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CISLUNAR NAVIGATION SIGHTING DATA FOR APOLLO 11 (MISSION G) JULY 18, 1969

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PROJECT APOLLO

CISLUNAR NAVIGATION SIGHTING DATA FOR APOLLO 11 (MISSION G): JULY 18, 1969 LAUNCH

By Charles A. Denham
Mathematical Physics Branch

July 30, 1969

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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CISLUNAR NAVIGATION SIGHTING DATA FOR

APOLLO 11 (MISSION G): JULY 18, 1969 LAUNCH

By Charles A. Denham

1.0 SUMMARY

The navigation data are presented for use during the Apollo 11 (Mission G) July 18, 1969, launch window. These data include the star/horizon combinations available for use with P23, the Command Module Computer (CMC) Cislunar Midcourse Navigation Program, and the crew charts which will be used if there is a loss of communications after translunar injection (TLI) or after lunar module (LM) jettison in lunar orbit.

The data contained in this report have previously been transmitted to the Flight Crew Support Division in the form of memoranda, crew charts, and rough drafts.

2.0 INTRODUCTION

The Cislunar Midcourse Navigation Program (P23) is a CMC program used to compute the current vehicle position and velocity from the measured angle between a star (or planet) and an earth (or lunar) horizon (or landmark). If ground communication is lost, P23 will be the primary mode of navigation. Theoretically, the crewman-computer combination requires no previous information to do this navigation. However, the usable stars are near the earth and/or moon, and the crewman cannot recognize the star fields because of scattered light; in addition, prior knowledge of stars which do not violate current mission sighting constraints will save crewman time and effort and vehicle fuel. There are 37 star positions stored in the CMC fixed memory for use with P23, and the crewman may use any other celestial body for sightings as long as he knows its location. All stars or planets which are visible to the crewman may not be usable for star/horizon sightings because of current sextant, light scattering, and optimum navigation constraints.

The purpose of this document is to present the crew charts which will be used if communication with the ground should be lost after TLI and during lunar orbit, star avaiabilities for tests to be conducted during the translunar and transearth trajectories, star availability and sighting schedule if there is a loss of communications on the transearth trajectory, and constraints which affect the choice of navigation stars.

3.0 SYMBOLS

ALO	abort from lunar orbit
AOS	acquisition of star
CMC	Command Module Computer
CSM	command and service module
EI	earth entry interface
g.e.t.	ground elapsed time
G.m.t.	Greenwich mean time
LM	lunar module
LOI	lunar orbit insertion
LOS	loss of star
MCC	midcourse correction
PAD	preadvisory data
PERI	perilune
PTC	passive thermal control
P23	program 23, Cislunar Midcourse Navigation
REV	revolution
TE	transearth

TEI transearth injection

TLA translunar abort

TLI translunar injection

4.0 CURRENT STAR AVAILABILITY CONSTRAINTS

All of the stars which are visible to the crewman are not usable for onboard navigation. The stars which cannot be used are deleted for one or more violations of sighting constraints; these constraints are described in reference 1 and are listed here.

4.1 Trunnion Angle

The trunnion angle, the angle between the star line of sight and horizon (or landmark) line of sight, which is measured by the crewman, must be less than 50° unless the sun is within 45° of the horizon (or landmark) line of sight, in which case the maximum trunnion angle is 45°. The minimum trunnion angle is 2°. The 50° maximum is a mechanical constraint; the 45° maximum and the 2° minimum are operational constraints based on scattered light in the sextant.

4.2 Star Magnitude

The dimmest stars which can be used when the earth is the target body are of 3.0 magnitude; when the moon is the target, 3.5 magnitude stars may be used. These constraints are based on light scattering from the target body and on horizon definition. The actual usable star magnitude is a function of several variables which include the sun-vehicle-target and star-vehicle-sun angles.

4.3 Sun Elevation

The local sun elevation at the target point must be great enough to provide illumination without distortion. Current constraints are a 5° minimum for lunar sightings and a 10° minimum for earth sightings.

5.0 MARKING PROCEDURES

Unlike the moon, the earth does not have a definite horizon locator because of the light scattering properties of the atmosphere. During translunar coast, two batches of star/earth horizon marks are scheduled to ascertain the horizon locator altitude and sextant error model. The recommended procedures to perform these marks, as well as all other star/horizon marks, are shown in figures 1 and 2.

Procedures which have been designed to reduce the uncertainties in bias between successive marks are shown in figures 1 and 2. From figure 1, it is seen that the edge of the star and not the center should be placed on the horizon locator; and from figure 2, it is seen that the star should be positioned on the locator approaching from dark space and not from the marked body.

6.0 STAR AVAILABILITY DATA

Star availability data for the July 18, 1969, Apollo 11 (Mission G) launch date are given in the attached tables and figures. The data are included in the following order: crew charts, translunar star/horizon combinations, transearth star/horizon combinations for a nominal 30-revolution stay in lunar orbit, and transearth star/earth horizon combinations for sun elevation constraint tests.

6.1 Crew Charts

There are two sets of crew charts which contain star availability information that will be carried on board the Apollo vehicle. These charts are for crewman use if loss of communications should occur in the following two cases.

1. After TLI plus 25 minutes and before TLI plus 4 hours

2. During lunar orbit after LM jettison

The abort procedures and the conditions that require aborts of these two types are presented in reference 2. A brief summary is given here.

An abort from the translunar coast at TLI plus 4 hours is caused by a loss of communications after TLI plus 25 minutes and inability of the CSM to perform transposition, docking, and extraction of the LM. The TLI plus 4 hour abort PAD will be voiced up to the CSM during the earth parking orbit and will be updated at TLI plus 1 hour if communications exist at that time. The crew charts which give the star availability and detailed sighting schedules for aborts at TLI plus 4 hours are presented in figures 3 and 4. In these charts, the star availability is given for two possible launch azimuths and TLI opportunities which are identified on the figures. For aborts from trajectories other than from these two, the stars which will be available will be the same, but the acquisition and loss times will differ. These two charts provide navigation information which covers the entire window for aborts from translunar coast at TLI plus 4 hours.

Crew charts that give star availability and sighting schedules for aborts from lunar orbit are presented in figure 5. The data are presented for aborts caused by loss of communications after LM jettison. If CSM communications fail before LM jettison, the LM would provide some backup capability and could be retained for the transearth leg. The abort data for an early TEI burn will be uplinked one or more revolutions ahead during lunar orbit. (Nominal uplink times are contained in ref. 3.) The crew chart for possible aborts from lunar orbit contains information concerning two possible trajectories: a TEI after 28 revolutions in lunar orbit for a 72° launch azimuth, first TLI opportunity; and a TEI after 35 revolutions in lunar orbit for a 108° launch azimuth, second TLI opportunity. For aborts from trajectories other than these two, the available stars will be the same, but AOS and LOS times will change; the sighting schedule is valid for all trajectories between these two.

6.2 Nominal Star Selection Data

The star availability and horizon combinations for the nominal translunar trajectories are presented in figure 6. The current flight plan (ref. 3) provides for two batches of star/earth horizon sightings on the translunar leg of the mission, and the figures are marked to indicate these batches. These two batches will be used to verify or update the earth horizon altitude loaded in the CMC and to check the SXT error model. If these sightings are moved in the time line, sighting data may be read directly from figure 6. Numerical data for these marks are given in table I.

The stars used to determine these parameters are selected based on the following guidelines.

a. The angular separation between the stars should be as great as possible to use the maximum amount of visible horizon. (figs. 7 and 8).

b. If at all possible, one pair of stars should be selected such that their separation is 180° to minimize the effect of trunnion angle bias. If a pair with 180° of separation is not available, a pair with as close to 180° as possible should be used. Two pair are shown in figure 7; stars 01 and 02 have a separation of 176° and 02 and 44 have a separation of 189°. Only one pair in figure 8 have a separation near 180°; 07 and 44 are separated by 174°.

c. If five different stars are not available, the dimmest available star should be repeated to bring the total number of sets of marks to five. However, the total number of sets on a star should not exceed two. For example, note from table I that star 07, magnitude 2.8, is used for two sets of marks during the batch at 24 hours g.e.t.

The stars in figures 7 and 8 which are named and numbered have their positions stored in the CMC fixed memory. The additional stars pictured are from the first 158 in the RTCC star catalogue (ref. 4). These stars are not identified, but are included to show that the data in table I is the optimum sighting data.

The star/horizon combinations for the nominal transearth trajectory based on current sighting constraints are presented in figure 9. The sighting schedule if loss of communications occurs during the transearth leg is marked on these figures; the same data are carried on board in the flight plan (ref. 3) and are included in table II.

During the transearth coast, there are several opportunities for the navigator to attempt star/earth horizon sightings to validate or update the current 10° minimum sun elevation angle constraint. The suggested sighting schedule is given in table III and in figure 10 which shows the nominal transearth trajectory star availability. This schedule is based on the schedule in reference 5.

7.0 FORMAT OF FIGURES

Each of figures 3 through 6 and 9 and 10 are drawn with the same basic format. The horizontal grid lines represent the time in hours from the event given in the upper left corner of the figures; the vertical lines represent star availability with a particular body/horizon which is identified along the upper margin. Octal star numbers are given with two letters, with XY keyed as follows.

X = E means the earth is the target

X = M means the moon is the target

Y = N means the near horizon is used

Y = F means the far horizon is used

For example, the code 40EF means that star number 40, common name Altair, would be used with the earth far horizon.

The measured plane angle for each star/horizon combination is given at the bottom of the chart. This angle indicates the amount of information to be gained when this star/horizon combination is used to update the CMC state vector; Therefore, observations made with stars in the orbital plane should be emphasized. One set in which an out-of-plane star is used (measured plane angle > 45°) in every five sets is sufficient.

8.0 SUMMARY TABLES

Summaries of the information for each trajectory given in the figures are presented in table IV through XXIV. The following data are included for each trajectory.

a. Star number in octal and its associated horizon

b. Total availability time in minutes

c. Acquisition and loss times in hours to the nearest half-hour from the start and end of the trajectory

d. Star magnitude

e. Trunnion angle in degrees at acquisition and loss

f. Sun elevation angle at the substellar point in degrees at acquisition and loss

g. The scattered light factor, which is a function of star-sun-vehicle-body geometry and which determines if a star can be seen against the horizon

h. The measured plane angle in degrees at acquisition and loss

The general loss of communications navigation procedure to be followed in every case not covered by a crew chart or the flight plan are presented in table XXV.

9.0 DATA REFERENCES

The availability of star/horizon combinations for the several cases covered in this paper were generated by the program ORION, Optical Requirements Interrogator for Orbital Navigation (ref. 6). Nominal trajectory information for the aborts from translunar coast was provided by Lt. C. J. Laetz of Flight Analysis Branch, MPAD. Mr. G. L. Norbraten of Lunar Mission Analysis Branch, MPAD, provided the TEI vectors for the aborts from lunar orbit and for the nominal TEI trajectories. The remainder of the vectors were obtained from the Apollo 10 operational trajectories (ref. 7). The sighting schedule for the abort from lunar orbit crew chart was based on the nominal trans-earth schedule for a July 16 launch (ref. 5) and the data in table XXV. Data for W-matrix initialization for aborts from lunar orbit were taken from reference 8; data for W-matrix initialization for aborts from translunar coast were taken from reference 9, which also contains verification of the crew chart sighting schedule.

TABLE I.- TRANSLUNAR STAR/EARTH HORIZON SIGHTINGS

Time, g.e.t. hr:min,	Star, octal	Horizon	Sun elevation, deg	Trunnion angle, deg	Measurement plane angle, deg	Star magnitude
6:00	44	Far	34.2	35.0	56.4	2.5
	45	Far	32.8	33.3	310.5	1.3
	02	Near	27.2	17.4	245.3	2.2
	07	Near	57.2	48.4	200.0	2.8
	01	Near	36.1	27.8	134.8	2.1
24:00	44	Far	56.3	45.7	34.9	2.5
	45	Far	54.5	45.5	330.4	1.3
	02	Far	21.5	26.2	295.4	2.2
	07	Near	61.6	33.5	208.9	2.8
	07	Near	61.6	33.5	208.9	2.8

TABLE II.- STAR/HORIZON SIGHTING SCHEDULE IN THE EVENT OF

LOSS OF COMMUNICATIONS DURING TRANSEARTH COAST

Batch no.	Type	Time from TEI, hr:min	Time, hr:min, g.e.t.	Star number, octal	Horizon	Star magnitude	Sun elevation, deg	Trunnion angle, deg	Measurement plane angle, deg
1	5LH	1:30	136:20	33	Near	1.2	12.8	39.0	175.0
				33	Near	1.2	12.8	39.0	175.0
				37	Near	2.1	12.6	6.5	177.7
				37	Near	2.1	12.6	6.5	177.7
				42	Near	2.1	14.2	22.7	96.3
2	5LH	11:30	146:20	33	Near	1.2	22.0	30.3	173.7
				33	Near	1.2	22.0	30.3	173.7
				34	Near	1.9	10.8	45.3	107.7
				40	Far	0.9	13.6	39.1	297.2
				41	Far	3.2	21.6	25.1	339.6
3	5EH	13:00	147:50	13	Near	0.2	45.6	30.9	163.4
				13	Near	0.2	45.6	30.9	163.4
				12	Near	0.3	28.2	40.8	260.9
				01	Far	2.1	52.1	44.8	52.8
				07	Far	2.8	25.0	21.3	319.8
4	5EH	15:30	150:20	01	Far	2.1	52.2	45.0	51.8
				07	Far	2.8	25.4	21.6	319.7
				11	Near	1.1	50.4	17.2	234.2
				13	Near	0.2	45.3	30.5	162.6
				13	Near	0.2	45.3	30.5	162.6
5	3LH	19:00	153:30	33	Near	1.2	23.5	29.2	175.4
				33	Near	1.2	23.5	29.2	175.4
				37	Far	2.1	21.5	3.6	16.9

TABLE II.- STAR/HORIZON SIGHTING SCHEDULE IN THE EVENT OF

LOSS OF COMMUNICATIONS DURING TRANSEARTH COAST - Continued

Batch no.	Type	Time from TEI, hr:min	Time, hr:min, g.e.t.	Star number, octal	Horizon	Star magnitude	Sun elevation, deg	Trunnion angle, deg	Measurement plane angle, deg
6	5EH	22:30	157:20	07	Far	2.8	26.8	22.6	320.6
				01	Far	2.1	52.4	45.9	50.0
				12	Near	0.3	26.7	40.4	260.8
				13	Near	0.2	44.3	29.3	161.0
				13	Near	0.2	44.3	29.3	161.0
7	5EH	35:00	169:50	13	Near	0.2	41.3	26.3	158.6
				13	Near	0.2	41.3	26.3	158.6
				11	Near	1.1	40.3	14.6	243.5
				07	Far	2.8	29.4	25.2	324.5
				07	Far	2.8	29.4	25.2	324.5
8	3LH	37:00	171:50	33	Near	1.2	27.0	26.3	180.0
				37	Far	2.1	26.5	6.3	10.4
				41	Far	3.2	26.7	29.0	349.3
9	5EH	41:00	175:50	03	Far	2.1	16.1	46.2	91.4
				07	Far	2.8	30.6	27.3	326.9
				07	Far	2.8	30.6	27.3	326.9
				13	Near	0.2	38.8	23.9	156.9
				13	Near	0.2	38.8	23.9	156.9
10	5EH	44:30	179:20	12	Near	0.3	19.1	38.7	267.7
				13	Near	0.2	36.5	22.1	155.4
				13	Near	0.2	36.5	22.1	155.4
				07	Far	2.8	31.2	29.0	328.7
				11	Near	1.1	28.6	12.7	256.4

TABLE II.- STAR/HORIZON SIGHTING SCHEDULE IN THE EVENT OF

LOSS OF COMMUNICATIONS DURING TRANSEARTH COAST - Concluded

Batch no.	Type	Time from TEI, hr:min	Time, hr:min, g.e.t.	Star number, octal	Horizon	Star magnitude	Sun elevation, deg	Trunnion angle, deg	Measurement plane angle, deg
11	5EH	50:00	184:50	03	Far	2.1	20.3	47.4	85.4
				07	Far	2.8	31.5	33.3	332.3
				07	Far	2.8	31.5	33.3	332.3
				13	Near	0.2	30.5	17.8	151.0
				13	Near	0.2	30.5	17.8	151.0
12	5EH	55:00	189:50	07	Far	2.8	28.7	42.0	337.2
				07	Far	2.8	28.7	42.0	337.2
				10	Far	1.9	23.7	27.0	77.8
				13	Near	0.2	14.5	9.8	136.7
				16	Near	0.5	41.3	44.8	227.0
13	3EH	57:30	192:20	10	Far	1.9	28.8	33.6	57.7
				10	Far	1.9	28.8	33.6	57.7
				16	Near	0.5	30.1	35.8	234.0

TABLE III.- SUGGESTED SIGHTING SCHEDULE FOR SUN ELEVATION CONSTRAINT TESTS

DURING THE NOMINAL TRANSEARTH COAST

Time from TEI, hr:min	Time, hr:min, g.e.t.	Star, octal	Horizon	Magnitude	Sun elevation, deg
1:30	136:20	03	Far	2.1	9.6
		10	Near	1.9	13.1
		13	Near	0.2	46.1
13:00	147:50	03	Far	2.1	10.5
		10	Near	1.9	11.7
		13	Near	0.2	45.6
19:00	153:30	03	Far	2.1	11.3
		10	Near	1.9	10.2
		13	Near	0.2	45.6
37:30	172:20	03	Far	2.1	15.0
		12	Near	0.3	22.5
		13	Near	0.2	40.4
46:30	181:20	10	Far	1.9	5.3
		12	Near	0.3	17.8
		13	Near	0.2	34.8
49:30	184:20	03	Far	2.1	20.0
		10	Far	1.9	10.0
		12	Near	0.3	15.2
		13	Near	0.2	31.3

TABLE IV SUMMARY OF STAR/EARTH HORIZON SIGHTING
DATA FOR A LAUNCH ON 16 JULY, 1969, 72 DEGREE
LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY
ABORT FROM TRANSLUNAR COAST AT TLI PLUS 4 HOURS

STAR NO.		AVAILABILITY (MIN.)	AOS GET	LOS GET	AOS PERI	LOS PERI	AOS EI	LOS EI	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
002	N	120	7: 6	9: 6	0: 0	2: 0	-19:50	-17:50	2.2	16/15	24/ 10	5.0/5.0	74/ 90
001	N	390	7: 6	13:36	0: 0	6:30	-19:50	-13:20	2.1	28/21	31/ 12	5.0/5.0	42/ 71
044	F	510	7: 6	15:36	0: 0	8:30	-19:50	-11:20	2.5	37/50	38/ 58	5.0/5.0	58/ 39
045	F	510	7: 6	15:36	0: 0	8:30	-19:50	-11:20	1.3	33/49	38/ 57	5.0/5.0	39/ 24
003	N	390	15:36	22: 6	8:30	15: 0	-11:20	-4:50	2.1	50/40	25/ 11	5.0/5.0	57/ 71
002	F	660	12: 6	23: 6	5: 0	16: 0	-14:50	-3:50	2.2	26/48	10/ 47	5.0/5.0	72/ 32
007	N	990	7: 6	23:36	0: 0	16:30	-19:50	-3:20	2.8	46/11	60/ 18	5.0/5.0	23/ 78
001	F	390	18: 6	24:36	11: 0	17:30	-8:50	-2:20	2.1	29/46	11/ 45	5.0/5.0	88/ 44
010	N	570	15:36	25: 6	8:30	18: 0	-11:20	-1:50	1.9	50/15	53/ 13	5.0/5.0	29/ 62
007	F	30	25: 6	25:36	18: 0	18:30	-1:50	-1:20	2.8	31/36	11/ 19	5.0/5.0	64/ 48
011	N	510	17: 6	25:36	10: 0	18:30	-9:50	-1:20	1.1	49/ 3	80/ 28	5.0/3.5	16/ 53
012	N	210	22: 6	25:36	15: 0	18:30	-4:50	-1:20	.3	50/28	47/ 15	5.0/5.0	50/ 72
013	N	240	21:36	25:36	14:30	18:30	-5:20	-1:20	.2	49/14	63/ 29	5.0/3.5	18/ 34
015	N	29	25:36	26: 6	18:30	18:59	-1:20	0:50	-1.6	49/37	26/ 11	5.0/3.5	57/ 64
016	N	29	25:36	26: 6	18:30	18:59	-1:20	0:50	.5	47/31	42/ 24	3.3/3.1	28/ 32

TABLE V SUMMARY OF STAR/EARTH HORIZON SIGHTING
DATA FOR A LAUNCH ON 16 JULY, 1969, 108 DEGREE
LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY
ABORT FROM TRANSLUNAR COAST AT TLI PLUS 4 HOURS

STAR NO.		AVAILABILITY (MIN.)	AOS GET	LOS GET	AOS PERI	LOS PERI	AOS EI	LOS EI	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
002	N	60	6:59	7:59	0: 0	1: 0	-15:18	-14:18	2.2	15/15	19/ 11	5.0/5.0	81/ 89
001	N	300	6:59	11:59	0: 0	5: 0	-15:18	-10:18	2.1	27/21	29/ 11	5.0/5.0	50/ 71
044	F	360	6:59	12:59	0: 0	6: 0	-15:18	-9:18	2.5	39/49	41/ 57	5.0/5.0	55/ 40
045	F	390	6:59	13:29	0: 0	6:30	-15:18	-8:48	1.3	35/50	41/ 57	5.0/5.0	36/ 23
003	N	300	13:29	18:29	6:30	11:30	-8:48	-3:48	2.1	49/39	25/ 11	5.0/5.0	57/ 70
002	F	480	10:59	18:59	4: 0	12: 0	-11:18	-3:18	2.2	26/48	12/ 47	5.0/5.0	70/ 32
007	N	750	6:59	19:29	0: 0	12:30	-15:18	-2:48	2.8	43/10	62/ 19	5.0/5.0	24/ 77
001	F	300	15:29	20:29	8:30	13:30	-6:48	-1:48	2.1	30/49	11/ 44	5.0/5.0	88/ 42
010	N	420	13:29	20:29	6:30	13:30	-8:48	-1:48	1.9	49/16	53/ 19	5.0/5.0	28/ 56
011	N	390	14:29	20:59	7:30	14: 0	-7:48	-1:18	1.1	49/ 4	80/ 34	5.0/5.0	17/ 47
012	N	150	18:29	20:59	11:30	14: 0	-3:48	-1:18	.3	48/29	47/ 18	5.0/5.0	50/ 69
013	N	180	17:59	20:59	11: 0	14: 0	-4:18	-1:18	.2	48/16	63/ 33	5.0/5.0	18/ 30
016	N	30	20:59	21:29	14: 0	14:30	-1:18	0:48	.5	49/32	44/ 25	3.4/3.2	27/ 32

TABLE VI SUMMARY OF STAR/EARTH HORIZON SIGHTING
DATA FOR A LAUNCH ON 16 JULY, 1969, 108 DEGREE
LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY
ABORT FROM TRANSLUNAR COAST AT TLI PLUS 4 HOURS

STAR NO.		AVAILABILITY (MIN.)	AOS	LOS	AOS	LOS	AOS	LOS	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
			GET		PERI		EI						
002	N	60	8: 3	9: 3	0: 0	1: 0	-39:21	-38:21	2.2	14/14	21/ 13	5.0/5.0	80/ 69
001	N	390	8: 3	14:33	0: 0	6:30	-39:21	-32:51	2.1	27/22	29/ 11	5.0/5.0	49/ 70
044	F	630	8: 3	18:33	0: 0	10:30	-39:21	-28:51	2.5	39/50	40/ 59	5.0/5.0	57/ 40
045	F	690	8: 3	19:33	0: 0	11:30	-39:21	-27:51	1.3	34/50	41/ 58	5.0/5.0	34/ 21
003	N	870	20:33	35: 3	12:30	27: 0	-26:51	-12:21	2.1	50/43	23/ 10	5.0/5.0	58/ 70
002	F	1650	12:33	40: 3	4:30	32: 0	-34:51	-7:21	2.2	25/49	11/ 49	5.0/5.0	70/ 28
007	N	1950	8: 3	40:33	0: 0	32:30	-39:21	-6:51	2.8	43/14	62/ 10	5.0/5.0	24/ 88
001	F	1260	23: 3	44: 3	15: 0	36: 0	-24:21	-3:21	2.1	27/48	11/ 48	5.0/5.0	89/ 39
010	N	1470	19:33	44: 3	11:30	36: 0	-27:51	-3:21	1.9	50/16	52/ 11	5.0/5.0	28/ 64
007	F	120	43:33	45:33	35:30	37:30	-3:51	-1:51	2.8	27/39	11/ 23	5.0/3.5	65/ 40
011	N	1470	21: 3	45:33	13: 0	37:30	-26:21	-1:51	1.1	50/ 4	79/ 14	5.0/3.5	18/ 75
012	N	510	37: 3	45:33	29: 0	37:30	-10:21	-1:51	.3	50/31	45/ 11	5.0/5.0	53/ 79
013	N	690	34: 3	45:33	26: 0	37:30	-13:21	-1:51	.2	50/12	63/ 24	5.0/3.5	17/ 38
015	N	30	45:33	46: 3	37:30	38: 0	-1:51	-1:21	-1.6	50/44	24/ 16	3.5/3.5	61/ 65
016	N	30	46: 3	46:33	38: 0	38:30	-1:21	0:51	.5	37/22	31/ 14	3.3/2.9	34/ 41

TABLE VII SUMMARY OF STAR/EARTH HORIZON SIGHTING DATA FOR A LAUNCH ON 18 JULY, 1969, 89 DEGREE LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY TRANSLUNAR COAST

STAR NO.		AVAILABILITY (MIN.)	AOS	LOS	AOS	LOS	AOS	LOS	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
			GET		TLI		PERI						
043	N	30	3:18	3:48	0:30	1: 0	-69:57	-69:27	1.3	42/47	25/ 14	5.0/5.0	71/ 81
044	N	30	3:18	3:48	0:30	1: 0	-69:57	-69:27	2.5	10/ 9	30/ 17	5.0/5.0	43/ 75
045	N	30	3:18	3:48	0:30	1: 0	-69:57	-69:27	1.3	7/ 5	35/ 24	5.0/5.0	40/ 76
004	N	60	3:18	4:18	0:30	1:30	-69:57	-68:57	.6	39/47	31/ 13	5.0/5.0	72/ 89
002	N	300	3:18	8:18	0:30	5:30	-69:57	-64:57	2.2	32/17	36/ 12	5.0/5.0	26/ 83
001	N	990	3:18	19:48	0:30	17: 0	-69:57	-53:27	2.1	46/22	33/ 10	5.0/5.0	25/ 76
045	F	2670	4:18	48:48	1:30	46: 0	-68:57	-24:27	1.3	32/50	13/ 58	5.0/5.0	79/ 27
044	F	2700	4:18	49:18	1:30	46:30	-68:57	-23:57	2.5	35/50	16/ 60	5.0/5.0	84/ 32
003	N	449	64:48	72:18	62: 0	69:29	-8:27	0:57	2.1	50/50	21/ 21	5.0/5.0	66/ 66
011	N	599	62:18	72:18	59:30	69:29	-10:57	0:57	1.1	50/50	78/ 77	5.0/5.0	13/ 13
001	F	839	58:48	72:48	56: 0	69:59	-14:27	0:27	2.1	25/25	10/ 11	5.0/5.0	83/ 81
002	F	3479	14:48	72:48	12: 0	69:59	-58:27	0:27	2.2	25/29	11/ 35	5.0/5.0	76/ 52
007	N	4019	5:48	72:48	3: 0	69:59	-67:27	0:27	2.8	49/28	57/ 57	5.0/5.0	20/ 35
010	N	1797	43:18	73:16	40:30	70:27	-29:57	0: 0	1.9	50/48	51/ 51	5.0/5.0	34/ 37

TABLE VIII SUMMARY OF STAR/LUNAR HORIZON SIGHTING
DATA FOR A LAUNCH ON 18 JULY, 1969, 89 DEGREE
LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY
TRANSLUNAR COAST

STAR NO.		AVAILABILITY (MIN.)	AOS GET	LOS GET	AOS TLI	LOS TLI	AOS PERI	LOS PERI	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
031	F	270	3:18	7:48	0:30	5: 0	-69:57	-65:27	.2	49/50	34/ 33	3.5/3.5	40/ 47
016	N	240	4:18	8:18	1:30	5:30	-68:57	-64:57	.5	50/48	43/ 41	3.2/3.2	28/ 28
020	N	360	2:48	8:48	0: 0	6: 0	-70:27	-64:27	3.1	48/46	33/ 31	3.5/3.5	37/ 36
026	F	720	3:18	15:18	0:30	12:30	-69:57	-57:57	1.2	40/45	47/ 42	3.5/3.5	6/ 1
022	N	2640	2:48	46:48	0: 0	44: 0	-70:27	-26:27	1.3	13/ 2	47/ 30	3.5/3.5	6/ 32
021	N	3060	2:48	53:48	0: 0	51: 0	-70:27	-19:27	2.2	28/23	24/ 5	3.5/3.5	61/ 85
024	F	3240	3:18	57:18	0:30	54:30	-69:57	-15:57	2.8	31/45	39/ 27	3.5/3.5	33/ 21
020	N	3270	13:48	68:18	11: 0	65:30	-59:27	-4:57	3.1	45/29	29/ 6	3.5/3.5	37/ 56
023	F	3930	3:18	68:48	0:30	66: 0	-69:57	-4:27	2.2	14/37	24/ 17	3.5/2.5	55/ 22
022	F	630	59:18	69:48	56:30	67: 0	-13:57	-3:27	1.3	3/18	5/ 13	3.5/1.8	71/ 7
016	N	3060	19:18	70:18	16:30	67:30	-53:57	-2:57	.5	45/20	37/ 7	3.1/1.7	29/ 47

TABLE 1x SUMMARY OF STAR/EARTH HORIZON SIGHTING
DATA FOR A LAUNCH ON 16 JULY, 1969, 108 DEGREE
LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY
TRANSLUNAR COAST

STAR NO.		AVAILABILITY (MIN.)	AOS	LOS	AOS	LOS	AOS	LOS	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
			GET		TLI		PERI						
044	N	30	4:39	5: 9	0:30	1: 0	-69:59	-69:29	2.5	13/13	25/ 10	5.0/5.0	49/ 77
004	N	80	4:39	6: 0	0:30	1:50	-69:59	-68:38	.6	33/45	37/ 11	5.0/5.0	74/ 82
002	N	270	4:39	9: 9	0:30	5: 0	-69:59	-65:29	2.2	28/15	40/ 12	5.0/5.0	25/ 90
001	N	750	4:39	17: 9	0:30	13: 0	-69:59	-57:29	2.1	47/23	31/ 10	5.0/5.0	24/ 70
044	F	1830	5:39	36: 9	1:30	32: 0	-68:59	-38:29	2.5	39/50	21/ 60	5.0/5.0	85/ 38
045	F	2010	5:39	39: 9	1:30	35: 0	-68:59	-35:29	1.3	28/50	16/ 59	5.0/5.0	65/ 21
001	F	1710	45:39	74: 9	41:30	70: 0	-28:59	0:29	2.1	26/25	10/ 16	5.0/5.0	90/ 73
002	F	3630	13:39	74: 9	9:30	70: 0	-60:59	0:29	2.2	24/31	11/ 38	5.0/5.0	70/ 53
003	N	1380	51: 9	74: 9	47: 0	70: 0	-23:29	0:29	2.1	50/49	20/ 19	5.0/5.0	60/ 72
007	N	4050	6:39	74: 9	2:30	70: 0	-67:59	0:29	2.8	48/26	59/ 55	5.0/5.0	22/ 34
010	N	2310	35:39	74: 9	31:30	70: 0	-38:59	0:29	1.9	50/46	51/ 50	5.0/5.0	29/ 41
011	N	1710	45:39	74: 9	41:30	70: 0	-28:59	0:29	1.1	50/48	78/ 78	5.0/5.0	18/ 9

TABLE X SUMMARY OF STAR/LUNAR HORIZON SIGHTING DATA FOR A LAUNCH ON 18 JULY, 1969, 108 DEGREE LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY TRANSLUNAR COAST

STAR NO.		AVAILABILITY (MIN.)	AOS	LOS	AOS	LOS	AOS	LOS	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
			GET		TLI		PERI						
031	F	450	4:39	12: 9	0:30	8: 0	-69:59	-62:29	.2	48/50	33/ 32	3.5/3.5	89/ 43
016	N	270	9:39	14: 9	5:30	10: 0	-64:59	-60:29	.5	50/48	43/ 41	3.2/3.2	22/ 29
020	N	510	5:39	14: 9	1:30	10: 0	-68:59	-60:29	3.1	50/47	35/ 32	3.5/3.5	47/ 40
026	F	1140	4:39	23:39	0:30	19:30	-69:59	-50:59	1.2	38/45	49/ 42	3.5/3.5	43/ 1
022	N	3150	4: 9	56:39	0: 0	52:30	-70:29	-17:59	1.3	15/ 2	49/ 33	3.5/3.5	13/ 6
021	N	3450	4: 9	61:39	0: 0	57:30	-70:29	-12:59	2.2	29/22	26/ 5	3.5/3.5	66/ 80
024	F	3630	4:39	65: 9	0:30	61: 0	-69:59	-9:29	2.8	29/45	40/ 27	3.5/3.5	15/ 22
020	N	2880	23:39	71:39	19:30	67:30	-50:59	-2:59	3.1	45/28	29/ 5	3.5/3.5	41/ 59
022	F	60	70:39	71:39	66:30	67:30	-3:59	-2:59	1.3	10/14	21/ 17	2.8/2.0	4/ 2
023	F	4050	4:39	72: 9	0:30	68: 0	-69:59	-2:29	2.2	13/41	19/ 13	3.5/2.3	60/ 22
016	N	2760	26:39	72:39	22:30	68:30	-47:59	1:59	.5	45/18	37/ 6	3.1/1.9	26/ 40

TABLE XI SUMMARY OF STAR/EARTH HORIZON SIGHTING
DATA FOR A LAUNCH ON 16 JULY, 1969, 72 DEGREE
LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY
TRANSEARTH COAST WITH 28 REVOLUTIONS IN LUNAR ORBIT

STAR NO.		AVAILABILITY (MIN.)	AOS	LOS	AOS	LOS	AOS	LOS	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
			GET		TEI		EI						
010	N	2520	129:50	171:50	0:30	42:30	-66:49	-24:49	1.9	28/23	21/ 10	5.0/5.0	68/ 58
001	F	3210	129:50	183:20	0:30	54: 0	-66:49	-13:19	2.1	41/50	51/ 53	5.0/5.0	35/ 44
011	N	3600	129:50	189:50	0:30	60:30	-66:49	-6:49	1.1	22/12	60/ 11	5.0/5.0	24/ 84
012	N	3690	129:50	191:20	0:30	62: 0	-66:49	-5:19	.3	43/38	34/ 10	5.0/5.0	54/ 83
003	F	1620	165:20	192:20	36: 0	63: 0	-31:19	-4:19	2.1	45/50	10/ 24	5.0/3.5	81/ 78
007	F	3780	129:50	192:50	0:30	63:30	-66:49	-3:49	2.8	19/45	14/ 26	5.0/3.5	76/ 24
013	N	3780	129:50	192:50	0:30	63:30	-66:49	-3:49	.2	35/ 7	51/ 12	5.0/3.5	35/ 44
010	F	390	188:50	195:20	59:30	66: 0	-7:49	-1:19	1.9	24/45	11/ 21	5.0/3.1	83/ 41
016	N	300	190:20	195:20	61: 0	66: 0	-6:19	-1:19	.5	50/26	47/ 17	5.0/3.5	44/ 64

TABLE XII SUMMARY OF STAR/LUNAR HORIZON SIGHTING
DATA FOR A LAUNCH ON 16 JULY, 1969, 72 DEGREE
LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY
TRANSEARTH COAST WITH 28 REVOLUTIONS IN LUNAR ORBIT

STAR NO.		AVAILABILITY (MIN.)	AOS	LOS	AOS	LOS	AOS	LOS	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
			GET		TEI		EI						
004	N	30	129:50	130:20	0:30	1: 0	-66:49	-66:19	.6	29/45	30/ 22	5.0/5.0	81/ 70
037	F	30	130:20	130:50	1: 0	1:30	-66:19	-65:49	2.1	46/12	27/ 7	5.0/5.0	2/ 3
002	N	60	129:50	130:50	0:30	1:30	-66:49	-65:49	2.2	7/47	54/ 16	5.0/5.0	31/ 20
040	N	60	130:20	131:20	1: 0	2: 0	-66:19	-65:19	.9	19/24	8/ 5	5.0/5.0	71/ 89
044	N	60	130:20	131:20	1: 0	2: 0	-66:19	-65:19	2.5	16/31	19/ 6	5.0/5.0	58/ 44
045	N	90	130:20	131:50	1: 0	2:30	-66:19	-64:49	1.3	11/33	27/ 5	5.0/5.0	40/ 27
044	F	30	131:50	132:20	2:30	3: 0	-64:49	-64:19	2.5	49/50	12/ 13	5.0/5.0	41/ 40
045	F	120	132:20	134:20	3: 0	5: 0	-64:19	-62:19	1.3	48/50	10/ 12	5.0/5.0	26/ 24
042	N	300	129:50	134:50	0:30	5:30	-66:49	-61:49	2.1	21/30	6/ 5	5.0/5.0	48/ 81
037	N	450	130:50	138:20	1:30	9: 0	-65:49	-58:19	2.1	12/ 2	7/ 17	5.0/5.0	3/ 14
035	N	3270	130:50	185:20	1:30	56: 0	-65:49	-11:19	2.1	45/40	6/ 5	5.0/5.0	46/ 82
030	N	180	193:20	196:20	64: 0	67: 0	-3:19	0:19	2.3	50/48	31/ 33	5.0/5.0	12/ 88
033	N	3930	130:50	196:20	1:30	67: 0	-65:49	0:19	1.2	44/19	7/ 35	5.0/5.0	6/ 63
034	N	3990	129:50	196:20	0:30	67: 0	-66:49	0:19	1.9	47/42	6/ 9	5.0/5.0	48/ 36
037	F	2280	158:20	196:20	29: 0	67: 0	-38:19	0:19	2.1	2/14	11/ 35	5.0/5.0	57/ 66
040	F	3889	131:50	196:40	2:30	67:19	-64:49	0: 0	.9	40/46	11/ 25	5.0/5.0	86/ 71
041	F	3919	131:20	196:40	2: 0	67:19	-65:19	0: 0	3.2	17/36	12/ 35	5.0/5.0	68/ 36
042	F	2029	142:50	196:40	33:30	67:19	-33:49	0: 0	2.1	37/39	5/ 14	5.0/5.0	76/ 37

TABLE XIII SUMMARY OF STAR/EARTH HORIZON SIGHTING
DATA FOR A LAUNCH ON 16 JULY, 1969, 89 DEGREE
LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY
TRANSEARTH COAST WITH 30 REVOLUTIONS IN LUNAR ORBIT

STAR NO.		AVAILABILITY (MIN.)	AOS	LOS	AOS	LOS	AOS	LOS	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
			GET		TEI		EI						
010	N	1140	135:19	154:19	0:30	19:30	-59:38	-40:38	1.9	26/24	13/ 10	5.0/5.0	77/ 58
001	F	2430	135:19	175:49	0:30	41: 0	-59:38	-19: 8	2.1	44/50	52/ 52	5.0/5.0	30/ 46
011	N	3030	135:19	185:49	0:30	51: 0	-59:38	-9: 8	1.1	18/11	53/ 12	5.0/5.0	28/ 84
012	N	3150	135:19	187:49	0:30	53: 0	-59:38	-7: 8	.3	41/37	29/ 11	5.0/5.0	56/ 83
003	F	2730	143:49	189:19	9: 0	54:30	-51: 8	-5:38	2.1	46/50	10/ 23	5.0/3.5	77/ 79
007	F	3300	135:19	190:19	0:30	55:30	-59:38	-4:38	2.8	20/44	24/ 28	5.0/3.5	65/ 22
013	N	3300	135:19	190:19	0:30	55:30	-59:38	-4:38	.2	32/ 9	46/ 11	5.0/3.5	40/ 47
010	F	540	184:19	193:19	49:30	58:30	-10:38	-1:38	1.9	25/42	10/ 23	5.0/3.5	82/ 45
013	F	60	192:49	193:49	58: 0	59: 0	-2: 8	-1: 8	.2	19/33	19/ 14	3.5/1.9	75/ 33
016	N	420	186:49	193:49	52: 0	59: 0	-8: 8	-1: 8	.5	50/22	47/ 10	5.0/3.1	44/ 73

TABLE XIV SUMMARY OF STAR/EARTH HORIZON SIGHTING
DATA FOR A LAUNCH ON 16 JULY, 1969, 89 DEGREE
LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY
TRANSEARTH COAST WITH 30 REVOLUTIONS IN LUNAR ORBIT
WITH MINIMUM SUN ELEVATION OF 5 DEGREES

STAR NO.		AVAILABILITY (MIN.)	AOS GET	LOS GET	AOS TEI	LOS TEI	AOS EI	LOS EI	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
010	N	1890	135:19	166:49	0:30	32: 0	-59:38	-28: 8	1.9	26/23	13/ 5	5.0/5.0	77/ 63
001	F	2430	135:19	175:49	0:30	41: 0	-59:38	-19: 8	2.1	44/50	52/ 52	5.0/5.0	30/ 46
011	N	3120	135:19	187:19	0:30	52:30	-59:38	-7:38	1.1	18/11	53/ 6	5.0/5.0	28/ 77
003	F	3240	135:19	189:19	0:30	54:30	-59:38	+5:38	2.1	46/50	10/ 23	5.0/3.5	77/ 79
007	F	3300	135:19	190:19	0:30	55:30	-59:38	-4:38	2.8	20/44	24/ 28	5.0/3.5	65/ 22
012	N	3300	135:19	190:19	0:30	55:30	-59:38	-4:38	.3	41/37	29/ 6	5.0/3.5	56/ 78
013	N	3330	135:19	190:49	0:30	56: 0	-59:38	-4: 8	.2	32/ 7	46/ 6	5.0/3.5	40/ 52
010	F	720	181:19	193:19	46:30	58:30	-13:38	+1:38	1.9	25/42	5/ 23	5.0/3.5	76/ 45
011	F	120	191:19	193:19	56:30	58:30	-3:38	+1:38	1.1	25/41	7/ 6	3.5/3.5	49/ 30
013	F	90	192:19	193:49	57:30	59: 0	-2:38	-1: 8	.2	18/33	9/ 14	3.5/1.9	84/ 33
016	N	420	186:49	193:49	52: 0	59: 0	-6: 8	-1: 8	.5	50/22	47/ 10	5.0/3.1	44/ 73

TABLE XV SUMMARY OF STAR/LUNAR HORIZON SIGHTING
DATA FOR A LAUNCH ON 18 JULY, 1969, 89 DEGREE
LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY
TRANSEARTH COAST WITH 30 REVOLUTIONS IN LUNAR ORBIT

STAR NO.		AVAILABILITY (MIN.)	AOS GET	LOS GET	AOS TEI	LOS TEI	AOS EI	LOS EI	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
002	N	30	135:19	135:49	0:30	1: 0	-59:38	-59: 8	2.2	15/42	48/ 21	5.0/5.0	28/ 21
004	N	30	135:19	135:49	0:30	1: 0	-59:38	-59: 8	.6	32/48	32/ 20	5.0/5.0	78/ 68
040	N	60	135:19	136:19	0:30	1:30	-59:38	-58:38	.9	14/22	9/ 7	5.0/5.0	58/ 88
044	N	30	135:49	136:19	1: 0	1:30	-59: 8	-58:38	2.5	21/30	16/ 7	5.0/5.0	49/ 42
045	N	30	135:49	136:19	1: 0	1:30	-59: 8	-58:38	1.3	17/27	21/ 10	5.0/5.0	34/ 29
037	N	120	135:49	137:49	1: 0	3: 0	-59: 8	-57: 8	2.1	10/ 2	9/ 17	5.0/5.0	2/ 5
042	N	210	135:19	138:49	0:30	4: 0	-59:38	-56: 8	2.1	18/29	13/ 5	5.0/5.0	53/ 79
035	N	2670	135:49	180:19	1: 0	45:30	-59: 8	-14:38	2.1	43/40	8/ 5	5.0/5.0	46/ 81
030	N	240	190:49	194:49	56: 0	60: 0	-4: 8	0: 8	2.3	50/48	31/ 33	5.0/5.0	13/ 55
033	N	3540	135:49	194:49	1: 0	60: 0	-59: 8	0: 8	1.2	42/19	9/ 35	5.0/5.0	4/ 29
034	N	3570	135:19	194:49	0:30	60: 0	-59:38	0: 8	1.9	44/42	12/ 9	5.0/5.0	49/ 70
037	F	2730	149:19	194:49	14:30	60: 0	-45:38	0: 8	2.1	3/13	19/ 35	5.0/5.0	26/ 35
040	F	3488	136:49	194:57	2: 0	60: 8	-58: 8	0: 0	.9	41/46	13/ 25	5.0/5.0	82/ 70
041	F	3488	136:49	194:57	2: 0	60: 8	-58: 8	0: 0	3.2	20/36	15/ 34	5.0/5.0	44/ 35
042	F	2828	147:49	194:57	13: 0	60: 8	-47: 8	0: 0	2.1	37/39	5/ 14	5.0/5.0	71/ 38

TABLE XVI SUMMARY OF STAR/EARTH HORIZON SIGHTING
DATA FOR A LAUNCH ON 18 JULY, 1969, 108 DEGREE
LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY
TRANSEARTH COAST WITH 30 REVOLUTIONS IN LUNAR ORBIT

STAR NO.		AVAILABILITY (MIN.)	AOS GET	LOS GET	AOS TEI	LOS TEI	AOS EI	LOS EI	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
010	N	600	134:39	144:39	0:30	10:30	-57:50	-47:50	1.9	26/25	11/ 10	5.0/5.0	80/ 55
001	F	2190	134:39	171: 9	0:30	37: 0	-57:50	-21:20	2.1	45/50	51/ 52	5.0/5.0	29/ 46
011	N	2910	134:39	183: 9	0:30	49: 0	-57:50	-9:20	1.1	17/11	51/ 10	5.0/5.0	29/ 82
012	N	3030	134:39	185: 9	0:30	51: 0	-57:50	-7:20	.3	40/37	28/ 10	5.0/5.0	57/ 83
003	F	3120	134:39	186:39	0:30	52:30	-57:50	-5:50	2.1	46/50	11/ 23	5.0/3.5	76/ 79
007	F	3180	134:39	187:39	0:30	53:30	-57:50	-4:50	2.8	21/43	26/ 28	5.0/3.5	63/ 22
013	N	3180	134:39	187:39	0:30	53:30	-57:50	-4:50	.2	31/ 9	45/ 10	5.0/3.5	42/ 47
010	F	570	181: 9	190:39	47: 0	56:30	-11:20	-1:50	1.9	25/40	10/ 25	5.0/3.5	82/ 48
013	F	60	190: 9	191: 9	56: 0	57: 0	-2:20	-1:20	.2	18/28	16/ 19	3.5/2.4	82/ 40
016	N	420	184: 9	191: 9	50: 0	57: 0	-8:20	-1:20	.5	49/24	47/ 14	5.0/3.4	44/ 69

TABLE XVII SUMMARY OF STAR/EARTH HORIZON SIGHTING
DATA FOR A LAUNCH ON 18 JULY, 1969, 108 DEGREE
LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY
TRANSEARTH COAST WITH 30 REVOLUTIONS IN LUNAR ORBIT
WITH MINIMUM SUN ELEVATION OF 5 DEGREES

STAR NO.		AVAILABILITY (MIN.)	AOS GET	LOS GET	AOS TEI	LOS TEI	AOS EI	LOS EI	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
010	N	1560	134:39	160:39	0:30	26:30	-57:50	-31:50	1.9	26/23	11/ 5	5.0/5.0	80/ 63
001	F	2190	134:39	171: 9	0:30	37: 0	-57:50	-21:20	2.1	45/50	51/ 52	5.0/5.0	29/ 46
011	N	2970	134:39	184: 9	0:30	50: 0	-57:50	-8:20	1.1	17/11	51/ 0	5.0/5.0	29/ 78
003	F	3120	134:39	186:39	0:30	52:30	-57:50	-5:50	2.1	46/50	11/ 23	5.0/3.5	76/ 79
007	F	3180	134:39	187:39	0:30	53:30	-57:50	-4:50	2.8	21/43	26/ 28	5.0/3.5	63/ 22
012	N	3180	134:39	187:39	0:30	53:30	-57:50	-4:50	.3	40/37	28/ 6	5.0/3.5	57/ 77
013	N	3210	134:39	188: 9	0:30	54: 0	-57:50	-4:20	.2	31/ 7	45/ 6	5.0/3.5	42/ 52
010	F	780	177:39	190:39	43:30	56:30	-14:50	-1:50	1.9	25/40	5/ 25	5.0/3.5	76/ 48
011	F	150	188: 9	190:39	54: 0	56:30	-4:20	-1:50	1.1	23/38	5/ 7	3.5/3.5	53/ 31
013	F	90	189:39	191: 9	55:30	57: 0	-2:50	-1:20	.2	17/28	7/ 19	3.5/2.4	80/ 40
016	N	420	184: 9	191: 9	50: 0	57: 0	-8:20	-1:20	.5	49/24	47/ 14	5.0/3.4	44/ 69

TABLE XVIII SUMMARY OF STAR/LUNAR HORIZON SIGHTING
DATA FOR A LAUNCH ON 16 JULY, 1969, 108 DEGREE
LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY
TRANSEARTH COAST WITH 30 REVOLUTIONS IN LUNAR ORBIT

STAR NO.		AVAILABILITY (MIN.)	AOS	LOS	AOS	LOS	AOS	LOS	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
			GET		TEI		EI						
002	N	30	134:39	135: 9	0:30	1: 0	-57:50	-57:20	2.2	15/43	47/ 20	5.0/5.0	28/ 21
004	N	30	134:39	135: 9	0:30	1: 0	-57:50	-57:20	.6	32/49	32/ 20	5.0/5.0	77/ 67
040	N	60	134:39	135:39	0:30	1:30	-57:50	-56:50	.9	13/23	10/ 7	5.0/5.0	59/ 86
044	N	30	135: 9	135:39	1: 0	1:30	-57:20	-56:50	2.5	22/31	15/ 6	5.0/5.0	47/ 41
045	N	30	135: 9	135:39	1: 0	1:30	-57:20	-56:50	1.3	18/29	20/ 9	5.0/5.0	34/ 28
037	N	90	135: 9	136:39	1: 0	2:30	-57:20	-55:50	2.1	9/ 2	11/ 17	5.0/5.0	2/ 4
042	N	180	134:39	137:39	0:30	3:30	-57:50	-54:50	2.1	17/29	14/ 6	5.0/5.0	53/ 79
035	N	2520	134:39	176:39	0:30	42:30	-57:50	-15:50	2.1	44/40	6/ 5	5.0/5.0	41/ 81
030	N	240	188: 9	192: 9	54: 0	58: 0	-4:20	0:20	2.3	50/48	31/ 33	5.0/5.0	13/ 77
033	N	3420	135: 9	192: 9	1: 0	58: 0	-57:20	0:20	1.2	41/19	11/ 35	5.0/5.0	4/ 52
034	N	3450	134:39	192: 9	0:30	58: 0	-57:50	0:20	1.9	43/42	13/ 9	5.0/5.0	49/ 47
037	F	2760	146: 9	192: 9	12: 0	58: 0	-46:20	0:20	2.1	3/14	20/ 35	5.0/5.0	21/ 56
040	F	3380	136: 9	192:30	2: 0	58:20	-56:20	0: 0	.9	42/46	13/ 25	5.0/5.0	79/ 70
041	F	3380	136: 9	192:30	2: 0	58:20	-56:20	0: 0	3.2	21/36	16/ 34	5.0/5.0	40/ 35
042	F	2990	142:39	192:30	8:30	58:20	-49:50	0: 0	2.1	37/39	5/ 14	5.0/5.0	71/ 38

TABLE XIX. SUMMARY OF STAR/EARTH HORIZON SIGHTING DATA FOR A LAUNCH ON 18 JULY, 1969, 89 DEGREE LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY TRANSEARTH COAST WITH 25 REVOLUTIONS IN LUNAR ORBIT

STAR NO.		AVAILABILITY (MIN.)	AOS GET	LOS GET	AOS TEI	LOS TEI	AOS EI	LOS EI	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
001	F	750	145:16	157:46	0:30	13: 0	-49:54	-37:24	2.1	49/50	51/ 51	5.0/5.0	21/ 50
011	N	2190	145:16	181:46	0:30	37: 0	-49:54	-13:24	1.1	13/11	40/ 11	5.0/5.0	35/ 81
012	N	2400	145:16	185:16	0:30	40:30	-49:54	-9:54	.3	38/37	22/ 10	5.0/5.0	57/ 81
003	F	2520	145:16	187:16	0:30	42:30	-49:54	-7:54	2.1	47/50	14/ 23	5.0/5.0	66/ 82
013	N	2610	145:16	188:46	0:30	44: 0	-49:54	-6:24	.2	27/11	39/ 12	5.0/3.5	52/ 46
007	F	2670	145:16	189:46	0:30	45: 0	-49:54	-5:24	2.8	24/44	33/ 29	5.0/3.5	59/ 18
011	F	60	191:16	192:16	46:30	47:30	-3:54	-2:54	1.1	26/30	10/ 11	3.5/3.5	41/ 35
010	F	840	179:16	193:16	34:30	48:30	-15:54	-1:54	1.9	25/41	10/ 24	5.0/3.5	81/ 48
013	F	90	192:16	193:46	47:30	49: 0	-2:54	-1:24	.2	18/29	13/ 16	3.5/2.2	90/ 39
016	N	630	183:16	193:46	38:30	49: 0	-11:54	-1:24	.5	50/24	47/ 14	5.0/3.3	45/ 72

TABLE XX SUMMARY OF STAR/EARTH HORIZON SIGHTING
DATA FOR A LAUNCH ON 16 JULY, 1969, 89 DEGREE
LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY
TRANSEARTH COAST WITH 35 REVOLUTIONS IN LUNAR ORBIT
WITH MINIMUM SUN ELEVATION OF 5 DEGREES

STAR NO.		AVAILABILITY (MIN.)	AOS GET	LOS GET	AOS TEI	LOS TEI	AOS EI	LOS EI	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
001	F	750	145:16	157:46	0:30	13: 0	-49:54	-37:24	2.1	49/50	51/ 51	5.0/5.0	21/ 60
011	N	2310	145:16	183:46	0:30	39: 0	-49:54	-11:24	1.1	13/11	40/ 6	5.0/5.0	35/ 76
003	F	2520	145:16	187:16	0:30	42:30	-49:54	-7:54	2.1	47/50	14/ 23	5.0/5.0	66/ 82
012	N	2640	145:16	189:16	0:30	44:30	-49:54	-5:54	.3	38/37	22/ 5	5.0/3.5	57/ 75
007	F	2670	145:16	189:46	0:30	45: 0	-49:54	-5:24	2.8	24/44	33/ 29	5.0/3.5	59/ 18
013	N	2670	145:16	189:46	0:30	45: 0	-49:54	-5:24	.2	27/ 9	39/ 6	5.0/3.5	52/ 62
010	F	1260	172:16	193:16	27:30	48:30	-22:54	-1:54	1.9	26/41	5/ 24	5.0/3.5	75/ 48
011	F	240	189:16	193:16	44:30	48:30	-5:54	-1:54	1.1	21/39	6/ 7	3.5/3.5	53/ 27
013	F	120	191:46	193:46	47: 0	49: 0	-3:24	-1:24	.2	17/29	6/ 18	3.5/2.2	78/ 39
016	N	630	183:16	193:46	38:30	49: 0	-11:54	-1:24	.5	50/24	47/ 14	5.0/3.3	45/ 72

TABLE XXI SUMMARY OF STAR/LUNAR HORIZON SIGHTING
DATA FOR A LAUNCH ON 16 JULY, 1969, 89 DEGREE
LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY
TRANSEARTH COAST WITH 35 REVOLUTIONS IN LUNAR ORBIT

STAR NO.		AVAILABILITY (MIN.)	AOS GET	LOS GET	AOS TEI	LOS TEI	AOS EI	LOS EI	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
037	N	30	145:16	145:46	0:30	1: 0	-49:54	-49:24	2.1	8/ 2	11/ 17	5.0/5.0	1/ 1
040	N	30	145:16	145:46	0:30	1: 0	-49:54	-49:24	.9	11/20	16/ 9	5.0/5.0	71/ 85
044	N	30	145:16	145:46	0:30	1: 0	-49:54	-49:24	2.5	8/28	27/ 8	5.0/5.0	57/ 40
045	N	30	145:16	145:46	0:30	1: 0	-49:54	-49:24	1.3	2/26	35/ 12	5.0/5.0	44/ 29
042	N	120	145:16	147:16	0:30	2:30	-49:54	-47:54	2.1	14/28	21/ 5	5.0/5.0	63/ 77
035	N	1680	145:16	173:16	0:30	28:30	-49:54	-21:54	2.1	39/40	12/ 5	5.0/5.0	44/ 79
030	N	329	189:16	194:46	44:30	50: 0	-5:54	0:24	2.3	50/46	31/ 33	5.0/5.0	14/ 76
033	N	2970	145:16	194:46	0:30	50: 0	-49:54	0:24	1.2	41/19	12/ 35	5.0/5.0	3/ 51
034	N	2970	145:16	194:46	0:30	50: 0	-49:54	0:24	1.9	39/42	18/ 9	5.0/5.0	51/ 49
037	F	2640	150:46	194:46	6: 0	50: 0	-44:24	0:24	2.1	5/14	24/ 35	5.0/5.0	7/ 54
040	F	2934	146:16	195:10	1:30	50:24	-48:54	0: 0	.9	44/46	15/ 25	5.0/5.0	75/ 71
041	F	2934	146:16	195:10	1:30	50:24	-48:54	0: 0	3.2	24/36	20/ 34	5.0/5.0	34/ 36
042	F	2844	147:46	195:10	3: 0	50:24	-47:24	0: 0	2.1	39/39	6/ 14	5.0/5.0	74/ 37

TABLE XXII SUMMARY OF STAR/EARTH HORIZON SIGHTING
DATA FOR A LAUNCH ON 18 JULY, 1969, 108 DEGREE
LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY
TRANSEARTH COAST WITH 35 REVOLUTIONS IN LUNAR ORBIT

STAR NO.		AVAILABILITY (MIN.)	AOS	LOS	AOS	LOS	AOS	LOS	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
			GET		TEI		EI						
001	F	60	145: 6	146: 6	1: 0	2: 0	-47:36	-46:36	2.1	50/50	50/ 50	5.0/5.0	18/ 74
011	N	2010	144:36	178: 6	0:30	34: 0	-48: 6	-14:36	1.1	13/11	37/ 11	5.0/5.0	37/ 81
012	N	2250	144:36	182: 6	0:30	38: 0	-48: 6	-10:36	.3	38/37	21/ 10	5.0/5.0	57/ 81
003	F	2400	144:36	184:36	0:30	40:30	-48: 6	-8: 6	2.1	47/50	15/ 23	5.0/3.5	64/ 82
013	N	2490	144:36	186: 6	0:30	42: 0	-48: 6	-6:36	.2	26/11	37/ 11	5.0/3.5	54/ 47
007	F	2550	144:36	187: 6	0:30	43: 0	-48: 6	-5:36	2.8	25/44	34/ 29	5.0/3.5	58/ 18
011	F	90	188:36	190: 6	44:30	46: 0	-4: 6	-2:36	1.1	25/33	11/ 10	3.5/3.5	41/ 31
010	F	930	175: 6	190:36	31: 0	46:30	-17:36	-2: 6	1.9	26/40	10/ 20	5.0/3.5	80/ 50
016	N	690	179:36	191: 6	35:30	47: 0	-13: 6	-1:36	.5	50/26	48/ 17	5.0/3.5	45/ 70
013	F	120	189:36	191:36	45:30	47:30	-3: 6	-1: 6	.2	17/36	12/ 10	3.5/2.5	87/ 30

TABLE XXIII SUMMARY OF STAR/EARTH HORIZON SIGHTING DATA FOR A LAUNCH ON 18 JULY, 1969, 108 DEGREE LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY TRANSEARTH COAST WITH 35 REVOLUTIONS IN LUNAR ORBIT WITH MINIMUM SUN ELEVATION OF 5 DEGREES

STAR NO.		AVAILABILITY (MIN.)	AOS	LOS	AOS	LOS	AOS	LOS	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
			GET		TEI		EI						
001	F	60	145: 6	146: 6	1: 0	2: 0	-47:36	-46:36	2.1	50/50	50/ 50	5.0/5.0	18/ 74
011	N	2160	144:36	180:36	0:30	36:30	-48: 6	-12: 6	1.1	13/11	37/ 5	5.0/5.0	37/ 74
003	F	2400	144:36	184:36	0:30	40:30	-48: 6	-8: 6	2.1	47/50	15/ 23	5.0/3.5	64/ 82
012	N	2490	144:36	186: 6	0:30	42: 0	-48: 6	-6:36	.3	38/37	21/ 6	5.0/3.5	57/ 75
007	F	2550	144:36	187: 6	0:30	43: 0	-48: 6	-5:36	2.8	25/44	34/ 29	5.0/3.5	58/ 18
013	N	2550	144:36	187: 6	0:30	43: 0	-48: 6	-5:36	.2	26/ 9	37/ 5	5.0/3.5	54/ 52
010	F	1440	166:36	190:36	22:30	46:30	-26: 6	-2: 6	1.9	26/40	5/ 26	5.0/3.5	74/ 50
011	F	270	186: 6	190:36	42: 0	46:30	-6:36	-2: 6	1.1	20/37	5/ 8	3.5/3.5	54/ 28
013	F	150	189: 6	191:36	45: 0	47:30	-3:36	-1: 6	.2	17/36	5/ 10	3.5/2.5	76/ 30
016	N	720	179:36	191:36	35:30	47:30	-13: 6	-1: 6	.5	50/21	48/ 8	5.0/2.8	45/ 81
022	N	30	191: 6	191:36	47: 0	47:30	-1:36	-1: 6	1.3	45/34	20/ 10	3.3/2.8	23/ 26

TABLE XXIV SUMMARY OF STAR/LUNAR HORIZON SIGHTING
DATA FOR A LAUNCH ON 16 JULY, 1969, 106 DEGREE
LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY
TRANSEARTH COAST WITH 35 REVOLUTIONS IN LUNAR ORBIT

STAR NO.		AVAILABILITY (MIN.)	AOS	LOS	AOS	LOS	AOS	LOS	STAR MAG.	TRUNNION ANGLE	SUN ELEVATION	SCATTERED LIGHT	MEASURED PLANE ANGLE
			GET		TEI		EI						
040	N	30	144:36	145: 6	0:30	1: 0	-48: 6	-47:36	.9	11/20	17/ 9	5.0/5.0	73/ 83
044	N	30	144:36	145: 6	0:30	1: 0	-48: 6	-47:36	2.5	8/30	27/ 7	5.0/5.0	55/ 39
045	N	30	144:36	145: 6	0:30	1: 0	-48: 6	-47:36	1.3	3/27	34/ 10	5.0/5.0	43/ 29
042	N	90	144:36	146: 6	0:30	2: 0	-48: 6	-46:36	2.1	13/26	22/ 7	5.0/5.0	64/ 78
035	N	1440	144:36	168:36	0:30	24:30	-48: 6	-24: 6	2.1	38/40	13/ 5	5.0/5.0	45/ 79
030	N	330	186:36	192: 6	42:30	48: 0	-6: 6	0:36	2.3	50/48	31/ 33	5.0/5.0	14/ 85
033	N	2880	144:36	192:36	0:30	48:30	-48: 6	0: 6	1.2	39/19	13/ 35	5.0/5.0	3/ 26
034	N	2880	144:36	192:36	0:30	48:30	-48: 6	0: 6	1.9	38/42	19/ 9	5.0/5.0	51/ 73
037	F	2580	149:36	192:36	5:30	48:30	-43: 6	0: 6	2.1	6/13	25/ 35	5.0/5.0	5/ 32
040	F	2826	145:36	192:42	1:30	48:36	-47: 6	0: 0	.9	44/46	16/ 25	5.0/5.0	73/ 71
041	F	2826	145:36	192:42	1:30	48:36	-47: 6	0: 0	3.2	25/36	21/ 34	5.0/5.0	31/ 36
042	F	2766	146:36	192:42	2:30	48:36	-46: 6	0: 0	2.1	40/39	7/ 14	5.0/5.0	75/ 37

TABLE XXV.- LOSS OF COMMUNICATIONS NAVIGATION PROCEDURES

1. TLI plus 4 hr abort (detailed schedules provided)

a. Make abort burn.

b. Initialize W-matrix at the first mark to value given on the detailed sighting schedule.

c. Initiate sighting as soon as possible after abort according to the schedule given in the crew chart.

1. The horizontal lines represent the start of the sighting intervals.

2. The vertical lines represent stars which are available for use with P23.

3. The numbers adjacent to the vertical lines are the sightings required with the given star.

4. Only earth horizon marks will be made.

d. Crew charts are provided for each day to insure coverage for the entire daily launch window. The charts provide data for a short return time (25 hr or less) and for a long return time (greater than 25 hr); targets for aborts from trajectories other than those given on the crew charts are the same, but acquisition and loss times of the stars will differ.

2. Lunar orbit aborts (detailed schedules provided)

a. The first 17 hr and the last 25 hr of the schedule should not be changed.

b. The data in the middle of the TE leg may be rearranged for rest periods and midcourse maneuvers.

c. CHANGE TO THE EI CHART AT EI MINUS 40 HR.

d. The key for the detailed schedule is as follows.

1. The vertical solid line indicates star/horizon combinations available for the earliest TEI caused by loss of communications TEI (28 revolutions in lunar orbit, 72° launch azimuth, first TLI opportunity).

2. The vertical dashed line indicates star/horizon combinations available for a later TEI (35 revolutions in lunar orbit, 108° launch azimuth, second TLI opportunity).

3. The horizontal solid line indicates the start of a sighting interval.

4. The numbers adjacent to the vertical lines are the required sightings with the given star.

TABLE XXV.- LOSS OF COMMUNICATIONS NAVIGATION PROCEDURES - Continued

3. For loss of communications during the nominal transearth trajectory, the scheduled sightings and initial W-matrices provided in the Flight Plan should be followed.

4. General TE optical navigation rules for cases not included in the crew charts and the Flight Plan.

a. A sighting is to consist of three marks.

b. A sighting interval is to consist of at least three star/horizon sightings, although as many as five are advisable (five should be used at the end of every sleep period). Observations made with stars in the orbital plane should be emphasized. One sighting made with an out-of-plane star (ange > 45° to the orbit plane) in every five sets is sufficient. If only three stars are grouped together, all stars should be inplane.

c. The navigation sighting intervals should be scheduled so that, immediately after a period of length Δt, not to exceed 3 hours in a non-PTC mode, five times Δt should be spent in a PTC mode (based on thermal constraints), provided it does not interfere with navigation sightings which are essential for a safe entry.

d. The sextant calibration routine will be exercised at least every half hour while navigation sightings are in progress. The sextant calibration will be repeated until at least two checks (not necessarily sequential ones) are in agreement to within 0.003°.

e. If an abort burn is performed during translunar coast, the W-matrix will be initialized to 10 000 feet and to 10 ft/sec for onboard processing of the transearth sighting data. Navigation sightings will be scheduled every 2.5 hours in the short return trajectory, and only star/earth horizon marks will be made. The last sighting interval will be scheduled just after the last midcourse correction at EI minus 3 hours.

f. The transearth navigation sighting schedule in the flight plan is designed for a 60-hour return trajectory (30 revolutions in lunar orbit). If the return time is altered because of an early TEI caused by communications loss or any other reason, the following rules are to be followed to set up a navigation sighting schedule to ensure a safe entry.

1. TEI through TEI plus 17 hr

The nominal schedule is to be followed from TEI to TEI plus 17 hr. The first two batches of sightings are to be on the moon, and the second two batches are to be on the earth. They are scheduled at

TABLE XXV.- LOSS OF COMMUNICATIONS NAVIGATION PROCEDURES - Concluded

approximately TEI plus 1 hr 30 min, TEI plus 11 hr 30 min, TEI plus 13 hr, and TEI plus 15 hr. The corresponding sightings are shown in the flight plan.

2. EI minus 25 hr through EI

The nominal schedule is also to be followed from EI minus 25 hr to EI. The navigation sightings are scheduled at approximately EI minus 25 hr, EI minus 23 hr, EI minus 19 hr, EI minus 15 hr, EI minus 10 hr, EI minus 5 hr, and EI minus 2 hr 30 min. The corresponding central body for the star horizon sightings is shown in the flight plan.

3. TEI plus 17 hr through EI minus 25 hr

Between TEI plus 17 hr and EI minus 25 hr, schedule two-thirds as many sightings as there are hours of coast during this period. Sightings should be scheduled in a ratio of 2 to 1 (earth to moon) with a minimum of 10 sightings during this coast period (i.e., if the time between TEI plus 17 hr and EI minus 25 hr is less than 18 hr, 10 sightings will be required).

g. Large state vector corrections may be expected at the following times.

1. At initiation of tracking
2. At the first switch of reference bodies
3. After a long period of no sightings
4. During the last hours of TE coast when the vehicle is near the earth

If a large state vector correction (greater than 50 n. mi. in position and 50 fps in velocity) is displayed during the V06N49 display in P23, the mark should be rejected and repeated. If the large correction occurs again, it should be accepted and incorporated.

h. Star availability is directly related to the G.m.t. of entry interface. If an abort should occur which is not covered by a crew chart but which has an EI time that is the same as the one on a crew chart, the star availability from the crew chart may be used near the earth.

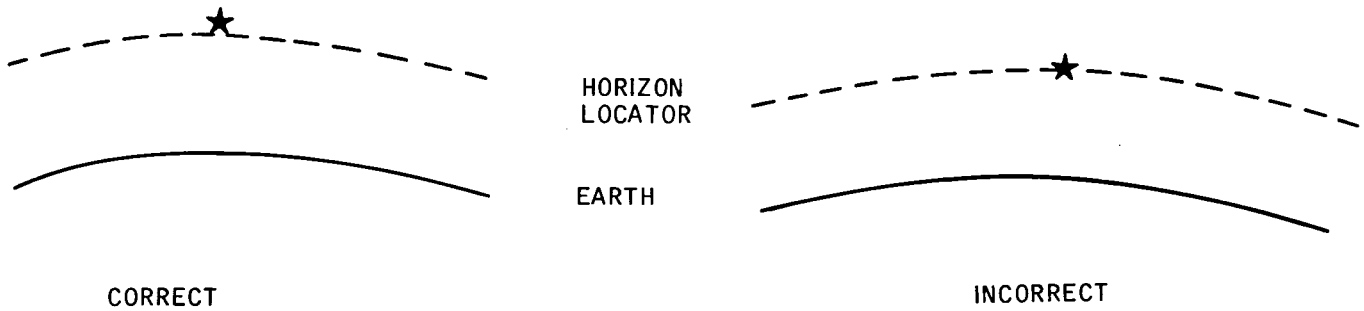

FIGURE 1.- LOCATION OF STAR WITH RESPECT TO HORIZON LOCATOR FOR STAR/EARTH HORIZON MARKS DURING P23.

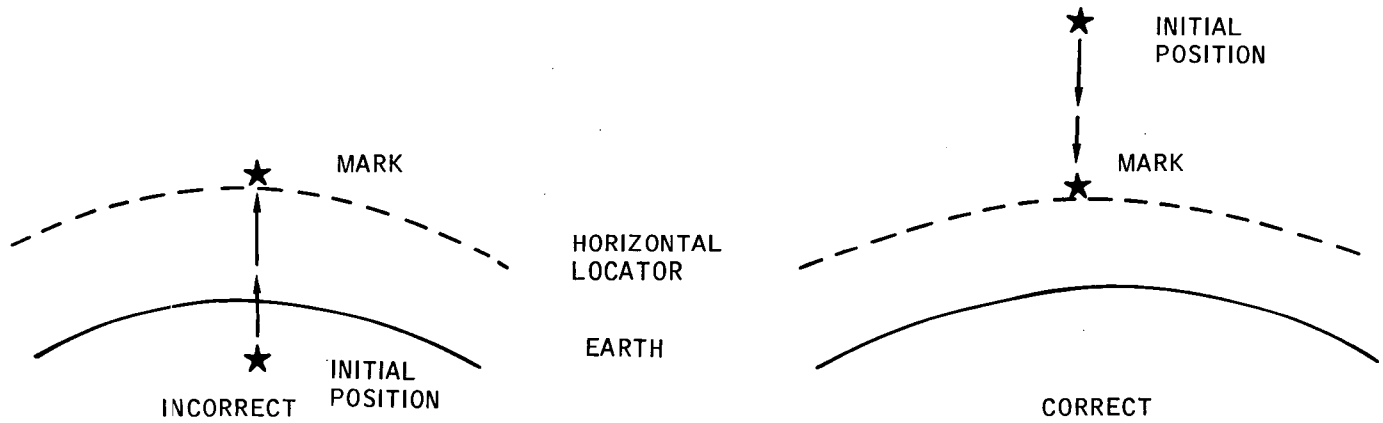

FIGURE 2.- PROCEDURE USED TO SUPERIMPOSE STAR ON EARTH HORIZON DURING P23 MARK.

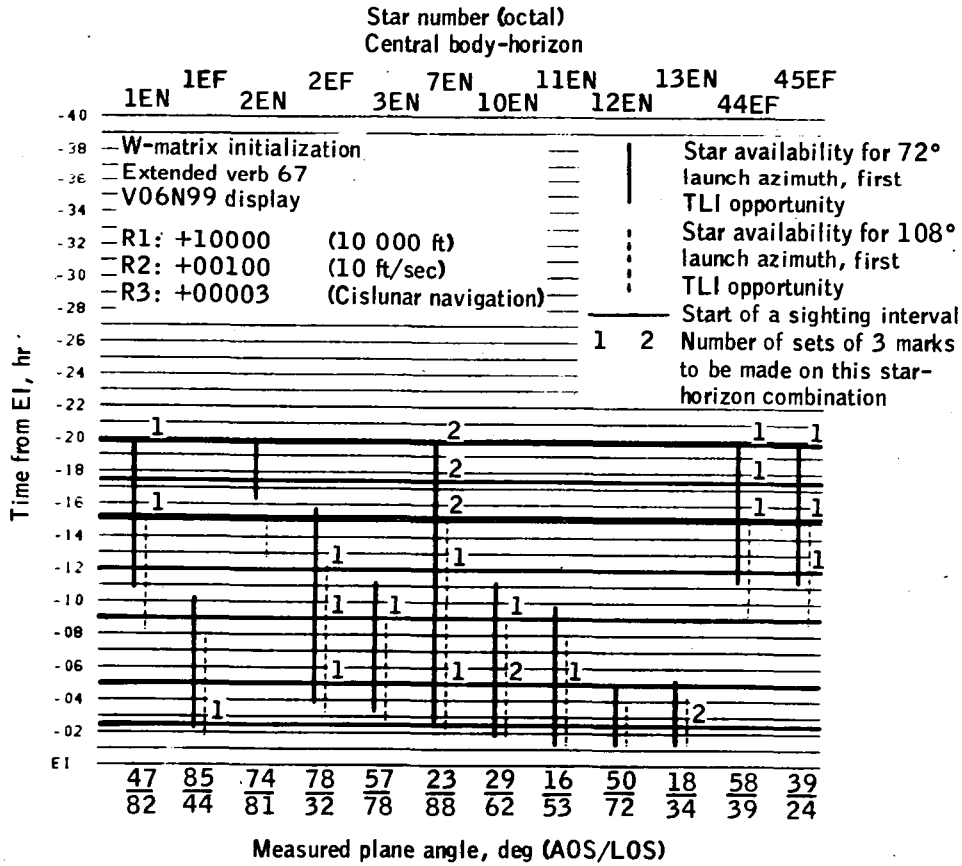

FIGURE 3 (CREW CHART) STAR AVAILABILITY AND SIGHTING SCHEDULE FOR AN ABORT FROM TRANSLUNAR COAST AT TLI PLUS 4 HOURS, SHORT RETURN FOR A LAUNCH ON 16 JULY, 1969

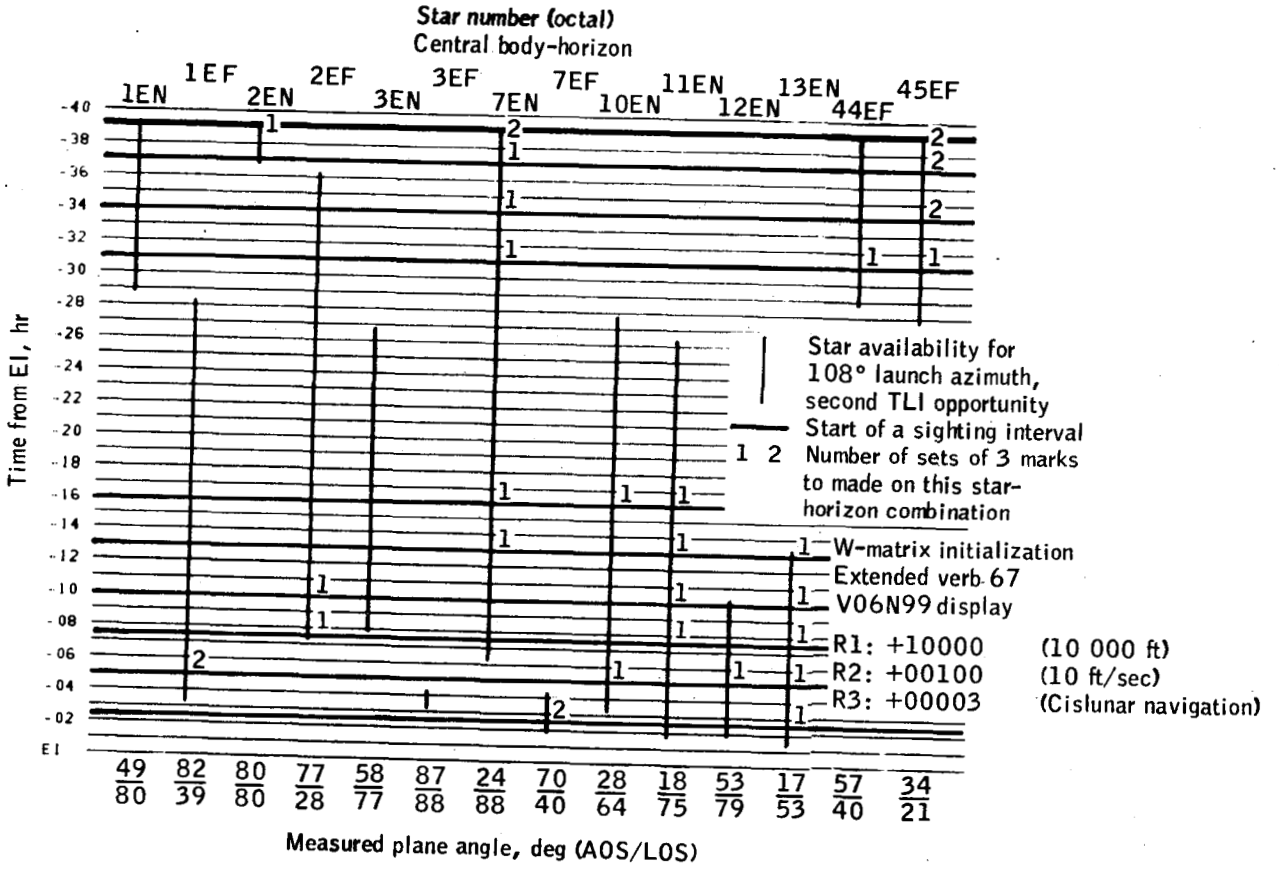

FIGURE 4 (CREW CHART) STAR AVAILABILITY AND SIGHTING SCHEDULE FOR AN ABORT FROM TRANSLUNAR COAST AT TLI PLUS 4 HOURS, LONG RETURN FOR A LAUNCH ON 18 JULY, 1969

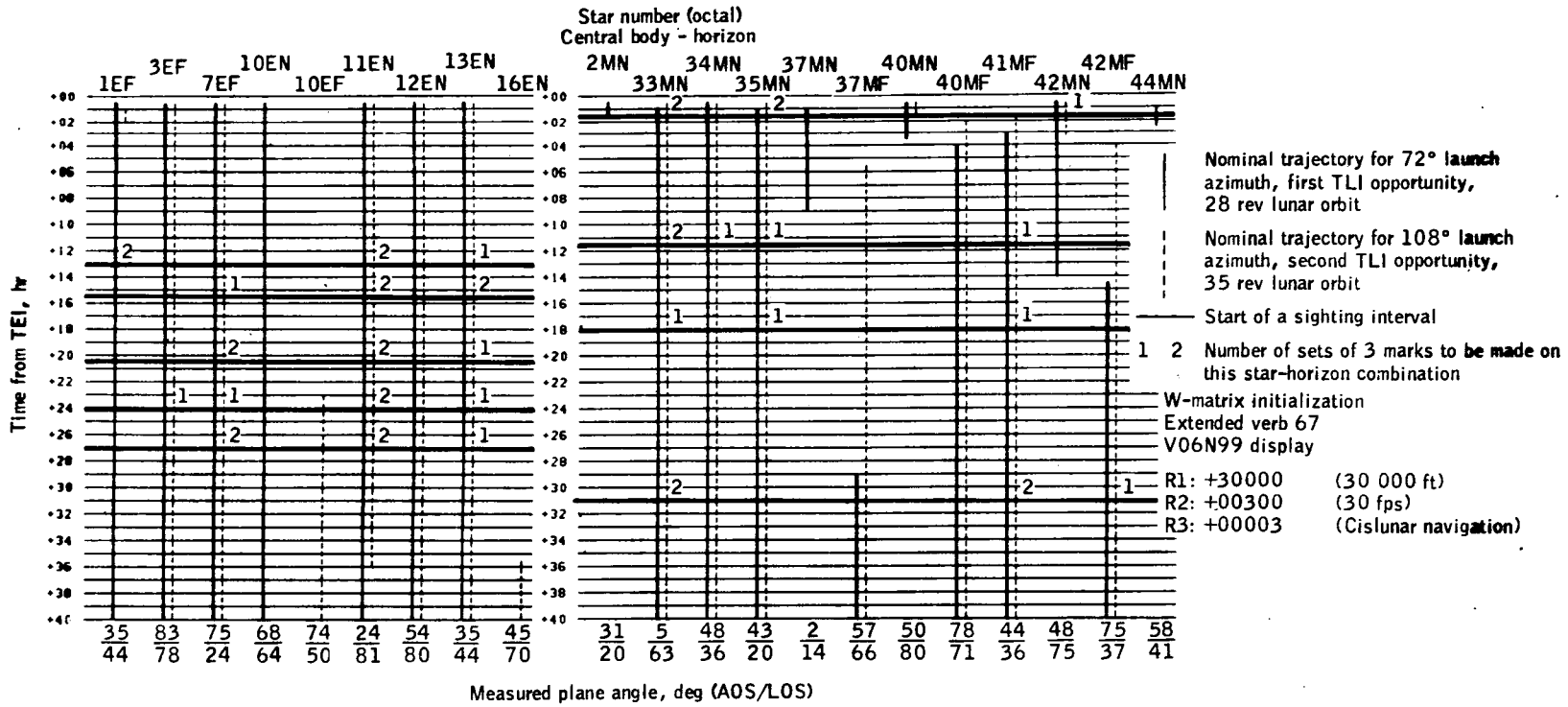

FIGURE 4 (CREW CHART) STAR AVAILABILITY AND SIGHTING SCHEDULE FOR AN ABORT FROM LUNAR ORBIT FOR A LAUNCH ON 18 JULY, 1969
(A) TEI TO TEI PLUS 40 HOURS

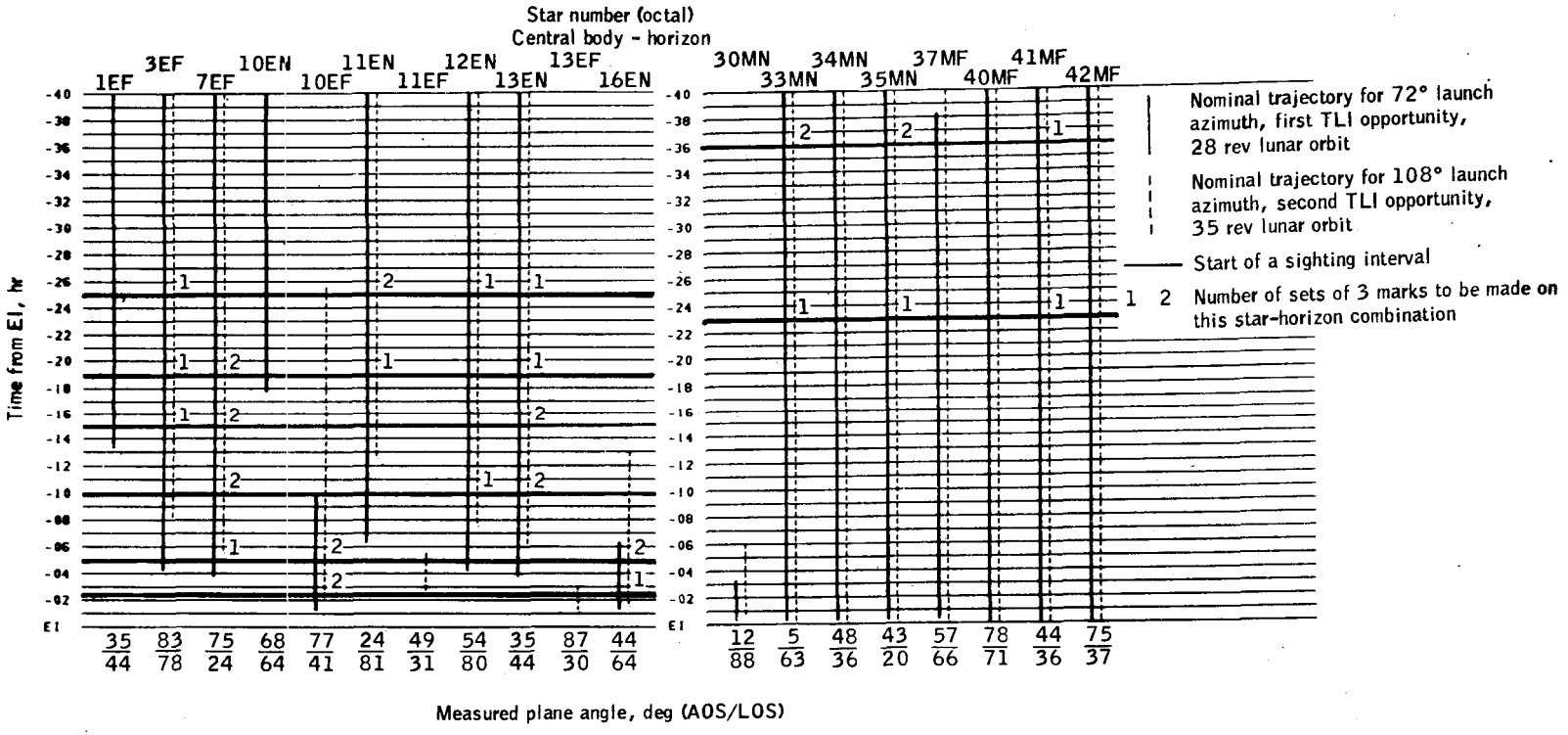

FIGURE 5 (CREW CHART) STAR AVAILABILITY AND SIGHTING SCHEDULE FOR AN ABORT FROM LUNAR ORBIT FOR A LAUNCH ON 18 JULY, 1969
(B) EI MINUS 40 HOURS TO EI

KEY TO FIGURE -

SOLID VERTICAL LINE - NOMINAL TRAJECTORY FOR 89 DEG LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY

DASHED VERTICAL LINE - NOMINAL TRAJECTORY FOR 108 DEG LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY

HEAVY HORIZONTAL LINE - START OF A SIGHTING INTERVAL

N - NUMBER OF SETS OF 3 MARKS TO BE MADE ON THIS STAR-HORIZON COMBINATION

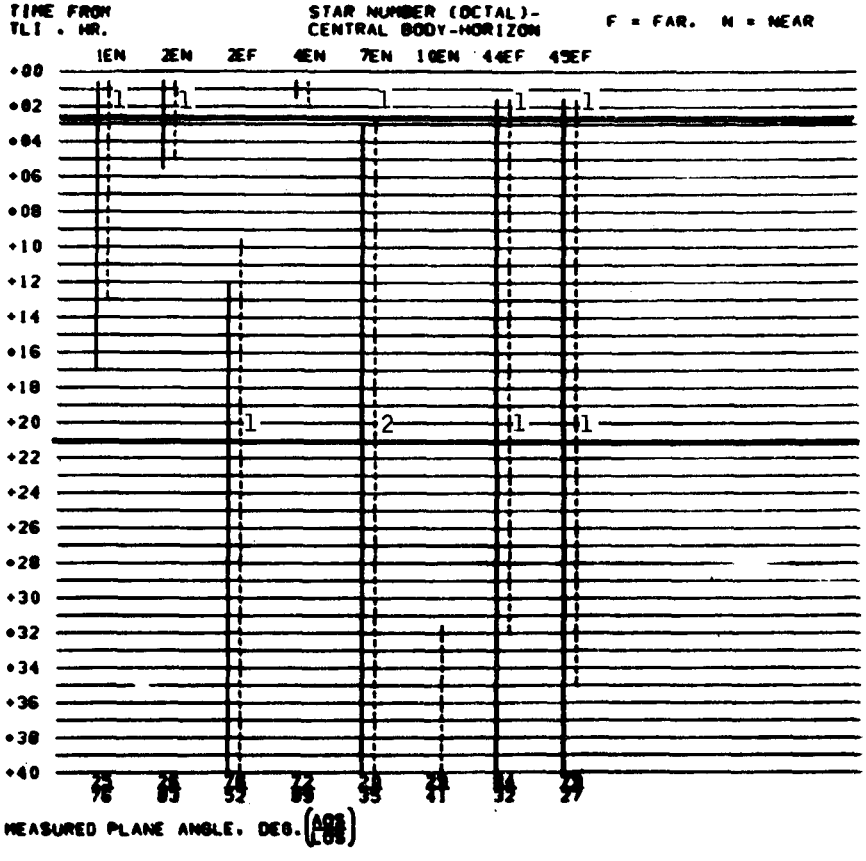

FIGURE 1 STAR AVAILABILITY AND SIGHTING SCHEDULE DURING TRANSLUNAR COAST FOR A LAUNCH ON 19 JULY, 1969 (AT EARTH HORIZON, TLI TO TLI PLUS 40 HOURS)

KEY TO FIGURE -

SOLID VERTICAL LINE - NOMINAL TRAJECTORY FOR 89 DEG LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY

DASHED VERTICAL LINE - NOMINAL TRAJECTORY FOR 105 DEG LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY

HEAVY HORIZONTAL LINE - START OF A SIGHTING INTERVAL

N - NUMBER OF SETS OF 3 MARKS TO BE MADE ON THIS STAR-HORIZON COMBINATION

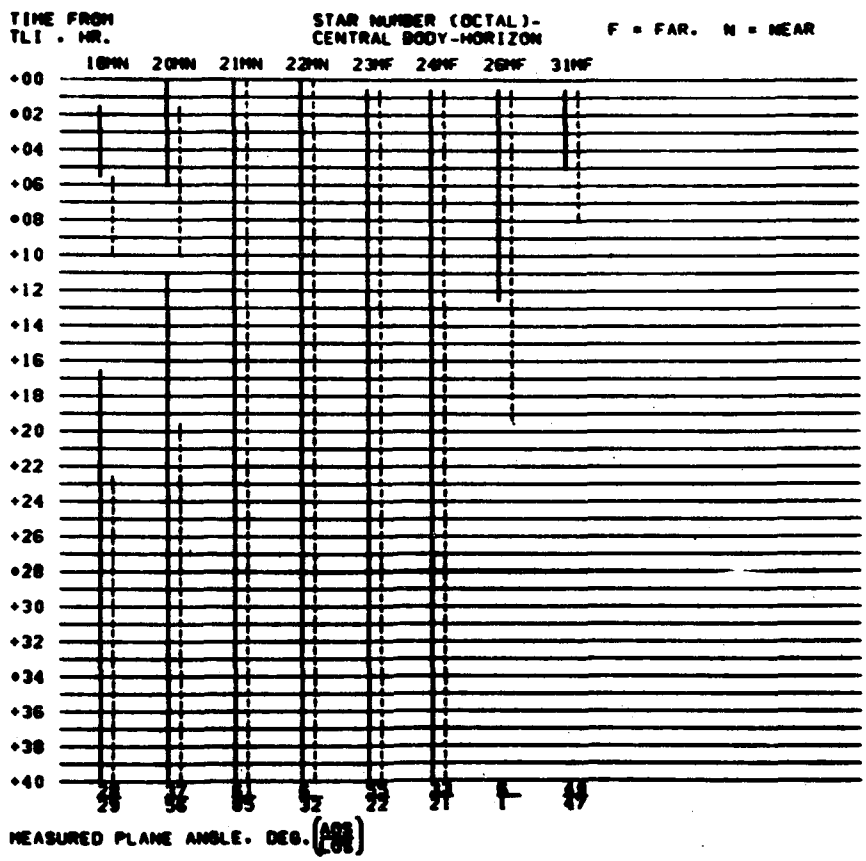

FIGURE 6 STAR AVAILABILITY AND SIGHTING SCHEDULE DURING TRANSLUNAR COAST FOR A LAUNCH ON 16 JULY, 1969
(B) LUNAR HORIZONS, TLI TO TLI PLUS 40 HOURS

KEY TO FIGURE -

SOLID VERTICAL LINE - NOMINAL TRAJECTORY FOR BY LEG LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY

DASHED VERTICAL LINE - NOMINAL TRAJECTORY FOR 10M H.G LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY

HEAVY HORIZONTAL LINE - START OF A SIGHTING INTERVAL

N = NUMBER OF SIGHTS OR A MARK TO BE MADE ON THIS STAR-HORIZON COMBINATION

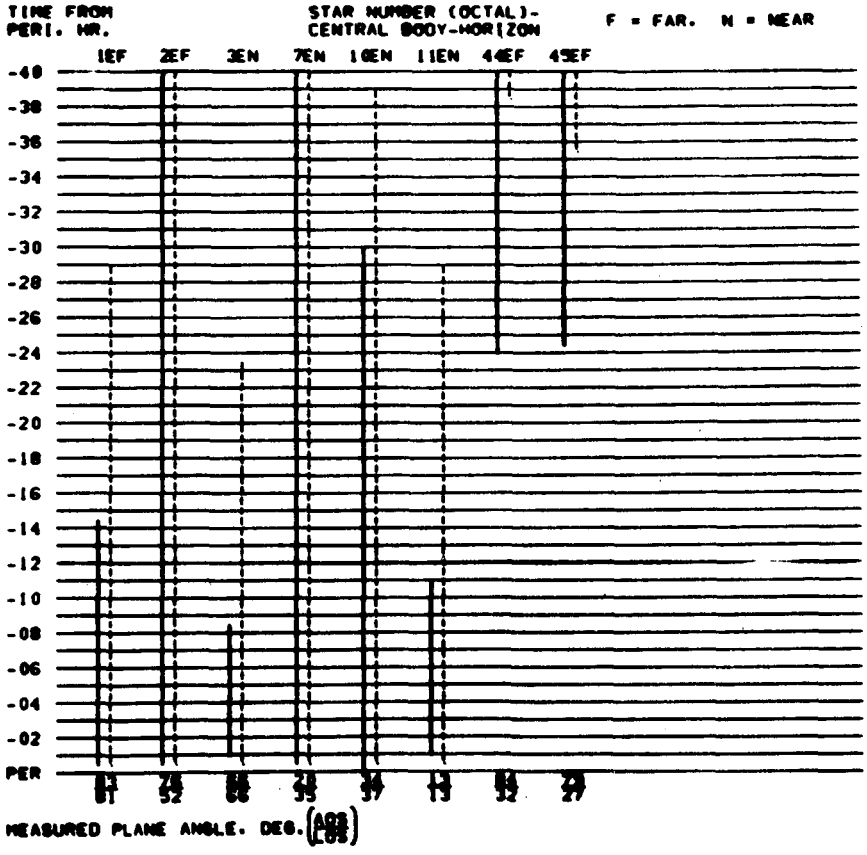

FIGURE C. STAR AVAILABILITY AND SIGHTING SCHEDULE DURING TRANSLUNAR COAST FOR A LAUNCH ON 14 JULY, 1969

(C) EARTH HORIZONS, LOI-1 MINUS 40 HOURS TO LOI-1

KEY TO FIGURE -

SOLID VERTICAL LINE - NOMINAL TRAJECTORY FOR 65 DEG LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY

DASHED VERTICAL LINE - NOMINAL TRAJECTORY FOR 105 DEG LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY

HEAVY HORIZONTAL LINE - START OF A SIGHTING INTERVAL

N - NUMBER OF SETS OF 3 MARKS TO BE MADE ON THIS STAR-HORIZON COMBINATION

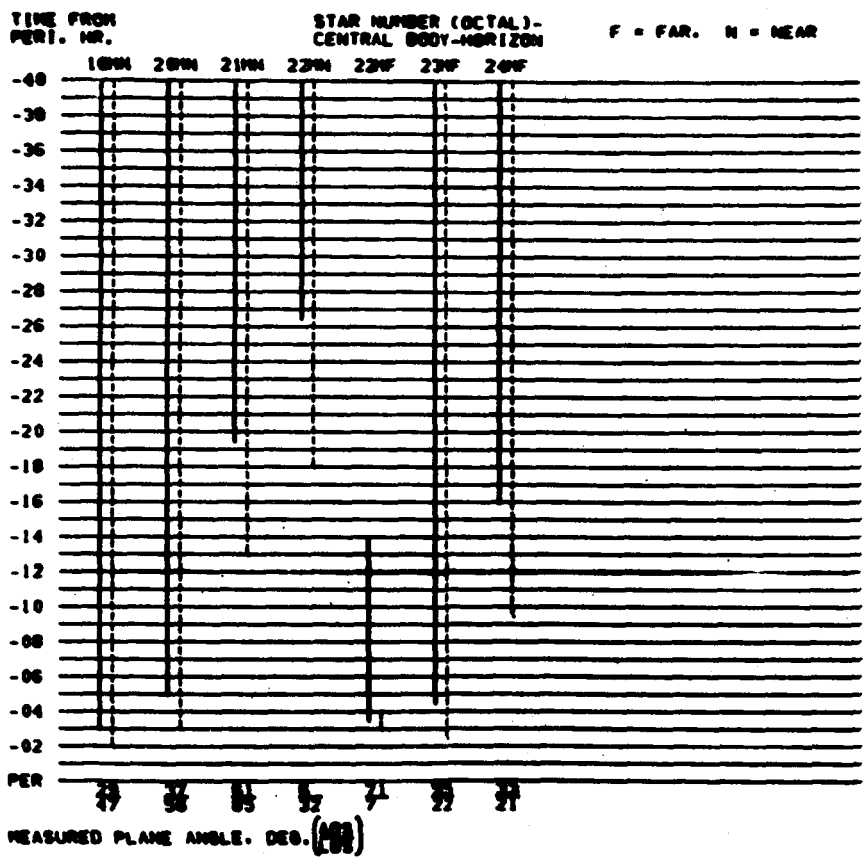

FIGURE 6 STAR AVAILABILITY AND SIGHTING SCHEDULE DURING TRANSLUNAR COAST FOR A LAUNCH ON 16 JULY, 1969 (B) LUNAR HORIZONS, LOI-1 MINUS 40 HOURS TO LOI-1

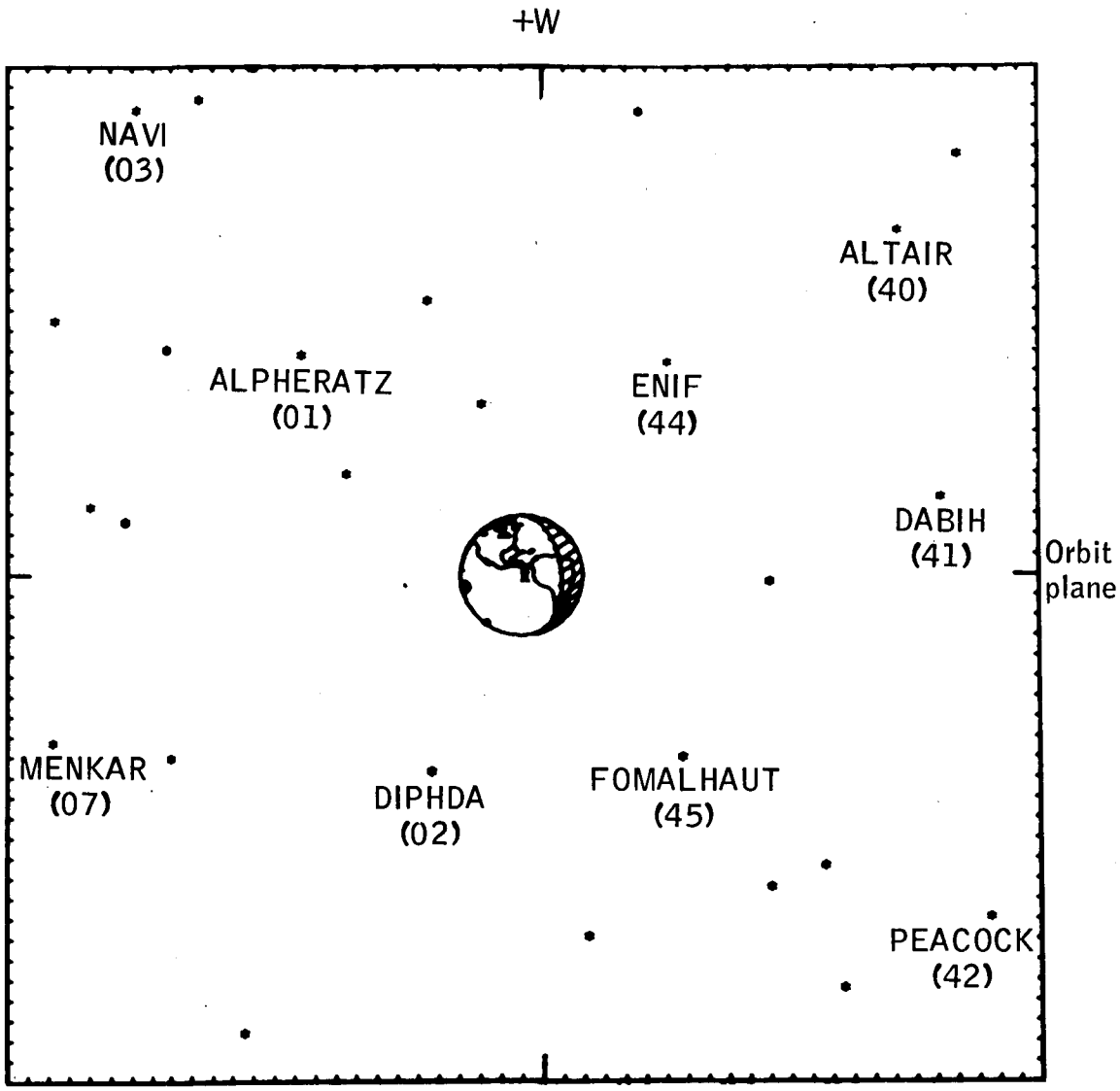

Figure 7.- Relative star positions at 6 hours g.e.t.

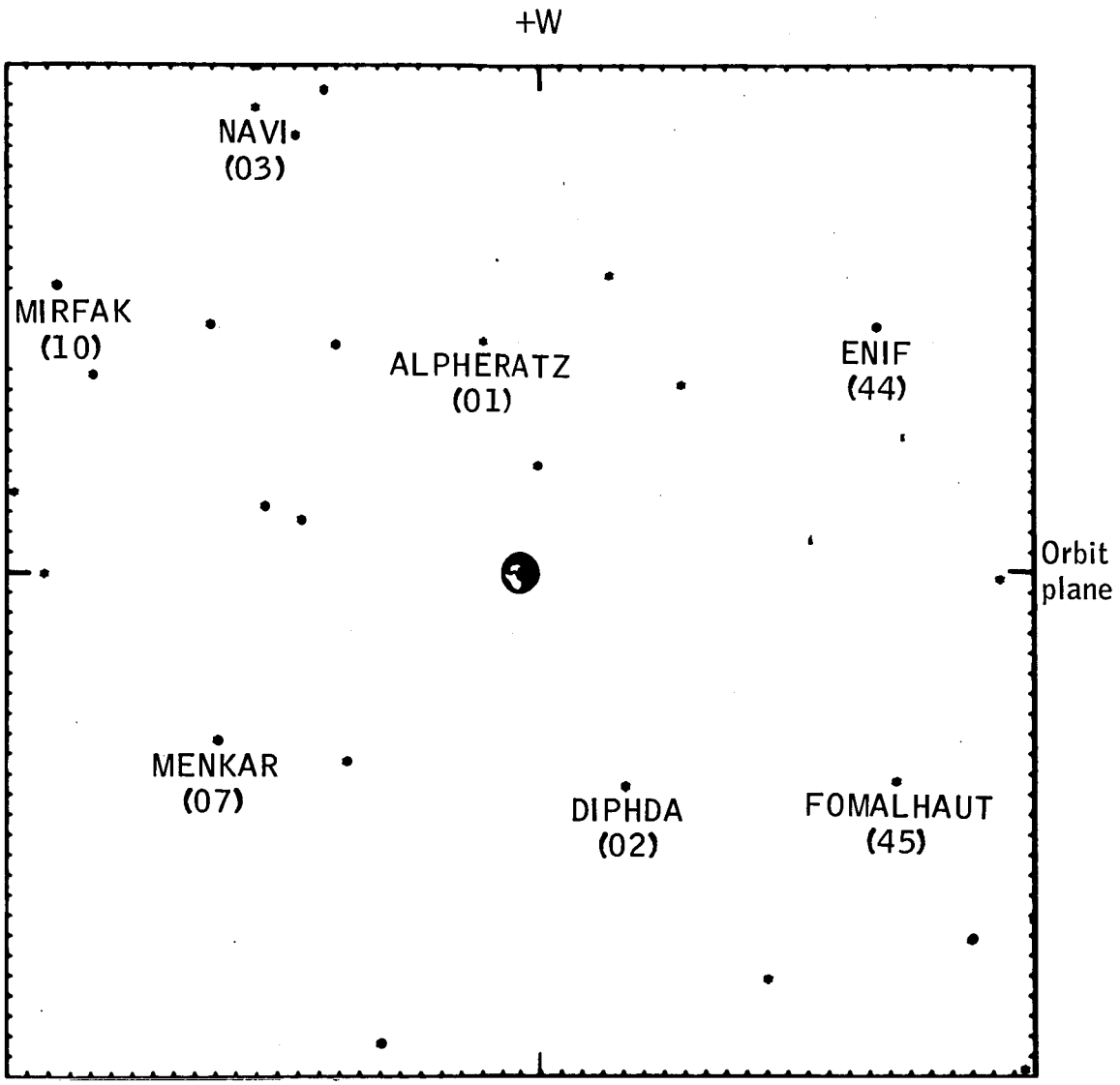

Figure 8.- Relative star positions at 24 hours g.e.t.

KEY TO FIGURE -

SOLID VERTICAL LINE - NOMINAL TRAJECTORY FOR 89 DEG LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY

DASHED VERTICAL LINE - NOMINAL TRAJECTORY FOR 109 DEG LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY

HEAVY HORIZONTAL LINE - START OF A SIGHTING INTERVAL

N - NUMBER OF SETS OF 3 MARKS TO BE MADE ON THIS STAR-HORIZON COMBINATION

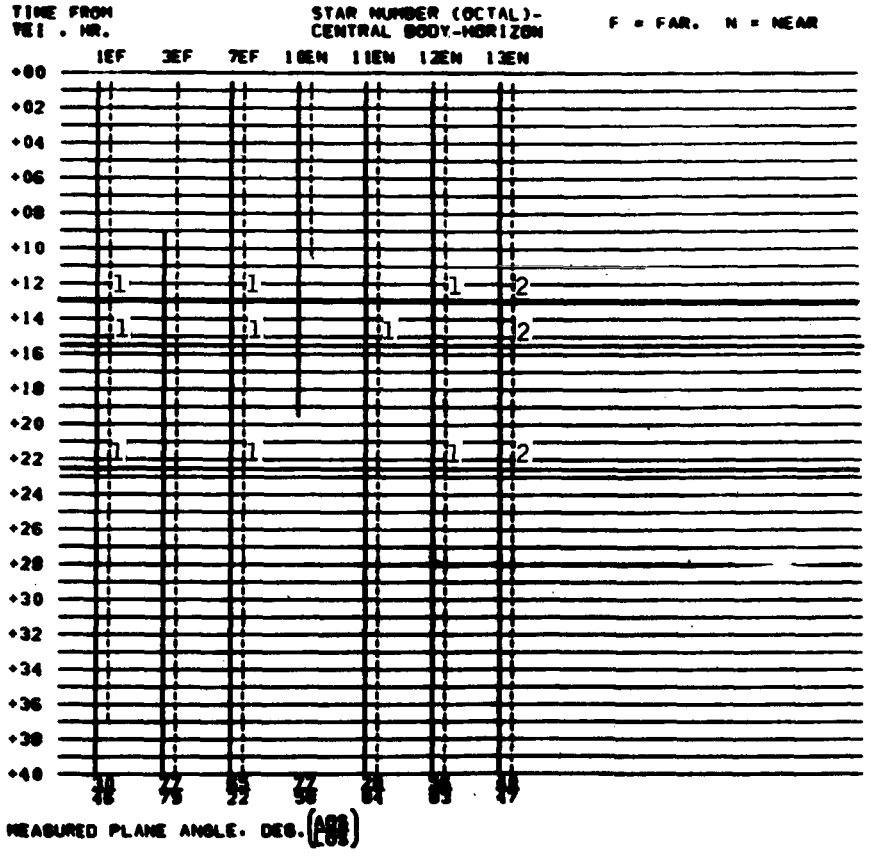

FIGURE 9 STAR AVAILABILITY AND SIGHTING SCHEDULE DURING TRANSEARTH COAST FOR A LAUNCH ON 13 JULY, 1969 30 REVOLUTIONS IN LUNAR ORBIT

(A) EARTH HORIZONS, TEI TO TEI PLUS 40 HOURS

KEY TO FIGURE -

SOLID VERTICAL LINE - NOMINAL TRAJECTORY FOR 69 DEG LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY

DASHED VERTICAL LINE - NOMINAL TRAJECTORY FOR 102 DEG LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY

HEAVY HORIZONTAL LINE - START OF A SIGHTING INTERVAL

N - NUMBER OF SETS OF 3 MARKS TO BE MADE ON THIS STAR-HORIZON COMBINATION

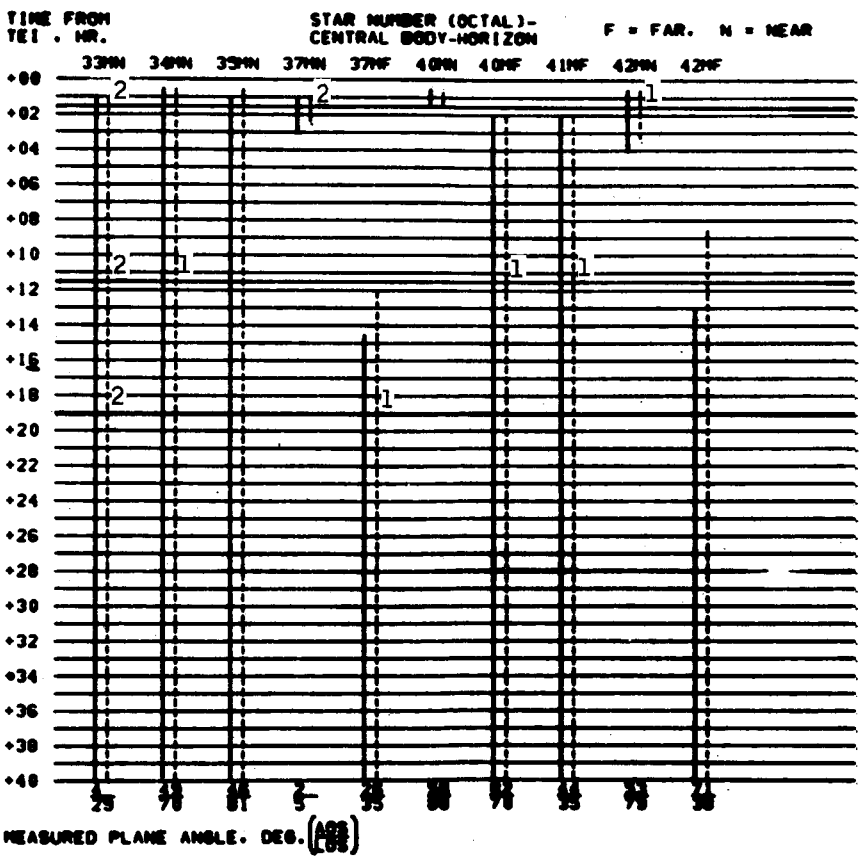

FIGURE 5 STAR AVAILABILITY AND SIGHTING SCHEDULE DURING TRANSEARTH COAST FOR A LAUNCH ON 14 JULY, 1969
30 REVOLUTIONS IN LUNAR ORBIT
(B) LUNAR HORIZONS, TEI TO TEI PLUS 40 HOURS

KEY TO FIGURE -

SOLID VERTICAL LINE - NOMINAL TRAJECTORY FOR 89 DEG LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY

DASHED VERTICAL LINE - NOMINAL TRAJECTORY FOR 108 DEG LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY

HEAVY HORIZONTAL LINE - START OF A SIGHTING INTERVAL

N - NUMBER OF SETS OF 3 MARKS TO BE MADE ON THIS STAR-HORIZON COMBINATION

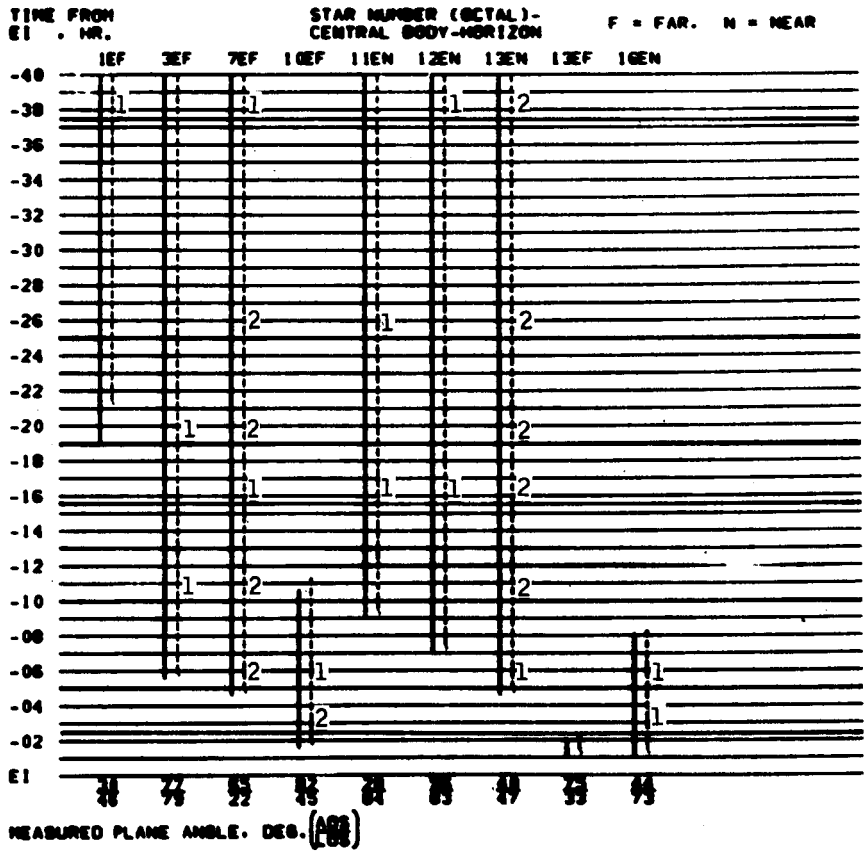

FIGURE 9 STAR AVAILABILITY AND SIGHTING SCHEDULE DURING TRANSEARTH COAST FOR A LAUNCH ON 16 JULY, 1969
30 REVOLUTIONS IN LUNAR ORBIT
(C) EARTH HORIZONS, EI MINUS 40 HOURS TO EI

KEY TO FIGURE -

SOLID VERTICAL LINE - NOMINAL TRAJECTORY FOR
85 DEG LAUNCH AZIMUTH, FIRST TLI OPPORTUNITY
DASHED VERTICAL LINE - NOMINAL TRAJECTORY FOR
105 DEG LAUNCH AZIMUTH, SECOND TLI OPPORTUNITY
HEAVY HORIZONTAL LINE - START OF A SIGHTING INTERVAL
N - NUMBER OF SETS OF 2 MARKS TO BE MADE ON
THIS STAR-HORIZON COMBINATION

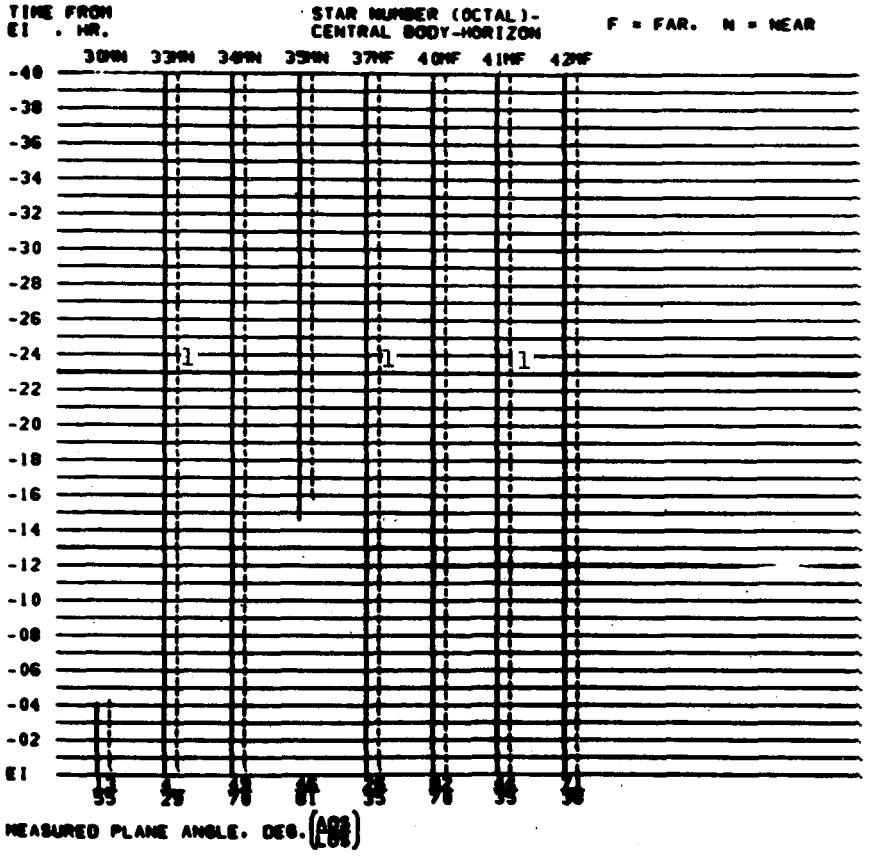

FIGURE 9 STAR AVAILABILITY AND SIGHTING SCHEDULE
DURING TRANSEARTH COAST FOR A LAUNCH ON 16 JULY, 1969
30 REVOLUTIONS IN LUNAR ORBIT
(U) LUNAR HORIZONS, EI MINUS HOURS TO EI

KEY TO FIGURE -

SOLID VERTICAL LINE - 10 DEGREE MINIMUM SUN ELEVATION
DASHED VERTICAL LINE - 5 DEGREE MINIMUM SUN ELEVATION
HEAVY HORIZONTAL LINE - START OF A SIGHTING INTERVAL
N - NUMBER OF SETS OF 3 MARKS TO BE MADE ON
THIS STAR-HORIZON COMBINATION

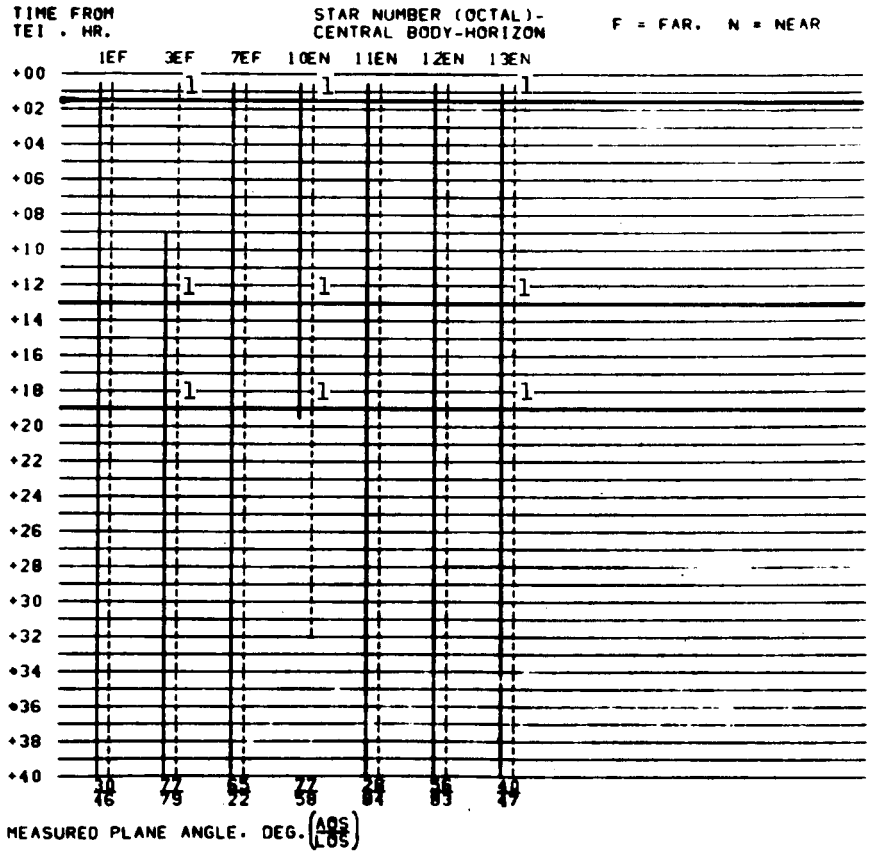

FIGURE 10 STAR AVAILABILITY AND SIGHTING SCHEDULE
FOR SUN ELEVATION CONSTRAINT TEST ON THE 39 DEGREE,
FIRST LAUNCH OPPORTUNITY, TRANSEARTH TRAJECTORY
FOR A LAUNCH ON 16 JULY, 1969 WITH 30 REVOLUTIONS
IN LUNAR ORBIT
(A) TEI TO TEI PLUS 40 HOURS

KEY TO FIGURE -

SOLID VERTICAL LINE - 10 DEGREE MINIMUM SUN ELEVATION
DASHED VERTICAL LINE - 5 DEGREE MINIMUM SUN ELEVATION
HEAVY HORIZONTAL LINE - START OF A SIGHTING INTERVAL
N - NUMBER OF SETS OF 3 MARKS TO BE MADE ON THIS STAR-HORIZON COMBINATION

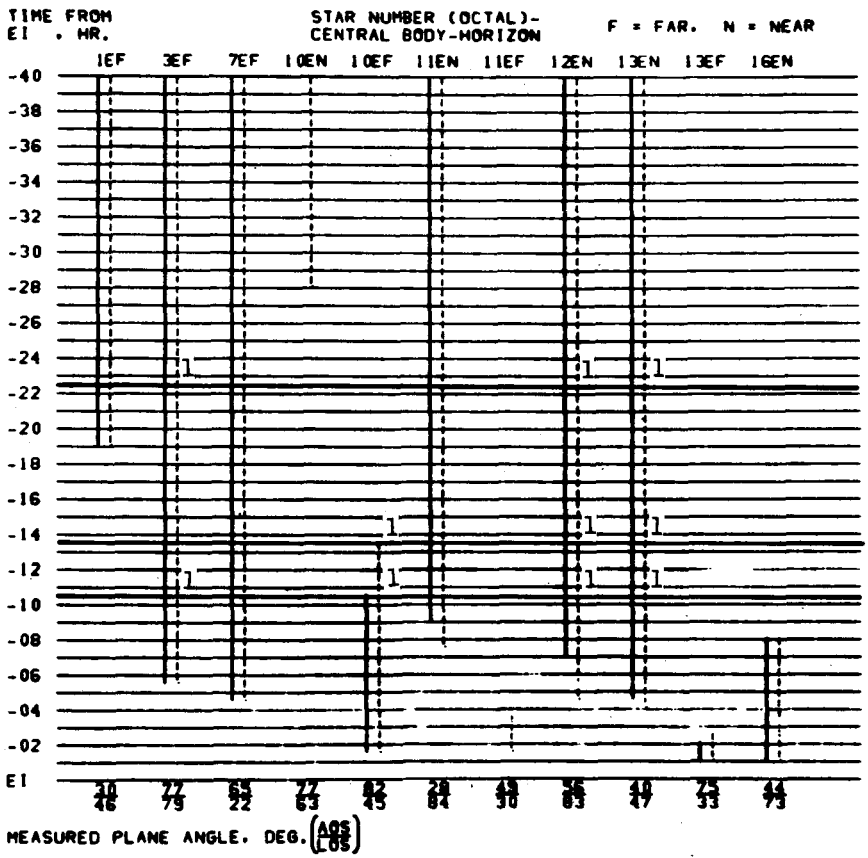

FIGURE 10 STAR AVAILABILITY AND SIGHTING SCHEDULE FOR SUN ELEVATION CONSTRAINT TEST ON THE 89 DEGREE, FIRST ILI OPPORTUNITY, TRANSEARTH TRAJECTORY FOR A LAUNCH ON 18 JULY, 1969 WITH 30 REVOLUTIONS IN LUNAR ORBIT
(B) EI MINUS 40 HOURS TO EI

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