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ON ANALYSIS OF AREA COVERAGE BY ORBITAL PHOTOIMAGING SYSTEMS

By G. R. Woodcock
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ABSTRACT

This report describes initial steps taken toward developing an automated analysis of planetary surface area-coverage provided by an orbital photoimaging system from the baseline orbit. It is intended to facilitate mission design for a planetary orbiter, such as the previously proposed Voyager 1973 Mars mission which has since been deleted from planning.

NASA-GEORGE C. MARSHALL SPACE FLIGHT CENTER

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G. R. Woodcock

ADVANCED SYSTEMS OFFICE
RESEARCH AND DEVELOPMENT OPERATIONS

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INTRODUCTION

During mission design studies by the Voyager Interim Project Office for the proposed Voyager 1973 Mars mission,* the requirement arose to determine the surface area of Mars which could be encompassed by the area-coverage, photoimaging system from the baseline orbit. Hand calculations were employed [1] but were laborious and were not highly accurate; the slowness of these calculations prevented comparison of photo coverage from various orbits by various candidate photoimaging systems. This internal note describes initial steps toward an automated analysis of orbital photoimaging coverage intended to facilitate planetary orbiter mission design.

ANALYSIS

Orbit Path

The orbit is assumed given in terms of the following parameters (see Appendix A for complete nomenclature):

Periapsis altitude, h_p

Apoapsis altitude, h_a, or period, p.

Latitude of periapsis, L_p

Inclination to Mars equator, i

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*Voyager 1973 has not been funded and will not take place.

The initial point of the photographic pass is assumed given in terms of longitude and latitude of the sub-spacecraft point. Time interval between pictures is assumed given. Figure 1 summarizes the geometry.

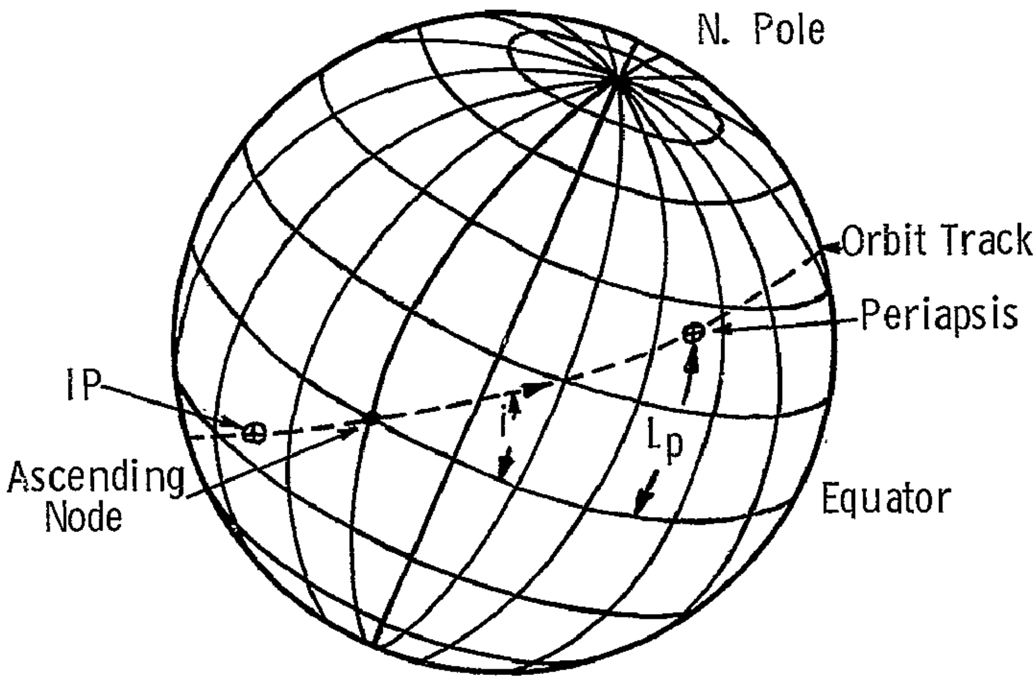

FIGURE 1. PHOTO MISSION ORBIT GEOMETRY

The true anomaly (θ) from the ascending node to periapsis is given by:

$$\sin \Delta\theta_1 = \sin L_p / \sin i \tag{1}$$

where $\Delta\theta$ may be either less than, or greater than, $\pi/2$, which must be specified. Thus true anomaly of the ascending node is $2\pi - \Delta\theta_1$.

The true anomaly from the ascending node to the initial point of the pass is, similarly:

$$\sin \Delta\theta_2 = \sin L_I / \sin i \quad . \tag{2}$$

Then the true anomaly from the initial point to periapsis will be

$$\Delta\theta = \Delta\theta_1 - \Delta\theta_2 \quad . \tag{3}$$

For the geometry shown, the true anomaly at the initial point will be

$$\theta = 2\pi - \Delta\theta \quad . \tag{4}$$

A table may be constructed of time versus true anomaly from the initial point. An explicit relation of true anomaly versus time is not known; therefore, interpolation from the table will be used. If the orbit size is given by h_a and h_p,

$$r_a = r_♂ + h_a \tag{5}$$

$$r_p = r_♂ + h_p \tag{6}$$

$$a = (r_a + r_p)/2 \tag{7}$$

$$e = r_a/a - 1 \quad . \tag{8}$$

If the orbit size is given in terms of r_p and p,

$$a = \left(\frac{p\sqrt{\mu_♂}}{2\pi}\right)^{2/3} \tag{9}$$

$$e = 1 - r_p/a \quad . \tag{10}$$

The table is constructed by taking values of θ at ten degree intervals,, beginning with the initial point.

$$\cos \mathcal{E}_j = \frac{e + \cos\theta_j}{1 + e\cos\theta_j} \tag{11}$$

where

$$\theta_j = \theta_I + j\delta\theta; \ \delta\theta = 10^\circ$$

Then

$$\Delta t_j = \left(\frac{a}{\mu_{\delta}^{1/3}}\right)^{3/2} \left[\mathcal{E}_j - e \sin \mathcal{E}_j - (\mathcal{E}_I - e \sin \mathcal{E}_I)\right] \quad . \tag{12}$$

True anomaly corresponding to time Δt after time = 0 at the initial point may then be found by interpolation of the table. Newton's divided difference formula was used [2].

Altitude is found by

$$r = \frac{a(1 - e^2)}{1 + e \cos \theta} \tag{13}$$

$$h = r - r_{\delta} \quad . \tag{14}$$

It is necessary to state a convention of coordinates. The basis will be the polar axis of Mars, this being the Z-axis with Z positive north. The x axis will pass through 0 and 180 degrees longitude and the equator, positive toward 0 degrees longitude. The y-axis will pass through 90 and 270 degrees longitude, positive toward 90 degrees. Longitude is defined as increasing eastward, thus providing normal right-handed coordinates. See Figure 2. The angle Θ is longitude; φ is measured from the positive Z-axis. Note that latitude is

$$L = \pi/2 - \varphi \quad . \tag{15}$$

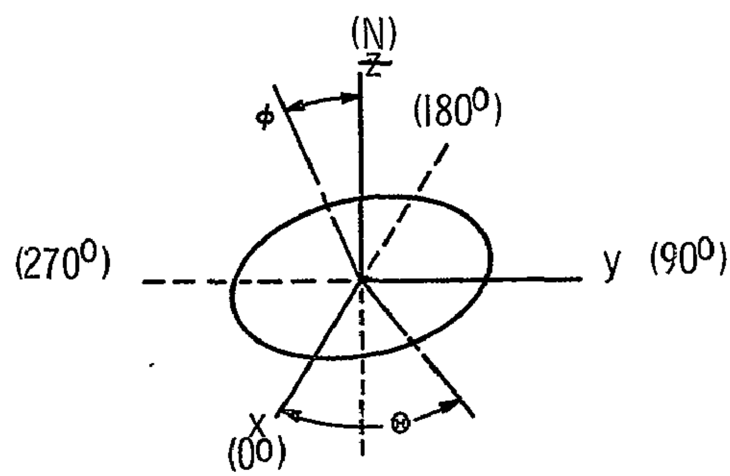

FIGURE 2. COORDINATE CONVENTION

The normal conversions from spherical to rectangular coordinates therefore apply:

$$x = r \sin \varphi \cos \Theta$$
$$y = r \sin \varphi \sin \Theta \qquad (16)$$
$$z = r \cos \varphi$$

$$\Theta = \tan^{-1} (y/x)$$
$$r = (x^2 + y^2 + z^2) \qquad (17)$$
$$\varphi = \cos^{-1} z/r \quad .$$

Later a convention will be adopted replacing x, y, and z with X_1, X_2, and X_3 for convenience in matrix notation.

The next step is to find the sub-spacecraft point, in longitude and latitude, over which each photo is taken. We know the following:

1. True anomaly at which the photo is taken.
2. Time at which the photo is taken.
3. Longitude, time, and true anomaly of initial point.
4. True anomaly of the ascending node.

Longitude of the ascending node is needed, and is found by:

$$\cos(\Theta_I - \Theta_n) = \cos(\Theta_I - \Theta_n)/\cos L_I \quad . \qquad (18)$$

Figure 3 shows the relevant geometry. Note that the angles θ_p, Θ_p, and Θ_a are negative according to the state convention. Longitude and latitude of the sub-spacecraft point will be found by a process of coordinate rotations. First, note that the coordinates of the sub-spacecraft point in the prime system are

$$
\begin{aligned}
x' &= x_1' = r_{\delta} \cos \theta_p \\
y' &= x_2' = r_{\delta} \sin \theta_p \qquad (19) \\
z' &= x_3' = 0
\end{aligned}
$$

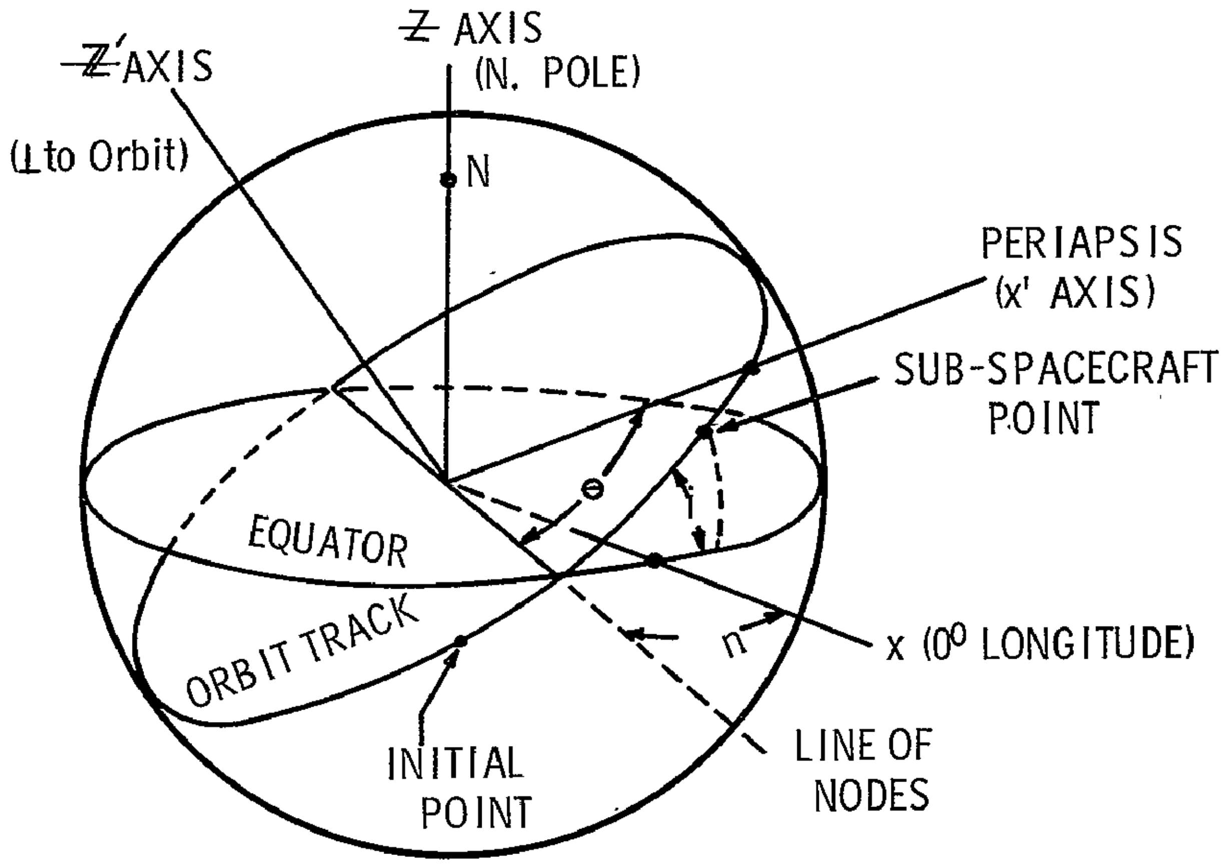

FIGURE 3. TRANSFORM GEOMETRY

The coordinates of equation 19 may be transformed to uprimed coordinates by [3]:

1. Rotating the prime coordinate system about the X_3' axis through the angle θ_n so that the X_1' axis passes through the line of nodes.

2. Rotating the system about the new X_1' axis (the line of nodes) through the angle -i so that the $X_1' X_2'$ plane coincides with the $X_1 S_2$ plane.

3. Rotating the system again about the X_3' axis through the angle -1_n so that the prime and unprime systems coincide.

These rotations are performed by matrix multiplication. Define three matrices:

$$B = \begin{bmatrix} \cos\theta_n & \sin\theta_n & 0 \\ -\sin\theta_n & \cos\theta_n & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{20}$$

$$C = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(-i) & \sin(-i) \\ 0 & -\sin(-i) & \cos(-i) \end{bmatrix} \tag{21}$$

$$D = \begin{bmatrix} \cos(-\Theta_n) & \sin(-\Theta_n) & 0 \\ -\sin(-\Theta_n) & \cos(-\Theta_n) & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{22}$$

and another matrix, $A = DCB$. (23)

Then the coordinates of the point are

$$x = Ax' \ . \tag{24}$$

Longitude and latitude may then be found by equations (17). A longitude correction for the planet's rotation is required: the longitude found assumes the planet did not rotate during the time the spacecraft passed from the initial point to the photo point. Rotation during this time will decrease the longitude at the photo point by an amount, $\omega_{\delta}\ \delta t$; this amount is subtracted from the computed longitude.

The azimuth of the flight path at the photo point may now be computed.

Azimuth is $$\zeta = \tan^{-1}\left(\frac{\partial\Theta \cos L}{\partial L}\right) \ . \tag{25}$$

In order to account for the rotation of Mars, we must express this as:

$$\xi = \tan^{-1}\left(\frac{\partial\Theta/\partial t \cos L}{\partial L/\delta t}\right). \tag{25a}$$

It is convenient to use coordinate transformation to obtain $\partial\Theta/\partial t$ and $\partial L/\partial t$. The angular rate of the spacecraft in its orbit is

$$\omega_s = V_p \; r_p/r^2 \text{ where } V_p = \sqrt{\frac{\mu_\delta\,(\epsilon + 1)}{r_p}}$$

Then $\partial x_1'/\partial t = r_\delta\,\omega_s\,(-\sin\theta)$

$$\partial x_2'/\partial t = r \;\; \omega_s \cos\theta \tag{26}$$

$$\partial x_3'/\partial t = 0$$

where equations 26 are in the spacecraft orbit coordinate system. By coordinate transform,

$$\partial x/\partial t = A \;\; \partial x'/\partial t \tag{27}$$

where A is defined by equation 23. Differentiating the inverse relations of equation (17) we find:

$$\left.\begin{aligned} \partial\Theta/\partial t &= \frac{x_1 \;\; \partial x_2/\partial t - x_2 \;\; \partial x_1/\partial t}{x_1^2 + x_2^2} + \omega_\delta \\ \partial L/\partial t &= \frac{\partial}{\partial t}\,(\pi/2 - \varphi) = \frac{\partial x_3/\partial t}{\sqrt{1 - x_3^2/r_\delta^2}} \end{aligned}\right\} \tag{28}$$

where the planet rotation correction has been included in $\partial\Theta/\partial t$. These values may be substituted into equation 25a to derive azimuth.

Photo Coverage

With the determination of the longitude and latitude of the sub-spacecraft point and the azimuth of its path, we are now ready to begin analysis of the format of the picture itself. We will assume that the picture is rectangular with a view half-angle α in the transverse direction and γ in the fore-and-aft direction. We further assume that the camera may be looking to the right or left of vertical (forward or aft looking should also be considered, but has not been included in this analysis) at an angle β, with β positive looking right. Figure 4 illustrates

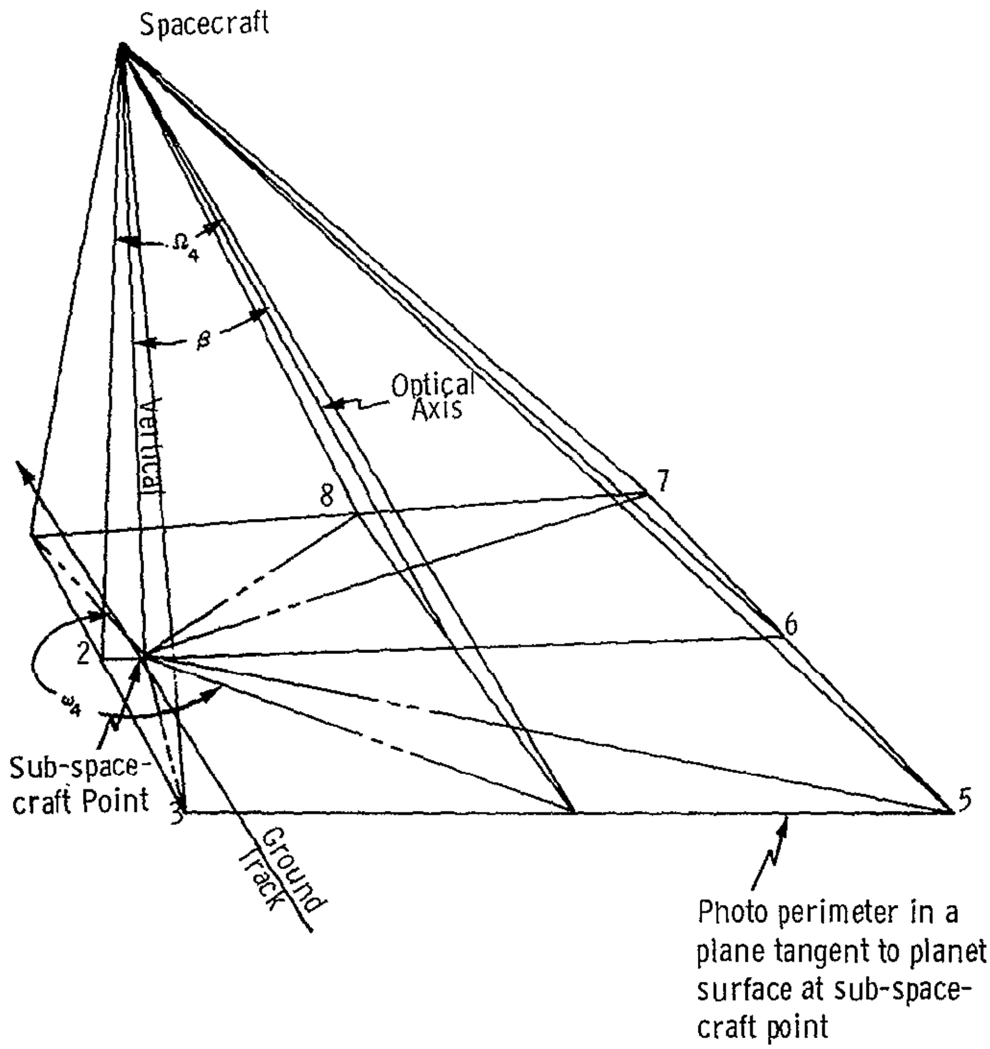

FIGURE 4. CAMERA VIEW GEOMETRY

the geometry, where, for the moment we have assumed the camera to be looking at a flat plane tangent to the planet surface at the sub-spacecraft point. The example shown has β positive. Based on this figure we wish to calculate sixteen relevant angles. These are the angles ω_i from the sub-spacecraft point to the four corners and mid points of the sides of the picture, and the angles Ω_i; from the vertical to the lines connecting the spacecraft to the previously mentioned points.

Referring to Figure 5, we see the picture format of the previous figure displayed on a coordinate system. This coordinate system is as if the spacecraft

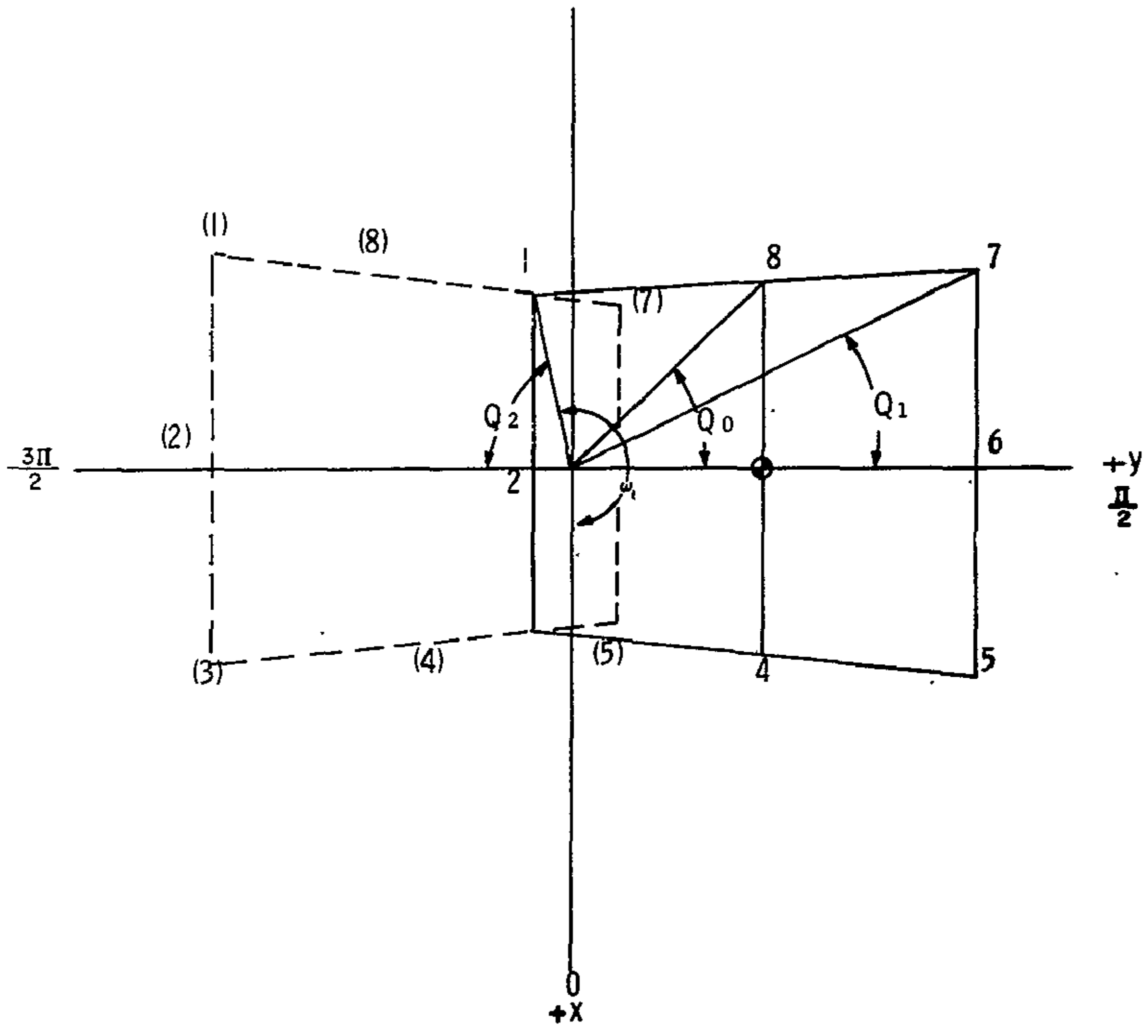

FIGURE 5. PHOTO GEOMETRY WITH DUMMY COORDINATES

had just flown up the zero longitude line and is directly over the north pole of the planet. Note the angles Q_0, Q_1, and Q_2. These are

$$Q_0 = \tan^{-1}\left(\frac{\tan\gamma}{\sin\beta}\right) \tag{29}$$

$$Q_1 = \tan^{-1}\left(\frac{\tan\gamma\cos\alpha}{\sin(\alpha+\beta)}\right) \tag{30}$$

$$Q_3 = \tan^{-1}\left(\frac{\tan\gamma\cos\alpha}{\sin(\alpha-\beta)}\right) \tag{31}$$

(Note: Derivation of these angle formulas from Figures 4 and 5 directly is quite difficult; they are for illustration only. If the reader wishes to derive the formulas, it is suggested that he draw a plane in Figure 4 perpendicular to the optical axis and containing the picture center.)

Referring now to Figure 5, we find that for the right-looking picture (β pos.)

$$\begin{aligned}
\omega_1 &= 3\pi/2 - Q_2 \\
\omega_2 &= 3\pi/2 \\
\omega_3 &= 3\pi/2 + Q_2 \\
\omega_4 &= \pi/2 - Q_0 \\
\omega_5 &= \pi/2 - Q_1 \\
\omega_6 &= \pi/2 \\
\omega_7 &= \pi/2 + Q_1 \\
\omega_8 &= \pi/2 + Q_0
\end{aligned} \tag{32}$$

and for the left-looking picture (β neg.),

$$
\begin{aligned}
\omega_1 &= 3\pi/2 - Q_1 \\
\omega_2 &= 3\pi/2 \\
\omega_3 &= 3\pi/2 + Q_1 \\
\omega_4 &= 3\pi/2 + Q_0 \\
\omega_5 &= \pi/2 - Q_2 \\
\omega_6 &= \pi/2 \\
\omega_7 &= \pi/2 + Q_2 \\
\omega_8 &= 3\pi/2 - Q
\end{aligned}
\tag{33}
$$

Note that by convention, ω_1 is the upper left-hand corner of the picture and we proceed around the picture in a counter-clockwise direction. Any other convention could, of course, be adopted.

To each angle ω_i there corresponds an angle Ω_i. For the right-looking and left-looking cases:

$$
\begin{aligned}
\Omega_1 &= \left| \tan^{-1} \left[\frac{\tan(\alpha - \beta)}{\sin \omega_1} \right] \right| \\
\Omega_2 &= | \alpha - \beta | \\
\Omega_3 &= \Omega_1 \\
\Omega_4 &= \left| \tan^{-1} \left[\frac{\tan \beta}{\sin \omega_4} \right] \right| \\
\Omega_5 &= \left| \tan^{-1} \left[\frac{\tan(\alpha + \beta)}{\sin \omega_5} \right] \right| \\
\Omega_6 &= | \alpha + \beta | \\
\Omega_7 &= \Omega_5 \\
\Omega_8 &= \Omega_4
\end{aligned}
\tag{34}
$$

where all Ω_i are defined as positive. Note, however, that β must be taken as negative for the left-looking case.

The next step is illustrated in Figure 6. The flat surface of Figures 4 and 5 provided a mental aid in determining the angles ω_i and Ω_i, but now we

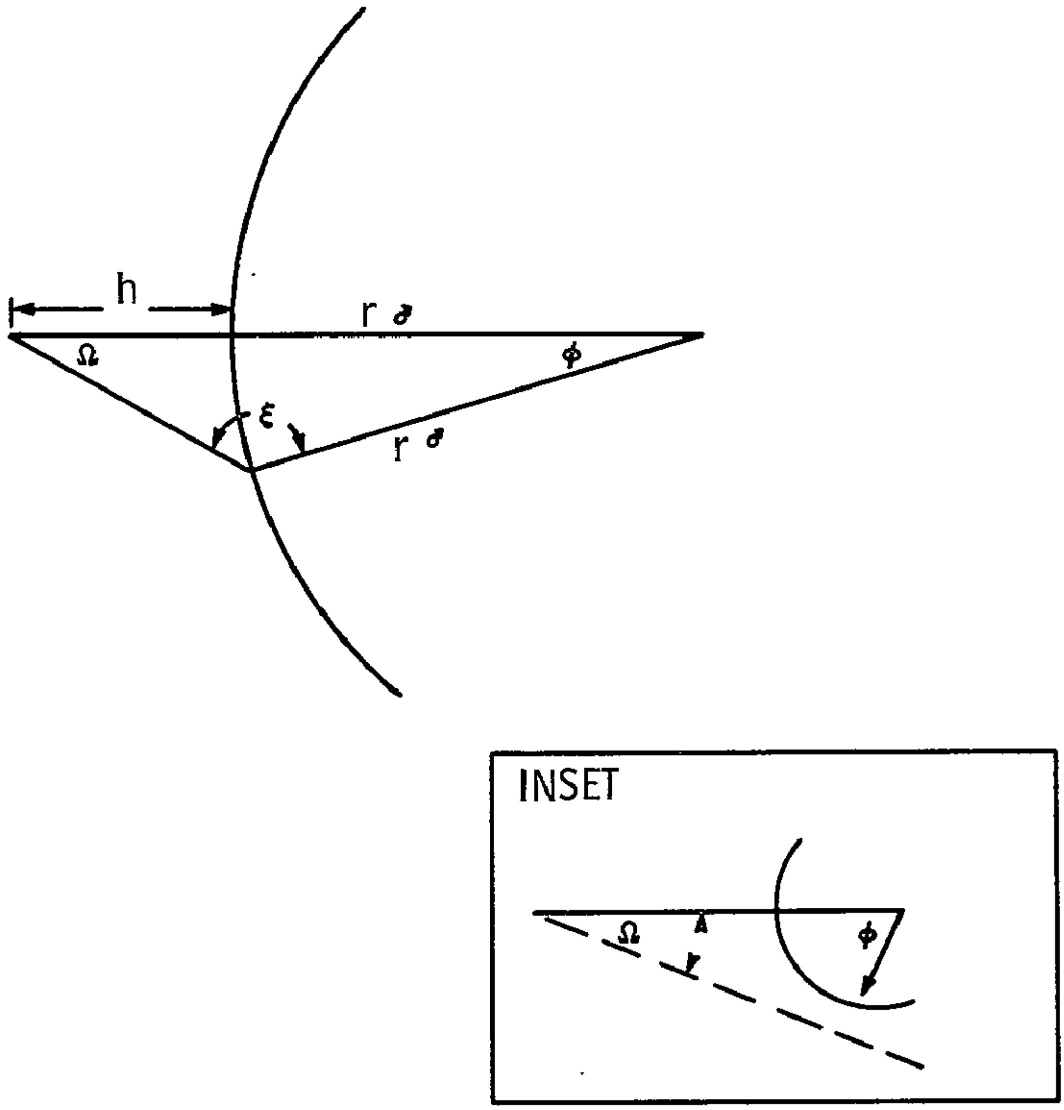

FIGURE 6. CONVERSION TO SPHERICAL SURFACE

must switch to a spherical surface. The angles of interest are φ_i the arc of planet surface viewed at the angle Ω_i from height h. By the law of sines,

$$\frac{r_\delta}{\sin \Omega_i} = \frac{r_\delta + h}{\sin \xi_i} \tag{35}$$

$$\sin \xi_i = \frac{r_\delta + h}{r_\delta} \sin \Omega_i \tag{36}$$

The value ξ_i thus determined will be double-valued, with one value less than $\pi/2$, and one greater; note that the actual angle ξ_i will always be $> \pi/2$. If the value, $\sin \xi_i$, in equation (36) is greater than 1, this corresponds to Figure 6 inset. In this case, $\xi_i = \pi/2$ and

$$\varphi_i = \cos^{-1}\left(\frac{r_\delta}{r_\delta + h}\right) \tag{37}$$

The normal case is

$$\varphi_i = \pi - \Omega_i - \xi_i \tag{38}$$

The eight points outlining the picture are now defined by the angles ω_i and φ_i. Note that the angles ω_i and φ_i are just the spherical coordinates of the picture points in a coordinate system in which the z-axis passes through the spacecraft.

And now to get the picture into normal coordinates: (1) Rotate it through an angle Θ so it appears as if the spacecraft has just flown up the longitude of the actual picture instead of longitude zero; (2) Slide it down this longitude line to the latitude of the actual picture; angle Φ; (3) Rotate it through an angle ζ to the correct azimuth. This is just like the coordinate transform previously described, except that instead of moving the coordinates we have moved the picture — in effect an inverse transform. Therefore, convert the angles ω_i and φ_i into X_1, X_2, X_3 by equation 16 and, defining:

$$B = \begin{bmatrix} \cos\Theta & \sin\Theta & 0 \\ -\sin\Theta & \cos\Theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{39}$$

$$C = \begin{bmatrix} \cos\Phi & 0 & \sin\Phi \\ 0 & 1 & 0 \\ -\sin\Phi & 0 & \cos\Phi \end{bmatrix} \tag{40}$$

$$D = \begin{bmatrix} \cos\zeta & \sin\zeta & 0 \\ -\sin\zeta & \cos\zeta & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{41}$$

$$A = DCB \tag{42}$$

$$A^{-1} = \tilde{A} \quad \text{(A transposed)} \tag{43}$$

$$x^1 = A^{-1}x$$

and, converting X' back to spherical coordinates, we have the longitudes and latitudes of the picture outline points.

Translation of this claptrap into Fortran provides the mechanization for convenient determination of photoimaging system area-coverage from candidate orbits.

COMPUTER PROGRAM

A Fortran IV computer program was written for the CDC 3200 to perform the calculations defined by the previous analysis. The program is capable of providing useful results, but addition of an automatic plot routine would be a great help.

The program operates in two modes. Mode 0, the normal mode, accepts inputs in the form of orbit parameters and computes photo formats for one imaging swath. Mode 1 is a simple mode wherein the location over the planet for each picture is specified. The program is in the form of a main routine and six subroutines:

PHØTØ - main routine (photo format analysis).

SUBROUTINE ORBIT - performs flight path calculations.

SUBROUTINE NEWT - Performs interpolations by Newton's divided difference formula. This subroutine as listed includes provisions for numerical integration which is not used here.

SUBROUTINE XFØRM2 - Performs coordinate transformations for flight path analysis.

SUBROUTINE CØØRD - Converts spherial to Cartesian coordinates and the reverse for photo format analysis.

SUBROUTINE XFØRM - Performs coordinate transforms for photo format analysis.

SUBROUTINE MMPY3 - Matrix multiplication.

The program has been used for several calculations of photo coverage of Mars by orbiting spacecraft. However, all possible combinations of orbit orientation and inclination have not been tried; so the possibility exists that the program still contains some "bugs."

If camera parameters and and spacecraft altitude are such that the limb of the planet is seen, the points are so labeled (see case 4 of the examples); and the coordinates calculated are those of the limb. However, the picture will not be a distorted rectangle (see Fig. 7) and cannot, therefore, be plotted with accuracy.

The program described here is considered an initial step toward a very effective analytical device for mission analysis, and is useful as presented. However, many valuable additions may be visualized:

1. Automatic plotting of results
2. Addition of off-vertical pointing capability in the fore-and-aft directions (presently capable of only side-looking)
3. Analysis of lighting angles and resolution
4. Reference to spacecraft and planet scan platform coordinates to get actual look angles
5. Calculation of additional points to better define "limb view" pictures
6. Internal calculation of framing rate to minimize overlap,

Items 3 and 4 above would require a major effort as they involve celestial references and solar system geometry. See Appendix B for Fortran listing.

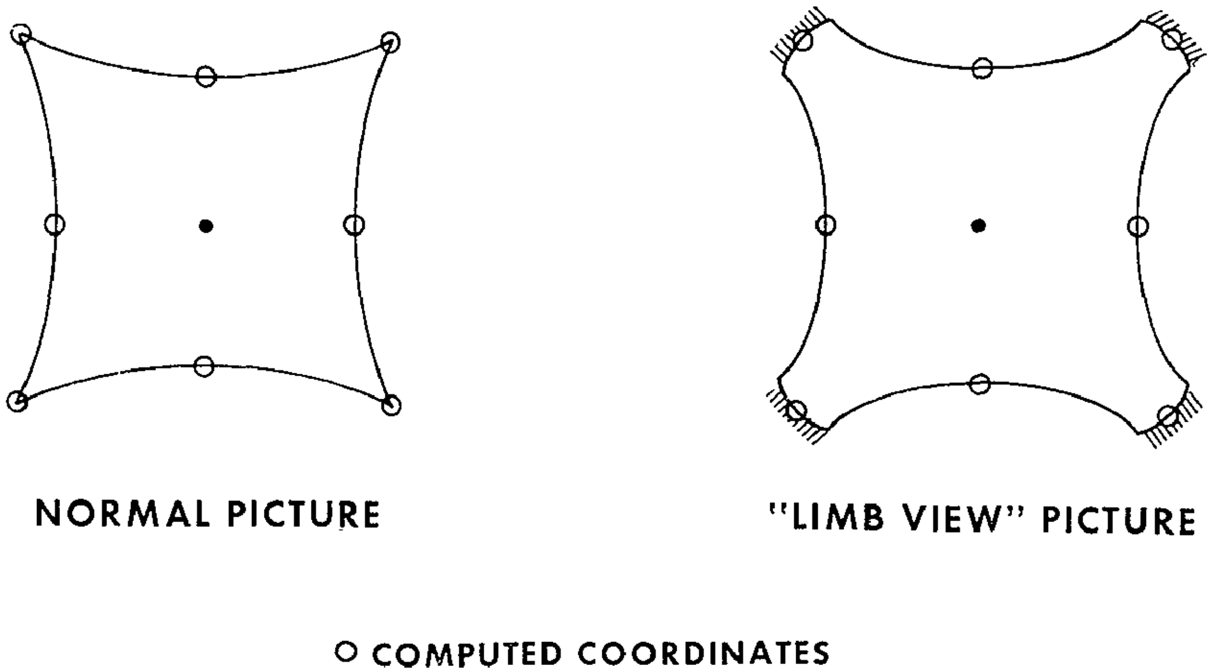

FIGURE 7. NORMAL VERSUS LIMB PICTURE SHAPES

Program Inputs

The first input card for a run indicates the number of cases to be executed (NCASE). One case is one orbital pass, or one group of pictures, to by analyzed by single-picture analysis. For the latter, all pictures in the group must have the same camera parameters. When camera parameters are changed, this must be a new case.

Any number of cases from 1 to 99 may be run. The number is punched, in integer form, on the card, ending in column 2 (I2 format).

The first card for each case identifies the type of analysis (MODE), the number of pictures in the case (NPIC), whether or not the side-looking angle is to alternate between positive and negative (KSLA), and location of periapsis with respect to initial point (KORB). For single-picture analysis only the first two of these are needed; the other two may be left blank. These variables are entered in integer format, each occupying two columns (format 4I2).

A value of 1 or greater for MODE will result in single-picture analysis; 0 or less in an orbit pass analysis. NPIC may have any value from 1 to 99. A value of 0 or less for KSLA results in side-looking angle alternating from positive to negative (alternately right and left-looking). The example calculations given are of this form. A value of 1 or greater for KSLA results in side-looking angle being fixed at the input value. A value of 0 or less for KORB results in the orbit periapsis being placed between 0 and 90 degrees forward in true anomaly from the node nearest the initial point. A value of 1 or greater for KORB places periapsis between 90 and 180 degrees from this node. This allows handling of ordinary cases of morning and evening terminator orbits. Locations of periapsis in one of the other two quadrants is possible but was not provided for.

The next card (second card for each case) provides camera parameters PALFA and PGAMMA (view half-angles) and PSLA (side-looking angle). These are entered in degrees of arc and are internally converted to radians for computation. These are entered in F10.0 format: PALFA located anywhere in columns 1 through 10 with decimal point included in the number; PGAMMA located in the 11-20 field and PSLA in the 21-30 field.

For single-picture analysis, one card must be provided for each picture, giving HP (altitude in km from which picture is taken), PCLAT (latitude in degrees at which picture is taken; southerly latitudes are negative), PCLONG (longitude in degrees from which picture is taken), and PAZM (flight path azimuth in degrees at time picture is taken). F10.0 format is used.

For orbit pass analysis, the third and last card for each case provides orbit parameters: HP (periapsis altitude in km), HA (apoapsis altitude in km), PER (orbit period in hours), PLAT (periapsis latitude in degrees), OI (orbit inclination to equator in degrees), DTPIC (time interval between pictures in seconds), XIPLAT (latitude in degrees of first picture), and XIPLING (longitude in degrees of first picture). NOTE: Either HA or PER should be specified (not both); the other should be entered as 0.0 and will then be computed by the program. F10.0 format is used.

Table I shows input data for the five cases presented as example calculations.

TABLE I. INPUT DATA FOR EXAMPLE CALCULATIONS

```
5

1 3
  13.5     13.5     12.5
 2260.    -20.      0.        0.
 2260.    -20.      5.        0.
 2260.    -20.      5.        5
026 0
 13.5     13.5      12.5
 1000.    17989.   0.         43.      90.       72.5      -20.      0.
033 0
  13.5    13.5      12.5
 1000.    0.        14.       22.      25.       120.      -10.      0.
030 0 1
 13.5     13.5      12.5
 1000.    0.        14.       22.      25.       120.      9.        39.71
030 0 1
  13.5    13.5      12.5
 1000.    0.        14.       22.      25.       72.5      23.25     80.
```

Example Calculations

Several example calculations with plots of computed coverage are given n this section to illustrate the use of this computer program. The first case (Table II) is a single-picture analysis which illustrates the capability of the program to move a picture on the surface of the planet. In this case, orbit parameters are not computed and are, therefore, not printed out. A typical picture is shown (Fig. 8) first centered at 0 degrees longitude and 20 degrees latitude; the picture is then shown move 5 degrees eastward in longitude, then it is rotated 5 degrees in azimuth.

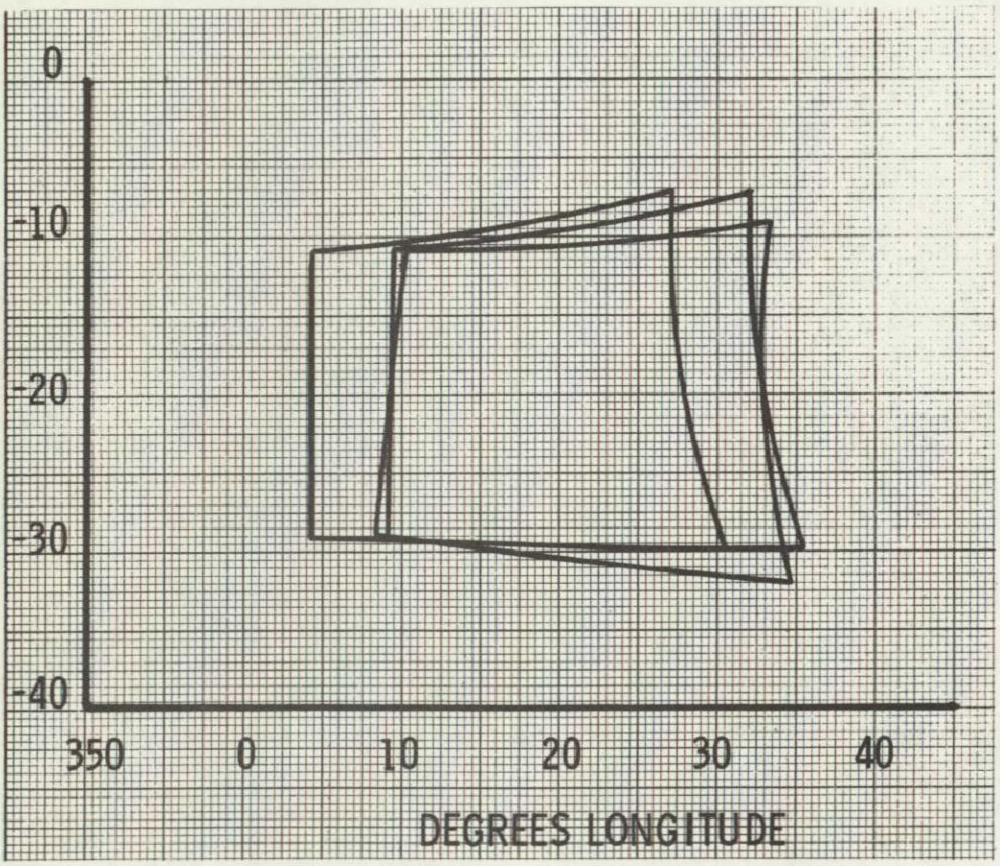

FIGURE 8. SINGLE-PICTURE ANALYSES - CASE 1

The principal utility of the program is in analyzing coverage obtainable from candidate orbits. The second case (Table III) presented shows the analysis of photo coverage corresponding to the baseline orbit in the Voyager 1973 mission baseline description. Results presented are identical to those shown in that document except that the calculations shown include effects of planet rotation. Input data are listed under camera parameters and orbit parameters. Outputs shown under computed orbit parameters and the interpolation table correspond to the analysis previously given for equations 1 through 18. The interpolation table is printed out as a check, since this program is somewhat experimental. Under photo format data, the locations from which each photograph is taken, as calculated by equations 19 through 28, are given, along with the points defining the picture itself as calculated by the remainder of the analysis. Figure 9 is a plot of these results.

Table IV and Figure 10 present analysis and show coverage from a 70 degree orbit in which the period is adjusted for complete longitude coverage in 17 orbits. The last two cases, Tables V and VI and Figure 11, present analyses and show coverages from a 25-degree orbit. The first of these shows coverage with a time interval between pictures of 120 seconds; and the second with a time interval of 72.5 seconds. Data from these two cases were combined in the accompanying figure to show coverage from a 25-degree orbit with a change in framing rate during the pass.

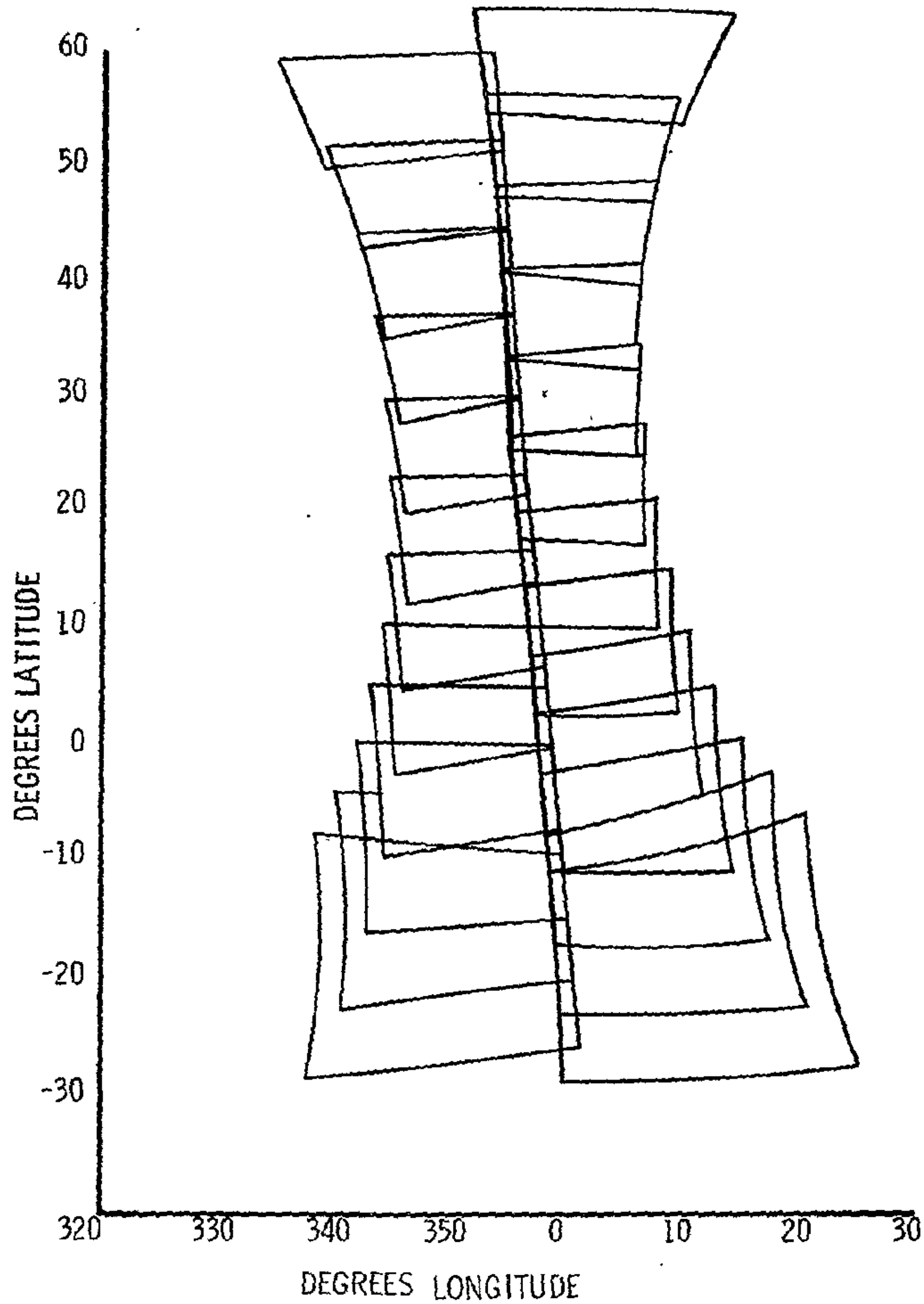

FIGURE 9. AREA COVERAGE PHOTOGRAPHY FROM POLAR ORBIT - CASE 2

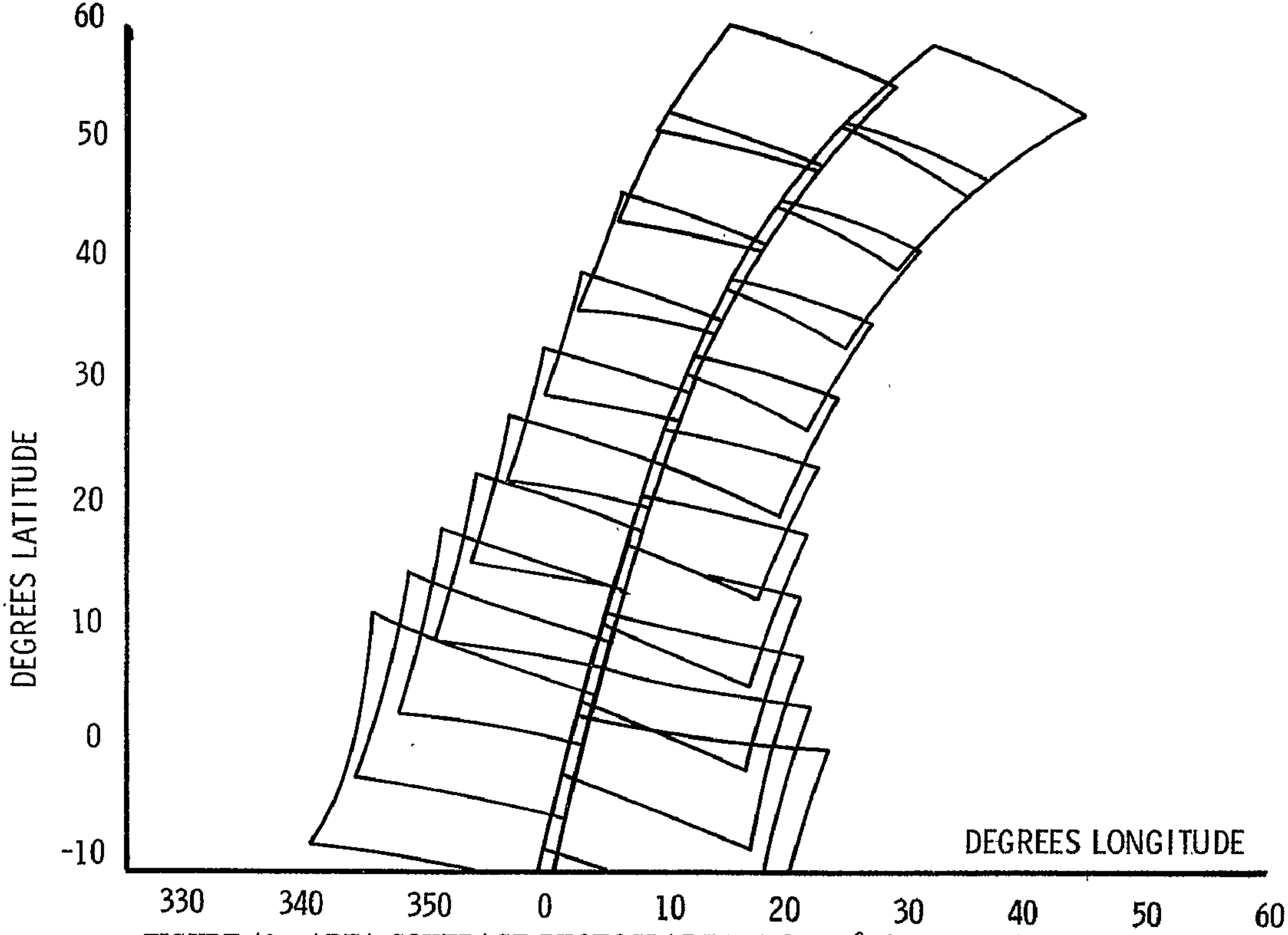

FIGURE 10. AREA COVERAGE PHOTOGRAPHY FROM 70° ORBIT - CASE 3

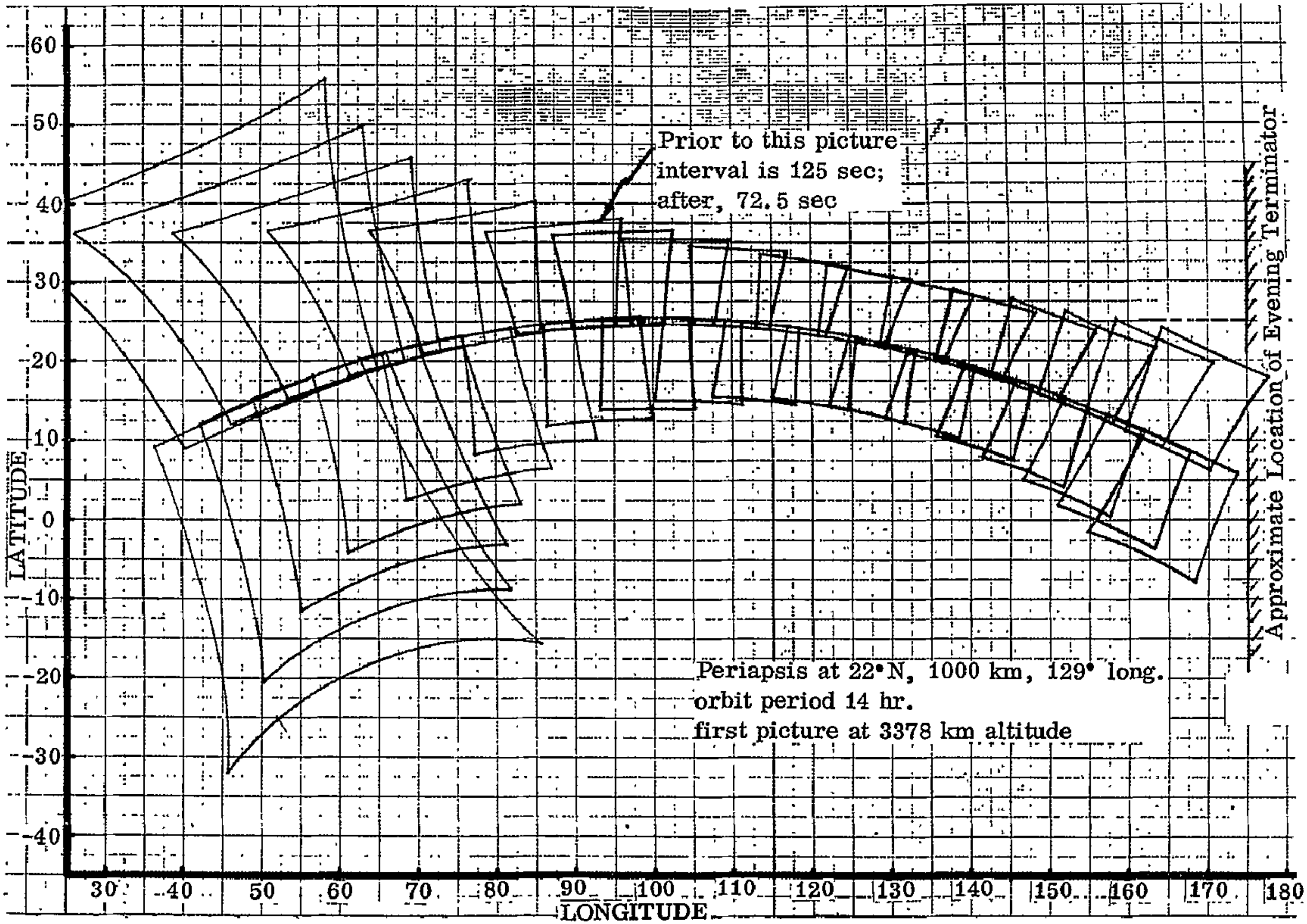

FIGURE 11. AREA COVERAGE PHOTOGRAPHY FROM 25° ORBIT - CASES 4 & 5

TABLE II. ORBITAL PHOTOIMAGING COVERAGE ANALYSIS - CASE 1

INPUT DATA

CAMERA PARAMETERS

VIEW HALF-ANGLES, TRANSVERSE = 13.50 DEG, FORE-AND-AFT = 13.50 DEG
SIDE-LOOKING ANGLE = 12.50 DEG

PHOTO FORMAT DATA

(LATITUDE)
(LONGITUDE)

	TRUE ANOM	TIME SEC	ALT KM	AZIM DEG	FOTO CTR LAT DEG	FOTO CTR LONG DEG	UPR LF	LF SIDE	LWR LF	BOT	LWR RF	RH SIDE	UPR RH	TOP
1	0	0	2260.00	0	-20.00	0	-10.84	-20.00	-29.16	-29.58	-29.75	-18.62	-7.14	-9.90
							359.31	359.29	359.22	10.22	25.35	22.25	22.00	9.01
2	0	0	2260.00	0	-20.00	5.00	-10.84	-20.00	-29.16	-29.58	-29.75	-18.62	-7.14	-9.90
							4.31	4.29	4.22	15.22	30.35	27.25	27.00	14.01
3	0	0	2260.00	5.00	-20.00	5.00	-10.81	-19.94	-29.06	-30.38	-31.73	-20.40	-6.94	-10.68
							5.12	4.29	3.31	14.26	29.52	27.42	26.09	14.88

TABLE III. ORBITAL PHOTOIMAGING COVERAGE ANALYSIS - CASE 2

CASE 2

INPUT DATA

CAMERA PARAMETERS

VIEW HALF-ANGLES, TRANSVERSE = 13.50 DEG, FORE-AND-AFT = 13.50 DEG
SIDE-LOOKING ANGLE = 12.50 DEG

ORBIT PARAMETERS

PERIAPSIS ALT = 1000.00 KM

APOAPSIS ALT = 17989.00 KM

PERIAPSIS LATITUDE = 43.00 DEG
ORBIT INCL = 90.00 DEG
TIME INTERVAL
BETWEEN PICTURES = 72.50 SEC
INITIAL POINT LATITUDE = -20.00 DEG
INITIAL POINT LONGITUDE = 0 DEG

COMPUTED ORBIT PARAMETERS

APOAPSIS RADIUS = 21367.00 KM
PERIAPSIS RADIUS = 4378.00 KM
TRUE ANOMALY
OF INITIAL POINT = 297.00 DEG
ORBIT ECCENTRICITY = .6599
TRUE ANOMALY
OF ASCENDING NODE = 317.00 DEG

LONGITUDE OF
ASCENDING NODE = 0 DEG
ORBIT PERIOD = 12.2956 HR

INTERPOLATION TABLE

TIME	TR ANOM	ECC ANOM
0	5.18	5.74
286.86	5.36	5.84
538.25	5.53	5.93
764.31	5.71	6.02
972.76	5.88	6.10
1169.87	6.06	6.18
1360.83	6.23	6.26
1550.41	6.41	6.34
1743.23	6.58	6.42
1944.20	6.75	6.50
2158.89	6.93	6.58
2394.04	7.10	6.67

TABLE III. (Continued)

2658.23	7.28	6.77
2962.86	7.45	6.87
3323.61	7.63	6.97
3762.39	7.80	7.09
4310.66	7.98	7.23
5013.98	8.15	7.38
5936.15	8.33	7.56
7176.66	8.50	7.76
8855.47	8.67	7.99
11125.22	8.85	8.27
14121.39	9.02	8.58
17874.52	9.20	8.93
22199.40	9.37	9.31
26675.70	9.55	9.69
30810.87	9.72	10.06
34269.25	9.90	10.40
36962.73	10.07	10.70
38977.50	10.25	10.96
40463.12	10.42	11.18
41562.63	10.59	11.37
42386.94	10.77	11.53
43023.64	10.94	11.68
43523.57	11.12	11.80
43927.98	11.29	11.92

PHOTO FORMAT DATA

(LATITUDE)
(LONGITUDE)

	TRUE ANOM	TIME SEC	ALT KM	AZIM DEG	FOTO CTR LAT DEG	FOTO CTR LONG DEG	UPR LH	LH SIDE	LWR LH	BOT	LWR RH	RH SIDE	UPR RH	TOP
1	297.00	0	2213.80	353.28	-20.00	360.00	-11 16	-20.08	-28.98	-28.22	-26.68	-16.36	-5.26	-9.22
							358.26	359.31	.44	11.10	25.42	21.28	19.82	7.59
2	299.39	72.50	2111.45	353.43	-17.61	359.71	-8 23	-18.76	-29.29	-27.53	-26.02	-17.54	-9.05	-9.22
							338.26	339.28	338.17	351.63	1.49	.36	359.36	350.32
3	301.87	145.00	2011.33	353.58	-15.13	359.41	-7 12	-15.20	-23.28	-22.72	-21.93	-12.34	-2.40	-5.47
							357.89	358.80	359.74	8.94	21.04	18.12	17.08	6.27
4	304.45	217.50	1913.84	353.74	-12.55	359.12	-4.47	-13.84	-23.26	-21.52	-20.17	-12.49	-4.81	-5.01
							340.23	341.32	340.91	352.12	.62	359.69	358.85	350.76
5	307.12	290.00	1819.35	353.91	-9.88	356.82	-2 64	-9.94	-17.23	-16.84	-16.44	-7.76	1.11	-1.26
							357.50	358.28	359.07	7.05	17.33	15.30	14.59	5.02
6	309.89	362.50	1728.24	354.08	-7.11	358.53	-0.11	-8.44	-16.83	-15.18	-13.98	-7.06	-0.14	-0.34
							341 84	342.94	342.95	352.41	359.80	359.04	358.33	351.08

TABLE III. (Continued)

7	312,75	435.00	1640,84	354.25	-4.25	358.23	2.27	-4.30	-10.87	-10.60	-10.46	-2.66	5.25	3.43
							357.08	357,75	358.41	5.39	14.21	12.81	12.37	3.86
8	315.71	507.50	1557,52	354.42	-1.29	357.94	4 82	-2,58	-10.05	-8.52	-7.47	-1.24	4.99	4.79
							343.09	344.16	344.43	352.53	359.02	358.40	357.80	351.27
9	318,78	580.00	1478,52	354.60	1.78	-2.36	7.65	1,74	-4.16	-4.00	-4.04	2.95	10.00	8.62
							356.64	357,21	357.76	3.94	11.62	10.67	10.42	2.79
10	321,94	652.50	1404,26	354.78	4.94	-2.65	10.30	3,71	-2.95	-1.56	-0.63	4.98	10.59	10.40
							343.98	345,02	345.42	352.50	358,28	357.77	357,26	351.31
11	325,20	725.00	1335,19	354.96	8.20	-2.94	13.49	8,16	2.83	2.93	2.76	9.05	15.36	14.31
							356.16	356,66	357.13	2.69	9.49	6.87	8.77	1.82
12	328,55	797.50	1271,61	355.14	11.55	-3.24	16.30	10,39	4.43	5.69	6.50	11.58	16.66	16.49
							344.50	345,50	346.00	352.33	357,58	357.14	356,71	351.20
13	331,99	870.00	1213,88	355,33	14.99	-3.53	19.80	14,96	10.11	10.15	9.50	15,58	21,28	20.46
							355.66	356.10	356.50	1.62	7,81	7.42	7,45	.98
14	335,51	942.50	1162,43	355.52	18.51	-3.83	22.78	17,43	12.02	13.18	13.69	18.53	23.17	23.02
							344.62	345,61	346.17	352.00	356.90	356.53	356.15	350.92
15	339,10	1015.00	1117,54	355.71	22.10	-4.12	26.54	22,08	17.62	17.61	17.29	22.50	27.71	27.11
							355.13	355,52	355.88	.74	6,55	6.34	6.50	.28
16	342,77	1087.50	1079,53	355.90	25.77	-4.42	29.68	24,74	19.75	20.84	21.48	25.79	30.10	29.96
							344.28	345,31	345.94	351.52	356.26	355.94	355.60	350.44
17	346,49	1160.00	1048,70	356.09	29.49	-4.71	33.65	29,47	25.29	25.23	24.83	29.70	34.57	34.14
							354.57	354,93	355.26	.06	5.76	5.71	6.02	359.76
18	350,26	1232.50	1025,25	356.28	33,26	-5,01	36.91	32,24	27,53	28.56	29.19	33,28	37.37	37.24
							343.40	344,54	345.26	350.86	355.65	355.36	355,04	349,72
19	354,06	1305.00	1009,37	356.47	37.06	-5.30	41.06	37,04	33.01	32.91	32.42	37.09	41.76	41.48
							353.97	354.33	354.64	359.61	5.48	5.62	6.13	359.50
20	357,88	1377.50	1001,19	356.67	40.88	-5.59	44.35	39,83	35.24	36.32	36.90	40.90	44.89	44.77
							341.78	343,16	344.05	349.96	355.07	354.80	354.50	348.67
21	361,71	1450.00	1000,77	356.87	44.71	-5.89	48.68	44.69	40.70	40.54	39.91	44.54	49.14	49.04
							353.33	353,70	354.01	359.45	5.84	6.24	7.11	359.59
22	365,53	1522.50	1008,12	357.08	48.53	-6.18	51.88	47,36	42.76	43.94	44.52	48.55	52.57	52.43
							339.09	340,94	342.14	348.77	354.53	354,27	353.97	347.13

TABLE III. (Concluded)

23	369,34	1595,00	1023,16	357.28	52.34	-6.48	50.40 352 62	52,32 356,03	48.24 353.30	48.01 359.68	47.16 7.05	51.88 7.90	56,54 9.44	56,69 .28
24	373,11	1667,50	1045,62	357.49	56.11	-6.77	59 29 334 67	54,68 337.48	49.95 339.26	51.32 347.13	51.94 354.03	56.12 353.78	60.30 353.49	60.11 344.78
25	376,84	1740,00	1075,89	357.71	59.84	-7.07	64.12 351.80	59.82 352.30	55.52 352.67	55.16 .46	54.00 9.46	58.92 11.18	63.72 14.15	64.30 2.04
26	380,50	1812,50	1113,12	357.93	63,50	-7.36	66.32 327.12	61.60 332.02	56.64 335.02	58.37 344.61	59.06 353.60	63.51 353.38	67.97 353.16	67.67 340.89

TABLE IV. ORBITAL PHOTOIMAGING COVERAGE ANALYSIS - CASE 3

INPUT DATA

CAMERA PARAMETERS

VIEW HALF-ANGLES, TRANSVERSE = 13.50 DEG, FORE-AND-AFT = 13.50 DEG
SIDE-LOOKING ANGLE = 12.50 DEG

ORBIT PARAMETERS

PERIAPSIS ALT = 1000.00 KM

ORBIT PERIOD = 13.05 HR

PERIAPSIS LATITUDE = 50.00 DEG
ORBIT INCL = 70.00 DEG
TIME INTERVAL
BETWEEN PICTURES = 72.50 SEC
INITIAL POINT LATITUDE = -10.00 DEG
INITIAL POINT LONGITUDE = 0 DEG

COMPUTED ORBIT PARAMETERS

APOAPSIS RADIUS = 22415.10 KM
PERIAPSIS RADIUS = 4378.00 KM
TRUE ANOMALY
OF INITIAL POINT = 294.74 DEG
ORBIT ECCENTRICITY = .6732
TRUE ANOMALY
OF ASCENDING NODE = 305.39 DEG

LONGITUDE OF
ASCENDING NODE = 3.68 DEG
ORBIT PERIOD = 13.0540 HR

INTERPOLATION TABLE

TIME	TR ANOM	ECC ANOM
0	5.14	5.73
297.24	5.32	5.83
555.66	5.49	5.92
786.35	5.67	6.00
997.66	5.84	6.09
1196.16	6.02	6.16
1387.35	6.19	6.24
1576.08	6.37	6.32
1767.02	6.54	6.40
1965.03	6.72	6.48
2175.53	6.89	6.56
2405.03	7.06	6.64

TABLE IV. (Continued)

2661.79	7.24	6.73
2956.71	7.41	6.83
3304.71	7.59	6.93
3726.82	7.76	7.05
4253.28	7.94	7.18
4928.22	8.11	7.32
5816.37	8.29	7.49
7011.76	8.46	7.69
8645.75	8.63	7.91
10885.77	8.81	8.18
13903.71	8.98	8.49
17786.88	9.16	8.84
22400.57	9.33	9.22
27316.95	9.51	9.61
31958.92	9.68	9.99
35885.40	9.86	10.35
38946.97	10.03	10.66
41223.00	10.21	10.92
42883.61	10.38	11.15
44098.19	10.55	11.35
44999.55	10.73	11.52
45683.65	10.90	11.66
46216.52	11.08	11.79
46643.17	11.25	11.91

PHOTO FORMAT DATA

(LATITUDE)
(LONGITUDE)

	TRUE ANOM	TIME SEC	ALT KM	AZIM DEG	FOTO CTR LAT DEG	FOTO CTR LONG DEG	U R H	LF SIDE	LWR LF	BOT	LWR RH	RH SIDE	UPR RH	TOP
1	294.74	0	2336.97	13.13	-10.00	360.00	-0.60 1.46	-9.84 359.32	-19.06 357.00	-21.98 7.14	-26.11 21.55	-14.15 21.97	-2.59 25.08	-1.97 11.30
2	297.04	72.50	2230.82	13.24	-7.85	.51	8.44 342.15	-2.72 340.35	-13.25 336.19	-15.14 349.35	-16.80 359.04	-8.00 1.16	.80 3.23	3.69 354.21
3	299.43	145.00	2126.67	13.37	-5.61	1.04	2.92 2.40	-5.46 .43	-13.82 358.36	-16.51 7.26	-20.36 19.33	-9.74 20.37	.51 23.34	1.54 11.30
4	301.91	217.50	2024.90	13.53	-3.28	1.60	11.09 345.19	1.15 343.61	-8.38 340.34	-9.90 351.69	-11.37 .26	-3.42 2.19	4.54 4.11	7.15 355.93
5	304.48	290.00	1925.86	13.74	-0.86	2.19	6.83 3.48	-0.72 1.64	-8.27 359.76	-10.75 7.59	-14.31 17.82	-4.91 19.23	4.15 22.07	5.46 11.52
6	307.15	362.50	1829.93	13.98	1.65	2.81	14.37 348.13	5.53 346.72	-3.04 344.09	-4.31 353.96	-5.64 1.56	1.52 3.34	8.68 5.15	11.05 357.72
7	309.92	435.00	1737.43	14.26	4.25	3.46	11.16	4.38	-2.40	-4.69	-7.98	.31	8.31	9.79

TABLE IV. (Continued)

							4.70	2.96	1.24	8.17	16.93	18.57	21.28	11.98
8	312.78	507.50	1648.72	14.59	6.94	4.16	18.26	10.40	2.73	1.63	.40	6.82	13.23	15.40
							350.99	349.68	347.52	356.18	2.97	4.64	6.36	359.60
9	315.75	580.00	1564.07	14.97	9.73	4.90	15.92	9.85	3.77	1.64	-1.39	5.91	12.95	14.56
							6.12	4.45	2.82	9.01	16.62	18.39	21.01	12.74
10	318.82	652.50	1483.84	15.42	12.61	5.70	22.74	15.75	8.90	7.90	6.74	12.49	18.22	20.24
							353.60	352.56	350.70	358.41	4.54	6.13	7.82	1.61
11	321.99	725.00	1408.50	15.93	15.57	6.56	21.12	15.68	10.24	8.24	5.42	11.85	18.06	19.75
							7.78	6.14	4.57	10.10	16.87	16.74	21.31	13.87
12	325.25	797.50	1338.41	16.52	18.62	7.48	27.79	21.56	15.43	14.48	13.35	18.50	23.64	25.54
							356.61	355.38	353.70	.69	6.31	7.88	9.57	3.81
13	328.61	870.00	1273.87	17.21	21.75	8.49	26.73	21.86	16.97	15.07	12.40	18.09	23.58	25.35
							9.78	8.11	6.54	11.67	17.71	19.68	22.27	15.46
14	332.06	942.50	1215.37	17.99	24.95	9.60	33.38	27.78	22.26	21.32	20.20	24.84	29.45	31.29
							359.48	358.21	356.61	3.11	8.37	9.98	11.72	6.28
15	335.60	1015.00	1163.24	18.90	28.21	10.82	32.72	28.32	23.91	22.04	19.46	24.54	29.42	31.29
							12.22	10.45	8.81	13.64	19.21	21.34	24.03	17.65
16	339.21	1087.50	1117.79	19.95	31.53	12.17	39.46	34.37	29.34	28.36	27.21	31.42	35.60	37.44
							2.52	1.11	359.49	5.74	10.81	12.53	14.43	9.14
17	342.89	1160.00	1079.40	21.16	34.89	13.67	39.02	35.00	30.96	29.08	26.51	31.09	35.47	37.48
							15.29	13.31	11.50	16.19	21.49	23.65	26.79	20.63
18	346.62	1232.50	1048.32	22.57	38.27	15.36	45.95	41.23	36.56	35.50	34.27	38.15	41.99	43.90
							5.87	4.21	2.43	8.70	13.76	15.72	17.91	12.59
19	350.41	1305.00	1024.77	24.22	41.65	17.27	45.50	41.78	38.02	36.05	33.37	37.56	41.53	43.78
							19.27	16.90	14.78	19.49	24.70	27.46	30.86	24.71
20	354.22	1377.50	1008.97	26.14	45.02	19.45	52.75	48.27	43.84	42.64	41.25	44.89	48.47	50.55
							9.79	7.67	5.54	12.16	17.44	19.82	22.53	16.96
21	358.06	1450.00	1001.01	28.40	48.35	21.94	51.98	48.49	44.93	42.77	39.85	43.73	47.33	49.97
							24.61	21.55	18.89	23.78	29.06	32.47	36.64	30.35
22	361.91	1522.50	1000.97	31.08	51.60	24.84	59.74	55.38	51.05	49.62	47.99	51.45	54.81	57.21
							14.75	11.76	8.98	16.36	22.13	25.24	28.86	22.83

TABLE IV. (Concluded)

23	365.74	1595.00	1008.86	34.24	54.75	28.20	58.20	54.92	51.52	49.03	45.70	49.30	52.51	55.72
							32.03	27.77	24.16	29.39	34.83	39.26	44.66	38.19
24	369.56	1667.50	1024.60	38.01	57.76	32.15	66.71	62.40	58.08	56.30	54.28	57.57	60.68	63.60
							21.72	16.99	12.98	21.70	28.24	32.59	37.79	31.22
25	373.34	1740.00	1048.08	42.49	60.57	36.79	63.76	60.78	57.56	54.57	50.63	53.89	56.57	60.59
							42.68	36.32	31.08	36.71	42.24	48.15	55.29	49.03
26	377.08	1812.50	1079.09	47.82	63.14	42.26	73.35	69.17	64.82	62.47	59.87	62.90	65.58	69.28
							33.12	24.42	17.94	28.79	36.32	42.73	50.54	44.02
27	380.76	1885.00	1117.42	54.11	65.40	48.67	68.04	65.66	62.79	59.10	54.33	57.09	58.95	63.97
							57.86	48.20	40.29	46.06	51.26	59.13	68.33	63.31
28	384.37	1957.50	1162.81	61.42	67.27	56.07	78.90	75.47	71.13	67.91	64.46	66.97	68.79	73.43
							55.50	36.66	24.71	38.59	46.95	56.49	67.90	63.85
29	387.91	2030.00	1214.87	69.69	68.70	64.42	70.25	69.04	66.89	62.33	56.58	58.57	59.28	65.29
							77.65	64.07	52.39	57.44	61.46	71.44	82.41	80.08
30	391.36	2102.50	1273.32	78.72	69.61	73.48	81.13	80.29	76.86	72.26	67.71	69.24	69.62	74.87
							98.01	80.55	35.25	52.41	60.39	73.69	88.21	90.45
31	394.72	2175.00	1337.82	88.09	69.99	82.88	69.87	70.39	69.52	64.07	57.30	58.26	57.57	64.36
							98.60	82.84	67.35	70.12	71.87	83.62	95.47	96.59
32	397.98	2247.50	1407.84	97.31	69.84	92.09	78.27	81.98	81.61	75.07	69.38	69.43	68.02	73.15
							136.84	103.38	55.18	71.15	75.83	91.94	107.06	115.71
33	401.15	2320.00	1483.15	105.94	69.22	100.69	67.28	69.64	70.50	64.32	56.66	56.43	54.24	61.60
							115.99	101.03	83.68	82.69	81.36	94.22	106.08	110.25

TABLE V. ORBITAL PHOTOIMAGING COVERAGE ANALYSIS - CASE 4

INPUT DATA

CAMERA PARAMETERS

VIEW HALF-ANGLES, TRANSVERSE = 13.50 DEG, FORE-AND-AFT = 13.50 DEG
SIDE-LOOKING ANGLE = 12.50 DEG

ORBIT PARAMETERS

PERIAPSIS ALT = 1000.00 KM

ORBIT PERIOD = 14.00 HR

PERIAPSIS LATITUDE = 22.00 DEG
ORBIT INCL = 25.00 DEG
TIME INTERVAL
BETWEEN PICTURES = 120.00 SEC
INITIAL POINT LATITUDE = 9.00 DEG
INITIAL POINT LONGITUDE = 39.71 DEG

COMPUTED ORBIT PARAMETERS

APOAPSIS RADIUS = 23694.38 KM
PERIAPSIS RADIUS = 4378.00 KM
TRUE ANOMALY
OF INITIAL POINT = 264.15 DEG
ORBIT ECCENTRICITY = .6881
TRUE ANOMALY
OF ASCENDING NODE = 242.42 DEG

LONGITUDE OF
ASCENDING NODE = 19.85 DEG
ORBIT PERIOD = 14.0000 HR

INTERPOLATION TABLE

TIME	TR ANOM	ECC ANOM
0	4.61	5.39
547.99	4.78	5.52
983.93	4.96	5.64
1340.89	5.13	5.74
1641.60	5.31	5.84
1902.04	5.48	5.92
2133.76	5.66	6.01
2345.42	5.83	6.09
2543.79	6.01	6.16
2734.47	6.18	6.24
2922.38	6.36	6.31
3112.25	6.53	6.39

TABLE V. (Continued)

3308.94	6.70	6.47
3517.90	6.88	6.55
3745.66	7.05	6.63
4000.48	7.23	6.72
4293.35	7.40	6.81
4639.36	7.58	6.91
5059.86	7.75	7.02
5585.85	7.93	7.15
6263.01	8.10	7.29
7159.33	8.28	7.46
8375.42	8.45	7.65
10055.61	8.62	7.87
12390.98	8.80	8.13
15590.55	8.97	8.44
19783.83	9.15	8.80
24851.86	9.32	9.19
30316.76	9.50	9.59
35495.49	9.67	9.99
39855.58	9.85	10.35
43219.66	10.02	10.67
45687.85	10.20	10.94
47464.95	10.37	11.17
48748.51	10.54	11.36
49691.09	10.72	11.53

PHOTO FORMAT DATA

(LATITUDE)
(LONGITUDE)

	TRUE ANOM	TIME SEC	ALT KM	AZTH DEG	FOTO CTR LAT DEG	FOTO CTR LONG DEG	UPR LH	LH SIDE	LWR LH	BOT	LWR RH	RH SIDE	UPR RH	TOP
1	264,15	0	4570,00	59.30	9.00	39.71	19.54	10.16	.15	-19.04	-55.75	-44.61	-23.42	2.36
							56.38	39,01	22.53	30.85	44.00 **	80.19 **	97.19 **	68,48
2	266,15	120.00	4370,66	60.16	9.79	41.08	73 85	57,50	33.07	14.33	-0.72	8,67	17,17	35,97
							35.23 **	344,62 **	335,64 **	13.00	25,97	41,74	58.38	51,42
3	268,24	240,00	4171,73	61.03	10.61	42.56	19 71	11,69	3.01	-14.29	-52.80	-34.72	-23.35	3.81
							58 01	41,95	26.72	33.99	43,93 **	70.41	97,34 **	68.19
4	270,45	360.00	3972,99	61.94	11.45	44.14	74.10	49,85	35.23	16.24	2.34	10.41	17.64	34,56
							44.07 **	12.16	339.67 **	19.02	30,19	44,71	60.03	54,14
5	272,77	480.00	3774,40	62.88	12.33	45.86	20.07	13,32	5.92	-9.59	-49.48	-25.17	-23.03	5.51
							60.08	45.33	31.35	37,62	44,61 **	65,61	97.67 **	68.54
6	275,23	600.00	3576,11	63.87	13.24	47.71	68.91	46,31	36.86	18.19	5.48	12.29	18.30	33,42
							52 09	24,34	350.84	25,43	34.92	48.19	62.19	57.32
7	277,84	720.00	3378,44	64.91	14.18	49.73	20.63	15,08	8.90	-4.91	-42.16	-17.87	-14.62	7.45

TABLE V. (Continued)

							62.70	49.29	36.54	41.83	47.21	64.63	86.50	69.60
8	280.60	840.00	3181.86	66.02	15.14	51.92	55.98	43.84	35.94	20.21	8.68	14.28	19.16	32.55
							56.68	34.37	12.23	32.36	40.27	52.31	64.97	61.09
9	283.54	960.00	2986.98	67.21	16.14	54.30	21.37	16.95	11.93	-0.25	-20.48	-11.37	-8.08	9.69
							66.02	53.95	42.43	46.75	50.96	65.59	82.25	71.51
10	286.66	1080.00	2794.73	68.48	17.15	56.90	50.02	41.98	35.87	22.26	11.92	16.38	20.19	31.92
							62.44	43.85	25.97	39.95	46.38	57.21	68.54	65.58
11	289.98	1200.00	2605.71	69.86	18.17	59.72	22.27	18.90	14.98	4.35	-11.59	-5.36	-2.70	11.87
							70.19	59.44	49.13	52.53	55.70	68.11	81.64	74.41
12	293.51	1320.00	2420.74	71.36	19.20	62.80	45.92	40.54	36.06	24.30	15.13	18.52	21.35	31.50
							68.96	53.42	38.51	48.37	53.40	63.04	73.06	70.98
13	297.27	1440.00	2240.80	73.00	20.22	66.16	23.27	20.85	17.97	8.78	-4.01	.23	2.16	14.23
							75.40	65.95	56.62	59.33	61.57	72.13	83.33	78.49
14	301.28	1560.00	2067.12	74.79	21.20	69.82	42.81	39.37	36.32	26.23	18.21	20.61	22.56	31.22
							76.42	63.49	51.00	57.77	61.51	70.00	78.74	77.46
15	305.54	1680.00	1900.91	76.75	22.15	73.81	24.26	22.69	20.75	12.90	2.58	5.33	6.54	16.50
							81.86	73.67	65.68	67.36	68.76	77.73	87.05	63.95
16	310.08	1800.00	1743.55	78.89	23.01	78.15	40.30	38.32	36.49	27.91	20.98	22.50	23.66	30.96
							85.01	74.35	63.92	68.31	70.87	78.25	85.79	65.22
17	314.89	1920.00	1596.74	81.21	23.76	82.83	25.06	24.23	23.10	16.48	8.11	9.71	10.27	18.48
							89.76	82.76	75.85	76.75	77.41	85.01	92.79	90.99
18	319.98	2040.00	1461.99	83.73	24.37	87.89	38.09	37.20	36.35	29.11	23.17	23.94	24.44	30.54
							94.86	86.13	77.49	80.05	81.59	87.94	94.35	94.40
19	325.35	2160.00	1341.24	86.42	24.80	93.28	25.42	25.19	24.75	19.17	12.33	13.05	13.07	19.86
							99.20	93.25	87.34	87.57	87.57	94.03	100.54	99.71
20	330.98	2280.00	1236.16	89.27	24.99	99.00	35.86	35.77	35.70	29.55	24.46	24.63	24.59	29.69
							106.00	98.83	91.67	92.87	93.56	99.00	104.45	105.00
21	336.85	2400.00	1148.59	92.22	24.92	104.99	25.00	25.26	25.36	20.61	14.90	14.95	14.51	20.24
							110.07	105.00	99.92	99.58	99.03	104.59	110.12	110.01
22	342.92	2520.00	1060.11	95.23	24.55	111.18	33.37	33.86	34.37	29.02	24.55	24.23	23.77	28.15
							116.21	112.20	106.16	106.38	106.42	111.15	115.85	116.80

TABLE V. (Concluded)

23	349.16	2640.00	1032.67	98.23	23.87	117.49	23.52	24.18	24.70	20.50	15.51	15.05	14.21	19.28
							121.99	117.54	113.04	112.25	111.23	116.17	121.05	121.49
24	355.50	2760.00	1005.50	101.14	22.88	123.63	30.42	31.37	32.30	27.43	23.30	22.59	21.75	25.74
							131 10	125.78	120.42	119.95	119.47	123.77	128.01	129.31
25	361.89	2880.00	1000.97	103.90	21.59	130.10	20.86	21.88	22.79	18.81	14.09	13.20	11.97	16.81
							134.33	130.18	125.97	124.77	123.30	127.98	132.56	133.45
26	368.26	3000.00	1018.60	106.44	20.04	136.22	27.05	28.44	29.90	24.97	20.64	19.75	18.55	22.46
							144 14	139.04	133.90	132.67	131.55	136.13	140.25	141.91
27	374.55	3120.00	1058.00	108.74	18.27	142.12	17.16	18.56	19.88	15.79	10.93	9.58	7.89	12.96
							146 42	142.23	137.97	136.34	134.35	139.16	143.83	145.16
28	380.70	3240.00	1118.29	110.76	16.34	147.75	23 47	25.37	27.39	22.01	17.56	16.03	14.40	18.57
							156 87	151.54	146.17	144.59	143.24	147.63	151.95	154.05
29	386.66	3360.00	1198.28	112.49	14.30	153.07	12.75	14.03	16.42	11.91	6.51	4.64	2.34	8.07
							157.76	153.21	148.59	146.44	143.76	149.08	154.22	156.05
30	392.39	3480.00	1296.42	113.96	12.21	158.07	20.02	22.53	25.20	19.01	13.92	11.86	9.71	14.43
							169.01	163.03	157.05	154.86	153.01	157.91	162.72	165.39

** LIMB OF PLANET IN VIEW

TABLE VI. ORBITAL PHOTOIMAGING COVERAGE ANALYSIS - CASE 5

INPUT DATA

CAMERA PARAMETERS

VIEW HALF-ANGLES, TRANSVERSE = 13.50 DEG, FORE-AND-AFT = 13.50 DEG
SIDE-LOOKING ANGLE = 12.50 DEG

ORBIT PARAMETERS

PERIAPSIS ALT = 1000.00 KM

ORBIT PERIOD = 14.00 HR

PERIAPSIS LATITUDE = 22.00 DEG
ORBIT INCL = 25.00 DEG
TIME INTERVAL
BETWEEN PICTURES = 72.50 SEC
INITIAL POINT LATITUDE = 23.25 DEG
INITIAL POINT LONGITUDE = 80.00 DEG

COMPUTED ORBIT PARAMETERS

APOAPSIS RADIUS = 23694.38 KM
PERIAPSIS RADIUS = 4378.00 KM
TRUE ANOMALY
OF INITIAL POINT = 311.50 DEG
ORBIT ECCENTRICITY = .6881
TRUE ANOMALY
OF ASCENDING NODE = 242.42 DEG

LONGITUDE OF
ASCENDING NODE = 12.88 DEG
ORBIT PERIOD = 14.0000 HR

INTERPOLATION TABLE

TIME	TR ANOM	ECC ANOM
0	5.44	5.90
238.39	5.61	5.99
454.65	5.79	6.07
655.96	5.96	6.14
848.18	6.13	6.22
1036.38	6.31	6.29
1225.25	6.48	6.37
1419.63	6.66	6.45
1624.75	6.83	6.52
1846.61	7.01	6.61
2093.53	7.18	6.69
2375.04	7.36	6.78

TABLE VI. (Continued)

2705.18	7.53	6.88
3103.39	7.71	6.99
3597.68	7.88	7.11
4229.22	8.05	7.25
5059.18	8.23	7.41
6178.41	8.40	7.59
7718.74	8.58	7.81
9859.75	8.75	8.06
12811.73	8.93	8.36
16739.70	9.10	8.70
21607.69	9.28	9.08
27031.33	9.45	9.49
32350.12	9.63	9.88
36959.57	9.80	10.26
40586.16	9.97	10.59
43273.49	10.15	10.87
45213.12	10.32	11.11
46610.64	10.50	11.31
47631.46	10.67	11.49
48394.02	10.85	11.64
48979.10	11.02	11.77
49440.99	11.20	11.89
49816.36	11.37	12.00
50130.16	11.55	12.09

PHOTO FORMAT DATA

	TRUE ANOM	TIME SEC	ALT KM	AZIM DEG	FOTO CTR LAT DEG	FOTO CTR LONG DEG	UPR LH	LH SIDE	LWR LH	BOT	LWR RH	RH SIDE	UPR RH	TOP
							(LATITUDE) / (LONGITUDE)							
1	311.50	0	1698.14	79.57	23.25	80.00	24.82	23.74	22.34	15.31	6.31	8.28	9.06	17.84
							87.31	79.90	72.63	73.79	74.69	82.75	91.04	88.82
2	314.42	72.50	1610.24	80.98	23.70	82.85	39.28	37.84	36.48	28.52	22.06	23.23	24.07	30.80
							89.78	80.03	70.45	73.95	76.03	82.93	89.94	89.67
3	317.44	145.00	1526.53	82.47	24.10	85.84	25.21	24.54	23.60	17.26	9.32	10.67	11.09	18.91
							92.50	85.77	79.13	79.85	80.33	87.63	95.06	93.52
4	320.58	217.50	1447.54	84.03	24.43	88.96	37.96	37.13	36.33	29.15	23.27	24.01	24.47	30.50
							95.94	87.31	78.76	81.23	82.72	89.01	95.36	95.44
5	323.81	290.00	1373.72	85.65	24.70	92.21	25.41	25.10	24.57	18.86	11.83	12.66	12.75	19.71
							98.26	92.17	86.13	86.44	86.53	93.14	99.81	98.86
6	327.14	362.50	1305.52	87.33	24.89	95.57	36.64	36.30	35.99	29.50	24.14	24.50	24.63	30.04
							102.57	94.92	87.29	88.90	89.66	95.59	101.35	101.74
7	330.56	435.00	1243.31	89.06	24.99	99.05	25.34	25.35	25.17	20.01	13.75	14.14	13.93	20.18

TABLE VI. (Continued)

							104.55	99.04	93.54	93.49	93.22	99.23	105.25	104.78
8	334.07	507.50	1187.39	90.83	24.99	102.63	35.24	35.32	35.42	29.52	24.61	24.64	24.47	29.36
							109.62	102.81	95.99	96.89	97.39	102.62	107.85	108.51
9	337.66	580.00	1138.19	92.63	24.89	106.29	24.94	25.23	25.35	20.65	15.00	15.02	14.55	20.22
							111.33	106.31	101.27	100.90	100.32	105.83	111.30	111.24
10	341.32	652.50	1096.06	94.45	24.68	110.03	33.72	34.14	34.58	29.15	24.61	24.36	23.94	28.40
							117.05	110.91	104.75	105.08	105.19	110.00	114.78	115.68
11	345.05	725.00	1061.24	96.27	24.36	113.82	24.14	24.67	25.06	20.71	15.53	15.23	14.52	19.76
							118.48	113.85	109.20	108.55	107.67	112.78	117.83	118.11
12	348.83	797.50	1034.06	98.07	23.92	117.64	32 03	32.75	33.49	28.40	24.12	23.61	22.97	27.12
							124.74	119.12	113.46	113.32	113.10	117.59	122.03	123.15
13	352.65	870.00	1014.71	99.85	23.36	121.47	22.91	23.66	24.30	20.19	15.31	14.73	13.79	18.75
							125.86	121.52	117.14	116.23	115.09	119.93	124.68	125.25
14	356.50	942.50	1003.33	101.58	22.70	125.29	30.17	31.16	32.18	27.27	23.15	22.41	21.54	25.51
							132.60	127.31	121.98	121.46	120.95	125.23	129.45	130.77
15	360.36	1015.00	1000.04	103.25	21.92	129.09	21.24	22.21	23.08	19.09	14.36	13.52	12.34	17.19
							133.33	129.16	124.93	123.78	122.37	127.06	131.66	132.49
16	364.22	1087.50	1004.84	104.85	21.05	132.83	28.16	29.41	30.71	25.83	21.74	20.76	19.68	23.58
							140.49	135.37	130.20	129.35	128.57	132.75	136.87	138.41
17	368.06	1160.00	1017.71	106.37	20.09	136.51	19.18	20.38	21.48	17.48	12.75	11.65	10.21	15.10
							140.73	136.60	132.41	131.01	129.30	133.99	138.57	139.67
18	371.88	1232.50	1038.54	107.79	19.05	140.11	26.03	27.56	29.17	24.15	19.97	18.75	17.44	21.39
							148.32	143.19	138.02	136.84	135.60	140.01	144.16	145.93
19	375.65	1305.00	1067.16	109.11	17.94	143.62	16.79	18.23	19.59	15.47	10.58	9.19	7.46	12.56
							147.94	143.73	139.45	137.78	135.73	140.57	145.27	146.63
20	379.37	1377.50	1103.35	110.34	16.77	147.02	23.86	25.70	27.65	22.35	17.55	16.46	14.89	19.01
							155.96	150.69	145.37	143.86	142.55	146.90	151.18	153.24
21	383.02	1450.00	1146.85	111.46	15.56	150.32	14.16	15.88	17.52	13.16	7.57	6.27	4.18	9.66
							154.85	150.44	145.97	143.99	141.54	146.67	151.62	153.29
22	386.59	1522.50	1197.31	112.48	14.32	153.49	21.72	23.91	26.20	20.51	15.78	14.00	12.12	16.53
							163.44	157.83	152.21	150.34	148.75	153.35	157.88	160.25

TABLE VI. (Concluded)

23	390.09	1595.00	1254.44	113.40	13.06	156.55	11.37	13.41	15.36	10.67	5.04	2.98	.46	6.49
							161.41	156.71	151.93	149.60	146.68	152.22	157.57	159.57
24	393.49	1667.50	1317.81	114.22	11.80	159.49	19.70	22.27	25.09	18.72	13.56	11.44	9.26	14.02
							170.65	164.58	158.52	156.28	154.37	159.33	164.21	166.94
25	396.80	1740.00	1387.04	114.95	10.53	162.31	8.52	10.90	13.21	8.09	1.90	-0.56	-3.54	3.16
							167.59	162.49	157.31	154.59	151.10	157.20	163.07	165.44
26	400.01	1812.50	1461.81	115.60	9.27	165.02	17.85	20.85	24.20	17.06	11.37	8.88	6.31	11.56
							177.62	170.95	164.33	161.67	159.43	164.83	170.15	173.29
27	403.12	1885.00	1541.63	116.16	8.03	167.61	5.68	8.44	11.14	5.51	-1.37	-4.27	-7.82	-0.26
							173.40	167.81	162.15	158.99	154.80	161.61	168.13	170.91
28	406.13	1957.50	1626.11	116.65	6.81	170.09	16.25	19.69	23.64	15.58	9.26	6.38	3.41	9.21
							184.34	176.94	169.65	166.54	163.94	169.87	175.72	179.30
29	409.03	2030.00	1714.94	117.08	5.62	172.46	2.90	6.07	9.18	2.98	-4.69	-8.08	-12.28	-3.70
							178.85	172.69	166.47	162.82	157.81	165.46	172.76	176.00
30	411.84	2102.50	1807.74	117.44	4.45	174.72	14.92	18.83	23.47	14.30	7.29	3.98	.59	7.02
							190.86	182.58	174.51	170.93	167.95	174.48	180.94	184.99

∧ *TOTAL 3200 CPU TIME 0.029 HOURS, TOTAL OPERATING EXPENSE $ 3.91 ^^

APPENDIX A

APPENDIX A

Nomenclature

This list of nomenclature combines mathematical nomenclature and Fortran variables and is arranged in terms of Fortran variables in order of appearance.

MAIN PROGRAM (PHOTO)

FORTRAN NAME	MATH SYMBOL	MEANING
LAT	L	Latitude of a point defining picture outline; math symbol L applies to latitude in general.
LONG	Θ	Longitude of a point defining picture outline; math symbol Θ applies to longitude in general.
OM	ω	See Figure 4.
BOM	Ω	See Figure 4.
MARK	none	Labelling variable used to label data where planet limb is seen.
N	none	Counter for case numbers.
INV	none	Set = -1, causes XFØRM to execute universe transform.
NQ	none	Not used.
NCASE	none	Number of cases to be run.
MODE	none	Type of case (see input instructions).
NPIC	none	Number of pictures to be analyzed.

FORTRAN NAME	MATH SYMBOL	MEANING
KSCA	none	See input instructions.
KORB	none	See input instructions.
NMARK	none	When > 0, calls for point of format statement #137.
IMARK	none	Labelling variable - 4 blanks.
KMARK	none	Labelling variable - 2 blanks and 2 asterisks.
PI	π	
RM	$R_{♂}$	See comment in listing.
XMU	$\mu_{♂}$	See comment in listing.
SPIN	$\omega_{♂}$	See comment in listing.
PALFA	α	View half-angle; see Figure 4.
PGAMMA	γ	View half-angle; see Figure 4.
PSLA	β	Side-looking angle; see Figure 4.

(ALFA; GAMMA; SLA are above converted to radius.)

NTIME	none	Counter for number of pictures analyzed
HP	h_p	Periapsis altitude
HA	h_a	Apoapsis altitude.
PER	P	Orbit period.
PLAT	L_p	Periapsis latitude
OI	i	Orbit inclination.

FORTRAN NAME	MATH SYMBOL	MEANING
DTPIC	δt	Time increment between pictures.
XIPLAT	L_I	Initial point latitude.
XIPLNG	Θ_I	Initial point longitude.
H	h	Altitude.
CLAT	L	Latitude at which picture is taken.
CLØNG	Θ	Longitude at which picture is taken.
AZM	ζ	Ground track azimuth.
TA	θ	True anomaly.
Q	φ	Angle in latitude from north pole.
ISLA	none	Indicator used to select proper set of equations for computing ω.

(XLA, TSLA, TG, SAB1, SAB2, TASLA, TZSLA are interim variables used in calculating angles ω and Ω.)

R	Same as RM	
Q_0, Q_1, Q_2	Q_0, Q_1, Q_2	See Figure 5.
SINX	$\sin \xi$	See Figure 6.
COSC	$\cos \varphi_i$	See Figure 6.
SINC	$\sin \varphi_i$	See Figure 6.
C	φ_i	See Figure 6.
COSX	$\cos \xi$	See Figure 6.

FORTRAN NAME	SUBROUTINE ORBIT	MEANING
TABTA	θ_j	Array of true anomaly for interpolation table.
TABT	Δt_j	Array of time for interpolation table.
X	x_i	Cartesian coordinates.
XD	dx_i/dt	Cartesian components of velocity.
DTANP	$\Delta\theta_1$	True anomaly from ascending node to periapsis.
TAN	θ_n	True anomaly of node.
DTAIPN	$\Delta\theta_2$	True anomaly from initial point to node.
TAIP	θ_I	True anomaly of initial point
ECC	e	Orbit eccentricity
A	a	Semimajor axis
DIP	$\Theta_n - \Theta_{\epsilon I}$	Longitude* distance from initial point to node.
XLN	Θ_n	Longitude* of node.
EA	$\mathcal{E}_j$	Eccentric anomaly
R	r	Radius from planet center to spacecraft.
XLONG, XLAT	Θ, L	Longitude* and latitude of spacecraft.
VP	V_p	Spacecraft perigee velocity.
AR	ω_s	Spacecraft angular rate.
DTHDT	$\partial\Theta/\partial t$	——

*Not corrected for planet rotation.

FORTRAN NAME	SUBROUTINE ORBIT	MEANING
DLDT	$\partial L/\partial t$	—
XLONGZ	Θ	Longitude with planet rotation correction included.

APPENDIX B

Fortran Printout

```
                              3200  FORTRAN  (2.1.0)/(RTS)

      PROGRAM PHOTO
      REAL LAT,LONG
      DIMENSION LAT(8),LONG(8),OM(8),BOM(8),MARK(8)
      N=0
      INV=-1
      NQ=0
 1100 FORMAT (1H1,40X,38HORBITAL PHOTOIMAGING COVERAGE ANALYSIS //)
      READ (60,510) NCASE
   99 READ (60,510) MODE,NPIC,KSLA,KORB
  510 FORMAT (4I2)
      NMARK=0
      IMARK=60606060B
      KMARK=60605454B
      PI=3.1415926
      RM=3378.
      XMU=42978.
      SPIN= 0.0040612*PI/180.
C     CONSTANTS ARE RM - MARS RADIUS IN KM, XMU - MARS GRAVITATIONAL
C     CONSTANT IN KM3/SEC2, SPIN - MARS AXIAL ROTATION RATE IN RAD/SEC.
      N=N+1
      WRITE (61,1100)
      WRITE (61,114) N
  114 FORMAT (1H0,55X,4HCASE,I3,//30X,10HINPUT DATA///)
      READ (60,12) PALFA,PGAMMA,PSLA
C     ALL ANGLES ARE READ AND PRINTED IN DEGREES, BUT CONVERTED INTER-
C     NALLY TO RADIANS
      WRITE (61,511) PALFA,PGAMMA,PSLA
  511 FORMAT (1H0,30X,17HCAMERA PARAMETERS,//10X,31HVIEW HALF-ANGLES, TR
     1ANSVERSE = F10.2,6H DEG, ,15HFORE-AND-AFT = F10.2,4H DEG/10X,21HSI
     2DE-LOOKING ANGLE = F10.2,4H DEG )
      ALFA=PALFA/180.*PI
      GAMMA=PGAMMA/180.*PI
      SLA=PSLA/180.*PI
      NTIME=0
      IF (MODE) 112,112,132
C     BRANCH TO SWATH ANALYSIS (112) OR SINGLE-PICTURE ANALYSIS (132).
  112 READ (60,2) HP,HA,PER,PLAT,OI,DTPIC,XIPLAT,XIPLNG
    2 FORMAT (8F10.0)
      WRITE (61,1103)
 1103 FORMAT (1H0,//30X,16HORBIT PARAMETERS /)
      IF (PER) 115,115,116
  115 WRITE (61,117) HP,HA
  117 FORMAT (10X,16HPERIAPSIS ALT = F12.2,3H KM,//10X,15HAPOAPSIS ALT =
     1 F12.2,3H KM/)
      GO  TO 118
  116 WRITE (61,119) HP,PER
  119 FORMAT (10X,16HPERIAPSIS ALT = F12.2,3H KM,//10X,15HORBIT PERIOD =
     1 F12.2,3H HR/)
  118 WRITE (61,120) PLAT,OI,DTPIC,XIPLAT,XIPLNG
  120 FORMAT (10X,21HPERIAPSIS LATITUDE = F12.2,4H DEG,/10X,13HORBIT INC
     1L = F12.2,4H DEG,/10X,13HTIME INTERVAL/10X,19HBETWEEN PICTURES = F
     212.2,4H SEC,/10X,25HINITIAL POINT LATITUDE = F12.2,4H DEG,/10X,26H
     3INITIAL POINT LONGITUDE = F12.2,4H DEG)
      PER=PER*3600.
      PLAT=PLAT/180.*PI
      OI=OI/180.*PI
      XIPLAT=XIPLAT/180.*PI
      XIPLNG=XIPLNG/180.*PI
      TA=FLOAT(KORB)
C     TA IS USED HERE TO SIGNAL ORBIT WHETHER PERIAPSIS IS LESS THAN OR
```

APPENDIX B

```
C       GREATER THAN 90 DEG IN TRUE ANOMALY FROM ASCENDING NODE.
        CALL ORBIT (HP,HA,PER,PLAT,OI,DTPIC,XIPLAT,XIPLNG,H,CLAT,CLONG,
       1 AZM,PI,0,RM,XMU,SPIN,TA,DTIME)
C       AT THIS POINT ORBIT COMPUTES ORBIT PARAMETERS.
        WRITE (61,1102)
 1102 FORMAT (1H0,//40X,17HPHOTO FORMAT DATA //70X,10H(LATITUDE),/70X,11
       1H(LONGITUDE)/)
        WRITE (61,1101)
 1101 FORMAT (7X,4HTRUE,4X,4HTIME,5X,3HALT,4X,4HAZIM,4X,4HFOTO,4X,4HFOTO
       1,5X,3HUPR,6X,2HLH,5X,3HLWR,5X,3HBOT,5X,3HLWR,6X,2HRH,5X,3HUPR,5X,3
       2HTOP,/7X,4HANOM,5X,3HSEC,6X,2HKM,5X,3HDEG,5X,3HCTR,5X,3HCTR,6X,2HL
       3H,4X,4HSIDE,6X,2HLH,14X,2HRH,4X,4HSIDE,6X,2HRH,/40X,3HLAT,4X,4HLON
       4G,/40X,3HDEG,5X,3HDEG/)
  113 NTIME=NTIME+1
        CALL ORBIT (HP,HA,PER,PLAT,OI,DTPIC,XIPLAT,XIPLNG,H,CLAT,CLONG,
       1 AZM,PI,NTIME,RM,XMU,SPIN,TA,DTIME)
C       AT THIS POINT ORBIT DETERMINES LOCATION AT WHICH INDIVIDUAL
C       PICTURE IS TAKEN.
        GO TO 123
  132 WRITE (61,1102)
        WRITE (61,1101)
  111 READ (60,12) H,PCLAT,PCLONG,PAZM
        NTIME=NTIME+1
   12 FORMAT (7F10.0)
        CLAT=PCLAT/180.*PI
        CLONG=PCLONG/180.*PI
        AZM=PAZM/180.*PI
        ISLA=1
        GO TO 125
C       FORM HERE TO END IS ANALYSIS OF PICTURE GEOMETRY.
  123 IF (KSLA) 124,124,125
  124 IF (NTIME-1) 125,125,127
  127 SLA=-SLA
  125 U=PI/2.-CLAT
        IF (SLA) 21,22,27
   21 ISLA=-1
        GO TO 23
   22 ISLA=0
        GO TO 23
   27 ISLA=1

   23 XLA=ABS(SLA)
        TSLA=SIN(SLA)/COS(SLA)
        R=3378.
        TG=SIN(GAMMA)/COS(GAMMA)
        SAB1=SIN(ALFA+SLA)
        SAB2=SIN(ALFA-SLA)
        TASLA=SAB1/COS(SLA+ALFA)
        TZSLA=SAB2/COS(ALFA-SLA)
        IF (ISLA.EQ.0) 30,31
   30 Q0=PI/2.
        GO TO 32
   31 Q0=ATAN(TG/SIN(XLA))
   32 Q1=ATAN(TG*COS(ALFA)/SIN(ALFA+XLA))
        Q2=ATAN(TG*COS(ALFA)/SIN(ALFA-XLA))
        IF (ISLA) 24,24,26
   26 IF (XLA.GT.ALFA) 60,61
   60 UM(1)=PI/2.+Q2
        UM(2)=PI/2.
        UM(3)=PI/2.-Q2
        GO TO 62
   61 UM(1)=1.5*PI-Q2
```

```
      OM(2)=1.5*PI
      OM(3)=1.5*PI+Q2
   62 OM(4)=PI/2.-Q0
      OM(5)=PI/2.-Q1
      OM(6)=PI/2.
      OM(7)=PI/2.+Q1
      OM(8)=PI/2.+Q0
      GO TO 25
   24 OM(1)=1.5*PI-Q1
      OM(2)=1.5*PI
      OM(3)=1.5*PI+Q1
      OM(4)=1.5*PI+Q0
      IF (XLA.GT.ALFA) 63,64
   63 OM(5)=1.5*PI+Q2
      OM(6)=1.5*PI
      OM(7)=1.5*PI-Q2
      GO TO 65
   64 OM(5)=PI/2.-Q2
      OM(6)=PI/2.
      OM(7)=PI/2.+Q2
   65 OM(8)=1.5*PI-Q0
   25 BOM(1)=ABS(ATAN(TZSLA/SIN(OM(1))))
      BOM(2)=ABS(ALFA-SLA)
      BOM(3)=BOM(1)
      BOM(4)=ABS(ATAN(TSLA/SIN(OM(4))))
      IF (TSLA.EQ.0) 28,29
   28 BOM(4)=GAMMA
   29 BOM(5)=ABS(ATAN(TASLA/SIN(OM(5))))
      BOM(6)=ABS(ALFA+SLA)
      BOM(7)=BOM(5)
      BOM(8)=BOM(4)
      DO 20 I=1,8
      SINX=(R+H)/R*SIN(BOM(I))
      IF (SINX.GT.1.) 50,51
   50 COSC=R/(R+H)
      MARK(I)=KMARK
      KMARK=1
      SINC=SQRT(1.-COSC**2)
      C=ATAN(SINC/COSC)
      GO TO 52
   51 MARK(I)=IMARK
      COSX=SQRT(1.-SINX**2)
      C=ABS(ATAN(SINX/COSX))
      C=C-BOM(I)
   52 Z1=-Q
      Z2=-AZM
      CALL COORD (C,OM(I),R,CLONG,Z1,Z2,INV,PI)
      LAT(I)=(PI/2.-C)*180./PI
   20 LONG(I)=OM(I)*180./PI
      PCLONG=CLONG*180./PI
      PCLAT=CLAT*180./PI
      PAZM=AZM*180./PI
      PTA=TA*180./PI
      WRITE (61,40) NTIME,PTA,DTIME,H,PAZM,PCLAT,PCLONG,(LAT(I),I=1,8)
      WRITE(61,41)(LONG(I),I=1,8)
      WRITE (61,42) (MARK(I),I=1,8)
   42 FORMAT (52X,8(2X,A4,2X)/)
   40 FORMAT (1X,I2,1X,14F8.2)
   41 FORMAT (52X,8F8.2 )
      IF (NPIC-NTIME) 130,130,131
  131 IF (MODE  ) 113,113,111
  130 IF (NMARK) 136,136,135
```

```
  135 WRITE (61,137)
  137 FORMAT (1H0,10X,25H** LIMB OF PLANET IN VIEW )
  136 IF (N.EQ.NCASE) 44,99
   44 STOP
      END

          3200 FORTRAN DIAGNOSTIC RESULTS - FOR   PHOTO

NO ERRORS
```

```
      SUBROUTINE ORBIT (HP,HA,PER,PLAT,OI,DTPIC,XIPLAT,XIPLNG,H,XLAI,XLO
     1NG2,AZM,PI,NTIME,RM,XMU,SPIN,TA,DTIME)
C     FIRST PART OF THIS SUBROUTINE (122 TO 121) COMPUTES AND PRINTS
C     ORBIT PARAMETERS AND SETS UP INTERPOLATION TABLE.  IT IS CALLED
C     ONLY ONCE FOR EACH CASE.  SECOND PART COMPUTES SPACECRAFT LOCATION
C     FOR EACH PICTURE, IS CALLED ONCE FOR EACH PICTURE.  EXCEPT NOTE
C     THIS SUBROUTINE NOT USED FOR SINGLE PICTURE ANALYSIS.
      DIMENSION TABTA(37),TABT(37),X(3) ,XD(3)
      IF (NTIME.GT.0) 121,122
  122 SINX=SIN(PLAT)/SIN(OI)
      Y=SQRT(1.-SINX**2)
      DTANP=ATAN(SINX/Y)
      IF (TA.GT.0.5) 50,51
   50 DTANP=PI-DTANP
   51 TAN=2.*PI-DTANP
      SINX=SIN(XIPLAT)/SIN(OI)
      Y=SQRT(1.-SINX**2)
      DTAIPN=ATAN(SINX/Y)
      TAIP=TAN+DTAIPN
      IF (PER) 3,3,4
    3 RA=RM+HA
      RP=RM+HP
      A=(RA+RP)/2.
      ECC=RA/A-1.
      PER=(A/XMU**(1./3.))**1.5*2.*PI
      GO TO 5
    4 A=(PER*SQRT(XMU)/(2.*PI))**(2./3.)
      RP=RM+HP
      RA=2.*A-RP
      ECC=1.-RP/A
    5 TABTA(1)=TAIP
      COSDIP=COS(TAN-TAIP)/COS(XIPLAT)
      SINDIP=SQRT(1.-COSDIP**2)
      DIP=ATAN(SINDIP/COSDIP)
      IF ((TAN-TAIP).LT.0.) 15,16
   15 DIP=-DIP
   16 XLN=XIPLNG+DIP
      PTAIP=TAIP*180./PI
      PTAN=TAN*180./PI
      PXLN=XLN*180./PI
      XPER=PER/3600.
      WRITE (61,221) RA,RP,PTAIP,ECC,PTAN
      WRITE (61,225) PXLN,XPER
  221 FORMAT (1H0,20X,25HCOMPUTED ORBIT PARAMETERS,//10X,18HAPOAPSIS RAD
     1IUS = F12.2,3H KM,/10X,19HPERIAPSIS RADIUS = F12.2,3H KM/10X,12HTR
     2UE ANOMALY ,/10X,19HOF INITIAL POINT = F12.2,4H DEG,/10X,21HORBIT
     3ECCENTRICITY = F12.4/10X,12HTRUE ANOMALY,/10X,20HOF ASCENDING NODE
     4 = F12.2,4H DEG/)
  225 FORMAT (10X,12HLONGITUDE OF/ 10X,17HASCENDING NODE = F12.2,4H DEG
     1,/10X,15HORBIT PERIOD = F12.4,3H HR /)
      TABT(1)=0.
      WRITE (61,224)
  224 FORMAT (1H0,2X,19HINTERPOLATION TABLE ,//9X,4HTIME,7X,7HTR ANOM,5X
     1, 8HECC ANOM /)
      DO 10 I=1,36
C     THIS DO LOOP SETS UP TABLE OF TA VS TIME FOR ONE COMPLETE ORBIT
C     FROM INITIAL POINT.  VALUES OF TA LARGER THAN 2 PI ARE USED TO
C     OBTAIN SIMPLE MONOTONICALLY INCREASING RELATIONSHIP.
      COSEA=(ECC+COS(TABTA(I)))/(1.+ECC*COS(TABTA(I)))
      SINEA=SQRT(1.-COSEA**2)
```

```
      EA=ATAN(SINEA/COSEA)
      TX=TABTA(I)
      IF (TABTA(I).GT.2.*PI) 84,85
   84 TX=TABTA(I)-2.*PI
   85 IF (EA.GT.0..AND.TX.GT.PI) 9,81
    9 EA=2.*PI-EA
      GO TO 6
   81 IF (EA.LT.0..AND.TX.LT.PI) 6,71
    6 EA=EA+PI
      GO TO 8
   71 IF (EA.LT.0..AND.TX.GT.PI) 7,8
    7 EA=PI-EA
    8 IF (TABTA(I).GT.2.*PI) 82,83
   82 EA=EA+2.*PI
   83 IF (I-1) 11,12,11
   12 EAX=EA
   11 TABT(I)=(A/XMU**(1./3.))**1.5*(EA-ECC*SIN(EA)-EAX+ECC*SIN(EAX))
      WRITE (61,222) TABT(I),TABTA(I),EA
  222 FORMAT(5X,3F12.2)
   10 TABTA(I+1)=TABTA(I)+PI/18.
      GO TO 223
  121 DTIME=FLOAT(NTIME-1)*DTPIC
      DO 101 K=1,36
      IF (DTIME-TABT(K)) 103,103,101
  101 CONTINUE
  103 IF (K-2) 104,104,105
  104 J=1
      GO TO 110
  105 IF (K-35) 106,107,107
  107 J=33
      GO TO 110
  106 J=K-2
  110 CALL NEWT (3,DTIME,TABT(J),TABT(J+1),TABT(J+2),TABT(J+3),TABTA(J),
     1TABTA(J+1),TABTA(J+2),TABTA(J+3),TA,XINGRL,ND)
C     NEWT INTERPOLATES TABLE TO GET TA.  XINGRL AND ND ARE DUMMY VAR-
C     IABLES, NOT USED.
      R=A*(1.-ECC**2)/(1.+ECC*COS(TA))
      H=R-RM
C     BEGIN COMPUTATION OF LATITUDE AND LONGITUDE.
      X(1)=COS(TA)
      X(2)=SIN(TA)
      X(3)=0.
      CALL XFORM2(X,TAN,OI,XLN)
      XLONG=ATAN(X(2)/X(1))
      IF (X(1).LT.0.) 202,203
  202 XLONG=XLONG+PI
      GO TO 204
  203 IF (X(2).LT.0.) 205,204
  205 XLONG=XLONG+2.*PI
  204 COSLAT=X(3)
      IF (X(3).EQ.0.) 240,241
  240 XLAT=0.
      GO TO 242
  241 SINLAT=SQRT(1.-COSLAT**2)
      XLAT=ATAN(SINLAT/COSLAT)
      IF (X(3).LT.0.) 206,207
  206 XLAT=XLAT+PI
  207 XLAT=PI/2.-XLAT
C     BEGIN COMPUTATION OF AZIMUTH.
  242 VP=SQRT(XMU*(ECC+1.)/RP)
      AR=VP/R**2*RP
      XD(1)=AR*(-SIN(TA))
```

```
              XD(2)=AR*COS(TA)
              XD(3)=0,
              CALL XFORM2 (XD,TAN,CI,XLN)
              DTHDT=(X(1)*XD(2)-X(2)*XD(1))/(X(1)**2+X(2)**2)-SPIN
              DLDT= XD(3)/SQRT(1.-X(3)**2)
              AZM=ATAN(DTHDT/DLDT*COS(XLAT))
              IF (DLDT*COS(XLAT).LT.0,) 232,233
          232 AZM=AZM+PI
              GO TO 234
          233 IF (DTHDT.LT,0,) 235,234
          235 AZM=AZM+2,*PI
          234 XLONG2=XLONG-DTIME*SPIN
              IF (XLONG2.GE,2,*PI) 226,223
          226 XLONG2=XLONG2-2,*PI
          223 RETURN
              END

                3200 FORTRAN DIAGNCSTIC RESULTS - FOR   ORBIT

NO ERRORS
LOAD,56
RUN,10
```

```
                        3200  FORTRAN  (2,1,0)/(RTS)
      SUBROUTINE XFORM2 (X,TAN,OI,DIP)
      DIMENSION X(3),A(3,3),B(3,3),C(3,3),D(3,3),E(3,3),XPR(3)
      DO 1 I=1,3
      XPR(I)=0.
      DO 1 J=1,3
    1 A(I,J)=B(I,J)=C(I,J)=D(I,J)=E(I,J)=0.
      B(3,3)=C(1,1)=D(3,3)=1.
      B(1,1)=B(2,2)=COS(TAN)
      B(1,2)=SIN(TAN)
      B(2,1)=-B(1,2)
      C(2,2)=C(3,3)=COS(-OI)
      C(2,3)=SIN(-OI)
      C(3,2)=-C(2,3)
      D(1,1)=D(2,2)=COS(-DIP)
      D(1,2)=SIN(-DIP)
      D(2,1)=-D(1,2)
      CALL MMPY3 (C,B,E)
      CALL MMPY3 (D,E,A)
      DO 5 J=1,3
      DO 5 I=1,3
    5 XPR(J)=XPR(J)+X(I)*A(J,I)
      DO 8 I=1,3
    8 X(I)=XPR(I)
      RETURN
      END

   3200 FORTRAN DIAGNOSTIC RESULTS - FOR   XFORM2

NO ERRORS
```

3200 FORTRAN (2.1.0)/(RTS)

```
      SUBROUTINE NEWT (N,X,X0,X1,X2,X3,F0,F1,F2,F3,F,XINGRL,KUMMY)
      F01=(F0-F1)/(X0-X1)
      L=1
      IF (N) 7,8,8
    7 L=-1
      N=-N
    8 A=X0
      B=X
      IF (X-X0) 13,12,13
   12 A=X1
      B=X0
   13 F=F0+(X-X0)*F01
      IF (L) 4,4,40
    4 XINGRL=F01
      GO TO 44
   40 XINGRL=F0*(B-A)+F01*(B*B/2.-A*A/2.-X0*(B-A))
   44 IF (N-2) 3,11,11
   11 F12=(F2-F1)/(X2-X1)
      F012=(F01-F12)/(X0-X2)
      F=F+(X-X0)*(X-X1)*F012
      IF (L) 5,5,50
    5 XINGRL=XINGRL+(2.*X-(X0+X1))*F012
      GO TO 55
   50 XINGRL=XINGRL+((B**3-A**3)/3.-(B*B/2.-A*A/2.)*(X0+X1)+(B-A)*X0*X1)
     1*F012
   55 IF (N-3) 3,21,21
   21 F23=(F3-F2)/(X3-X2)
      F123=(F12-F23)/(X1-X3)
      F0123=(F012-F123)/(X0-X3)
      F=F+(X-X0)*(X-X1)*(X-X2)*F0123
      IF (L) 6,6,60
    6 XINGRL=XINGRL+(3.*X*X-2.*X*(X0+X1+X2) +X0*X1+X0*X2+X1*X2)*F0123
      GO TO 3
   60 XINGRL=XINGRL+((B**4-A**4)/4.-(B**3-A**3)/3.*(X0+X1+X2)+(B*B/2.+A*
     1A/2.)*(X0*X1+X0*X2+X1*X2)-(B-A)*X0*X1*X2)*F0123
    3 RETURN
      END
```

3200 FORTRAN DIAGNOSTIC RESULTS - FOR NEWT

NO ERRORS

```
                                      3200   FORTRAN   (2.1.0)/(RTS)

      SUBROUTINE COORD (PHI,THETA,R,RIGD,XI,D,INV,PI)
      DIMENSION X(3)
      X(1)=   SIN(PHI)*COS(THETA)
      X(2)=   SIN(PHI)*SIN(THETA)
      X(3)=   COS(PHI)
C     RIGD=CLONG,XI=CLAT,D=AZIM
      CALL XFORM (X,R(3),XI,D,INV)
      COSPHI=X(3)
      SINPHI=SQRT(1.-COSPHI**2)
      PHI=ATAN(SINPHI/COSPHI)
      THETA=ATAN(X(2)/X(1))
      IF  (X(1).LT.0.) 2,3
    2 THETA=THETA+PI
      GO TO 12
    3 IF  (X(2).LT.0.) 5,12
    5 THETA=THETA+2.*PI
   12 SINPHI=X(2)/SIN(THETA)
      IF  (COSPHI.GT.0..AND.SINPHI.LT.0.) 7,8
    7 PHI=2.*PI-PHI
      GO TO 4
    8 IF  (COSPHI.LT.0..AND.SINPHI.LT.0.) 9,10
    9 PHI=PI-PHI
      GO TO 4
   10 IF  (COSPHI.LT.0..AND.SINPHI.GT.0.) 11,4
   11 PHI=PI+PHI
    4 RETURN
      END

          3200 FORTRAN DIAGNOSTIC RESULTS - FOR    COORD

NO ERRORS
LOAD,56
RUN,10
```

```
                                    3200   FORTRAN   (2.1.0)/(RTS)

      SUBROUTINE XFORM (X,BIGO,XI,O,INV)
      DIMENSION X(3),XPR(3),A(3,3),B(3,3),C(3,3),D(3,3),E(3,3)
      DO 1 I=1,3
      DO 1 J=1,3
    1 A(I,J)=B(I,J)=C(I,J)=D(I,J)=E(I,J)=0.
      D(1,1)=D(2,2)=COS(BIGO)
      D(1,2)=SIN(BIGO)
      D(2,1)=-D(1,2)
      D(3,3)=C(2,2)=B(3,3)=1.
      C(1,1)=C(3,3)=COS(XI)
      C(1,3)=SIN(XI)
      C(3,1)=-C(1,3)
      B(1,1)=B(2,2)=COS(O)
      B(1,2)=SIN(O)
      B(2,1)=-B(1,2)
      CALL MMPY3 (C,D,E)
      CALL MMPY3 (B,E,A)
      DO 4 I=1,3
      DO 4 J=1,3
    4 E(I,J)=A(J,I)
      XPR(1)=XPR(2)=XPR(3)=0.
      IF (INV) 3,2,2
    3 DO 5 J=1,3
      DO 5 I=1,3
    5 XPR(J)=XPR(J)+X(I)*E(J,I)
      GO TO 6
    2 DO 7 J=1,3
      DO 7 I=1,3
    7 XPR(J)=XPR(J)+X(I)*A(J,I)
    6 DO 8 I=1,3
    8 X(I)=XPR(I)
      RETURN
      END

        3200 FORTRAN DIAGNOSTIC RESULTS - FOR   XFORM

NO ERRORS
LOAD,56
```

```
                                   3200  FORTRAN  (2,3.0)/(RTS)

      SUPROUTINE MMPY3 (A,B,C)
      DIMENSION A(3,3),B(3,3),C(3,3)
      DO 2 N=1,3
      DO 2 L=1,3
      ELEMT=0.
      DO 3 M=1,3
    3 ELEMT=ELEMT+A(L,M)*B(M,N)
    2 C(L,N)=ELEMT
      RETURN
      END

          3200 FORTRAN DIAGNOSTIC RESULTS - FOR   MMPY3

NO ERRORS
LOAD,56
LOADING DELETED
```

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APPROVAL

ON ANALYSIS OF AREA COVERAGE BY ORBITAL PHOTOIMAGING SYSTEMS

By

G. R. Woodcock

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

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

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