NASA TM X- 70653

ATS-F LAUNCH PLANNING
DOCUMENT

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GSFC — **GODDARD SPACE FLIGHT CENTER** —

GREENBELT, MARYLAND

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I. LAUNCH VEHICLE TRAJECTORY

A. Introduction

The Applications Technology Satellite-F (ATS-F) is placed into its targeted synchronous orbit by a Titan III-C launch vehicle. During the time interval from liftoff at the Air Force Eastern Test Range to payload separation in synchronous orbit approximately 6.7 hours later, the launch vehicle trajectory is completely controlled by an automatic inertial guidance system located aboard the Titan vehicle. Thus, the entire trajectory is accomplished without any ground commanding to either the Titan or ATS. To monitor the performance of the Titan launch vehicle, the Titan telemetry is transmitted via S-Band PCM/FM during various intervals, and C-band radar tracking is conducted during various intervals. Selected Titan Mark Events and Standard Orbital Parameter Messages are transmitted to ATSOCC at various points in the Titan trajectory.

The Titan launch vehicle trajectory consists of seven major sequenced phases:

- boost

- parking orbit

- transtage first burn

- transfer orbit

- transtage second burn

- synchronous orbit

- retro burn

B. Titan Launch Vehicle Description

The Titan III-C launch vehicle consists of a three-stage liquid propellant core supplemented by two solid rocket motor strap-ons. The complete four-stage launch vehicle with payload and fairing has an overall length of approximately 140 feet and a liftoff weight of about 1.4 million pounds.

Stage 0

Stage 0 consists of two identical solid rocket motors (SRM) mounted 180 degrees apart on the core vehicle. The solid rocket motors lift the vehicle off the launch pad with a combined thrust of approximately 2.4 million pounds. The length of each SRM is 80 feet.

Stage 1

Stage 1 consists of two gimbaled liquid propellant engines. The stage is 10 feet in diameter and approximately 71.5 feet long. The combined thrust is approximately 520 thousand pounds.

Stage 2

Stage 2 consists of one gimbaled liquid propellant engine. The stage is 10 feet in diameter and approximately 31 feet long. The thrust is approximately 100 thousand pounds.

Transtage

The transtage (Stage 3) consists of two gimbaled liquid propellant engines. The stage is 10 feet in diameter and approximately 14.5 feet long. The combined thrust is 16 thousand pounds. The transtage is unique due to its multiple start capability. The transtage contains an inertial guidance system, C-band pulse tracking transponder, UHF flight safety receivers, S-band telemetry transmitter, flight control subsystem, and attitude control subsystem.

Fairing

The metal payload fairing is 30 feet in length and consists of three longitudinal separation joints located 120 degrees apart, with end joints containing ordnance devices for separation.

A pictorial view of the Titan III-C launch vehicle, including the payload fairing, during liftoff is shown in Figure I-1. A cutaway view of the Titan is shown in Figure I-2.

ATS Interface to the Titan Transtage

The Titan III-C has an orthogonal coordinate reference system such that the positive Titan X-axis is directed along the longitudinal axis from tail to nose. The Titan Z-axis is directed along the Titan target axis, and the Titan Y-axis completes the right-handed system.

ATS-F has its own orthogonal coordinate reference system such that the positive ATS Z-axis is directed from the parabolic reflector hub along the center line of the truss towards the earth viewing module (EVM). The positive ATS Y-axis is directed from the center of the EVM towards the south face of the EVM. The positive ATS X-axis is directed from the center of the EVM towards the east face of the EVM.
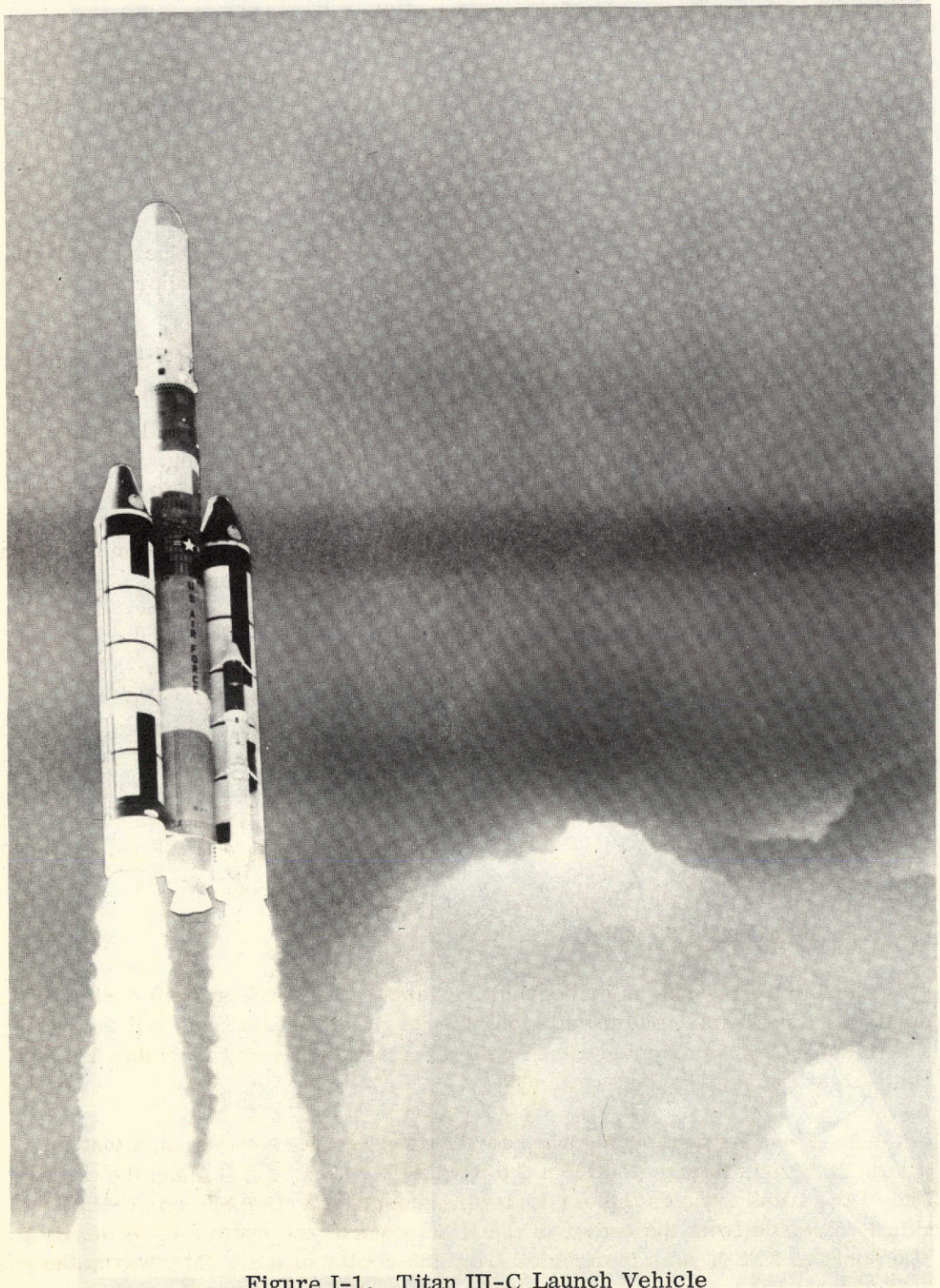
Figure I-1. Titan III-C Launch Vehicle

1. PAYLOAD FAIRING.
2. CONTROL MODULE.
3. TRANSTAGE OXIDIZER TANK.
4. TRANSTAGE FUEL TANK.
5. TRANSTAGE ENGINE.
6. SECOND STAGE OXIDIZER TANK.
7. SECOND STAGE FUEL TANK.
8. SECOND STAGE ENGINE.
9. FIRST STAGE OXIDIZER TANK.
10. FIRST STAGE FUEL TANK.
11. FIRST STAGE ENGINE.
12. BOOSTER STAGE SOLID ROCKET MOTORS.
13. BOOSTER STAGE TVC TANKS.
14. BOOSTER STAGE SEPARATION ROCKETS.
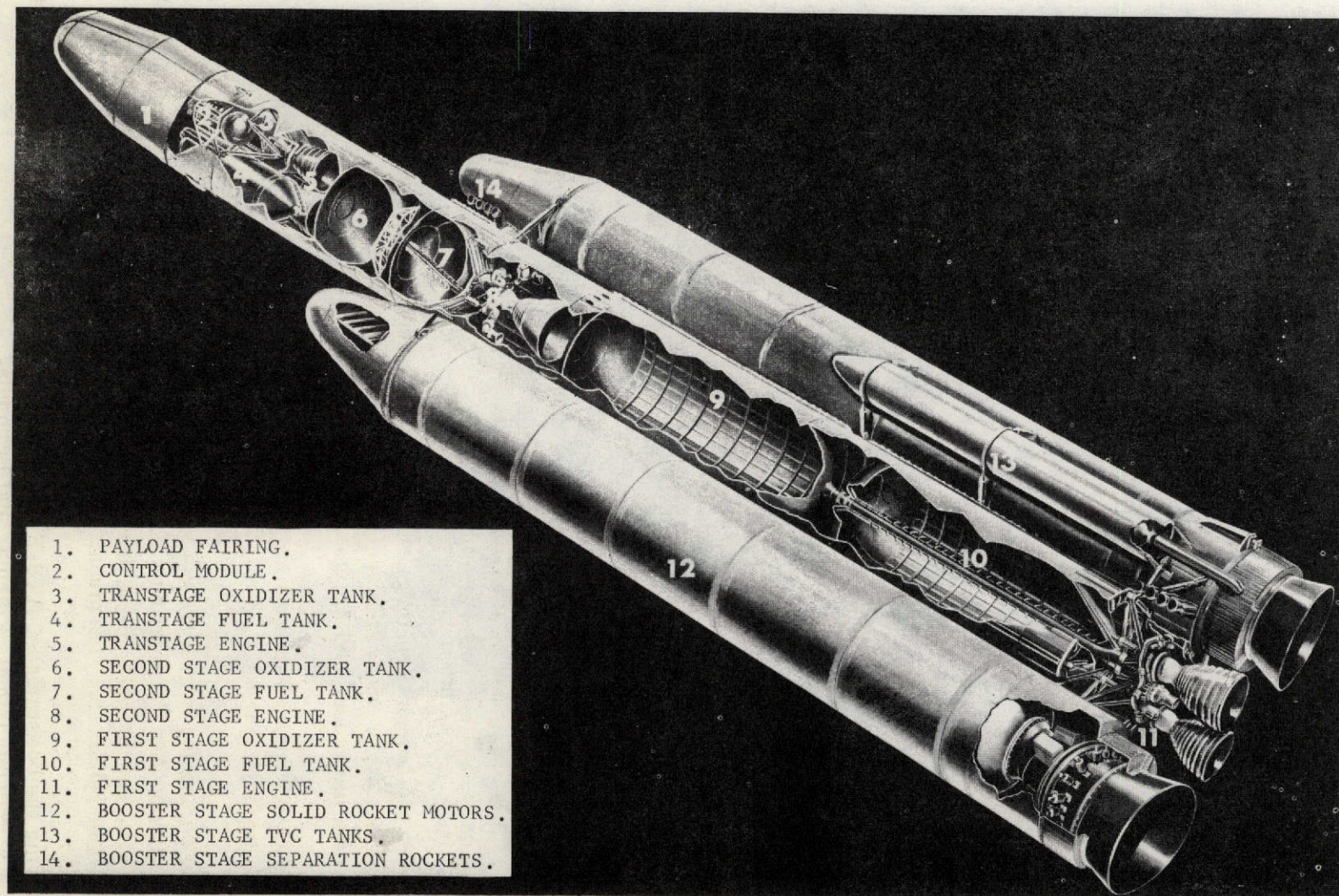
Figure I-2. Titan III-C Cutaway View

The adapter attaching the ATS-F structure to the top of the Titan transtage is aligned such that the correspondance between the Titan and ATS-F reference axes is as follows:

Titan III-C Reference System		ATS-F Reference System
+X-axis	=	-Z-axis
+Y-axis	=	-X-axis
+Z-axis	=	-Y-axis

C. Boost Phase

The boost phase starts at liftoff from Pad 40 at the Eastern Test Range with a 93 degree flight azimuth and ends about eight minutes later when the transtage is injected into the park orbit. The flight begins with ignition of the solid rocket motors. After 109 seconds from liftoff, Stage 1 ignition occurs. During the Stage 1 burn, the solid rocket motors are jettisoned. Stage 1 tailoff occurs approximately 256 seconds after liftoff, and is quickly followed by Stage 2 ignition and then Stage 1 jettison. During the Stage 2 burn, the payload fairing is also jettisoned. At 464 seconds after liftoff, the Stage 2 tailoff occurs, followed by the jettison of Stage 2 and the transtage injection into the parking orbit at 480 seconds after liftoff.

At the time of park orbit injection, the transtage is approximately 910 nautical miles from the launch pad and at an altitude of approximately 82 nautical miles. This corresponds to a subsatellite point of about 26.5 degrees north latitude and 63.7 degrees west longitude.

During the launch trajectory, C-band radar tracking is accomplished from six ground stations: Merritt Island, Patrick AFB, Grand Bahama Island, Grand Turk, Bermuda, and Antigua.

Two NASA ground stations also support Titan C-band RADAR tracking: Bermuda and Tananarive.

Also during the launch trajectory, Titan S-band telemetry is being received at the following Air Force ground stations: Patrick AFB, Grand Bahama Island, Grand Turk, and Antigua. In addition, four NASA ground stations also support Titan S-band telemetry: Bermuda, Carnarvon, Hawaii, and Merritt Island.

During the boost phase, ATS-F VHF telemetry is received by NASA ground stations at Merritt Island, Florida, and Bermuda.

ATS

TITAN IIIC

INSTANTANEOUS CG

YAW AXIS

ROLL AXIS

PITCH AXIS

(TARGET)

REFERENCE AXIS CORRESPONDENCE

TITAN IIIC	ATS (STOWED)
-x (ROLL)	+z (YAW)
+y (PITCH)	-x (ROLL)
-z (YAW)	-y (PITCH)

NOTE:
Titan III Flight Coordinate
Axes Shown
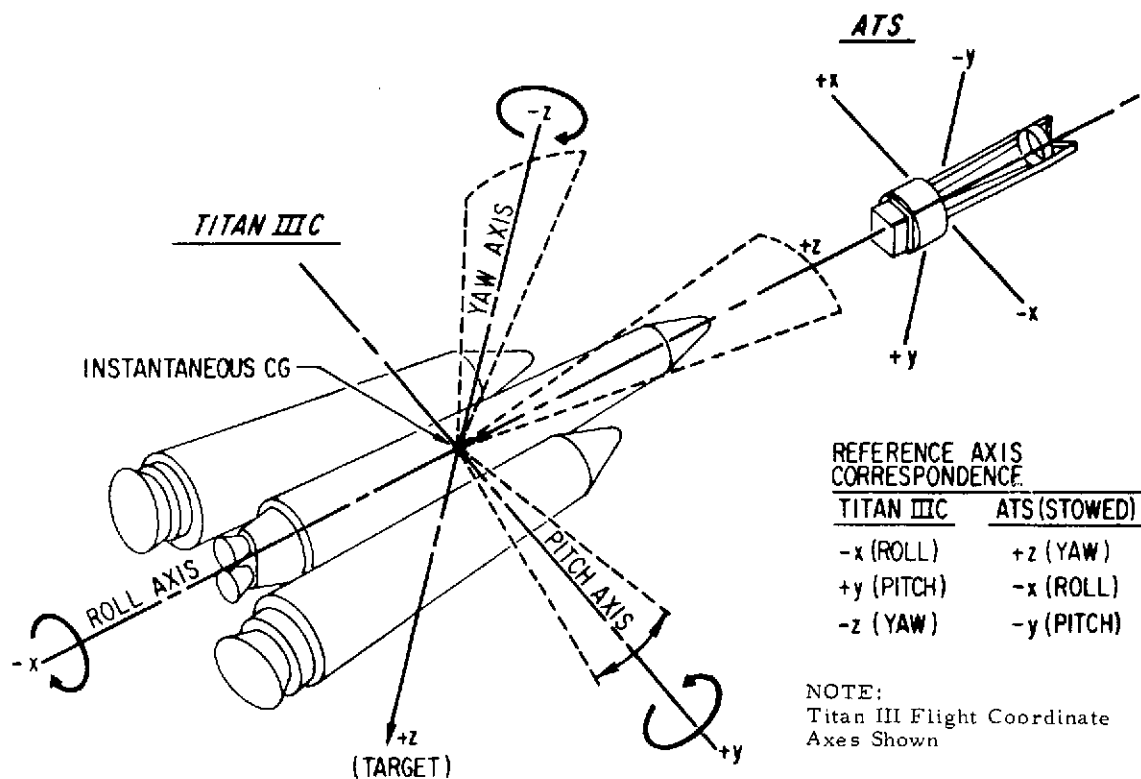
Figure I-3 Titan III/ATS-F Coordinate Axes

D. Park Orbit Phase

The park orbit phase starts at the jettison of Stage 2, which is about 480 seconds from liftoff, and ends at the first ignition of the transtage, which is approximately 4346 seconds from liftoff. The targeted elliptical park orbit is 82 x 233 nautical miles. The park orbit inclination is about 28.6 degrees from the equatorial plane.

Immediately after injection into the parking orbit, the transtage attitude is adjusted such that the Titan positive X-axis is orthogonal to the geocentric radius vector and coincident with the velocity vector. The attitude is such that the Titan positive Z-axis is pointed to the center of the earth.

During the park orbit phase, ATS-F VHF telemetry is received by NASA ground stations at Bermuda, Ascension, Johannesburg, Tananarive, and Carnarvon.

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E. Transstage First Burn Phase

The transstage first burn begins at the second equatorial crossing (first crossing in a northerly direction) which is 4346 seconds from liftoff and ends about 5.5 minutes later, causing the transstage to be injected into the transfer orbit. The transstage subsatellite point is at about 0 degrees latitude and 165 degrees east longitude at the start of the burn. This burn produces a transfer orbit with an apogee at a nominal synchronous altitude and also reduces the orbital inclination from 28.6 degrees to 26.4 degrees with respect to the equatorial plane.

During part of the transstage first burn, ATS-F telemetry is received by the NASA ground station at Guam.

F. Transfer Orbit Phase

The transfer orbit begins after the transstage first burn (4657 seconds from liftoff) and ends 5.3 hours later at the start of the transstage second burn (23816 seconds from liftoff). The perigee of the orbit is nominally 200 nautical miles, and has a three sigma perigee dispersion of ±20 nautical miles. The orbital inclination is about 26.4 degrees with respect to the equatorial plane.

For most of the transfer orbit phase, the transstage performs a thermal maneuver to provide for ATS-F thermal control. During this thermal maneuver, the transstage X-axis attitude is held constant with the transstage +X-axis pointed generally southward, while the transstage maintains a continous roll rate within 0.25 to 1.75 degrees per second and averaging 1 degree per second. The rotational direction for the thermal maneuver is clockwise as viewed from the transstage nose looking aft.

The transstage thermal maneuver is interrupted three times to permit the readout of Titan telemetry to earth ground stations by reorienting the transstage attitude. For the first telemetry dipout (Titan telemetry window #5), the transstage's broadbeam telemetry antenna axis is approximately directed towards the center of the earth. During the last two telemetry dipouts (Titan telemetry windows #7 and #9), the transstage's narrow beam telemetry antenna is directed approximately towards the center of the earth. The duration of each telemetry dipout is approximately 6.5 minutes. Table I-1 lists the events associated with the three Titan telemetry dipouts.

During the transfer orbit phase, ATS-F VHF telemetry is received by NASA ground stations at Mojave and Rosman.

Table I-1

Titan Telemetry Windows

Time After Liftoff (Seconds)			Event
Window #5	Window #7	Window #9	
6002	12260	18518	Start TM orientation maneuver and apply power to TM transmitter
≈6062	≈12320	≈18578	TM transmitter warmed up and on (approximately 52 to 55 seconds, for warm-up)
≈6092	≈12350	≈18608	Reached TM attitude
6200	12450	18690	Middle of TM attitude
6302	12560	18818	Start return to thermal attitude
≈6390	≈12660	≈19090	Reached thermal attitude
6652	12910	19168	TM transmitter turned off

G. Transtage Second Burn Phase

At the first apogee of the transfer orbit (23816 seconds from launch), the transtage engines are ignited for the second time and are burned for about 109 seconds, causing the transtage to be injected into a nearly circular synchronous orbit. This manuever also further reduces the orbital inclination from 26.4 to 1.8 degrees with respect to the earth's equatorial plane.

The transtage has an optional capability to rotate the right ascension of the ascending node of the final orbit, as part of the the transtage second burn, if so desired. Further discussion of nodal rotation is made in Section V-A. The desired final node range is within the interval 266 to 274 degrees.

During the transtage second burn phase, ATS-F VHF telemetry is received by NASA ground stations at Mojave and Rosman.

H. Synchronous Orbit Phase

The Transtage is injected into synchronous orbit upon the second burn cut-off. This orbit is circular and has a 1.8 degree inclination with respect to the equator. The right ascension of the ascending node for the orbit will be between 240 degrees and 280 degrees, though for most days in the launch window the node range is 266 to 274 degrees. The subsatellite position will be within the range of 93.3 to 98.0 degrees west longitude, to offer the necessary field of view for United States based experiments. The maximum (three sigma) Titan IIIC injection errors imparted to the spacecraft are as follows:

apogee altitude	± 198 nautical miles
perigee altitude	± 176 nautical miles
period	± 11 minutes
eccentricity	0.0066
inclination	± 0.165 degrees
subsatellite point drift	± 2.76 degrees longitude per day

About 173 seconds after injection into synchronous orbit, the Titan transtage issues a separation fire signal to release ATS-F. Three seconds after issuing the first separation fire signal, the fire signal is repeated as a backup measure.

The same NASA ground stations receiving ATS-F VHF telemetry during the transtage second burn phase will continue to receive telemetry in the synchronous orbit.

In order to meet certain experiment requirements, it is desired that the ATS-F orbital inclination remains below two degrees for at least the first four years after launch. Since a synchronous satellite's orbit is perturbed by the influences of celestial gravitational fields as well as solar pressure, it was determined that the above inclination requirement could only be met by having the synchronous orbit's right ascension of the ascending node (RAAN) be within the range of 260 to 280 degrees. Furthermore, an initial inclination near two degrees is required in order to meet the above four year requirement. Therefore, an initial inclination of 1.8 degrees was selected. Figure I-4 shows synchronous orbit inclination versus time for various RAANs.

Two different computer programs were used to generate the data presented in Figure I-4. One program is called the Launch Window Program (LWP), and
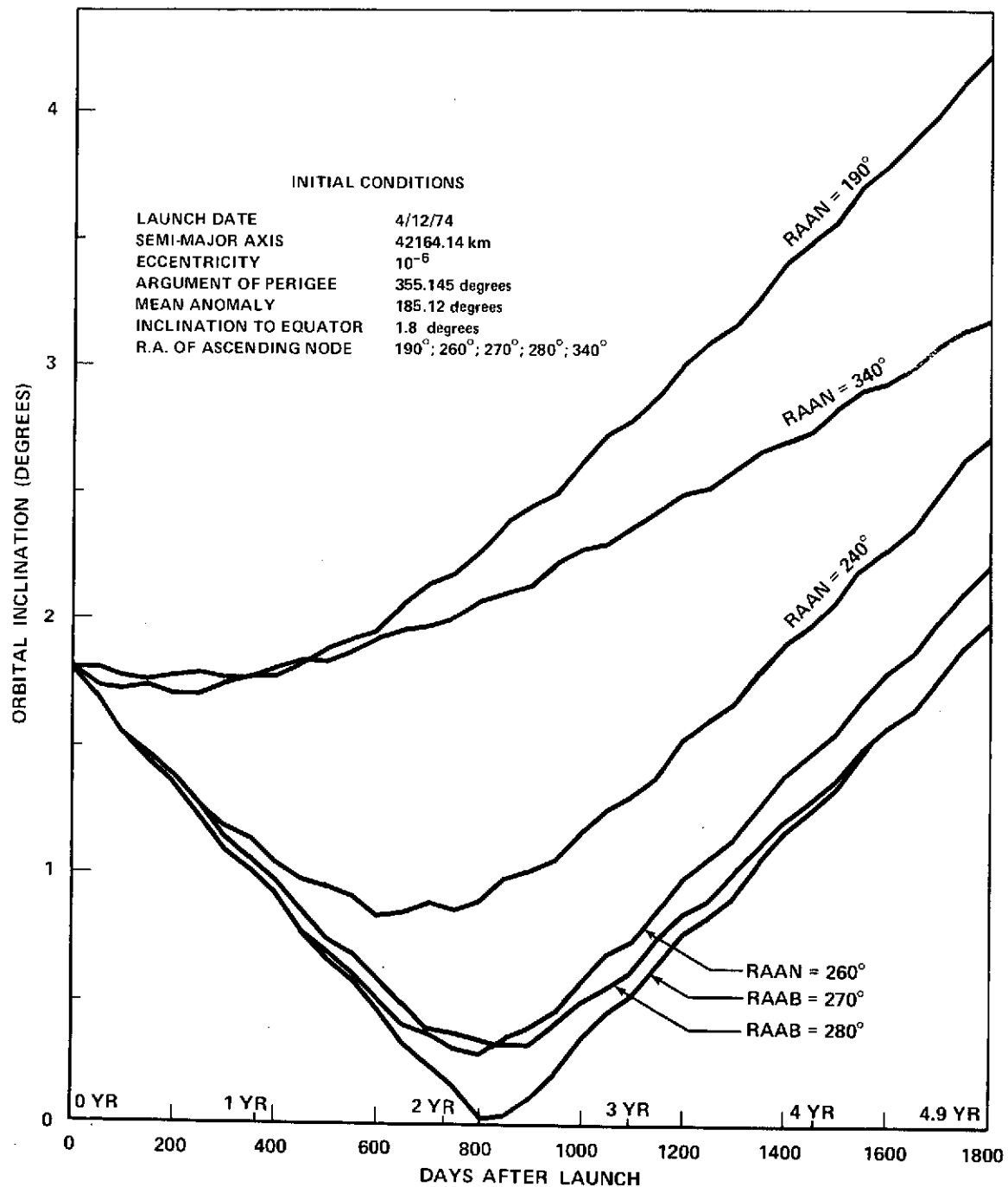
Figure I-4. Synchronous Orbit Inclination Versus Time

the second program is called the Goddard Trajectory Determination System (GTDS). Both programs compute inclination histories, but GTDS is much more accurate than LWP for low eccentricity—low inclination orbits.

The following computer runs were made by Mr. George Marechek, Jr., of Code 552.1, the Orbit Determination and Maneuver Section of the Trajectory and Dynamics Branch, all using an IBM 360/95:

Date of Run	Program Used	Launch Date	Initial Inclination (deg)	Initial Sync Orbit Nodal Ranges (deg)
9/14/72	LWP	4/17/74	1.8	210 to 290, by 5
9/27/72	LWP	10/21/74	1.8	190 to 340, by 10
10/10/72	GTDS	4/17/74	0.0001	260 to 280, by 5
11/10/72	GTDS	4/17/74	1.0	250 to 290, by 10

The results between the first and second runs above indicate that the inclination history is relatively unaffected by the launch date alone.

I. Retro Burn Phase

About 1626 seconds after separation, the Transtage performs a 60-second retro burn maneuver. This terminal maneuver removes the Titan transtage from the orbital path of ATS, and thus further precludes any subsequent interference with ATS orbit operations. The Transtage's retro burn is directed opposite the velocity vector of an impulse of 10 to 12 feet per second.

J. Summary of the Launch Trajectory

The sequence of major launch events is listed in Table I-2. A ground plot of the launch trajectory is shown in Figure I-5, while an altitude profile is displayed in Figure I-6. A polar view of the launch trajectory is shown in Figure I-7. An artistic view of the trajectory, showing major attitude changes is displayed in Figure I-8, and is accompanied with a description in Table I-3.

II. LAUNCH VEHICLE MARK EVENTS

During the Titan launch vehicle trajectory, thirteen mark events have been identified as ATS/Titan mark events and are listed in Table II-1. Shortly after

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Table I-2

ATS-F Launch Sequence

Time After Liftoff (sec)	Event
0	Liftoff with solid rocket motor ignition
109	Stage I ignition
121	Jettison solid rocket motors
256	Stage I tailoff, stage II ignition
257	Jettison Stage I
305	Jettison payload fairing
464	Stage II tailoff
480	Jettison Stage II, injection into parking orbit
4331	Orient for first burn of transtage
4346	Transtage ignition
4657	Transtage cutoff, injection into trans-stage orbit
4759	Begin thermal maneuver
6002	Orient to first telemetry attitude
6302	Return to thermal maneuver
12260	Orient to second telemetry attitude
12560	Return to thermal maneuver
18518	Orient to third telemetry attitude
18818	Return to thermal maneuver
23660	Orient for second burn of transtage
23816	Transtage second ignition
23925	Transtage cutoff, injection into synchronous orbit
24098 = 6.69 hours	Payload separation fire signal
24102	Payload separation fire signal (backup)

Table I-2 (Continued)

Time After Liftoff (sec)	Event
24767	Payload separation fire signal (backup)
25724	Begin transtage retro maneuver
25784	Complete transtage retro maneuver
26300 = 7. 31 hours	Disable transtage power buses
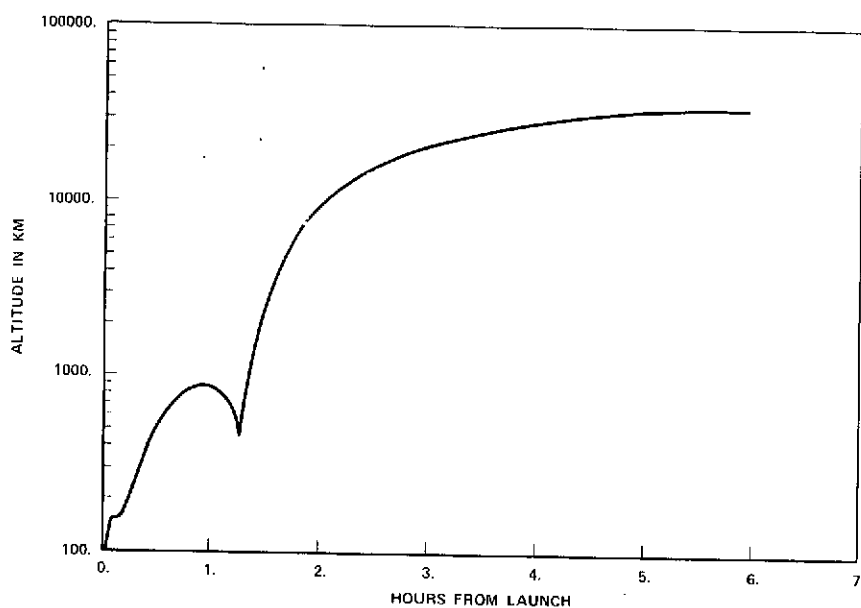
Figure I-6. Altitude Profile of the Launch Trajectory
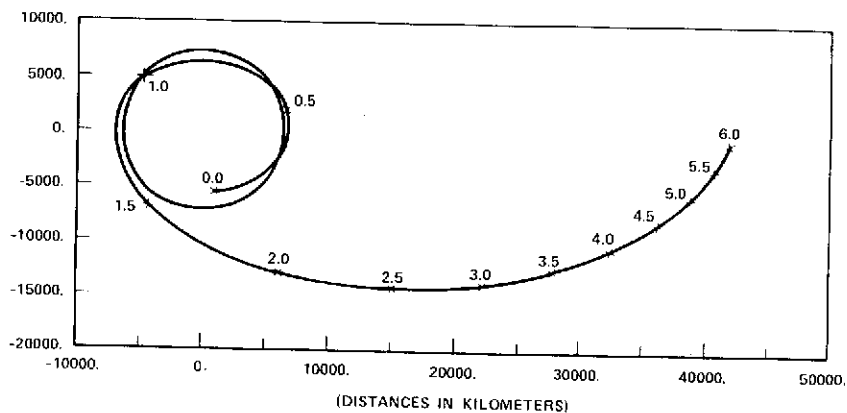
Figure I-7. Polar View of the Launch Trajectory (in GMIC System)

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First 8 events take place within 8 minutes after launch.

Parking orbit

1 sec

1°/sec

1°/sec

1°/sec

17
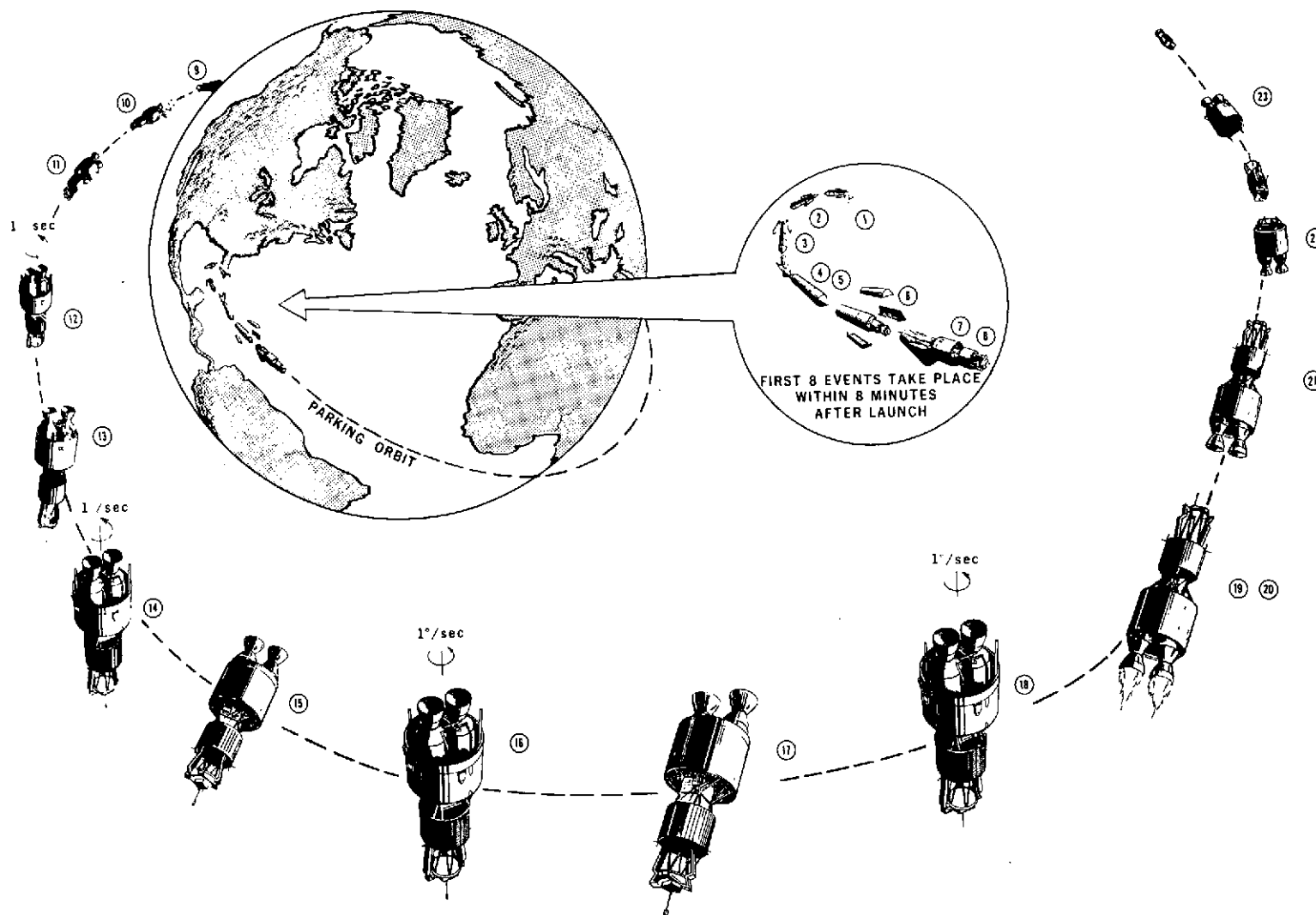
Figure I-8. ATS-F Launch Trajectory Sequence Through Spacecraft Separation

Table I-3

Launch and Separation Time Line*

No.	Event
1	Liftoff solid rocket motor ignition
2	Stage I ignition
3	Jettison solid rocket motors
4	Stage I shutdown and stage II ignition
5	Jettison stage I
6	Jettison payload fairing
7	Stage II burnout
8	Jettison stage II and injection into parking orbit
9	Reorientation for transtage (stage III) burn
10	Transtage ignition
11	Transtage initial cutoff and injection into transfer orbit
12	Begin first thermal orientation maneuver to reorient transtage so the satellite's Z-axis is approximately parrallel to the earth's axis. The satellite derives maximum power in this position because the sun's rays are nearly perpendicular to the solar panels for maximum power. Also in this position, the launch vehicle rotates about its longitudinal axis (satellite Z-axis) at a rate of about 1 degree per second so the sun's energy is equally distributed over the satellite's surface to minimize satellite thermal gradients.
13	Begin first launch vehicle telemetry orientation maneuver to reorient the transtage so widebeam telemetry antenna (low gain) is in proper position for transmitting launch vehicle performance data to ground stations.
14	Reorient transtage to thermal position as in event 12.
15	Begin second telemetry orientation of transtage so the narrowbeam telemetry antenna (high gain) is in proper position for transmitting launch vehicle performance data to ground stations.
16	Reorient transtage to thermal position as in event 12.
17	Begin third telemetry orientation of transtage to narrowbeam (high gain) telemetry readout position as in event 15.
18	Reorient transtage to thermal position as in event 12.
19	Reorientation for second transtage burn.
20	Transtage reignition.
21	Transtage final cutoff and injection into geosynchronous orbit over the equator at approximately 95° West longitude.
22	ATS separates from transtage and adapter.
23	Transtage retros to preclude possible interaction with ATS.

*Events are keyed to Figure I-7.

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the occurrence of each of these events, the ATS Operations Control Center at NASA/GSFC (ATSOCC), will receive both voice announcements and TWX messages from the Air Force stating their occurrence, and time. These mark events are identified in Table II-1.

Table II-1

ATS-F/TITAN-III-C Mark Events

Mark Event No.	Approx. Time from Liftoff (sec)	Event
I	109	Start stage 1 engines
II	121	Jettison SRMs
III	256	Shutdown stage 1 engines and start stage 2 engine
IV	305	Jettison payload fairing
V	464	Shutdown stage 2 engine
VI	480	Jettison stage 2
VII	4346	Start transtage engines
VIII	4657	Shutdown transtage engines
IX	23816	Start transtage engines
X	23925	Shutdown transtage engines
XI	24097	Enable separation fire signal
XII	24098	Separation fire signal
XIII	26300	Turn off TM transmitter and power buss

III. STANDARD ORBITAL PARAMETER MESSAGES

Standard Orbital Parmeter Messages (SOPM) will be sent via teletype from the Air Force to ATSOCC during the launch trajectory to describe the park, transfer, and final orbits. The messages will be based upon C-band pulse radar tracking of the Titan transtage from either single or multiple Titan ground stations. A sample SOPM is shown in Figure III-1.

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The following SOPMs will be sent:

1. Initial Park Orbit (computed on data taken 30 seconds after injection)

2. Refined Park Orbit (multiple station, sent to ATSOCC about time of transfer orbit injection)

3. Initial Transfer Orbit (computed on data taken by Hawaii)

4. Interim Transfer Orbit (single station data during TM windows 7 or 8)

5. Refined transfer Orbit (multiple station)

6. Initial Pre-separation Orbit (single station)

7. Refined Pre-separation Orbit (multiple station)

8. Initial Post-separation Orbit (single station)

9. Refined Post-separation Orbit (multiple station)

10. Initial Post-retro Orbit (single station)

11. Refined Post-retro Orbit (multiple station)

```
OCD 183A
SS GDCS GCDF GCDF
DE GCDU
14/0005Z

GRTS ORBITAL PARAMETER MESSAGE
SUPIDEN 1022
VEHICLE ATS-F
 1 EPOCH 4/18/1973        0 0 : 0.0 GMT
 2 GEOD LAT                     0.0 DEG
 3 LONG                    201.4107 DEG
 4 INCL                  99.0912137 DEG
 5 FLT PATH ANG             -0.0000 DEG
 6 HEIGHT                  917.2262 KM
 7 INER VEL               7.3913417 KM/SEC
 8 APOCTR HT               917.2262 KM
 9 PERICTR HT              915.6933 KM
10 SEMAJAX                7294.6248 KM
11 ECC                  0.000105075
12 AZ                     -170.9088 DEG
13 R A OF ASC NODE         227.616 DEG
14 ARG OF PERICTR          360.000 DEG
15 TRU ANOM               -180.000 DEG
16 PERIOD                 103.3386 MIN
17 T OF PERICTR             51.669 MIN
18 X       0.491778570999999980D 04 KM
   Y       0.538870273199999990D 04 KM
   Z       0.0                       KM
19 XDOT    0.862649289999999990D 00 KM/SEC
   YDOT   -0.787262649999999990D 00 KM/SEC
   ZDOT   -0.729849199999999990D 01 KM/SEC

14/0005Z APR GCQU
```

Figure III-1. Sample Orbital Parameter Message

IV. STADAN GROUND STATION VISIBILITY

Fifteen Space Tracking and Data Acquisition Network (STADAN) ground stations will support the ATS-F/Titan launch trajectory. These stations are in addition to stations operated by the U. S. Air Force for the support of the Titan vehicle. Table IV-1 lists each of the STADAN stations and their supporting responsibility during the launch trajectory. Figure IV-1 summarizes the tracking and telemetry ground station visibilities throughout the launch trajectory. Note that there are five gaps in ATS-F telemetry coverage:

ATS Telemetry Gaps

From	To	Duration
9.5 minutes after launch	21.2 minutes	11.7 minutes
25.7	29.5	3.8 minutes
47.5	50.1	2.6 minutes
65.5	68.7	3.2 minutes
73.0	88.0	15 minutes

The look angles for each of STADAN stations during the launch trajectory are plotted in Figures IV-2 through IV-16. The radio horizon was assumed to be three degrees in elevation, unless the actual station mask was known.

Table IV-1

STADAN Stations Supporting ATS-F Launch

Station Name	Code	ATS TM Reception	ATS Commanding	Titan C-band Tracking	Titan S-band TM
Merritt I.	MIL	X	X		X
Quito, Equador	QUI		X		
Santiago, Chile	AGO		X		
Bermuda I.	BDA	X		X	X
Ascension I.	ACN	X	X		
Winkfield, England	WNK		X		
Johannesburg, S. Africa	BUR	X	X		
Tananarive, Madagascar	TAN	X	X	X	
Carnarvon, Australia	CRO	X			X
Hawaii I.	HAW				X
Mojave, California	MOJ	X	X		
Hybrid (at Mojave)	HYB	X	X		
Rosman, North Carolina	ROS	X	X		
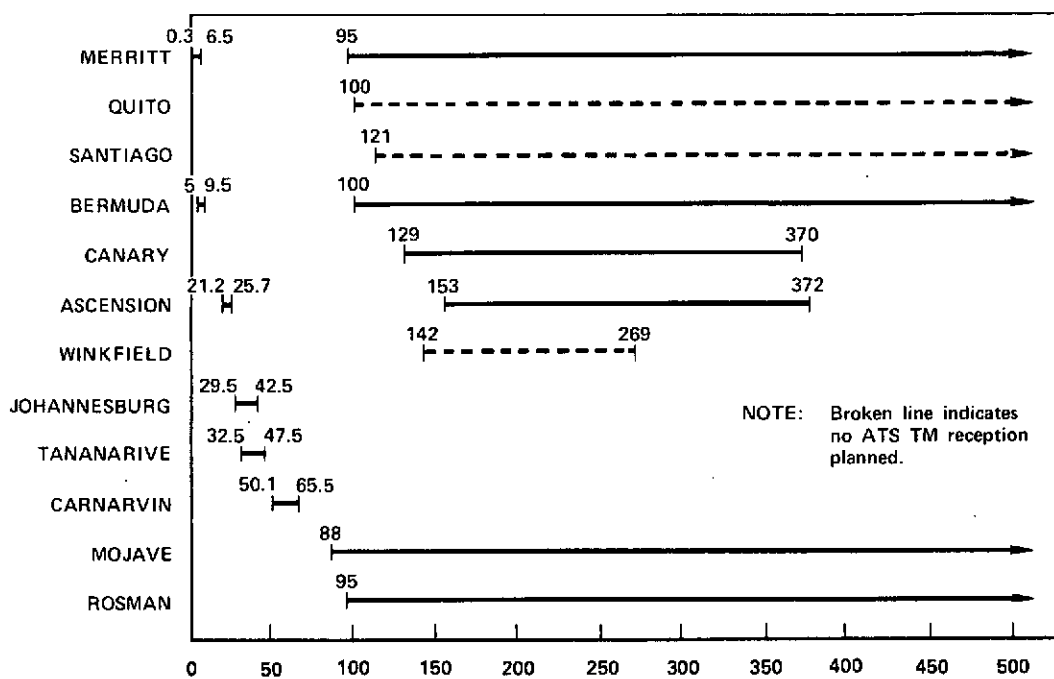
Figure IV-1. Station Visibility Summary
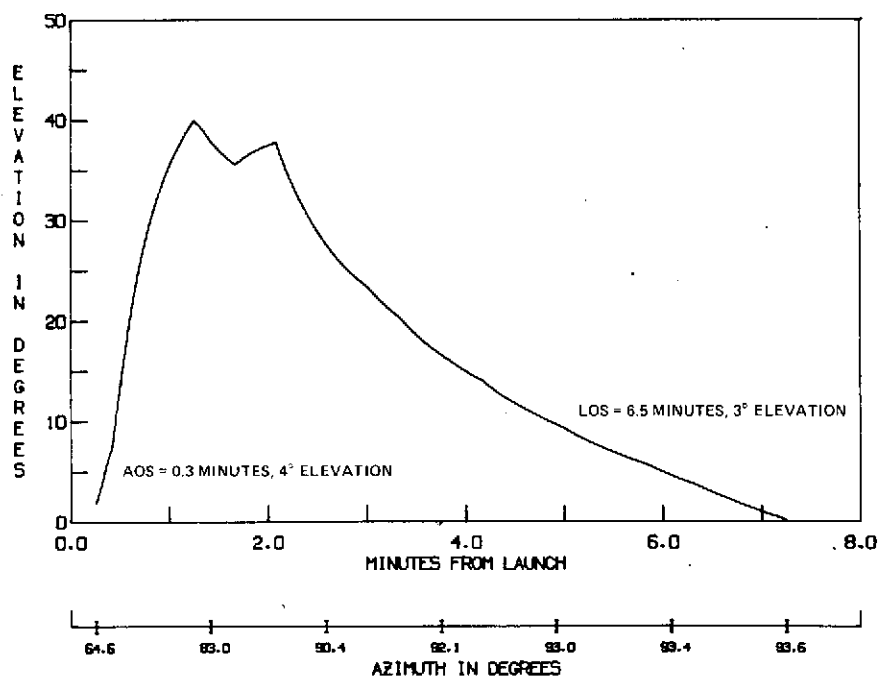
Figure IV-2. Look Angles for Merritt
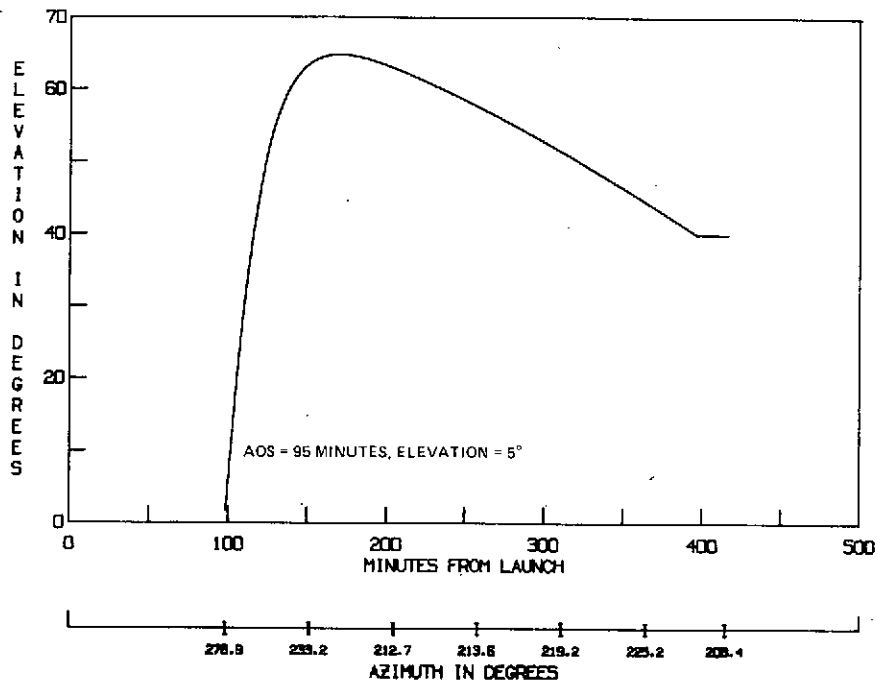
Figure IV-3. Look Angles for Merritt
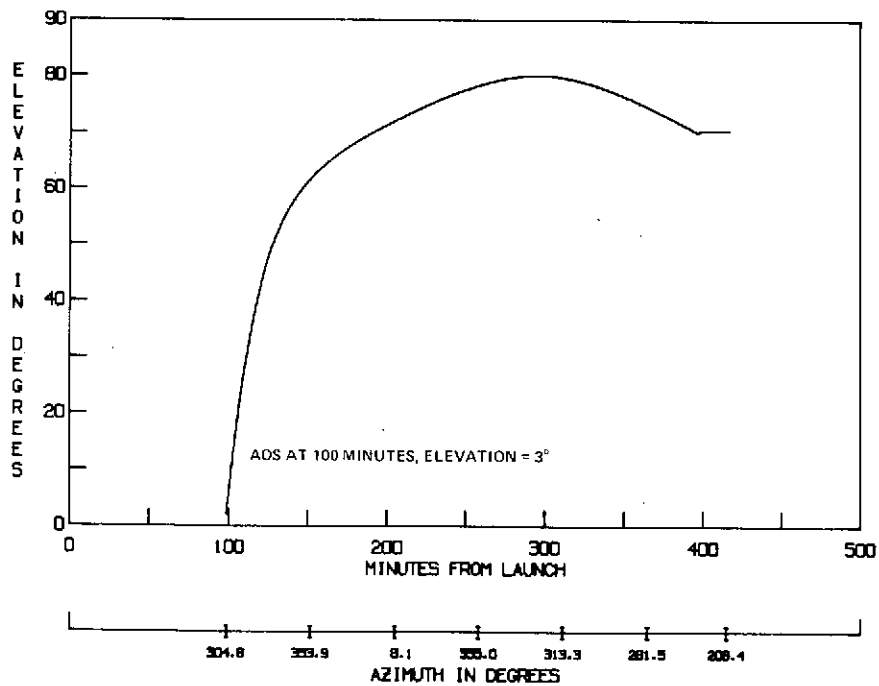
Figure IV-4. Look Angles for Quito
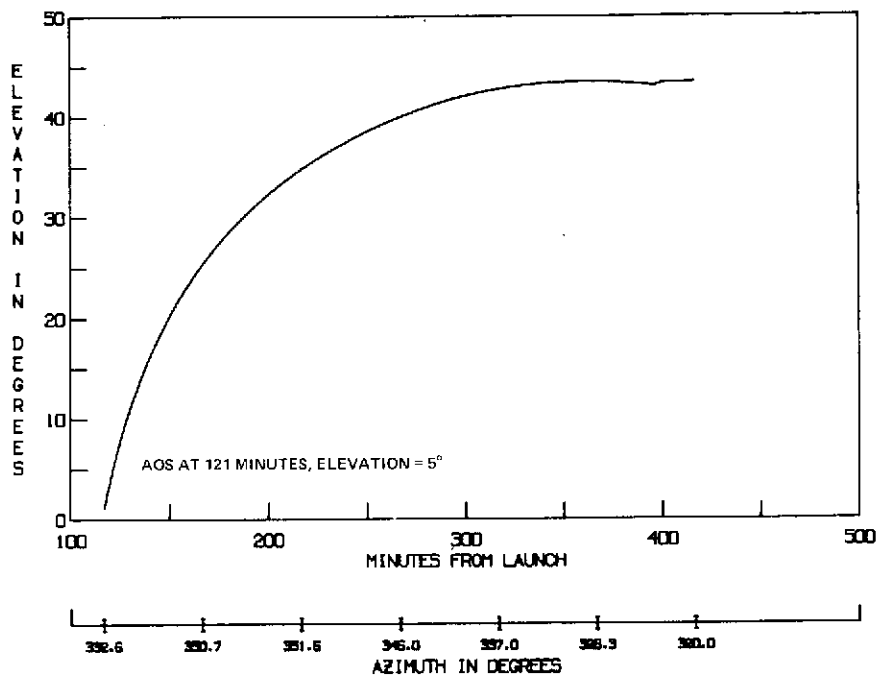
Figure IV-5. Look Angles for Santiago
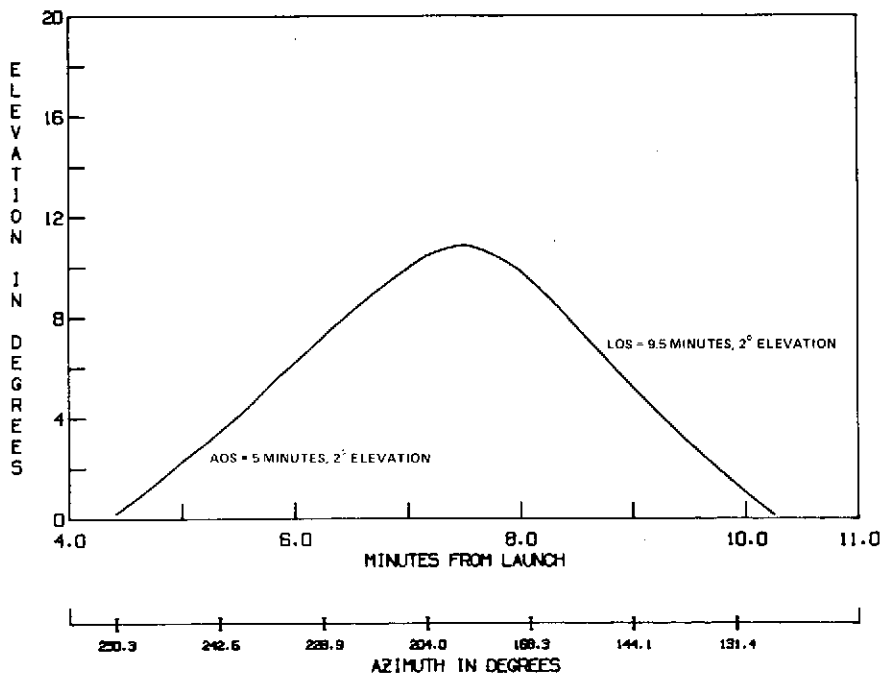
Figure IV-6. Look Angles for Bermuda

25
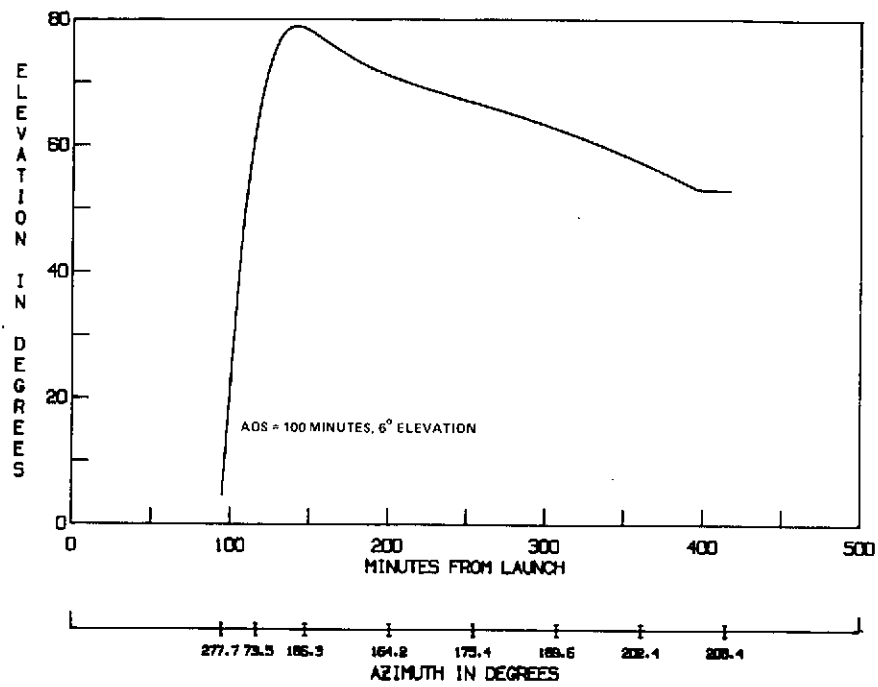
Figure IV-7. Look Angles for Bermuda
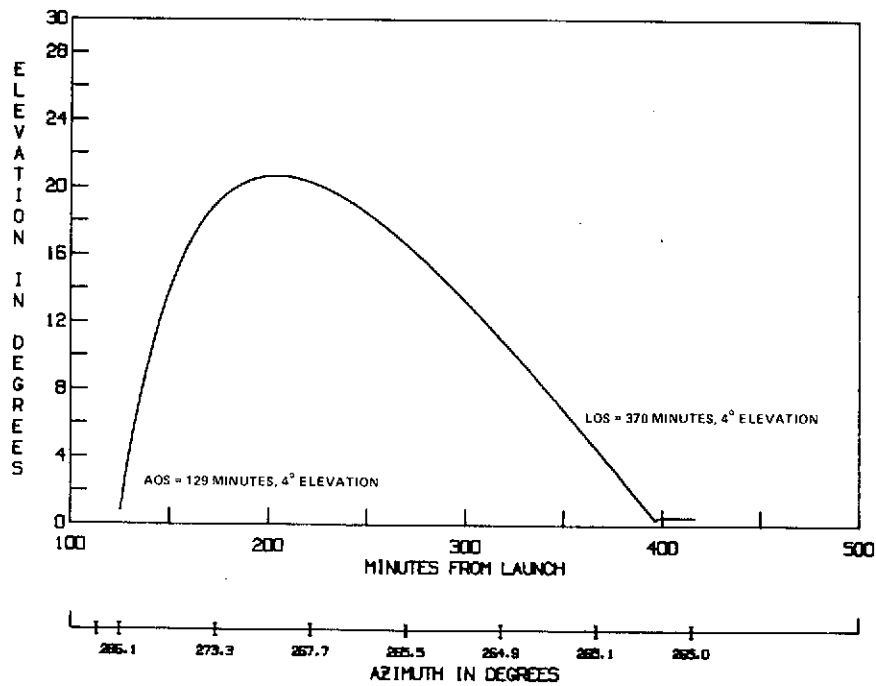
Figure IV-8. Look Angles for Canary
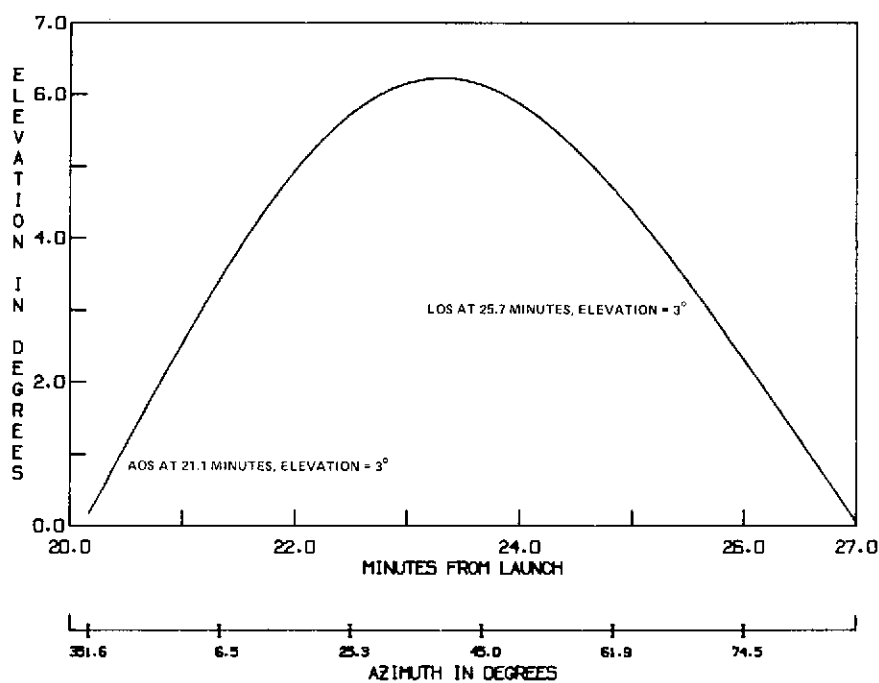
Figure IV-9. Look Angles for Ascension
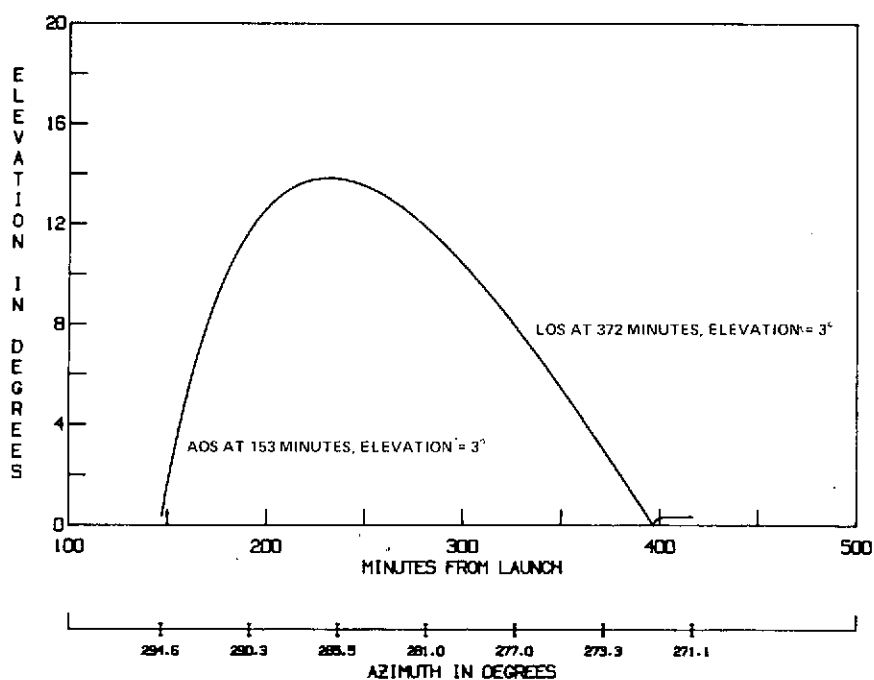
Figure IV-10. Look Angles for Ascension

27
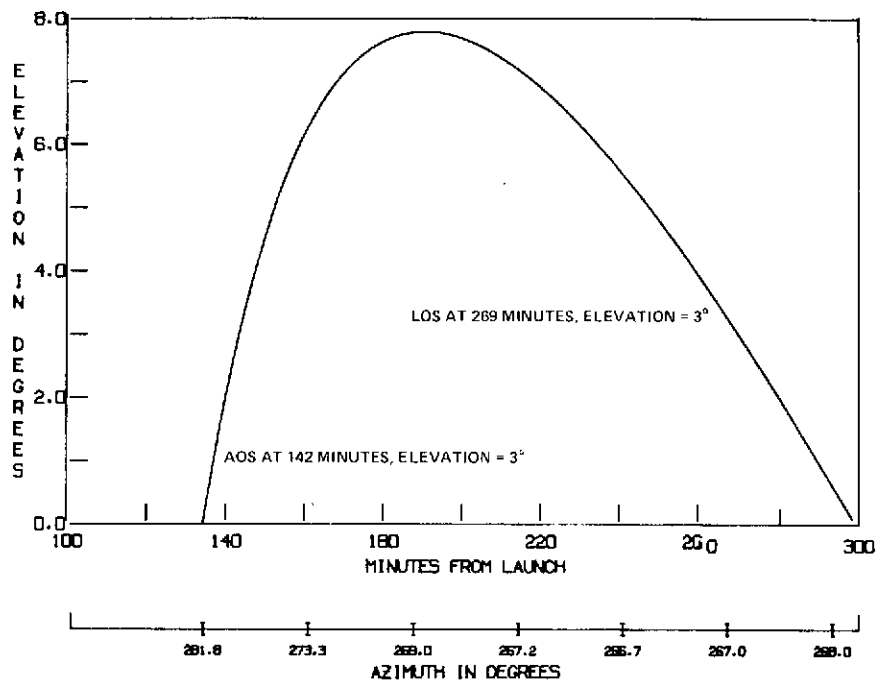
Figure IV-11. Look Angles for Winkfield
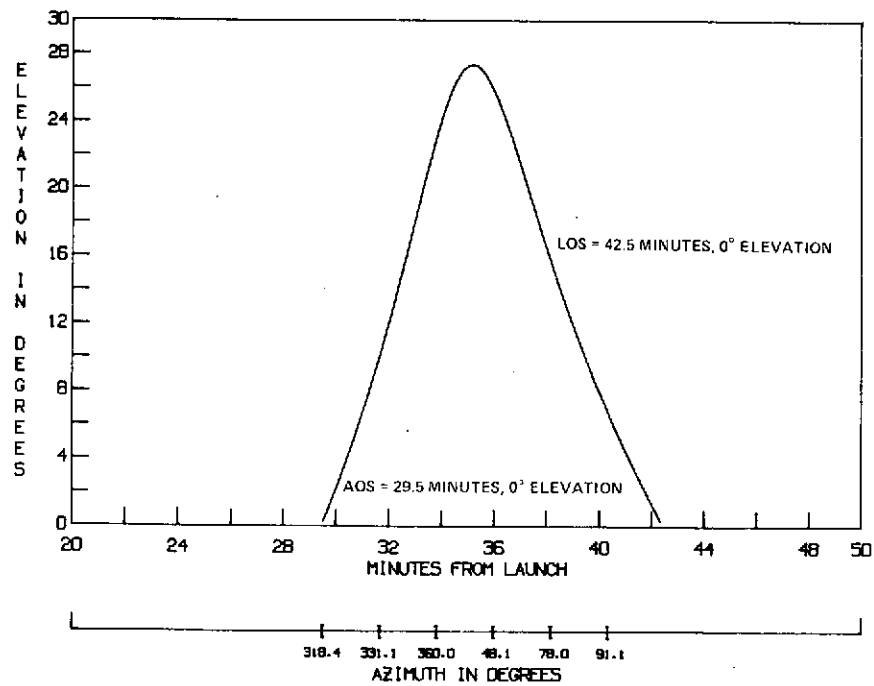
Figure IV-12. Look Angles for Johannesburg

28
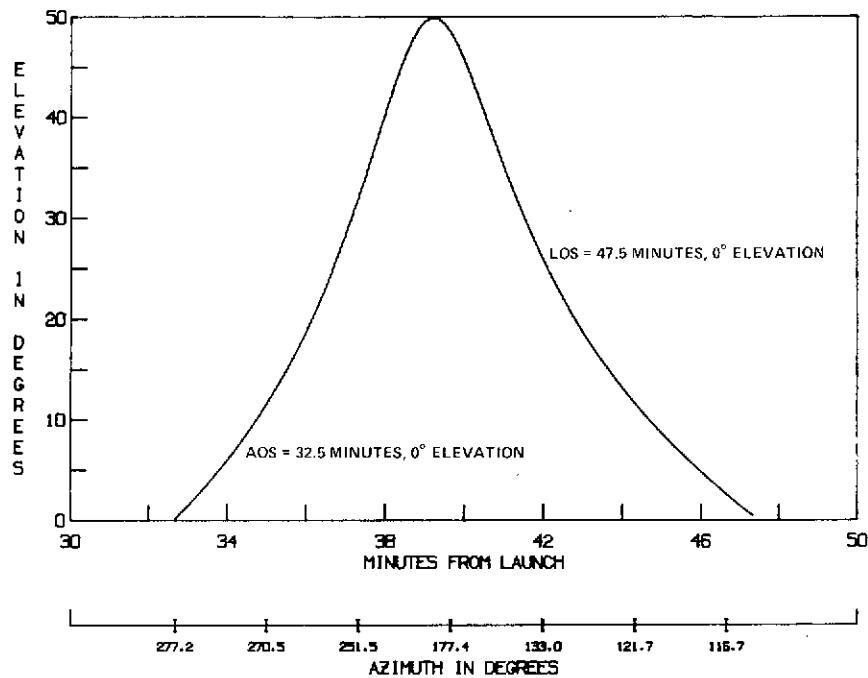
Figure IV-13. Look Angles for Tananarive
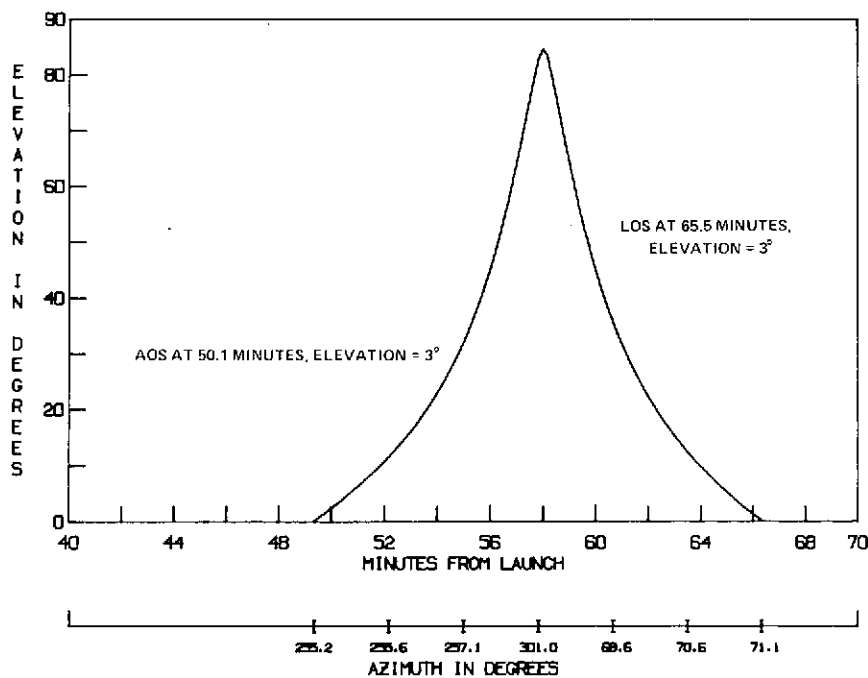
Figure IV-14. Look Angles for Carnarvon
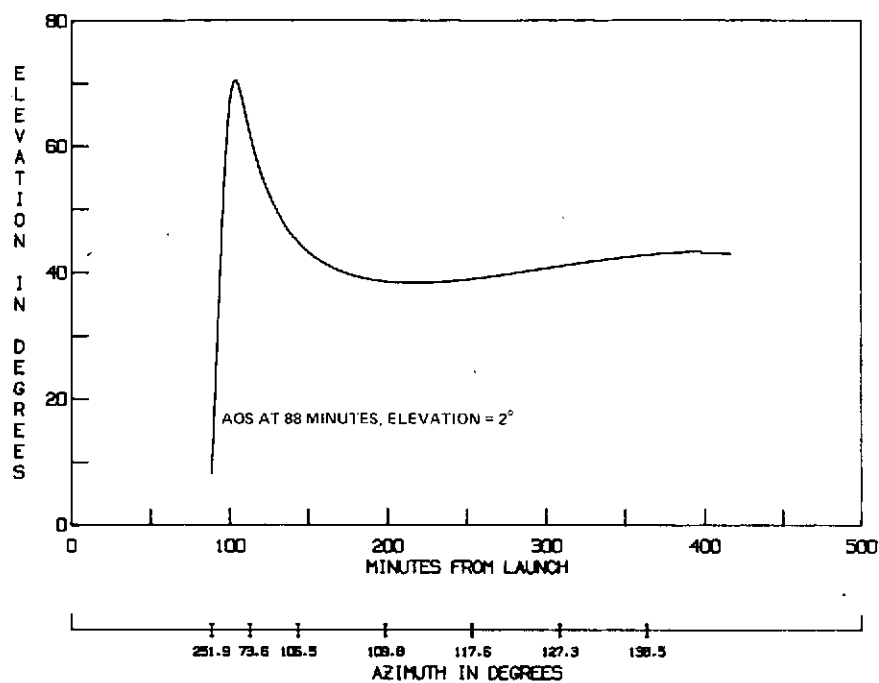
Figure IV-15. Look Angles for Mojave
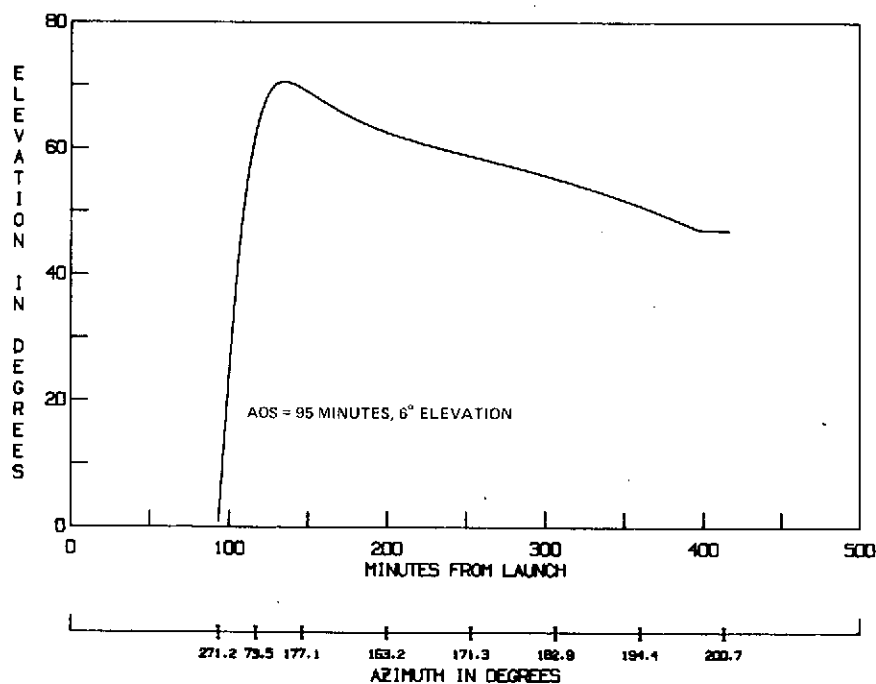
Figure IV-16. Look Angles for Rosman

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V. LAUNCH WINDOW

A. RAAN Selection Requirements

The right ascension of the ascending node (RAAN) of the synchronous orbit shall be between 266 to 274 degrees, as previously discussed in Section I-H. If other spacecraft requirements do not permit the park and transfer orbit to have the same node as the synchronous orbit, then nodal rotation by the Transtage during its second burn will be necessary. Based on the expected payload mass of about 3100 pounds, the Titan Transtage will be able to rotate the node within ±50 degrees, if necessary, though a 50 pound payload penalty is introduced by the additional fuel requirements.

B. Shadow Duration Requirements

The shadow duration from the time of fairing jettison to injection into synchronous orbit shall not exceed 40 minutes. Furthermore, the transfer orbit shadow duration is never to exceed 30 minutes. These shadow duration requirements are due to thermal and solar-cell power considerations. Also, the spacecraft shall not be in shadow for the one-hour period prior to synchronous injection.

C. Sun Angle Requirements

To enhance solar power generation during the transfer orbit coast period to meet the power needs of the Attitude Control Subsystem, and the Telemetry and Command Subsystem during launch, the sun vector shall be within ±30 degrees from a plane normal to the launch vehicle roll axis.

D. Width of Launch Window Requirement

A minimum 30 minute window must be available for each day during the 12 months starting April 1, 1974 to provide ample launch flexibility.

E. Synchronous Orbit Eclipse Periods

For a 1.8 degree synchronous orbit inclination, the spacecraft will be in shadow for part of its orbit during the vernal and autumnal equinox periods.

During these eclipse seasons, it is also desirable to avoid having the spacecraft injection occur during shadow or within 3.5 hours of entering shadow. This requirement is satisfied by not injecting the spacecraft into synchronous orbit between 0200 GMT and 1030 GMT during these eclipse seasons.

F. Calculation of Launch Hour

In preparing the launch window, the launch hour required to obtain a given RAAN for the park orbit on each day of the year was computed. A Fortran program was written by R. Walsh for this calculation. A listing of the daily opening and closing of the launch window is made in Table V-1. These times agree with data supplied by Martin Marietta in December 1973.

G. Calculation of Length of Trajectory Shadow Periods

In selecting a launch window for each day of the year, the penumbra shadow enter and exit times for the trajectory were determined using a Fortran program written by R. Walsh for this calculation.

H. Calculation of Synchronous Orbit Shadow Periods

The synchronous orbit shadow periods were calculated using a Fortran program written by R. Walsh. For a synchronous orbit with an inclination of 1.8 degrees, the 1974 Spring eclipse season can begin as early as 20 February 1974 and end as late as 19 April 1974, depending upon the actual orbit. Likewise, for a synchronous orbit with an inclination of 1.8 degrees, the 1974 Fall eclipse season can begin as early as 25 August 1974 and end as late as 22 October 1974, depending upon the actual orbit. For 1975, the Spring eclipse season can begin as early as 21 February 1975 and end as late as 19 April 1975.

Using a subsatellite point of 94.0 degrees west longitude, eclipse season boundaries are listed in Table V-2. These results were verified by another program written by Goddard entitled, ITEM.

I. Description of the Launch Window Selected

The launch window for days 091 to 264 is between RAANs in the interval of 266 to 274 degrees, and all requirements are met. For days 265 to 294, launch window is shifted later in time, because otherwise the 30 minute maximum shadow duration in the transfer orbit would be violated with RAANs between 266 to 274 degrees. For days 295 to 345, the launch window is shifted even later in time, in order to have the launch window be as close to a RAAN of 270 degrees, without exceeding the 30 minute maximum shadow duration. For day 346 to 1974 to day 091 of 1975, the launch window is between RAANs in the interval of 266 to 274 degrees. The resulting launch window is approximately 32 minutes in duration for every day of the year. The launch window is shown in Figure V-1.

Table V-1
Time of Launch

YEAR.DAY	MONTH.DAY	RAAN°		LIFTOFF (GMT)	
		OPENING	CLOSING	OPENING	CLOSING
1974.091	4.01	266.00	274.00	1651.30	1723.24
1974.092	4.02	266.00	274.00	1647.34	1719.28
1974.093	4.03	266.00	274.00	1643.38	1715.33
1974.094	4.04	266.00	274.00	1639.42	1711.37
1974.095	4.05	266.00	274.00	1635.46	1707.41
1974.096	4.06	266.00	274.00	1631.50	1703.45
1974.097	4.07	266.00	274.00	1627.54	1659.49
1974.098	4.08	266.00	274.00	1623.58	1655.53
1974.099	4.09	266.00	274.00	1620.02	1651.57
1974.100	4.10	266.00	274.00	1616.06	1648.01
1974.101	4.11	266.00	274.00	1612.11	1644.05
1974.102	4.12	266.00	274.00	1608.15	1640.09
1974.103	4.13	266.00	274.00	1604.19	1636.13
1974.104	4.14	266.00	274.00	1600.23	1632.18
1974.105	4.15	266.00	274.00	1556.27	1628.22
1974.106	4.16	266.00	274.00	1552.31	1624.25
1974.107	4.17	266.00	274.00	1548.35	1620.30
1974.109	4.18	266.00	274.00	1544.39	1616.34
1974.109	4.19	266.00	274.00	1540.43	1612.38
1974.110	4.20	266.00	274.00	1536.47	1608.42
1974.111	4.21	266.00	274.00	1532.51	1604.46
1974.112	4.22	266.00	274.00	1528.56	1600.50
1974.113	4.23	266.00	274.00	1524.60	1556.54
1974.114	4.24	266.00	274.00	1521.04	1552.58
1974.115	4.25	266.00	274.00	1517.08	1549.03
1974.116	4.26	266.00	274.00	1513.12	1545.07
1974.117	4.27	266.00	274.00	1509.16	1541.11
1974.118	4.28	266.00	274.00	1505.20	1537.15
1974.119	4.29	266.00	274.00	1501.24	1533.19
1974.120	4.30	266.00	274.00	1457.28	1529.23
1974.121	5.01	266.00	274.00	1453.32	1525.27
1974.122	5.02	266.00	274.00	1449.36	1521.31
1974.123	5.03	266.00	274.00	1445.41	1517.35
1974.124	5.04	266.00	274.00	1441.45	1513.39
1974.125	5.05	266.00	274.00	1437.49	1509.43
1974.126	5.06	266.00	274.00	1433.53	1505.48
1974.127	5.07	266.00	274.00	1429.57	1501.52
1974.128	5.08	266.00	274.00	1426.01	1457.55
1974.129	5.09	266.00	274.00	1422.05	1453.60
1974.130	5.10	266.00	274.00	1418.09	1450.04
1974.131	5.11	266.00	274.00	1414.13	1446.08
1974.132	5.12	266.00	274.00	1410.17	1442.12
1974.133	5.13	266.00	274.00	1406.21	1438.15
1974.134	5.14	266.00	274.00	1402.26	1434.20
1974.135	5.15	266.00	274.00	1358.30	1430.24
1974.136	5.16	266.00	274.00	1354.34	1426.28

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Table V-1 (Cont'd.)

YEAR.DAY	MONTH.DAY	RAAN°		LIFTOFF (GMT)	
		OPENING	CLOSING	OPENING	CLOSING
1974.137	5.17	266.0 C	274.0 0	1350.38	1422.33
1974.138	5.18	266.00	274.00	1346.42	1418.37
1974.139	5.19	266.C C	274.0 0	1342.46	1414.41
1974.140	5.20	266.0 C	274.0 0	1338.50	1410.45
1974.141	5.21	266.0 C	274.00	1334.54	1406.49
1974.142	5.22	266.C C	274.0 0	1330.58	1402.53
1974.143	5.23	266.00	274.0 C	1327.02	1358.57
1974.144	5.24	266.0 C	274.C C	1323.06	1355.01
1974.145	5.25	266.C C	274.00	1319.10	1351.05
1974.146	5.26	266.0 C	274.00	1315.15	1347.09
1974.147	5.27	266.0 C	274.C C	1311.19	1343.13
1974.148	5.28	266.C 0	274.0 C	1307.23	1339.18
1974.149	5.29	266.0 C	274.00	1303.27	1335.22
1974.150	5.30	266.0 C	274.0 0	1259.31	1331.26
1974.151	5.31	266.C C	274.C C	1255.35	1327.30
1974.152	6.01	266.0 0	274.00	1251.39	1323.34
1974.153	6.02	266.0 C	274.0 0	1247.43	1319.38
1974.154	6.03	266.C C	274.00	1243.47	1315.42
1974.155	6.04	266.0 C	274.C C	1239.51	1311.45
1974.156	6.05	266.0 C	274.C C	1235.55	1307.50
1974.157	6.06	266.0 C	274.00	1231.60	1303.54
1974.158	6.07	266.0 C	274.0 C	1228.04	1259.58
1974.159	6.08	266.C 0	274.00	1224.08	1256.03
1974.160	6.09	266.C C	274.C 0	1220.12	1252.07
1974.161	6.10	266.0 C	274.C C	1216.16	1248.11
1974.162	6.11	266.0 C	274.C 0	1212.20	1244.15
1974.163	6.12	266.0 C	274.C 0	1208.24	1240.19
1974.164	6.13	266.0 C	274.0 0	1204.28	1236.23
1974.165	6.14	266.C C	274.0 0	1200.32	1232.27
1974.166	6.15	266.0 C	274.0 C	1156.36	1228.31
1974.167	6.16	266.C C	274.C 0	1152.40	1224.35
1974.168	6.17	266.0 C	274.C 0	1148.45	1220.39
1974.169	6.18	266.0 C	274.C 0	1144.49	1216.43
1974.170	6.19	266.C 0	274.C C	1140.53	1212.48
1974.171	6.20	266.0 0	274.0 C	1136.57	1208.52
1974.172	6.21	266.C 0	274.C 0	1133.01	1204.56
1974.173	6.22	266.0 C	274.00	1129.05	1200.60
1974.174	6.23	266.0 C	274.C C	1125.09	1157.04
1974.175	6.24	266.0 C	274.C 0	1121.13	1153.08
1974.176	6.25	266.0 C	274.00	1117.17	1149.12
1974.177	6.26	266.0 C	274.00	1113.21	1145.16
1974.178	6.27	266.0 C	274.C 0	1109.25	1141.20
1974.179	6.28	266.0 0	274.0 0	1105.30	1137.24
1974.180	6.29	266.0 C	274.0 0	1101.34	1133.28
1974.181	6.30	266.C C	274.C 0	1057.38	1129.33
1974.182	7.01	266.C C	274.C 0	1053.42	1125.37

Table V-1 (Cont'd.)

YEAR.DAY	MONTH.DAY	RAAN°		LIFTOFF (GMT)	
		OPENING	CLOSING	OPENING	CLOSING
1974.183	7.02	266.00	274.00	1049.46	1121.41
1974.184	7.03	266.00	274.00	1045.50	1117.45
1974.185	7.04	256.00	274.00	1041.54	1113.49
1974.186	7.05	266.00	274.00	1037.58	1109.53
1974.187	7.06	266.00	274.00	1034.02	1105.57
1974.188	7.07	266.00	274.00	1030.06	1102.01
1974.189	7.08	266.00	274.00	1026.10	1058.05
1974.190	7.09	266.00	274.00	1022.15	1054.09
1974.191	7.10	266.00	274.00	1018.19	1050.13
1974.192	7.11	266.00	274.00	1014.23	1046.18
1974.193	7.12	266.00	274.00	1010.27	1042.22
1974.194	7.13	266.00	274.00	1006.31	1038.25
1974.195	7.14	266.00	274.00	1002.35	1034.30
1974.196	7.15	266.00	274.00	958.39	1030.34
1974.197	7.16	266.00	274.00	954.43	1026.38
1974.198	7.17	266.00	274.00	950.47	1022.42
1974.199	7.18	266.00	274.00	946.51	1018.46
1974.200	7.19	266.00	274.00	942.55	1014.50
1974.201	7.20	266.00	274.00	938.60	1010.54
1974.202	7.21	266.00	274.00	935.04	1006.58
1974.203	7.22	256.00	274.00	931.08	1003.03
1974.204	7.23	266.00	274.00	927.12	959.07
1974.205	7.24	266.00	274.00	923.16	955.11
1974.206	7.25	266.00	274.00	919.20	951.15
1974.207	7.26	266.00	274.00	915.24	947.19
1974.208	7.27	266.00	274.00	911.28	943.23
1974.209	7.28	266.00	274.00	907.32	939.27
1974.210	7.29	266.00	274.00	903.36	935.31
1974.211	7.30	266.00	274.00	859.40	931.35
1974.212	7.31	266.00	274.00	655.45	927.39
1974.213	8.01	266.00	274.00	851.49	923.43
1974.214	8.02	266.00	274.00	847.53	919.48
1974.215	8.03	266.00	274.00	843.57	915.52
1974.216	8.04	266.00	274.00	840.01	911.56
1974.217	8.05	266.00	274.00	836.05	907.60
1974.218	8.06	266.00	274.00	832.09	904.04
1974.219	8.07	266.00	274.00	628.13	900.08
1974.220	8.08	266.00	274.00	824.17	856.12
1974.221	8.09	266.00	274.00	820.21	852.15
1974.222	8.10	266.00	274.00	816.25	848.20
1974.223	8.11	266.00	274.00	812.30	844.24
1974.224	8.12	266.00	274.00	808.34	840.28
1974.225	8.13	266.00	274.00	804.38	836.32
1974.226	8.14	266.00	274.00	800.42	832.37
1974.227	8.15	266.00	274.00	756.46	828.41
1974.228	8.16	266.00	274.00	752.50	824.45

Table V-1 (Cont'd.)

		RAAN°		LIFTOFF (GMT)	
YEAR.DAY	MONTH.DAY	OPENING	CLOSING	OPENING	CLOSING
1974.229	8.17	266.00	274.00	748.54	820.49
1974.230	8.18	266.00	274.00	744.58	816.53
1974.231	8.19	266.00	274.00	741.02	812.57
1974.232	8.20	266.00	274.00	737.06	809.61
1974.233	8.21	266.00	274.00	733.10	805.05
1974.234	8.22	266.00	274.00	729.15	801.09
1974.235	8.23	266.00	274.00	725.19	757.13
1974.236	8.24	266.00	274.00	721.23	753.17
1974.237	8.25	266.00	274.00	717.27	749.22
1974.238	8.26	266.00	274.00	713.31	745.26
1974.239	8.27	266.00	274.00	709.35	741.30
1974.240	8.28	266.00	274.00	705.39	737.34
1974.241	8.29	266.00	274.00	701.43	733.38
1974.242	8.30	266.00	274.00	657.47	729.42
1974.243	8.31	266.00	274.00	653.51	725.45
1974.244	9.01	266.00	274.00	649.55	721.51
1974.245	9.02	266.00	274.00	645.60	717.54
1974.246	9.03	266.00	274.00	642.04	713.58
1974.247	9.04	266.00	274.00	638.08	710.02
1974.248	9.05	266.00	274.00	634.12	706.07
1974.249	9.06	266.00	274.00	630.16	702.11
1974.250	9.07	266.00	274.00	626.20	658.15
1974.251	9.08	266.00	274.00	622.24	654.19
1974.252	9.09	266.00	274.00	618.28	650.23
1974.253	9.10	266.00	274.00	614.32	646.27
1974.254	9.11	266.00	274.00	610.36	642.31
1974.255	9.12	266.00	274.00	606.40	638.35
1974.256	9.13	266.00	274.00	602.45	634.39
1974.257	9.14	266.00	274.00	558.49	630.43
1974.258	9.15	266.00	274.00	554.53	626.47
1974.259	9.16	266.00	274.00	550.57	622.52
1974.260	9.17	266.00	274.00	547.01	618.56
1974.261	9.18	266.00	274.00	543.05	614.60
1974.262	9.19	266.00	274.00	539.09	611.04
1974.263	9.20	266.00	274.00	535.13	607.08
1974.264	9.21	266.00	274.00	531.17	603.12
1974.265	9.22	312.00	320.00	830.51	902.45
1974.266	9.23	312.00	320.00	826.55	858.50
1974.267	9.24	312.00	320.00	822.59	854.54
1974.268	9.25	312.00	320.00	819.03	850.58
1974.269	9.26	312.00	320.00	815.08	847.02
1974.270	9.27	312.00	320.00	811.12	843.06
1974.271	9.28	312.00	320.00	807.16	839.11
1974.272	9.29	312.00	320.00	803.20	835.15
1974.273	9.30	312.00	320.00	759.24	831.19
1974.274	10.01	312.00	320.00	755.28	827.23

Table V-1 (Cont'd.)

YEAR.DAY	MONTH.DAY	RAAN°		LIFTOFF (GMT)	
		OPENING	CLOSING	OPENING	CLOSING
1974.275	10.02	312.00	320.00	751.32	823.27
1974.276	10.03	312.00	320.00	747.36	819.31
1974.277	10.04	312.00	320.00	743.40	815.35
1974.278	10.05	312.00	320.00	739.44	811.39
1974.279	10.06	312.00	320.00	735.48	807.43
1974.280	10.07	312.00	320.00	731.53	803.47
1974.281	10.08	312.00	320.00	727.57	799.51
1974.282	10.09	312.00	320.00	724.01	755.55
1974.283	10.10	312.00	320.00	720.05	751.60
1974.284	10.11	312.00	320.00	716.09	748.04
1974.285	10.12	316.00	324.00	728.10	800.05
1974.286	10.13	316.00	324.00	724.14	756.09
1974.287	10.14	316.00	324.00	720.19	752.13
1974.288	10.15	316.00	324.00	716.23	748.17
1974.289	10.16	316.00	324.00	712.27	744.22
1974.290	10.17	316.00	324.00	708.31	740.25
1974.291	10.18	317.00	325.00	708.34	740.29
1974.292	10.19	318.00	326.00	708.38	740.32
1974.293	10.20	319.00	327.00	708.41	740.35
1974.294	10.21	320.00	328.00	708.45	740.39
1974.295	10.22	197.00	205.00	2250.13	2322.08
1974.296	10.23	198.00	206.00	2250.17	2322.12
1974.297	10.24	200.00	208.00	2254.20	2326.14
1974.298	10.25	201.00	209.00	2254.23	2326.18
1974.299	10.26	203.00	211.00	2258.26	2330.21
1974.300	10.27	204.00	212.00	2258.29	2330.24
1974.301	10.28	206.00	214.00	2302.32	2334.27
1974.302	10.29	208.00	216.00	2306.35	2338.30
1974.303	10.30	210.00	218.00	2310.38	2342.32
1974.304	10.31	212.00	220.00	2314.40	2346.35
1974.305	11.01	214.00	222.00	2318.43	2350.38
1974.306	11.02	215.00	223.00	2318.47	2350.41
1974.307	11.03	216.00	224.00	2318.50	2350.45
1974.308	11.04	216.00	224.00	2314.54	2346.49
1974.309	11.05	216.00	224.00	2310.58	2342.53
1974.310	11.06	216.00	224.00	2307.02	2338.57
1974.311	11.07	216.00	224.00	2303.06	2335.01
1974.312	11.08	216.00	224.00	2259.10	2331.05
1974.313	11.09	217.00	225.00	2259.14	2331.09
1974.314	11.10	219.00	227.00	2303.17	2335.11
1974.315	11.11	220.00	228.00	2303.20	2335.15
1974.316	11.12	220.00	228.00	2259.24	2331.19
1974.317	11.13	220.00	228.00	2255.28	2327.23
1974.318	11.14	220.00	228.00	2251.32	2323.27
1974.319	11.15	220.00	228.00	2247.36	2319.31
1974.320	11.16	220.00	228.00	2243.41	2315.35

Table V-1 (Cont'd.)

		RAAN°		LIFTOFF (GMT)	
YEAR.DAY	MONTH.DAY	OPENING	CLOSING	OPENING	CLOSING
1974.321	11.17	220.0 C	228.C 0	2239.45	2311.39
1974.322	11.18	220.0 C	228.00	2235.49	2307.44
1974.323	11.19	220.0 C	228.00	2231.53	2303.48
1974.324	11.20	220.0 C	228.00	2227.57	2259.52
1974.325	11.21	220.0 C	228.C0	2224.01	2255.56
1974.326	11.22	220.0 C	228.C 0	2220.05	2251.60
1974.327	11.23	220.0 C	228.C 0	2216.09	2248.C4
1974.328	11.24	220.0 C	228.06	2212.13	2244.08
1974.329	11.25	220.0 C	228.C0	2208.17	2240.12
1974.330	11.26	220.0 C	228.C0	2204.21	2236.15
1974.331	11.27	220.0 C	228.C0	2200.26	2232.20
1974.332	11.28	220.0 C	228.C C	2156.30	2228.24
1974.333	11.29	220.0 C	228.C0	2152.34	2224.29
1974.334	11.30	220.0 C	228.C0	2148.38	2220.33
1974.335	12.01	220.0 C	228.C0	2144.42	2216.37
1974.336	12.02	220.0 C	228.C0	2140.46	2212.41
1974.337	12.03	220.C C	228.00	2136.50	2208.45
1974.338	12.04	220.0 C	228.C0	2132.54	2204.49
1974.339	12.05	220.0 C	228.C0	2128.58	2200.53
1974.340	12.06	220.0 C	228.C0	2125.02	2156.57
1974.341	12.07	220.00	228.C0	2121.06	2153.01
1974.342	12.08	220.0 C	228.C0	2117.11	2149.05
1974.343	12.09	220.0 C	228.C0	2113.15	2145.09
1974.344	12.10	220.0 C	228.C0	2109.19	2141.14
1974.345	12.11	220.00	228.00	2105.23	2137.18
1974.346	12.12	266.00	274.00	8.53	40.47
1974.347	12.13	266.00	274.00	4.57	36.52
1974.348	12.14	266.00	274.00	1.01	32.56
1974.349	12.15	266.C C	274.C0	2353.09	28.60
1974.350	12.16	266.00	274.C0	2349.13	25.04
1974.351	12.17	266.00	274.C C	2345.17	21.08
1974.352	12.18	266.00	274.C0	2341.21	17.12
1974.353	12.19	266.00	274.C0	2337.25	13.16
1974.354	12.20	266.0 C	274.C0	2333.30	9.20
1974.355	12.21	266.00	274.C0	2329.34	5.24
1974.356	12.22	266.C C	274.00	2325.38	1.28
1974.357	12.23	266.C C	274.00	2321.42	2353.37
1974.358	12.24	266.00	274.C0	2317.46	2349.41
1974.359	12.25	266.00	274.00	2313.50	2345.45
1974.360	12.26	266.00	274.00	2309.54	2341.49
1974.361	12.27	266.0 C	274.00	2305.58	2337.53
1974.362	12.28	266.00	274.C0	2302.02	2333.57
1974.363	12.29	266.0 C	274.00	2258.06	2330.01
1974.364	12.30	266.00	274.00	2254.10	2326.05
1974.365	12.31	266.00	274.00	2250.15	2322.09
1975.001	1.01	266.0 C	274.C0	2246.19	2318.13

Table V-1 (Cont'd.)

		RAAN°		LIFTOFF (GMT)	
YEAR.DAY	MONTH.DAY	OPENING	CLOSING	OPENING	CLOSING
1975.002	1.02	266.0C	274.C0	2242.23	2314.17
1975.003	1.03	266.0C	274.C0	2238.27	2310.22
1975.004	1.04	266.0C	274.C0	2234.31	2306.25
1975.005	1.05	266.0C	274.C0	2230.35	2302.30
1975.006	1.06	266.00	274.C0	2226.39	2258.34
1975.007	1.07	266.0C	274.C0	2222.43	2254.38
1975.008	1.08	266.0C	274.CC	2218.47	2250.42
1975.009	1.09	266.0C	274.C0	2214.51	2246.46
1975.010	1.10	266.0C	274.CC	2210.55	2242.50
1975.011	1.11	266.00	274.C0	2206.60	2238.54
1975.012	1.12	266.00	274.00	2203.04	2234.58
1975.013	1.13	266.00	274.C0	2159.08	2231.02
1975.014	1.14	266.0C	274.C0	2155.12	2227.07
1975.015	1.15	266.00	274.C0	2151.16	2223.11
1975.016	1.16	266.0C	274.CC	2147.20	2219.15
1975.017	1.17	266.0C	274.C0	2143.24	2215.19
1975.018	1.18	266.0C	274.C0	2139.28	2211.23
1975.019	1.19	266.00	274.CC	2135.32	2207.27
1975.020	1.20	266.CC	274.00	2131.36	2203.31
1975.021	1.21	266.0C	274.CC	2127.40	2159.35
1975.022	1.22	266.00	274.CC	2123.44	2155.39
1975.023	1.23	266.0C	274.C0	2119.49	2151.43
1975.024	1.24	266.00	274.C0	2115.53	2147.47
1975.025	1.25	266.0C	274.CC	2111.57	2143.52
1975.026	1.26	266.CC	274.C0	2108.01	2139.55
1975.027	1.27	266.0C	274.CC	2104.05	2135.60
1975.028	1.28	266.CC	274.C0	2100.09	2132.04
1975.029	1.29	266.0C	274.C0	2056.13	2128.08
1975.030	1.30	266.00	274.C0	2052.17	2124.12
1975.031	1.31	266.00	274.C0	2048.21	2120.15
1975.032	2.01	266.0C	274.C0	2044.25	2116.20
1975.033	2.02	266.00	274.CC	2040.29	2112.24
1975.034	2.03	266.CC	274.C0	2036.34	2108.28
1975.035	2.04	266.00	274.C0	2032.38	2104.32
1975.036	2.05	266.0C	274.CC	2028.42	2100.37
1975.037	2.06	266.00	274.CC	2024.46	2056.41
1975.038	2.07	266.00	274.CC	2020.50	2052.45
1975.039	2.08	266.0C	274.C0	2016.54	2048.49
1975.040	2.09	266.0C	274.CC	2012.58	2044.53
1975.041	2.10	266.0C	274.C0	2009.02	2040.57
1975.042	2.11	266.0C	274.CU	2005.06	2037.01
1975.043	2.12	266.0C	274.C0	2001.10	2033.05
1975.044	2.13	266.0C	274.C0	1957.14	2029.09
1975.045	2.14	266.0C	274.CC	1953.19	2025.13
1975.046	2.15	266.00	274.00	1949.23	2021.17
1975.047	2.16	266.00	274.C0	1945.27	2017.22

Table V-1. (Cont'd.)

YEAR.DAY	MONTH.DAY	RAAN° OPENING	RAAN° CLOSING	LIFTOFF (GMT) OPENING	LIFTOFF (GMT) CLOSING
1975.048	2.17	266.00	274.00	1941.31	2013.25
1975.049	2.18	266.00	274.00	1937.35	2009.30
1975.050	2.19	266.00	274.00	1933.39	2005.34
1975.051	2.20	266.00	274.00	1929.43	2001.38
1975.052	2.21	266.00	274.00	1925.47	1957.42
1975.053	2.22	266.00	274.00	1921.51	1953.45
1975.054	2.23	266.00	274.00	1917.55	1949.50
1975.055	2.24	266.00	274.00	1913.59	1945.54
1975.056	2.25	266.00	274.00	1910.04	1941.58
1975.057	2.26	266.00	274.00	1906.08	1938.02
1975.058	2.27	266.00	274.00	1902.12	1934.07
1975.059	2.28	266.00	274.00	1858.16	1930.11
1975.060	3.01	266.00	274.00	1854.20	1926.15
1975.061	3.02	266.00	274.00	1850.24	1922.19
1975.062	3.03	266.00	274.00	1846.28	1918.23
1975.063	3.04	266.00	274.00	1842.32	1914.27
1975.064	3.05	266.00	274.00	1838.36	1910.31
1975.065	3.06	266.00	274.00	1834.40	1906.35
1975.066	3.07	266.00	274.00	1830.44	1902.39
1975.067	3.08	266.00	274.00	1826.49	1858.43
1975.068	3.09	266.00	274.00	1822.53	1854.47
1975.069	3.10	266.00	274.00	1818.57	1850.52
1975.070	3.11	266.00	274.00	1815.01	1846.55
1975.071	3.12	266.00	274.00	1811.05	1842.60
1975.072	3.13	266.00	274.00	1807.09	1839.04
1975.073	3.14	266.00	274.00	1803.13	1835.08
1975.074	3.15	266.00	274.00	1759.17	1831.12
1975.075	3.16	266.00	274.00	1755.21	1827.15
1975.076	3.17	266.00	274.00	1751.25	1823.20
1975.077	3.18	266.00	274.00	1747.29	1819.24
1975.078	3.19	266.00	274.00	1743.34	1815.28
1975.079	3.20	266.00	274.00	1739.38	1811.32
1975.080	3.21	266.00	274.00	1735.42	1807.37
1975.081	3.22	266.00	274.00	1731.46	1803.41
1975.082	3.23	266.00	274.00	1727.50	1759.45
1975.083	3.24	266.00	274.00	1723.54	1755.49
1975.084	3.25	266.00	274.00	1719.58	1751.53
1975.085	3.26	266.00	274.00	1716.02	1747.57
1975.086	3.27	266.00	274.00	1712.06	1744.01
1975.087	3.28	266.00	274.00	1708.10	1740.05
1975.088	3.29	266.00	274.00	1704.14	1736.09
1975.089	3.30	266.00	274.00	1700.19	1732.13
1975.090	3.31	266.00	274.00	1656.23	1728.17
1975.091	4.01	266.00	274.00	1652.27	1724.22

Table V-2

Eclipse Season Boundaries

inclination = 1.8°   subsatellite point = 94.0°

| RAAN°	Start of Season		End of Season	
0	2/24/74	0622Z	4/14/74	0627Z
45	2/21/74	0628Z	4/10/74	0628Z
90	2/22/74	0621Z	4/8/74	0625Z
135	2/24/74	0626Z	4/8/74	0627Z
180	2/28/74	0621Z	4/11/74	0623Z
225	3/2/74	0625Z	4/14/74	0626Z
270	3/3/74	0618Z	4/17/74	0624Z
315	2/28/74	0622Z	4/17/74	0625Z
0	8/29/74	0608Z	10/18/74	0609Z
45	8/26/74	0611Z	10/14/74	0609Z
90	8/26/74	0615Z	10/11/74	0613Z
135	8/29/74	0612Z	10/12/74	0556Z
180	9/2/74	0609Z	10/14/74	0612Z
225	9/4/74	0612Z	10/18/74	0608Z
270	9/5/74	0605Z	10/21/74	0603Z
315	9/2/74	0608Z	10/21/74	0606Z
0	2/24/75	0625Z	4/15/75	0622Z
45	2/22/75	0620Z	4/11/75	0622Z
90	2/22/75	0622Z	4/8/75	0627Z
135	2/25/75	0620Z	4/9/75	0620Z
180	2/28/75	0622Z	4/11/75	0625Z
225	3/3/75	0619Z	4/13/75	0631Z
270	3/3/75	0618Z	4/17/75	0624Z
315	2/28/75	0622Z	4/17/75	0625Z
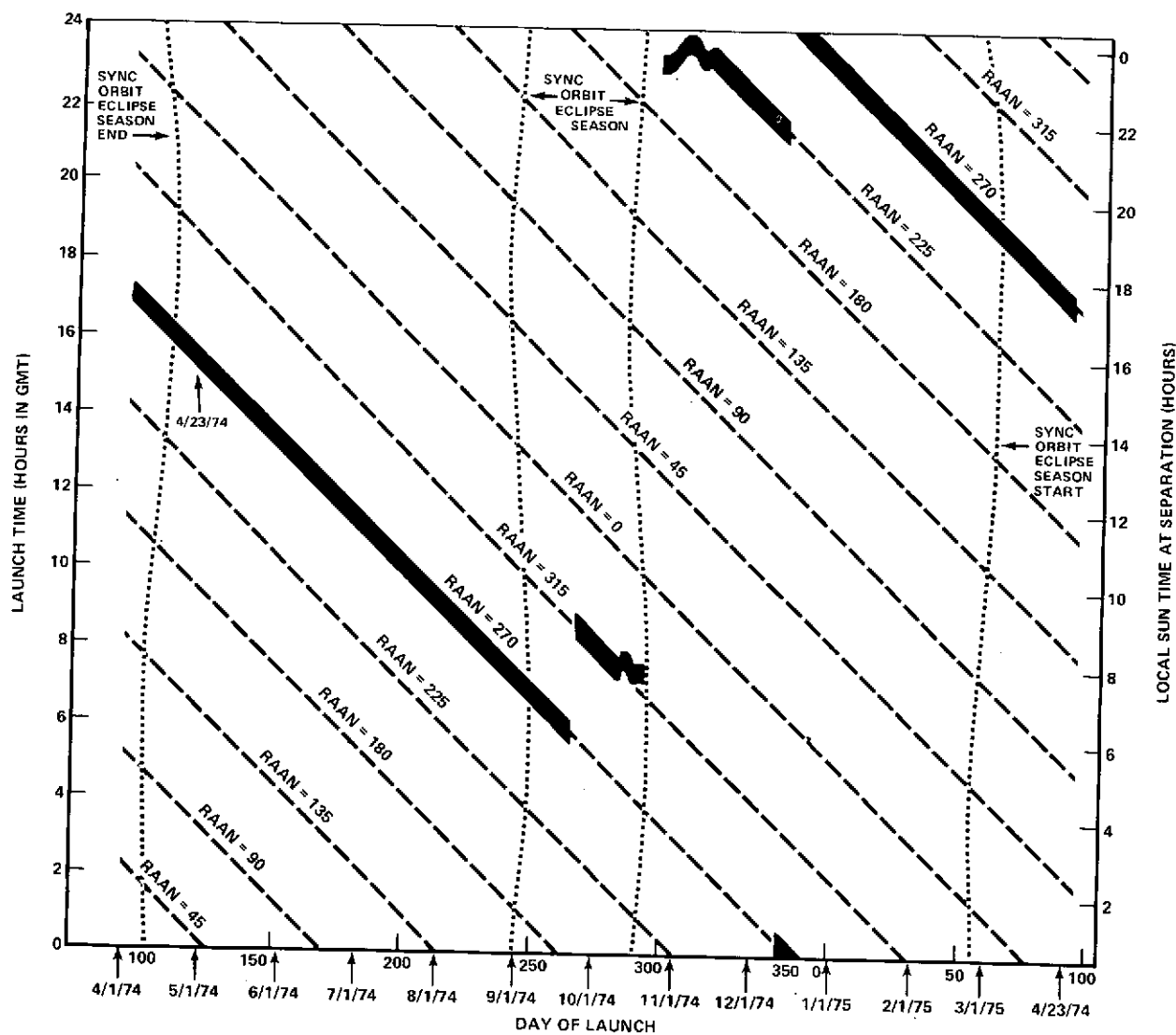
Figure V-1.   ATS-F Launch Window

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The local solar time at separation is referenced on the right-hand side of the launch window figure. The separation occurs at about 6.69 hours after lift-off. The subsatellite point of 94 degrees west longitude has a local solar time of about 6.27 hours earlier than on the greenwich meridian. Therefore, the local solar time at separation is 0.42 hours (6.69 - 6.27) later than the GMT of launch.

J. Shadow History

The shadow entrance and exit times are displayed for the middle of each daily launch window in Figure V-2. Note that the spacecraft is in shadow for the first 305 seconds from liftoff for every day, due to the presence of the payload fairing. The data presented in this figure was independently verified by Martin Marietta in December 1973.

The sum of all shadow periods for the trajectory is plotted in Figure V-3, and shows that the 45 minute maximum requirement is never exceeded. The duration of the shadow period present in the transfer orbit is plotted in Figure V-4, and shows that the 30 minute maximum requirement is never exceeded.
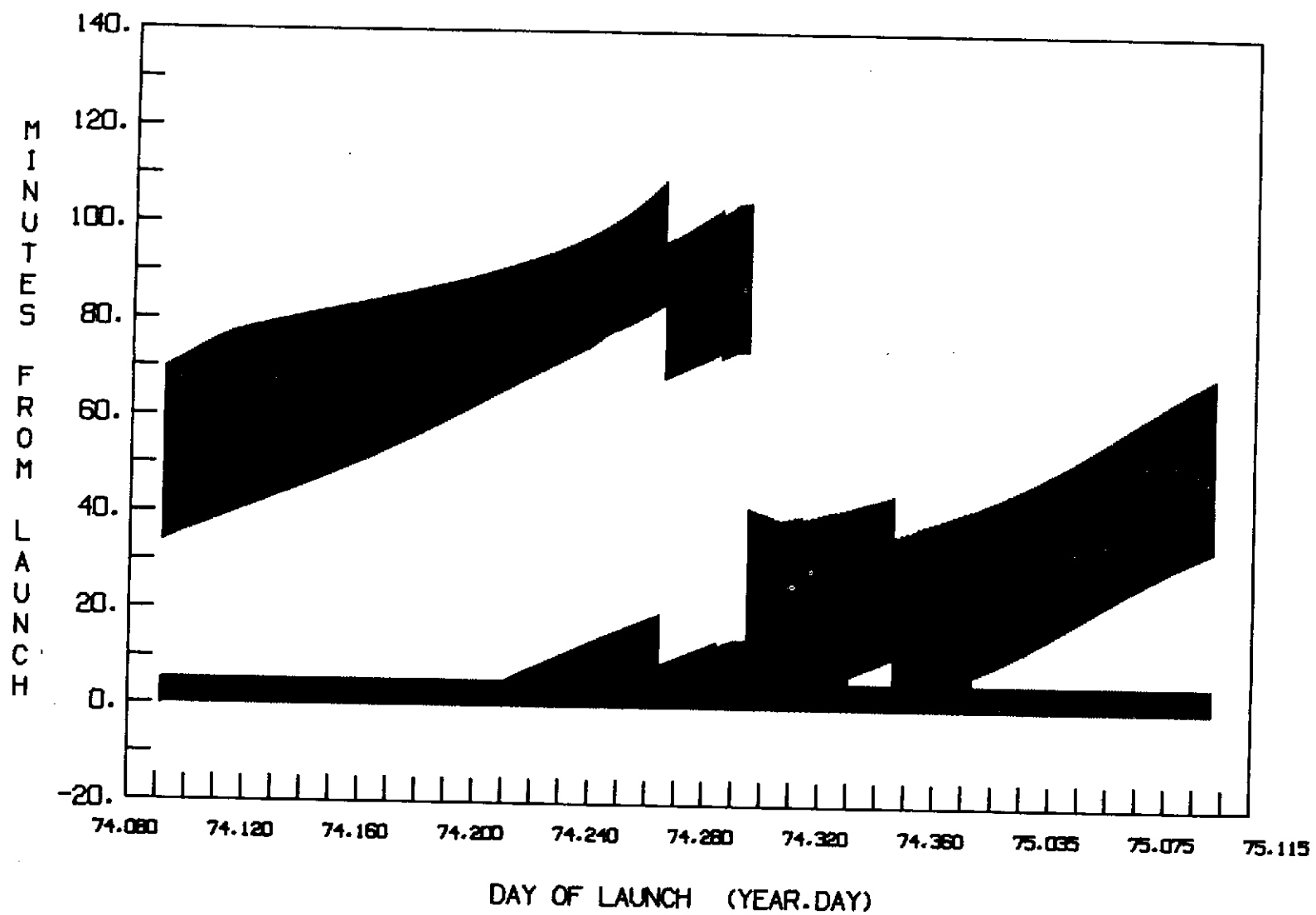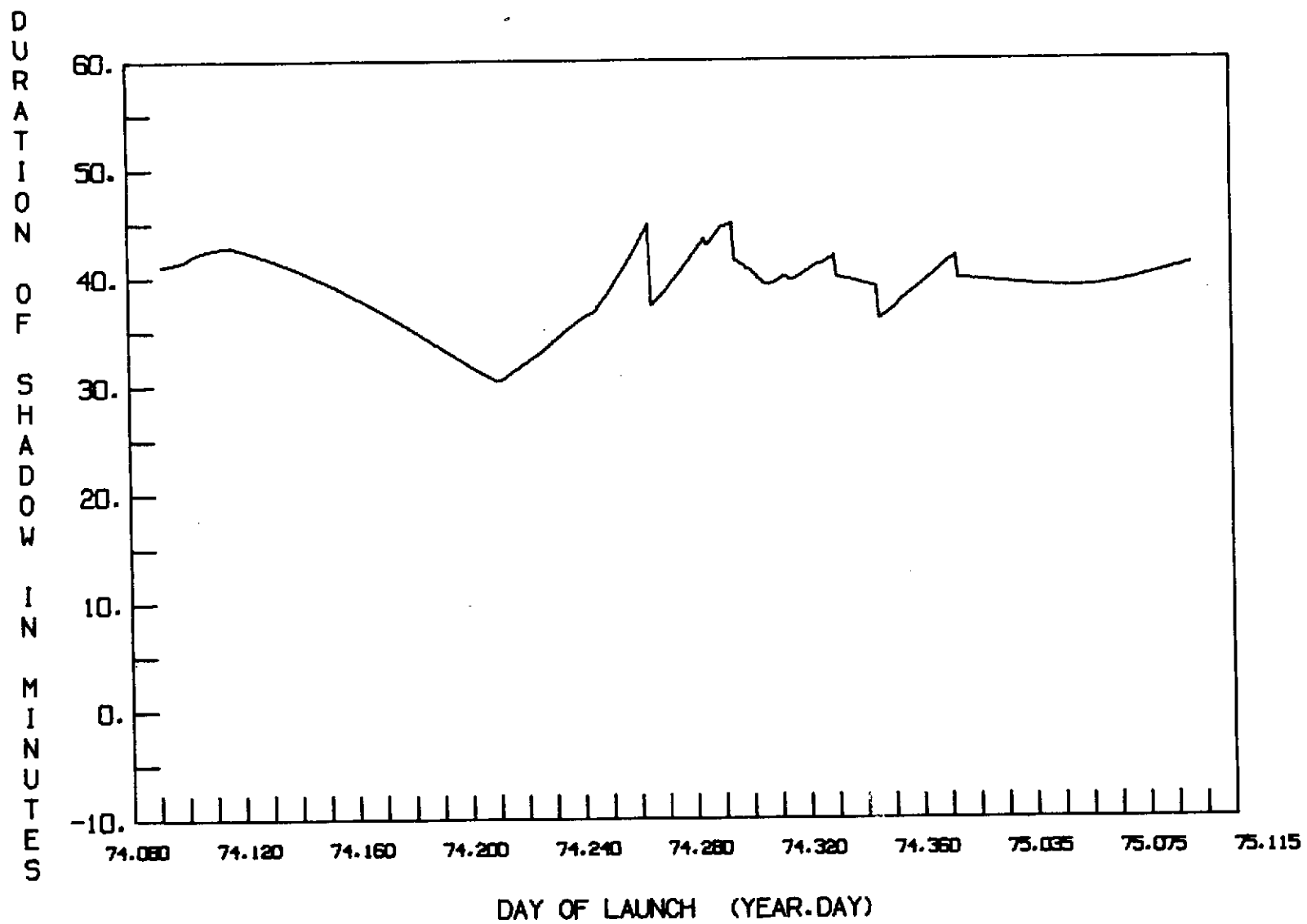
Figure V-2. Trajectory Shadow Periods
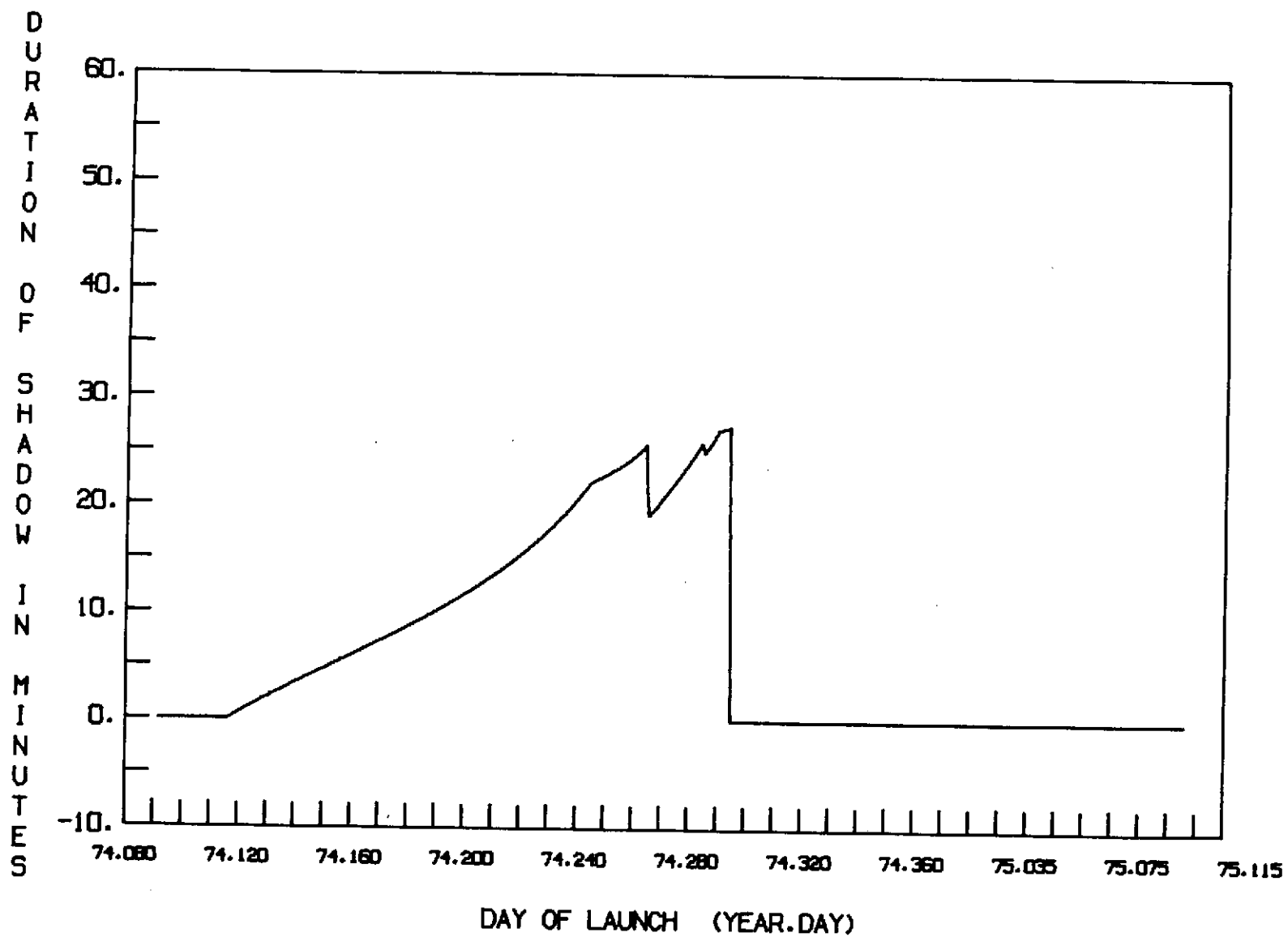
44

Figure V-3. Trajectory Shadow Duration

Figure V-4.   Transfer Orbit Shadow Duration

VI. SEPARATION

A. Separation Attitude

Four requirements were established in selecting a spearation attitude. The first requirement is that the transtage's high gain telemetry antenna must be directed roughly toward a Titan ground station, to insure adequate telemetry coverage. A second requirement is that ATS's VHF omni antennas must have a favorable attitude for both telemetry reception as well as commanding after separation. In order to remove the transtage from close proximity to ATS, the attitude relationship at the time of separation affects how quickly the separation distance increases. Therefore, a third requirement is established that the positive ATS Z-axis should be directed below the equatorial plane at an angle of 45.0 degrees. If the spacecraft's Z-axis maintains a small angle to the sun line for an extended period of time after separation, thermal and battery power problems could develop. Therefore, the ATS Z-axis is required to be more than 38.0 degrees from the sun line at the time of separation.

The minimum and maximum angles between the positive ATS Z-axis and the sun line are plotted in Figure VI-1 for each daily launch window. The angle never is less than 40 degrees or greater than 140 degrees. These angles were independently verified by Martin Marietta in November 1973.

B. Separation Events

As soon as the transtage is injected into synchronous orbit, it is reoriented to the separation attitude described above. The ATS positive X-axis is directed toward the earth's geocenter, and the ATS negative Z-axis is directed above the equatorial plane at an angle of 45.0 degrees.

At 173 seconds after injection, the transtage issues the separation fire signal, followed 4 seconds later with a redundant separation fire signal. The two bodies will separate at a rate of about 4 feet per second. If the first two separation fire signals failed to release ATS, then ATS ground stations have an opportunity to send separation commands directly to ATS for 15 minutes. The Transtage Attitude Control System thrusters are disabled from 172 to 179 seconds after injection.

At 533 seconds, the solar array will be released by the automatic six minute timer, assuming that separation properly occurred at 173 seconds after injection. At 842 seconds, another redundant separation fire signal will be sent by the transtage, and it will have no effect if separation previously occured. At 952 seconds after injection, the skewed hinge will be released by a six minute
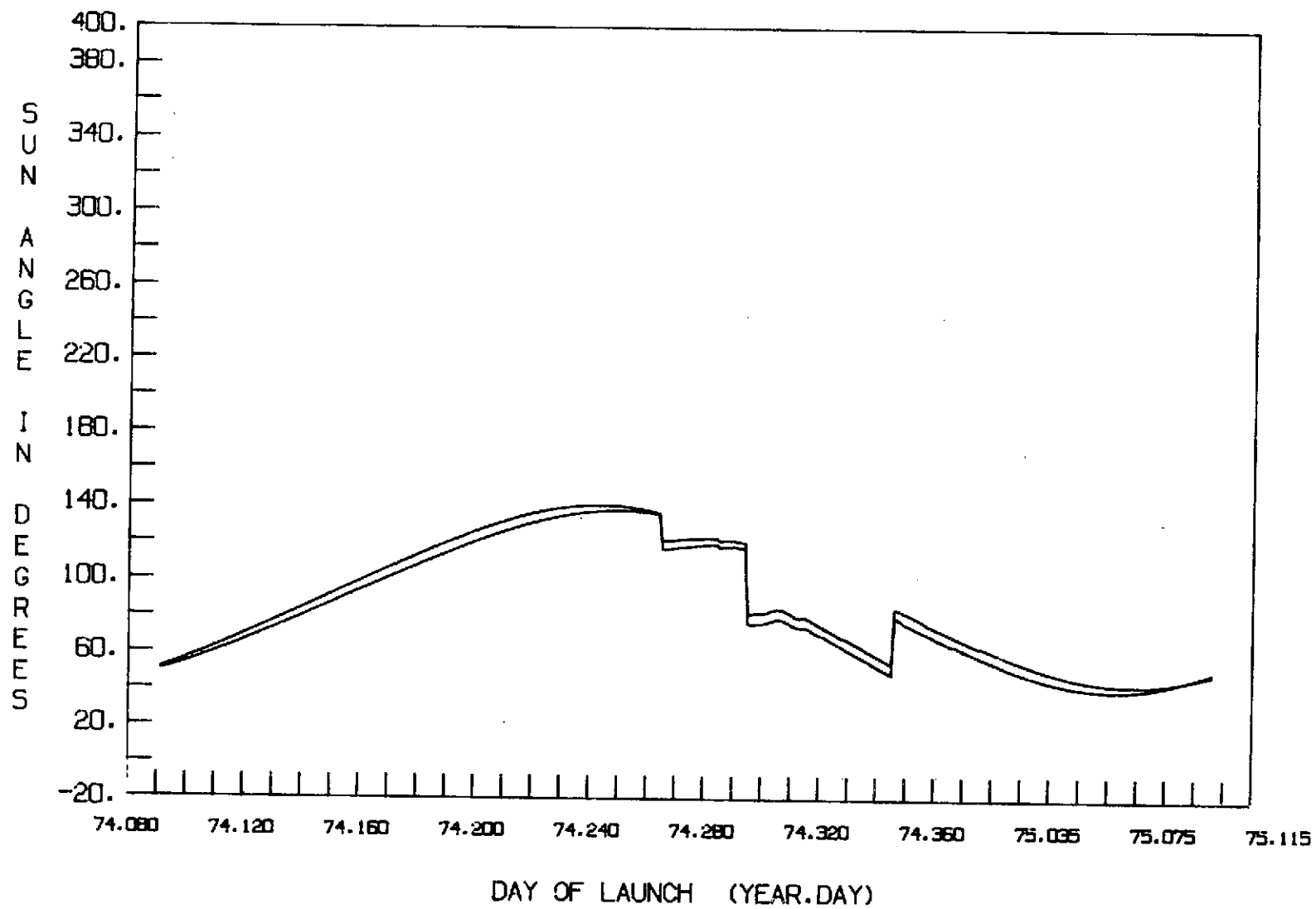
47

Figure VI-1. Sun Angle of Separation

timer command, assuming that the solar array release was completed at 592 seconds after injection.

At 1109 seconds after injection, the transtage will orient for a retro manuever such that the transtage's positive X-axis is directed opposite the velocity vector.

The reflector deployment should occur at about 1462 seconds after injection initiated by a six minute timer command and assuming that the skewed hinge release occured at the expected time.

The transtage retro maneuver begins at 1799 seconds after injection, and lasts for about 60 seconds. The transtage should reach a speed of about 50 feet per second with respect to ATS.

The final boom motion should occur at about 1882 seconds after injection initiated by a six minute timer command and assuming that the reflector deployment occured at the expected time. At 2375 seconds after launch, the transtage's power buss will be permanently disabled, thus completing the Titan mission. A pictorial diagram of the separation and deployment sequence is shown in Figure VI-2.

VII. VHF OMNI EARTH COVERAGE ANTENNA

In order to determine if the ATS telemetry and command link will be satisfactory during the launch phase, the VHF omni antenna patterns must be related to the ATS ground station positions at Mojave and Rosman for various points in the launch trajectory. A special investigation was made for Mr. Max Schmitt of Fairchild by R. Walsh to determine the omni antenna attitudes for six different position/attitude configuration of ATS during the launch trajectory. The six configurations are: at the middle of each Titan telemetry dipout, and at separation for three different separation attitude cases.

An IBM 360/91 FORTRAN computer program called "ANT" was written by R. Walsh to compute the coordinates of the Mojave and Rosman ground stations at the six above points in the launch trajectory. These ground station coordinates were computed with respect to a spacecraft centered coordinate system defined below. This coordinate system was used to define the antenna patterns.

Coordinate System Definition:

Let the point (X, Y, Z) equal the rectangular coordinates of a ground station referenced from the ATS "+X Axis", ATS "+Y Axis", "+Z Axis" respectively.
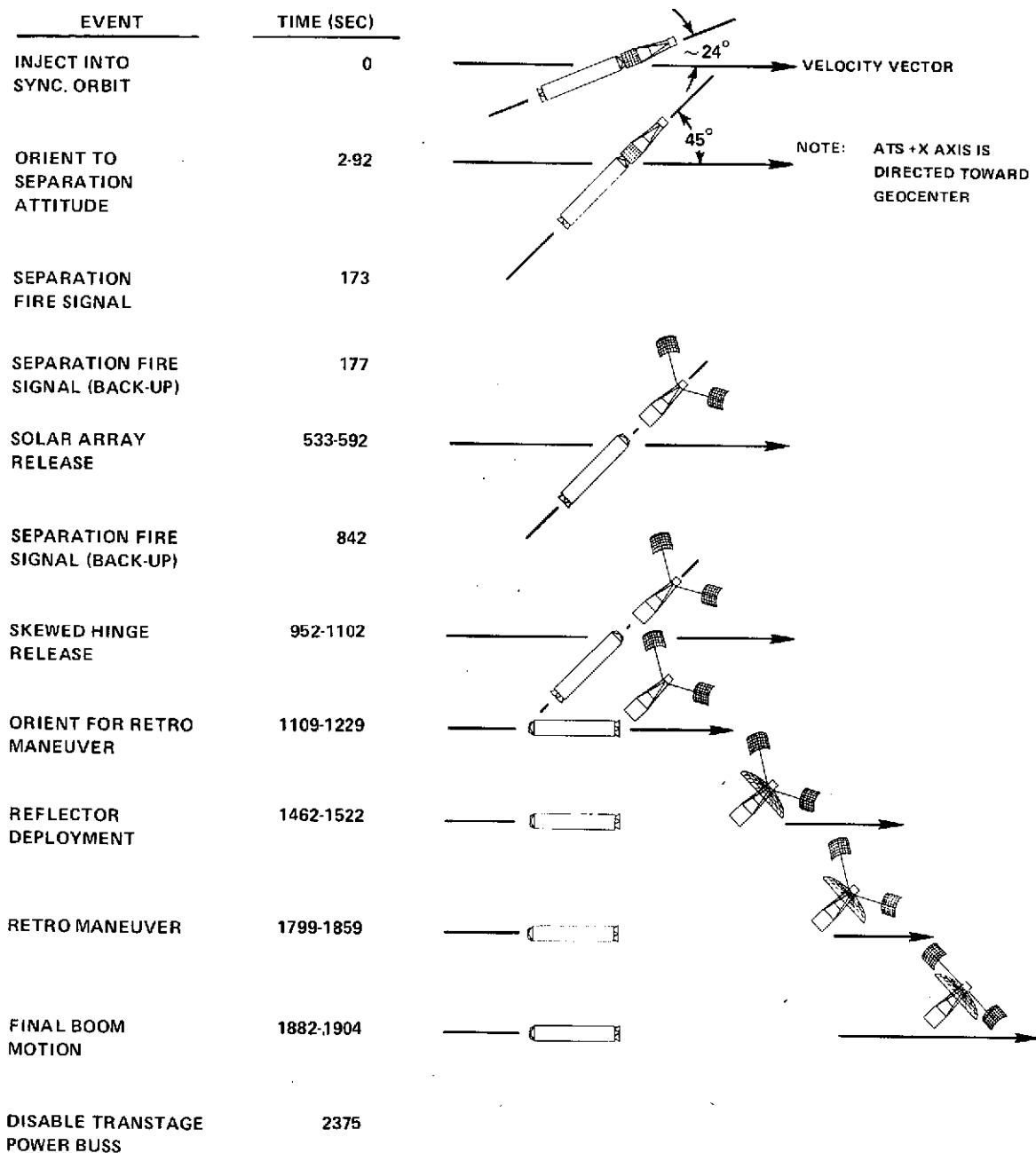
EVENT	TIME (SEC)
INJECT INTO SYNC. ORBIT	0
ORIENT TO SEPARATION ATTITUDE	2-92
SEPARATION FIRE SIGNAL	173
SEPARATION FIRE SIGNAL (BACK-UP)	177
SOLAR ARRAY RELEASE	533-592
SEPARATION FIRE SIGNAL (BACK-UP)	842
SKEWED HINGE RELEASE	952-1102
ORIENT FOR RETRO MANEUVER	1109-1229
REFLECTOR DEPLOYMENT	1462-1522
RETRO MANEUVER	1799-1859
FINAL BOOM MOTION	1882-1904
DISABLE TRANSTAGE POWER BUSS	2375

~24° → VELOCITY VECTOR

45°

NOTE: ATS +X AXIS IS DIRECTED TOWARD GEOCENTER

Figure VI-2.   ATS-F Sequence of Events

Then: $\phi = \text{ARCTAN} \dfrac{X}{Y}$, where $0° \leqslant \phi \leqslant 360°$

$\theta = \text{ARCTAN} \dfrac{\sqrt{X^2 + Y^2}}{-Z}$, where $0° \leqslant \phi \leqslant 180°$

The resulting coordinates are as follows:

Table of Ground Station Coordinates from Spacecraft

Event	Mojave ϕ	Gnd Sta θ	Rosman ϕ	Gnd Sta θ
(a) Middle of 1st TM dipout	153.4	99.5	179.2	101.6
(b) Middle of 2nd TM dipout	89.9	86.4	84.4	84.2
(c) Middle of 3rd TM dipout	93.3	84.8	89.1	82.7
(d) Separation with ATS "+Z Axis" inclined 45 degrees below the equatorial plane	98.7	90.7	95.4	87.4

The analysis of these results, along with the antenna patterns for both omni antennas with various polarizations was made by Fairchild, and it was determined that a satisfactory link is present for each of the six configurations described above.

REFERENCES

1. P. A. Bloomgren, Martin Marietta Corporation, ATS-F Mission Planning Trajectory, September 1971, MCR-71-221.

2. H. Sokoloff, Aerospace Corporation, Program 624A Discrete List for Flight Plan V11F, December 26, 1972, Aerospace Report Number TOR-0172(2112-02)-14 Reissue A.