00000E+00	0.0000	0.0967
.16798	0.29095	1.7321	0.00000	0.00000E+00	0.0000	0.0995
.17267	0.29907	1.7321	0.00000	0.00000E+00	0.0000	0.1023
.17735	0.30718	1.7321	0.00000	0.00000E+00	0.0000	0.1050
.18204	0.31530	1.7321	0.00000	0.00000E+00	0.0000	0.1078
.18672	0.32341	1.7321	0.00000	0.00000E+00	0.0000	0.1106
.19141	0.33153	1.7321	0.00000	0.00000E+00	0.0000	0.1134
.19609	0.33964	1.7321	0.00000	0.00000E+00	0.0000	0.1161
.20078	0.34775	1.7321	0.00000	0.00000E+00	0.0000	0.1189
.20546	0.35587	1.7321	0.00000	0.00000E+00	0.0000	0.1217
.21015	0.36398	1.7321	0.00000	0.00000E+00	0.0000	0.1245
.21483	0.37210	1.7321	0.00000	0.00000E+00	0.0000	0.1272
.21952	0.38021	1.7321	0.00000	0.00000E+00	0.0000	0.1300
.22420	0.38833	1.7321	0.00000	0.00000E+00	0.0000	0.1328
.22889	0.39644	1.7321	0.00000	0.00000E+00	0.0000	0.1356
.23357	0.40456	1.7321	0.00000	0.00000E+00	0.0000	0.1383
.23826	0.41267	1.7321	0.00000	0.00000E+00	0.0000	0.1411
.24294	0.42078	1.7321	0.00000	0.00000E+00	0.0000	0.1439
.24763	0.42890	1.7321	0.00000	0.00000E+00	0.0000	0.1467
.25231	0.43701	1.7321	0.00000	0.00000E+00	0.0000	0.1494
.25699	0.44513	1.7321	0.00000	0.00000E+00	0.0000	0.1522
.26168	0.45324	1.7321	0.00000	0.00000E+00	0.0000	0.1550
.26636	0.46136	1.7321	0.00000	0.00000E+00	0.0000	0.1577
.27105	0.46947	1.7321	0.00000	0.00000E+00	0.0000	0.1605
.27573	0.47759	1.7321	0.00000	0.00000E+00	0.0000	0.1633
.28042	0.48570	1.7321	0.00000	0.00000E+00	0.0000	0.1661
.28510	0.49381	1.7321	0.00000	0.00000E+00	0.0000	0.1688
.28979	0.50193	1.7321	0.00000	0.00000E+00	0.0000	0.1716
.29447	0.51004	1.7321	0.00000	0.00000E+00	0.0000	0.1744
.29916	0.51816	1.7321	0.00000	0.00000E+00	0.0000	0.1772
.30384	0.52627	1.7321	0.00000	0.00000E+00	0.0000	0.1799

TABLE 2. (Continued)

X	R	Rx	Rphi	Rxx	Rxp	Rpp
.30853	0.53439	1.7321	0.00000	0.00000E+00	0.0000	0.1827
.31321	0.54250	1.7321	0.00000	0.00000E+00	0.0000	0.1855
.31790	0.55062	1.7321	0.00000	0.00000E+00	0.0000	0.1883
.32258	0.55873	1.7321	0.00000	0.00000E+00	0.0000	0.1910
.32727	0.56684	1.7321	0.00000	0.00000E+00	0.0000	0.1938
.33195	0.57496	1.7321	0.00000	0.00000E+00	0.0000	0.1966
.33664	0.58307	1.7321	0.00000	0.00000E+00	0.0000	0.1994
.34132	0.59119	1.7321	0.00000	0.00000E+00	0.0000	0.2021
.34601	0.59930	1.7321	0.00000	0.00000E+00	0.0000	0.2049
.35069	0.60742	1.7321	0.00000	0.00000E+00	0.0000	0.2077
.35538	0.61553	1.7321	0.00000	0.00000E+00	0.0000	0.2105
.36006	0.62365	1.7321	0.00000	0.00000E+00	0.0000	0.2132
.36475	0.63176	1.7321	0.00000	0.00000E+00	0.0000	0.2160
.36943	0.63987	1.7321	0.00000	0.00000E+00	0.0000	0.2188
.37412	0.64799	1.7321	0.00000	0.00000E+00	0.0000	0.2216
.37880	0.65610	1.7321	0.00000	0.00000E+00	0.0000	0.2243
.38349	0.66422	1.7321	0.00000	0.00000E+00	0.0000	0.2271
.38817	0.67233	1.7321	0.00000	0.00000E+00	0.0000	0.2299
.39286	0.68045	1.7321	0.00000	0.00000E+00	0.0000	0.2327
.39754	0.68856	1.7321	0.00000	0.00000E+00	0.0000	0.2354
.40223	0.69668	1.7321	0.00000	0.00000E+00	0.0000	0.2382
.40691	0.70479	1.7321	0.00000	0.00000E+00	0.0000	0.2410
.41160	0.71290	1.7321	0.00000	0.00000E+00	0.0000	0.2438
.41628	0.72102	1.7321	0.00000	0.00000E+00	0.0000	0.2465
.42097	0.72913	1.7321	0.00000	0.00000E+00	0.0000	0.2493
.42565	0.73683	1.4997	0.00000	-58.566	0.0000	0.1791
.43033	0.74328	1.2678	0.00000	-42.100	0.0000	0.1083
.43502	0.74880	1.0946	0.00000	-32.592	0.0000	0.0554
.43970	0.75360	0.95713	0.00000	-26.523	0.0000	0.0134
.44439	0.75781	0.84315	0.00000	-22.379	0.0000	-0.0214
.44907	0.76152	0.74563	0.00000	-19.409	0.0000	-0.0511
.45376	0.76481	0.66011	0.00000	-17.203	0.0000	-0.0773
.45844	0.76772	0.58362	0.00000	-15.522	0.0000	-0.1006
.46313	0.77029	0.51409	0.00000	-14.216	0.0000	-0.1219
.46781	0.77255	0.44999	0.00000	-13.186	0.0000	-0.1414
.47250	0.77451	0.39021	0.00000	-12.369	0.0000	-0.1597
.47718	0.77621	0.33384	0.00000	-11.718	0.0000	-0.1769
.48187	0.77765	0.28021	0.00000	-11.201	0.0000	-0.1933
.48655	0.77884	0.22872	0.00000	-10.795	0.0000	-0.2090
.49124	0.77979	0.17891	0.00000	-10.484	0.0000	-0.2242
.49592	0.78051	0.13036	0.00000	-10.256	0.0000	-0.2390
.50061	0.78101	0.82701E-01	0.00000	-10.103	0.0000	-0.2536
.50529	0.78129	0.35594E-01	0.00000	-10.019	0.0000	-0.2680
.50998	0.78135	-.11278E-01	0.00000	-10.002	0.0000	-0.2823
.51466	0.78118	-.58224E-01	0.00000	-10.051	0.0000	-0.2966
.51935	0.78080	-.10556	0.00000	-10.168	0.0000	-0.3111
.52403	0.78019	-.15360	0.00000	-10.356	0.0000	-0.3257
.52872	0.77936	-.20271	0.00000	-10.623	0.0000	-0.3407
.53340	0.77829	-.25327	0.00000	-10.977	0.0000	-0.3562
.53809	0.77698	-.30573	0.00000	-11.434	0.0000	-0.3722

TABLE 3. Body Coordinates and Partial Derivatives for Sample Case (ϕ = 45 deg.)

Phi = 45. deg

X	R	Rx	Rphi	Rxx	Rxp	Rpp
.06960	0.00000	0.17000E+39	0.00000	-.17000E+39	0.0000	0.0000
.07122	0.04183	12.927	-.00863	-4024.0	-2.6658	0.0053
.07283	0.05910	9.1162	-.01219	-1426.5	-1.8799	0.0075
.07444	0.07232	7.4231	-.01491	-778.61	-1.5308	0.0092
.07606	0.08343	6.4111	-.01721	-507.09	-1.3221	0.0106
.07767	0.09320	5.7185	-.01922	-363.83	-1.1793	0.0119
.07929	0.10200	5.2059	-.02103	-277.53	-1.0736	0.0130
.08090	0.11007	4.8064	-.02270	-220.84	-0.9912	0.0140
.08252	0.11756	4.4835	-.02424	-181.25	-0.9246	0.0150
.08413	0.12458	4.2153	-.02569	-152.31	-0.8693	0.0159
.08575	0.13120	3.9878	-.02706	-130.40	-0.8224	0.0167
.08736	0.13748	3.7915	-.02835	-113.34	-0.7819	0.0175
.08898	0.14346	3.6199	-.02958	-99.746	-0.7465	0.0183
.09059	0.14918	3.4680	-.03076	-88.705	-0.7152	0.0190
.09221	0.15467	3.3323	-.03190	-79.592	-0.6872	0.0197
.09382	0.15995	3.2101	-.03298	-71.966	-0.6620	0.0204
.09544	0.16504	3.0992	-.03404	-65.507	-0.6391	0.0211
.09705	0.16997	2.9980	-.03505	-59.979	-0.6182	0.0217
.09867	0.17473	2.9051	-.03603	-55.204	-0.5991	0.0223
.10028	0.17935	2.8194	-.03699	-51.045	-0.5814	0.0229
.10190	0.18384	2.7400	-.03791	-47.397	-0.5650	0.0235
.10351	0.18821	2.6661	-.03881	-44.176	-0.5498	0.0240
.10513	0.19246	2.5971	-.03969	-41.314	-0.5356	0.0246
.10674	0.19660	2.5325	-.04054	-38.757	-0.5222	0.0251
.10836	0.20064	2.4718	-.04138	-36.463	-0.5097	0.0256
.10997	0.20458	2.4146	-.04219	-34.394	-0.4979	0.0261
.11159	0.20844	2.3606	-.04298	-32.520	-0.4868	0.0266
.11320	0.21221	2.3094	-.04376	-30.818	-0.4763	0.0271
.11482	0.21590	2.2609	-.04452	-29.264	-0.4662	0.0275
.11643	0.21951	2.2149	-.04527	-27.843	-0.4567	0.0280
.11805	0.22305	2.1710	-.04600	-26.537	-0.4477	0.0285
.11966	0.22653	2.1291	-.04671	-25.336	-0.4391	0.0289
.12128	0.22993	2.0891	-.04742	-24.227	-0.4308	0.0293
.12289	0.23327	2.0508	-.04811	-23.200	-0.4229	0.0298
.12451	0.23656	2.0141	-.04878	-22.248	-0.4153	0.0302
.12612	0.23978	1.9789	-.04945	-21.362	-0.4081	0.0306
.12774	0.24295	1.9451	-.05010	-20.537	-0.4011	0.0310
.12935	0.24606	1.9125	-.05074	-19.767	-0.3944	0.0314
.13097	0.24914	1.9023	-.05138	0.00000E+00	-0.3923	0.0318
.13258	0.25221	1.9023	-.05201	0.00000E+00	-0.3923	0.0322
.13420	0.25528	1.9023	-.05264	0.00000E+00	-0.3923	0.0326
.13581	0.25835	1.9023	-.05328	0.00000E+00	-0.3923	0.0330
.13743	0.26143	1.9023	-.05391	0.00000E+00	-0.3923	0.0334
.13904	0.26450	1.9023	-.05454	0.00000E+00	-0.3923	0.0337
.14066	0.26757	1.9023	-.05518	0.00000E+00	-0.3923	0.0341
.14227	0.27054	1.7649	-.06024	-83.466	-3.0475	-0.0406
.14389	0.27328	1.6407	-.06477	-70.934	-2.5899	-0.0154
.14550	0.27584	1.5341	-.06866	-61.413	-2.2423	0.0045
.14712	0.27825	1.4412	-.07205	-53.976	-1.9708	0.0208
.14873	0.28051	1.3590	-.07506	-48.034	-1.7538	0.0343
.15035	0.28264	1.2855	-.07774	-43.197	-1.5772	0.0458

TABLE 3. (Continued)

X	R	Rx	Rphi	Rxx	Rxp	Rpp
.15196	0.28466	1.2190	-.08017	-39.197	-1.4312	0.0557
.15358	0.28658	1.1585	-.08238	-35.844	-1.3087	0.0643
.15519	0.28841	1.1030	-.08440	-33.000	-1.2049	0.0719
.15681	0.29015	1.0517	-.08628	-30.564	-1.1159	0.0786
.15842	0.29180	1.0041	-.08801	-28.458	-1.0391	0.0847
.16004	0.29339	0.95963	-.08964	-26.623	-0.9721	0.0901
.16165	0.29491	0.91797	-.09116	-25.013	-0.9133	0.0951
.16327	0.29636	0.87874	-.09259	-23.592	-0.8614	0.0997
.16488	0.29775	0.84168	-.09394	-22.330	-0.8153	0.1039
.16650	0.29908	0.80654	-.09523	-21.205	-0.7742	0.1078
.16811	0.30035	0.77313	-.09645	-20.195	-0.7374	0.1115
.16973	0.30157	0.74126	-.09761	-19.287	-0.7042	0.1148
.17134	0.30275	0.71079	-.09872	-18.467	-0.6743	0.1180
.17296	0.30387	0.68157	-.09979	-17.724	-0.6471	0.1210
.17457	0.30495	0.65350	-.10081	-17.048	-0.6224	0.1238
.17619	0.30598	0.62648	-.10180	-16.432	-0.6000	0.1265
.17780	0.30697	0.60040	-.10275	-15.869	-0.5794	0.1290
.17942	0.30792	0.57520	-.10367	-15.353	-0.5606	0.1314
.18103	0.30883	0.55079	-.10456	-14.880	-0.5433	0.1337
.18265	0.30970	0.52712	-.10543	-14.445	-0.5274	0.1359
.18426	0.31053	0.50411	-.10627	-14.045	-0.5128	0.1380
.18588	0.31133	0.48174	-.10709	-13.676	-0.4993	0.1400
.18749	0.31209	0.45993	-.10788	-13.335	-0.4869	0.1420
.18911	0.31282	0.43865	-.10866	-13.021	-0.4754	0.1439
.19072	0.31351	0.41786	-.10942	-12.730	-0.4648	0.1457
.19234	0.31417	0.39752	-.11016	-12.462	-0.4550	0.1474
.19395	0.31479	0.37760	-.11089	-12.213	-0.4459	0.1491
.19557	0.31538	0.35806	-.11160	-11.984	-0.4375	0.1507
.19718	0.31595	0.33888	-.11230	-11.771	-0.4298	0.1523
.19880	0.31648	0.32003	-.11299	-11.575	-0.4226	0.1539
.20041	0.31698	0.30149	-.11367	-11.394	-0.4160	0.1554
.20203	0.31745	0.28322	-.11433	-11.227	-0.4099	0.1569
.20364	0.31790	0.26522	-.11499	-11.073	-0.4043	0.1583
.20526	0.31831	0.24745	-.11564	-10.932	-0.3992	0.1597
.20687	0.31870	0.22990	-.11628	-10.803	-0.3944	0.1611
.20849	0.31905	0.21255	-.11691	-10.685	-0.3901	0.1624
.21010	0.31938	0.19538	-.11754	-10.578	-0.3862	0.1637
.21172	0.31968	0.17838	-.11816	-10.481	-0.3827	0.1650
.21333	0.31996	0.16152	-.11878	-10.394	-0.3795	0.1663
.21495	0.32021	0.14480	-.11939	-10.316	-0.3767	0.1675
.21656	0.32043	0.12820	-.11999	-10.248	-0.3742	0.1688
.21818	0.32062	0.11170	-.12060	-10.188	-0.3720	0.1700
.21979	0.32079	0.95290E-01	-.12120	-10.137	-0.3701	0.1712
.22141	0.32093	0.78955E-01	-.12179	-10.094	-0.3685	0.1723
.22302	0.32104	0.62684E-01	-.12239	-10.059	-0.3673	0.1735
.22464	0.32113	0.46461E-01	-.12298	-10.032	-0.3663	0.1746
.22625	0.32119	0.30275E-01	-.12357	-10.014	-0.3656	0.1758
.22787	0.32123	0.14113E-01	-.12416	-10.003	-0.3652	0.1769
.22948	0.32124	-.20376E-02	-.12475	-10.000	-0.3651	0.1780
.23110	0.32122	-.18190E-01	-.12534	-10.005	-0.3653	0.1791

TABLE 4. Body Coordinates and Partial Derivatives for Sample Case (ϕ = - 45 deg.)

Phi = -45. deg

X	R	Rx	Rphi	Rxx	Rxp	Rpp
.06960	0.00000	0.17000E+39	0.00000	-.17000E+39	0.0000	0.0000
.07341	0.06414	8.3898	0.01323	-1116.3	1.7301	0.0082
.07721	0.09051	5.8944	0.01866	-397.19	1.2155	0.0115
.08102	0.11061	4.7815	0.02281	-217.60	0.9860	0.0141
.08482	0.12745	4.1138	0.02628	-142.25	0.8483	0.0163
.08863	0.14219	3.6552	0.02932	-102.44	0.7538	0.0181
.09244	0.15542	3.3144	0.03205	-78.439	0.6835	0.0198
.09624	0.16751	3.0478	0.03454	-62.654	0.6285	0.0214
.10005	0.17869	2.8315	0.03685	-51.618	0.5839	0.0228
.10385	0.18911	2.6511	0.03900	-43.545	0.5467	0.0241
.10766	0.19890	2.4976	0.04102	-37.426	0.5150	0.0254
.11147	0.20815	2.3646	0.04292	-32.656	0.4876	0.0266
.11527	0.21692	2.2478	0.04473	-28.852	0.4635	0.0277
.11908	0.22528	2.1440	0.04646	-25.760	0.4421	0.0287
.12288	0.23326	2.0510	0.04810	-23.205	0.4230	0.0298
.12669	0.24090	1.9669	0.04968	-21.066	0.4056	0.0307
.13050	0.24824	1.9023	0.05119	0.00000E+00	0.3923	0.0317
.13430	0.25548	1.9023	0.05269	0.00000E+00	0.3923	0.0326
.13811	0.26272	1.9023	0.05418	0.00000E+00	0.3923	0.0335
.14192	0.26996	1.9023	0.05567	0.00000E+00	0.3923	0.0344
.14572	0.27720	1.9023	0.05716	0.00000E+00	0.3923	0.0354
.14953	0.28444	1.9023	0.05866	0.00000E+00	0.3923	0.0363
.15333	0.29168	1.9023	0.06015	0.00000E+00	0.3923	0.0372
.15714	0.29892	1.9023	0.06164	0.00000E+00	0.3923	0.0381
.16095	0.30616	1.9023	0.06314	0.00000E+00	0.3923	0.0391
.16475	0.31340	1.9023	0.06463	0.00000E+00	0.3923	0.0400
.16856	0.32064	1.9023	0.06612	0.00000E+00	0.3923	0.0409
.17236	0.32788	1.9023	0.06762	0.00000E+00	0.3923	0.0418
.17617	0.33512	1.9023	0.06911	0.00000E+00	0.3923	0.0428
.17998	0.34236	1.9023	0.07060	0.00000E+00	0.3923	0.0437
.18378	0.34960	1.9023	0.07209	0.00000E+00	0.3923	0.0446
.18759	0.35684	1.9023	0.07359	0.00000E+00	0.3923	0.0455
.19139	0.36408	1.9023	0.07508	0.00000E+00	0.3923	0.0464
.19520	0.37132	1.9023	0.07657	0.00000E+00	0.3923	0.0474
.19901	0.37856	1.9023	0.07807	0.00000E+00	0.3923	0.0483
.20281	0.38581	1.9023	0.07956	0.00000E+00	0.3923	0.0492
.20662	0.39305	1.9023	0.08105	0.00000E+00	0.3923	0.0501
.21042	0.40029	1.9023	0.08255	0.00000E+00	0.3923	0.0511
.21423	0.40753	1.9023	0.08404	0.00000E+00	0.3923	0.0520
.21804	0.41477	1.9023	0.08553	0.00000E+00	0.3923	0.0529
.22184	0.42201	1.9023	0.08703	0.00000E+00	0.3923	0.0538
.22565	0.42925	1.9023	0.08852	0.00000E+00	0.3923	0.0548
.22945	0.43649	1.9023	0.09001	0.00000E+00	0.3923	0.0557
.23326	0.44373	1.9023	0.09150	0.00000E+00	0.3923	0.0566
.23707	0.45097	1.9023	0.09300	0.00000E+00	0.3923	0.0575
.24087	0.45821	1.9023	0.09449	0.00000E+00	0.3923	0.0585
.24468	0.46545	1.9023	0.09598	0.00000E+00	0.3923	0.0594
.24848	0.47269	1.9023	0.09748	0.00000E+00	0.3923	0.0603
.25229	0.47993	1.9023	0.09897	0.00000E+00	0.3923	0.0612
.25610	0.48717	1.9023	0.10046	0.00000E+00	0.3923	0.0622
.25990	0.49441	1.9023	0.10196	0.00000E+00	0.3923	0.0631

TABLE 4. (Continued)

X	R	Rx	Rphi	Rxx	Rxp	Rpp
.26371	0.50165	1.9023	0.10345	0.00000E+00	0.3923	0.0640
.26752	0.50889	1.9023	0.10494	0.00000E+00	0.3923	0.0649
.27132	0.51613	1.9023	0.10644	0.00000E+00	0.3923	0.0658
.27513	0.52337	1.9023	0.10793	0.00000E+00	0.3923	0.0668
.27893	0.53061	1.9023	0.10942	0.00000E+00	0.3923	0.0677
.28274	0.53785	1.9023	0.11091	0.00000E+00	0.3923	0.0686
.28655	0.54509	1.9023	0.11241	0.00000E+00	0.3923	0.0695
.29035	0.55233	1.9023	0.11390	0.00000E+00	0.3923	0.0705
.29416	0.55957	1.9023	0.11539	0.00000E+00	0.3923	0.0714
.29796	0.56681	1.9023	0.11689	0.00000E+00	0.3923	0.0723
.30177	0.57405	1.9023	0.11838	0.00000E+00	0.3923	0.0732
.30558	0.58129	1.9023	0.11987	0.00000E+00	0.3923	0.0742
.30938	0.58853	1.9023	0.12137	0.00000E+00	0.3923	0.0751
.31319	0.59577	1.9023	0.12286	0.00000E+00	0.3923	0.0760
.31699	0.60301	1.9023	0.12435	0.00000E+00	0.3923	0.0769
.32080	0.61025	1.9023	0.12584	0.00000E+00	0.3923	0.0779
.32461	0.61749	1.9023	0.12734	0.00000E+00	0.3923	0.0788
.32841	0.62473	1.9023	0.12883	0.00000E+00	0.3923	0.0797
.33222	0.63197	1.9023	0.13032	0.00000E+00	0.3923	0.0806
.33602	0.63921	1.9023	0.13182	0.00000E+00	0.3923	0.0815
.33983	0.64618	1.6921	0.09387	-75.930	-13.9045	-2.6295
.34364	0.65213	1.4480	0.04916	-54.490	-9.9784	-1.9337
.34744	0.65728	1.2662	0.01588	-42.004	-7.6919	-1.5322
.35125	0.66182	1.1226	-.01041	-33.983	-6.2230	-1.2768
.35505	0.66586	1.0044	-.03206	-28.471	-5.2137	-1.1032
.35886	0.66949	0.90398	-.05045	-24.496	-4.4858	-0.9795
.36267	0.67276	0.81667	-.06644	-21.522	-3.9411	-0.8880
.36647	0.67572	0.73929	-.08061	-19.233	-3.5220	-0.8186
.37028	0.67840	0.66965	-.09336	-17.432	-3.1922	-0.7648
.37408	0.68082	0.60614	-.10499	-15.990	-2.9281	-0.7225
.37789	0.68302	0.54759	-.11572	-14.820	-2.7138	-0.6888
.38170	0.68500	0.49307	-.12570	-13.860	-2.5381	-0.6618
.38550	0.68678	0.44187	-.13507	-13.067	-2.3929	-0.6400
.38931	0.68836	0.39343	-.14395	-12.409	-2.2724	-0.6226
.39311	0.68977	0.34727	-.15240	-11.862	-2.1723	-0.6086
.39692	0.69101	0.30301	-.16050	-11.408	-2.0891	-0.5976
.40073	0.69208	0.26033	-.16832	-11.034	-2.0205	-0.5890
.40453	0.69299	0.21893	-.17590	-10.728	-1.9644	-0.5827
.40834	0.69375	0.17859	-.18329	-10.482	-1.9195	-0.5783
.41215	0.69435	0.13907	-.19052	-10.292	-1.8846	-0.5757
.41595	0.69481	0.10019	-.19764	-10.151	-1.8589	-0.5746
.41976	0.69512	0.61744E-01	-.20468	-10.057	-1.8417	-0.5751
.42356	0.69528	0.23572E-01	-.21167	-10.008	-1.8327	-0.5771
.42737	0.69530	-.14496E-01	-.21864	-10.003	-1.8318	-0.5806
.43118	0.69517	-.52628E-01	-.22563	-10.042	-1.8388	-0.5855
.43498	0.69490	-.90990E-01	-.23265	-10.124	-1.8540	-0.5919
.43879	0.69448	-.12976	-.23975	-10.254	-1.8777	-0.5999
.44259	0.69391	-.16910	-.24696	-10.432	-1.9103	-0.6096
.44640	0.69319	-.20923	-.25431	-10.664	-1.9528	-0.6212
.45021	0.69231	-.25035	-.26184	-10.955	-2.0061	-0.6348

TABLE 5. Body Coordinates and Partial Derivatives for Sample Case (ϕ = 0 deg.)

Phi = 0. deg

X	R	Rx	Rphi	Rxx	Rxp	Rpp
.06960	0.00000	0.17000E+39	0.00000	-.17000E+39	0.0000	0.0000
.07191	0.05612	12.119	0.00000	-2644.3	0.0000	-0.0292
.07422	0.07927	8.5365	0.00000	-938.51	0.0000	-0.0412
.07653	0.09695	6.9428	0.00000	-512.84	0.0000	-0.0504
.07884	0.11181	5.9891	0.00000	-334.40	0.0000	-0.0581
.08115	0.12484	5.3356	0.00000	-240.21	0.0000	-0.0649
.08346	0.13658	4.8514	0.00000	-183.45	0.0000	-0.0710
.08577	0.14733	4.4736	0.00000	-146.15	0.0000	-0.0766
.08808	0.15730	4.1678	0.00000	-120.09	0.0000	-0.0817
.09038	0.16662	3.9135	0.00000	-101.04	0.0000	-0.0866
.09269	0.17540	3.6976	0.00000	-86.610	0.0000	-0.0911
.09500	0.18372	3.5111	0.00000	-75.370	0.0000	-0.0955
.09731	0.19164	3.3477	0.00000	-66.411	0.0000	-0.0996
.09962	0.19920	3.2030	0.00000	-59.132	0.0000	-0.1035
.10193	0.20644	3.0736	0.00000	-53.122	0.0000	-0.1073
.10424	0.21341	2.9569	0.00000	-48.092	0.0000	-0.1109
.10655	0.22011	2.8509	0.00000	-43.830	0.0000	-0.1144
.10886	0.22658	2.7540	0.00000	-40.181	0.0000	-0.1177
.11117	0.23284	2.6650	0.00000	-37.028	0.0000	-0.1210
.11348	0.23889	2.5827	0.00000	-34.282	0.0000	-0.1241
.11579	0.24477	2.5063	0.00000	-31.872	0.0000	-0.1272
.11810	0.25047	2.4353	0.00000	-29.744	0.0000	-0.1301
.12041	0.25602	2.3688	0.00000	-27.852	0.0000	-0.1330
.12272	0.26142	2.3065	0.00000	-26.162	0.0000	-0.1358
.12503	0.26668	2.2478	0.00000	-24.645	0.0000	-0.1386
.12733	0.27180	2.1925	0.00000	-23.277	0.0000	-0.1412
.12964	0.27681	2.1402	0.00000	-22.037	0.0000	-0.1438
.13195	0.28174	2.1351	0.00000	0.00000E+00	0.0000	-0.1464
.13426	0.28667	2.1351	0.00000	0.00000E+00	0.0000	-0.1489
.13657	0.29160	2.1351	0.00000	0.00000E+00	0.0000	-0.1515
.13888	0.29653	2.1351	0.00000	0.00000E+00	0.0000	-0.1541
.14119	0.30146	2.1351	0.00000	0.00000E+00	0.0000	-0.1566
.14350	0.30639	2.1351	0.00000	0.00000E+00	0.0000	-0.1592
.14581	0.31132	2.1351	0.00000	0.00000E+00	0.0000	-0.1618
.14812	0.31625	2.1351	0.00000	0.00000E+00	0.0000	-0.1643
.15043	0.32118	2.1351	0.00000	0.00000E+00	0.0000	-0.1669
.15274	0.32611	2.1351	0.00000	0.00000E+00	0.0000	-0.1694
.15505	0.33105	2.1351	0.00000	0.00000E+00	0.0000	-0.1720
.15736	0.33598	2.1351	0.00000	0.00000E+00	0.0000	-0.1746
.15967	0.34091	2.1351	0.00000	0.00000E+00	0.0000	-0.1771
.16198	0.34584	2.1351	0.00000	0.00000E+00	0.0000	-0.1797
.16429	0.35077	2.1351	0.00000	0.00000E+00	0.0000	-0.1823
.16659	0.35570	2.1351	0.00000	0.00000E+00	0.0000	-0.1848
.16890	0.36063	2.1351	0.00000	0.00000E+00	0.0000	-0.1874
.17121	0.36556	2.1351	0.00000	0.00000E+00	0.0000	-0.1899
.17352	0.37049	2.1351	0.00000	0.00000E+00	0.0000	-0.1925
.17583	0.37542	2.1351	0.00000	0.00000E+00	0.0000	-0.1951
.17814	0.38035	2.1351	0.00000	0.00000E+00	0.0000	-0.1976
.18045	0.38528	2.1351	0.00000	0.00000E+00	0.0000	-0.2002
.18276	0.39022	2.1351	0.00000	0.00000E+00	0.0000	-0.2028
.18507	0.39515	2.1351	0.00000	0.00000E+00	0.0000	-0.2053

TABLE 5. (Continued)

X	R	Rx	Rphi	Rxx	Rxp	Rpp
.18738	0.40008	2.1351	0.00000	0.00000E+00	0.0000	-0.2079
.18969	0.40501	2.1351	0.00000	0.00000E+00	0.0000	-0.2104
.19200	0.40994	2.1351	0.00000	0.00000E+00	0.0000	-0.2130
.19431	0.41487	2.1351	0.00000	0.00000E+00	0.0000	-0.2156
.19662	0.41980	2.1351	0.00000	0.00000E+00	0.0000	-0.2181
.19893	0.42473	2.0997	-.00460	-125.79	-16.3113	-2.3298
.20124	0.42927	1.8503	-.03693	-93.043	-12.0651	-1.7391
.20354	0.43332	1.6605	-.06155	-72.828	-9.4439	-1.3687
.20585	0.43697	1.5089	-.08121	-59.313	-7.6913	-1.1170
.20816	0.44031	1.3835	-.09746	-49.747	-6.4509	-0.9360
.21047	0.44338	1.2772	-.11125	-42.681	-5.5346	-0.8001
.21278	0.44622	1.1851	-.12319	-37.285	-4.8349	-0.6945
.21509	0.44886	1.1041	-.13370	-33.055	-4.2863	-0.6104
.21740	0.45132	1.0318	-.14307	-29.666	-3.8469	-0.5418
.21971	0.45363	0.96658	-.15153	-26.902	-3.4884	-0.4848
.22202	0.45579	0.90718	-.15923	-24.613	-3.1917	-0.4368
.22433	0.45782	0.85262	-.16631	-22.695	-2.9429	-0.3957
.22664	0.45973	0.80213	-.17285	-21.068	-2.7320	-0.3603
.22895	0.46153	0.75513	-.17895	-19.676	-2.5515	-0.3293
.23126	0.46322	0.71111	-.18466	-18.476	-2.3958	-0.3020
.23357	0.46482	0.66967	-.19003	-17.433	-2.2605	-0.2778
.23588	0.46632	0.63049	-.19511	-16.521	-2.1423	-0.2562
.23819	0.46773	0.59328	-.19994	-15.720	-2.0385	-0.2367
.24049	0.46906	0.55781	-.20454	-15.013	-1.9468	-0.2192
.24280	0.47031	0.52388	-.20894	-14.387	-1.8657	-0.2032
.24511	0.47148	0.49130	-.21316	-13.831	-1.7935	-0.1886
.24742	0.47258	0.45995	-.21723	-13.336	-1.7293	-0.1752
.24973	0.47361	0.42967	-.22115	-12.893	-1.6719	-0.1629
.25204	0.47456	0.40036	-.22495	-12.498	-1.6207	-0.1515
.25435	0.47546	0.37191	-.22864	-12.145	-1.5749	-0.1410
.25666	0.47628	0.34424	-.23223	-11.829	-1.5339	-0.1313
.25897	0.47705	0.31725	-.23573	-11.547	-1;4973	-0.1222
.26128	0.47775	0.29088	-.23915	-11.296	-1.4647	-0.1137
.26359	0.47839	0.26506	-.24250	-11.072	-1.4358	-0.1058
.26590	0.47897	0.23972	-.24578	-10.874	-1.4101	-0.0984
.26821	0.47950	0.21481	-.24901	-10.700	-1.3875	-0.0915
.27052	0.47997	0.19028	-.25219	-10.548	-1.3678	-0.0850
.27283	0.48038	0.16608	-.25533	-10.417	-1.3508	-0.0789
.27514	0.48073	0.14215	-.25844	-10.305	-1.3362	-0.0731
.27744	0.48103	0.11847	-.26151	-10.211	-1.3241	-0.0677
.27975	0.48128	0.94978E-01	-.26455	-10.136	-1.3143	-0.0627
.28206	0.48147	0.71641E-01	-.26758	-10.077	-1.3067	-0.0580
.28437	0.48161	0.48421E-01	-.27059	-10.035	-1.3013	-0.0535
.28668	0.48170	0.25279E-01	-.27359	-10.010	-1.2980	-0.0494
.28899	0.48173	0.21768E-02	-.27659	-10.000	-1.2967	-0.0455
.29130	0.48171	-.20922E-01	-.27958	-10.007	-1.2976	-0.0419
.29361	0.48163	-.44054E-01	-.28258	-10.029	-1.3005	-0.0385
.29592	0.48150	-.67256E-01	-.28559	-10.068	-1.3055	-0.0355
.29823	0.48132	-.90568E-01	-.28861	-10.123	-1.3127	-0.0326
.30054	0.48108	-.11403	-.29165	-10.196	-1.3221	-0.0301

FIGURE 5: Graphical Results of Sample Case (ϕ = 90 deg.)

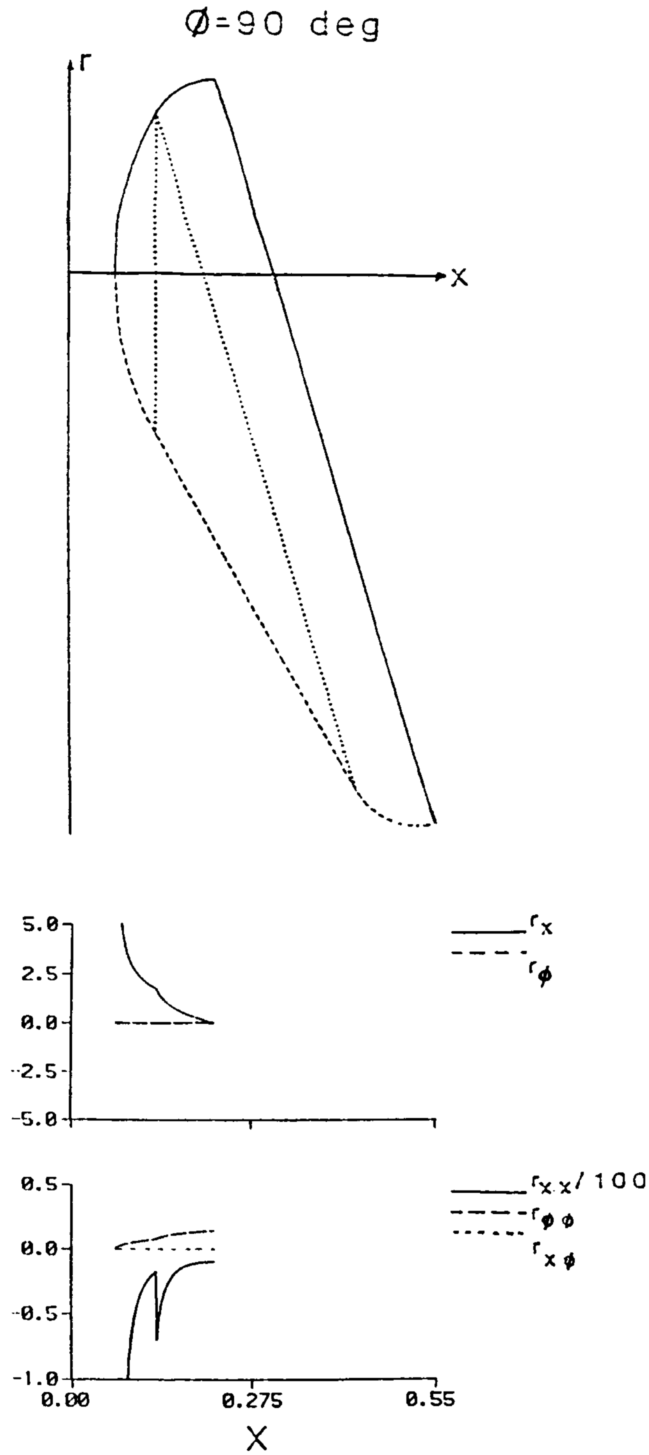


FIGURE 6: Graphical Results of Sample Case (ϕ = - 90 deg.)

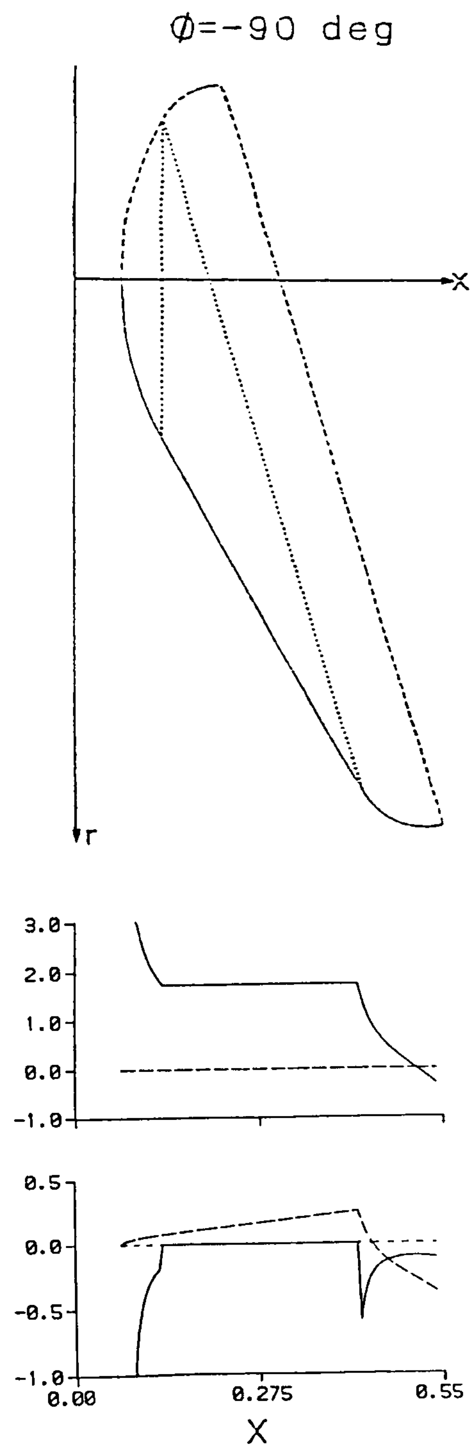


FIGURE 7: Graphical Results of Sample Case (ϕ = 45 deg.)

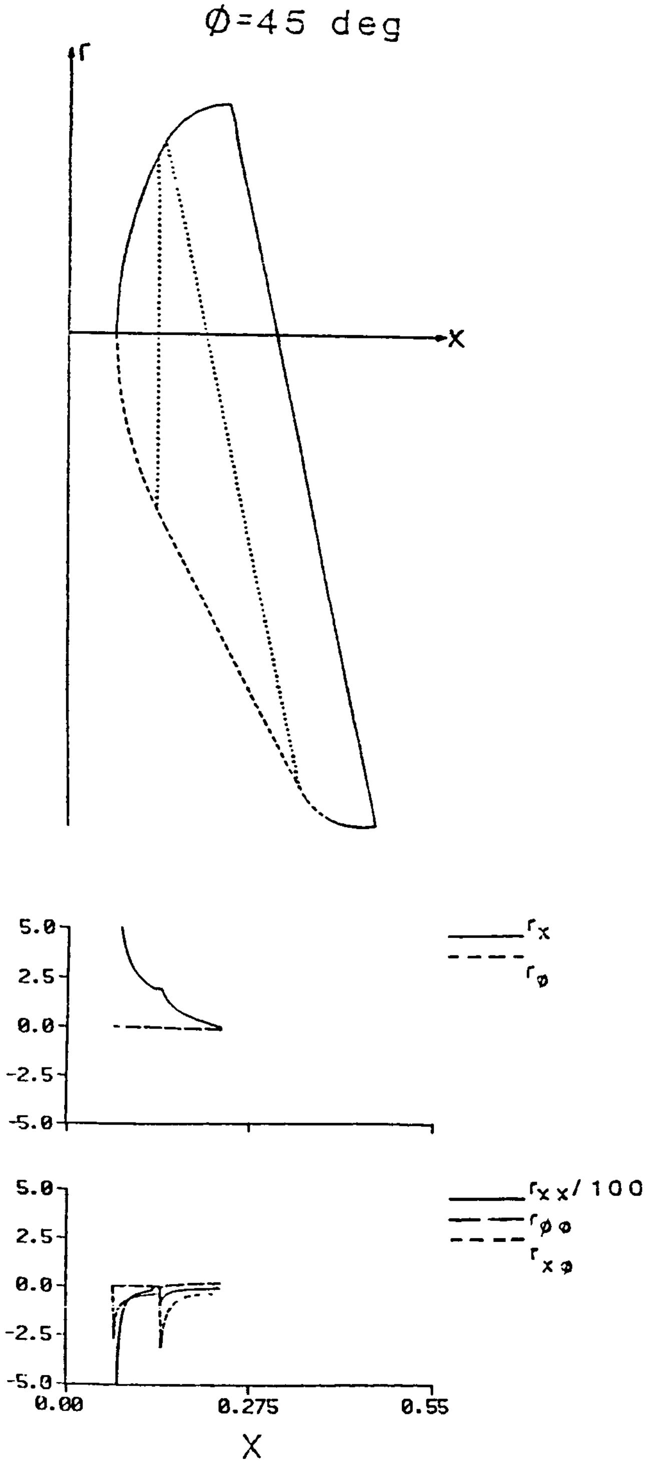


FIGURE 8: Graphical Results of Sample Case (ϕ = - 45 deg.)

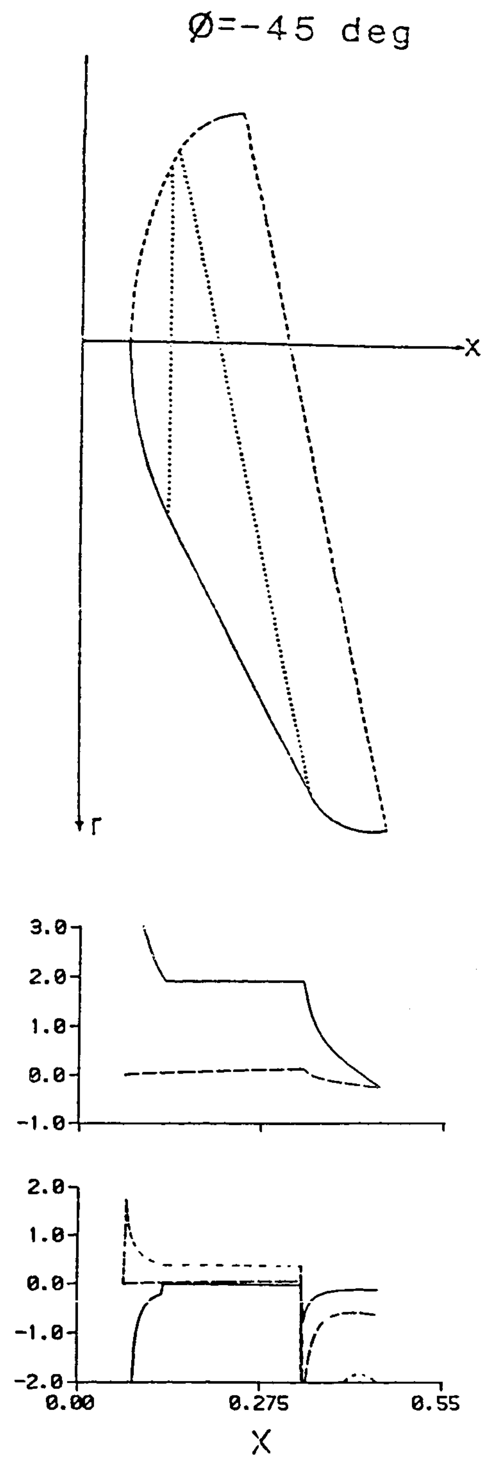
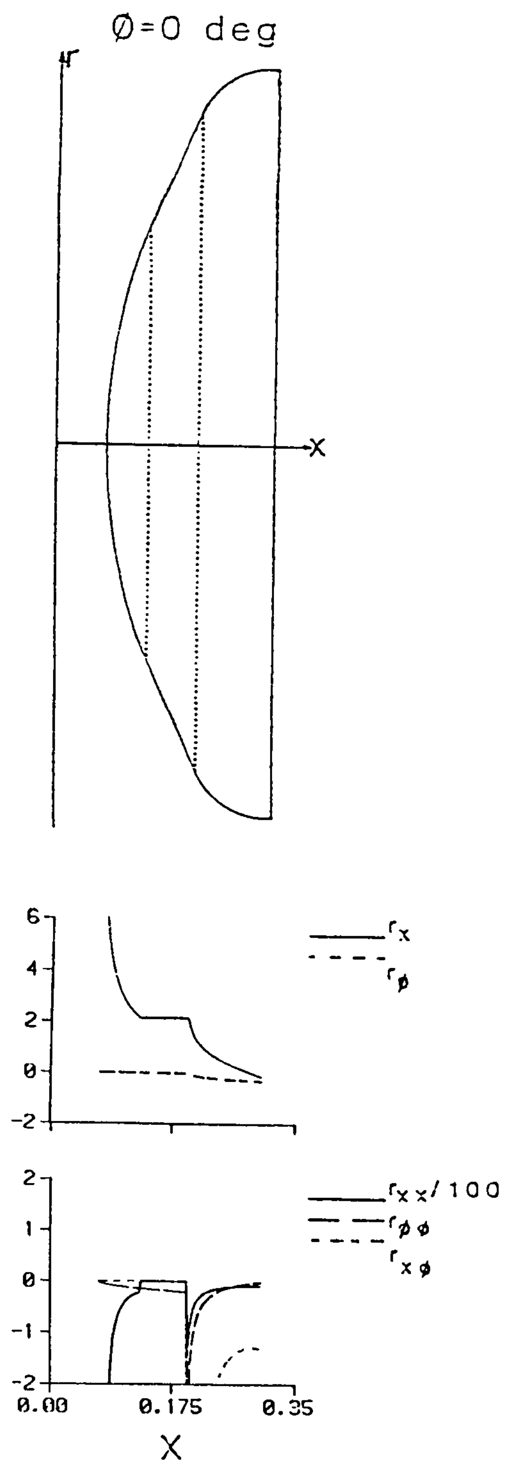


FIGURE 9: Graphical Results of Sample Case (ϕ = 0 deg.)



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16. Abstract
One geometry currently under consideration for the Aeroassist Flight Experiment (AFE) vehicle is composed of several segments of simple general conics: an ellipsoidal nose tangent to an elliptical cone and a base skirt with the base plane raked relative to the body axis. An analytic representation for the body coordinates and first and second partial derivatives of this configuration has been developed. Equations are given which define the body radius and partial derivatives for a prescribed axial and circumferential position on the vehicle. The results for a sample case are tabulated and presented graphically.

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