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SYSTEM DESCRIPTION AND OPERATING GUIDE FOR DSAS ILLUMINATION AND MOON CONFLICT PROGRAMS

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SYSTEM DESCRIPTION AND OPERATING GUIDE
FOR
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Section 1

Introduction

1.1 Purpose

The DSAS Illumination and Moon Conflict programs will provide the times during an orbit when the DSAS (Digital Solar Aspect Sensor) will record the direct rays of the sun, and the periods of time when the horizon scanners will come in conflict with the moon. The DSAS Illumination Program makes use of an orbit tape (or epoch time and orbital elements) in addition to an ephemeris tape containing positions of the sun and moon. The Moon Conflict Program makes use of the same ephemeris tape with sun and moon positions, but uses only epoch time and orbital elements for the satellite positions. These programs were designed for the TIROS or ITOS series spacecraft but may be utilized by any spacecraft with similar sensors.

1.2 General Characteristics

The DSAS Illumination Program uses orbital information, either from an ORB1 tape or Brouwer mean orbital elements, and ephemeris positions of the sun. The Moon Conflict Program uses Brouwer mean orbital elements with a Brouwer orbit generator and ephemeris positions of the moon. These programs are not entirely restricted to the TIROS (ITOS) series of satellites. With proper adjustment of mounting angles and testing times, these programs could be used on satellites with configurations and sensor equipment similar to TIROS (ITOS). The only restrictions in these programs are that the satellite spin axis pitch angle must be near zero degrees in the DSAS Illumination Program and that the spin axis have a nominal attitude of $\psi=\phi=\theta=0^\circ$ in the Moon Conflict Program. Further information on the configuration of the TIROS (ITOS) spacecraft and mission objectives can be found in the attitude determination system documentation generated for support of these satellites. This can be obtained from the GSFC Computer Program Library, filed under Program Number G00198 (TADS). The DSAS Illumination Program ("SUNILL") is filed under G00392; the Moon Conflict Program ("MONCON") under G00393.

2. DSAS Illumination Program

2.1 Analysis

The test for illumination of the Digital Solar Aspect Sensor (DSAS) will be made using the known sun position and the satellite orbital position at a predetermined time. This test will be performed at any increment of time provided the time step is in whole minutes. Under normal operating conditions the satellite attitude is assumed nominal, that is, Yaw (ψ) = Roll (ϕ) = Pitch (θ) = 0° . Allowance is made for a variation in the nominal attitude by inputting the current values for ψ , ϕ and θ .

The satellite position in inertial coordinates is calculated from the predicted orbital position using the equations:

$$\hat{r} = \frac{\vec{R}}{|\vec{R}|}$$

$$\hat{n} = \frac{\vec{R} \times \vec{V}}{|\vec{R} \times \vec{V}|}$$

$$\hat{t} = \hat{n} \times \hat{r}$$

where \vec{R} = the inertial satellite position vector
 \vec{V} = the inertial satellite velocity vector
 \hat{r} = unit position vector in inertial coordinates
 \hat{n} = unit vector normal to R and V in inertial coordinates
 \hat{t} = unit vector normal to N and R in inertial coordinates

If the satellite attitude is $\psi=\phi=\theta=0^\circ$, then the satellite spin axis attitude in inertial coordinates is calculated using:

$$\hat{s} = \hat{n}$$

where \hat{s} = spin axis vector in inertial coordinates (S_x, S_y, S_z). If the satellite attitude is not nominal, then the right ascension (α) and declination (δ) of the spin axis must be input. In this case, the spin axis attitude in inertial coordinates is obtained from:

$$\hat{S} = \begin{cases} S_x = \cos \alpha \cos \delta \\ S_y = \sin \alpha \cos \delta \\ S_z = \sin \delta \end{cases}$$

To determine if the DSAS will be illuminated, the sun's vector must be known in the satellite coordinate system. Given the position vector of the satellite (from orbital data) and the sun's vector to the earth (from an ephemeris tape), both at the desired point in time, the sun vector to the satellite is obtained by the equation:

$$\hat{P} = \frac{\vec{Q} - \vec{R}}{|\vec{Q} - \vec{R}|}$$

where \hat{P} = unit satellite to sun vector
 \hat{Q} = earth to sun vector
 (see Figure 1)

If it is assumed that the satellite does not have a nominal attitude, that is, $\psi \neq 0^\circ$ and/or $\phi \neq 0^\circ$ and/or $\theta \neq 0^\circ$, then the spin axis vector \hat{S} is resolved in the rotating orbit frame by:

$$S_r = \hat{r} \cdot \hat{s}$$

$$S_t = \hat{t} \cdot \hat{s}$$

$$S_n = \hat{n} \cdot \hat{s}$$

where (S_r, S_t, S_n) are the orbit frame coordinates of the satellite spin axis.

The satellite pitch angle θ is automatically maintained near 0° by the satellite.

ψ and ϕ must be solved for in terms of S_r, S_t, S_n . This can be accomplished by two consecutive right-handed rotations of the body frame vector $(0, 0, 1)$ through the angle $(-\phi)$ and then $(-\psi)$. ψ and ϕ are solved using:

$$\psi = \tan^{-1} \left(\frac{S_t}{S_n} \right) \text{ with quadrant check}$$

$$\phi = \sin^{-1} (s_r)$$

Having determined the angles ψ, ϕ and θ , the sun vector \hat{P} is then resolved in the body frame by first resolving it in the orbit frame:

$$P_r = \hat{r} \cdot \hat{P} = r_x P_x + r_y P_y + r_z P_z$$

$$P_t = \hat{t} \cdot \hat{P} = t_x P_x + t_y P_y + t_z P_z$$

$$P_n = \hat{n} \cdot \hat{P} = n_x P_x + n_y P_y + n_z P_z$$

Then, transform \hat{P} into the body frame using three right-handed rotations through $\psi,$

ϕ and θ :

$$P_1' = P_r$$

$$P_2' = P_t \cos \psi + P_n \sin \psi$$

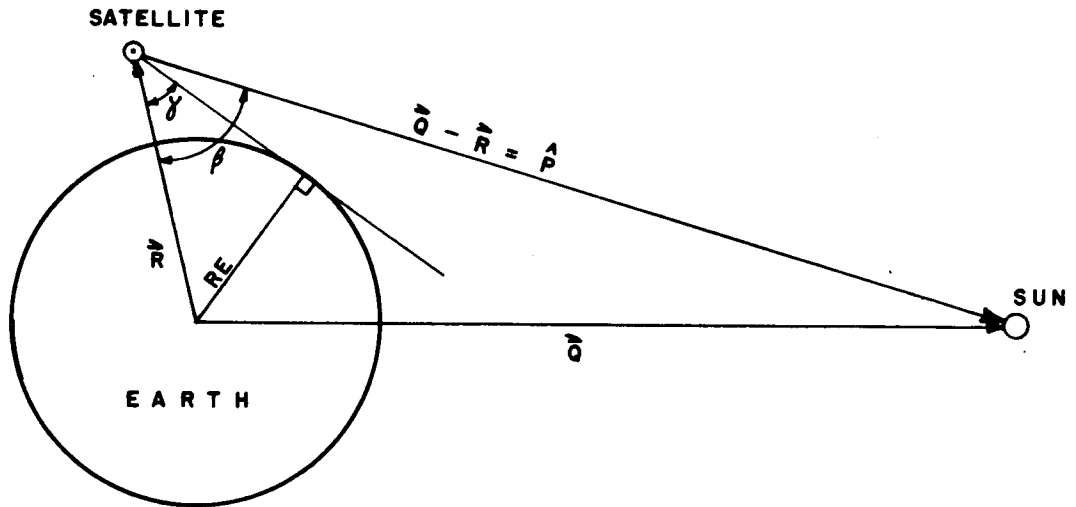
$$P_3' = -P_t \sin \psi + P_n \cos \psi \quad (1)$$

$$P_1'' = -P_3' \sin \phi + P_1' \cos \phi$$

$$P_2'' = P_2' \quad (2)$$

$$P_3'' = P_3' \cos \phi + P_1' \sin \phi$$

SATELLITE IN SUNLIGHT TEST



RE = Earth's Radius

\vec{R} = Radius Vector of Satellite Orbital Position

\vec{Q} = Earth to Sun Vector

\hat{P} = Unit Satellite to Sun Vector

Satellite will be in Sunlight if $\beta - \gamma > 0$

FIGURE - 1

$$P_1 = P_1'' \cos \theta + P_2'' \sin \theta$$

$$P_2 = P_1'' \sin \theta + P_2'' \cos \theta \quad (3)$$

$$P_3 = P_3''$$

where (P_1, P_2, P_3) are the coordinates of the sun vector in the body frame.

(see Figure 2)

If the satellite has a nominal attitude, that is, $\psi = \phi = \theta = 0^\circ$, then equations 1, 2 and 3 will reduce to:

$$P_1 = P_r$$

$$P_2 = P_t$$

$$P_3 = P_n$$

To determine if the DSAS will record the sun, several tests must be made. The first is a test to see if the satellite is in sunlight. Using the satellite position vector \vec{R} and the position coordinate of the sun vector in the orbit frame (P_r) , one can calculate the angles $\gamma + \beta$ using:

$$\gamma = \arcsin \left(\frac{R_e}{|\vec{R}|} \right)$$

where R_e = earth's radius in kilometers

$$\beta = \arccos (-P_r)$$

(see Figure 1)

The satellite will be in sunlight if $\beta - \gamma > 0$.

The next tests involve the DSAS body frame sensing plane vectors \hat{D} and \hat{E} . \hat{D} is the unit normal vector and \hat{E} is the unit centerline vector. These vectors are resolved in the body frame by:

$$D_1 = \cos B$$

$$D_2 = \sin B$$

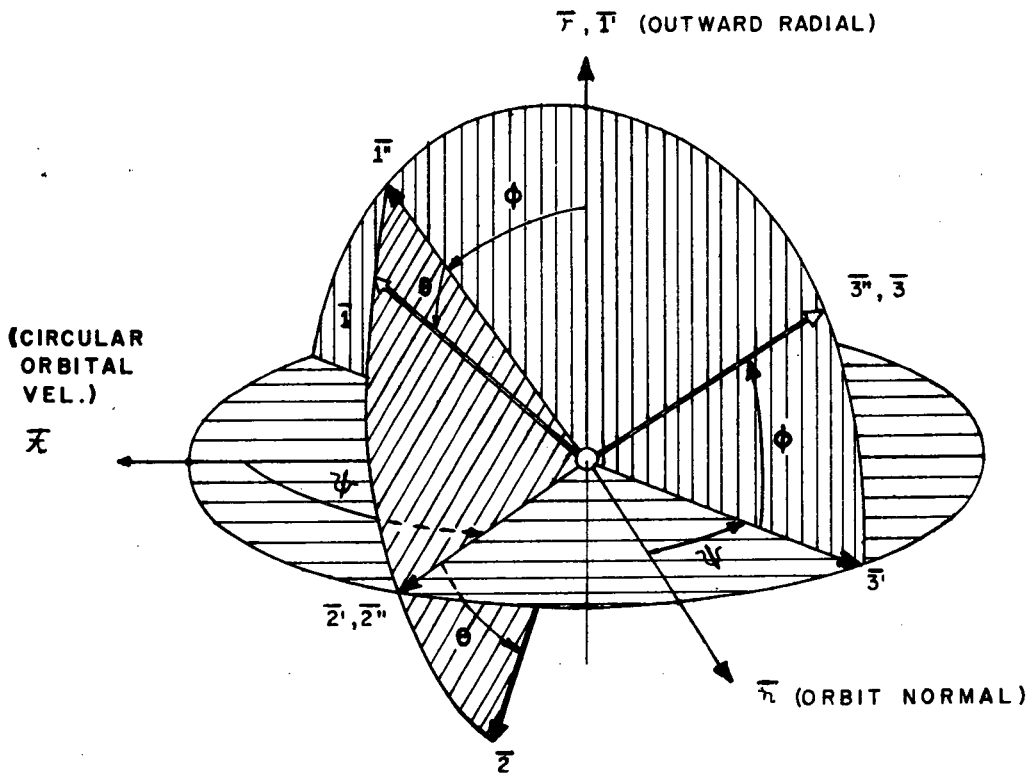
$$D_3 = 0$$

$$E_1 = \sin B$$

$$E_2 = \cos B$$

$$E_3 = 0$$

BODY ORIENTATION ANGLES



EULER SEQUENCE

- YAW ψ ABOUT \bar{r} to $\bar{1} \equiv \bar{r}, \bar{2}, \bar{3}$; $0^\circ \leq \psi < 360^\circ$
- ROLL ϕ ABOUT $\bar{2}$ to $\bar{1}'' \equiv \bar{2}, \bar{3}''$; $-90^\circ \leq \phi \leq 90^\circ$
- PITCH θ ABOUT $\bar{3}''$ to $\bar{1}, \bar{2}, \bar{3} \equiv \bar{3}''$; $-90^\circ \leq \theta \leq 90^\circ$

NOTE: For Nominal Mission Mode Attitude,

$\bar{1}, \bar{2}, \bar{3}$ coincide with $\bar{r}, \bar{i}, \bar{n}$, and $\psi = \phi = \theta = 0$

FIGURE - 2

where B = the mounting angle of the DSAS measured from yaw axis. (D_3 and E_3 are 0 since the sensor is mounted 90° to the pitch (spin) axis.) (See Figure 3.) A test must be made to determine if the sun's rays will strike the sensing side of the DSAS. The angle between the DSAS sensing centerline \hat{E} and the sun vector \hat{P} is found by:

$$AEP = \arccos (\hat{E} \cdot \hat{P})$$

where AEP = the angle between \hat{E} and \hat{P} . If $AEP < 90^\circ$, then the sun's rays will strike the sensing side of the DSAS.

The next test will determine if the sun's rays fall within the field of view of the DSAS. The angle between the spin axis and the sun vector \hat{P} is found by:

$$ASAP = \arccos (P_3)$$

where $ASAP$ = angle between spin axis and \hat{P} . If the lower viewing angle of the DSAS is greater than $ASAP$ and $ASAP$ is less than the upper viewing angle, then the sun's rays are within the field of view of the DSAS as measured from the positive spin axis.

When all the preceding tests are passed, the only remaining test is to determine exactly when the sun is recorded. In this test the angle between the sun vector \hat{P} and the DSAS sensing plane normal \hat{D} must be calculated from:

$$DOT = \hat{D} \cdot \hat{P}$$

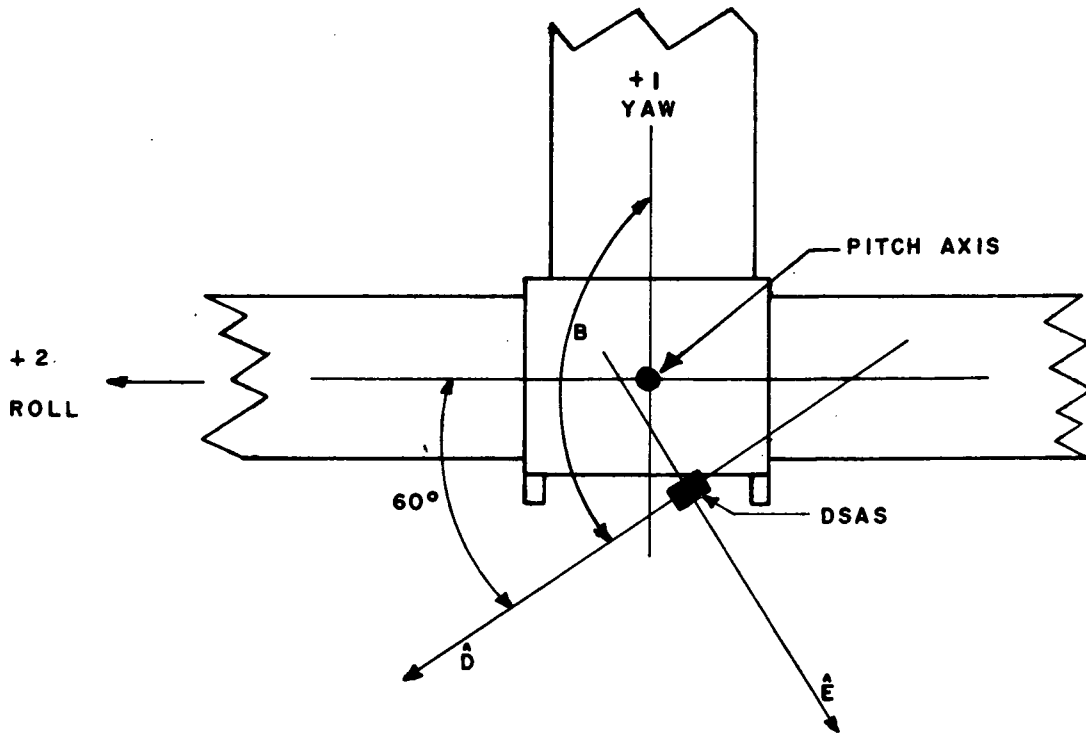
where DOT = cosine of the angle between \hat{D} and \hat{P} . This test will not be passed until the sun's rays cross perpendicular to \hat{D} and the cosine changes in sign. This then is the interval of time when the DSAS will record the sun pulse.

2.2 Setup

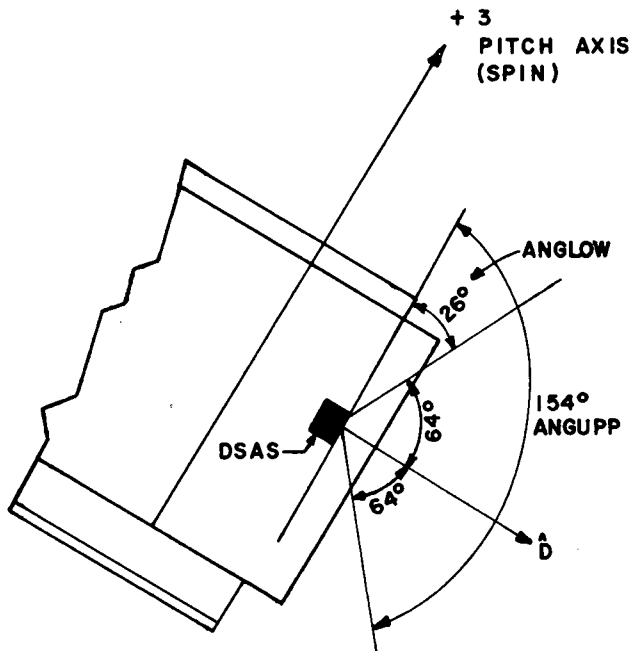
2.2.1 Resources

1. Card reader
2. Three tape drives (two if orbital elements are used)
3. Three tapes---system tape, sun and moon ephemeris tape, and orbit tape (omit orbit tape if orbital elements are used.)

DSAS MOUNTING AND VIEWING ANGLES



FOR TIROS-M, $B = 90^\circ + 60^\circ = 150^\circ$



For TIROS-M Viewing Readout Range for DSAS is 128°

FIGURE - 3

4. Card deck - JCL and data cards.

2.2.2 JCL before data (see Figure 4)

```
// JOB card (use 2 minutes CPU and I/O time estimate)
//A EXEC LOADER,PARM='EP=MAIN',REGION=250K
//SYSLIN DD UNIT=(2400-9,,DEFER),LABEL=(1,BLP),DISP=(OLD,KEEP),
//DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200,DEN=2),VOL=SER=33462J
```

This JCL is for the 9-track system tape containing both the DSAS Illumination Program and the Moon Conflict Program. The DSAS Illumination Program is located in File 1 of the system tape, the Moon Conflict Program in File 2. As of January 1973 there exist two duplicate system tapes. The tape numbers, either of which is to be inserted after "SER=", are 33462J and 33568J.

```
//GO.FT28FO01 DD DSN=GDRTAP,UNIT=2400-9,LABEL=(,BLP),
// VOLUME=SER=____,DISP=(NEW,PASS),DCB=(,LRECL=8276,
// BLKSIZE=8280,DEN=2,RECFM=V)
```

(FT28FO01 describes the 9-track sun and moon ephemeris tape. The current (January 1973) tape number is 30278K, which is to be entered after "SER=.")

```
//GO.GENTAP DD UNIT=2400-7,DISP=(OLD,KEEP),LABEL=(,BLP),
// DCB=(,DEN=1,BUFL=4212,BLKSIZE=4212),VOLUME=SER=_____
```

(GENTAP defines the 7-track orbital tape. The number is entered after "SER="). (If orbital elements are used, these two cards are to be removed).

```
//GO.FT09FO01 DD SYSOUT=A,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=7265)
//GO.FT10FO01 DD DUMMY
```

(The FT09FO01 and FT10FO01 are the unit descriptions for the output units. The FT09 description prints the data left-adjusted on the paper, the FT10 prints the data center-adjusted on the paper. Only one statement should be used, the other would then be set up as DUMMY).

```
//GO.DATA5 DD*
```

2.2.3 Data Cards

Card #1

<u>COL</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DESCRIPTION</u>
1-2	I2	NORB1	00 = orbit tapes not used. Epoch time and orbital elements used. 01 = orbit tape used. Epoch time and orbital elements flagged with 9's (see orbital elements and epoch time.)

Card #2

<u>COL</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DESCRIPTION</u>
1-10	F10.3	HRDIFF	See below
11-15	I5	ISMALL	Time increment for testing illuminations. (Normally 1 minute)
16-20	I5	IDELT	Time jump in minutes after a conflict has occurred, this will minimize CPU in testing for the next illumination.
24-30	A4,A3	IDSAT1,IDSAT2	7 alphanumeric characters designating the satellite name (s).

HARDIFF=The difference between the input epoch time and orbital elements and the desired epoch time. This difference is in hours. This variable will also update the elements to correspond to the desired epoch time. This variable is normally 0.000 with the decimal in column 7. By setting the variable to 0.000, the time and elements will not be updated. This method should only be used to update the epoch time and orbital elements when the desired values are not available.

Card #3

<u>COL</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DESCRIPTION</u>
1-4	I4	IEDATE(1)	Epoch Year in 4 digits, e.g. 1972
5-6	I2	IEDATE(2)	Epoch Month in 2 digits, e.g. 01
7-8	I2	IEDATE(3)	Epoch Day in 2 digits, e.g. 15
9	Leave blank		
10-11	I2	IEDATE(4)	Epoch Hour in 2 digits, e.g. 12
12-13	I2	IEDATE(5)	Epoch Minutes in 2 digits, e.g. 36
14-15	I2	IEDATE(6)	Epoch Seconds in 2 digits, e.g. 26

(Be careful to use minutes and seconds. If orbit tape is used for input, be sure to make each digit a "9" e.g. IEDATE(1) =9999.)

Card #4 (Orbital Elements)

<u>COL</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DESCRIPTION</u>
1-10	F10.2	E(1)	a, semi-major axis in kilometers
11-20	F10.5	E(2)	e, eccentricity (no units)
21-30	F10.3	E(3)	i, inclination in degrees
31-40	F10.3	E(4)	m, mean anomaly in degrees
41-50	F10.3	E(5)	w, argument of perigee in degrees
51-60	F10.3	E(6)	0, right ascension of ascending node in degrees

(If orbit tape is used as input, make each digit a "9", e.g. E(1)=9999999999).

Card #5

<u>COL</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DESCRIPTION</u>
1-10	F10.1	B	See below
11-20	F10.1	ANGLOW	"
21-30	F10.1	ANGUPP	"

B= Sun sensor mounting angle in degrees measured from Yaw axis to DSAS center line in direction of Roll axis. (reference spacecraft documentation).

ANGLOW= Lower viewing angle limit of the sun sensor measured from the positive spin axis (equal to 26.5 degrees for ITOS spacecraft).

ANGUPP= Upper viewing angle limit of the sun sensor measured from the positive spin axis (equal to 153.5 degrees for ITOS spacecraft).

Card #6 (Start date and time for program)

<u>COL</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DESCRIPTION</u>
1-4	I4	ISTR(1)	Year
5-8	I4	ISTR(2)	Month
9-12	I4	ISTR(3)	Day
13-16	I4	ISTR(4)	Hours
17-20	I4	ISTR(5)	Minutes
21-24	I4	ISTR(6)	Seconds (The seconds are not used)

Card #7 (End date and time for program)

<u>COL</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DESCRIPTION</u>
1-4	I4	IEND(1)	Year
5-8	I4	IEND(2)	Month
9-12	I4	IEND(3)	Day
13-16	I4	IEND(4)	Hours
17-20	I4	IEND(5)	Minutes
21-24	I4	IEND(6)	Seconds (the seconds are not used)

Card #8

<u>COL</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DESCRIPTION</u>
1-10	F10.3	PSI	Yaw angle of spin axis in degrees (nominally 0.000)
11-20	F10.3	PHI	Roll angle of spin axis in degrees (nominally 0.000)
21-30	F10.3	THETA	Pitch angle of spin axis in degrees (nominally 0.000)
31-40	F10.3	ALPHA	Right ascension of spin axis in degrees (nominally 0.000)
41-50	F10.3	DELTA	Declination of the spin axis in degrees (nominally 0.000)

/*(end of file)

//(null) (Not used if following JCL is used)

2.2.4 JCL After Data

If more than one copy of the listing is desired the Utility Program PATRICK may be used. The setup to invoke PATRICK is as follows:

```
//STEP EXEC PGM=PATRICK,PARM='9TN,001,001',REGION=100K
```

```
//IN1 DD DSN=*.A.GO.FT09F001,DISP=(OLD,PASS)
```

(This card references STEP A in the EXEC card at the beginning of JCL. If output is to be written to unit 10 instead of unit 09, then FT09 in the above step must be changed to FT10.)

NOTE: The FT09 definition must be changed if it is desired to write to the disk rather than SYSOUT=A. The cards should be:

```
//GO.FT09F001 DD DSN=&&DUM1,DCM=(RECFM=VBA,LRECL=137,BLKSIZE=7265),
```

```
// DISP=(NEW,PASS),SPACE=(TRK,(50,10)),UNIT=DISK
```

(If FT10 is used, than change the statement to FT10F001)

```
//OUT1 DD SYSOUT=A,SPACE=(CYL,(5,1)),
```

```
// DCB=(RECFM=VBA,LRECL=137,BLKSIZE=7265
```

These six cards may be repeated as many times as output is needed. Each set is an exact duplicate of the other.

```
/* (End of file)
```

```
// (Null)
```

This completes the setup for the cards to run the DSAS Illumination program.

2.3 Flowchart

A flowchart of the general functions of the DSAS Illumination Program is given in Figure 5. This diagram shows the transformations and tests used to determine when DSAS (Sun Sensor) illumination has occurred.

JCL DECK FOR DSAS ILLUMINATION PROGRAM

```

//ZNSRMSUN JOB (GH6501601B,P,G00392,002002),AAA,MSGLEVEL=1
//A EXEC LOADER,PARM='EP=MAIN',REGION=250K
//SYSLIN DD UNIT=(2400-9,,DEFER),LABEL=(1,BLP),DISP=(OLD,KEEP),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200,DEN=2),VOL=SER=33462J
//GO.FT28F001 DD DSNAME=GDRTAP,UNIT=2400-9,LABEL=(,BLP),
//          VOLUME=SER=30278K,DISP=(NEW,PASS),DCB=(,LRECL=8276,
//          BLKSIZE=8280,DEN=2,RECFM=V)
//GO.GENTAP DD UNIT=2400-7,DISP=(OLD,KEEP),LABEL=(,BLP),
// DCB=(,DEN=1,BUFL=4212,BLKSIZE=4212),VOLUME=SER=1234M
//GO.FT09F001 DD SYSOUT=A,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=7265)
//GO.FT10F001 DD DUMMY
//GO.DATA5 DD *
01
    0.000      1    50    ITOS-D
99999999 999999
    9999.99    9.99999  999.999    9.999    999.999    999.999
        30.0      26.5      153.5
1972  10  15  17  28  00
1972  10  18  00  00  00
        0.000      0.000      0.000    0.000    0.000
/*
//

```

FIGURE - 4

FLOW DIAGRAM OF DSAS ILLUMINATION PROGRAM

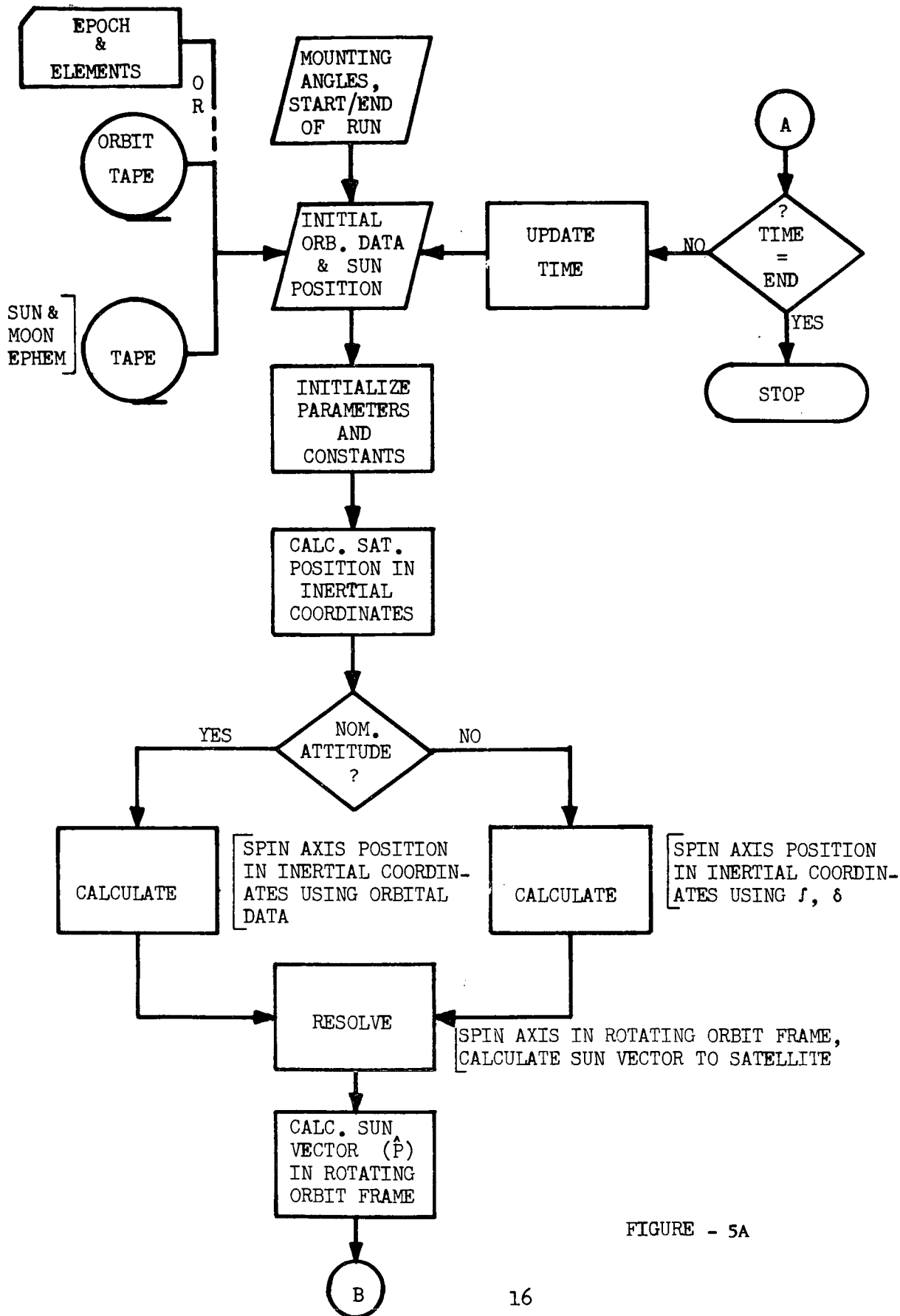


FIGURE - 5A

FLOW DIAGRAM OF DSAS ILLUMINATION PROGRAM(CONT'D)

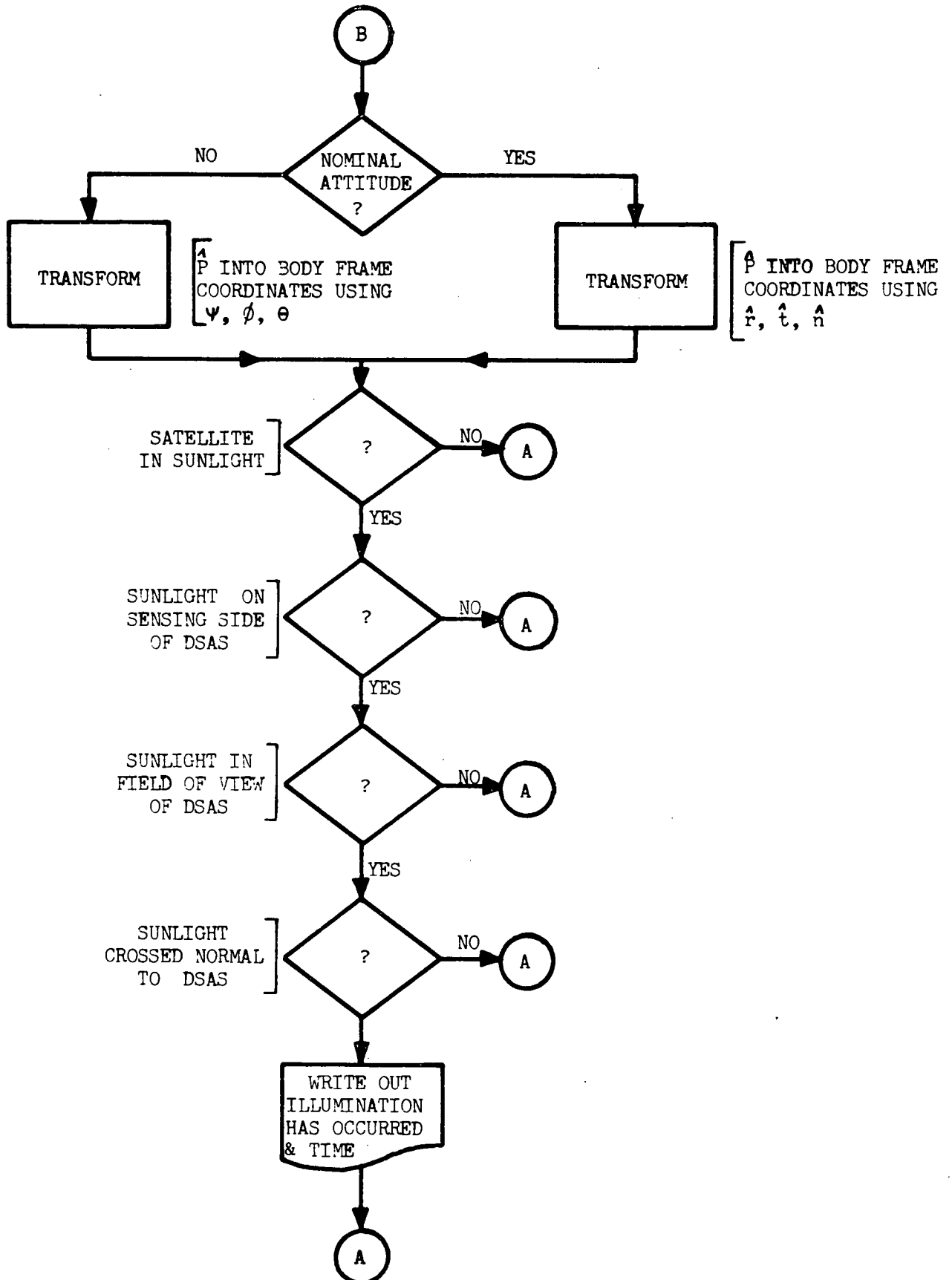


FIGURE - 5B

2.4 Subroutines

The following subroutines are used within the DSAS Illumination Program:

BRRV	XKEP
BBRWR	DJUL
ALLOT	MAD
ALLOTZ	RQ4M2T
BRWR1	RDJPL
BRWR2	DAYS
ELRV	DPRB1
ATANQ	D2PRB1
DMAD	DELTAD

The subroutines BRRV (main program), BBRWR, ALLOT, ALLOTZ, BRWR1, BRWR2, ELRV, ATANQ, DMAD and XKEP are used in the Brouwer mean orbital generator. The function of these subroutines is to provide orbital position parameters for the input satellite using epoch and orbital elements. Documentation for the Brouwer mean orbital generator can be found in "A Mutual Visibility Computer Program for Communication Satellites," (X-547-65-222), by G. D. Repass and R. G. Chaplick, (May 1965).

The subroutine DAYS computes the number of days since the beginning of the input year for use in the orbit subroutine D2PRB1.

The subroutines DJUL and MAD are used to calculate the Julian date for use in the Brouwer orbital generator and in the subroutines RDJPL and RQ4M2T. The MAD subroutine performs the same function as the MOD function on the IBM 360 system. Subroutine DJUL is documented in the same document as the Brouwer orbital generator.

The subroutine RDJPL reads the JPL ephemeris tape for the inertial sun and moon position vectors at the input time. RQ4M2T then rotates the sun and moon vectors to the true equator and equinox of that date.

The subroutine DPRB1 reads the header record of a double precision seven track ORB1 tape. D2PRB1 reads the double precision seven track ORB1 tape to obtain inertial radius and velocity vectors of the satellite position.

Subroutine DELTAD was written for the DSAS Illumination and Moon Conflict Programs for the purpose of updating the time-keeping parameters within the main programs. The time variables used in DELTAD are:

IDATE (1) = year	IDATE (4) = hour
IDATE (2) = month	IDATE (5) = minute
IDATE (3) = day	IDATE (6) = second

MINUTE = number of minutes to update time (5 digits maximum). Time will be updated by any positive number of whole minutes up to five digits maximum. Updating for seconds was not needed and therefore not programmed. A general flow diagram is given in Figure 6.

2.5 Output Description (see figure 7)

A printed listing (multiple copies possible) is the primary output from the DSAS Illumination Program. If output on tape is desired, the JCL must be changed to meet this end. The output will consist of the following:

1. The first page is a title: "Sun Sensor Illumination Test for * Satellite".

*The satellite name will be entered in this space from card #2.

FLOW DIAGRAM OF SUBROUTINE DELTA D

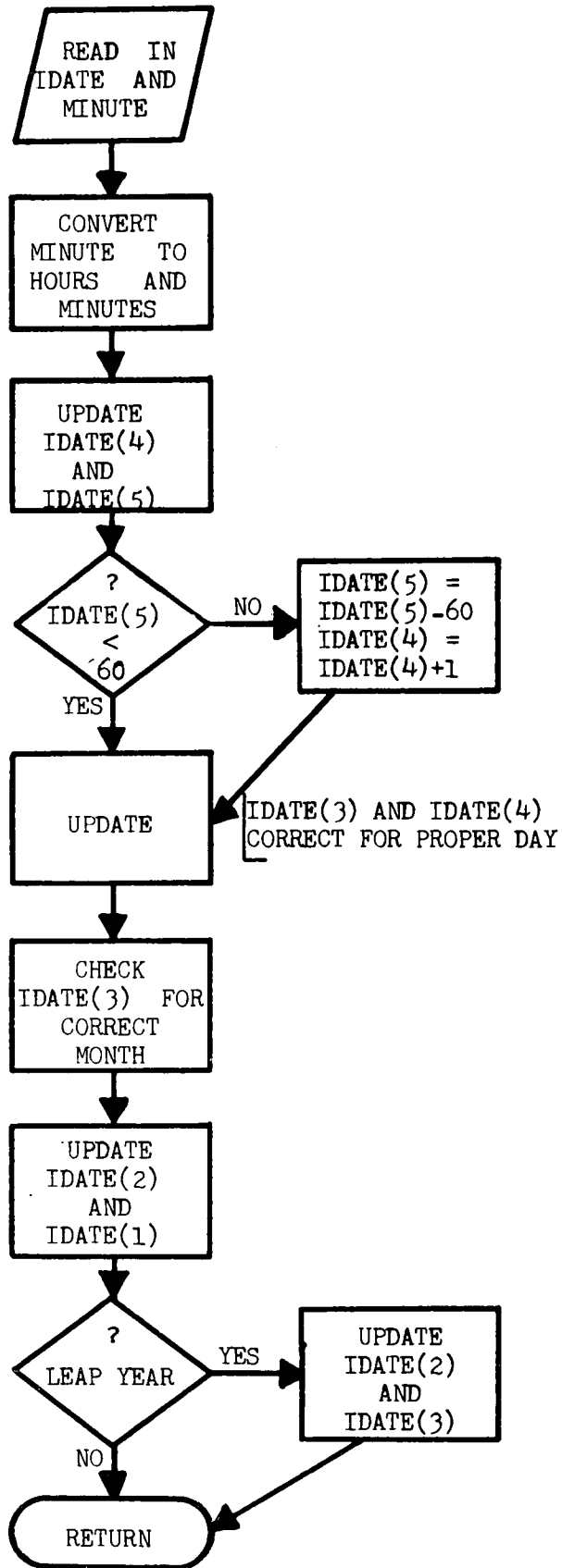


FIGURE - 6

2. The second page contains pertinent information: Sun Sensor mounting angle, Sensor viewing angle from positive spin axis, epoch time and orbital elements (9's are inserted if orbit tape is used), and starting and ending date in year, month, day, hour, minute and second.
3. The following pages usually contain two times during which an illumination occurred. These two times will be within one minute of each other. The format of the times are year, month, day, hour and minute. No seconds are written out. It is possible to obtain only one time, that is, when an illumination occurred on the minute. The output for this case will be one time and the message "Direct Illumination".

*** SUN SENSOR ILLUMINATION TEST ***
*** FOR ITOS - 1 SATELLITE ***

Figure 7A

SUN SENSOR MOUNTING ANGLE
 (DEGREES)
 (150

SENSOR VIEWING ANGLE FROM POSITIVE SPIN AXIS
 (DEGREES)
 26.5 to 153.5

EPOCH

YEAR	MONTH	DAY	HOUR	MINUTE	SECOND
1970	1	15	12	36	26

ORBITAL ELEMENTS

A (KILOMETERS) 7840.40	E (NO UNITS) 0.00023	I (DEGREES) 101.739
ARG. OF PER. (DEGREES) 68.272 68.272	M (DEGREES) 291.037	R.A. OF NODE (DEGREES) 339.615

START DATE

YEAR	MONTH	DAY	HOUR	MINUTE	SECOND
1970	1	15	0	0	0

END DATE

YEAR	MONTH	DAY	HOUR	MINUTE	SECOND
1970	1	22	0	0	0

YEAR	MO	DA	HR	MN	ILLUMINATION HAS OCCURRED	YEAR	MO	DA	HR	MN
1970	1	15	1	37	ILLUMINATION HAS OCCURRED	1970	1	15	1	38
1970	1	15	3	32	ILLUMINATION HAS OCCURRED	1970	1	15	3	33
1970	1	15	5	28	ILLUMINATION HAS OCCURRED	1970	1	15	5	29
1970	1	15	7	23	ILLUMINATION HAS OCCURRED	1970	1	15	7	24
1970	1	15	9	18	ILLUMINATION HAS OCCURRED	1970	1	15	9	19
1970	1	15	11	14	ILLUMINATION HAS OCCURRED	1970	1	15	11	15
1970	1	15	13	9	ILLUMINATION HAS OCCURRED	1970	1	15	13	10
1970	1	15	15	4	ILLUMINATION HAS OCCURRED	1970	1	15	15	5
1970	1	15	16	59	ILLUMINATION HAS OCCURRED	1970	1	15	17	0
1970	1	15	18	55	ILLUMINATION HAS OCCURRED	1970	1	15	18	56
1970	1	15	20	50	ILLUMINATION HAS OCCURRED	1970	1	15	20	51
1970	1	15	22	45	ILLUMINATION HAS OCCURRED	1970	1	15	22	46
1970	1	16	0	40	ILLUMINATION HAS OCCURRED	1970	1	16	0	41
1970	1	16	2	36	ILLUMINATION HAS OCCURRED	1970	1	16	2	37
1970	1	16	4	31	ILLUMINATION HAS OCCURRED	1970	1	16	4	32
1970	1	16	6	26	ILLUMINATION HAS OCCURRED	1970	1	16	6	27
1970	1	16	8	21	ILLUMINATION HAS OCCURRED	1970	1	16	8	22
1970	1	16	10	17	ILLUMINATION HAS OCCURRED	1970	1	16	10	18
1970	1	16	12	12	ILLUMINATION HAS OCCURRED	1970	1	16	12	13
1970	1	16	14	7	ILLUMINATION HAS OCCURRED	1970	1	16	14	8
1970	1	16	16	2	ILLUMINATION HAS OCCURRED	1970	1	16	16	3
1970	1	16	17	56	ILLUMINATION HAS OCCURRED	1970	1	16	17	59
1970	1	16	19	53	ILLUMINATION HAS OCCURRED	1970	1	16	19	54
1970	1	16	21	48	ILLUMINATION HAS OCCURRED	1970	1	16	21	49
1970	1	16	23	43	ILLUMINATION HAS OCCURRED	1970	1	16	23	44
1970	1	17	1	39	ILLUMINATION HAS OCCURRED	1970	1	17	1	40
1970	1	17	3	34	ILLUMINATION HAS OCCURRED	1970	1	17	3	35
1970	1	17	5	29	ILLUMINATION HAS OCCURRED	1970	1	17	5	30
1970	1	17	7	24	ILLUMINATION HAS OCCURRED	1970	1	17	7	25
1970	1	17	9	20	ILLUMINATION HAS OCCURRED	1970	1	17	9	21
1970	1	17	11	15	ILLUMINATION HAS OCCURRED	1970	1	17	11	16
1970	1	17	13	10	ILLUMINATION HAS OCCURRED	1970	1	17	13	11
1970	1	17	15	6	ILLUMINATION HAS OCCURRED	1970	1	17	15	7

Figure 7c

Section 3

Moon Conflict Program

3.1 Analysis

The test for a moon conflict with the earth horizon scanners will be made using the known moon position and the satellite orbital position at a predetermined time. Each test will be made at the time step increment beginning with the initial start time of the run. The satellite attitude is assumed to be constant with the Yaw (ψ)=Roll (ϕ)=Pitch (θ)=0°. These values cannot be changed unless the program itself is changed.

The satellite spin axis vector is considered to be parallel with orbit normal and is obtained from the radius and velocity vectors of the orbital position, R and V respectively. Hence, the unit spin axis is defined by:

$$\hat{SA} = \frac{\vec{R} \times \vec{V}}{|\vec{R} \times \vec{V}|}$$

The unit vector from the satellite to the moon (\hat{M}) can be found using:

$$\hat{M} = \frac{\vec{UTM} - \vec{R}}{|\vec{UTM} - \vec{R}|}$$

where \vec{UTM} =vector from earth to moon obtained from the ephemeris tape.

The angle between the vector from the satellite to the moon and the vector from the satellite tangent to the moon can be determined. This angle will be called SIGMA(σ) (see Figure 8) and will be calculated using:

$$SIGMA = \tan^{-1} \left(\frac{R_m}{|\vec{M}|} \right)$$

where R_m =radius of the moon in kilometers

\hat{M} =non-unit vector from the satellite to the moon

The angle LAMBDA (λ) between unit \hat{M} and the positive spin axis unit vector can be defined by:

$$\text{LAMBDA} = \cos^{-1} (\hat{S} \cdot \hat{M})$$

(see Figure 8)

Given the mounting angles of Scanner #1 and Scanner #2 as DELTA1 and DELTA2 respectively, a moon conflict will occur when the vector from the satellite tangent to the moon falls within the field of view of a scanner. This criterion will be met when:

$$(1) \quad \text{DELTA1} - \text{OMEGA} - \text{SIGMA} \leq \text{LAMBDA} \leq \text{DELTA1} + \text{OMEGA} + \text{SIGMA}$$

or

$$(2) \quad \text{DELTA2} - \text{OMEGA} - \text{SIGMA} \leq \text{LAMBDA} \leq \text{DELTA2} + \text{OMEGA} + \text{SIGMA}$$

where OMEGA=half viewing angle of the scanners

Case 1 is a conflict test with the scanner with DELTA1 mounting angle while Case 2 is a conflict test with the scanner with DELTA2 mounting angle. This latter case is illustrated in Figure 8, moon position 3. There will be a short period of time (a few hours) when the moon will lie between the viewing fields of both scanners but not in conflict with either one. This case is illustrated in Figure 8, moon position 2.

Since the moon's orbital period is about twenty-eight days, it can be expected to cause conflicts every fourteen days. However, during one period of conflict, the moon will either be dark or only partially illuminated. To allow for this problem, the right ascensions of both the sun and moon are computed using:

$$\text{RAMOON} = \tan^{-1} \left(\frac{\text{UTM}(2)}{\text{UTM}(1)} \right)$$

MOON CONFLICT DIAGRAM

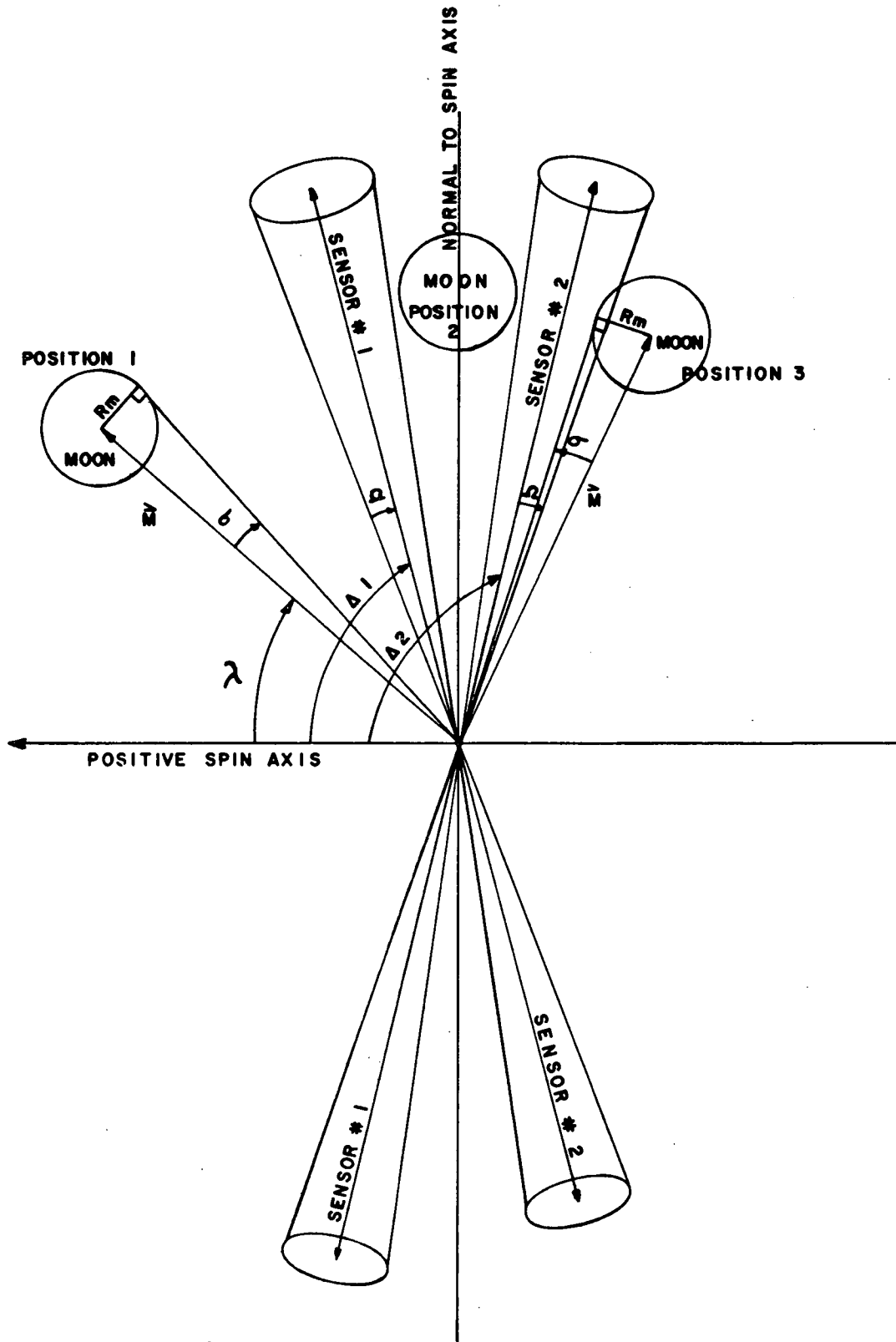


FIGURE - 8

$$\text{RASUN} = \tan^{-1} \left(\frac{\text{UTS}(2)}{\text{UTS}(1)} \right)$$

where RAMOON=right ascension of the moon

RASUN=right ascension of the sun

UTM(1)=X component of $\overrightarrow{\text{UTM}}$ (earth to moon vector obtained from the ephemeris tape)

UTM(2)=Y component of $\overrightarrow{\text{UTM}}$ (earth to moon vector obtained from the ephemeris tape)

UTS(1)=X component of the earth to sun vector obtained from the ephemeris tape.

UTS(2)=Y component of the earth to sun vector obtained from the ephemeris tape.

The difference between these right ascensions are computed from:

$$\text{DIFFERENCE} = |\text{RAMOON} - \text{RASUN}|$$

This difference is then converted to a MOD 180°. When the value obtained is greater than 90°, a true conflict will occur. If the difference is less than 90°, then the moon is only partially illuminated, and in the case of the TIROS-M (ITOS-1) satellite this was not considered to be a true conflict. Therefore, true conflict periods only occur once every twenty-eight days.

3.2 Setup

3.2.1 Resources

1. Card reader
2. Two tape drives
3. Two tapes (system tape and ephemeris tape)
4. Card deck (JCL and data cards)

3.2.2 JCL Before Data (see Figure 9)

```
//JOB card (Use 4 minutes CPU and I/O time estimate)
```

```
//B EXEC LOADER,PARM='EP=MAIN',REGION=250K
```

(This is step name B for the Moon Conflict Program)

```
//SYSLIN DD UNIT=(2400-9,,DEFER),LABEL=(2,BLP),DISP=(OLD,KEEP),
```

```
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200,DEN=2),VOL=SER=33462J
```

(These cards reference the second file on the 9-track systems tape for the DSAS Illumination and Moon Conflict programs. The tape number to be inserted after SER= is either 33462J or 33568J (Note: these are duplicate tapes; either may be used).

```
//GO.FT28F001 DD DSNAME=GDR TAP,UNIT=2400-9,LABEL=(,BLP),
```

```
// VOLUME=SER=___,DISP=(NEW,PASS),DCB=(LRECL=8276,
```

```
// BLKSIZE=8280,DEN=2,RECFM=V)
```

(This is the 9-track ephemeris tape for the positions of the sun and moon. Currently the tape used is 30278K and is inserted after SER=.)

```
//GO.FT09F001 DD SYSOUT=A,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=7265)
```

```
//GO.FT10F001 DD DUMMY
```

(The FT09F001 and FT10F001 are the unit descriptions for the output units. The FT09 description prints the data left-adjusted on the paper, the FT10 prints the data center-adjusted on the paper. Only one statement should be used, the other can be set up as DUMMY.)

//GO.DATAS DD*

3.2.3 Data Cards

Card #1

<u>COL</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DESCRIPTION</u>
1-10	F10.3	DELTA1	Mounting angle of Scanner #1 from the positive spin axis measured in degrees (approximately 87.000 degrees).
11-20	F10.3	DELTA2	Mounting angle of Scanner #2 from the positive spin axis measured in degrees (approximately 93.000 degrees).
21-30	F10.3	OMEGA	Scanner half viewing angle measured in degrees (approximately 1.500 degrees).
34-40	A4,A3	IDSAT1,IDSAT2	7 alphanumeric characters designating the satellite name(s).

Card #2

<u>COL</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DESCRIPTION</u>
1-4	I4	IEDATE(1)	Epoch Year (e.g. 1972)
5-6	I2	IEDATE(2)	Epoch Month (e.g. 12)
7-8	I2	IEDATE(3)	Epoch Day (e.g. 12)
9	blank		
10-11	I2	IEDATE(4)	Epoch Hour (e.g. 01)
12-13	I2	IEDATE(5)	Epoch Minutes (e.g. 25)
14-15	I2	IEDATE(6)	Epoch Seconds (e.g. 20)

Card #3 (Orbital Elements)

<u>COL</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DESCRIPTION</u>
1-10	F10.2	E(1)	a, semi-major axis in kilometers
11-20	F10.5	E(2)	e, eccentricity (no units)
21-30	F10.3	E(3)	i, inclination in degrees
31-40	F10.3	E(4)	m, mean anomaly in degrees
41-50	F10.3	E(5)	w, argument of perigee in degrees
51-60	F10.3	E(6)	Ø, right ascension of the ascending node in degrees

Card #4

<u>COL</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DESCRIPTION</u>
1-10	F10.3	HRDIFF	See below
11-15	I5	MINUTE	" "

HRDIFF=The difference between the input epoch time with its corresponding orbital elements and the desired epoch time. This difference is expressed in hours. This variable will also update the elements to correspond to the desired epoch time. This variable normally should be 0.000 with the decimal point in column 7 which does not update the time or elements. This method of updating the epoch should only be used when desired epoch times and orbital elements are not available.

MINUTE=The DELTA T for time stepping to test for a moon conflict (in minutes).

Card #5 (Start date and time for this program)

<u>COL</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DESCRIPTION</u>
1-4	I4	IDATE(1)	YEAR (e.g. 1972)
5-6	I2	IDATE(2)	MONTH (e.g. 12)
7-8	I2	IDATE(3)	DAY (e.g. 14)
9	blank		
10-11	I2	IDATE(4)	HOUR(e.g. 02)
12-13	I2	IDATE(5)	MINUTE(e.g. 35)
14-15	I2	IDATE(6)	SECOND (e.g. 00)

(The seconds are not used)

Card #6 (End date and time for this program)

<u>COL</u>	<u>FORMAT</u>	<u>VARIABLE</u>	<u>DESCRIPTION</u>
1-4	I4	IEND(1)	YEAR (e.g. 1972)
5-6	I2	IEND(2)	MONTH (e.g. 12)
7-8	I2	IEND(3)	DAY (e.g. 31)
9	blank		
10-11	I2	IEND(4)	HOUR (e.g. 23)
12-13	I2	IEND(5)	MINUTE (e.g. 59)
14-15	I2	IEND(6)	SECOND (e.g. 00)

(The seconds are not used)

3.2.4 JCL After Data

If more than one copy of the listing is desired, the Utility Program PATRICK may be used. The setup to invoke PATRICK is as follows:

```
//STEP EXEC PGM=PATRICK,PARM='9TN,001,001',REGION=100K
```

```
//IN1 DD DSN=*.B.GO.FT09F001,DISP=(OLD,PASS)
```

(This card references STEPB in the EXEC card at the beginning of JCL. If output is to be written to unit 10 instead of unit 09, then FT09 in the above step must be changed to FT10.)

NOTE: The FT09 definition must be changed if it is desired to write to disk rather than SYSOUT=A. The cards should be:

```
//GO.FT09F001 DD DSN=&&DUM2,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=1265),
```

```
// DISP=(NEW,PASS),SPACE=(TRK,(50,10)),UNIT=DISK
```

(If FT10 is used, than change the statement to FT10F001)

```
//OUT1 DD SYSOUT=A,SPACE=(CYL,(5,1)),
```

```
// DCB=(RECFM=VBA,LRECL=137,BLKSIZE=7265)
```

These six cards may be repeated as many times as output is needed. Each set is an exact duplicate of the other.

/*(End of file)

// (Null)

This completes the setup for the cards to run the Moon Conflicts
Program.

JCL DECK FOR MOON CONFLICT PROGRAM

```
//ZNSRMMON JOB (GH65016018,P,G00392,004004),AAA,MSGLEVEL=1
//B EXEC LOADER,PARM='EP=MAIN',REGION=250K
//SYSLIN DD UNIT=(2400-9,,DEFER),LABEL=(2,BLP),DISP=(OLD,KEEP),
//DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200,DEN=2),VOL=SER=33462J
//GO.FT28F001 DD DSNAME=GDRTAP,UNIT=2400-9,LABEL=(,BLP),
//VOLUME=SER=30278K,DISP=(NEW,PASS),DCB=(,LRECL=8276,
//BLKSIZE=8280,DEN=2,RECFM=V)
//GO.FT09F001 DD SYSOUT=A,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=7265)
//GO.FT10F001 DD DUMMY
//GO.DATA5 DD *
130.000 130.000 1.375 ITOS-D
19721011 181918
7839.840 0.00025 101.760 265.920 78.400 332.556
0.000 50
19721011 171800
19721031 235000
/*
//
```

FIGURE - 9

3.3 Flowchart

A flowchart of the general functions of the Moon Conflict Program is given in Figure 10. This diagram shows the general data flow of the system and the method used for obtaining satellite, sun and moon positions.

FLOW DIAGRAM OF MOON CONFLICT PROGRAM

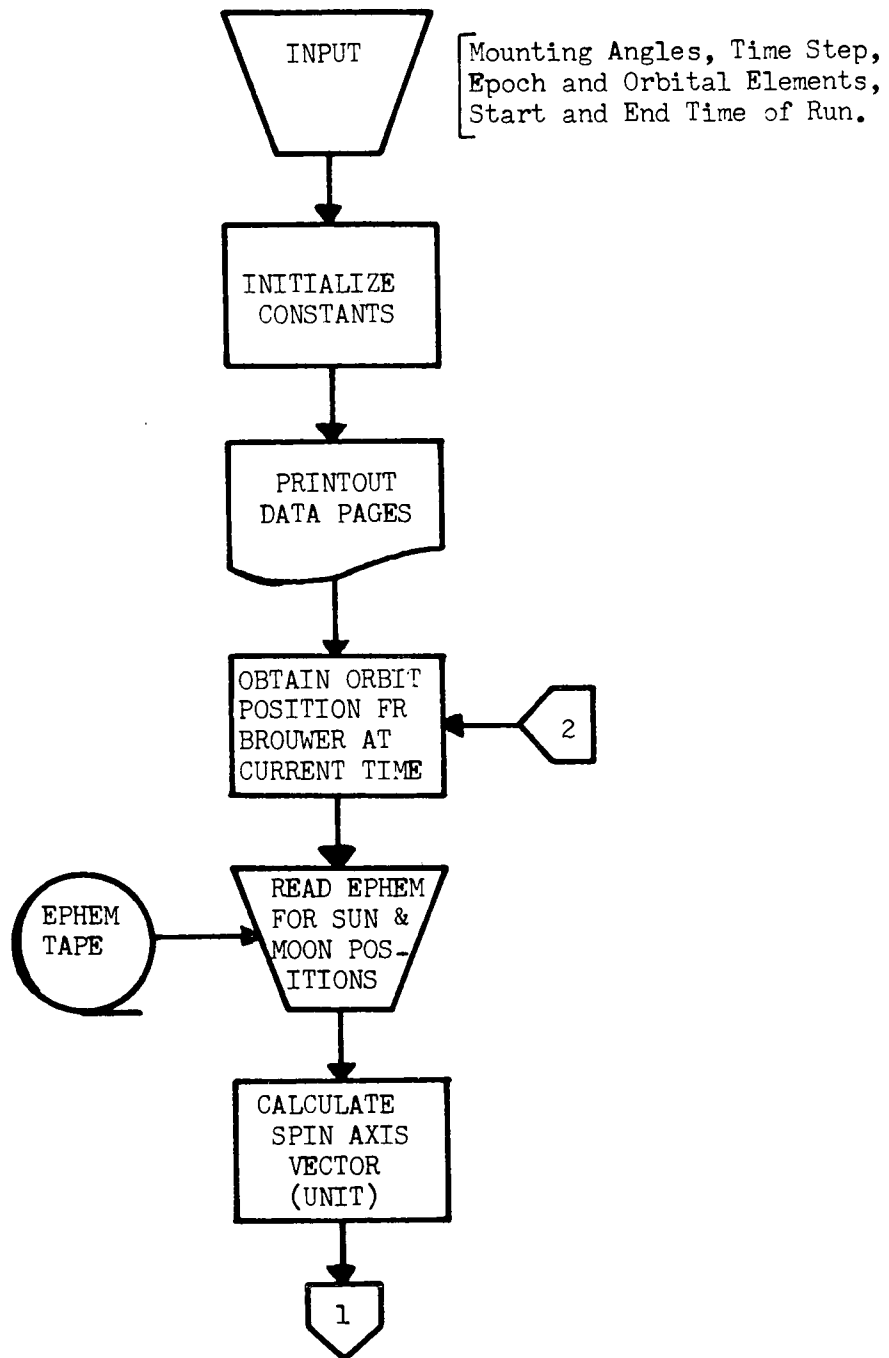


FIGURE - 10A

FLOW DIAGRAM OF MOON CONFLICT PROGRAM (CONT'D)

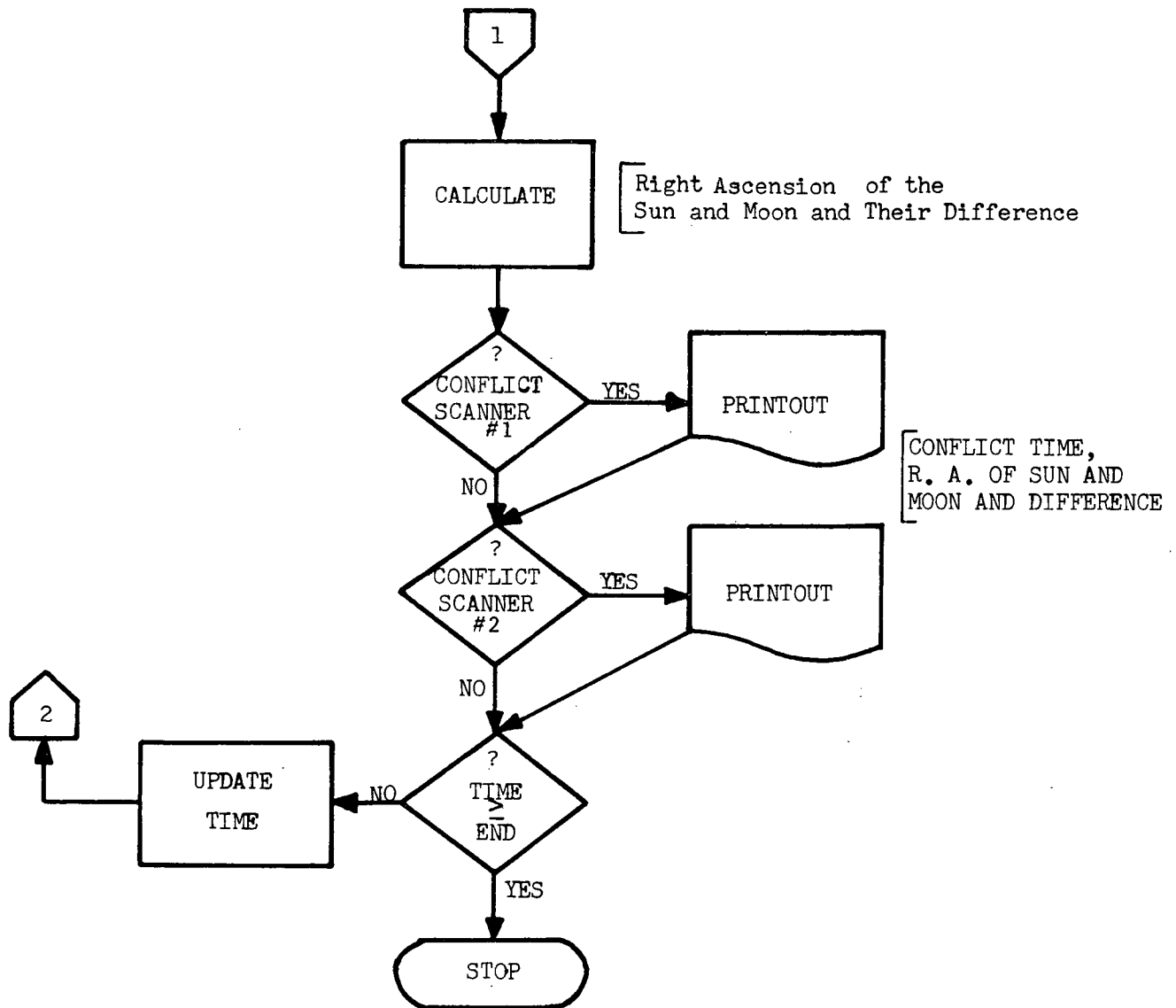


FIGURE - 10B

3.4 Subroutines

Below are listed all the subroutines necessary in the Moon Conflict Program. All of these routines are mentioned or described in the Subroutine section of the DSAS Illumination Program description. Refer to that section (2.4) for further details.

BRRV	DMAD
BBWR	ELRV
BRWR1	MAD
BRWR2	XKEP
ALLOT	RQ4M2T
ALLOTZ	RDJPL
ATANQ	DELTAD
DJUL	

3.5 Output Description (see Figure 11)

A printed listing is the only output from the Moon Conflict Program. If tape output is desired, the JCL must be changed to write a tape. A description of the output is as follows:

1. The first page is a title page containing the program identification-
"Moon Conflict Test for _____ * _____ Satellite.
* The satellite name will be entered in this space.
2. The second page contains pertinent information about the mounting angles of the horizon scanners from the positive spin axis, the epoch time in year, month, day, hours, minutes and seconds, and the orbital elements used in this program. Also included is the start and end times of the program.

3. The next page and any following pages contain the times during a month when each scanner will be in conflict with the moon. Each time is given in year, month, day, hour, and minute, and corresponding to each time is given the right ascension in degrees of the sun and moon. The column labelled "difference" gives the difference in degrees between the right ascension of the sun and moon on the basis of 180 degrees. When the difference is greater than 90 degrees, then an actual conflict will occur. When the difference is less than 90 degrees, then the illuminated disk of the moon is not enough to cause a real conflict with the horizon scanner.

***-----MON . CONFLICT . TEST . ***
*** FOR ITOS- 1 SATELLITE ***

Figure 11A

DELTA1 MOUNTING ANGLE OF SCANNER NO.1
 MEASURED FROM POSITIVE SPIN AXIS
 87.0 DEG

DELTA2 MOUNTING ANGLE OF SCANNER NO.2
 MEASURED FROM POSITIVE SPIN AXIS
 93.0 DEG

SCANNER VIEWING ANGLE OMEGA
 1.5 DEG

EPOCH		
YEAR	MONTH	DAY
1970	1	19
		12
		36
		26

ORBITAL ELEMENTS

A	E	I
(KILOMETERS)	(NO UNITS)	(DEGREES)
7840.40	0.0	101.739
ARG. OF PER.	M	R.A. OF NODE
(DEGREES)	(DEGREES)	(DEGREES)
68.254	291.055	343.558

Figure 11B

START DATE			END DATE		
YEAR	MONTH	DAY	YEAR	MONTH	DAY
1970	1	19			
		0			
		0			
		0			

START DATE			END DATE		
YEAR	MONTH	DAY	YEAR	MONTH	DAY
1970	2	19			
		0			
		0			
		0			

CONFLICTS WITH SCANNER WITH DELTA1 MOUNTING ANGLE		CONFLICTS WITH SCANNER WITH DELTA2 MOUNTING ANGLE		R.A. MUON DEG	R.A. SUN DEG	DIFFERENCE
YEAR	MO DA HR MN	YEAR	MO DA HR MN			
1970	1 26 19 12	1970	1 26 4 48	166.53	-51.40	141.67
1970	1 26 21 36	1970	1 26 7 12	167.59	-51.70	140.71
1970	1 27 0 0	1970	1 26 9 36	168.66	-51.59	139.75
1970	2 9 4 48	1970	1 26 12 0	169.72	-51.49	138.79
1970	2 9 7 12	1970	1 26 19 12	172.91	-51.18	135.91
1970	2 9 9 36	1970	1 26 21 36	173.98	-51.07	134.95
		1970	1 27 0 0	175.04	-50.97	133.99
		1970	2 9 4 48	-0.38	-37.56	37.18
		1970	2 9 7 12	0.89	-37.46	38.35
		1970	2 9 9 36	2.16	-37.36	39.52
		1970	2 9 14 24	4.69	-37.16	41.85
		1970	2 9 16 48	5.95	-37.06	43.01
		1970	2 9 19 12	7.20	-36.96	44.17

Figure 11C

References

1. Repass, G. D. and R. G. Chaplick, A Mutual Visibility Computer Program for Communication Satellites, NASA-GSFC: X-547-65-222, May 1965.
2. Tiros-M Attitude Determination System, IBM Document under NASA Contract NAS5-10022, March 1970.