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JUN 26 1968

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 68-FM-121

May 23,1968

1969

68-FM-121

SIGHTING COMBINATIONS FOR ORBITAL AND MIDCOURSE NAVIGATION DURING THE THIRD AND FOURTH HIGH ELLIPSES OF MISSION E

By Richard E. Eckelkamp,
Mathematical Physics Branch

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MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

(NASA-TM-X-69682) SIGHTING COMBINATIONS FOR ORBITAL AND MIDCOURSE NAVIGATION DURING THE THIRD AND FOURTH HIGH ELLIPSES OF MISSION E (NASA) 68 p

N74-70529

Unclas
00/99 16349

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PROJECT APOLLO

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By Richard E. Eckelkamp
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May 23, 1968

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MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

Approved: James C. McPherson
James C. McPherson, Chief
Mathematical Physics Branch

Approved: Howard W. Tindall, Jr.
for John P. Mayer, Chief
Mission Planning and Analysis Division

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SIGHTING COMBINATIONS FOR ORBITAL AND MIDCOURSE NAVIGATION DURING THE THIRD AND FOURTH HIGH ELLIPSES OF MISSION E

By Richard E. Eckelkamp

SUMMARY

Available sighting combinations for midcourse and orbital navigation during the third and fourth high ellipses of Mission E are discussed and the method of obtaining these combinations is given. The results point out the scarcity of possible sighting combinations and the need for auxiliary real-time planning.

INTRODUCTION

The third and fourth high ellipses on Mission E offer opportunities to simulate sextant midcourse navigation (Colossus program P23) and, for the first time, orbital navigation at lunar orbit rates (Colossus program P22). In midcourse navigation star-landmark and star-horizon sightings are statistically weighted to correct the command module computer (CMC) estimate of position and velocity, or state. This method is to be used during the translunar and transearth phases of the lunar missions. Orbital navigation corrects the CMC estimate of both the state and the position of a landmark by processing sightings on a landmark. This process can determine both the orbit and a landing site.

Performing midcourse navigation on Mission E will produce information valuable to the lunar missions on instrument errors, horizon and landmark perceptability, astronaut technique, and fuel requirements. The navigation results can be used for postflight analysis and improving the horizon error model. Paramount among these results is the latter. Improvement or verification of the horizon error model is necessary before navigation plans can be made for Missions F and G. Accurate estimation of the horizon is hampered by cloud coverage, airglow, effects of the solar cycle, asphericity of the earth's surface, and bias in the astronaut's determination of the horizon. Horizon definition error by far exceeds the error due to deviations in estimated perpendicularity for star-horizon observations (ref. 1).

Selection of a navigation plan to accomplish the goals of Mission E, or any mission, involves a detailed analysis of all the possible sighting combinations within the time allotted for the navigation. This paper presents sighting combinations for such an analysis, and a resulting sample plan. Computer programs needed for generation of navigation plans exist both in the Mathematical Physics Branch and at MIT IL.

Once the objectives of performing a midcourse or orbital navigational sequence have been established, the principal element to be considered in the selection of a navigation plan is the sighting schedule. Other factors, such as time of CMC update, number of marks taken per sighting combination, and time of inertial measurement unit (IMU) alignment can then be obtained.

This procedure occurs because sighting combinations are often scarce. These combinations are scarce primarily because the CMC has only 37 stars fixed in memory. (Additional stars may be punched into the CMC with mark routine R53.)

DETERMINATION OF SIGHTING COMBINATIONS

To determine the availability of sighting combinations at any time during the third and fourth high ellipses of Mission E, an ephemeris of the CSM trajectory was generated from the following initial conditions:

x, ft	-12 676 435
y, ft	38 619 550
z, ft	-19 190 194
$\dot{x}$, fps	-13 336.600
$\dot{y}$, fps	-2054.7177
$\dot{z}$, fps	4685.2392
Time of vector, minutes g.e.t.	451.60665
Date of launch	Sept. 30, 1968
Time of launch, hours G.m.t.	1900

(These conditions were obtained from a preliminary reference trajectory generated by the Orbital Mission Analysis Branch.)

At fixed intervals of 30 seconds, a check was made to determine the available star-landmark and star-horizon combinations. Spacecraft optics constraints eliminated most of the possible sightings. The trunnion angle, an optically-measured angle between the star and landmark or horizon had to be less than 45°. Further, a star could not appear within 15° of the

optical line of sight to the sun nor within 1° of the earth's horizon (ref. 2). To see landmarks, the CSM had to be within 55° of the local vertical to the landmark (ref. 3). Landmarks and horizons had to be sunlit.

Some constraints have not yet been determined. The time required to perform and process a star-horizon or star-landmark measurement will be determined in hybrid simulations. The precise thickness of cloud coverage required to make a landmark imperceptible must await the actual mission.

Table I presents the resulting acquisition and loss times for the possible combinations on the third and fourth high ellipses of Mission E. Figures 1 and 2 show graphs of the results. The landmarks usable with stars during the navigation periods are shown along with ground tracks in figure 3.

As expected, there was a scarcity of sighting combinations, particularly for midcourse navigation. Due to constraints on the trajectory of the high ellipses, star-landmark combinations that can be seen for sufficient time for sighting on are rare. Star-horizon combinations are plentiful on Mission E, but will be scarcer on the lunar mission if supplementary stars are not punched into the CMC.

SELECTION OF A SIGHTING SCHEDULE

Close analysis of the results reveals that, as expected, star-landmark combinations with a duration of 10 minutes or longer are scarce while the CSM is above the 3000-n. mi. altitude constraint originally proposed for Mission E midcourse navigation. Although landmarks below 3000 n. mi. have appreciably higher angular rates relative to the CSM (ref. 4), they can still be used for midcourse navigation. Below 2000 n. mi. orbital navigation becomes more desirable. Star-horizon combinations are plentiful.

Choice of a midcourse navigation sighting schedule in this instance involves selecting star-landmark combinations when they exist, then completing the schedule with star-horizon sightings. Two sample schedules are presented in tables II and III. A 10-minute sighting interval was selected. The length can be better determined after hybrid simulations.

Choosing an orbital navigation schedule involves selection of landmarks only. The star-landmark combination entries can be used for this purpose. Other available landmarks, which could not be linked with stars, are not included in this paper. A sample schedule for orbital navigation is not given

REAL-TIME SCHEDULE SELECTION

As noted, the launch date for the ephemeris was taken to be September 30, 1968. For launches in earlier or later months, the sighting combinations change. Since the orbits for the Mission E high ellipses are fixed relative to the earth, the available landmarks will remain the same for the nominal mission. The available stars, however, will change with launch date and time. Table IV, reprinted from reference 5, indicates dependence on launch date by an analysis of star-horizon combinations.

Deviations from the nominal mission alter the acquisition and loss times of both landmark and stars. A change in the hour of launch causes some nominal landmarks to be dark and new ones to be lighted. Real-time sighting schedule planning is thus necessitated. Real-time planning also offers the ability to select combinations which will test constraints, optimize navigation performance, and avoid attempting sightings on cloud-covered landmarks. Information from the Weather Bureau may be used to aid in the latter.

CONCLUDING REMARKS

This paper has presented the material and outlined the principles for the selection of nominal midcourse and orbital navigation plans required for Mission E. Additional real-time planning is necessary, however, since shifts in the trajectory and change in experimental conditions affect the availability of sighting combinations. The analysis presented shows a scarcity of star-landmark sighting combinations.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
27/NH	417.20360	453.10665	29/406	468.10665	481.35665
23/NH	417.70360	451.70360	30/406	468.10665	483.60665
25/NH	419.20360	449.20360	29/407	468.60665	481.60665
26/NH	433.45360	467.85665	30/407	468.60665	483.35665
31/NH	444.70360	520.10665	1/240	469.10665	471.35665
5/NH	445.20360	453.85665	1/245	469.10665	471.60665
35/241	446.70360	448.20360	35/NH	470.35665	512.85665
36/241	449.20360	461.60665	35/245	470.35665	471.60665
36/242	449.45360	461.60665	35/242	470.35665	472.60665
29/NH	453.10665	493.35665	35/241	470.35665	472.10665
33/NH	462.85665	477.10665	35/401	470.35665	490.35665
33/241	463.35665	473.35665	35/402	470.35665	489.85665
1/242	464.85665	477.10665	35/406	470.35665	485.35665
30/NH	465.10665	500.10665	35/407	470.35665	484.60665
1/241	465.85665	477.10665	35/409	470.35665	481.60665
30/409	466.35665	481.85665	29/408	470.60665	482.35665
29/409	466.35665	481.60665	30/408	470.60665	483.85665
33/240	466.60665	471.35665	33/409	470.60665	477.10665
29/402	466.85665	478.60665	35/408	470.60665	485.10665
30/402	466.85665	484.85665	29/404	471.60665	493.35665
29/401	467.60665	478.60665	30/404	471.60665	485.85665
30/401	467.60665	485.35665	35/404	471.60665	489.35665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
29/403	471.60665	481.35665	30/413	479.10665	483.85665
30/403	471.60665	486.10665	35/413	479.10665	480.85665
35/403	471.60665	490.10665	29/414	479.35665	484.60665
29/405	472.35665	482.60665	30/414	479.35665	484.10665
30/405	472.35665	485.35665	35/414	479.35665	480.85665
35/405	472.35665	487.85665	31/413	479.85665	496.85665
33/407	472.60665	477.10665	34/NH	479.85665	533.10665
29/351	472.85665	478.60665	31/414	480.10665	496.60665
30/351	472.85665	487.10665	29/353	480.35665	481.85665
35/351	472.85665	492.85665	30/353	480.35665	489.60665
33/406	472.85665	477.10665	35/353	480.35665	495.35665
33/408	472.85665	477.10665	31/505	481.35665	494.85665
3/NH	474.10665	531.10665	37/NH	481.35665	491.60665
33/405	474.85665	477.10665	29/502	482.10665	485.35665
37/241	475.85665	477.10665	30/502	482.10665	484.35665
37/242	476.85665	477.10665	31/502	482.10665	498.10665
29/410	477.60665	483.85665	29/411	483.10665	485.60665
30/410	477.60665	487.85665	30/411	483.10665	489.60665
35/410	477.60665	490.85665	35/411	483.10665	492.60665
29/352	477.85665	481.35665	30/354	483.85665	490.85665
30/352	477.85665	488.85665	35/354	483.85665	496.60665
35/352	477.85665	494.85665	31/506	484.10665	487.35665
29/413	479.10665	484.60665	31/504	484.35665	494.85665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
37/506	486.60665	487.35665	32/351	489.35665	495.10665
30/412	486.85665	490.85665	32/403	489.35665	496.10665
35/412	486.85665	494.10665	32/352	489.35665	496.85665
1/NH	487.35665	528.60665	32/406	489.35665	495.35665
30/417	487.35665	489.35665	32/404	489.35665	496.35665
31/421	487.35665	500.60665	32/407	489.35665	495.35665
35/417	487.35665	490.85665	32/409	489.35665	496.10665
30/415	487.60665	488.35665	32/405	489.35665	496.60665
30/416	487.60665	488.10665	32/408	489.35665	496.10665
35/415	487.60665	488.35665	32/353	489.35665	498.35665
35/416	487.60665	487.85665	32/354	489.35665	499.35665
30/418	487.85665	489.85665	32/410	489.35665	498.35665
31/419	487.85665	500.35665	32/411	489.35665	500.35665
35/418	487.85665	491.60665	32/505	489.35665	494.10665
37/505	487.85665	491.60665	32/413	489.35665	497.60665
31/420	488.10665	500.60665	32/414	489.35665	497.85665
37/504	488.35665	491.60665	32/504	489.35665	494.85665
37/409	488.85665	491.60665	32/502	489.35665	498.35665
31/503	489.10665	492.60665	32/412	489.35665	501.60665
37/503	489.10665	491.60665	32/503	489.35665	491.60665
32/NH	489.35665	517.35665	32/417	489.35665	501.60665
32/401	489.35665	494.35665	32/418	489.35665	501.60665
32/402	489.35665	494.10665	32/415	489.35665	501.10665
			32/416	489.35665	501.10665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
32/421	489.35665	499.10665	32/425	494.35665	503.10665
32/419	489.35665	500.10665	33/NH	494.35665	527.10665
32/420	489.35665	499.85665	33/401	494.35665	496.10665
2/NH	489.85665	496.10665	33/402	494.35665	496.60665
37/407	490.10665	491.60665	33/351	494.35665	495.35665
1/351	490.35665	502.85665	33/403	494.35665	499.35665
31/416	490.35665	496.60665	33/352	494.35665	496.85665
37/406	490.35665	491.60665	33/406	494.35665	499.85665
37/408	490.85665	491.60665	33/404	494.35665	500.10665
1/401	491.85665	498.85665	33/407	494.35665	500.10665
1/352	491.85665	504.35665	33/409	494.35665	499.85665
4/NH	492.10665	510.35665	33/405	494.35665	500.85665
7/NH	492.35665	511.35665	33/408	494.35665	500.85665
34/505	492.85665	494.85665	33/353	494.35665	499.35665
1/402	493.10665	497.60665	33/354	494.35665	500.10665
32/430	493.35665	503.85665	33/410	494.35665	502.10665
34/504	493.35665	494.85665	33/411	494.35665	503.85665
35/430	493.35665	497.10665	33/505	494.35665	494.85665
32/429	493.85665	503.85665	33/413	494.35665	503.35665
35/429	493.85665	498.85665	33/414	494.35665	503.35665
1/353	494.35665	504.10665	33/504	494.35665	494.85665
31/425	494.35665	501.10665	33/502	494.35665	504.10663

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
33/412	494.35665	505.10665	35/428	495.35665	499.60665
33/417	494.35665	505.85665	2/406	495.85665	496.10665
33/418	494.35665	506.10665	32/431	495.85665	504.85665
33/415	494.35665	506.10665	32/427	495.85665	504.35665
33/416	494.35665	506.10665	33/431	495.85665	508.10665
33/421	494.35665	505.10665	33/427	495.85665	508.85665
33/419	494.35665	505.60665	35/431	495.85665	498.35665
33/420	494.35665	505.60665	31/424	497.35665	502.10665
33/429	494.35665	506.35665	32/423	497.35665	505.10665
33/430	494.35665	507.10665	32/424	497.35665	504.35665
33/425	494.35665	508.10665	33/423	497.35665	509.35665
6/NH	494.60665	510.10665	33/424	497.35665	509.10665
2/102	494.85665	496.10665	31/435	497.60665	503.10665
31/422	494.85665	502.35665	32/435	497.60665	504.10665
32/422	494.85665	499.60665	33/435	497.60665	509.10665
32/426	494.85665	504.10665	34/422	498.60665	504.10665
33/422	494.85665	504.10665	31/436	499.10665	504.60665
33/426	494.85665	508.35665	32/436	499.10665	503.60665
1/354	495.10665	505.60665	33/436	499.10665	509.10665
2/101	495.10665	496.10665	34/421	499.10665	506.85665
2/409	495.35665	496.10665	34/502	499.60665	507.85665
32/428	495.35665	504.35665	34/413	499.85665	507.60665
33/428	495.35665	506.60665	34/414	499.85665	507.60665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
34/420	500.60665	508.85665	6/405	504.35665	509.10665
4/409	500.85665	505.60665	32/432	504.35665	506.85665
34/419	501.10665	509.35665	33/432	504.35665	511.60665
4/406	501.85665	507.60665	34/416	504.35665	510.60665
4/407	501.85665	507.35665	34/436	504.35665	512.60665
4/408	502.35665	507.85665	4/410	504.85665	510.35665
4/405	503.10665	509.10665	7/351	504.85665	509.85665
4/413	503.10665	507.60665	34/415	504.85665	510.35665
6/409	503.10665	505.60665	4/419	505.10665	509.35665
4/414	503.35665	507.60665	4/420	505.10665	508.85665
6/402	503.35665	508.10665	6/351	505.10665	509.85665
4/404	503.60665	509.35665	34/425	505.10665	513.35665
4/502	503.60665	507.85665	34/435	505.35665	513.85665
6/401	503.60665	508.35665	7/401	505.60665	508.35665
6/406	503.60665	507.60665	6/410	505.85665	510.10665
6/407	503.60665	507.35665	7/352	505.85665	511.35665
4/402	503.85665	508.10665	8/NH	505.85665	531.85665
4/403	504.10665	509.60665	9/NH	505.85665	521.35665
6/408	504.10665	507.85665	4/415	506.10665	510.35665
4/401	504.35665	508.35665	4/416	506.10665	510.35665
4/421	504.35665	506.85665	6/413	506.10665	507.60665
6/403	504.35665	509.60665	6/414	506.10665	507.60665
6/404	504.35665	509.35665	34/424	506.10665	514.35665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
4/411	506.35665	510.35665	6/415	508.35665	510.10665
6/352	506.35665	510.10665	6/416	508.35665	510.10665
7/402	506.35665	508.10665	6/419	508.35665	509.35665
4/417	506.60665	510.35665	6/420	508.35665	510.10665
4/418	506.85665	510.35665	34/427	508.35665	512.85665
6/353	506.85665	510.10665	4/426	508.60665	510.35665
6/502	506.85665	510.10665	4/435	508.60665	510.35665
4/351	507.10665	509.85665	34/432	508.60665	516.60665
6/411	507.35665	510.10665	4/424	508.85665	510.35665
7/353	507.35665	511.35665	4/427	509.10665	510.35665
10/NH	507.35665	518.85665	12/NH	509.10665	520.10665
4/412	507.60665	510.35665	36/NH	509.10665	528.35665
4/425	507.85665	510.35665	36/428	509.10665	509.35665
6/354	507.85665	510.10665	36/431	509.10665	509.35665
6/420	507.85665	508.85665	36/432	509.10665	509.85665
7/354	507.85665	511.35665	4/430	509.85665	510.35665
34/426	507.85665	512.60665	4/423	509.85665	510.35665
4/353	508.10665	510.35665	34/423	510.35665	512.35665
4/352	508.35665	510.35665	28/NH	510.85665	534.8566
4/436	508.35665	510.35665	10/353	512.10665	512.35665
6/412	508.35665	510.10665	10/354	512.60665	513.35665
6/417	508.35665	510.10665	12/411	512.60665	512.85665
6/418	508.35665	510.10665	33/434	512.60665	515.35665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
34/434	512.60665	519.85665	25/NH	536.35665	537.60665
36/434	512.60665	513.35665	24/NH	574.10664	582.10664
12/418	513.10665	513.35665	18/NH	574.35665	579.10665
12/412	513.35665	514.10665	27/NH	587.10665	623.10664
13/NH	513.35665	522.60665	23/NH	587.60665	621.35664
12/426	514.35665	515.10665	23/226	588.10665	603.85665
12/430	514.60665	516.35665	23/227	588.35665	603.35664
12/427	514.60665	515.35665	23/225	588.60664	605.10664
15/NH	514.85665	523.85665	23/228	588.60664	601.60664
12/429	515.10665	516.60665	26/225	589.10664	603.60664
12/423	515.10665	516.35665	23/223	601.10664	610.10664
12/431	515.35665	517.10665	25/223	601.10664	601.35664
10/429	515.60665	516.60665	23/239	601.35664	610.85664
10/428	515.60665	517.10665	25/239	601.35664	608.85664
12/428	515.60665	517.10665	23/220	601.60664	608.60664
11/NH	516.85665	533.10665	23/250	602.60664	611.85664
21/HN	518.60665	530.60665	25/250	602.60664	607.10664
14/NH	518.85665	527.10665	26/NH	603.10664	644.10664
17/NH	522.60665	529.60665	26/224	603.10664	613.10665
18/NH	526.35665	533.10665	26/220	603.10664	612.10664
37/NH	527.35665	530.35665	26/221	603.10664	612.60664
16/NH	527.60665	535.35665	26/222	603.10664	613.35664
24/NH	528.35665	536.85665	26/225	603.10664	614.35664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
25/222	595.60664	601.10664	26/235	603.10664	621.10664
23/233	598.35664	604.85664	23/236	603.35664	608.60664
25/233	598.35664	608.85664	25/236	603.35664	610.85664
23/224	599.10664	606.10664	26/236	603.35664	622.60664
23/221	599.10664	608.60664	35/220	603.60664	618.10664
25/224	599.10664	601.85664	35/221	603.85665	618.10664
25/221	599.10664	600.10664	23/238	604.35664	610.35664
23/234	599.35664	605.60665	23/237	604.35664	609.60665
25/234	599.35664	609.35664	25/238	604.35664	611.10664
23/235	600.60664	607.35665	25/239	604.35664	611.10664
25/235	600.60664	609.85664	26/238	604.35664	622.85664
26/226	603.10664	614.35664	26/237	604.35664	622.85664
26/223	603.10664	614.10664	35/224	604.60664	618.10664
26/227	603.10664	614.60664	35/222	604.60664	618.10664
26/228	603.10664	614.60664	35/223	605.10664	618.10664
26/229	603.10664	614.60664	23/251	605.60665	612.85664
26/230	603.10664	614.85665	25/251	605.60665	608.35664
26/231	603.10664	616.60665	26/251	605.60665	621.10664
26/250	603.10664	619.60664	23/219	606.35664	608.35664
26/232	603.10664	617.10664	26/219	606.35664	611.35665
26/239	603.10664	620.85664	35/219	606.35664	618.10664
26/233	603.10664	619.60664	23/252	606.60664	613.35664
26/234	603.10664	620.35664	25/252	606.60664	608.35664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
26/252	606.60664	621.35664	25/240	610.85664	613.10665
35/225	607.10664	618.10664	26/240	610.85664	624.85664
23/244	607.60664	613.10665	32/224	610.85664	611.35665
23/243	607.60664	612.60664	23/255	611.10664	614.60664
25/244	607.60664	610.85664	26/255	611.10664	621.35664
25/243	607.60664	611.35665	35/255	611.35665	618.10664
26/244	607.60664	623.60664	35/254	611.35665	618.10664
26/243	607.60664	623.85664	35/251	611.85664	618.10664
32/229	607.60664	611.35665	35/252	611.85664	618.10664
32/228	608.10664	611.35665	35/228	612.10664	618.10664
32/230	608.10664	611.35665	35/253	612.10664	618.10664
35/226	608.35664	618.10664	35/217	612.60664	618.10664
32/226	608.60664	611.35665	35/239	613.10665	618.10664
32/227	608.60664	611.35665	35/229	613.35664	618.10664
23/253	608.85664	614.10664	31/NH	614.35664	697.60665
26/253	608.85664	621.85664	35/230	614.60664	618.10664
32/225	609.60665	611.35665	5/NH	614.85665	623.35664
32/231	609.60665	611.35665	35/218	614.85665	618.10664
35/227	609.60665	618.10664	23/256	615.10664	615.85664
32/232	609.85664	611.35665	26/256	615.10664	623.35664
23/254	610.35664	614.35665	35/99	615.10664	618.10664
26/254	610.35664	621.35664	35/256	615.10664	618.10664
35/250	610.60664	618.10664	35/244	615.35664	618.10664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
26/247	615.60664	626.35664	36/227	620.85664	631.60665
26/246	615.85664	627.35664	33/228	621.10664	645.60664
35/243	615.85664	618.10664	36/228	621.10664	631.60665
26/248	616.60665	626.10664	36/229	621.35664	631.60665
26/245	616.60665	627.60665	36/230	621.85664	631.60665
35/248	616.60665	618.10664	33/231	622.10664	645.60664
35/238	617.10664	618.10664	26/259	622.35665	623.35664
35/247	617.10664	618.10664	26/258	622.35665	624.60664
35/231	617.35664	618.10664	33/232	622.35665	645.60664
26/257	617.60664	623.60664	29/NH	622.85664	669.10664
26/249	617.60664	626.35664	29/224	622.85664	624.60664
35/232	617.60664	618.10664	29/225	622.85664	627.35664
35/257	617.60664	618.10664	29/226	622.85664	632.60664
35/249	617.60664	618.10664	29/227	622.85664	633.10664
35/235	617.85664	618.10664	29/228	622.85664	634.10664
35/237	617.85664	618.10664	29/229	622.85664	634.10664
26/241	619.35664	633.10664	29/230	622.85664	634.60664
26/242	619.85664	633.10664	29/231	622.85664	636.60664
33/229	620.35664	645.60664	29/250	622.85664	636.60664
33/230	620.60665	645.60664	29/232	622.85664	637.10664
36/226	620.60665	631.60665	29/251	622.85664	638.10664
36/224	620.85664	631.60665	29/239	622.85664	638.60665
36/225	620.85664	631.60665	29/252	622.85664	638.60665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
29/255	622.85664	638.10664	36/222	623.35664	631.60665
29/254	622.85664	638.10664	36/218	623.60664	631.60665
29/253	622.85664	638.60665	36/219	623.60664	631.60665
29/233	622.85664	639.10664	36/220	623.60664	631.60665
29/234	622.85664	639.60664	36/221	623.60664	631.60665
29/235	622.85664	640.10664	36/231	623.85664	631.60665
29/256	622.85664	640.10664	33/226	624.10665	645.60664
29/244	622.85664	641.60664	36/232	624.10665	631.60665
29/257	622.85664	640.60664	36/223	625.35664	631.60665
29/238	622.85664	641.60664	33/233	625.60665	645.60664
29/243	622.85664	642.10664	33/234	626.35664	645.60664
29/236	622.85664	641.60664	33/225	626.60664	645.60664
29/237	622.85664	641.60664	36/233	626.60664	631.60665
29/259	622.85664	640.10664	36/234	627.35664	631.60665
29/258	622.85664	641.60664	36/250	627.60665	631.60665
29/248	622.85664	644.10664	33/235	627.85664	645.60664
29/249	622.85664	644.10664	36/239	627.85664	631.60665
29/247	622.85664	644.60664	36/235	627.85664	631.60665
29/246	622.85664	646.10665	1/218	628.10664	645.10664
29/240	622.85664	645.10664	1/99	628.10664	640.60664
29/245	622.85664	646.60664	1/217	628.10664	645.60664
29/242	622.85664	648.60664	3/99	628.10664	640.60664
29/241	622.85664	648.60664	5/NH	628.10664	640.60664
33/227	623.10664	645.60664	23/NH	628.10664	628.60664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
26/257	628.10664	628.60664	33/239	608.10664	645.60664
26/259	628.10664	628.60664	33/238	608.10664	645.60664
26/258	628.10664	629.60664	33/236	608.10664	645.60664
26/248	628.10664	630.60664	33/237	608.10664	645.60664
26/249	628.10664	631.10664	33/240	608.10664	645.60664
26/247	628.10664	630.60664	36/251	608.10664	631.60665
26/246	628.10664	631.60665	36/252	608.10664	631.60665
26/240	628.10664	629.10664	36/255	608.10664	631.60665
26/245	628.10664	632.10664	36/254	608.10664	631.60665
27/NH	608.10664	641.10664	36/253	608.10664	631.60665
29/224	608.10664	630.10664	36/244	628.10664	631.60665
29/221	608.10664	628.60664	36/238	628.10664	631.60665
29/222	608.10664	629.60664	36/243	628.10664	631.60665
29/225	608.10664	632.10664	36/236	628.10664	631.60665
29/223	608.10664	630.10664	36/237	628.10664	631.60665
31/228	608.10664	640.60664	1/219	628.60664	649.10664
31/229	608.10664	642.60665	36/256	628.60664	631.60665
31/230	608.10664	644.10664	36/240	628.60664	631.60665
31/231	608.10664	647.10664	1/220	629.10664	650.60664
31/232	608.10664	647.60664	3/217	629.10664	640.10664
31/233	608.10664	649.10664	31/235	629.10664	647.60664
31/234	608.10664	649.10664	36/257	629.10664	631.60665
31/240	608.10664	656.60664	1/221	629.60664	651.60664
33/224	608.10664	645.60664	36/247	629.60664	631.60665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
26/260	630.10664	630.60664	30/NH	634.60664	675.10664
33/243	630.10664	645.60664	30/218	634.60664	641.10664
36/259	630.10664	631.60665	30/99	634.60664	640.60664
36/248	630.10664	631.60665	30/217	634.60664	641.10664
36/249	630.10664	631.60665	30/219	634.60664	641.10664
36/246	630.10664	631.60665	30/224	634.60664	638.60665
1/222	630.60664	652.60664	30/220	634.60664	641.10664
33/244	630.60664	645.60664	30/221	634.60664	641.10664
33/241	630.60664	645.60664	30/222	634.60664	640.10664
36/258	630.60664	631.60665	30/225	634.60664	640.10664
36/245	630.60664	631.60665	30/226	634.60664	637.10664
1/224	631.10664	650.60664	30/223	634.60664	642.60665
1/223	631.10664	654.10664	30/227	634.60664	637.10664
29/261	631.10664	640.10664	30/228	634.60664	636.60664
3/218	631.60665	636.10664	30/229	634.60664	636.10664
31/236	631.60665	648.60664	30/230	634.60664	636.10664
33/250	631.60665	645.60664	30/231	634.60664	637.60664
33/242	631.60665	645.60664	30/250	634.60664	644.60664
33/222	632.10664	645.60664	30/232	634.60664	638.10664
33/251	632.60664	645.60664	30/251	634.60664	645.60664
33/246	632.60664	645.60664	30/239	634.60664	644.10664
33/245	632.60664	645.60664	30/252	634.60664	646.10665
33/252	633.10664	645.60664	30/255	634.60664	647.60664
29/262	634.60664	640.60664	30/254	634.60664	647.60664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
30/255	634.60664	647.10664	33/247	634.60664	645.60664
30/233	634.60664	640.60664	33/253	635.10665	645.60664
30/234	634.60664	641.10664	1/225	635.60664	651.60664
30/235	634.60664	642.10664	31/237	635.60664	646.10665
30/256	634.60664	649.10664	31/241	635.60664	646.10665
30/244	634.60664	646.60664	33/221	635.60664	645.60664
30/257	634.60664	650.10665	33/248	636.10664	645.60664
30/238	634.60664	644.60664	33/249	636.60664	645.60664
30/243	634.60664	646.60664	33/254	637.10664	645.60664
30/236	634.60664	643.60664	37/228	637.10664	649.60664
30/237	634.60664	644.60664	37/229	637.10664	649.10664
30/261	634.60664	652.60664	37/230	637.10664	649.60664
30/259	634.60664	651.10664	1/250	637.60664	661.60664
30/258	634.60664	651.60664	31/242	637.60664	657.10665
30/262	634.60664	653.60664	33/223	637.60664	645.60664
30/260	634.60664	652.60664	33/255	637.60664	645.60664
30/248	634.60664	650.60664	1/226	638.10664	650.60664
30/249	634.60664	650.60664	33/220	638.10664	645.10664
30/247	634.60664	650.10665	37/227	638.10664	650.60664
30/246	634.60664	649.60665	1/255	638.60665	665.10664
30/240	634.60664	645.10664	33/256	638.60665	645.60664
30/245	634.60664	650.10665	37/226	638.60665	650.60664
30/242	634.60664	650.10665	37/231	638.60665	652.10664
30/241	634.60664	649.60665	37/232	638.60665	652.60664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
1/251	639.10664	663.60661	35/228	640.10664	641.10664
1/254	639.10664	665.10664	35/229	640.10664	640.60664
34/NH	639.10664	703.10664	35/231	640.10664	641.10664
1/252	639.60664	664.10664	35/250	640.10664	651.60664
1/253	639.60664	665.10664	35/232	640.10664	641.10664
37/225	639.60664	651.60664	35/251	640.10664	652.60664
1/263	640.10664	664.60665	35/239	640.10664	650.10665
3/263	640.10664	662.10664	35/252	640.10664	653.10664
30/263	640.10664	652.60664	35/255	640.10664	655.10664
33/257	640.10664	645.60664	35/254	640.10664	655.10664
35/NH	640.10664	687.10664	35/253	640.10664	654.10664
35/218	640.10664	645.10664	35/233	640.10664	643.60664
35/99	640.10664	640.60664	35/234	640.10664	644.60664
35/217	640.10664	645.60664	35/263	640.10664	662.10664
35/219	640.10664	649.10664	35/235	640.10664	646.10665
35/224	640.10664	647.10664	35/256	640.10664	656.60664
35/220	640.10664	650.60664	35/244	640.10664	652.60664
35/221	640.10664	650.60664	35/257	640.10664	657.10665
35/222	640.10664	650.10665	35/238	640.10664	649.10664
35/225	640.10664	645.10664	35/243	640.10664	652.10664
35/226	640.10664	643.60664	35/236	640.10664	647.60664
35/223	640.10664	652.10664	35/237	640.10664	648.60664
35/227	640.10664	643.10664	35/261	640.10664	661.10665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
35/259	640.10664	658.60664	1/262	642.10664	670.10664
35/258	640.10664	659.10664	37/234	642.10664	658.10664
35/262	640.10664	662.10664	1/258	642.60665	670.10664
35/260	640.10664	661.10665	33/258	643.10664	645.60664
35/248	640.10664	656.60664	37/235	643.10664	661.60664
35/249	640.10664	656.60664	1/260	643.60664	671.60664
35/247	640.10664	655.60664	37/236	644.10664	661.60664
35/246	640.10664	654.60664	1/244	644.60664	665.10664
35/240	640.10664	647.10664	2/226	644.60664	650.60664
35/245	640.10664	654.10664	2/224	645.10664	650.60664
35/242	640.10664	653.10664	2/225	645.10664	651.60664
35/241	640.10664	652.10664	2/227	645.10664	650.60664
1/227	640.60664	650.60664	2/228	645.10664	649.60665
29/264	640.60664	649.60665	2/229	645.10664	649.10664
30/264	640.60664	675.10664	37/237	645.10664	661.60664
35/264	640.60664	665.10664	1/243	645.60664	664.60665
1/256	641.10664	667.60664	1/248	645.60664	668.60664
1/259	641.10664	668.60664	1/249	645.60664	669.10664
37/233	641.10664	657.10665	2/230	645.60664	649.60665
1/257	641.60664	668.10665	37/239	645.60664	661.60664
1/261	641.60664	669.10664	37/238	645.60664	661.60664
37/224	641.60664	650.60664	37/222	646.10665	652.60664
1/239	642.10664	662.10664	37/240	646.10665	661.60664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
1/247	646.60664	667.60664	2/235	650.10665	660.10664
2/222	647.10664	652.60664	37/253	650.10665	661.60664
2/231	647.10664	652.10664	37/241	650.10665	661.60664
2/221	647.60664	651.60664	37/246	650.60664	661.60664
2/232	647.60664	652.60664	37/245	650.60664	661.60664
37/221	647.60664	651.60664	37/242	650.60664	661.60664
37/250	647.60664	661.60664	2/251	651.10664	663.60664
37/243	647.60664	661.60664	2/236	651.10664	662.10664
2/219	648.10664	649.10664	37/254	651.10664	661.60664
2/220	648.10664	650.60664	1/246	651.60664	664.60665
37/220	648.10664	650.60664	2/252	651.60664	664.10664
37/244	648.10664	661.60664	2/238	651.60664	663.60664
37/219	648.60664	649.10664	2/237	651.60664	663.10664
37/251	648.60664	661.60664	37/255	651.60664	661.60664
1/238	649.10664	659.60664	37/247	651.60664	661.60664
2/223	649.10664	654.10664	37/248	652.10664	661.60664
2/233	649.10664	657.10665	2/254	652.60664	665.10664
37/223	649.10664	654.10664	2/253	652.60664	665.10664
37/252	649.10664	661.60664	2/244	652.60664	665.60664
2/234	649.60665	658.10664	2/243	652.60664	665.60664
1/264	650.10665	675.60665	37/249	652.60664	661.60664
2/250	650.10665	661.60664	1/245	653.10664	663.10664
2/239	650.10665	662.10664	2/255	653.10664	665.10664
			37/256	653.10664	661.60664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
2/240	654.10664	664.10664	32/242	659.10664	661.60664
37/257	654.10664	661.60664	32/241	659.10664	661.60664
2/256	654.60664	666.10664	32/264	659.10664	664.60665
2/257	655.10664	666.10664	34/240	659.10664	664.10664
2/247	655.10664	666.10664	2/263	659.60664	664.60664
2/248	655.60664	666.10664	2/262	659.60664	666.10664
2/249	655.60664	666.10664	37/260	659.60664	661.60664
2/246	655.60664	666.10664	6/NH	661.10665	680.10664
2/259	656.10664	666.10664	37/261	661.10665	661.60664
2/245	656.10664	666.10664	4/237	662.60664	663.10664
37/258	656.10664	661.60664	4/240	662.60664	664.10664
2/258	656.60664	666.10664	7/NH	662.60664	681.10664
37/259	656.60664	661.60664	2/264	663.10664	666.10664
2/242	657.10665	666.10664	4/238	663.10664	663.60664
2/241	657.10665	666.10664	7/255	663.10664	665.10664
4/NH	657.60664	680.10664	7/254	663.60664	665.10664
2/261	658.60664	666.10664	7/253	663.60664	665.10664
2/260	658.60664	666.10664	4/243	664.60665	665.60664
32/NH	659.10664	691.10664	7/256	664.60665	667.60664
32/260	659.10664	659.60664	7/257	664.60665	668.10665
32/249	659.10664	659.60664	7/259	664.60665	668.60664
32/246	659.10664	660.10664	33/NH	664.60665	700.10664
32/245	659.10664	660.60665	33/245	664.60665	665.10664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
33/242	664.60665	667.10664	6/242	667.60664	670.60664
33/241	664.60665	667.10664	6/241	667.60664	669.60664
4/244	665.10664	665.60664	7/247	667.60664	669.60664
4/241	665.10664	669.60664	4/248	668.10665	670.10664
6/244	665.10664	665.60664	4/249	668.60664	670.10664
6/243	665.10664	665.60664	6/258	669.10664	670.10664
7/258	665.10664	670.10664	7/264	670.10664	677.60664
34/241	665.10664	669.60664	6/260	671.10664	671.60664
4/242	665.60664	670.60664	9/NH	672.10665	691.10664
7/262	665.60664	670.10664	6/264	673.10664	677.60664
8/NH	665.60664	701.60665	28/NH	674.10664	704.60664
4/246	666.10664	670.10664	10/NH	674.60664	688.60664
4/245	666.10664	670.10664	12/NH	676.60664	690.10665
7/260	666.10664	671.60664	36/NH	679.10665	698.60664
6/246	666.60664	670.10664	13/NH	681.10664	692.60664
4/247	666.60664	669.60664	11/NH	682.60664	703.10664
6/256	666.60664	667.60664	15/NH	682.60664	694.10665
6/248	666.60664	670.10664	21/NH	685.60664	700.60664
6/247	666.60664	669.60664	14/NH	687.10664	697.10664
6/245	666.60664	670.10664	17/NH	691.10664	699.60664
7/248	666.60664	670.10664	18/NH	695.10664	703.10664
7/249	666.60664	670.10664	16/NH	696.10664	705.10665
6/249	667.60664	670.10664	24/NH	696.10664	706.60664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquistion	Loss
37/NH	697.10664	700.10664	36/141	789.60665	801.10665
27/NH	704.10661	706.10664	29/NH	792.60664	839.10664
23/NH	705.10665	706.60664	29/141	792.60664	795.60664
25/NH	705.10665	707.60664	29/143	792.60664	796.10664
17/NH	742.10665	743.10664	29/142	792.60664	796.10664
18/NH	744.10664	752.60665	29/140	792.60664	796.60664
24/NH	744.10664	759.60664	29/144	793.10665	795.60664
27/NH	756.60665	811.10664	36/144	793.10665	801.10665
23/NH	757.60664	798.10664	26/224	794.10664	804.10665
5/NH	785.10664	810.10664	29/224	794.10664	820.10664
25/NH	759.10664	795.10664	26/214	794.60664	796.10664
26/NH	773.10664	814.10664	29/214	794.60664	806.10664
5/140	779.10664	785.60665	26/225	795.60664	803.10664
23/140	779.10664	782.10665	29/213	795.60664	806.10664
26/140	779.10664	786.10665	29/225	795.60664	820.10664
35/140	779.10664	788.10664	26/226	796.10664	801.60664
32/140	780.10664	781.10664	29/226	796.10664	819.10665
31/NH	784.10664	867.60664	31/226	796.10664	834.10665
35/143	787.60664	788.10664	1/144	796.60664	815.60665
35/142	787.60664	788.10664	1/141	796.60664	815.60665
36/143	787.60664	801.10665	33/226	796.60664	815.10665
36/142	787.60664	801.10665	1/143	797.10665	816.60664
36/140	788.60664	801.10665	1/142	797.10665	816.60664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
29/212	797.10665	805.60664	1/145	801.10665	813.60664
1/140	798.10664	818.10664	33/145	801.10665	813.60664
26/227	798.10664	801.60664	33/224	801.10665	815.10665
29/227	798.10664	819.10665	26/217	801.60664	806.10664
31/227	798.10664	832.10664	29/217	801.60664	820.60664
33/225	798.10664	815.10665	33/143	801.60664	815.10665
33/227	798.10664	815.10665	1/146	802.10664	813.10664
31/225	798.60664	833.60665	29/228	802.10664	818.60664
33/144	798.60664	815.10665	31/228	802.10664	826.10665
36/212	798.60664	801.10665	33/146	802.10664	813.10664
36/213	798.60664	801.10665	33/228	802.10664	815.10665
36/214	798.60664	801.10665	1/139	803.10664	810.60664
26/222	799.60664	806.10664	33/142	803.60664	815.10665
29/222	799.60664	822.10664	26/223	804.10665	807.60664
26/219	800.10664	806.10664	29/223	804.10665	823.10665
26/221	800.10664	806.10664	26/99	804.60665	806.10664
29/219	800.10664	821.10664	29/99	804.60665	820.10664
29/221	800.10664	821.60664	29/229	804.60665	818.10664
26/218	800.60665	805.60664	30/NH	804.60665	844.60665
26/220	800.60665	806.10664	30/146	804.60665	805.60664
29/218	800.60665	820.10664	30/145	804.60665	806.60664
29/220	800.60665	821.60664	30/139	804.60665	808.60664
			30/144	804.60665	808.10665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
30/141	804.60665	809.10664	33/229	804.60665	815.10665
30/143	804.60665	808.60664	33/222	805.10664	815.10665
30/142	804.60665	809.10664	3/211	805.60664	828.10664
30/140	804.60665	810.60664	30/211	805.60664	819.60664
30/212	804.60665	819.60664	33/141	805.60664	814.10664
30/213	804.60665	819.60664	1/147	806.10664	812.10665
30/214	804.60665	819.60664	1/211	806.10664	828.10664
30/218	804.60665	825.10664	29/215	806.10664	818.60664
30/99	804.60665	826.60665	30/215	806.10664	827.10664
30/217	804.60665	826.60665	33/147	806.10664	812.10665
30/219	804.60665	825.10664	33/221	806.10664	815.10665
30/224	804.60665	820.60664	33/220	807.10664	815.10665
30/220	804.60665	825.10664	33/223	807.10664	815.10665
30/221	804.60665	824.60664	1/212	807.60664	833.60665
30/222	804.60665	824.10664	1/213	807.60664	834.60664
30/225	804.60665	818.60664	33/219	807.60664	815.10665
30/226	804.60665	816.60664	1/214	808.10665	835.10664
30/223	804.60665	826.10665	37/147	808.10665	812.10665
30/227	804.60665	816.10664	1/148	808.60664	811.10664
30/228	804.60665	814.60664	33/148	808.60664	811.10664
30/229	804.60665	813.60664	34/NH	808.60664	873.10664
31/224	804.60665	831.10664	37/148	808.60664	811.10664
31/229	804.60665	815.10665	35/NH	809.10664	857.10664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
35/148	809.10664	811.10664	35/225	809.10664	817.60664
35/147	809.10664	812.10665	35/226	809.10664	814.60664
35/146	809.10664	813.10664	35/223	809.10664	829.60664
35/145	809.10664	813.60664	35/227	809.10664	812.10665
35/139	809.10664	810.60664	37/146	809.10664	813.10664
35/144	809.10664	815.60665	1/210	810.10664	824.60664
35/141	809.10664	815.60665	3/210	810.10664	824.60664
35/143	809.10664	816.60664	3/212	810.10664	823.60664
35/142	809.10664	816.60664	30/210	810.10664	819.60664
35/140	809.10664	818.10664	35/210	810.10664	824.60664
35/211	809.10664	828.10664	33/217	809.60664	815.10665
35/212	809.10664	829.10664	33/218	809.10664	815.10665
35/213	809.10664	828.60664	37/145	811.60665	813.60664
35/214	809.10664	828.60664	33/99	812.10665	815.10665
35/215	809.10664	833.60665	2/146	812.60664	813.10664
35/218	809.10664	830.60665	29/230	812.60664	815.60665
35/99	809.10664	832.60664	30/230	812.60664	813.60664
35/217	809.10664	831.10664	31/236	812.60664	815.60665
35/219	809.10664	829.60664	33/230	812.60664	815.10665
35/224	809.10664	822.10664	3/213	813.10664	821.10664
35/220	809.10664	829.10664	29/250	813.10664	826.60665
35/221	809.10664	817.60664	30/250	813.10664	825.60664
35/222	809.10664	827.10664	31/250	813.10664	839.10664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
33/250	813.10664	815.10665	35/252	818.60664	827.60664
35/250	813.10664	826.10665	37/227	818.60664	831.10664
37/144	813.60664	815.60665	37/226	819.10665	831.10664
31/222	813.60664	829.10664	1/215	819.60664	844.60665
2/144	814.60664	815.60665	29/255	820.10664	829.10664
37/143	815.10665	816.60664	29/254	820.10664	828.60664
2/143	815.60665	816.60664	29/253	820.10664	828.60664
37/142	815.60665	816.60664	30/255	820.10664	829.10664
2/142	816.10664	816.60664	30/254	820.10664	829.10664
2/140	817.60664	818.10664	30/253	820.10664	828.10664
29/251	817.60664	827.60664	31/255	820.10664	840.10664
30/251	817.60664	826.60665	31/254	820.10664	840.60664
31/251	817.60664	840.60664	31/253	820.10664	841.10665
35/251	817.60664	827.10664	35/255	820.10664	831.10664
37/229	817.60664	822.10664	35/254	820.10664	830.60665
29/239	818.10664	826.10665	35/253	820.10664	829.10664
30/239	818.10664	823.60664	37/225	820.10664	831.10664
31/239	818.10664	840.60664	34/229	821.10664	822.10664
35/239	818.10664	821.10664	1/99	821.60664	843.10664
37/228	818.10664	826.10665	37/224	821.60664	831.10664
29/252	818.60664	828.10664	31/223	822.10664	825.60664
30/252	818.60664	827.10664	34/228	822.10664	826.10665
31/252	818.60664	840.60664	1/218	822.60665	840.60664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
1/217	823.10665	841.10665	34/225	827.10664	837.10665
34/227	824.10664	841.10665	35/257	827.10664	833.10664
37/222	824.60664	831.10664	37/250	827.10664	831.10664
29/256	825.10664	830.60665	1/220	827.60664	836.60664
30/256	825.10664	830.60665	29/244	827.60664	828.60664
31/256	825.10664	842.60664	29/259	827.60664	831.60664
34/226	825.10664	834.10665	30/259	827.60664	833.10664
35/256	825.10664	831.60664	31/244	827.60664	843.10664
37/220	825.10664	831.10664	31/259	827.60664	841.10665
37/221	825.10664	831.10664	35/259	827.60664	835.60664
1/219	825.60664	838.10664	37/214	828.10664	831.10664
37/239	825.60664	831.10664	37/251	828.10664	831.10664
2/212	826.10665	833.60665	37/244	828.10664	831.10664
2/213	826.10665	834.60664	2/224	828.60664	835.60664
2/214	826.10665	835.10664	37/252	828.60664	831.10664
37/219	826.10665	831.10664	2/225	829.10664	835.60664
37/218	826.60665	831.10664	2/226	829.10664	834.10665
37/223	826.60665	831.10664	32/NH	829.10664	860.60664
2/211	827.10664	828.10664	32/215	829.10664	833.60665
4/NH	827.10664	850.10664	32/218	829.10664	834.10665
29/257	827.10664	831.10664	32/99	829.10664	834.60664
30/257	827.10664	831.60664	32/217	829.10664	834.10665
31/257	827.10664	843.10664	32/219	829.10664	834.10665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
32/224	829.10664	833.10664	37/212	829.60664	831.10664
32/220	829.10664	834.60664	2/218	830.10665	835.60664
32/221	829.10664	834.60664	2/219	830.10665	835.60664
32/222	829.10664	834.60664	29/258	830.10665	832.10664
32/225	829.10664	832.60664	30/258	830.10665	833.10664
32/226	829.10664	832.10664	31/258	830.10665	843.60664
32/223	829.10664	835.60664	32/258	830.10665	843.60664
32/227	829.10664	832.10664	35/258	830.10665	835.10664
32/250	829.10664	837.60665	37/255	830.10665	831.10664
32/251	829.10664	839.10664	37/254	830.10665	831.10664
32/239	829.10664	837.60665	1/221	830.60665	834.10665
32/252	829.10664	839.10664	2/220	830.60665	835.60664
32/255	829.10664	840.60664	2/221	830.60665	835.60664
32/254	829.10664	840.10664	2/222	830.60665	835.60664
32/253	829.10664	840.10664	6/NH	830.60665	849.60664
32/256	829.10664	841.60665	31/243	830.60665	840.10664
32/244	829.10664	839.60664	32/243	830.60665	839.60664
32/257	829.10664	842.60664	34/239	830.60665	841.60665
32/259	829.10664	843.10664	37/215	830.60665	831.10664
37/213	829.10664	831.10664	37/243	830.60665	831.10664
37/99	829.10664	831.10664	2/99	831.10664	835.60664
37/253	829.10664	831.10664	30/263	831.10664	836.10664
2/227	829.60664	832.10664	32/263	831.10664	844.10664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
2/215	831.60664	835.60664	32/249	834.10665	843.10664
29/261	831.60664	832.10664	33/NH	834.10665	870.10664
30/261	831.60664	835.60664	33/218	834.10665	837.10665
32/261	831.60664	844.60665	33/99	834.10665	836.10664
35/261	831.60664	839.10664	33/217	834.10665	837.10665
2/223	832.10664	835.60664	33/219	834.10665	838.10664
7/NH	832.10664	851.10664	33/224	834.10665	838.60664
34/224	832.10664	841.10665	33/220	834.10665	838.60664
34/244	832.60664	843.10664	33/221	834.10665	838.60664
7/212	833.10664	833.60665	33/222	834.10665	839.10664
7/213	833.10664	834.60664	33/225	834.10665	837.10665
7/214	833.10664	835.10664	33/223	834.10665	840.10664
1/263	833.60665	849.10664	33/250	834.10665	843.60664
30/262	833.60665	836.10664	33/251	834.10665	844.60665
30/260	833.60665	835.10664	33/239	834.10665	841.60665
31/260	833.60665	843.10664	33/252	834.10665	844.60665
31/248	833.60665	846.10664	33/255	834.10665	845.10665
32/262	833.60665	845.60664	33/254	834.10665	845.10665
32/260	833.60665	845.60664	33/253	834.10665	845.10665
32/240	833.60665	842.60664	33/263	834.10665	846.60664
35/262	833.60665	840.10664	33/256	834.10665	846.60664
35/260	833.60665	838.10664	33/244	834.10665	843.10664
31/249	834.10665	846.10664	33/257	834.10665	847.10664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
33/243	834.10665	840.10664	6/224	838.10664	841.10665
33/261	834.10665	848.10665	34/254	838.10664	849.60665
33/259	834.10665	847.10664	4/221	838.60664	845.10665
33/258	834.10665	848.10665	34/255	838.60664	849.60664
33/262	834.10665	848.60665	4/219	839.10664	845.60664
33/260	834.10665	849.10664	4/220	839.10664	850.10664
33/248	834.10665	848.10665	4/239	839.10664	841.60665
33/249	834.10665	848.10665	7/215	839.10664	846.60664
34/250	834.10665	846.10665	34/256	839.10664	850.60664
4/225	834.60664	837.10665	4/223	839.60664	846.60664
34/251	834.60664	846.60664	4/250	839.60664	846.10664
2/250	835.10664	835.60664	6/221	839.60664	845.10665
34/252	835.10664	847.10664	6/222	839.60664	844.60665
4/224	835.60664	841.10665	4/218	840.10664	845.60664
8/NH	835.60664	871.60664	6/218	840.10664	845.60664
31/247	836.10664	846.10664	6/219	840.10664	845.60664
32/247	836.10664	845.10665	6/220	840.10664	845.60664
33/247	836.10664	846.10664	7/99	840.10664	846.60664
34/247	836.10664	846.10664	34/257	840.10664	851.60664
34/253	836.60664	848.60665	4/217	840.60664	846.10664
34/248	837.10665	848.60665	4/251	840.60664	846.60664
34/249	837.60665	849.10664	6/217	840.60664	846.10664
4/222	838.10664	844.60664	6/223	840.60664	846.60664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
4/252	841.10665	847.10664	4/248	844.10664	848.60665
4/244	841.10665	843.10664	4/247	844.10664	846.10664
6/99	841.10665	846.60664	6/252	844.10664	847.10664
7/218	841.10665	845.60664	7/220	844.10664	845.60664
7/217	841.10665	846.10664	28/NH	844.10664	874.60665
4/253	841.60665	848.60665	4/215	844.60665	846.60664
1/262	842.10664	843.60664	4/249	844.60665	849.10664
4/254	842.10664	849.60664	6/255	844.60665	849.60664
6/215	842.10664	846.60664	6/254	844.60665	849.60664
9/NH	842.10664	861.10664	6/253	844.60665	848.60665
32/247	842.10664	842.10664	10/NH	844.60665	858.60664
34/258	842.10664	853.10664	4/259	845.10665	850.10664
4/99	842.60664	846.10664	4/258	845.60665	850.10664
4/255	842.60664	849.60664	31/264	845.60665	850.10664
6/250	842.60664	846.10664	32/264	845.60665	849.10665
1/267	843.10664	855.10664	33/264	845.60665	853.60664
7/219	843.10664	845.60664	34/260	845.60665	853.10664
32/267	843.10664	845.10665	6/256	846.10664	849.60664
34/259	843.10664	851.60664	6/257	846.60664	849.60664
35/267	843.10664	847.10665	12/NH	846.60664	859.60665
4/256	843.60664	850.10664	6/259	847.10664	849.60664
6/251	843.60664	846.10664	34/264	847.10664	857.60664
4/257	844.10664	850.10664	4/261	847.60664	850.10664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
4/260	847.60664	850.10664	10/263	853.10664	855.60665
6/258	847.60664	849.60664	12/261	853.10664	855.10664
6/248	847.60664	848.60665	12/260	853.10664	855.10664
4/262	848.10665	850.10664	12/263	853.60664	855.60665
6/249	848.10665	849.10664	12/262	853.60664	856.10665
6/263	848.60665	849.60664	10/261	854.60664	855.10664
6/261	848.60665	849.60664	10/267	854.60664	857.10664
36/NH	848.60665	868.60664	10/262	855.10664	856.10665
36/263	848.60665	849.10664	13/263	855.10664	855.60665
36/262	848.60665	849.10664	15/262	855.60665	856.10665
36/264	848.60665	852.10665	21/NH	855.60665	870.60665
36/267	848.60665	851.10664	12/264	856.10665	857.60664
4/263	849.10664	850.10664	14/NH	857.10664	866.60665
6/262	849.10664	849.60664	17/NH	861.10664	869.10664
6/260	849.10664	849.60664	18/NH	864.60664	872.60664
7/263	849.10664	851.10664	16/NH	865.60664	875.10664
7/267	849.10664	851.10664	24/NH	866.10664	876.60664
13/NH	851.10664	862.10664	37/NH	867.10665	870.10664
12/259	852.10665	853.10664	27/NH	873.60664	876.10664
12/258	852.10665	853.10664	25/NH	874.60665	877.10664
11/NH	852.60665	872.60664	23/NH	875.10664	876.60664
15/NH	852.60665	863.60665	17/NH	912.10664	913.10664
9/267	853.10664	857.10664	24/NH	913.60664	929.10665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
18/NH	914.10664	922.60665	23/118	941.10665	949.60664
27/NH	926.60664	981.10665	25/118	941.10665	945.10664
23/NH	927.10664	968.10664	35/118	941.10665	958.10664
25/NH	928.60664	965.10664	35/120	941.10665	958.10664
23/120	931.10664	950.10664	35/121	941.10665	958.10664
25/120	931.10664	946.60664	26/NH	942.60664	983.60664
23/121	932.10664	951.10665	26/118	942.60664	956.60664
23/122	932.10664	951.10665	26/119	942.60664	957.10664
25/121	932.10664	947.60665	26/120	942.60664	957.60664
25/122	932.10664	948.10665	26/121	942.60664	958.60665
23/119	934.10664	950.10664	26/122	942.60664	959.60664
25/119	934.10664	946.10664	26/157	942.60664	961.10664
23/157	935.60664	946.60664	26/156	942.60664	961.60664
25/157	935.60664	951.10665	26/155	942.60664	963.10665
23/156	936.10664	946.60664	26/154	942.60664	963.10665
25/156	936.10664	951.10665	26/153	942.60664	946.10664
23/155	939.10664	948.60664	35/122	943.10664	958.10664
23/154	939.10664	948.60664	32/118	946.10664	950.60664
25/155	939.10664	952.60664	32/157	946.10664	950.60664
25/154	939.10664	952.60664	23/151	946.60664	953.60664
23/153	940.10665	949.60664	25/151	946.60664	956.10664
25/153	940.10665	953.10664	26/151	946.60664	967.60664
35/119	940.60665	958.10664	32/119	946.60664	950.60664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
32/120	946.60664	950.60664	25/147	952.60664	958.10664
32/156	946.60664	950.60664	26/116	952.60664	955.10665
23/117	947.10664	949.10664	26/147	952.60664	970.10665
26/117	947.10664	955.60665	35/116	952.60664	958.10664
32/117	947.10664	950.60664	35/155	952.60664	958.10664
35/117	947.10664	958.10664	35/154	952.60664	958.10664
32/121	947.60665	950.60664	35/153	953.10664	958.10664
32/122	947.60665	950.60664	5/104	953.60664	962.10665
32/155	948.10665	950.60664	26/104	953.60664	955.60665
32/154	948.10665	950.60664	31/NH	953.60664	
32/153	948.60664	950.60664	35/104	953.60664	958.10664
23/150	949.10664	954.10664	35/151	954.10664	958.10664
25/150	949.10664	956.60664	23/146	954.60664	957.10664
26/150	949.10664	968.60664	25/146	954.60664	958.60665
23/144	950.10664	954.10664	26/146	954.60664	971.10664
25/144	950.10664	957.10664	35/150	954.60664	958.10664
26/144	950.10664	968.60664	35/144	955.10665	958.10664
23/148	951.60665	955.10665	35/148	955.10665	958.10664
25/148	951.60665	957.60664	35/147	955.10665	958.10664
26/148	951.60665	969.60665	35/146	955.10665	958.10664
35/157	951.60665	958.10664	35/115	955.60665	958.10664
35/156	952.10665	958.10664	36/115	955.60665	970.60664
23/147	952.60664	955.60665	36/116	955.60665	970.60664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
36/117	956.10664	970.60664	36/104	960.60664	970.60664
36/118	956.60664	970.60664	36/157	960.60664	970.60664
36/119	957.10664	970.60664	26/144	961.10664	973.10665
36/120	957.10664	970.60664	31/155	961.10664	991.10664
23/137	957.60664	961.10664	31/154	961.10664	991.10664
23/145	957.60664	959.10665	36/156	961.10664	970.60664
25/145	957.60664	959.10665	3/103	961.60664	974.10665
26/137	957.60664	969.10664	5/135	961.60664	963.60664
26/145	957.60664	972.10664	26/135	961.60664	964.10664
33/157	957.60664	984.60665	26/136	961.60664	967.60664
33/156	957.60664	984.60665	26/152	961.60664	967.60664
35/137	957.60664	958.10664	36/103	961.60664	970.60664
35/145	957.60664	958.10664	36/113	962.10665	970.60664
31/157	958.10664	990.10664	29/NH	962.60665	
31/156	958.10664	990.60664	29/113	962.60665	965.60664
36/114	958.10664	970.60664	29/114	962.60665	966.60665
36/121	958.10664	970.60664	29/115	962.60665	967.10664
36/122	958.60665	970.60664	29/116	962.60665	967.60664
23/138	959.60664	961.60664	29/117	962.60665	968.60664
26/138	959.60664	971.10664	29/104	962.60665	964.10664
33/155	959.60664	984.60665	29/118	962.60665	969.60665
33/154	959.60664	984.60665	29/119	962.60665	970.10665
33/153	960.60664	984.60665	29/120	962.60665	970.60664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
29/121	962.60665	971.60664	3/102	963.10665	970.10665
29/122	962.60665	973.10665	33/120	963.10665	984.60665
29/135	962.60665	974.60664	36/102	963.10665	970.60664
29/157	962.60665	977.60665	36/153	963.10665	970.60664
29/156	962.60665	978.10664	3/105	963.60664	978.60664
29/155	962.60665	979.10664	26/139	963.60664	973.10665
29/154	962.60665	979.10664	29/139	963.60664	987.60664
29/136	962.60665	979.10664	33/119	963.60664	984.60665
29/153	962.60665	979.60664	33/122	963.60664	984.60665
29/152	962.60665	979.10664	36/105	963.60664	970.60664
29/137	962.60665	981.60665	3/104	964.10664	983.60664
29/151	962.60665	983.10664	26/143	964.10664	974.10665
29/138	962.60665	984.10664	29/143	964.10664	989.10664
29/150	962.60665	984.10664	33/117	964.10664	984.60665
29/149	962.60665	984.10664	33/118	964.10664	984.60665
29/148	962.60665	985.10665	5/130	964.60664	965.60664
29/147	962.60665	985.60664	5/70	964.60664	965.60664
29/146	962.60665	986.10664	26/142	964.60664	974.10665
29/145	962.60665	987.10664	29/112	964.60664	965.10664
29/144	962.60665	988.10665	29/130	964.60664	967.60664
31/153	962.60665	991.10665	29/70	964.60664	967.60664
36/155	962.60665	970.60664	29/142	964.60664	989.10664
36/154	962.60665	970.60664	33/121	964.60664	984.60665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
36/112	964.60664	970.60664	36/134	967.10664	970.60664
36/130	964.60664	970.60664	36/135	967.10664	970.60664
36/70	964.60664	970.60664	1/115	967.60664	987.10664
26/141	965.10664	974.10665	1/104	967.60664	983.60664
29/141	965.10664	989.10664	33/114	967.60664	984.60665
33/116	965.10664	984.60665	33/130	967.60664	984.60665
33/151	965.10664	984.60665	36/150	967.60664	970.60664
1/106	965.60664	979.10664	36/149	967.60664	970.60664
1/105	965.60664	978.60664	36/148	968.10664	970.60664
3/106	965.60664	979.10664	1/107	968.60664	981.60662
33/150	965.60664	984.60665	1/116	968.60664	988.10665
36/106	965.60664	970.60664	3/107	968.60664	978.60664
1/112	966.10665	984.60665	29/133	968.60664	971.60664
1/103	966.10665	974.10665	36/107	968.60664	970.60664
1/102	966.10665	970.10665	36/133	968.60664	970.60664
33/149	966.10665	984.60665	36/147	968.60664	970.60664
1/113	966.60665	985.60664	3/132	969.10664	990.10664
33/115	966.60665	984.60665	26/140	969.10664	975.60664
33/148	966.60665	984.60665	29/140	969.10664	990.60664
36/151	966.60665	970.60664	31/151	969.10664	992.60665
1/114	967.10664	986.60664	33/146	969.10664	984.60665
3/130	967.10664	990.10664	36/132	969.10664	970.60664
3/70	967.10664	990.10664	36/136	969.10664	970.60664

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
36/152	969.10664	970.60664	1/111	973.10665	981.60665
36/137	969.10664	970.60664	3/134	973.10665	994.60664
1/117	969.60665	989.10664	33/144	973.10665	984.60665
31/150	969.60665	993.60664	1/121	973.60665	993.60664
31/149	969.60665	994.60664	1/109	973.60665	979.60664
33/113	969.60665	984.60664	1/110	947.10665	980.60665
36/146	969.60665	970.60664	30/NH	974.10665	
3/131	970.10665	988.10665	30/108	974.10665	979.10664
36/131	970.10665	970.60664	30/107	974.10665	978.60664
1/118	970.60664	990.10664	30/112	974.10665	978.10664
31/148	970.60664	995.10664	30/106	974.10665	979.10664
1/130	971.10664	990.10664	30/113	974.10665	978.10664
1/70	971.10664	990.10664	30/105	974.10665	978.60664
33/112	971.10664	984.60664	30/114	974.10665	977.60665
1/108	971.60664	979.10664	30/115	974.10665	977.60665
1/119	971.60664	991.10664	30/116	974.10665	977.60665
1/131	971.60664	988.10665	30/117	974.10665	977.60665
3/108	971.60664	975.10664	30/104	974.10665	982.10664
33/145	971.60664	984.60664	30/118	974.10665	978.10664
1/132	972.10664	990.10664	30/119	974.10665	978.10664
31/147	972.10664	995.10664	30/120	974.10665	978.60664
1/120	972.60664	991.60665	30/121	974.10665	979.60664
3/133	972.60664	995.60665	30/130	974.10665	985.10665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
30/122	974.10665	979.60664	30/139	974.10665	992.60665
30/131	974.10665	985.60664	30/144	974.10665	991.10664
30/70	974.10665	985.10665	30/141	974.10665	993.10664
30/132	974.10665	986.10664	30/143	974.10665	992.60665
30/133	974.10665	988.10665	30/142	974.10665	992.60665
30/134	974.10665	988.10665	30/140	974.10665	994.60664
30/135	974.10665	988.10665	30/110	974.10665	978.10664
30/157	974.10665	977.60665	30/111	974.10665	977.60665
30/156	974.10665	978.10664	30/109	974.10665	978.60664
30/155	974.10665	979.60664	1/133	974.60664	998.10664
30/154	974.10665	979.60664	1/134	974.60664	998.60664
30/136	974.10665	990.10664	33/143	974.60664	984.60664
30/153	974.10665	980.10664	1/122	975.10664	994.60664
30/152	974.10665	990.10664	31/146	975.10664	994.60664
30/137	974.10665	990.10664	33/142	975.10664	984.60665
30/151	974.10665	984.10664	33/111	975.10664	981.60665
30/138	974.10665	991.10664	33/141	975.60664	984.60665
30/150	974.10665	985.10665	1/135	976.10664	
30/149	974.10665	985.10665	33/139	976.60664	984.60665
30/148	974.10665	986.10664	33/138	977.10665	984.60665
30/147	974.10665	986.60664	33/140	977.10665	984.60665
30/146	974.10665	987.60664	33/137	978.10664	984.60665
30/145	974.10665	989.60664	34/NH	978.60664	

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
35/NH	978.60664		35/156	978.60664	979.60664
35/108	978.60664	979.10664	35/155	978.60664	981.60665
35/112	978.60664	984.60664	35/154	978.60664	981.60665
35/106	978.60664	979.10664	35/136	978.60664	998.10664
35/113	978.60664	985.60664	35/153	978.60664	982.60664
35/114	978.60664	986.60664	35/152	978.60664	998.10664
35/115	978.60664	987.10664	35/137	978.60664	997.10664
35/116	978.60664	986.60664	35/151	978.60664	986.60664
35/117	978.60664	986.60664	35/138	978.60664	997.10664
35/104	978.60664	986.10664	35/150	978.60664	987.60664
35/118	978.60664	986.60664	35/149	978.60664	987.60664
35/119	978.60664	986.60664	35/148	978.60664	988.60665
35/120	978.60664	986.10664	35/147	978.60664	989.10664
35/121	978.60664	987.10664	35/146	978.60664	990.60664
35/130	978.60664	990.10664	35/145	978.60664	993.60664
35/122	978.60664	986.60664	35/139	978.60664	998.10664
35/131	978.60664	988.10665	35/144	978.60664	995.10664
35/70	978.60664	990.10664	35/141	978.60664	997.60664
35/132	978.60664	990.10664	35/143	978.60664	996.60664
35/133	978.60664	998.10664	35/142	978.60664	997.10664
35/134	978.60664	997.60664	35/140	978.60664	998.60664
35/135	978.60664	997.60664	35/110	978.60664	980.60665
35/157	978.60664	979.60664	35/111	978.60664	981.60665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
35/109	978.60664	979.60664	37/113	983.60664	985.60664
37/157	978.60664	992.60665	2/116	984.10664	988.10665
37/156	979.10664	992.60665	2/117	984.10664	989.10664
1/136	980.10664		2/114	984.60665	986.60664
1/152	980.10664		2/115	984.60665	987.10664
1/74	980.60665	992.60665	2/118	984.60665	990.10664
3/74	980.60665	992.60665	2/119	984.60665	991.10664
30/74	980.60665	988.60665	3/135	984.60665	985.60664
35/74	980.60665	992.60665	37/151	984.60665	
37/155	980.60665	996.10665	2/113	985.10665	985.60664
37/154	980.60665	995.60664	2/120	985.10665	991.60665
37/117	981.10665	989.10664	1/138	985.60664	
37/118	981.10665	990.10664	2/121	985.60664	993.60664
37/119	981.10665	991.10664	2/122	985.60664	994.60664
37/120	981.10665	991.60665	37/150	985.60664	
37/153	981.10665	997.10664	37/149	986.10664	
37/116	981.60665	988.10665	37/148	986.60664	
37/122	981.60665	994.60664	37/147	987.10664	
37/121	982.10664	993.60664	2/157	988.10665	992.60665
1/137	982.60664		2/156	988.10665	992.60665
37/115	982.60664	987.10664	37/146	988.60665	
31/145	983.10664	990.60664	2/155	989.10664	996.10665
37/114	983.10664	986.60664	2/154	989.10664	995.60665

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Continued

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
2/153	989.60664	997.10664	29/213	944.60664	
1/139	990.10664		29/214	944.60664	
37/145	990.10664		30/211	944.60664	
29/209	990.60664	993.60664	30/212	944.60664	
30/209	990.60664		30/213	944.60664	
35/209	990.60664		30/214	944.60664	
37/144	991.60665		35/211	944.60664	
2/151	992.10665		35/212	944.60664	
2/150	993.10664		35/213	944.60664	
37/137	993.10664		35/214	944.60664	
37/143	993.10664		1/142	995.10664	
2/149	993.60664		1/140	995.10664	
37/138	993.60664		2/133	995.10664	998.10664
37/141	993.60664		2/134	995.10664	998.60664
37/142	993.60664		2/137	995.10664	
1/141	994.10664		2/146	995.10664	
1/148	994.10664		29/210	995.10664	997.10664
37/139	994.10664		30/210	995.10664	
1/209	944.60664		35/210	995.10664	
2/135	944.60664		37/140	995.10664	
2/147	944.60664		2/136	995.60665	
29/211	944.60664	997.60664	2/152	995.60665	
29/212	944.60664	999.10665	1/143	996.10665	

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE I.- SIGHTING COMBINATIONS AVAILABLE FOR MISSION E NAVIGATION - Concluded

Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch		Star/horizon or star/landmark combination (a)	Interval when both objects are visible, minutes from launch	
	Acquisition	Loss		Acquisition	Loss
2/138	996.10665		32/210	998.60664	
2/145	996.10665		32/211	998.60664	
37/136	996.10665		32/212	998.60664	
37/152	996.10665		32/213	998.60664	
37/144	996.10665		32/214	998.60664	
2/144	997.10664		1/210	999.10665	
4/NH	997.10664				
37/135	997.10664				
2/139	997.60664				
2/143	998.10664				
2/142	998.60664				
32/NH	998.60664				
32/138	998.60664				
32/147	998.60664	999.10665			
32/146	998.60664				
32/145	998.60664				
32/139	998.60664				
32/144	998.60664				
32/141	998.60664				
32/143	998.60664				
32/142	998.60664				
32/140	998.60664				
32/209	998.60664				

[a]The star locations are given in reference 7, and the landmark locations in reference 8.

TABLE II.- MISSION E PRELIMINARY NAVIGATION SIGHTING SCHEDULE

Complete sighting interval, hr:min from launch		Apollo star number (a)	Object sighted (b)	Interval when both star and object are visible, hr:min from launch	
Start	End			Acquisition	Loss
Third apogee pass					
9:45	9:55	23	Near horizon	9:47.6	10:21.3
9:55	10:05	23	L 232	9:53.6	10:01.8
		25	L 232	9:53.6	10:06.8
10:05	10:15	26	L 221	10:03.1	10:12.6
		35	L 221	10:03.8	10:18.1
10:15	10:25	31	Near horizon	10:14.4	11:37.6
10:25	10:35	29	Near horizon	10:22.8	11:31.9
10:35	10:45	30	L 248	10:34.6	10:50.6
		33	L 248	10:36.1	10:45.6
10:45	10:55	30	L 264	10:40.6	11:15.1
		35	L 264	10:40.6	11:05.1
Fourth apogee pass					
12:35	12:45	27	Near horizon	12:36.6	13:31.1
12:45	12:55	23	Near horizon	12:37.6	13:18.1
12:55	13:05	26	Near horizon	12:53.1	13:34.1
13:05	13:15	25	Near horizon	12:39.1	13:15.1
13:15	13:25	26	L 224	13:14.1	13:24.1
		29	L 224	13:14.1	13:40.1
13:25	13:35	30	L 140	13:24.6	13:30.6
		35	L 140	13:29.1	13:38.1
13:35	13:45	29	L 250	13:33.1	13:45.6
		35	L 250	13:33.1	13:46.1

[a]See table V.

[b]Landmarks are defined in reference 7.

TABLE III.- ALTERNATE MISSION E NAVIGATION SIGHTING SCHEDULE

Complete sighting interval, hr:min from launch		Apollo star number (a)	Object sighted (b)	Interval when both star and object are visible, hr:min from launch	
Start	End			Acquisition	Loss
Third apogee pass					
9:45	9:55	23	L 226	9:48.1	10:03.9
		25	L 226	9:49.1	10:03.9
9:55	10:05	25	Near horizon	9:49.1	10:18.9
10:05	10:15	25	L 236	10:03.3	10:10.9
		26	L 236	10:03.3	10:22.6
10:15	10:25	35	L 230	10:14.6	10:20.6
		33	L 230	10:20.6	10:45.6
10:25	10:35	27	Near horizon	10:28.1	10:41.1
10:35	10:45	33	L 108	10:37.6	10:45.6
		35	L 108	10:40.1	10:52.1
10:45	10:55	35	L 242	10:40.1	10:53.1
		37	L 242	10:50.6	11:01.6
Fourth apogee pass					
12:35	12:45	24	Near horizon	12:24.1	12:39.6
12:45	12:55	27	Near horizon	12:36.6	13:31.1
12:55	13:05	23	Near horizon	12:37.6	13:18.1
13:05	13:15	26	L 140	12:59.1	13:06.1
		29	L 140	13:12.6	13:16.6
13:15	13:25	36	L 141	13:09.6	13:21.1
		1	L 141	13:16.6	13:35.6
13:25	13:35	1	L 145	13:21.1	13:33.6
		33	L 145	13:21.1	13:33.6
13:35	13:45	30	L 224	13:24.6	13:40.6
		37	L 224	13:41.6	13:51.1

[a]See table V.

[b]Landmarks are defined in reference 7.

TABLE IV.- STAR-HORIZON NAVIGATION SIGHTINGS FOR MISSION E

Apollo star number	High apogee pass number	g.e.t. acquired, sec	g.e.t. loss sec	Total time, sec
(a) Assumed launch December 1, 1968, 1900 hours				
2	3	47 500	49 050	1550
3	3	48 460	49 580	1120
4	3	48 540	49 580	1040
5	3	47 980	48 650	670
6	3	48 220	49 580	1360
26	3	45 226	46 050	824
29	3	45 226	47 000	1774
30	3	45 810	48 110	2300
31	3	45 226	46 550	1324
32	3	45 930	48 720	2790
33	3	45 226	48 800	3574
35	3	46 870	49 480	2610
36	3	47 450	49 580	2130
37	3	45 820	49 580	3760
2	4	57 660	59 200	1540
3	4	58 620	59 736	1116
4	4	58 720	59 736	1016
5	4	58 140	58 750	610
6	4	58 380	59 736	1356

TABLE IV.- STAR-HORIZON NAVIGATION SIGHTINGS FOR MISSION E - Continued

Apollo star number	High apogee pass number	g.e.t. acquired, sec	g.e.t. loss sec	Total time, sec
(a) Assumed launch December 1, 1968, 1900 hours - Concluded				
26	4	55 383	56 200	817
29	4	55 383	57 080	1697
30	4	55 940	58 280	2340
31	4	55 385	56 710	1325
32	4	55 000	58 870	3870
33	4	55 383	58 900	3517
35	4	57 000	59 600	2600
36	4	57 600	59 736	2136
37	4	55 970	59 736	3766
(b) Assumed launch January 1, 1969, 1900 hours				
1	3	48 050	49 580	1530
2	3	45 820	49 580	3760
3	3	47 620	49 580	1960
4	3	48 700	49 580	880
6	3	47 100	49 580	2480
8	3	48 940	49 580	640
12	3	48 960	49 580	620
29	3	45 226	45 830	604

TABLE IV.- STAR-HORIZON NAVIGATION SIGHTINGS FOR MISSION E - Continued

Apollo star number	High apogee pass number	g.e.t. acquired, sec	g.e.t. loss, sec	Total time, sec
(b) Assumed launch January 1, 1969, 1900 hours - Concluded				
30	3	45 226	46 880	1654
32	3	45 226	47 000	1774
35	3	45 790	48 230	2440
36	3	45 850	48 600	2750
37	3	45 226	49 070	3844
1	4	58 170	59 736	1566
2	4	55 980	59 736	3756
3	4	57 780	59 736	1956
4	4	58 760	59 736	976
6	4	57 270	59 736	2466
8	4	59 100	59 736	636
12	4	59 120	59 736	616
29	4	55 383	55 990	607
30	4	55 383	56 960	1577
32	4	55 383	57 100	1717
35	4	55 950	58 380	2430
36	4	56 000	58 770	2770
37	4	55 383	59 250	3867

TABLE IV.- STAR-HORIZON NAVIGATION SIGHTINGS FOR MISSION E - Continued

Apollo star number	High apogee pass number	g.e.t. acquired, sec	g.e.t. loss, sec	Total time, sec
(c) Assumed launch February 1, 1969, 1900 hours				
1	3	45 550	47 710	2160
2	3	45 226	46 920	1694
3	3	45 460	48 560	3100
5	3	46 300	48 570	2270
6	3	45 226	47 500	2274
7	3	46 350	49 580	3230
8	3	47 080	49 580	2500
9	3	48 570	49 580	1010
10	3	46 780	49 580	2800
11	3	48 150	49 580	1430
12	3	47 990	49 580	1590
13	3	47 620	48 850	1230
15	3	48 080	49 580	1500
16	3	48 340	49 580	1240
17	3	48 700	49 350	650
18	3	48 940	49 580	640
19	3	48 940	49 580	640
35	3	45 226	46 000	774
1	3	55 700	57 840	2140

TABLE IV.- STAR-HORIZON NAVIGATION SIGHTINGS FOR MISSION E - Continued

Apollo star number	High apogee pass number	g.e.t. acquired, sec	g.e.t. loss, sec	Total time, sec
(c) Assumed launch February 1, 1969, 1900 hours - Concluded				
2	4	55 383	57 150	1767
3	4	55 620	58 700	3080
5	4	56 460	58 690	2230
6	4	55 383	57 670	2287
7	4	56 480	59 736	3256
8	4	57 220	59 736	2516
9	4	58 700	59 736	1036
10	4	56 940	59 736	2796
11	4	58 250	59 736	1486
12	4	58 250	59 736	1486
13	4	57 780	58 990	1210
15	4	58 250	59 736	1486
16	4	58 500	59 736	1236
17	4	58 860	59 490	630
18	4	59 100	59 736	636
19	4	59 100	59 736	636
35	4	55 383	56 150	767
(d) Assumed launch March 1, 1969, 1900 hours				
1	3	45 226	46 390	1164
3	3	45 226	47 580	2354

TABLE IV.- STAR-HORIZON NAVIGATION SIGHTINGS FOR MISSION E - Continued

Apollo star number	High apogee pass number	g.e.t. acquired, sec	g.e.t. loss, sec	Total time, sec
(d) Assumed launch March 1, 1969, 1900 hours - Continued				
5	3	45 940	48 480	2540
7	3	45 300	47 940	2640
8	3	46 090	48 720	2630
9	3	46 770	49 480	2710
10	3	45 820	49 580	3760
11	3	47 140	49 580	2440
12	3	48 680	49 580	900
13	3	46 780	49 580	2800
15	3	47 480	49 580	2100
16	3	47 500	49 580	2080
19	3	48 820	49 430	610
20	3	48 820	49 580	760
22	3	48 820	49 580	760
23	3	47 980	49 580	1600
25	3	48 700	49 580	880
1	4	55 383	56 580	1197
3	4	55 383	57 680	2297
5	4	56 100	58 630	2530
7	4	55 490	58 100	2610

TABLE IV.- STAR-HORIZON NAVIGATION SIGHTINGS FOR MISSION E - Concluded

Apollo star number	High apogee pass number	g.e.t. acquired, sec	g.e.t. loss, sec	Total time, sec
(d) Assumed launch March 1, 1969, 1900 hours - Concluded				
8	4	56 220	58 870	2650
9	4	56 930	59 640	2710
10	4	55 980	59 736	3756
11	4	57 300	59 736	2436
12	4	58 760	59 736	976
13	4	56 940	59 736	2796
15	4	57 570	59 736	2166
16	4	57 660	59 736	2076
19	4	58 980	59 590	610
20	4	58 980	59 736	756
22	4	58 980	59 736	756
23	4	58 140	59 736	1596
25	4	59 000	59 736	736

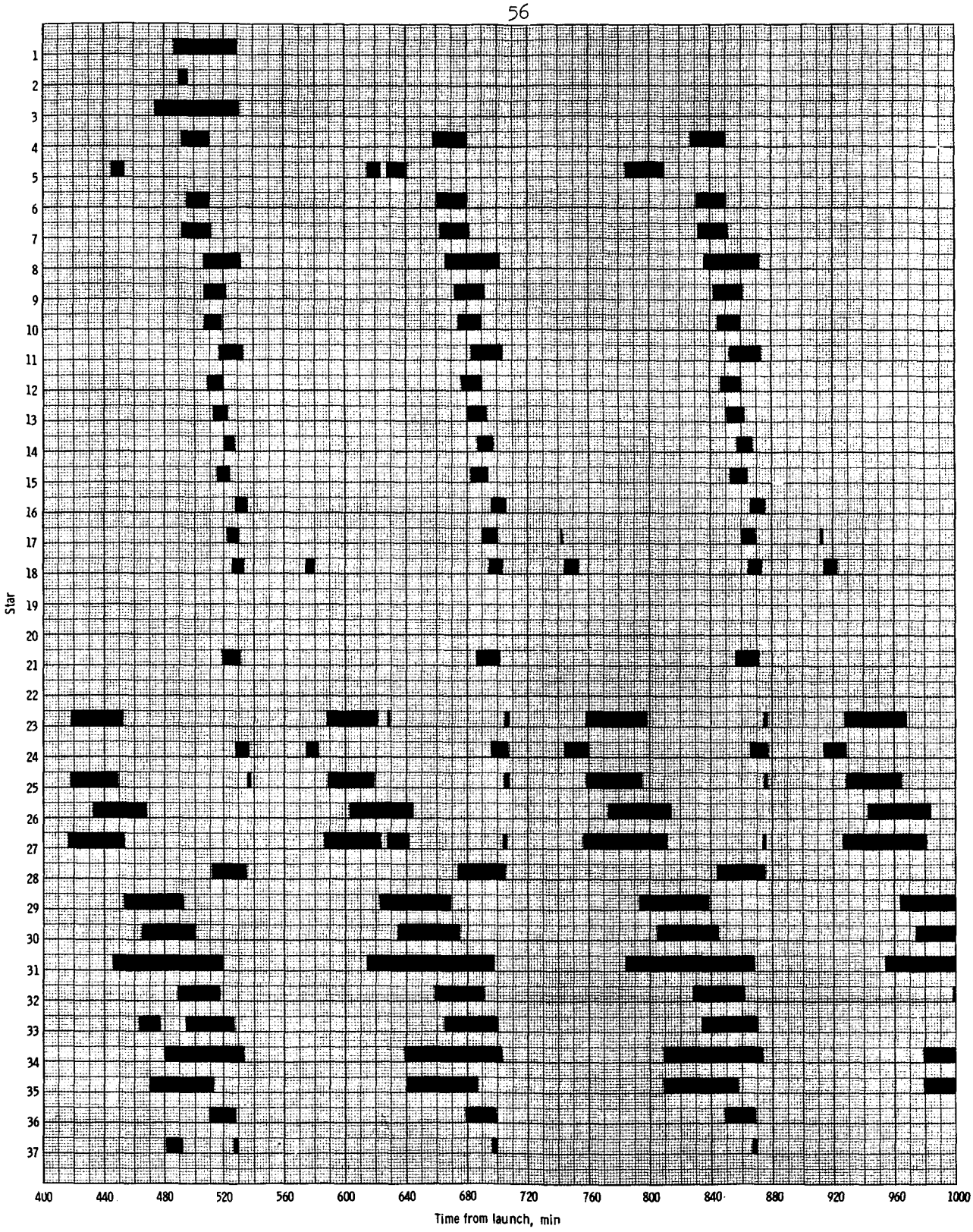
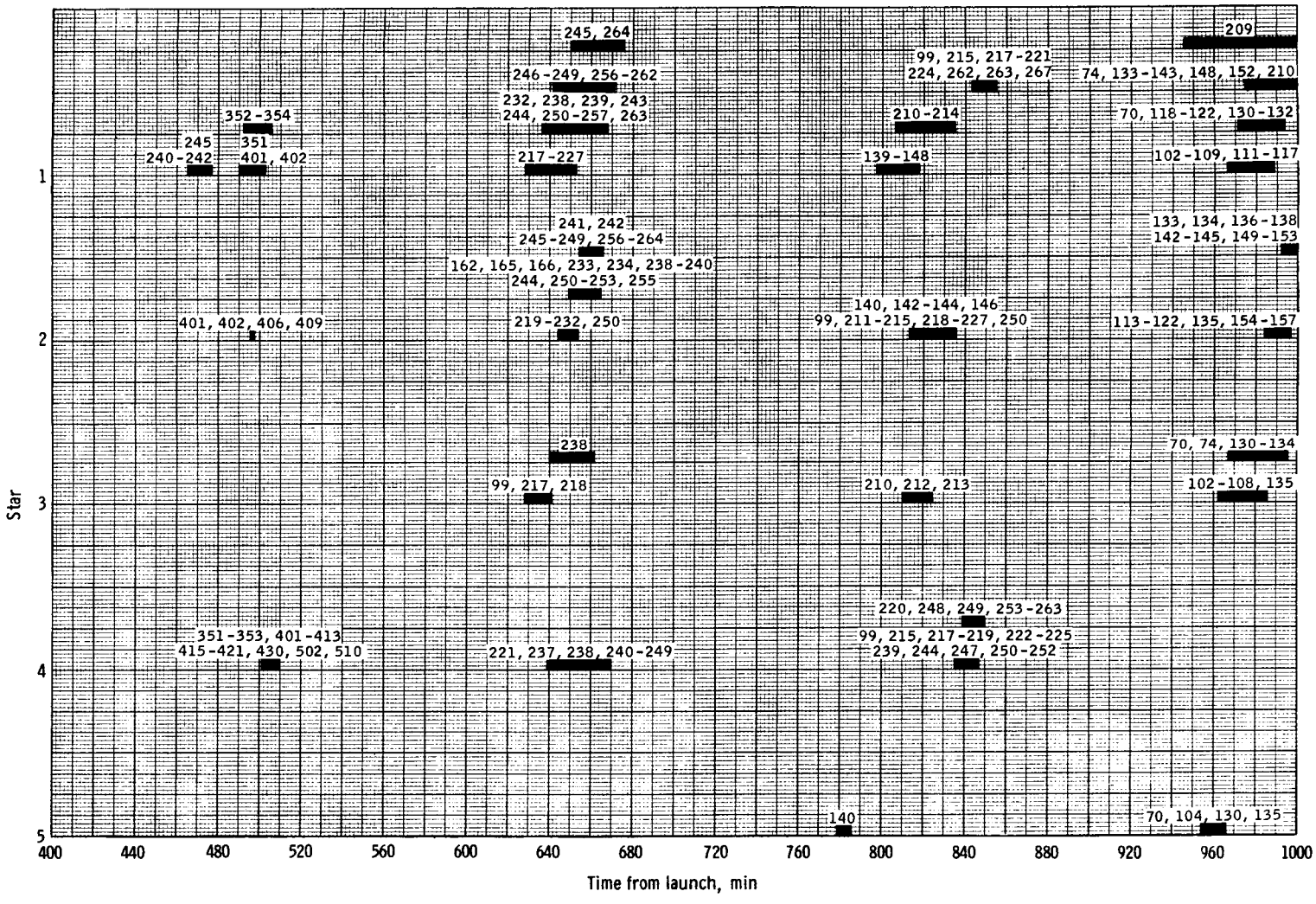
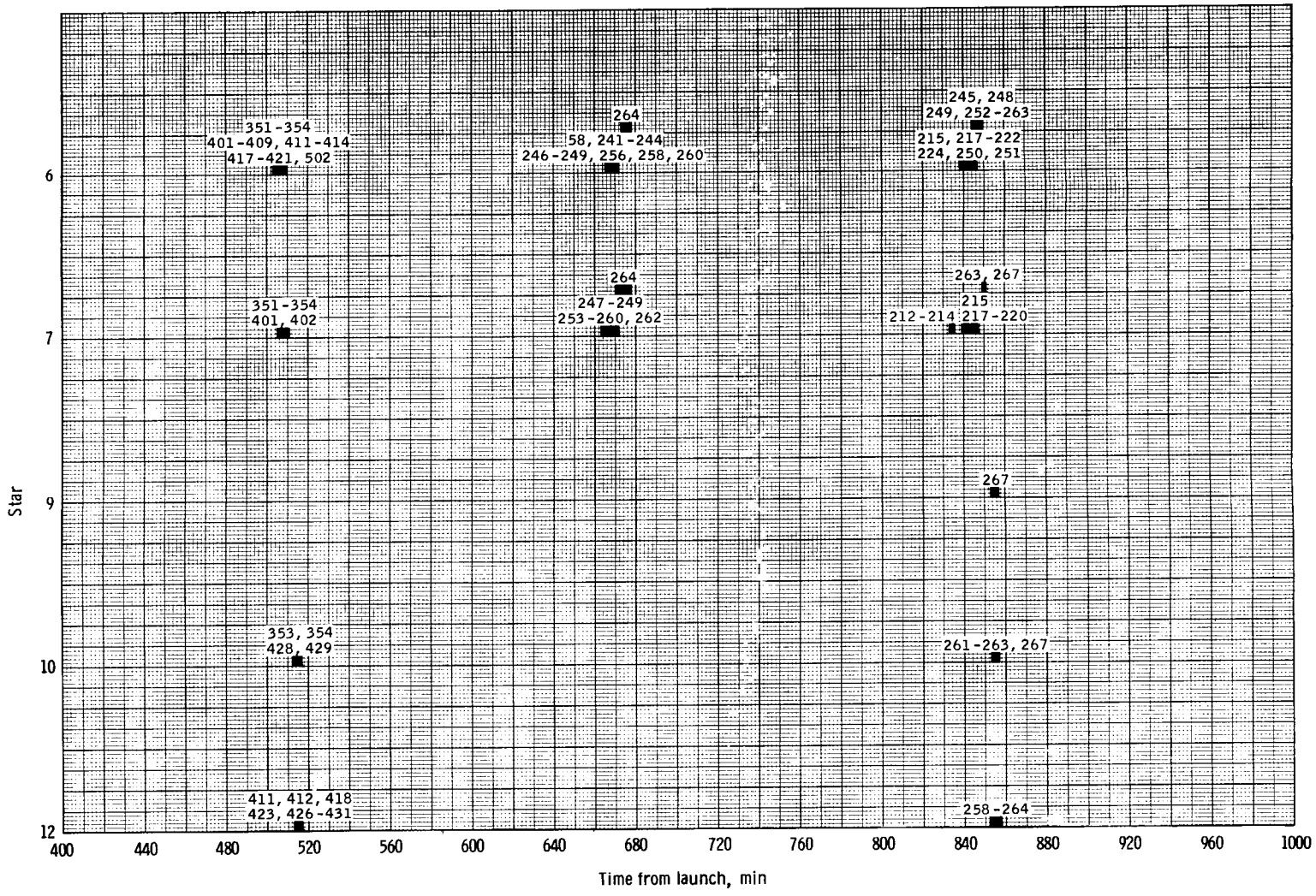


Figure 1. - Available star/horizon combinations.



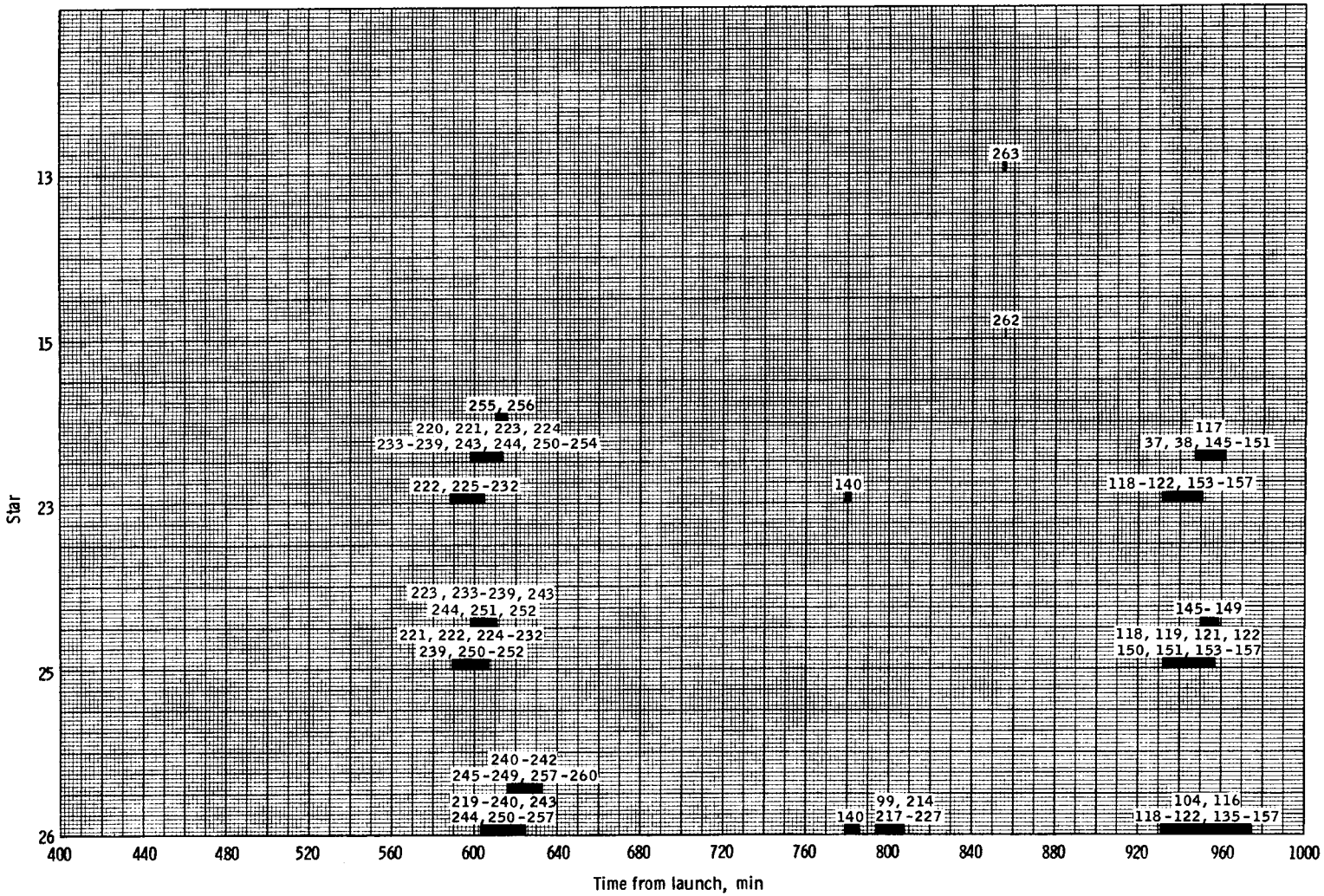
(a) Star 1-5.

Figure 2. - Available star/landmark combinations.



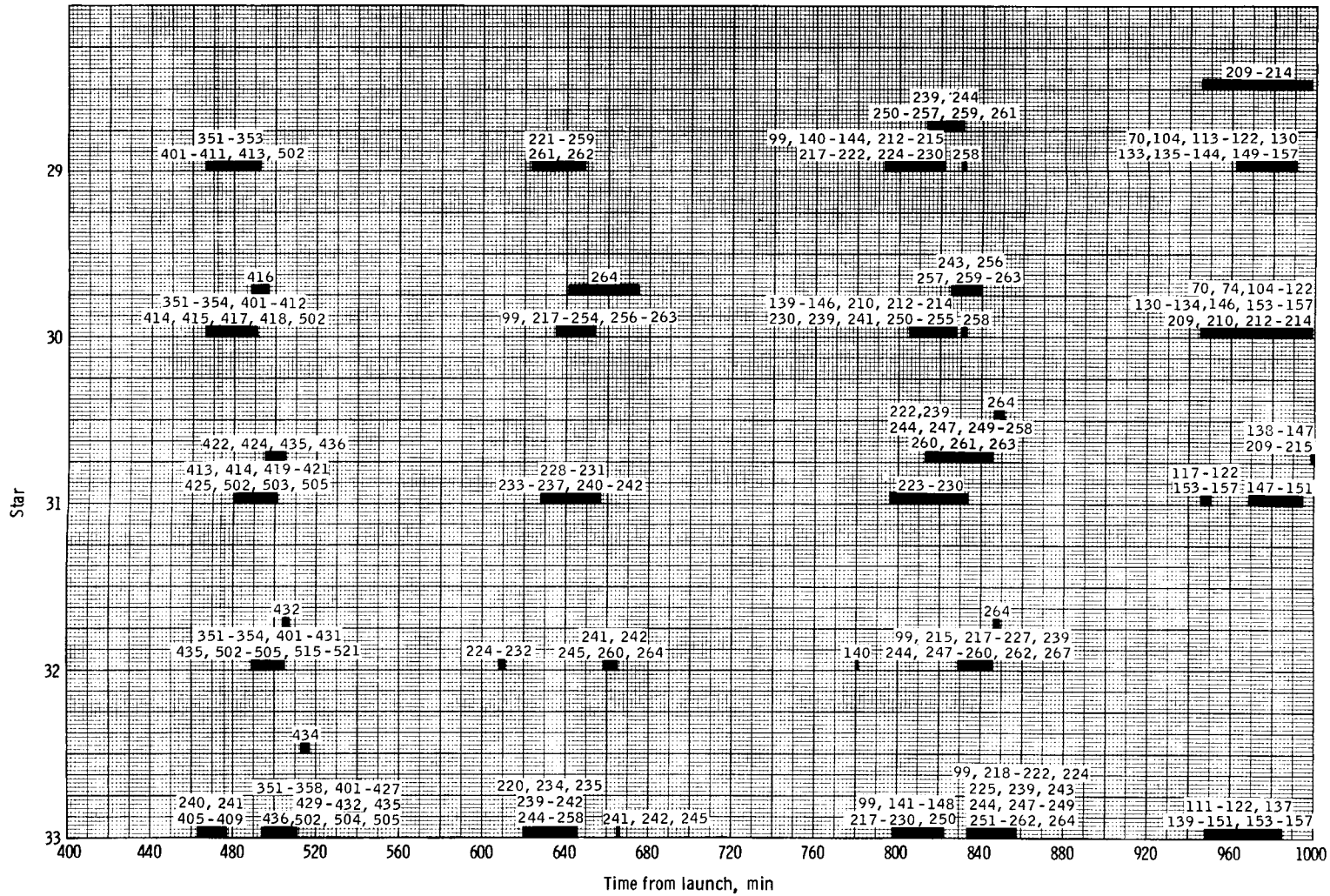
(b) Stars 6, 7, 9, 10 and 12.

Figure 2. - Continued.



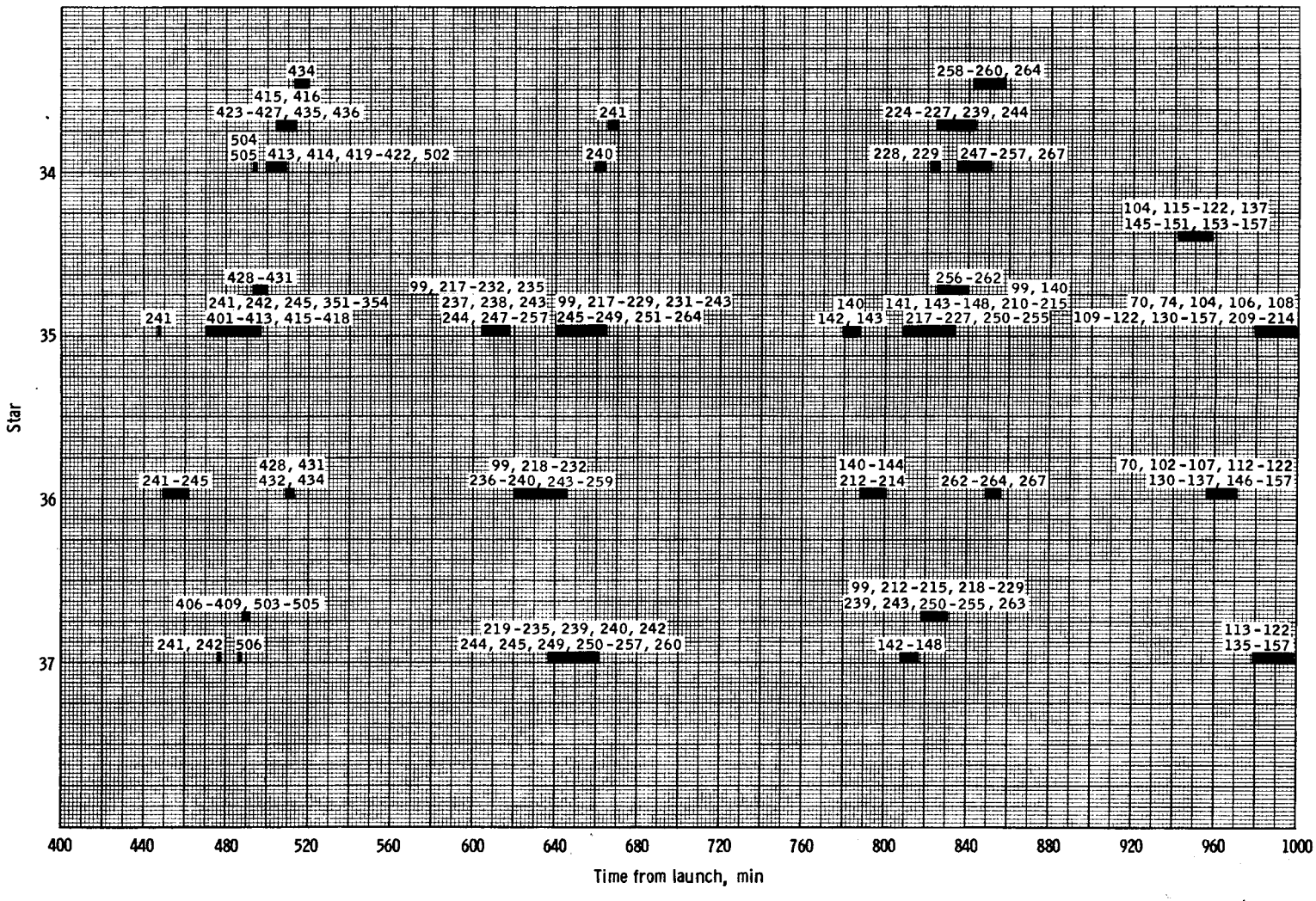
(c) Stars 13, 15, 23, 25 and 26.

Figure 2.- Continued.



(d) Stars 29 - 33.

Figure 2. - Continued.



(e) Stars 34 - 37.

Figure 2. - Concluded.

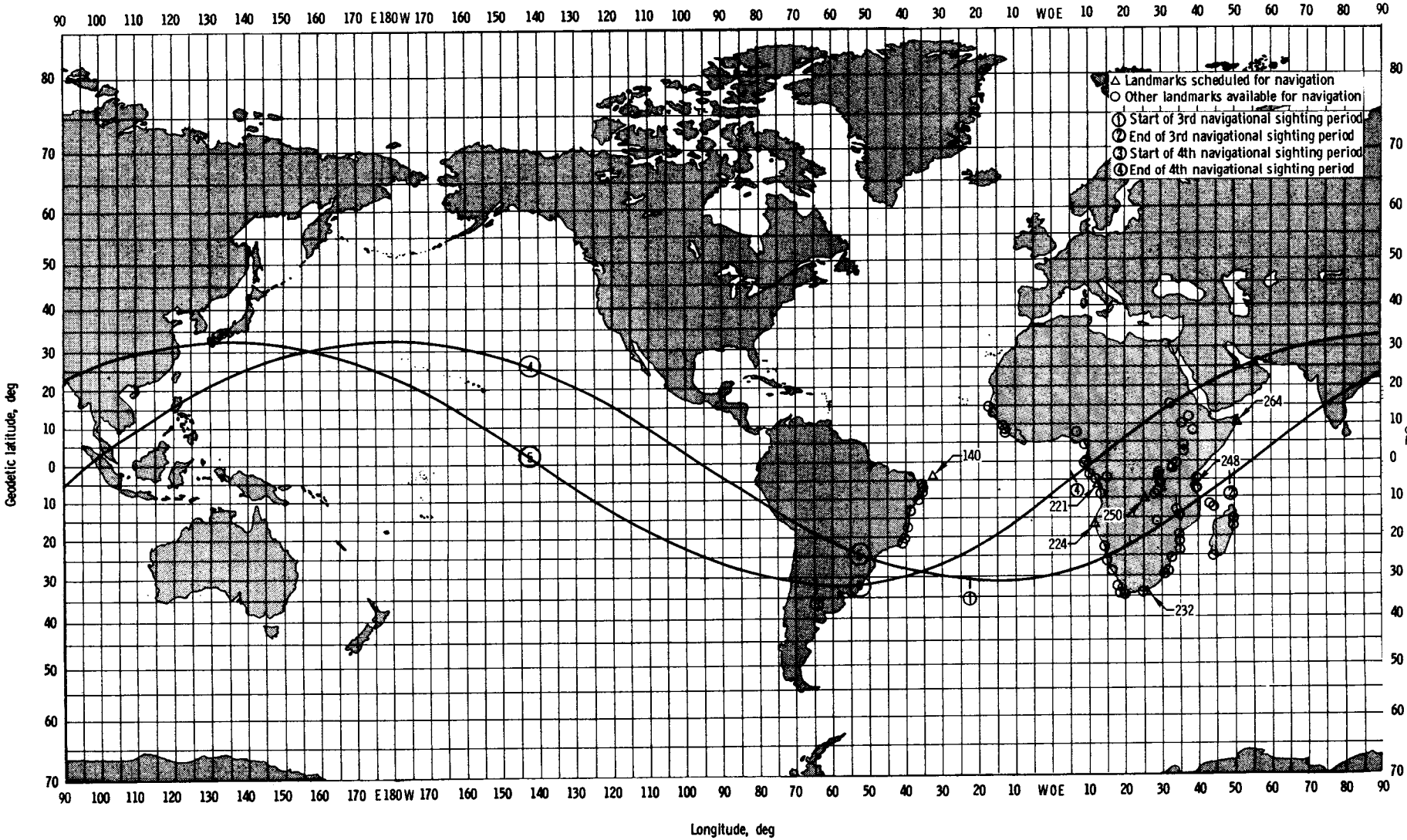


Figure 3. - Available landmarks for Mission E P23 navigation.

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