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USER'S GUIDE FOR LANGLEY RESEARCH CENTER ORBITAL LIFETIME PROGRAM

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SUMMARY

This paper describes the Langley Research Center Orbital Lifetime program which analyzes motion of Earth-orbiting spacecraft based on perturbations due to atmospheric drag, solar radiation pressure, and gravitational effects of the Sun, the Moon, and Earth oblateness. The program can be used to generate time histories of the orbital elements, total lifetime and decay rates, and plot data. Operation instructions, descriptions of the input and output, and several sample cases are included in this paper.

SYMBOLS

Symbol	Definition
A_D	Area of spacecraft projected perpendicular to velocity, cm^2
A_{DR}	Acceleration of spacecraft due to atmospheric drag, cm/sec^2
A_p	Geomagnetic index, dimensionless
A_R	Area of spacecraft projected perpendicular to Sun's direction, cm^2
A_{RP}	Acceleration of spacecraft due to solar radiation pressure, cm/sec^2
Az	Inertial azimuth, measured positive clockwise from north, deg.
a	Semimajor axis of orbit, R_e
C	OL program FORTRAN array containing floating point input data
c	Speed of light, cm/sec
C_D	Spacecraft drag coefficient, dimensionless
e	Eccentricity of orbit, dimensionless
$F_{10.7}$	10.7 cm solar flux, 10^{-22} watts/m^2/Hz
$\bar{F}_{10.7}$	13-month averaged 10.7 cm solar flux, 10^{-22} watts/m^2/Hz
h_a	Height of apogee above Earth, km
h_p	Height of perigee above Earth, km
I	Solar flux near the Earth, dynes/cm/sec
i	Inclination of orbit, deg.

J_2, J_3, J_4, J_5	Earth oblateness coefficients corresponding to the second, third, fourth, and fifth harmonics, respectively, dimensionless
k	Spacecraft reflection coefficient, dimensionless
K	OL program FORTRAN array containing integer input data
M	Spacecraft mass, g
p	Semilatus rectum of orbit, R_e
Q	OL program FORTRAN array (see ref. 2)
R_e	Earth radius, 6.378145×10^8 cm
R_i	Initial geocentric radius, km
V	Spacecraft velocity in direction of flight, cm/sec
V_i	Spacecraft inertial velocity, km/sec
γ	Inertial flight path angle, deg.
Δa	Change in semimajor axis, R_e
Δe	Change in eccentricity, dimensionless
Δp	Change in semilatus rectum, R_e
ΔV	Change in spacecraft velocity, R_e/sec
λ	Initial longitude, positive east of Greenwich, deg.
ρ	Atmospheric density, g/cm^3
σ	Standard deviation
Φ	Initial latitude, deg.
Ω	Right ascension of ascending node, deg.
ω	Argument of perigee, deg.

INTRODUCTION

The Langley Research Center (LaRC) Orbital Lifetime (OL) program analyzes the long-term motion of Earth-orbiting spacecraft for altitudes up to 2500 km. It models perturbations to the orbit caused by atmospheric drag, solar radiation pressure, and gravitational effects due to the Sun, the Moon, and the oblateness of the Earth. Available output includes time histories of the orbital elements, total lifetime and decay rates, and plot data.

The OL program was originally developed at the Massachusetts Institute of Technology Lincoln Laboratory (ref. 1) and was modified by the Rand Corporation (ref. 2). NASA LaRC obtained the program from Rand and further changes have been made by LaRC personnel. These changes include correction of program errors, updating to later versions of FORTRAN, and replacing the atmospheric density model. This user's guide and its references constitute all of the documentation available for the OL program. The theory in reference 2 is still reliable, but most information in that document specific to the program code itself is no longer accurate because the code has been changed. Although this paper accounts for the changes that were made after NASA LaRC obtained the program, the program still contains some calculations which were originally in the code but were never documented.

The purpose of this paper is to provide a user's guide that is consistent with the current version of the OL program. This paper gives, without going into very much mathematical detail, an overview of the method of computation and the modeling approach and underlying assumptions for each perturbation. As mentioned above, the theory behind the program (i.e. the equations of motion of the orbital elements and derivations of expressions for the perturbing accelerations) appears in reference 2. The atmospheric density model is documented in references 3-5. This paper includes instructions for setting up the input and running the program, as well as sample cases which illustrate many of the options available. The OL program is available in FORTRAN 77 on VAX and Prime computers and in FORTRAN V on CDC Cyber machines. The instructions and sample cases in this paper refer to VAX computers and the VAX/VMS operating system.

This paper is intended to provide all of the documentation needed for the general user to run the OL program with confidence.

PROGRAM DESCRIPTION

The OL program calculates changes in spacecraft orbits, given such input quantities as spacecraft physical characteristics, initial orbit parameters, and launch date. The calculations begin with the assumption that the spacecraft is in the initial orbit specified, so launch date is actually treated as initial time in orbit. The orbit is allowed to decay due to environmental perturbations, and no reboost operations can be taken into account. (There is a seldom-used option that allows for a ΔV kick at perigee; this is not reboost.) For purposes of this program, only long-term changes are considered; short-period variations (e.g. within a single orbit) are assumed to average out and are not included in the calculations. Therefore, the OL program cannot be used to investigate short-term behavior of spacecraft flight. The perturbations to the orbit are calculated to first order only (except for Earth oblateness, which can include a second-order term in the gravity model; see Earth Oblateness subsection below).

The spacecraft orbit is represented in the program by the orbital elements p (semilatus rectum), e (eccentricity), i (inclination), ω (argument of perigee), and Ω (right ascension of the ascending node). Epoch (time of perigee passage) is not included because the program is not concerned with the exact position of the spacecraft in its orbit at any given time. Changes in

the orbital elements are calculated based on solutions to their equations of motion expressed in terms of the perturbing accelerations and the orbital elements themselves. The equations, which are of the form

$$\frac{d(\text{element})}{dt} = f(p, e, i, \omega, \Omega, \text{perturbing accelerations}),$$

are integrated over a single orbit, holding constant the orbital elements which appear on the right-hand side of the equation. Each perturbation is handled separately (see descriptions in the following section). The integrations are analytic for all of the perturbations except drag, for which an approximation technique is used. The integration results are used to update the orbital elements at user-specified intervals (input as number of orbits per calculation), assuming that their rates of change remain constant over the computation interval. The updated orbital elements then describe a new spacecraft orbit for which the equations of motion are again integrated. The cycle continues until a user-specified maximum orbit number is reached or the spacecraft reaches the Earth. The condition for reaching the Earth is that the height of perigee be below 64 km; the atmosphere is so dense at that altitude that the spacecraft would fall from there to the ground in a matter of minutes.

Appendix A contains a brief description of each routine in the program.

PERTURBATIONS

A brief explanation of each perturbation is provided here. For more mathematical detail, see reference 2.

Solar Radiation Pressure

In the OL program, solar radiation pressure is represented by an acceleration of the spacecraft in a radial direction away from the Sun:

$$A_{RP} = k\ (I/c)\ (A_R/M)$$

where

A_{RP} = acceleration of spacecraft due to solar radiation pressure

k = spacecraft reflection coefficient; $0 \leq k \leq 4/3$
- k = 0: transparent
- k = 1: perfectly absorbing
- k = 4/3: flat, specularly reflecting

I = solar flux near the Earth

c = speed of light

A_R = area projected perpendicular to Sun's direction

M = spacecraft mass

The solar flux, I, is assumed to vary only with the Earth's distance from the Sun (the Earth-Sun distance varies because the Earth's orbit is elliptical). The program uses $I/c = 4.5 \times 10^5$ dynes/cm^2 at an Earth-Sun distance of one astronomical unit.

The effect of the Earth's shadow is taken into account in calculating the radiation pressure by excluding from the orbital integration that portion of the orbit, if any, which lies in the Earth's shadow. The true anomalies on entering and leaving the shadow are printed in the output, and there is an option to calculate and print the amount of time the spacecraft spends in the shadow.

Subroutine RADPR calculates the solar radiation pressure effects and subroutine SHADOW calculates the true anomalies on entering and leaving the Earth's shadow.

Earth Oblateness

The OL program includes the gravitational effects of the oblateness of the Earth through an expansion of the gravitational potential in spherical harmonics. Zonal harmonics are included through J_5. It is assumed that the Earth's mass distribution has azimuthal symmetry (i.e. that it is independent of longitude), so no tesseral harmonics are used.

As mentioned above, there is an option to include a second-order correction in the Earth oblateness calculation. This correction is the J_2^2 term, and this option was included because it contributes as much to the gravitational potential as the J_3, J_4, and J_5 terms do.

It should be noted that the changes in the semimajor axis, a, due to Earth oblateness should be very small compared to the changes due to drag. However, the Δp and Δe originally calculated in the program gave rise to long-term oscillatory variation in a ($a = p/(1-e^2)$) with Δa per orbit of the same order of magnitude as Δa due to drag. The reason for this error has not been found. Therefore, Δp and Δe were set equal to zero in the program to yield more accurate results.

The Earth oblateness calculations appear in subroutine EARTH.

Moon's Gravity

The OL program accounts for the gravitational attraction both between the Moon and the spacecraft and between the Moon and the Earth. That is, it calculates the acceleration of the spacecraft due to the Moon's gravity relative to the acceleration of the Earth due to the Moon's gravity. The calculations account for distance variations due to the Moon's orbital motion. Terms linear in the ratio of Earth-spacecraft distance to Earth-Moon distance are included, but higher powers of that ratio are not.

Subroutine MOON contains the computation for the Moon's gravity.

Sun's Gravity

The gravitational effects of the Sun on the orbit are handled in the OL program in a manner analagous to the method used for the Moon's gravity calculations.

Subroutine SUN contains the calculations for the Sun's gravitational effects.

Atmospheric Drag

The OL program calculates the acceleration of the spacecraft due to atmospheric drag in a direction opposite to the spacecraft velocity according to:

$$A_{DR} = (1/2)\ (C_D\ A_D/M)\ \rho V^2$$

where

A_{DR} = acceleration of spacecraft due to atmospheric drag

A_D = area projected perpendicular to the velocity, averaged over one orbit

C_D = spacecraft drag coefficient

M = mass of spacecraft

ρ = atmospheric density

V = velocity of spacecraft

The equations of motion in which this expression appears cannot be integrated analytically because the atmospheric density, ρ, appears inside the integrand, and it varies throughout the orbit in a complicated way (see below for a description of the atmospheric density model used). Therefore, the integration is approximate; six 9-point Gaussian quadratures are used, and there is an option to change the number of quadratures. An oblate Earth is used for the drag calculation, i.e. the height at which the atmospheric density is calculated is the height above an oblate rather than a spherical Earth. In addition, there is an option to use a rotating atmosphere.

The atmospheric density models used in the OL program's drag calculations are the U.S. Standard Atmosphere 1976 (ref. 3) for altitudes below 90 km and the Jacchia 1970 atmospheric density model (refs. 4 and 5) for altitudes above 90 km. The Jacchia 1970 model is recommended by NASA for use in space vehicle design and development studies (ref. 6). These models are new to the LaRC program and replace the models used in the Rand version of the program (ref. 2).

The Jacchia 1970 atmospheric density model of the neutral atmosphere is valid from 90 km to 2500 km. It includes variations with altitude, solar activity (i.e. with the 11-year solar cycle), and geomagnetic activity. It also includes the semiannual variation (characterized by maxima in April and October and minima in January and July), the diurnal variation (density is higher on the light side of the Earth than on the dark side), and seasonal-latitudinal variations in helium density and total density. The OL program calculates the seasonal-latitudinal variations based on the Jacchia 1971 atmospheric density model (ref. 7).

To account for solar activity and geomagnetic activity, the Jacchia 1970 model uses the 13-month smoothed 10.7 cm solar flux, $\bar{F}_{10.7}$, and the geomagnetic index, A_p. Density increases as either of these increases, but $\bar{F}_{10.7}$ has a greater effect. Since the OL program is used primarily to predict lifetimes for future flights of spacecraft, it uses predictions of monthly values of $\bar{F}_{10.7}$ and A_p. These predictions are provided by the Atmospheric Sciences Division of the NASA Marshall Space Flight Center (MFSC) and are updated

bi-monthly. The OL program reads these predictions from a flux input file, and both nominal (50th percentile) and $+2\sigma$ (97.7th percentile) predictions are available for use. A listing of the flux input file containing the MSFC predictions from the June 1985 update is provided in Appendix B. The earliest date for which solar flux data exists in the flux file is the earliest launch date for which the program can be run (January 1984 for the file in Appendix B). The date of the last flux data point (November 1998 for the file in Appendix B) presents no such restriction because for dates beyond the end of the flux data, the 11-year solar cycle is assumed to repeat as many times as necessary.

The atmospheric drag calculations appear in the program in subroutine DRAG1, and atmospheric densities are calculated in function RHA.

HOW TO RUN THE OL PROGRAM

These instructions for compiling and running the OL program apply to VAX computers with the VAX/VMS operating system. The sample cases below were run on a VAX 11/785 with the VMS 4.1 operating system.

Compiling the OL program is straightforward because there are no libraries or special options required. If the FORTRAN source code is in the file OL.FOR, the following sequence of commands compiles, links, and runs the program:

FOR OL	Compiles the highest-numbered version of OL.FOR and creates a new version of OL.OBJ
LINK OL	Links the highest-numbered version of OL.OBJ and creates a new version of OL.EXE
RUN OL	Runs the highest-numbered version of OL.EXE

There are two input files required to run the program:

1. Case-specfic input data file: This file, created by the user, contains information such as initial orbit parameters and case flags. Its format is described in detail in the Input Format section below. The input data file may have any name of the form filename.DAT, which the user specifies at the beginning of each run (see example below). Two cases using the same input file may not be run simultaneously because this file is open during the entire run.

2. Flux data file: This is a file named FLUX.DAT which contains predictions of solar flux and geomagnetic index needed for the atmospheric density model. Appendix B contains a copy of the flux data file used in the sample cases below. The flux file is read at the start of each run and is closed immediately after it is read. If the flux file is already open when the program tries to read it, the program tries again until it becomes available. Therefore, multiple cases may be run simultaneously using the same flux file.

The two input files must exist in the directory under which the program is run.

The OL program generates two output files: one contains the output listing and one contains data for plotting (see sample cases below). The user specifies names for the output listing and plot files at the beginning of the run (see example below).

When the program is run interactively, it prompts the user for relevant file names at the terminal. The following is a sample terminal session which runs the program file OL.EXE, using input file OLIN.DAT and flux file FLUX.DAT (required name). The run generates output listing file OLOUT.DAT and plot data file OLPLT.DAT. Lower case letters indicate user input. $ is the system prompt.

```
$ run ol
 ENTER "INPUT FILE" NAME.
olin
 ASSIGNING FLUX FILE.
 ENTER "OUTPUT FILE" NAME.
olout
 ENTER "PLOT FILE" NAME.
olplt
5000
$
```

The three file name prompts appear at the beginning of program execution. The number 5000 appears when the program terminates normally. If the specified input file does not exist, execution ends and

```
FILE ERROR
$
```

appears in place of the remaining prompts. If the flux file does not exist,

```
EOF FLUXIN
```

appears in place of 5000. If any other error occurs during execution, the appropriate system error message appears.

It is recommended that the OL program be run in batch mode because execution times are typically too long for interactive execution of the program to be convenient (see sample cases below), especially for multiple cases. To run in batch mode, a command file must be created and submitted. The following command file, named OL.COM, sets up the case in the above interactive example to execute under the directory LHO.OL:

```
$SET DEFAULT [LHO.OL]
$RUN OL
OLIN
OLOUT
OLPLT
$EXIT
```

The command

```
SUBMIT OL
```

submits the highest numbered version of the file OL.COM for a batch run.

INPUT FORMAT

There are four types of data in the OL program input file. They are, in order of appearance:

1. Initial line which specifies run number and the numbers of lines each of character, integer, and real data that follow;
2. Lines containing character data to be used as an output heading;
3. Lines containing integer data such as output flags; and
4. Lines containing real data such as orbit specifications.

A sample input file for one of the five sample cases described below can be seen in Table 1.

Initial Line

All values are integer and must be right justified in their fields.

Column #'s	Default	Definition
1-6	0	Run number. Used only as a label on the output.
25-30	0	Number of lines containing integer data.
31-36	0	Number of lines containing real data.
55-60	0	Number of lines containing character data.

Columns 7-24, 37-54, and 61-72 are ignored.

Character Data

Up to two 72-character lines of text may be input to be used as an output heading. There is no default heading.

Integer Data

All input integers are assigned to elements of an array named K in the program. The array index and the value of the input integer must be listed consecutively, with six columns for each, right justified. Read format is 12I6, so up to six such pairs may be included in each line. The order of input is arbitrary; e.g. K(10) may precede K(2). Blank pairs of fields are ignored.

The most commonly used elements are:

K Index	Default	Definition
1	2	Maximum number of orbits in case. Case ends when K(1) orbits are reached or when spacecraft reaches Earth, whichever occurs first. K(1) = 999999 gives whole lifetime for most cases.
2	1	Number of orbits per calculation.
5	6	Number of Gaussian quadratures in drag calculation. Number of calculation points per orbit = K(5)*9.
10	1	Print interval. Print every K(10) orbits. Actual print interval is least common multiple of K(2) and K(10).
50	0	Orbit specification option. K(50) = -1: Input C(1108), C(1110), C(1111), C(1112), C(1113), C(1114) K(50) = 0: Input C(537), C(538), C(539), C(540), C(541) K(50) = 1: Input C(539), C(541), C(1111), C(1121), C(1122) The C array contains real input data and is described below.
54	0	Solar flux flag. K(54) = 0: Nominal solar flux and geomagnetic index predictions used. K(54) = 1: $+2\sigma$ predictions used.

Less often used elements of K are:

K Index	Default	Definition
14	0	Orbit number at which print interval changes to K(15).
15	0	Print interval after orbit number K(14).
71	0	Gravity model flag for Earth oblateness calculation. K(71) = 1: J_2^2 term included. K(71) = 0: J_2^2 term not included.
82	0	Shadow flag. K(82) = 1: Time in shadow per orbit printed. K(82) = 0: Time in shadow not printed.
111-118	0	Flags to delete perturbations. Setting any one of K(111) - K(118) equal to one of the numbers below deletes the effect of the perturbation associated with that number: Solar radiation pressure = 5 Earth oblateness = 7 Moon's gravity = 8 Sun's gravity = 9 Drag = 6 Using this option does not save any computation time; changes due to the specified perturbations are calculated in the usual way and then set equal to 0.

The following elements of K generate more detailed output and are rarely used:

K Index	Default	Definition
18	0	Flag for number of lines of printout per print interval (K(10) or K(15)). K(18) = 0 or 1: One line K(18) = 2: Two lines K(18) $\geq$ 3: K(18) lines K(18) $\leq$ -3: -K(18) lines See ref. 2 for more details.

20	0	Print interval for long output, which can include contributions of each perturbation to changes of the orbital elements; see K(24) below. Actual long output print interval = least common multiple of K(2), K(10), and K(20). This long output is in addition to normal output controlled by K(10).
21	0	Orbit number to begin long output.
22	0	Orbit number to end long output.
24	0	Flag for number of lines of long output. K(24) = 0: seven lines K(24) > 0: K(24) lines The first two lines contain parameters describing the orbit. The next five lines list the contributions of each perturbation to changes in the orbital elements. There is no useful information beyond the seventh line.
25-29	0	Row of Q array to be included in long output. See reference 2.

Real Data

All input real numbers are assigned to elements of an array named C in the program. As with integers, the array index and value of the element are listed in pairs. There are 4 columns for the array index, which is integer and right justified, and 14 columns for the value of the element, which is real. Blanks are read as zeroes. Read format is 4(I4, E14.7), so up to four pairs will fit on a line, and the order of input is arbitrary, e.g. C(1111) may precede C(539). Blank pairs of fields are ignored.

The most commonly used elements are:

Spacecraft Characteristics

C Index	Units	Default	Definition
531	cm^2/g	0.0	kA_R/M, where k = spacecraft reflection coefficient k = 0: transparent k = 1: perfectly absorbing k = 4/3: flat, specularly reflecting A_R = area projected perpendicular to direction of Sun, cm^2

			M = total mass of spacecraft, g If C(531) < 10^{-8}, radiation pressure calculation is omitted.
532	cm^2/g	0.0	$C_D A_D/2M$, where C_D = spacecraft drag coefficient A_D = area projected perpendicular to velocity, cm^2 M = total mass of spacecraft, g If C(532) < 10^{-8}, drag calculation is omitted.

Orbit Specification

There are three ways to specify the initial orbit, given by K(50) = 0, 1, or -1. There is some redundancy among the three options (* indicates element common to two options). The first two options, K(50) = 0 or 1, assume that the initial condition is at perigee. For the third option, K(50) = -1, the program calculates the time since perigee and backs up the initial time to correspond to perigee. If either of the two options K(50) = ±1 is selected, the program calculates the orbital elements corresponding to K(50) = 0; see Appendix C. Note that the maximum allowed altitude is 2500 km.

For K(50) = 0:

C Index	Units	Default	Definition
537	R_e	0.0	p = semilatus rectum of orbit
538	--	0.0	e = eccentricity of orbit
539*	deg	0.0	ω = argument of perigee
540	deg	0.0	Ω = right ascension of ascending node
541*	deg	0.0	i = inclination of orbit

For K(50) = 1:

C Index	Units	Default	Definition
539*	deg	0.0	ω = argument of perigee
541*	deg	0.0	i = inclination of orbit
1111*	deg	0.0	λ = longitude
1121	km	0.0	h_p = height of perigee above Earth
1122	km	0.0	h_a = height of apogee above Earth

For K(50) = -1:

C Index	Units	Default	Definition
1108	deg	0.0	Az = inertial azimuth
1110	deg	0.0	ϕ = latitude
1111*	deg	0.0	λ = longitude
1112	km	0.0	R_i = geocentric radius
1113	km/sec	0.0	V_i = initial velocity
1114	deg	0.0	γ = flight path angle

Launch Date

Launch date (initial time) can be input either as Julian date (C(542)) or as calendar date (C(1115)-C(1120)):

C Index	Units	Default	Definition
542	days	0.0	Julian date
1115	years AD	0.0	Year
1116	months	0.0	Month
1117	days	0.0	Day
1118	hours	0.0	Hour
1119	minutes	0.0	Minute
1120	sec	0.0	Second

Seldom used elements of C are:

C Index	Units	Default	Definition
564	--	0.0	Rotating atmosphere flag. C(564) = 1.0: Uses rotating atmosphere C(564) = 0.0: Uses non-rotating atmosphere
565	R_e	.0004	Change in semimajor axis of orbit (Δa) at which to reduce computation and print intervals to one. When Δa >C(565) from one orbit to the next, K(2) and K(10) are set equal to one.

566	--	0.0	Flag for computing gamma in drag calculation (see ref. 2. for definition of gamma). C(566) = 1.0: Gamma computed C(566) = 0.0: Gamma = 1.0 When gamma is computed, it should appear in the integrand in the orbital integrations. However, in the program, it appears outside the integral as a multiplier, so choosing to have gamma computed does not necessarily give better results than letting gamma = 1.
570	R_e/sec	0.0	ΔV kick at perigee.

SAMPLE CASES

Tables 1, 2, and 4-11 contain input and output files for each of five sample cases. Table 3 is a listing of the plot data file for case 1, and fig. 1 is the corresponding lifetime plot. The first four cases represent the NASA Space Station Reference Configuration (ref. 8) in a 500 km (270 nmi) circular orbit. Case 5 represents a spherical satellite in a 600 km by 900 km polar orbit. Each case illustrates several input and output options.

Case 1

Table 1 shows the input file for sample case 1. Integer data for the K array appear in the fourth line:

K(1) = 999999 = Maximum orbit number: gives entire lifetime.

K(2) = 10: Calculates every 10 orbits.

K(10) = 100: Prints every 100 orbits.

K(71) = 1: Includes J_2^2 term in Earth oblateness calculation.

K(50) = 1: Selects orbital input option where C(539), C(541), C(1111), C(1121), and C(1122) must be input.

K(54) = 1: + 2σ flux predictions used.

Real data for the C array appear in the fifth through seventh lines:

Spacecraft:

C(531) = 0.1543 = kA_R/M for reference configuration

C(532) = 0.1365 = $C_D A_D/2M$ for reference configuration

Orbit:

C(539) = 0.0 = argument of perigee

C(541) = 28.5 = inclination

C(1111) = 0.0 = longitude

C(1121) = 500.0393 = height of perigee above Earth

C(1122) = 500.0393 = height of apogee above Earth

This is a circular, 500 km orbit, inclined 28.5° to the equator.

Launch date:

C(1116) = 6.0 = month

C(1117) = 1.0 = day

C(1120) = 1.0 = second

C(1115) = 1991.0 = year

Launch is 1 second after midnight June 1, 1991. This launch date corresponds to flight during a maximum in solar activity and thus, a maximum in atmospheric density (see Appendix B).

Table 2 is a listing of the output file generated for case 1. The first four lines on the first page repeat the K and C values and array indices that were input. The next printed line lists the Julian and calendar dates (GMT is Greenwich mean time). Next is the heading from the input (this is the only place where the heading appears). Following the heading is a line which repeats information from the first line of the input file:

NUR = run number

NK = number of lines containing K array data

NC = number of lines containing C array data

NH = number of lines containing character data

The final three lines on the first page of output display initial values of some variables and some constants:

RAM = kA_R/M, cm^2/g

DAM = $C_D A_D/2M$, cm^2/g

XP = initial semilatus rectum of orbit, R_e

XE = initial eccentricity of orbit (Note that although height of perigee and apogee are equal in the input, XE is not identically zero. XE is set equal to 10^{-8} in the program to avoid problems associated with division by zero.)

XOMEGD = initial argument of perigee, deg.

XASCND = initial right ascension of ascending node, deg.

XOINCD = initial inclination of orbit, deg.

XDAY = initial number of days since midnight, 12/30/57, days

PSID = angle between equatorial and ecliptic planes, deg.

DH = altitude below which spacecraft is considered to have reached the Earth, 10^4 m

GM = universal gravitational constant times Earth mass, cm^3/sec^2

RE = Earth radius, cm

OS = angular velocity of Earth about Sun, rad/day

RADP = solar radiation pressure at Earth s surface, $dyne/cm^2$

The second page of printout begins a table which lists various orbit parameters as they evolve:

J = orbit number

P = semilatus rectum of orbit, R_e

E = eccentricity of orbit

OMEGAD = argument of perigee, deg.

ASCND = right ascension of ascending node, deg.

OINCD = inclination of orbit, deg

M.J.D. = modified Julian date, days

A = semimajor axis of orbit, R_e

HTPER = height of perigee above Earth, R_e

DAY = number of days since launch, days

ALT. = height of perigee above Earth, nmi

V1D = true anomaly on entering Earth's shadow, deg.

V2D = true anomaly on leaving Earth's shadow, deg. (If V1D = V2D = -777.7777, the spacecraft does not enter the Earth's shadow.)

After printing values for the initial orbit (whose orbit number is 0), the program prints information about solar flux. It then continues calculating and printing at the specified intervals until the next calculation would either bring the spacecraft below 63 km or change the semimajor axis by more than 0.0004 R_e (default value for C(565)). If either of these conditions

is met, the calculation and print intervals are reduced to one and the calculations resume. For case 1, this occurs after orbit 3560; see Table 2. When the spacecraft reaches the Earth, the program prints out the final orbit number, "SATELLITE IS DOWN," final modified Julian date, semimajor axis, height of perigee, and end of run statement. It also prints the total lifetime in days (230.5 for this case) and linear decay rate in nautical miles per day from initial perigee altitude to 200 nautical miles.

Table 3 is a listing of the plot data file generated for case 1. The first number is the number of points the file contains. Each following line consists of time since launch in days and perigee altitude in nautical miles; these are the same numbers that appear in the output listing under "DAY" and "ALT." The data in Table 3 are shown plotted in figure 1. The plot itself was generated using a separate plotting program.

The run time for case 1 was 14 minutes and 49 seconds (CPU time on the VAX 11/785).

Case 2

Table 4 shows the input file for sample Case 2. This is the same spacecraft, orbit, and launch date as case 1, with some different options. The orbit is specified according to K(50) = 0 rather than 1, so C(537) - C(541) are given. Launch date is input as Julian date, C(542), rather than calendar date. Other differences are:

K(82) = 1: Prints time in shadow per orbit.

K(5) = 5: Uses five Gaussian quadratures in drag calculation.

K(14) = 2000 and K(15) = 50: After orbit 2000 prints every 50 orbits.

Table 5 shows the output generated for case 2. The time in shadow is now part of the output, and the print interval is reduced to 50 at orbit 2000. The total lifetime is 232.3 days, essentially the same as for case 1; the slight difference is due to using five Gaussian quadratures (K(5)) for drag, rather than the six used by default for case 1. Another effect of using five Gaussian quadratures is a reduction in run time: CPU time for case 2 was 12 minutes and 26 seconds.

Case 3

Table 6 shows the input file for sample case 3, which has the same spacecraft and orbit as cases 1 and 2, but a different launch date, January 1, 1997. As can be seen in Appendix B, the late 1990's are characterized by lower solar activity than the early 1990's, when the launch date for cases 1 and 2 occurs. Because of this, atmospheric density is lower and the total orbital lifetime will be longer. Therefore, to reduce run time and amount of printout, the calculation interval K(2) was increased to 40 and the print interval K(10) was increased to 200. Also, the number of Gaussian quadratures (K(5)) is five as in case 2.

Table 7 shows the output listing for case 3. The total lifetime is 1408 days, longer than cases 1 and 2, as expected.

Run time was 19 minutes and 5 seconds.

Case 4

Table 8 is the input file for case 4. It represents the same spacecraft, orbit, and launch date as case 3, but uses nominal solar flux predictions (K(54) = 0) rather than the $+2\sigma$ flux used in case 3. Nominal flux predictions represent an average case; $+2\sigma$ values represent worst case. Therefore, the atmospheric density is lower than in case 3, and the lifetime is longer (1950 days), as can be seen in Table 9. Case 4 uses an additional output option: K(20) = 200 and K(22) = 1000, which generates long output every 200 orbits through orbit 1000. The long output here consists of seven lines, the first of which is identical to the normal output and corresponds to the printed column headings. The second line is not labeled; there are twelve numbers listed, and they are (left to right):

Distance to perigee from center of Earth, 10^8 cm
Change in log of period for one orbit
Period, days
Zero
Zero
True longitude of sun, deg.
Six Zeroes

Each of the last five long output lines lists the changes over one orbit in eight parameters of the orbit due to a specific perturbation:

RADPR = solar radiation pressure
DRAG = atmospheric drag
EARTH = Earth oblateness
MOON = Moon's gravity
SUN = Sun's gravity

The eight changes are:

D(P) = change in semilatus rectum, R_e
D(E) = change in eccentricity
D(OMEGAD) = change in argument of perigee, deg.
D(ASCND) = change in right ascension of ascending node, deg.
D(OINCD) = change in inclination, deg.
D(A) = change in semimajor axis, R_e
D(LOG(PERIOD)) = change in log of period
D(HTPER) = change in height of perigee above Earth, R_e

Run time was 25 minutes and 56 seconds.

Case 5

The input file for sample case 5 is shown in Table 10. The spacecraft and orbit are different from the first four cases: $C_D A_D/2M = kA_R/M$ here, which might represent a spherical spacecraft (equal projected areas for drag and solar radiation pressure) with $C_D = 2.0$ and $k = 1.0$. The orbit is elliptical, 600 km by 900 km, and polar; i.e. the inclination is 90°. Launch date is February 13, 1985. $+2\sigma$ solar flux is used (K(54) = 1), and J_2 terms are not included in the Earth oblateness calculations (K(71) = 0). The maximum orbit number (K(1)) is 20,000.

Table 11 shows the output file for case 5. From the DAY and ALT columns, it is clear that this is a very slowly decaying orbit--the perigee drops by less than a nautical mile in almost 4 years. This is because the atmospheric density is extremely low at this orbit's altitudes.

Note that for some orbits, V1D and V2D are -777.7777. This indicates that the spacecraft never enters the Earth's shadow during these orbits.

As specified by the input, the run terminates after 20,000 orbits, before the spacecraft reaches the Earth. Therefore, lifetime and decay rate are not printed. A plot file is still generated.

Run time for case 5 was 22 minutes and 32 seconds.

COMMENTS ON PROGRAM OPERATION

In the discussion of the sample cases, the consequences of making certain input choices were pointed out. A few are repeated here along with other information to keep in mind when running the OL program.

The OL program takes a relatively long time to run, and thus should be run in batch mode rather than interactively. The run times for the sample cases were on the order of about 20 CPU minutes. Actual turnaround times averaged about 1 hour when the computer had few users. The main contributor to the long execution time is the integration scheme in the atmospheric density model (function RHA) used for the drag calculations (subroutine DRAG1). Therefore, one way to reduce run time is to reduce K(5), the number of Gaussian quadratures used in the drag calculation, as was done in sample case 2. Case 1 used the default six quadratures; case 2 used five quadratures for the same orbit and the run time was reduced by about a sixth. Some accuracy was lost, but the difference in total lifetimes for the two cases was less than 1 percent. It should be noted that the orbit was circular for these cases and an elliptical orbit would be more sensitive to a lower K(5).

Another way to control run time is through the choice of the calculation interval K(2), since run time is approximately proportional to K(2). Its choice should be governed by expected lifetime, which depends primarily on these factors:

$C_DA_D/2M$: Drag increases with $C_DA_D/2M$, so the higher its value, the shorter the lifetime.

Altitude: Atmospheric density decreases roughly exponentially as altitude increases, so lifetime increases with increasing initial altitude. For very high altitudes, the OL program calculations may not be sensitive enough for the orbit to decay at all.

Launch date: Atmospheric density varies by as much as an order of magnitude throughout the 11-year solar cycle. As solar flux increases, density increases, so a launch during high solar activity results in a shorter lifetime than a launch during low solar activity. By current predictions, solar activity will be high in the early 1990's and low in the late 1990's (see Appendix B for solar flux predictions through November 1998).

Nominal vs. $+2\sigma$ solar flux: Since nominal predicted flux values represent the 50th percentile and $+2\sigma$ values represent the 97.7th percentile, $+2\sigma$ values give shorter lifetimes than nominal values (see sample cases 3 and 4).

The following factors do not strongly affect total lifetime: kA_R/M, exact day and time of launch, inclusion of J_2^2 term in Earth's gravity model, and initial values of λ, ω, and Ω.

As mentioned in the input format section, the effects of individual perturbations may be deleted by using K(111) - K(118). Using these will not eliminate any calculations, so they cannot be used to reduce run time. However, the solar radiation pressure and drag calculations can be eliminated by setting kA_R/M (C(531)) and $C_DA_D/2M$ (C(532)), respectively, to values less than 10^{-8} g/cm^2.

For the drag and radiation pressure calculations, the same $C_DA_D/2M$ and kA_R/M values are used throughout the entire lifetime and, in particular, throughout each orbit. Therefore, if the projected area of the spacecraft is expected to change, the area input to the program must be an average area. Sample cases 1-4 represent the NASA Space Station Reference Configuration (ref. 8), which has solar arrays which track the Sun. The solar array projected areas used were averaged over an orbit.

The OL program will not run correctly for dates earlier than the first date in the flux data file (for the flux data listed in Appendix B, that date is January 15, 1984). To run the program for earlier dates, the flux file must be changed to include those dates. Dates later than the end of the flux data pose no problem because the solar cycle is assumed to repeat as necessary.

Multiple cases may be executed in a single run by combining input for the cases consecutively in one input file. This option is not recommended because the run time is the sum of the individual cases run times; it is faster to submit the cases separately and let them run concurrently.

CONCLUDING REMARKS

This paper described the LaRC Orbital Lifetime program, which is used to predict orbital lifetimes and decay rates of Earth-orbiting spacecraft. The input and output were described in detail, and several sample cases were included. Further information can be obtained from the Spacecraft Analysis Branch, Space Systems Division, NASA LaRC.

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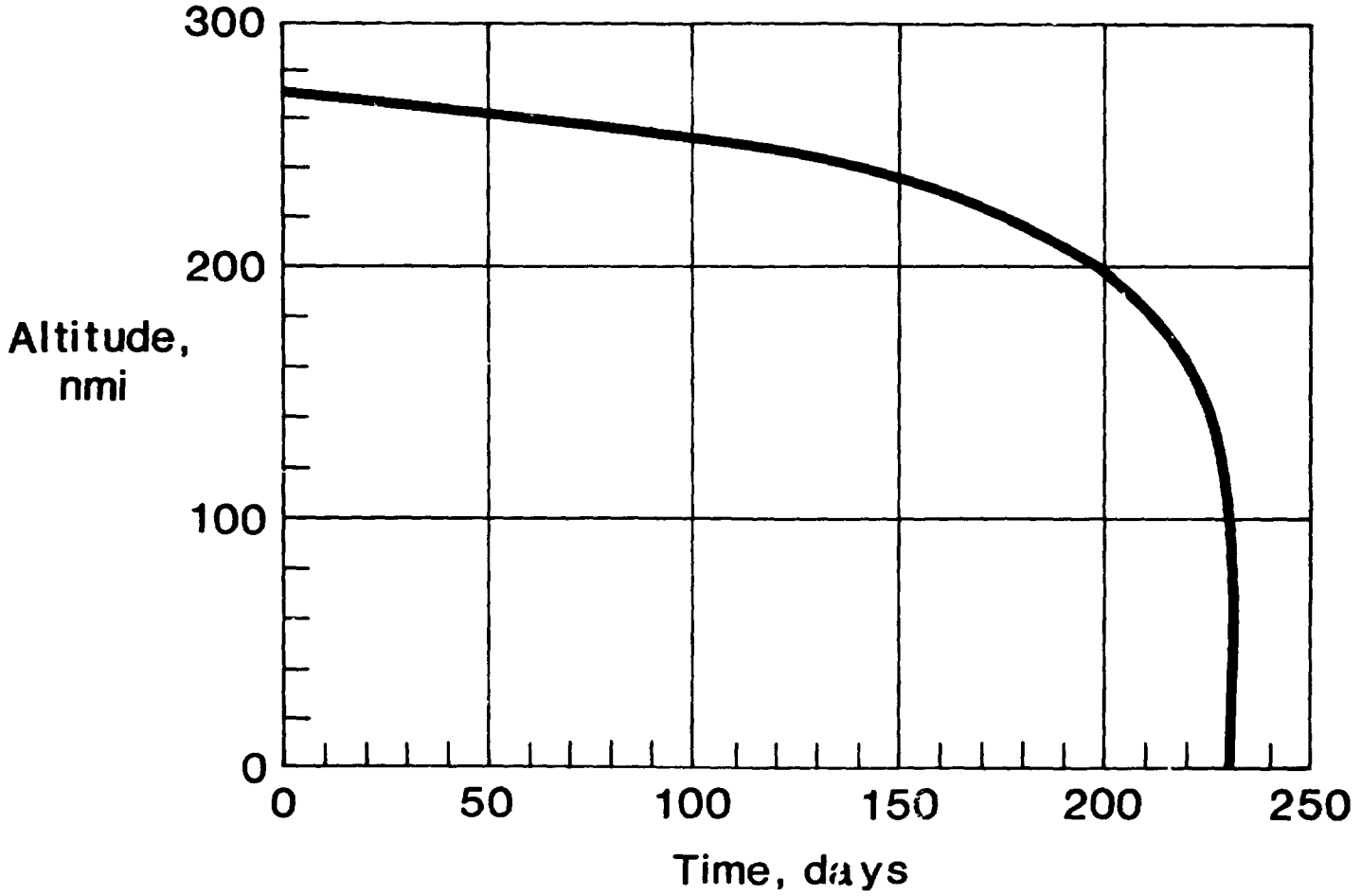

Figure 1. - Sample case 1 lifetime plot.

TABLE I. - SAMPLE CASE 1 INPUT FILE

```
     1                                  1      3                                  2
ORBITAL LIFETIME CASE 1
SPACE STATION REFERENCE CONFIGURATION  1991 LAUNCH
      1999999      2       10      10     100      71       1      50       1      54       1
  531 0.1543          532 0.1365          539 0.0
  541 28.5            1111 0.             1121 500.0393       1122 500.0393
 1116 0.              1117 1.             1120 1.             1115 1931.
```

TABLE II. - SAMPLE CASE 1 OUTPUT FILE


```
     1993333       2     10     10    100     71      1     50      1     54      1
  531 0.1543000E+00 532 0.1365000E+00 539 0.0000000E+00   0 0.0000000E+00
  541 0.2850000E+021111 0.0000000E+001121 0.5000393E+031122 0.5000393E+03
 1116 0.5000000E+011117 0.1000000E+011120 0.1000000E+011115 0.1991000E+04

 JULIAN DATE= 2448409.500012   1991.   6. 1.GMT= 0. 0. 1.

ORBITAL LIFETIME CASE 1
SPACE STATION REFERENCE CONFIGURATION  1991 LAUNCH

NUP=      1  NK=      1  NC=      3  NH=      2

RAM=    0.154300   DAM=    0.136500
  XP=  1.0783938E+00   KS=  0.00000001 XOMEGD=     0.000000 XASCND=  248.621198 XOINCD=   28.500000   XDAY=12205.000012
PSID=  2.3644615E+01   DM=  6.363000E+00   GM=  3.986300E+20   RE=  6.378145E+08   OS=  1.720290E-02 RADP=  4.500000E-05
```

TABLE II. - Continued.

J	P	E	OMEGAD	ASCND	OINCO	M.J.D.	A	MTPER	DAY	ALT.	V1D	V2D
0	1.0783989	0.0000000	0.0000	248.621	28.5000	18408.500	1.0783989	0.0783988	0.0000	269.831	282.2513	415.5853

FLUX DATA FROM THE 6/1985 NSFC MEMO EXTENDS FROM 1/1984 TO 11/1998
JD= 2441409.498 5/31/1991 FLUX INTERPOLATED BETWEEN 89 AND 90 AS 224.70
AP = 21.95
CYCLE REPEATED FOR DATES AFTER END OF FLUX DATA

100	1.0781135	0.0000026	169.4839	204.321	28.4998	18415.047	1.0781135	0.0781108	6.5468	268.848	167.5548	286.5535
200	1.0778364	0.0000000	109.8776	159.997	28.4989	18421.591	1.0778364	0.0778364	13.0911	267.896	302.9016	410.3052
300	1.0775474	0.0000000	27.6644	115.651	28.4996	18428.133	1.0775474	0.0775474	19.6328	266.901	76.1863	203.0136
400	1.0772558	0.0000243	76.0943	71.281	28.5008	18434.672	1.0772558	0.0772512	26.1718	265.881	67.3723	203.0001
500	1.0769578	0.0000022	33.7819	26.897	28.5010	18441.208	1.0769578	0.0769553	32.7080	264.863	153.9755	298.2452
600	1.0766833	0.0000233	113.8304	342.472	28.5014	18447.742	1.0766833	0.0766518	39.2418	263.818	120.7111	257.1860
700	1.0764029	0.0000340	316.4455	298.032	28.5005	18454.273	1.0764030	0.0763664	45.7729	262.836	323.1095	457.5029
800	1.0761254	0.0000311	102.2439	253.569	28.5002	18460.801	1.0761254	0.0760920	52.3015	261.892	231.7692	354.5015
900	1.0758452	0.0000343	90.3248	209.081	28.4995	18467.328	1.0758452	0.0758083	58.8275	260.915	314.6708	429.3027
1000	1.0755417	0.0000425	54.0007	164.569	28.4991	18473.851	1.0755417	0.0754960	65.3509	259.841	42.1090	172.1259
1100	1.0752222	0.0000421	239.1976	120.031	28.5002	18480.371	1.0752222	0.0754769	71.8714	258.742	257.5256	394.2909
1200	1.0748894	0.0000528	218.5879	75.466	28.5005	18486.889	1.0748894	0.0748326	78.3890	257.557	324.7138	460.3828
1300	1.0745393	0.0000897	240.3126	30.875	28.5010	18493.403	1.0745399	0.0744434	84.9034	256.218	333.7620	469.6355
1400	1.0741589	0.0001312	297.8791	346.254	28.5015	18499.915	1.0741589	0.0740180	91.4146	254.754	342.5906	479.6441
1500	1.0737452	0.0001103	296.1926	301.600	28.5007	18506.422	1.0737452	0.0736268	97.9221	253.407	34.0407	166.6184
1600	1.0732892	0.0000328	298.9961	256.909	28.4998	18512.926	1.0732892	0.0732540	104.4256	252.124	100.6125	229.5305
1700	1.0727490	0.0000006	60.7582	212.176	28.4989	18519.425	1.0727490	0.0727484	110.9246	250.384	39.7264	175.0348
1800	1.0721478	0.0000410	356.6176	167.395	28.4991	18525.918	1.0721478	0.0721039	117.4184	248.46	127.2187	264.5347
1900	1.0715029	0.0000266	338.6235	122.561	28.4996	18532.406	1.0715029	0.0714746	123.9065	246.908	197.1309	328.6397
2000	1.0707973	0.0000375	94.8593	77.670	28.4994	18538.888	1.0707973	0.0707574	130.3884	243.531	148.5434	271.1757
2100	1.0700109	0.0001353	352.4771	32.720	28.5004	18545.364	1.0700109	0.0699731	136.8635	240.832	291.5127	428.5922
2200	1.0691503	0.0001627	192.1519	347.701	28.5007	18551.831	1.0691503	0.0691046	143.3314	237.843	147.5127	285.7192
2300	1.0682201	0.0000092	133.6825	302.607	28.5005	18558.291	1.0682201	0.0682113	149.7907	234.768	247.0622	384.2429
2400	1.0671727	0.0000310	331.4402	257.429	28.4998	18564.741	1.0671727	0.0671396	156.2412	231.000	97.6350	236.6711
2500	1.0660543	0.0000361	59.6946	212.158	28.4990	18571.182	1.0660543	0.0660139	162.6818	227.212	54.6805	191.1645
2600	1.0648676	0.0000551	56.1232	166.788	28.4990	18577.612	1.0648676	0.0648090	169.1119	223.058	117.8255	241.1895

TABLE II. - Concluded.

2700	1.0535340	0.0001342	303.4479	121.313	28.4987	18584.031	1.0635940	0.0634513	175.5309	218.385	301.4013	424.1529
2800	1.0621946	0.0002092	305.2047	75.726	28.4996	18590.438	1.0621946	0.0619724	181.9377	243.295	347.5123	484.2328
2900	1.0606555	0.0001313	300.7737	30.014	28.5008	18596.831	1.0606555	0.0605158	188.3313	208.282	34.8934	175.9136
3000	1.0589913	0.0000198	45.6681	344.164	28.5009	18603.210	1.0589913	0.0589714	194.7102	202.967	337.7306	479.1258
3100	1.0570088	0.0000116	138.0613	299.159	28.5006	18609.573	1.0570088	0.0569965	201.0728	196.169	292.1309	434.0709
3200	1.0546918	0.0000849	254.5255	251.965	28.4997	18615.916	1.0546918	0.0545924	207.4159	187.895	223.4295	360.2487
3300	1.0518379	0.0002691	296.3947	205.547	28.4987	18622.236	1.0518379	0.0515558	213.7359	177.444	248.8758	371.0773
3400	1.0479352	0.0005391	315.7597	158.840	28.4983	18628.526	1.0479355	0.0473705	220.0260	163.039	299.4009	431.0250
3500	1.0411895	0.0007175	337.0604	111.693	28.4983	18634.771	1.0411892	0.0404421	226.2706	139.193	222.0840	468.0730
3561	0299459	0.0004371	194.3730	61.162	28.4996	18638.533	1.0299461	0.0294960	230.0332	101.519	158.4084	310.6280
3562	1.0293671	0.0004125	191.6277	60.676	28.4996	18638.594	1.0293673	0.0289427	230.0942	99.614	162.0036	314.4877
3563	1.0287180	0.0003871	177.4772	60.190	28.4996	18638.655	1.0287181	0.0283198	230.1552	97.471	166.5006	319.2833
3564	1.0279750	0.0003608	173.3105	59.703	28.4996	18638.716	1.0279751	0.0276042	230.2162	95.008	170.9903	324.1189
3565	1.0270985	0.0003333	174.3009	59.216	28.4997	18638.777	1.0270986	0.0267562	230.2771	92.089	170.2882	323.8278
3566	1.0260130	0.0003045	2[illegible]9179	58.727	28.4997	18638.838	1.0260131	0.0257007	230.3379	88.456	115.8644	269.9040
3567	1.0245724	0.0002433	31[illegible]5770	58.238	28.4997	18638.899	1.0245725	0.0243232	230.3986	83.715	32.2657	187.0388
3568	1.0220297	0.0004403	83.2361	57.747	28.4997	18638.959	1.0220299	0.0215799	230.4591	74.273	261.5253	417.6652
		3568	SATELLITE IS DOWN					18639.01849	1.0000000	0.0000000	END OF RUN NUMBER	1

LIFETIME IS 230.5193 DAYS
LINEAR DECAY RATE = 0.3663453324463156 NMI/DAY (TO 200 NMI)

TABLE III. - SAMPLE CASE 1 PLOT FILE

45	
0.0000000000000000E+00	269.8314518016466
6.546814570968763	268.8399270964226
13.09107555440505	267.8956163548166
19.63277440435650	266.9008479280561
26.17179515708813	265.8813381683264
32.70804727135192	264.8632243993188
39.24176130513115	263.8183671735880
45.77289709863771	262.8361953446649
52.30148105216858	261.8917078974213
58.82752474063091	260.9153793741687
65.35091451648213	259.8406454540449
71.87144976147783	258.7422591364933
78.38900064705740	257.5570410513619
84.90344354032823	256.2177487423680
91.41456057026517	254.7535532210168
97.92205021981135	253.4069650771726
104.4255832028671	252.1240159323387
110.9245974707464	250.3838202194094
117.4183530096976	248.1655051699179
123.9064510188555	245.9997672680871
130.3883980442974	243.5312571787600
136.8635471513835	240.8317368463933
143.3311857114500	237.8428509449274
149.7906523488068	234.7681459465419
156.2411594264909	231.0795538809746
162.6817700997144	227.2119690179740
169.1118992779138	223.0580490320475
175.5308803545395	218.3852852287822
181.9377405837204	213.2953415646778
188.3312686964127	208.2818788443766
194.7102354615895	202.9666362367193
201.0728333489751	196.1693578227752
207.4159360464534	187.8948419870647
213.7359041838035	177.4437440630767
220.0260083426565	163.0388310364290
226.2706310950471	139.1927321490421
230.0331551513264	101.5185909840924
230.0942271708964	99.61433436588503
230.1552443018945	97.47062609603987
230.2161992263614	95.00754674772795
230.2770818163203	92.08904870322944
230.3378768166108	88.45601545391157
230.3985591042388	83.71503054708158
230.4590638356826	74.27330370054034
230.5184777826807	0.0000000000000000E+00

TABLE IV. - SAMPLE CASE 2 INPUT FILE

```
     2                                2      3                                  2
ORBITAL LIFETIME    CASE 2
SAME SPACECRAFT & ORBIT AS CASE 1; DIFFERENT I/O OPTIONS
      1999999       2     10     10    100     71      1     50       0     54      1
     82       1      5      5     14   2000     15     50
 531 0.1543          532 0.1365          539 0.0              540 248.621194
 541 28.5            537 1.07839886      538 0.
 542 2448408.50001
```

TABLE V. - SAMPLE CASE 2 OUTPUT FILE

```
     1993999      2     10     10    100     71      1     50      0     54      1
     92      1      5      5     14   2000     15     50      0      0      0      0
 531 0.1543000E+00 532 0.1365000E+00 539 0.0000000E+00 500 0.2486212E+03
 541 0.2850000E+02 537 0.1079399E+01 536 0.0000000E+00   0 0.0000000E+00
 542 0.2448409E+07   0 0.0000000E+00   0 0.0000000E+00   0 0.0000000E+00

 JULIAN DATE= 2448409.500010   1991.    6.  1.GMT= 0.  0.  1.

ORBITAL LIFETIME   CASE 2
SAME SPACECRAFT & ORBIT AS CASE 1; DIFFERENT I/O OPTIONS

NUM=      2  NK=      2  NC=      3  NH=      2

RAM=    0.154300   DAM=    0.136500
  XP=  1.07339994      XE=  0.00000001 XOMEGD=     0.000000 XASCND=  248.621194 XDINCD=   28.500000   XDAY=12205.000010
PSID=  2.3444411+01    DM=  6.363000E+00   GM=  3.986300E+20   RE=  6.378145E+06   OS=  1.720290E-02 RADP=  4.500000E-05
```

TABLE V. - Continued.

J	P	E	OMEGAD	ASCND	OINCD	M.J.D.	A	HTPER	DAY	ALT.	V1B	V2B
0	1.0783989	0.0000000	0.0000	249.621	28.5000	18409.500	1.0783989	0.0783988	0.0000	269.831	282.2513	415.5853

TIME IN SHADOW/ORBIT(MIN)= 35.042; ORBIT PERIOD(MIN)= 94.614

FLUX DATA FROM THE 6/1985 MSFC MEMO EXTENDS FROM 1/1984 TO 11/1998
JD= 2448409.498 5/31/1991 FLUX INTERPOLATED BETWEEN 89 AND 90 AS 224.70
AP = 21.95
CYCLE REPEATED FOR DATES AFTER END OF FLUX DATA

100	1.0781191	0.0000190	171.3958	204.321	28.4996	18415.047	1.0781191	0.0781083	6.5468	268.831	165.0459	284.0413

TIME IN SHADOW/ORBIT(MIN)= 31.262; ORBIT PERIOD(MIN)= 94.577

200	1.0778346	0.0000000	356.0994	159.396	28.4987	18421.591	1.0778346	0.0778346	13.0910	267.889	56.6799	164.0848

TIME IN SHADOW/ORBIT(MIN)= 29.206; ORBIT PERIOD(MIN)= 94.540

300	1.0775465	0.0000050	61.0456	115.649	28.4993	18428.133	1.0775465	0.0775412	19.6327	266.879	42.7253	169.6332

TIME IN SHADOW/ORBIT(MIN)= 33.314; ORBIT PERIOD(MIN)= 94.502

400	1.0772749	0.0000058	102.4777	71.279	28.5003	18434.672	1.0772749	0.0772686	26.1717	265.941	40.9924	176.6153

TIME IN SHADOW/ORBIT(MIN)= 35.588; ORBIT PERIOD(MIN)= 94.466

500	1.0770219	0.0000196	128.5423	26.889	28.5006	18441.208	1.0770219	0.0770007	32.7084	265.019	59.2202	195.4717

TIME IN SHADOW/ORBIT(MIN)= 35.741; ORBIT PERIOD(MIN)= 94.433

600	1.0767403	0.0000230	10.3355	342.478	28.5010	18447.743	1.0767408	0.0767107	39.2426	264.021	224.2094	360.6732

TIME IN SHADOW/ORBIT(MIN)= 35.782; ORBIT PERIOD(MIN)= 94.396

700	1.0764601	0.0000232	49.3347	298.044	28.5003	18454.274	1.0764601	0.0764351	45.7743	263.073	230.2262	364.6026

TIME IN SHADOW/ORBIT(MIN)= 35.220; ORBIT PERIOD(MIN)= 94.359

800	1.0761652	0.0000405	252.9478	253.585	28.4996	18460.803	1.0761852	0.0761416	52.3034	262.063	81.0533	203.7608

TIME IN SHADOW/ORBIT(MIN)= 32.152; ORBIT PERIOD(MIN)= 94.323

900	1.0759059	0.0000324	144.0239	209.101	28.4990	18467.330	1.0759051	0.0758702	58.8300	261.128	260.9669	375.5693

TIME IN SHADOW/ORBIT(MIN)= 30.014; ORBIT PERIOD(MIN)= 94.286

1000	1.0756068	0.0000435	17.3961	164.595	28.4987	18473.854	1.0756068	0.0755600	65.3540	260.061	78.7098	208.6979

TIME IN SHADOW/ORBIT(MIN)= 34.032; ORBIT PERIOD(MIN)= 94.247

TABLE V. - Continued.

1100	1.0752900	0.0000409	24.6320	120.042	28.4997	18480.375	1.0752900	0.0752460	71.8751	258.98[illegible]	112.0773	248.[illegible]154
TIME IN SHADOW/ORBIT(MIN)=		35.784;	ORBIT PERIOD(MIN)=		94.205							
1200	1.0749622	0.0000285	32.1695	75.503	28.5000	18486.893	1.0749622	0.0749316	78.3933	257.8[illegible]	151.1197	286.[illegible]616
TIME IN SHADOW/ORBIT(MIN)=		35.480;	ORBIT PERIOD(MIN)=		94.162							
1300	1.0746128	0.0000298	36.3064	30.918	28.5004	18493.408	1.0746128	0.0745808	84.9084	256.691	197.7591	333.6024
TIME IN SHADOW/ORBIT(MIN)=		35.514;	ORBIT PERIOD(MIN)=		94.116							
1400	1.0742407	0.0000012	8.1452	346.303	28.5009	18499.920	1.0742407	0.0742394	91.4202	255.515	272.3135	409.3373
TIME IN SHADOW/ORBIT(MIN)=		35.804;	ORBIT PERIOD(MIN)=		94.067							
1500	1.0738282	0.0000240	350.6414	301.655	28.5004	18506.428	1.0738282	0.0738025	97.9284	254.012	339.5627	472.1287
TIME IN SHADOW/ORBIT(MIN)=		34.613;	ORBIT PERIOD(MIN)=		94.013							
1600	1.0733780	0.0000336	178.7000	256.971	28.4999	18512.933	1.0733780	0.0733366	104.4327	252.408	210.8620	339.7562
TIME IN SHADOW/ORBIT(MIN)=		33.639;	ORBIT PERIOD(MIN)=		93.954							
1700	1.0728579	0.0000465	63.4777	212.246	28.4991	18519.433	1.0728579	0.0728079	110.9326	250.589	11.9570	147.2286
TIME IN SHADOW/ORBIT(MIN)=		35.277;	ORBIT PERIOD(MIN)=		93.886							
1800	1.0722777	0.0000544	240.1713	167.476	28.4994	18525.928	1.0722777	0.0722193	117.4275	248.563	243.6145	380.9058
TIME IN SHADOW/ORBIT(MIN)=		35.774;	ORBIT PERIOD(MIN)=		93.809							
1900	1.0716381	0.0000945	262.2502	122.653	28.4997	19532.417	1.0716381	0.0715368	123.9168	246.214	273.4302	404.9155
TIME IN SHADOW/ORBIT(MIN)=		34.227;	ORBIT PERIOD(MIN)=		93.725							
2000	1.0709333	0.0001944	299.6327	77.775	28.4994	18538.900	1.0709333	0.0707252	130.4000	243.420	295.6757	426.2815
TIME IN SHADOW/ORBIT(MIN)=		33.959;	ORBIT PERIOD(MIN)=		93.633							
2050	1.0705505	0.0002351	302.8635	55.314	28.5001	18542.139	1.0705507	0.0702990	133.6391	241.954	318.0928	452.1726
TIME IN SHADOW/ORBIT(MIN)=		34.843;	ORBIT PERIOD(MIN)=		93.583							
2100	1.0701476	0.0002593	305.0797	32.837	28.5003	18545.376	1.0701477	0.0698713	136.8764	240.481	338.8084	475.8537
TIME IN SHADOW/ORBIT(MIN)=		35.595;	ORBIT PERIOD(MIN)=		93.530							

TABLE V. - Continued.

2150 1.0697257 0.0002565 305.6115 10.342 28.5005 18548.612 1.0697258 0.0694514 140.1118 239.036 0.5687 138.9333
TIME IN SHADOW/ORBIT(MIN)= 35.922; ORBIT PERIOD(MIN)= 93.475

2200 1.0692857 0.0002249 303.7213 347.829 28.5006 18551.845 1.0692857 0.0690453 143.3453 237.639 25.8207 163.9946
TIME IN SHADOW/ORBIT(MIN)= 35.856; ORBIT PERIOD(MIN)= 93.417

2250 1.0688274 0.0001561 299.0165 325.238 28.5004 18555.077 1.0688274 0.0686499 146.5767 236.278 55.6312 192.9889
TIME IN SHADOW/ORBIT(MIN)= 35.625; ORBIT PERIOD(MIN)= 93.357

2300 1.0683497 0.0000920 292.1470 302.746 28.5003 18558.306 1.0683497 0.0682514 149.8060 234.906 88.4893 225.6219
TIME IN SHADOW/ORBIT(MIN)= 35.543; ORBIT PERIOD(MIN)= 93.294

2350 1.0679513 0.0000226 285.7314 290.174 28.4996 18561.533 1.0678513 0.0678272 153.0331 233.446 119.9827 257.9561
TIME IN SHADOW/ORBIT(MIN)= 35.732; ORBIT PERIOD(MIN)= 93.229

2400 1.0673489 0.0000049 106.6727 257.580 28.4994 18564.758 1.0673488 0.0673436 156.2578 231.782 322.3038 461.2908
TIME IN SHADOW/ORBIT(MIN)= 35.968; ORBIT PERIOD(MIN)= 93.163

2450 1.0667997 0.0000245 65.3134 234.964 28.4994 18567.980 1.0667997 0.0667735 159.4803 229.820 24.8630 163.7009
TIME IN SHADOW/ORBIT(MIN)= 35.902; ORBIT PERIOD(MIN)= 93.091

2500 1.0662398 0.0000128 256.0794 212.325 28.4996 18571.200 1.0662398 0.0662261 162.7001 227.936 218.1861 354.6349
TIME IN SHADOW/ORBIT(MIN)= 35.256; ORBIT PERIOD(MIN)= 93.018

2550 1.0656630 0.0000198 30.2488 189.660 28.4984 18574.417 1.0656630 0.0656430 165.9174 225.929 110.6679 241.7513
TIME IN SHADOW/ORBIT(MIN)= 33.843; ORBIT PERIOD(MIN)= 92.943

2600 1.0650631 0.0000327 152.9796 166.972 28.4988 18577.632 1.0650631 0.0650283 169.1320 223.813 20.7722 144.1051
TIME IN SHADOW/ORBIT(MIN)= 31.814; ORBIT PERIOD(MIN)= 92.864

2650 1.0644555 0.0000170 135.4774 144.256 28.4982 18580.844 1.0644555 0.0644374 172.3438 221.779 75.7158 194.1583
TIME IN SHADOW/ORBIT(MIN)= 30.527; ORBIT PERIOD(MIN)= 92.785

2700 1.0638550 0.0000128 280.7857 121.514 28.4983 18584.053 1.0638550 0.0638415 175.5530 219.728 323.9425 446.4905
TIME IN SHADOW/ORBIT(MIN)= 31.558; ORBIT PERIOD(MIN)= 92.706

TABLE V. - Continued.

2750	1.0631871	0.0000177	96.0852	98.747	28.4993	18587.259	1.0631871	0.0631683	178.7592	217.411	174.6818	305.2369
TIME IN SHADOW/ORBIT(MIN)=		33.589;	ORBIT PERIOD(MIN)=		92.619							
2800	1.0624931	0.0000283	30.1287	75.950	28.4994	18590.462	1.0624931	0.0624630	181.9623	214.984	262.5213	399.0956
TIME IN SHADOW/ORBIT(MIN)=		35.101;	ORBIT PERIOD(MIN)=		92.528							
2850	1.0617674	0.0000447	320.3890	53.123	29.5000	18593.662	1.0617674	0.0617206	185.1623	212.427	353.2415	493.0002
TIME IN SHADOW/ORBIT(MIN)=		35.883;	ORBIT PERIOD(MIN)=		92.433							
2900	1.0610120	0.0000383	1.0468	30.266	28.5005	18596.859	1.0610120	0.0609713	188.3588	209.850	334.4973	475.4131
TIME IN SHADOW/ORBIT(MIN)=		36.141;	ORBIT PERIOD(MIN)=		92.335							
2950	1.0602357	0.0000110	59.9615	7.374	28.5005	18600.052	1.0602357	0.0602240	191.5519	207.278	299.0048	440.1009
TIME IN SHADOW/ORBIT(MIN)=		36.149;	ORBIT PERIOD(MIN)=		92.234							
3000	1.0593909	0.0000374	17.5263	344.449	28.5006	18603.241	1.0593909	0.0593513	194.7413	204.274	5.6999	146.9699
TIME IN SHADOW/ORBIT(MIN)=		36.150;	ORBIT PERIOD(MIN)=		92.123							
3050	1.0584829	0.0000471	329.5564	321.485	28.5005	18606.427	1.0584829	0.0584331	197.9267	201.114	77.5425	219.2498
TIME IN SHADOW/ORBIT(MIN)=		36.218;	ORBIT PERIOD(MIN)=		92.005							
3100	1.0575107	0.0000381	67.8195	298.480	28.5004	18609.608	1.0575107	0.0574704	201.1079	197.801	2.2024	143.9908
TIME IN SHADOW/ORBIT(MIN)=		36.186;	ORBIT PERIOD(MIN)=		91.878							
3150	1.0564375	0.0000097	7.9280	275.433	28.5001	18612.785	1.0564375	0.0564272	204.2845	194.210	84.9258	225.3808
TIME IN SHADOW/ORBIT(MIN)=		35.792;	ORBIT PERIOD(MIN)=		91.738							
3200	1.0552997	0.0000423	164.2269	252.335	28.4992	18615.956	1.0552887	0.0552441	207.4560	190.138	313.4934	450.1542
TIME IN SHADOW/ORBIT(MIN)=		34.766;	ORBIT PERIOD(MIN)=		91.589							
3250	1.0540347	0.0000240	96.3669	229.185	28.4991	18619.122	1.0540347	0.0540094	210.6221	185.888	51.4893	181.1795
TIME IN SHADOW/ORBIT(MIN)=		32.937;	ORBIT PERIOD(MIN)=		91.426							
3300	1.0526073	0.0000433	325.1397	205.977	28.4989	18622.282	1.0526073	0.0525618	213.7822	180.906	220.3467	342.1669
TIME IN SHADOW/ORBIT(MIN)=		30.874;	ORBIT PERIOD(MIN)=		91.240							

TABLE V. - Concluded.

```
  3350 1.0509904 0.0003950 210.6991  182.702  28.4982 18625.435 1.0509904 0.0508906  216.9354  175.156  13.7453 135.6035
TIME IN SHADOW/ORBIT(MIN)=   30.312;   ORBIT PERIOD(MIN)=   91.030

  3400 1.0490619 0.0001741 308.0308  159.350  28.4987 18629.581 1.0490619 0.0488792  220.0806  168.231 306.9935 437.8380
TIME IN SHADOW/ORBIT(MIN)=   32.995;   ORBIT PERIOD(MIN)=   90.779

  3450 1.0466463 0.0003033 313.7025  135.906  28.4990 18631.716 1.0466463 0.0463288  223.2162  159.454 324.7142 464.1998
TIME IN SHADOW/ORBIT(MIN)=   35.038;   ORBIT PERIOD(MIN)=   90.466

  3500 1.0433869 0.0003768 322.8442  112.338  28.4988 18634.839 1.0433869 0.0429937  226.3391  147.975 336.3196 481.3440
TIME IN SHADOW/ORBIT(MIN)=   36.260;   ORBIT PERIOD(MIN)=   90.044

  3550 1.0392108 0.0003257 326.5100   88.534  28.4993 18637.944 1.0392108 0.0378727  229.4437  130.349 353.4030 502.0483
TIME IN SHADOW/ORBIT(MIN)=   36.836;   ORBIT PERIOD(MIN)=   89.374

                    3595  SATELLITE IS DOWN                                18640.76401  1.0066119  0.0066119END OF RUN NUMBER    2
          LIFETIME IS      232.2640 DAYS
LINEAR DECAY RATE =  0.35817061343610O9     NMI/DAY (TO 200 NMI)
```

TABLE VI. - SAMPLE CASE 3 INPUT FILE

```
      3                                 2      3                                 2
ORBITAL LIFETIME  CASE 3
SAME AS CASE 1 WITH 1997 LAUNCH
        1999999      2     40     10    200     71      1     50      1     54      1
        5       5
  531 0.1543          532 0.1365          539 0.0
  541 28.5           1111 0.             1121 500.0393      1122 500.0393
 1116 1.             1117 1.             1120 1.            1115 1997.
```

TABLE VII. - SAMPLE CASE 3 OUTPUT FILE

```
     1999999.      2     40     10    200     71      1     50      1     54      1
     5      5      0      0      0      0      0      0      0      0      0      0
  531 0.154300000E+00 532 0.136500000E+00 539 0.000000000E+00    0 0.000000000E+00
  541 0.298500000E+021111 0.000000002E+001121 0.500039300E+031122 0.500039300E+03
 1116 0.100000000E+011117 0.100000000E+011120 0.100000000E+011115 0.199700000E+04

 JULIAN DATE= 2450469.500012   1997.   1. 1.GMT= 0. 0. 1.

ORBITAL LIFETIME  CASE 3
SAME AS CASE 1 WITH 1997 LAUNCH

NUR=      3  NK=      2  NG=      3  NH=      2

RAM=    0.154300   DAM=    0.136500
  XP=  1.07839936      XE=  0.00000001 XOMEGD=     0.000000 XASCND=  100.251208 XOINCD=    28.500000    XDAY=14246.000012
PSID=  2.344461E+01    DM=  6.363000E+00   GM=  3.986300E+20   RE=  6.378145E+08    DS=  1.720290E-02 RADP=  4.500000E-05
```

TABLE VII. - Continued.

J	O	E	OMEGAD	ASCND	OINCD	M.J.D.	A	MTPER	DAY	ALT.	V1D	V2D
0	1.0783989	0.0000000	0.0000	100.251	28.5000	20449.500	1.0783989	0.0783988	0.0000	269.831	305.9466	439.1543

FLUX DATA FROM THE 6/1985 MSFC MEMO EXTENDS FROM 1/1984 TO 11/1998
JD= 2450449.491 12/31/1996 FLUX INTERPOLATED BETWEEN 156 AND 157 AS 98.15
AP = 18.74
CYCLE REPEATED FOR DATES AFTER END OF FLUX DATA

200	1.0782997	0.0000024	281.0725	11.667	28.5008	20462.595	1.0782997	0.0782971	13.0953	269.481	111.6185	247.4043
400	1.0782165	0.0000027	37.7046	283.072	28.5004	20475.689	1.0782165	0.0782137	26.1857	269.194	89.1303	218.9917
600	1.0781432	0.0000036	197.3754	194.457	28.4995	20488.781	1.0781432	0.0781329	39.2813	268.916	65.9884	189.8795
800	1.0780596	0.0000164	243.6755	105.832	28.5004	20501.872	1.0780596	0.0780419	52.3721	268.603	96.1372	231.5309
1000	1.0779685	0.0000109	136.1441	17.193	28.5010	20514.961	1.0779685	0.0779568	65.4613	268.310	304.9892	440.5796
1200	1.0778662	0.0000103	197.0303	293.540	28.5009	20528.049	1.0778662	0.0778551	78.5487	267.968	344.0712	474.3170
1400	1.0777649	0.0000088	334.4443	199.866	28.4995	20541.134	1.0777649	0.0777640	91.6342	267.646	306.3992	442.5902
1600	1.0776589	0.0000026	27.1166	111.174	28.4997	20554.218	1.0776589	0.0776562	104.7178	267.275	1.2865	125.2249
1800	1.0775284	0.0000031	247.6920	22.466	28.5009	20567.299	1.0775284	0.0775250	117.7993	266.824	240.5570	376.5141
2000	1.0774332	0.0000094	339.7496	293.740	28.5007	20580.379	1.0774332	0.0774242	130.8787	266.477	244.0798	379.7842
2200	1.0773514	0.0000090	36.9190	204.998	28.4993	20593.456	1.0773514	0.0773418	143.9565	266.193	280.5957	407.3341
2400	1.0772784	0.0000000	242.2087	116.238	28.4995	20606.533	1.0772784	0.0772784	157.0329	265.975	207.1315	329.1703
2600	1.0771977	0.0000165	228.0196	27.472	28.5010	20619.608	1.0771977	0.0771820	170.1079	265.643	305.1635	441.5046
2800	1.0771296	0.0000328	195.9976	298.693	28.5007	20632.681	1.0771286	0.0770932	183.1814	265.338	67.7934	203.1973
3000	1.0770692	0.0000300	255.6033	209.902	28.4995	20645.754	1.0770692	0.0770369	196.2539	265.144	129.6536	239.0804
3200	1.0770098	0.0000206	292.9907	121.099	28.4998	20658.825	1.0770098	0.0769878	209.3252	264.975	203.3908	338.2627
3400	1.0769504	0.0000269	281.7242	32.298	28.5011	20671.895	1.0769504	0.0769215	222.3955	264.747	296.6173	432.1102
3600	1.0768891	0.0000139	85.3063	303.470	28.5006	20684.965	1.0768891	0.0768677	235.4646	264.562	217.5024	349.8189
3800	1.0768235	0.0000225	23.4930	214.639	28.4997	20698.033	1.0768235	0.0767993	248.5327	264.326	46.0813	175.9445
4000	1.0767413	0.0000117	192.0922	125.794	28.4998	20711.099	1.0767413	0.0767288	261.5993	264.083	326.9231	460.7963
4200	1.0766503	0.0000201	40.4409	36.935	28.5006	20724.164	1.0766503	0.0766287	274.6644	263.739	226.0641	360.5048
4400	1.0765481	0.0000082	5.8764	308.065	28.5004	20737.228	1.0765481	0.0765393	287.7277	263.431	356.4040	490.2700
4600	1.0764355	0.0000045	335.6605	219.172	28.4998	20750.289	1.0764355	0.0764307	300.7890	263.057	122.7676	258.9931
4800	1.0763246	0.0000130	248.9811	130.261	28.4999	20763.348	1.0763246	0.0763106	313.8483	262.644	326.8083	443.6966
5000	1.0762159	0.0000133	335.8093	41.332	28.5010	20776.405	1.0762169	0.0762026	326.9056	262.272	336.1621	472.0182
5200	1.0761126	0.0000152	192.3738	312.390	28.5012	20789.461	1.0761126	0.0760962	339.9609	261.906	215.4406	352.0209

TABLE VII. - Continued.

5400	1.0760179	0.0000174	302.7819	223.428	28.4994	20802.514	1.0760179	0.0759992	353.0144	261.572	202.7597	325.3464
5600	1.0759401	0.0000195	277.0713	134.449	28.5000	20915.586	1.0759401	0.0759190	366.0664	261.296	0.2931	125.5494
5800	1.0758609	0.0000301	300.7616	45.460	28.5013	20828.617	1.0758609	0.0758284	379.1169	260.985	60.8759	197.4053
6000	1.0757801	0.0000238	354.3171	316.460	28.5015	20941.666	1.0757801	0.0757545	392.1660	260.730	100.5449	234.1669
6200	1.0757019	0.0000176	21.3746	227.445	28.4994	20854.714	1.0757019	0.0756829	405.2136	260.484	194.0687	312.8036
6400	1.0756229	0.0000128	160.8356	138.413	28.4995	20867.760	1.0756229	0.0756091	418.2598	260.230	149.4048	286.1401
6600	1.0755400	0.0000034	35.3044	49.371	28.5005	20880.804	1.0755400	0.0755310	431.3045	259.961	325.9984	460.0390
6800	1.0754450	0.0000130	38.9034	320.315	28.5006	20893.848	1.0754450	0.0754310	444.3476	259.617	107.7480	242.2915
7000	1.0753503	0.0000248	31.5950	231.243	28.4997	20906.889	1.0753503	0.0753237	457.3889	259.248	161.4032	296.7837
7200	1.0752575	0.0000197	305.6519	142.153	28.4990	20919.929	1.0752575	0.0752364	470.4285	258.947	43.9528	171.8520
7400	1.0751643	0.0000150	2.4659	53.047	28.5001	20932.966	1.0751643	0.0751482	483.4664	258.643	100.5318	234.1926
7600	1.0750737	0.0000149	243.1422	323.929	28.5001	20946.003	1.0750738	0.0750577	496.5026	258.332	291.6813	427.7891
7800	1.0749959	0.0000201	140.1060	234.796	28.4995	20959.037	1.0749959	0.0749743	509.5373	258.045	146.8216	280.8043
8000	1.0749299	0.0000157	77.8552	45.649	28.4986	20972.071	1.0749298	0.0749129	522.5707	257.834	340.9555	452.5743
8200	1.0748594	0.0000153	3.7564	56.490	28.4999	20985.103	1.0748594	0.0748429	535.6029	257.593	144.4802	281.0627
8400	1.0747953	0.0000193	43.1530	327.324	28.5002	20998.136	1.0747953	0.0747757	548.6337	257.361	190.7450	327.7315
8600	1.0747414	0.0000142	228.5435	236.146	28.4988	21011.164	1.0747414	0.0747262	561.6636	257.191	114.2419	233.5387
8800	1.0746899	0.0000036	230.8271	148.957	28.4991	21024.192	1.0746899	0.0746861	574.6924	257.053	232.9693	364.0989
9000	1.0746340	0.0000046	44.7128	57.760	28.4996	21037.220	1.0746340	0.0746290	587.7203	256.857	146.4892	282.5103
9200	1.0745832	0.0000026	130.1912	130.557	28.5002	21050.247	1.0745832	0.0745804	600.7473	256.689	156.3171	292.5845
9400	1.0745337	0.0000011	129.7586	241.345	28.4989	21063.273	1.0745337	0.0745326	613.7733	256.525	270.8318	397.6873
9600	1.0744673	0.0000104	51.1753	152.120	28.4994	21076.298	1.0744673	0.0744560	626.7983	256.261	81.5510	218.1476
9800	1.0743966	0.0000044	183.2083	62.896	28.4997	21089.322	1.0743966	0.0743897	639.8220	256.033	53.5521	185.5084
10000	1.0743213	0.0000013	46.3659	333.641	28.5004	21102.344	1.0743213	0.0743193	652.8443	255.790	289.2856	425.3446
10200	1.0742230	0.0000190	162.7949	244.382	28.4993	21115.365	1.0742230	0.0742123	665.8650	255.422	273.0013	410.0386
10400	1.0741365	0.0000160	263.2748	155.103	28.4998	21128.384	1.0741365	0.0741193	678.8841	255.102	277.3634	398.1039
10600	1.0740600	0.0000217	196.7049	65.813	28.5002	21141.402	1.0740600	0.0740367	691.9017	254.818	108.2203	241.9413
10900	1.0739886	0.0000210	152.9042	336.512	28.5005	21154.418	1.0739886	0.0739660	704.9179	254.575	232.2705	369.2226
11000	1.0739195	0.0000180	232.0389	247.201	28.4990	21167.433	1.0739195	0.0739002	717.9329	254.348	246.0461	376.9224
11200	1.0738615	0.0000244	291.1999	15..873	28.4985	21180.447	1.0738615	0.0738332	730.9467	254.117	324.0462	460.6177

TABLE VII. - Continued.

11400	1.0739014	0.0000324	246.8590	69.539	28.5002	21193.459	1.0738014	0.0737666	743.9594	253.488	93.3409	270.6019
11600	1.0737393	0.0000366	10.2125	339.197	28.5003	21206.471	1.0737383	0.0736990	756.9710	253.656	64.6182	281.8481
11800	1.0736733	0.0000396	134.9040	249.842	28.4996	21219.481	1.0736738	0.0736324	769.9814	253.426	49.0730	170.5254
12000	1.0736053	0.0000323	133.7335	160.476	28.4996	21232.491	1.0736053	0.0735707	782.9907	253.214	157.2023	297.3261
12200	1.0735297	0.0000302	133.7339	71.037	28.5004	21245.499	1.0735297	0.0734972	795.9986	252.951	254.2473	387.9678
12400	1.0734440	0.0000133	7.0007	341.708	28.5008	21258.505	1.0734440	0.0734233	809.0050	252.707	118.0906	254.9652
12600	1.0733566	0.0000158	310.7296	252.302	28.4996	21271.510	1.0733566	0.0733396	822.0099	252.419	281.3862	415.5179
12800	1.0732446	0.0000146	86.0421	162.891	28.4995	21284.513	1.0732664	0.0732487	835.0131	252.106	238.6956	371.2669
13000	1.0731749	0.0000192	21.6477	73.443	28.4996	21297.515	1.0731749	0.0731543	848.0147	251.781	62.6818	193.0348
13200	1.0730779	0.0000165	343.8935	343.993	28.5005	21310.515	1.0730779	0.0730602	861.0145	251.457	190.5807	327.5979
13400	1.0729929	0.0000216	262.4651	254.526	28.4992	21323.513	1.0729929	0.0729697	874.0127	251.146	5.7952	142.5117
13600	1.0729138	0.0000271	302.2034	165.043	28.4986	21336.509	1.0729138	0.0728847	887.0094	250.853	88.2863	198.2346
13800	1.0728311	0.0000195	0.5905	75.548	28.4996	21349.505	1.0728311	0.0728101	900.0046	250.596	131.4299	267.1872
14000	1.0727520	0.0000045	287.0304	346.041	28.5001	21362.498	1.0727520	0.0727450	912.9983	250.372	295.1850	432.6655
14200	1.0726761	0.0000016	14.5691	256.521	28.4987	21375.491	1.0726761	0.0726744	925.9906	250.129	303.5505	430.5163
14400	1.0725945	0.0000011	233.9563	166.984	28.4979	21388.481	1.0725945	0.0725934	938.9815	249.850	213.5846	340.2213
14600	1.0725174	0.0000000	349.2684	77.435	28.4998	21401.471	1.0725174	0.0725174	951.9709	249.589	183.5208	320.6118
14800	1.0724265	0.0000090	242.3040	347.875	28.5002	21414.459	1.0724265	0.0724179	964.9588	249.246	27.8243	164.6275
15000	1.0723315	0.0000000	158.0469	258.300	28.4990	21427.445	1.0723316	0.0723316	977.9451	248.949	220.4119	347.6300
15200	1.0722108	0.0000021	75.5072	168.703	28.4981	21440.429	1.0722108	0.0722085	990.9294	248.526	41.2532	178.9573
15400	1.0720543	0.0000152	308.6075	79.084	28.4990	21453.411	1.0720549	0.0720386	1003.9111	247.941	274.5028	405.5671
15600	1.0718777	0.0000131	352.7750	349.441	28.4998	21466.390	1.0718777	0.0718636	1016.8898	247.259	326.3186	463.8532
15800	1.0716599	0.0000119	144.3935	259.765	28.4989	21479.365	1.0716599	0.0716572	1029.8650	246.628	276.2421	413.3785
16000	1.0714369	0.0000406	324.8419	170.051	28.4978	21492.336	1.0714368	0.0713936	1042.8361	245.721	193.7982	320.1979
16200	1.0712059	0.0000421	136.9811	80.295	28.4998	21505.303	1.0712059	0.0711607	1055.8031	244.919	84.5410	216.1089
16400	1.0709703	0.0000295	329.4523	350.506	28.4999	21518.266	1.0709703	0.0709397	1068.7657	244.159	40.8496	178.6593
16600	1.0707300	0.0000391	64.9908	260.675	28.4989	21531.224	1.0707300	0.0706892	1081.7241	243.296	38.0666	172.8856
16800	1.0705070	0.0000454	295.4426	170.803	28.4995	21544.178	1.0705070	0.0704584	1094.6781	242.502	312.6428	425.0674
17000	1.0702733	0.0000736	260.4678	80.894	28.4991	21557.128	1.0702733	0.0701891	1107.6281	241.575	67.3415	205.3524
17200	1.0700214	0.0000297	90.8782	350.946	28.5000	21570.074	1.0700214	0.0699896	1120.5737	240.889	331.4843	469.7843

TABLE VII. - Continued.

17400	1.0697462	0.0000235	272.9349	260.954	28.4988	21583.014	1.0697462	0.0697211	1133.5144	239.965	253.2710	378.8528
17600	1.0694456	0.0001458	17.3322	170.909	28.4992	21595.950	1.0694456	0.0693966	1146.4499	238.848	263.2446	399.1061
17800	1.0690950	0.0000590	212.2029	90.814	28.4996	21608.880	1.0690950	0.0690212	1159.3795	237.556	162.7393	298.0772
18000	1.0686886	0.0000531	347.9448	350.657	28.5006	21621.802	1.0686886	0.0686318	1172.3022	236.216	126.4331	265.0108
18200	1.0682392	0.0000320	25.9973	260.413	28.4995	21634.717	1.0682392	0.0682050	1185.2171	234.747	195.4128	330.1695
18400	1.0677467	0.0000762	280.8804	170.117	28.4988	21647.623	1.0677467	0.0676654	1198.1234	232.889	33.6076	169.5458
18600	1.0672348	0.0000540	290.7876	79.722	28.5002	21660.521	1.0672348	0.0671772	1211.0206	231.209	144.1813	275.0764
18800	1.0666889	0.0000169	115.6337	349.242	28.5008	21673.408	1.0666889	0.0666708	1223.9081	229.466	50.6967	189.6527
19000	1.0661647	0.0000076	346.4756	258.669	28.5002	21686.286	1.0661647	0.0661566	1236.7859	227.696	275.2685	414.3387
19200	1.0656258	0.0000000	193.1719	168.004	28.4983	21699.154	1.0656258	0.0656258	1249.6540	225.869	180.8219	295.6025
19400	1.0650236	0.0000000	63.5445	77.237	28.5003	21712.012	1.0650236	0.0650236	1262.5116	223.797	83.7312	221.3542
19600	1.0643736	0.0000202	124.6482	346.373	28.5007	21724.858	1.0643736	0.0643521	1275.3580	221.486	93.3755	233.2275
19800	1.0636745	0.0000495	338.0341	255.392	28.4997	21737.692	1.0636745	0.0636230	1288.1920	218.976	336.0869	466.6952
20000	1.0629844	0.0000345	271.0295	164.289	28.4995	21750.514	1.0629844	0.0628840	1301.0135	216.433	174.9243	304.5634
20200	1.0621841	0.0000720	107.5090	73.061	28.5006	21763.322	1.0621841	0.0621077	1313.8216	213.761	65.0448	205.2148
20400	1.0612761	0.0000077	62.7489	341.693	28.5011	21776.114	1.0612761	0.0612679	1326.6142	210.870	207.4981	348.2251
20600	1.0602119	0.0000561	212.7196	250.156	28.4994	21788.889	1.0602119	0.0601523	1339.3891	207.031	169.9942	300.4687
20800	1.0587730	0.0002078	322.4392	158.410	28.4997	21801.642	1.0587730	0.0585530	1352.1415	201.525	159.0316	300.6385
21000	1.0568342	0.0001483	29.7532	66.380	28.5002	21814.364	1.0568342	0.0566775	1364.8635	195.071	199.5748	337.2981
21200	1.0540191	0.0000700	319.7540	333.962	28.5010	21827.044	1.0540192	0.0539454	1377.5435	185.668	6.7068	148.9577
21400	1.0496637	0.0000057	144.1602	240.952	28.4993	21839.660	1.0496637	0.0496567	1390.1601	170.907	286.6842	431.0194
21600	1.0406830	0.0000261	84.5286	146.910	28.4991	21852.165	1.0406830	0.0406558	1402.6646	139.928	90.6462	227.7240
21681	1.0303660	0.0010053	251.2152	90.525	28.4956	21857.151	1.0303671	0.0293312	1407.6511	100.952	0.2674	145.7583
21682	1.0298800	0.0009559	252.3388	90.040	28.4957	21857.212	1.0298810	0.0288965	1407.7122	99.455	359.4269	505.2705
21683	1.0293444	0.0009037	253.1653	89.554	28.4957	21857.273	1.0293453	0.0284151	1407.7733	97.798	359.0151	505.2460
21684	1.0287441	0.0008478	253.5299	89.068	28.4957	21857.334	1.0287468	0.0278746	1407.8343	95.938	359.0457	505.6998
21685	1.0280653	0.0007872	253.1522	88.581	28.4957	21857.395	1.0280659	0.0272566	1407.8953	93.811	359.7934	506.9182
21686	1.0272704	0.0007203	251.5443	88.093	28.4957	21857.456	1.0272710	0.0265310	1407.9562	91.314	1.7362	149.3987
21687	1.0263055	0.0006447	247.9696	87.605	28.4957	21857.517	1.0263059	0.0256443	1408.0170	88.262	5.5957	153.8984
21688	1.0250526	0.0005571	243.8146	97.116	28.4957	21857.578	1.0250530	0.0244819	1408.0777	84.261	9.9466	159.0724

TABLE VII. - Concluded.

```
21689 1.0232099 0.0004   0  23.7835   86.626  28.4957 21857.638 1.0232101 0.0227599 1408.1383   78.335 230.2177 380.5955
21690 1.0180062 0.0015797  38.2330   96.133  28.4957 21857.699 1.0180098 0.0163813 1408.1985   56.381 214.8902 368.9126
                21690  SATELLITE IS DOWN                                 21857.75778   1.0000000   0.0000000END OF RUN NUMBER    3

        LIFETIME IS    1409.2578 DAYS
LINEAR DECAY RATE =    5.4774374204551066E-02 NMI/DAY (TO 200 NMI)
```

TABLE VIII. - SAMPLE CASE 4 INPUT FILE

```
     4                                  2     3                                  2
ORBITAL LIFETIME  CASE 4
SAME AS CASE 3 WITH NOMINAL SOLAR FLUX
      1999999      2    40    10   200    71     1    50     1    54     0
      5     5     20   200    22  1000
  531 0.1543          532 0.1365          539 0.0
  541 28.5           1111 0.             1121 500.0393      1122 500.0393
 1116 1.             1117 1.             1120 1.            1115 1997.
```

TABLE IX. - SAMPLE CASE 4 OUTPUT FILE

```
     1999999.      2     40     10    200     71      1     50      1     54      0
     5       5     20    200     22   1000      0      0      0      0      0      0
 531 0.1543000E+00 532 0.1365000E+00 539 0.0000000E+00   0 0.0000000E+00
 541 0.2950000E+021111 0.0000000E+001121 0.5000393E+031122 0.5000393E+03
1116 0.1000000E+011117 0.1000000E+011120 0.1000000E+011115 0.1997000E+04

 JULIAN DATE= 2450449.500012   1997.   1. 1.GMT= 0. 0. 1.

ORBITAL LIFETIME  CASE 4
SAME AS CASE 3 WITH NOMINAL SOLAR FLUX

NUR=      4  NK=      2  NC=      3  NH=      2

RAM=    0.154300   DAM=    0.136500
  XP=  1.07339986      XE=  0.00000001 XOMEGD=    0.000000 XASCND=  100.251208 XOINCD=   28.500000   XDAY=14246.500012
PSID=  2.3444+1E+01    OM=  6.363000E+00   GM=  3.986300E+20   RE=  6.378145E+08   OS=  1.720290E-02 RADP=  4.500000E-05
```

TABLE IX. - Continued.

```
  J          P              E          OMEGAD     ASCND      OINCO       M.J.D.          A          MTPER          DAY          ALT.          V1O          V.O
  0 1.0783999 0.0000000     0.0000   100.251   28.5000 20449.500 1.0783989 0.0783988     0.0000   269.831 305.9466 43 .1543
    6.8781842 0.000E+000.0657040    0.0000    0.0000   280.6133    0.0000    0.0000     0.0000    0.0000    0.0000    0.0000
          D(P)          D(E)       D(OMEGAD)      D(ASCND)       D(OINCO)          D(A)      D(LOG(PERIOD))      D(MTPER)
 RADPR    0.0000E+00    0.0000E+00   0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0060E+00
DRAG      0.0000E+00    0.0000E+00   0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
EARTH     0.0000E+00    0.0000E+00   0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
MOON      0.0000E+00    0.0000E+00   0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
SUN       0.0000E+00    0.0000E+00   0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00

FLUX DATA FROM THE  6/1995 MSFC MEMO EXTENDS FROM  1/1984 TO 11/1998
JD= 2450449.491 12/31/1996 FLUX INTERPOLATED BETWEEN 156 AND  157 AS     79.90
                                    AP =    12.70
        CYCLE REPEATED FOR DATES AFTER END OF FLUX DATA
  200 1.0783509 0.0000036 315.5449   11.670   28.5008 20462.596 1.0783509 0.0783470    13.0957   269.653   77.1502 212.9224
    6.8776533-2.628E-070.0656996    0.0000    0.0000   291.2827    0.0000    0.0000     0.0000    0.0000    0.0000    0.0000
          D(P)          D(E)       D(OMEGAD)      D(ASCND)       D(OINCO)          D(A)      D(LOG(PERIOD))      D(MTPER)
 RADPR   -3.2928E-13    4.3596E-08   -8.7282E-01    1.9657E-07    1.4170E-08    1.0269E-14    1.4284E-14   -4.7012E-08
DRAG     -2.6290E-07   -1.8660E-09    2.9123E-01    0.0000E+00    0.0000E+00   -2.6280E-07   -3.6556E-07   -2.6078E-07
EARTH     0.0000E+00    0.0000E+00   -4.6017E+02   -4.4290E-01   -2.3525E-10    0.0000E+00    0.0000E+00    0.0000E+00
MOON      3.4302E-19   -2.2513E-13   -6.7806E-05   -2.1699E-05    4.5582E-06   -8.1040E-19   -1.1273E-18    2.4276E-13
SUN       6.8535E-19   -1.6361E-12   -6.0129E-06   -3.4268E-06    7.8251E-07   -5.8896E-18   -8.1925E-18    1.7643E-12

  400 1.0783096 0.0000047  80.2522  283.085   28.5002 20475.691 1.0783086 0.0783035    26.1907   269.503   46.5842 176.4205
    6.8775760-2.471E-070.0656958    0.0000    0.0000   304.6153    0.0000    0.0000     0.0000    0.0000    0.0000    0.0000
          D(P)          D(E)       D(OMEGAD)      D(ASCND)       D(OINCO)          D(A)      D(LOG(PERIOD))      D(MTPER)
 RADPR   -5.1167E-13    4.1353E-08    5.3361E-01   -7.1746E-08    2.8734E-07   -9.2990E-14   -1.2935E-13   -4.4591E-08
DRAG     -2.4709E-07   -2.4815E-09   -1.0708E+00    0.0000E+00    0.0000E+00   -2.4709E-07   -3.4373E-07   -2.4442E-07
EARTH     0.0000E+00    0.0000E+00   -2.5046E+02   -4.4294E-01   -6.5419E-10    0.0000E+00    0.0000E+00    0.0000E+00
MOON     -2.6680E-17    3.9403E-12    2.5727E-05   -2.7558E-06   -9.7355E-06    1.3214E-17    1.8382E-17   -4.2489E-12
SUN      -1.1953E-17    1.7505E-12   -1.0766E-05    5.3087E-06   -2.8077E-06    5.8706E-18    8.1664E-18   -1.8876E-12

  600 1.0782730 0.0000064  29.7282  194.487   28.4990 20488.785 1.0782730 0.0782661    39.2849   269.375  223.6323 347.4732
    6.8773375-1.644E-070.0655925    0.0000    0.0000   317.9097    0.0000    0.0000     0.0000    0.0000    0.0000    0.0000
          D(P)          D(E)       D(OMEGAD)      D(ASCND)       D(OINCO)          D(A)      D(LOG(PERIOD))      D(MTPER)
 RADPR    7.6369E-13   -2.9741E-08   -2.7209E-01    1.1214E-06   -2.0223E-07    3.5191E-13    4.8954E-13    3.2069E-08
DRAG     -1.6445E-07    3.6437E-08    2.3283E-01    0.0000E+00    0.0000E+00   -1.6445E-07   -2.2876E-07   -2.0373E-07
EARTH     0.0000E+00    0.0000E+00   -1.0662E+02   -4.4298E-01    6.9647E-10    0.0000E+00    0.0000E+00    0.0000E+00
MOON     -7.0383E-17    5.3043E-12   -4.1875E-07   -4.6493E-05    1.8410E-06    3.0679E-18    4.2678E-18   -5.7201E-12
SUN      -3.9030E-17    2.9418E-12    7.6440E-06   -1.4196E-05   -2.9857E-06    1.7013E-18    2.3666E-18   -3.1720E-12

  800 1.0782340 0.0000048 244.9791  105.885   28.5002 20501.879 1.0782340 0.0782288    52.3785   269.246   94.8097 230.1598
    6.8770338-1.740E-070.0656889    0.0000    0.0000   331.1455    0.0000    0.0000     0.0000    0.0000    0.0000    0.0000
          D(P)          D(E)       D(OMEGAD)      D(ASCND)       D(OINCO)          D(A)      D(LOG(PERIOD))      D(MTPER)
 RADPR    7.3408E-13   -4.2634E-08   -3.9184E-01    2.7254E-08    2.3111E-08    2.8903E-13    4.0208E-13    4.5969E-08
DRAG     -1.7401E-07    5.2943E-08    8.6748E-02    0.0000E+00    0.0000E+00   -1.7401E-07   -2.4208E-07   -2.3099E-07
EARTH     0.0000E+00    0.0000E+00   -8.5669E+01   -4.4300E-01   -1.2373E-09    0.0000E+00    0.0000E+00    0.0000E+00
MOON     -2.5545E-17    2.6727E-12   -5.7639E-05    1.9827E-06    7.5346E-06    2.3547E-18    3.2758E-18   -2.8818E-12
SUN      -2.6773E-17    2.8012E-12   -5.0111E-06    8.1741E-08   -3.6818E-07    2.4679E-18    3.4333E-18   -3.0203E-12

 1000 1.0781910 0.0000009  97.6657   17.279   28.5007 20514.971 1.0781910 0.0781900    65.4713   269.113  353.4307 488.9560
    6.8768522-2.707E-070.0654850    0.0000    0.0000   344.3060    0.0000    0.0000     0.0000    0.0000    0.0000    0.0000
          D(P)          D(E)       D(OMEGAD)      D(ASCND)       D(OINCO)          D(A)      D(LOG(PERIOD))      D(MTPER)
 RADPR    4.5964E-16   -1.1976E-08   -2.9176E+02    3.7638E-07   -1.4743E-07   -2.2293E-14   -3.1015E-14    1.2912E-08
DRAG     -2.7069E-07    3.3762E-08   -9.0374E+02    0.0000E+00    0.0000E+00   -2.7069E-07   -3.7659E-07   -3.0709E-07
EARTH     0.0000E+00    0.0000E+00    5.0378E+04   -4.4303E-01   -1.6869E-12    0.0000E+00    0.0000E+00    0.0000E+00
MOON     -2.6451E-22    1.2266E-14   -4.5375E-05   -1.4931E-05   -2.0376E-06    2.3050E-20    3.2068E-20   -1.3225E-14
SUN      -8.1422E-23    3.7753E-15    5.1583E-05   -2.0307E-06   -7.2832E-07    7.0955E-21    9.8713E-21   -4.0711E-15
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TABLE IX. - Continued.

1200	1.0781381	0.0000027	147.6432	298.665	28.5004	20529.063	1.0781381	0.0781352	78.5632	268.924	33.3651	163.5403
1400	1.0780840	0.0000016	315.9501	200.040	28.4990	20541.154	1.0780840	0.0780823	91.6542	268.742	324.7947	460.9002
1600	1.0780277	0.0000022	84.0519	111.403	28.4991	20554.244	1.0780277	0.0780254	104.7441	268.546	304.1643	427.9663
1800	1.0779739	0.0000095	88.7941	22.760	28.4999	20567.333	1.0779739	0.0779637	117.8330	268.334	39.2963	175.1216
2000	1.0779257	0.0000080	75.9876	294.110	28.4999	20580.421	1.0779257	0.0779171	130.9210	268.173	147.5952	283.1599
2200	1.0778867	0.0000043	352.4836	205.452	28.4988	20593.508	1.0778867	0.0778814	144.0082	268.050	324.6555	451.3317
2400	1.0778473	0.0000007	109.3626	116.783	28.4990	20606.595	1.0778473	0.0778465	157.0947	267.930	340.6605	462.2990
2600	1.0779194	0.0000047	272.6692	28.114	28.5003	20619.681	1.0778194	0.0778143	170.1805	267.819	260.0906	396.2682
2800	1.0777849	0.0000078	70.3863	299.439	28.5000	20632.766	1.0777849	0.0777765	183.2658	267.690	193.9243	329.1999
3000	1.0777566	0.0000061	40.8397	210.759	28.4990	20645.851	1.0777566	0.0777500	196.3505	267.598	343.4179	452.6694
3200	1.0777220	0.0000038	83.3086	122.068	28.4994	20658.935	1.0777220	0.0777179	209.4347	267.488	42.3631	176.9545
3400	1.0776930	0.0000025	342.4190	33.377	28.5008	20672.018	1.0776930	0.0776903	222.5182	267.393	235.0955	370.3572
3600	1.0776617	0.0000013	7.5640	304.683	28.5003	20685.101	1.0776617	0.0776603	235.6013	267.289	304.2494	436.5402
3800	1.0776281	0.0000000	190.8479	215.980	28.4997	20698.184	1.0776281	0.0776281	248.6837	267.179	237.6315	367.0632
4000	1.0775930	0.0000024	296.9166	127.271	28.4994	20711.265	1.0775830	0.0775804	261.7654	267.015	220.8193	354.5649
4200	1.0775453	0.0000050	323.5495	38.555	28.5001	20724.346	1.0775453	0.0775399	274.8463	266.875	301.8194	435.9146
4400	1.0774903	0.0000022	277.9430	309.836	28.5001	20737.427	1.0774903	0.0774880	287.9265	266.697	82.7962	216.4967
4600	1.0774446	0.0000017	267.1475	221.103	28.4994	20750.506	1.0774446	0.0 74428	301.0057	266.541	189.8531	325.8759
4800	1.0773951	0.0000095	31.3323	132.362	28.4994	20763.584	1.0773951	0.0773860	314.0839	266.345	182.2184	298.5222
5000	1.0773474	0.0000057	339.9196	43.614	28.5008	20776.661	1.0773474	0.0773413	327.1614	266.191	333.6025	469.0030
5200	1.0772933	0.0000036	76.6107	314.862	28.5011	20789.738	1.0772933	0.0772894	340.2379	266.013	329.4005	465.6380
5400	1.0772456	0.0000062	151.2583	226.100	28.4996	20802.813	1.0772456	0.0772389	353.3134	265.839	351.5937	474.6257
5600	1.0772104	0.0000069	252.4220	137.327	28.4996	20815.888	1.0772104	0.0772030	366.3882	265.716	23.0411	146.9699
5800	1.0771746	0.0000060	20.0185	48.551	28.5007	20828.962	1.0771746	0.0771682	379.4623	265.596	339.2767	475.4848
6000	1.0771313	0.0000054	128.4531	319.770	28.5010	20842.036	1.0771313	0.0771255	392.5358	265.449	324.6322	460.1279
6200	1.0770935	0.0000093	11.3046	230.981	28.4990	20855.108	1.0770935	0.0770835	405.6084	265.304	208.1841	318.4230
6400	1.0770586	0.0000084	165.4413	142.193	28.4994	20868.180	1.0770586	0.0770495	418.6805	265.187	142.0129	278.3044
6600	1.0770125	0.0000000	74.2548	53.381	28.5006	20881.252	1.0770125	0.0770125	431.7518	265.060	333.7237	467.0510
6800	1.0769667	0.0000000	204.3822	324.573	28.5008	20894.322	1.0769667	0.0769667	444.8222	264.902	298.6820	433.2350
7000	1.0769306	0.0000024	354.4729	235.756	28.5000	20907.392	1.0769306	0.0769280	457.8919	264.769	254.9014	389.5602

TABLE IX. - Continued.

7200	1.0769753	0.0000047	13.8697	146.930	28.4990	20920.461	1.0768753	0.0768702	470.9607	264.570	330.7971	458.8554
7400	1.0768273	0.0000015	331.6759	58.096	28.5010	20933.529	1.0768273	0.0768257	484.0286	264.417	127.8975	260.2716
7600	1.0767917	0.0000026	313.5180	329.259	28.5011	20946.596	1.0767917	0.0767889	497.0957	264.290	236.9173	372.6325
7800	1.0767644	0.0000009	181.3020	240.415	28.5005	20959.662	1.0767644	0.0767634	510.1623	264.203	101.2092	235.3460
8000	1.0767325	0.0000000	124.6321	151.564	28.4996	20972.728	1.0767325	0.0767325	523.2283	264.096	288.0517	397.2331
8200	1.0766985	0.0000017	296.0551	62.707	28.5010	20985.794	1.0766985	0.0766966	536.2938	263.973	207.9568	343.7729
8400	1.0766647	0.0000016	67.4740	333.849	28.5015	20998.859	1.0766647	0.0766630	549.3586	263.857	167.6220	304.1160
8600	1.0766376	0.0000039	270.9211	244.985	28.5002	21011.923	1.0766376	0.0766334	562.4228	263.755	64.3475	185.3710
8800	1.0766070	0.0000022	229.2638	156.113	28.5001	21024.987	1.0766070	0.0766046	575.4866	263.656	229.4499	358.5235
9000	1.0765833	0.0000000	63.5920	67.237	28.5008	21038.050	1.0765833	0.0765833	588.5498	263.583	116.2714	251.8470
9200	1.0765534	0.0000066	157.0205	338.359	28.5016	21051.113	1.0765534	0.0765463	601.6125	263.455	113.5872	249.7619
9400	1.0765245	0.0000013	106.6836	249.476	28.5000	21064.175	1.0765245	0.0765232	614.6747	263.376	285.4339	411.4263
9600	1.0764859	0.0000023	35.3769	160.584	28.5004	21077.236	1.0764859	0.0764835	627.7363	263.239	90.4696	226.8198
9800	1.0764527	0.0000044	299.3310	71.689	28.5003	21090.297	1.0764527	0.0764480	640.7973	263.117	294.2383	424.4075
10000	1.0764080	0.0000050	6.2482	342.788	28.5014	21103.357	1.0764080	0.0764026	653.8575	262.961	321.8790	457.8746
10200	1.0763502	0.0000045	62.0729	253.979	28.5003	21116.417	1.0763502	0.0763453	666.9168	262.764	6.2662	142.5114
10400	1.0762951	0.0000071	31.2440	164.957	28.4997	21129.475	1.0762951	0.0762875	679.9750	262.565	137.9256	259.8759
10600	1.0762468	0.0000098	308.4554	76.028	28.5011	21142.532	1.0762468	0.0762374	693.0323	262.392	339.8088	471.0944
10800	1.0762017	0.0000111	144.5140	347.094	28.5019	21155.589	1.0762017	0.0761898	706.0887	262.228	232.2848	368.6523
11000	1.0761588	0.0000062	26.3745	258.153	28.5011	21168.644	1.0761588	0.0761521	719.1444	262.099	82.5821	214.8039
11200	1.0761244	0.0000078	323.0773	169.201	28.4995	21181.699	1.0761244	0.0761160	732.1993	261.975	281.7192	393.3477
11400	1.0760895	0.0000077	156.8800	80.245	28.5011	21194.754	1.0760895	0.0760813	745.2536	261.855	174.6761	311.2132
11600	1.0760510	0.0000033	34.5625	351.296	28.5014	21207.807	1.0760510	0.0760474	758.3072	261.738	31.3158	167.9617
11800	1.0760074	0.0000054	258.6802	262.319	28.5008	21220.860	1.0760074	0.0760014	771.3601	261.580	270.8131	394.3876
12000	1.0759727	0.0000069	214.9300	173.342	28.4996	21233.912	1.0759727	0.0759654	784.4122	261.456	66.4157	200.7201
12200	1.0759328	0.0000093	277.0340	84.359	28.5003	21246.964	1.0759328	0.0759231	797.4637	261.307	98.5456	231.4026
12400	1.0758826	0.0000000	122.6565	355.372	28.5013	21260.014	1.0758826	0.0758826	810.5144	261.171	351.9241	488.5979
12600	1.0758317	0.0000071	46.3046	266.375	28.5006	21273.064	1.0758317	0.0758241	823.5641	260.970	172.9587	305.7567
12800	1.0757857	0.0000018	251.7049	177.370	28.5004	21286.113	1.0757857	0.0757837	836.6129	260.831	59.6490	193.3429
13000	1.0757395	0.0000009	323.7635	88.355	28.5005	21299.161	1.0757395	0.0757385	849.6609	260.675	108.7124	234.7199

TABLE IX. - Continued.

13200	1.0756993	0.0000121	13.6358	359.338	28.5017	21312.208	1.0756993	0.0756863	862.7082	260.495	148.3125	284.9502
13400	1.0756581	0.0000099	150.2770	270.312	28.5005	21325.255	1.0756581	0.0756474	875.7547	260.362	105.9966	242.5827
13600	1.0756221	0.0000080	189.8027	181.279	28.4999	21338.300	1.0756221	0.0756134	888.8004	260.245	179.3969	290.6403
13800	1.0755898	0.0000033	92.6430	92.237	28.5006	21351.346	1.0755898	0.0755862	901.8455	260.151	28.3933	161.3150
14000	1.0755527	0.0000052	209.4930	3.194	28.5017	21364.390	1.0755527	0.0755471	914.8900	260.017	359.2681	495.8734
14200	1.0755190	0.0000029	27.5926	274.146	28.5007	21377.434	1.0755190	0.0755159	927.9339	259.909	273.9742	404.5064
14400	1.0754854	0.0000005	95.2025	185.087	28.5000	21390.477	1.0754854	0.0754849	940.9771	259.802	337.0059	457.6521
14600	1.0754481	0.0000024	184.1876	96.025	28.5016	21403.520	1.0754481	0.0754456	954.0197	259.667	333.2292	469.9015
14800	1.0754181	0.0000011	98.0593	6.959	28.5021	21416.562	1.0754181	0.0754170	967.0617	259.569	157.3549	293.9883
15000	1.0753704	0.0000018	336.0307	277.889	28.5012	21429.603	1.0753704	0.0753685	980.1029	259.402	21.1642	149.4314
15200	1.0753255	0.0000021	21.9063	188.805	28.5001	21442.643	1.0753255	0.0753232	993.1434	259.246	79.1087	215.5201
15400	1.0752739	0.0000059	9.8492	99.714	28.5009	21455.683	1.0752739	0.0752676	1006.1830	259.054	192.8796	321.7338
15600	1.0752170	0.0000081	3.0544	10.618	28.5017	21468.722	1.0752170	0.0752083	1019.2216	258.850	299.9443	436.7637
15800	1.0751511	0.0000028	86.7111	281.511	28.5012	21481.759	1.0751511	0.0751481	1032.2590	258.643	315.6646	451.1655
16000	1.0750779	0.0000033	203.6396	192.391	28.4999	21494.795	1.0750779	0.0750744	1045.2952	258.389	292.0327	421.9839
16200	1.0750137	0.0000036	43.3828	103.257	28.5001	21507.830	1.0750137	0.0750098	1058.3301	258.167	221.7805	345.8741
16400	1.0749566	0.0000055	310.4349	14.118	28.5017	21520.864	1.0749566	0.0749507	1071.3639	257.964	41.3963	178.3174
16600	1.0748979	0.0000092	76.9240	294.968	28.5010	21533.897	1.0748979	0.0748880	1084.3966	257.748	7.7686	143.7350
16800	1.0748456	0.0000139	87.1784	195.808	28.4997	21546.928	1.0748456	0.0748306	1097.4283	257.550	121.0386	229.0154
17000	1.0747947	0.0000144	19.7485	106.637	28.4995	21559.959	1.0747947	0.0747792	1110.4591	257.373	291.0698	426.4701
17200	1.0747397	0.0000157	302.9094	17.460	28.5013	21572.989	1.0747397	0.0747217	1123.4889	257.175	98.9916	235.5569
17400	1.0746751	0.0000153	154.3331	288.275	28.5004	21586.018	1.0746751	0.0746587	1136.5177	256.959	343.6625	474.2334
17600	1.0746121	0.0000189	103.9296	199.074	28.4999	21599.045	1.0746121	0.0745918	1149.5452	256.729	148.5354	278.8767
17800	1.0745387	0.0000033	110.1482	109.865	28.5000	21612.072	1.0745387	0.0745351	1162.5716	256.533	237.6902	372.3851
18000	1.0744618	0.0000033	299.6013	20.642	28.5006	21625.097	1.0744618	0.0744582	1175.5965	256.269	152.5423	288.9676
18200	1.0743812	0.0000094	78.2564	291.410	28.4999	21638.120	1.0743812	0.0743711	1188.6200	255.969	113.5289	246.5775
18400	1.0742949	0.0000216	343.0820	202.158	28.4994	21651.142	1.0742949	0.0742717	1201.6420	255.627	304.4328	441.0673
18600	1.0742125	0.0000257	49.9833	112.894	28.4993	21664.162	1.0742125	0.0741849	1214.6624	255.328	354.7441	476.2508
18800	1.0741262	0.0000124	326.8894	23.617	28.5006	21677.181	1.0741262	0.0741129	1227.6813	255.080	173.4558	310.4736
19000	1.0740468	0.0000151	27.4971	294.328	28.5004	21690.199	1.0740468	0.0740305	1240.6987	254.797	207.2347	344.3736

TABLE IX. - Continued.

19200	1.0739761	0.0000142	267.2708	205.023	28.4990	21703.215	1.0739761	0.0739609	1253.7147	254.557	66.7144	188.0991
19400	1.0739024	0.0000150	296.3743	115.705	28.4994	21716.229	1.0739024	0.0738863	1266.7294	254.300	165.8707	293.6615
19600	1.0738249	0.0000161	343.7760	26.378	28.5006	21729.243	1.0738249	0.0738076	1279.7427	254.029	202.9952	340.1217
19800	1.0737563	0.0000221	136.6507	297.039	28.5003	21742.255	1.0737563	0.0737326	1292.7547	253.771	142.3071	277.4293
20000	1.0736902	0.0000143	243.4790	207.697	28.4990	21755.265	1.0736902	0.0736749	1305.7654	253.573	161.5763	276.7991
20200	1.0736108	0.0000157	176.8828	118.321	28.4998	21768.275	1.0736108	0.0735939	1318.7749	253.294	320.2520	457.4488
20400	1.0735283	0.0000209	71.6390	28.945	28.5008	21781.283	1.0735283	0.0735058	1331.7828	252.991	162.8927	299.1519
20600	1.0734382	0.0000105	261.3020	299.555	28.5006	21794.289	1.0734382	0.0734269	1344.7892	252.719	69.7770	202.1249
20800	1.0733372	0.0000004	55.5757	210.148	28.4997	21807.294	1.0733372	0.0733368	1357.7938	252.409	26.0713	161.1864
21000	1.0732063	0.0000097	67.8532	120.719	28.4995	21820.296	1.0732063	0.0731959	1370.7964	251.924	109.0156	240.1297
21200	1.0730344	0.0000021	300.8525	31.270	28.5008	21833.296	1.0730344	0.0730321	1383.7962	251.360	343.5960	479.9080
21400	1.0728465	0.0000027	293.9456	301.792	28.5002	21846.293	1.0728465	0.0728436	1396.7927	250.711	97.3311	233.0695
21600	1.0726632	0.0000001	34.3747	212.280	28.4998	21859.286	1.0726632	0.0726631	1409.7858	250.090	80.0113	214.7302
21800	1.0725049	0.0000007	299.2414	122.736	28.4991	21872.276	1.0725049	0.0725041	1422.7757	249.543	304.7361	423.0507
22000	1.0723192	0.0000014	90.2217	33.166	28.5004	21885.262	1.0723192	0.0723177	1435.7624	248.901	243.7403	381.3455
22200	1.0721661	0.0000044	163.6069	303.571	28.4999	21898.246	1.0721661	0.0721614	1448.7462	248.364	263.7210	401.3092
22400	1.0720177	0.0000072	46.7502	213.946	28.4985	21911.227	1.0720177	0.0720099	1461.7271	247.842	131.1701	245.7791
22600	1.0718809	0.0000094	81.9712	124.297	28.4994	21924.206	1.0718809	0.0718709	1474.7055	247.364	212.8689	346.4763
22800	1.0717303	0.0000215	34.6971	34.626	28.5005	21937.181	1.0717303	0.0717072	1487.6813	246.800	349.4663	486.6916
23000	1.0715626	0.0000249	142.3196	304.930	28.5004	21950.154	1.0715626	0.0715359	1500.6542	246.211	336.7788	471.5148
23200	1.0713933	0.0000210	117.8108	215.203	28.4984	21963.124	1.0713933	0.0713708	1513.6240	245.642	123.1194	250.8454
23400	1.0712045	0.0000130	132.2530	125.445	28.4994	21976.091	1.0712045	0.0711907	1526.5905	245.022	198.3260	335.2732
23600	1.0709921	0.0000035	274.6970	35.656	28.5004	21989.053	1.0709921	0.0709883	1539.5534	244.326	162.2762	298.5080
23800	1.0707373	0.0000000	164.6444	305.830	28.5001	22002.012	1.0707373	0.0707373	1552.5120	243.462	9.4967	144.3620
24000	1.0705075	0.0000000	121.4658	215.959	28.4984	22014.966	1.0705075	0.0705075	1565.4661	242.671	152.3485	290.5200
24200	1.0702627	0.0000218	267.3446	125.046	28.4984	22027.916	1.0702627	0.0702394	1578.4159	241.749	117.7453	240.5562
24400	1.0700121	0.0000214	162.4938	36.095	28.5004	22040.861	1.0700121	0.0699892	1591.3612	240.887	325.4427	463.0012
24600	1.0697670	0.0000505	107.7938	306.105	28.4999	22053.802	1.0697670	0.0697130	1604.3020	239.937	114.2639	252.3851
24800	1.0695386	0.0000210	342.5978	216.072	28.4990	22066.738	1.0695386	0.0695162	1617.2385	239.259	334.7118	462.5143
25000	1.0693154	0.0000137	334.0207	125.999	28.4985	22079.671	1.0693154	0.0693007	1630.1709	238.518	117.2298	242.6221

TABLE IX. - Concluded.

25200	1.0691012	0.0000083	349.2524	35.989	28.5001	22092.599	1.0691012	0.0690923	1643.0991	237.800	186.4606	324.9946
25400	1.0688771	0.0000234	205.1346	305.747	28.4996	22105.524	1.0688771	0.0688521	1656.0235	236.974	63.4934	201.0254
25600	1.0686619	0.0000000	269.3798	215.563	28.4983	22118.444	1.0686619	0.0686629	1668.9439	236.319	121.3521	237.5927
25800	1.0684353	0.0000089	294.3872	125.343	28.4984	22131.360	1.0684353	0.0684258	1681.8604	235.506	194.7271	332.9756
26000	1.0681681	0.0000470	139.3967	35.081	28.4996	22144.272	1.0681681	0.0681178	1694.7723	234.446	86.2830	223.8732
26200	1.0678762	0.0000421	346.7087	304.776	28.4992	22157.179	1.0678762	0.0678313	1707.6791	233.460	335.3617	470.3013
26400	1.0675189	0.0000397	315.3494	214.412	28.4980	22170.080	1.0675189	0.0674766	1720.5802	232.239	120.0445	255.9071
26600	1.0670804	0.0000224	297.6709	123.984	28.4987	22182.974	1.0670804	0.0670566	1733.4739	230.794	231.8732	366.0262
26800	1.0665644	0.0000498	70.3621	33.478	28.4999	22195.959	1.0665644	0.0665112	1746.3590	228.917	208.6032	346.5511
27000	1.0659659	0.0000462	304.0111	302.880	28.4998	22208.734	1.0659659	0.0659167	1759.2339	226.871	72.4053	209.9782
27200	1.0652937	0.0001283	234.3944	212.172	28.4982	22221.597	1.0652937	0.0651563	1772.0972	224.254	236.5924	374.1255
27400	1.0646084	0.0002026	199.8469	121.344	28.4982	22234.448	1.0646084	0.0643927	1784.9482	221.626	49.6976	171.6891
27600	1.0638650	0.0001742	357.4088	30.400	28.4998	22247.286	1.0638850	0.0636997	1797.7863	219.240	334.5693	474.5939
27800	1.0631507	0.0001379	9.5373	299.333	28.4995	22260.111	1.0631507	0.0630041	1810.6112	216.846	56.9984	197.1722
29000	1.0624182	0.0001520	153.2947	208.139	28.4995	22272.923	1.0624182	0.0622567	1823.4226	214.274	19.2284	137.4922
29200	1.0616543	0.0001334	250.9294	116.812	28.4990	22285.721	1.0616543	0.0615127	1836.2207	211.713	45.4725	182.7536
29400	1.0607979	0.0001569	190.4864	25.354	28.5007	22298.504	1.0607979	0.0606336	1849.0041	208.687	206.9392	347.5219
29600	1.0598209	0.0001969	277.1044	293.739	28.4999	22311.271	1.0598210	0.0596123	1861.7709	205.172	206.7077	343.6934
29800	1.0587003	0.0002627	257.1986	201.944	28.4992	22324.019	1.0587003	0.0584221	1874.5187	201.076	351.7765	485.0963
29000	1.0572978	0.0002534	350.4027	109.935	28.4995	22336.744	1.0572979	0.0570300	1887.2439	196.285	349.6208	490.4433
29200	1.0555144	0.0002333	263.3405	17.658	28.5007	22349.440	1.0555145	0.0552682	1899.9404	190.221	182.5369	324.7427
29400	1.0531359	0.0000832	326.2962	295.032	28.4996	22362.100	1.0531356	0.0530479	1912.5996	182.579	222.7484	361.9305
29600	1.0497632	0.0000906	250.4135	191.919	28.4989	22374.708	1.0497632	0.0496683	1925.2077	170.947	37.9974	182.1914
29800	1.0441842	0.0000721	269.3958	98.079	28.4992	22387.238	1.0441842	0.0441089	1937.7385	151.813	136.9317	274.1182
30000	1.0189990	0.0000000	124.0100	2.652	28.5004	22399.577	1.0189990	0.0189990	1950.0774	65.390	16.6609	174.4781

30000 SATELLITE IS DOWN 22399.62770 1.0000000 0.0000000END OF RL NUMBER 4

LIFETIME IS 1950.1277 DAYS
LINEAR DECAY RATE = 3.8370411741069760E-02 NMI/DAY (TO 200 NMI)

TABLE X. - SAMPLE CASE 5 INPUT FILE

```
    5                                   1      4                                    2
ORBITAL LIFETIME  CASE 5
   ELLIPTICAL, POLAR ORBIT
      1 20000      2     50     10   1000     71      0     50      1     54      1
  531 0.21           532 0.21           539 40.
  541 90.          1111 120.          1121 600.          1122 900.
 1116 2.           1117 13.           1118 1.            1119 30.
 1120 25.          1115 1985.
```

TABLE XI. - SAMPLE CASE 5 OUTPUT FILE

```
     1 20000.      2     50     10   1000     71      0     50      1     54      1
  531 0.2100000E+00 532 0.2100000E+00 539 0.4000000E+02    0 0.0000000E+00
  541 0.9001000E+021111 0.1200000E+031121 0.6000000E+031122 0.9000000E+03
 1116 0.2300000E+011117 0.1300000E+021118 0.1000000E+011119 0.3000000E+02
 1120 0.2500000E+021115 0.1955000E+04    0 0.0000000E+00    0 0.0000000E+00

 JULIAN DATE= 2446109.562789    1985.    2.13.GMT= 1.30.25.

ORBITAL LIFETIME  CASE 5
   ELLIPTICAL, POLAR ORBIT

NUM=      5  MK=      1  NC=      4  NM=      2

RAM=    0.210000    DAM=    0.210000
  XP=  1.11703415     XE=  0.02104334 XOMEGD=   40.000000 XASCND=  295.365682 XOINCD=   90.000000   XDAY= 9906.062789
PSID=  2.3446415+01   DH=  6.363000E+00   GM=  3.986300E+20   RE=  6.378145E+08   DS=  1.720290E-02 RADP=  4.500000E-05
```

TABLE XI. - Concluded.

J	P	E	OMEGAO	ASCND	OINCD	M.J.D.	A	MTPER	DAY	ALT.	V1O	V2O
0	1.1170942	0.0210433	40.0000	285.366	90.0000	16109.563	1.1175890	0.0940712	0.0000	323.772	66.4993	173.5270

FLUX DATA FROM THE 6/1985 MSFC MEMO EXTENDS FROM 1/1984 TO 11/1998
JD= 2446109.563 2/13/1985 FLUX INTERPOLATED BETWEEN 13 AND 14 AS 73.75
AP = 16.00

CYCLE REPEATED FOR DATES AFTER END OF FLUX DATA

1000	1.1170719	0.0210377	161.9669	285.358	89.9980	16178.880	1.1175665	0.0940555	69.3171	323.718	-777.7777	-777.7777
2000	1.1170474	0.0209998	292.9131	285.352	90.0007	16248.194	1.1175402	0.0940721	138.6316	323.775	337.9380	466.1897
3000	1.1170207	0.0209957	59.6968	285.350	89.9978	16317.507	1.1175133	0.0940504	207.9438	323.701	257.0866	325.7737
4000	1.1169822	0.0209879	182.3303	285.320	89.9979	16386.816	1.1174731	0.0940532	277.2529	323.710	282.7549	375.3941
5000	1.1169460	0.0209800	314.1073	285.301	89.9990	16456.121	1.1174379	0.0939941	346.5586	323.507	145.0257	267.1198
6000	1.1169170	0.0209331	78.9587	285.269	89.9948	16525.424	1.1174066	0.0940158	415.8611	323.582	-777.7777	-777.7777
7000	1.1168905	0.0209388	202.8775	285.221	89.9967	16594.724	1.1173807	0.0939843	485.1609	323.472	70.1303	189.4634
8000	1.1168635	0.0209971	334.8368	285.184	89.9945	16664.021	1.1173514	0.0940021	554.4579	323.534	311.1483	423.3049
9000	1.1168436	0.0209034	98.1141	285.119	89.9909	16733.316	1.1173318	0.0939757	623.7529	323.444	-777.7777	-777.7777
10000	1.1168062	0.0208783	223.8025	285.052	89.9925	16802.608	1.1172932	0.0939660	693.0451	323.410	231.2693	359.4310
11000	1.1167873	0.0209336	355.1371	284.983	89.9884	16871.898	1.1172755	0.0939316	762.3348	323.292	-777.7777	-777.7777
12000	1.1167621	0.0208861	117.3589	284.884	89.9877	16941.185	1.1172495	0.0939146	831.6226	323.233	165.2786	266.8724
13000	1.1167455	0.0208578	244.6802	284.797	89.9881	17010.471	1.1172315	0.0939286	900.9080	323.281	31.6454	153.8134
14000	1.1167284	0.0208528	15.0820	284.684	89.9843	17079.755	1.1172142	0.0939172	970.1920	323.242	-777.7777	-777.7777
15000	1.1167043	0.0209214	136.6052	284.562	89.9855	17149.036	1.1171886	0.0939272	1039.4737	323.277	314.8887	440.7517
16000	1.1166834	0.0208364	265.7780	284.440	89.9837	17218.316	1.1171684	0.0938906	1108.7536	323.151	216.3104	307.0293
17000	1.1166603	0.0204011	34.5791	284.288	89.9820	17287.594	1.1171441	0.0939063	1178.0313	323.205	266.8538	326.5537
18000	1.1166369	0.0208245	156.1190	284.138	89.9832	17356.870	1.1171214	0.0938578	1247.3070	323.038	119.3720	244.0336
19000	1.1166143	0.0207779	286.6206	283.977	89.9790	17426.143	1.1170966	0.0938856	1316.5803	323.134	-777.7777	-777.7777
20000	1.1165753	0.0207727	53.0447	283.788	89.9787	17495.414	1.1170574	0.0938531	1385.8509	323.022	41.0708	151.9751

20000 END OF RUN NUMBER 5

APPENDIX A. OL PROGRAM ROUTINES

The FORTRAN program units in the OL program are:

PROGRAM LIFTIME: Main program. Opens files and calls the subroutines which contain the perturbation calculations.

SUBROUTINE SETUP: Initializes constants and sets defaults.

FUNCTION TLONG: Calculates true longitude of the Sun (used in Earth shadow calculations).

BLOCK DATA: Contains altitudes and densities from 1976 Standard Atmosphere below 90 km.

SUBROUTINE INPUT: Reads user's input file containing case-specific data and sets up initial values of case-specific program variables. Writes initial information to output file.

SUBROUTINE OUTPUT: Writes output file and plot file.

SUBROUTINE SHADOW: Calculates true anomalies on entering and leaving Earth's shadow (used in solar radiation pressure calculations).

SUBROUTINE RADPR: Calculates changes in orbital elements due to solar radiation pressure.

FUNCTION TDIST: Calculates distance from Earth to Sun (used in solar radiation pressure calculations).

SUBROUTINE EARTH: Calculates changes in orbital elements due to gravitational effects of Earth oblateness.

SUBROUTINE MOON: Calculates changes in orbital elements due to gravitational effects of the Moon.

SUBROUTINE SUN: Calculates changes in orbital elements due to gravitational effects of the Sun.

SUBROUTINE DRAG1: Calculates changes in orbital elements due to atmospheric drag.

FUNCTION RHA: Calculates atmospheric density (used in atmospheric drag calculations).

SUBROUTINE CHANGE: Sums all changes in orbital elements and calculates new orbit parameters.

SUBROUTINE JULCAL: Converts Julian date to calendar date.

SUBROUTINE CALJUL: Converts calendar date to Julian date.

SUBROUTINE FLUXIN: Reads solar flux and geomagnetic index predictions from flux file.

APPENDIX B. SOLAR FLUX DATA

Table B.1 is a copy of the flux data file created from the June 1985 update of solar flux and geomagnetic index data obtained from the NASA Marshall Space Flight Center (MSFC). The first line consists of seven numbers: the year and month the data begin (January 1984), the year and month the data end (November 1998), the year and month the data were updated by MSFC (June 1985), and the number of data points (179). Each of the remaining lines contains the year and month (day is assumed to be the 15th), followed by the $+2\sigma$ and nominal predictions of the 10.7 cm solar flux $\bar{F}_{10.7}$ and the $+2\sigma$ and nominal predictions of the geomagnetic index, A_p, respectively. In the table, for the dates January 1984 through May 1985, actual measured monthly means of $F_{10.7}$ and A_p appear. Because these are actual values and not predictions, there is no distinction between nominal and $+2\sigma$ values. The predictions begin for June 1985.

TABLE B.1. - FLUX DATA FILE

1984	1	1998	11	1985	6 179
1984	1	116.1	116.1	13.0	13.0
1984	2	140.6	140.6	17.0	17.0
1984	3	122.0	122.0	21.0	21.0
1984	4	128.7	128.7	25.0	25.0
1984	5	128.3	128.3	17.0	17.0
1984	6	100.3	100.3	15.0	15.0
1984	7	89.3	89.3	16.0	16.0
1984	8	83.7	83.7	16.0	16.0
1984	9	78.1	78.1	24.0	24.0
1984	10	73.5	73.5	23.0	23.0
1984	11	76.3	76.3	21.0	21.0
1984	12	75.9	75.9	17.0	17.0
1985	1	74.5	74.5	16.0	16.0
1985	2	73.7	73.7	16.0	16.0
1985	3	73.3	73.3	12.0	12.0
1985	4	75.1	75.1	23.8	23.8
1985	5	80.4	80.4	11.0	11.0
1985	6	89.0	77.0	18.7	16.6
1985	7	88.9	76.7	19.4	16.6
1985	8	90.4	76.3	19.9	16.4
1985	9	90.1	75.8	20.1	16.0
1985	10	89.0	75.1	20.2	15.6
1985	11	87.6	74.4	19.7	15.2
1985	12	88.5	73.9	19.1	14.9
1986	1	89.0	73.6	18.6	14.5
1986	2	88.6	73.3	18.1	14.1
1986	3	88.2	72.9	17.5	13.7
1986	4	87.2	72.5	17.0	13.4
1986	5	86.5	72.3	16.5	13.0
1986	6	86.3	72.0	16.0	12.7
1986	7	85.6	71.8	15.5	12.3
1986	8	84.3	71.5	15.1	12.0
1986	9	83.2	71.3	14.6	11.7
1986	10	82.8	71.1	14.2	11.4
1986	11	82.2	70.9	13.8	11.1
1986	12	81.1	70.6	13.4	10.8
1987	1	79.8	70.4	13.0	10.5
1987	2	79.2	70.2	12.7	10.3
1987	3	78.9	70.1	12.3	10.0
1987	4	78.9	64.9	12.0	9.8
1987	5	78.5	70.0	11.8	9.6
1987	6	77.9	70.0	11.5	9.5
1987	7	77.1	69.9	11.3	9.5
1987	8	76.6	69.9	11.2	9.2
1987	9	76.0	69.9	11.0	9.1
1987	10	75.3	69.9	10.9	9.0
1987	11	74.8	70.0	10.9	9.0
1987	12	75.1	70.2	10.9	9.0
1988	1	76.5	70.3	11.0	9.1

TABLE B.1. - Continued.

1988	2	77.6	70.4	11.3	9.4
1988	3	78.9	70.6	11.4	9.5
1988	4	81.0	71.1	11.4	9.4
1988	5	83.0	71.5	11.3	9.5
1988	6	85.6	70.0	11.0	9.7
1988	7	88.8	72.2	10.9	9.8
1988	8	92.0	73.3	11.1	9.9
1988	9	95.0	73.9	11.4	10.0
1988	10	99.3	74.8	12.0	10.2
1988	11	104.9	76.0	12.9	9.9
1988	12	110.4	73.3	13.5	10.2
1989	1	115.0	78.7	14.1	10.4
1989	2	120.0	80.2	14.8	10.5
1989	3	123.7	81.6	15.6	10.9
1989	4	126.8	83.0	16.3	10.6
1989	5	130.9	85.0	17.3	11.4
1989	6	135.8	87.2	18.2	11.5
1989	7	141.4	89.3	18.5	11.4
1989	8	148.2	91.7	18.6	11.6
1989	9	154.2	94.1	18.5	11.8
1989	10	158.1	96.3	18.2	11.8
1989	11	160.6	98.3	18.0	11.8
1989	12	162.2	100.1	18.3	11.7
1990	1	164.5	102.0	18.3	11.9
1990	2	167.4	103.8	17.5	12.1
1990	3	171.0	105.2	17.0	12.8
1990	4	175.0	106.8	17.3	12.8
1990	5	179.1	109.7	17.3	12.4
1990	6	183.1	112.5	18.4	12.5
1990	7	187.2	115.3	19.7	12.8
1990	8	191.2	118.1	19.8	12.9
1990	9	195.1	120.8	19.8	12.9
1990	10	199.0	123.5	19.9	13.0
1990	11	202.8	126.1	20.2	13.1
1990	12	206.5	128.7	20.6	12.7
1991	1	210.1	131.2	20.7	12.7
1991	2	213.6	133.6	20.8	12.6
1991	3	216.9	135.9	21.0	13.4
1991	4	220.1	138.2	21.4	13.5
1991	5	223.2	140.3	21.9	13.5
1991	6	226.1	142.3	22.0	12.9
1991	7	228.8	144.2	20.8	12.9
1991	8	231.3	145.9	19.9	12.7
1991	9	233.6	147.5	19.6	12.3
1991	10	235.6	149.0	19.2	12.0
1991	11	237.5	150.2	19.1	12.1
1991	12	239.1	151.3	18.9	12.2
1992	1	240.6	152.4	18.7	12.4
1992	2	241.6	153.1	18.5	12.5
1992	3	242.3	153.6	18.5	12.4

TABLE B.1. - Continued.

1992	4	242.7	153.9	18.2	12.5
1992	5	242.9	154.0	18.1	12.6
1992	6	239.0	152.5	18.6	12.7
1992	7	234.2	150.5	19.1	12.6
1992	8	230.8	148.8	19.5	12.9
1992	9	231.2	143.3	20.1	13.2
1992	10	230.7	141.7	20.8	13.3
1992	11	228.2	140.2	21.2	13.4
1992	12	226.2	138.3	21.0	13.9
1993	1	225.7	136.4	20.3	13.8
1993	2	224.5	134.5	20.5	14.1
1993	3	223.2	132.9	21.7	14.3
1993	4	219.9	126.9	22.5	13.9
1993	5	215.0	125.[illegible]	22.5	14.2
1993	6	211.4	124.5	22.1	14.2
1993	7	205.9	124.1	21.5	13.9
1993	8	200.8	123.5	21.3	13.7
1993	9	195.4	125.9	21.9	13.3
1993	10	189.9	124.9	22.9	13.5
1993	11	185.5	123.8	23.3	13.5
1993	12	180.8	122.7	23.2	13.5
1994	1	176.4	121.5	23.1	13.5
1994	2	176.7	117.2	22.9	13.1
1994	3	178.1	118.2	21.6	13.0
1994	4	177.6	116.7	20.1	13.8
1994	5	175.5	115.4	19.5	14.0
1994	6	171.4	116.8	19.6	13.7
1994	7	165.8	114.7	19.9	13.4
1994	8	161.9	112.7	20.3	13.5
1994	9	160.8	113.4	20.5	13.6
1994	10	159.9	109.5	20.8	13.6
1994	11	158.1	108.1	20.9	13.5
1994	12	155.6	104.2	21.4	14.2
1995	1	151.4	100.7	22.0	14.0
1995	2	145.9	99.7	21.8	13.3
1995	3	139.8	96.8	21.8	13.2
1995	4	133.8	97.8	22.0	13.0
1995	5	128.6	98.4	22.3	12.3
1995	6	126.3	98.7	22.6	12.1
1995	7	124.7	96.1	23.3	12.3
1995	8	122.2	93.6	24.0	12.2
1995	9	119.9	91.4	24.4	11.7
1995	10	118.4	90.7	24.7	11.7
1995	11	117.5	88.6	24.6	11.7
1995	12	117.5	87.5	24.2	12.2
1996	1	116.3	86.3	23.4	12.2
1996	2	116.5	86.3	22.6	12.7
1996	3	117.5	86.6	21.9	12.8
1996	4	117.9	87.2	21.6	12.2
1996	5	118.0	86.3	21.2	11.9

TABLE B.1. - Concluded.

1996	6	117.7	85.4	20.9	12.0
1996	7	116.8	83.0	20.3	12.1
1996	8	115.5	82.1	19.6	12.4
1996	9	113.5	82.6	19.6	12.5
1996	10	109.2	81.8	19.6	12.7
1996	11	103.5	81.2	19.4	12.9
1996	12	98.2	79.9	19.0	12.8
1997	1	98.1	79.9	18.5	12.6
1997	2	98.8	78.3	17.8	12.6
1997	3	100.0	77.4	16.9	12.6
1997	4	100.4	76.9	16.4	12.5
1997	5	98.3	76.6	16.6	12.6
1997	6	95.2	76.3	16.8	12.7
1997	7	92.3	76.0	17.0	12.5
1997	8	91.0	75.6	17.3	12.4
1997	9	91.4	75.1	17.6	12.1
1997	10	91.6	73.8	17.5	12.0
1997	11	91.2	73.2	17.3	11.7
1997	12	90.8	72.6	16.8	11.6
1998	1	90.2	72.9	16.0	11.5
1998	2	89.4	71.8	14.6	11.3
1998	3	88.5	71.6	13.5	11.0
1998	4	87.5	71.3	13.6	10.6
1998	5	86.3	70.5	13.3	10.4
1998	6	84.7	70.4	12.8	10.0
1998	7	82.6	70.4	12.6	9.5
1998	8	80.0	70.1	12.3	9.6
1998	9	77.6	70.3	11.7	9.8
1998	10	76.7	70.8	11.2	10.0
1998	11	76.4	71.7	11.0	10.2

APPENDIX C. ORBITAL INPUT OPTIONS

Symbols

Az Inertial azimuth, measured positive clockwise from north, deg.

a Semimajor axis of orbit, R_e

e Eccentricity of orbit, dimensionless

h_a Height of apogee above Earth, km

h_p Height of perigee above Earth, km

i Inclination of orbit, deg.

K OL program FORTRAN array containing integer data

p Semilatus rectum of orbit, R_e

R_e Earth radius, 6.378145×10^8 cm

R_i Initial geocentric radius, km

v True anomaly, deg.

V_i Inertial velocity of spacecraft in direction of flight, km/sec

V_0 Square of the fraction of local circular orbit velocity at R_i, dimensionless

γ Inertial flight path angle, deg.

ΔT_G Number of days since January 1.0, 1965 Universal Time, days

Δt Fraction of day measured from Greenwich midnight, days

λ Initial longitude, positive east of Greenwich, deg.

λ_i Longitudinal increment between ascending node and initial orbit point, deg.

μ Product of universal gravitational constant and Earth mass, cm^3/sec^2

ϕ Initial latitude, deg.

Ω Right ascension of ascending node, deg.

Ω_G Instantaneous right ascension of Greenwich meridian, deg.

ω Argument of perigee, deg.

Calculation of Orbital Elements from Input

As mentioned in the Input Format section, there are three ways to input the orbit parameters, corresponding to three values of K(50).

K(50) = 0: Input the orbital elements p, e, ω, Ω, and i
K(50) = 1: Input ω, i, λ, h_p and h_a
K(50) = -1: Input the trajectory variables Az, ϕ, λ, R_i, V_i, and γ.

If K(50) = 1 or K(50) = -1, the orbital elements p, e, ω, Ω, and i are calculated as follows (see fig. C.1 for orbit geometry):

For K(50) = 1

e: $a = (h_p + h_a)*10^5/(2R_e)$

$e = (h_a*10^5/R_e + 1)/a - 1$

p: $p = a(1-e^2)$

ω: Input

Ω: $\Omega_G = 100.43735 + 0.98561\ \Delta T_G + 360.98561\ \Delta t$

$\lambda_i = \cos^{-1}(\cos(\omega + v)/\cos\phi)$

$\Omega = \Omega_G + \lambda - \lambda_i$

i: Input

For K(50) = -1

e: $V_o = (V_i*10^5)^2(R_i*10^5)/\mu$

$e = (1-(2-V_o)V_o\cos^2\gamma)^{1/2}$

p: $a = -\mu\ /(((V_i*\ 10^5)^2 - 2\mu/(R_i*10^5))*R_e)$

$p = a(1-e^2)$

ω: $\omega = \sin^{-1}(\sin\phi/\sin i) - v$

Ω: Same as for K(50) = 1

i: $i = \cos^{-1}(\sin Az\ \cos\phi)$

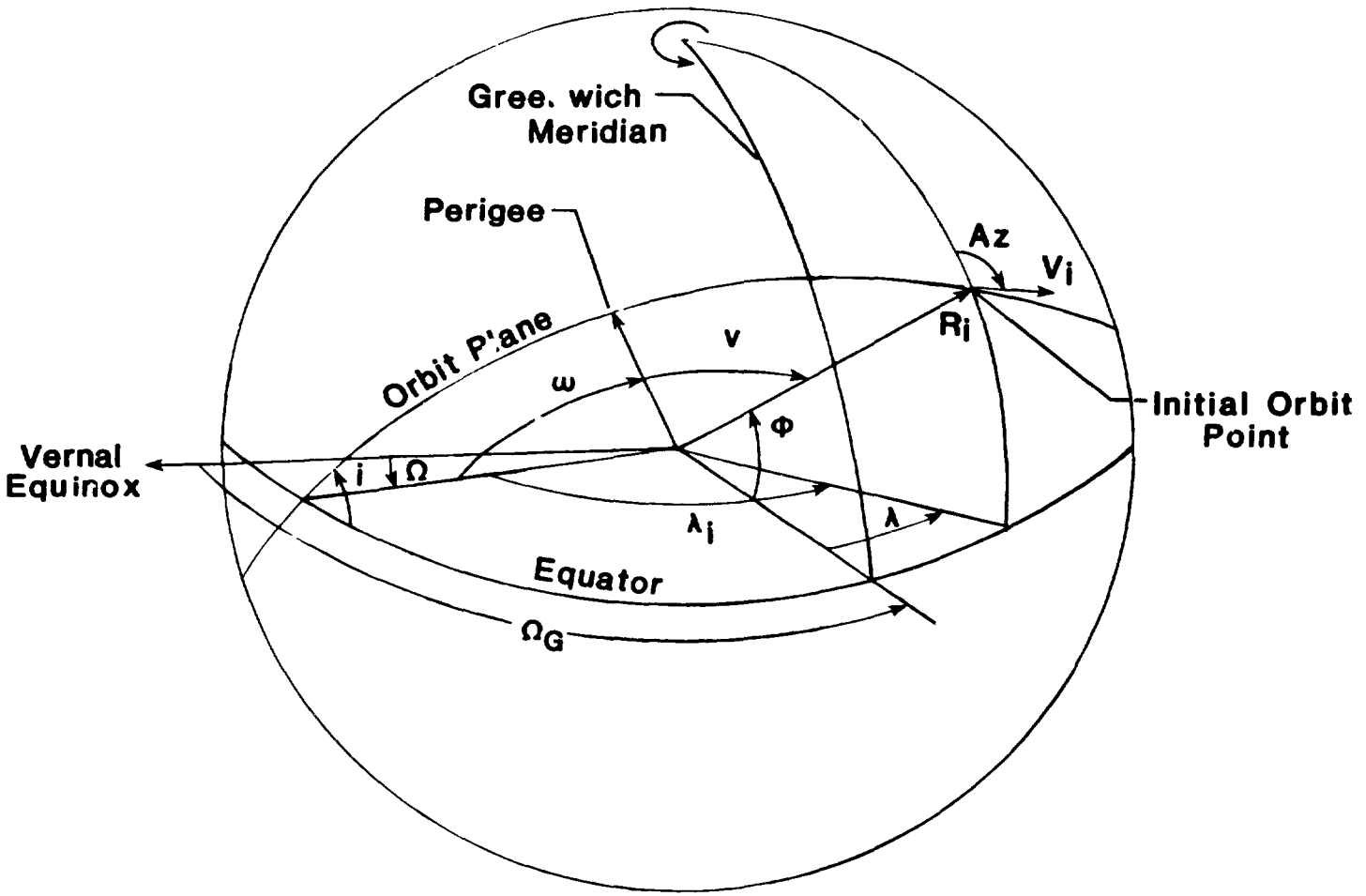

Figure C.1. - Orbit geometry for input.

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16. Abstract

A FORTRAN program used by Langley Research Center for analyzing orbital lifetimes of spacecraft is described. Calculations can, at the user's option, take into account perturbations in the orbit due to atmospheric drag, solar radiation pressure, and gravitational effects of the Sun, the Moon, and Earth oblateness. Instructions are provided for access and use of the program, and several sample cases are included with detailed descriptions of their associated input and output.

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