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PARAMETRIC STUDY FOR DETERMINING THE LAUNCH AZIMUTH AND TWO INJECTION OPPORTUNITIES FOR THE AS-503A OPERATIONAL TRAJECTORY

By Viet Hanssen
Mission Analysis Branch

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PROJECT APOLLO

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FIGURES

Figure		Page
1	Major mission events from lift-off to second SPS burn	6
2	Ground elapsed time of S-IVB ignition as a function of launch azimuth	7
3	Ground track of SPS burn occurring in second, third or fourth revolution with various longitudes of initial perigee	
	(a) Launch azimuth = 70°; altitude of perigee = 150 nautical miles	8
	(b) Launch azimuth = 72°; altitude of perigee = 150 nautical miles	9
	(c) Launch azimuth = 74°; altitude of perigee = 150 nautical miles	10
	(d) Launch azimuth = 80°; altitude of perigee = 150 nautical miles	11
	(e) Launch azimuth = 85°; altitude of perigee = 150 nautical miles	12
4	SPS burn tracking by Guam using various launch azimuths and a perigee altitude of 150 nautical miles	
	(a) Launch azimuth 70°	13
	(b) Launch azimuth 72°	14
	(c) Launch azimuth 74°	15
	(d) Launch azimuth 80°	16
	(e) Launch azimuth 85°	17
5	Total tracking time by Guam as a function of launch azimuths for two injection opportunities and two longitudes of initial perigee	18
6	Guam tracking from SPS cutoff as a function of launch azimuth for two injection opportunities and two longitudes of initial perigee	19
7	Time of Guam LOS after LOI cutoff for different longitudes of initial perigee	
	(a) 72° launch azimuth	20
	(b) 85° launch azimuth	21

Figure | Page

8 Guam tracking at various longitudes of initial perigee and different perigee altitudes

(a) 72° launch azimuth 22
(b) 85° launch azimuth 23

9 Ship tracking time prior to Guam AOS for different ship positions

(a) 72° launch azimuth; 60° longitude of initial perigee 24
(b) 72° launch azimuth; 65° longitude of initial perigee 25
(c) 85° launch azimuth; 60° longitude of initial perigee 26
(d) 85° launch azimuth; 65° longitude of initial perigee 27

10 LOI burn coverage using optimum ship location and Guam 28

PARAMETRIC STUDY FOR DETERMINING THE LAUNCH AZIMUTH AND TWO INJECTION OPPORTUNITIES FOR THE AS-503A OPERATIONAL TRAJECTORY

By Veit Hanssen

SUMMARY

The operational trajectory for the AS-503A earth-orbital mission requires continuous tracking for a translunar injection (TLI) simulated by the second S-IVB burn and a lunar orbit insertion (LOI) simulated by the second SPS burn. These tracking requirements have to be satisfied for two injection opportunities into a 103- by 3950-n. mi. ellipse followed by the two insertion opportunities into a 150- by 200-n. mi. CSM/LM orbit.

A parametric study was made to select the optimum launch azimuth that would satisfy the LOI tracking requirements for two injection opportunities for the AS-503A mission.

The results of the study showed that optimum tracking was obtained for the LOI burn on trajectories for which the launch azimuths were 72° and 84° and the perigee altitudes were 150 n. mi. The two injection opportunities occur at the beginning of the third and fourth parking-orbit revolutions for 72° launch azimuth, and at the beginning of the second and third revolutions for the 84° launch azimuth. Optimum tracking for the first opportunity is provided when the longitude of the first perigee occurs at 60° W, and for the second opportunity, at 65° W. The two injection opportunities require two targets for the S-IVB injection burn.

INTRODUCTION

The purpose of this document is to present the results of a parametric study made to select the optimum launch azimuth that would satisfy the LOI tracking requirements for two injection opportunities for the AS-503A mission.

As stated in the AS-503A mission requirements, the primary purposes of this mission are to demonstrate the capabilities of the launch vehicle, spacecraft, crew, and ground support facilities to perform the lunar orbital rendezvous (LOR) mission operations while following a lunar landing mission (LLM) timeline as closely as possible in earth orbit. Deviations from the LLM had to be made to comply with the constraints, to enhance crew safety, or to provide more meaningful systems tests. One of the biggest deviations from the LLM was the continuous tracking required for the simulated LOI burn for two simulated TLI opportunities.

Since cross-product steering instead of the planned iterative guidance mode was used to simulate the S-IVB TLI maneuver, no injection tracking data are presented. However, the preliminary MSC data indicate that there would be sufficient tracking prior to, during, and after the TLI maneuver for both launch azimuths and for both injection opportunities.

A brief description of the mission is as follows: The earth parking orbit (EPO) insertion of the CSM/S-IVB configuration will be into a near-circular orbit of 103-n. mi. altitude. Following the EPO coast phase a 156-second, S-IVB burn will raise the apogee altitude to 3950 n. mi. Since the scheduled activities for the high-apogee orbits exceed the time interval between the translunar injection and the second perigee point near Hawaii, it was decided to go to four high-apogee ellipses and select Guam as a location for the LOI maneuver. After the four high-apogee orbits, the 8-minute SPS burn simulating the LOI will decrease the apogee to approximately a 200-n. mi. altitude. Because both the TLI and LOI burns occur near perigee, the latitude and longitude of the LOI burn depends on the initial perigee longitude, the number of revolutions between the two maneuvers, and the launch azimuth. Since it is desirable to have continuous tracking from 2 minutes prior to 2 minutes after the burn for both maneuvers, the selection of burn locations is therefore rather limited. The translunar injection, which is the second S-IVB burn, requires high-speed tracking data which can be supplied only by Carnarvon or the Eastern Test Range (ETR). Since the northern hemisphere is more favorable from the viewpoint of tracking considerations, the TLI burn was planned to occur over the ETR. Since both burns occur near perigee, both maneuvers will occur at about the same latitude. This now leaves three locations for the lunar orbit insertion: first, 3 hours after the TLI maneuver over the ETR; secondly, after two revolutions near Hawaii; and finally, after four revolutions near Guam.

With Guam and the ETR as the location for the LOI and the TLI simulations, a second factor has to be considered. What if the TLI does not occur at the planned injection opportunity because of prolonged checkout procedures, detected systems, or crew trouble? In this

case, a second injection opportunity is required. To obtain sufficient tracking by Guam for both injection opportunities, the longitude of the first perigee point had to be optimized for each injection opportunity.

OPTIMIZATION OF PARAMETERS

To maximize tracking of the LOI for both injection opportunities the following parameters had to be optimized:

1. Launch azimuth - The launch azimuth has to be selected so that Guam is equal distance apart from the ground tracks of both injection opportunities. For range safety the launch azimuth had to be greater than 72°. To optimize this variable 70°, 72°, 80°, and 85° launch azimuths were applied. Launch azimuths between 90° and 108° would not satisfy the S-IVB TLI tracking requirements for two injection opportunities and were, therefore, not even considered.

2. The time spent in the earth parking orbit (EPO) - This parameter depends on the selected launch azimuth and is inversely proportional to it.

3. Longitude of initial perigee - The LOI will be initiated at a point in orbit which results in a minimum energy requirement for this long duration SPS burn. Since the location of perigee at SPS ignition depends on the resulting orbit of the TLI simulation, optimization of the initial perigee longitude as a result of the second S-IVB burn was necessary. The locations of the initial perigee of the high ellipse were selected at 40°, 50°, 60°, 65° and 70° W longitude.

4. Altitude of perigee after midcourse burn - A rendezvous following the LOI simulation requires a perigee altitude of approximately 130-n. mi. altitude. Therefore, a range from 100 n. mi. with no midcourse burn to 150 n. mi. after the midcourse burn is considered in this study.

DISCUSSION OF RESULTS

Figure 1 shows the major mission events from lift-off to the second SPS burn and is not drawn to any scale.

The second figure presents the orbit elapsed time of the TLI maneuver as a function of different launch azimuths. This graph shows that the first and second injection opportunities for a launch azimuth between 70° and 74° would be in the third and fourth revolution and for a launch

azimuth between 80° and 85° they would be in the second and third revolution. For a launch azimuth of 72° the 4.5-hour S-IVB EPO lifetime constraint would be violated, and for launch azimuths of 85° the allowable astronauts checkout time of 2 hours would be violated. Of prime concern for tracking optimization is the location of the LOI simulation with respect to Guam, which is covering the terminal phase of the burn. Since 2 minutes of tracking are desired after the burn, the variables have to be selected to provide (a) maximum tracking by Guam, and (b) Guam loss of station (LOS) at 2 minutes after cutoff.

Figures 3(a) through (e) present the ground tracks for both injection opportunities and various longitudes of initial perigee and illustrate the total tracking time by Guam as a function of launch azimuth. Since Guam tracking initiation and total tracking time vary only slightly for different longitudes of initial perigee, the mean values are presented on the ground tracks.

The actual tracking data are shown in figures 4(a) through (e). These bar charts show that longitudes of less than 60° W and greater than 70° W can be eliminated from further consideration. Total tracking time by Guam as a function of launch azimuth for 60° and 70° W longitude of initial perigee are presented in figure 5. The same data with respect to SPS cutoff are shown in figure 6. Since 2 minutes of Guam coverage after burnout is desired, the longitudes of the 2 minute line were transposed from figure 5 to figure 6 (dashed line). From the resulting curves the selection of launch azimuth can be made. For determination of optimum longitude of initial perigee and ship locations, a launch azimuth of 72° and 85° was chosen, although 71° and 83.5° would provide equal coverage for both injection opportunities. The selection was made for the following reasons:

(a) Range safety considerations eliminate a launch azimuth of less than 72°.

(b) The first injection opportunity, which will be used for the nominal mission, must have sufficient tracking.

(c) If the second injection opportunity provides adequate coverage, a range of variable launch azimuths can be determined.

Figures 7(a) and (b) show the time of Guam LOS as a function of longitudes of initial perigee for both injection opportunities. Since a Guam LOS at 2 minutes after SPS cutoff is desirable, the data indicates for both launch azimuths (72° and 85°) that 60° W will provide the optimum tracking for the first opportunity and that 65° W longitude of initial perigee provides the ideal coverage for the second injection opportunity.

The effect of altitude of perigee after the midcourse burn at Guam acquisition is shown in figures 8(a) and (b) for various longitudes of the initial perigee point. Ship locations were optimized in figures 9(a) through (d). The illustrations shown tracking at different longitudes and latitudes with respect to Guam. It indicates that a ship located at 23° N latitudes and 123° E longitude will provide optimum tracking for both launch azimuths (72° and 85°) and the two injection opportunities for ships positioned at different latitudes and longitudes.

Figure 10 presents the LOI coverage for 72° and 85° launch azimuth and optimized longitude of initial perigee, altitude of perigee (150 n.mi.) and ship locations. Madrid LOS occurs about 18 minutes prior to Mercury ship acquisition of signal.

CONCLUDING REMARKS

There are two ranges of launch azimuths, 69° to 72° and 82° to 85°, which provide optimum tracking of the LOI simulation for both injection opportunities for the AS-503A mission. Injection opportunities for a 72° launch azimuth would occur during third and fourth revolution. Depending on the selected launch azimuth, either the 2-hour crew constraint or the 4.5-hour S-IVB earth parking orbit constraint would be violated. For continuing mission planning purposes the 72° launch azimuth will be used.

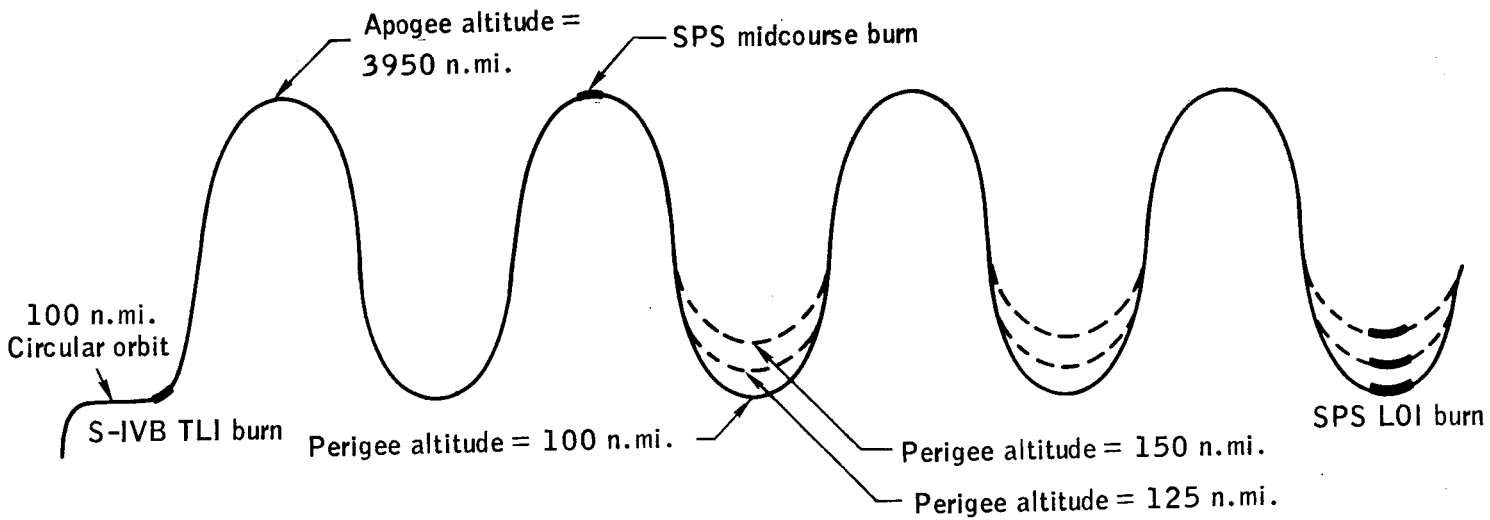


Figure 1.- Major mission events from lift-off to second SPS burn.

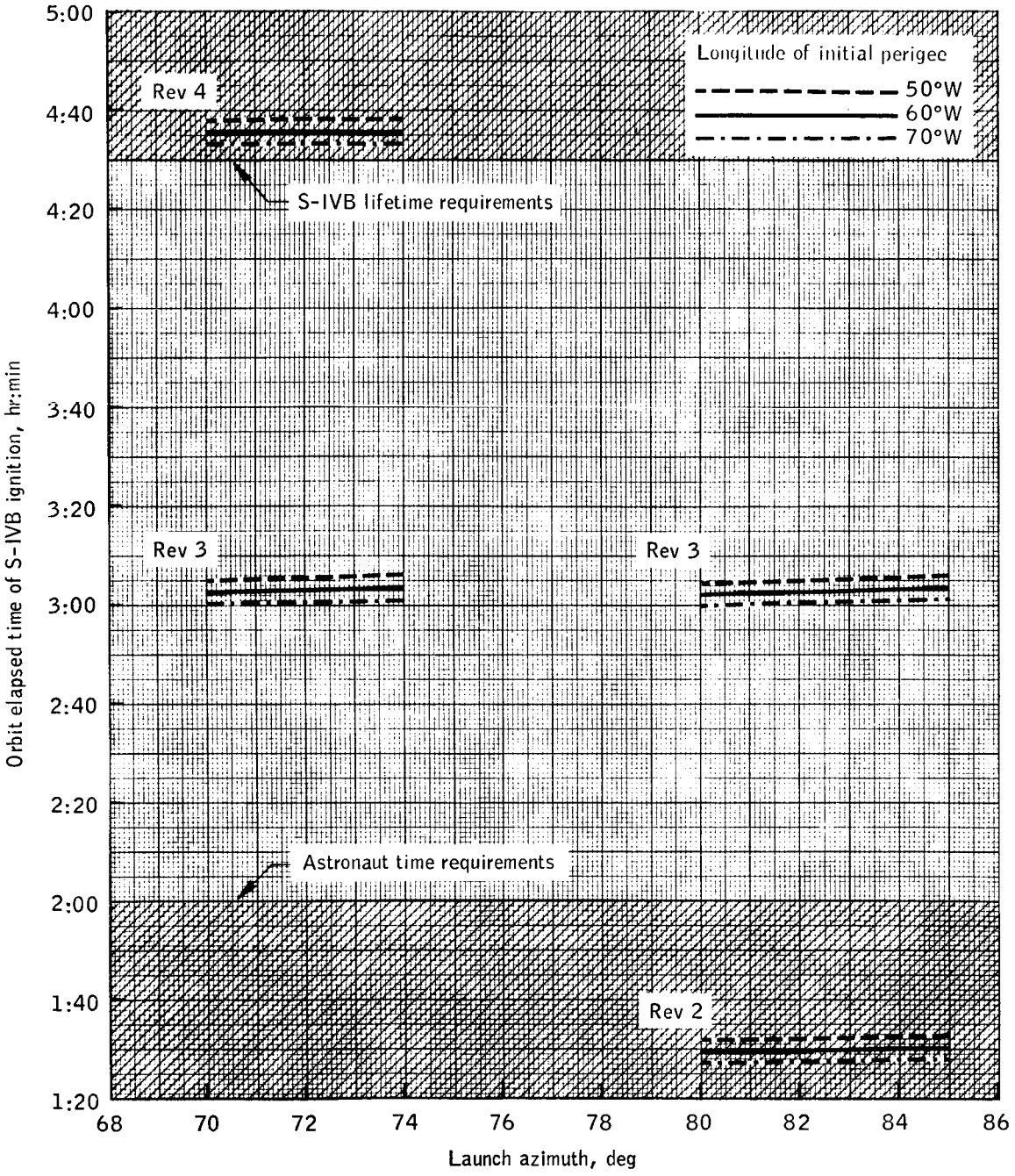
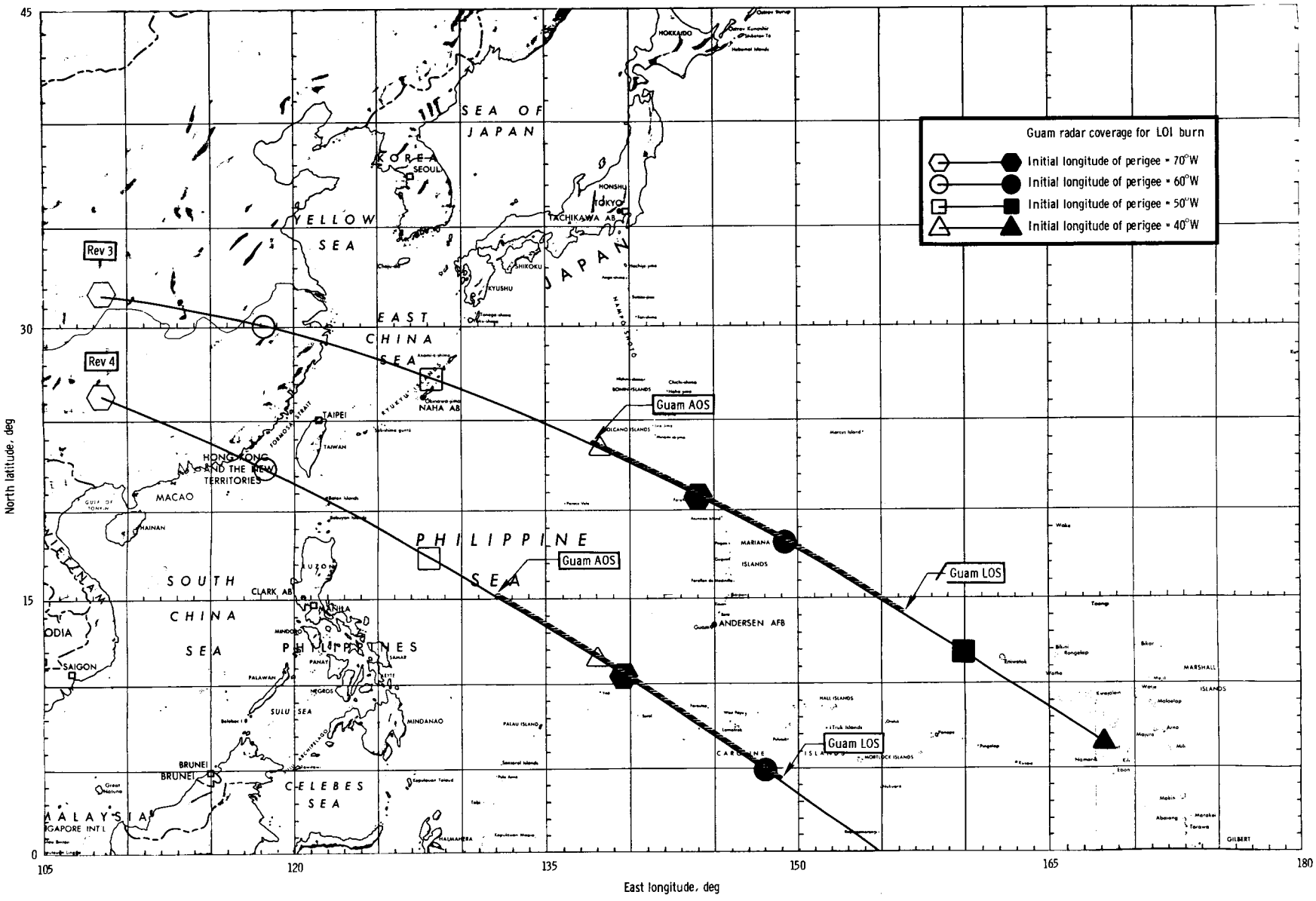
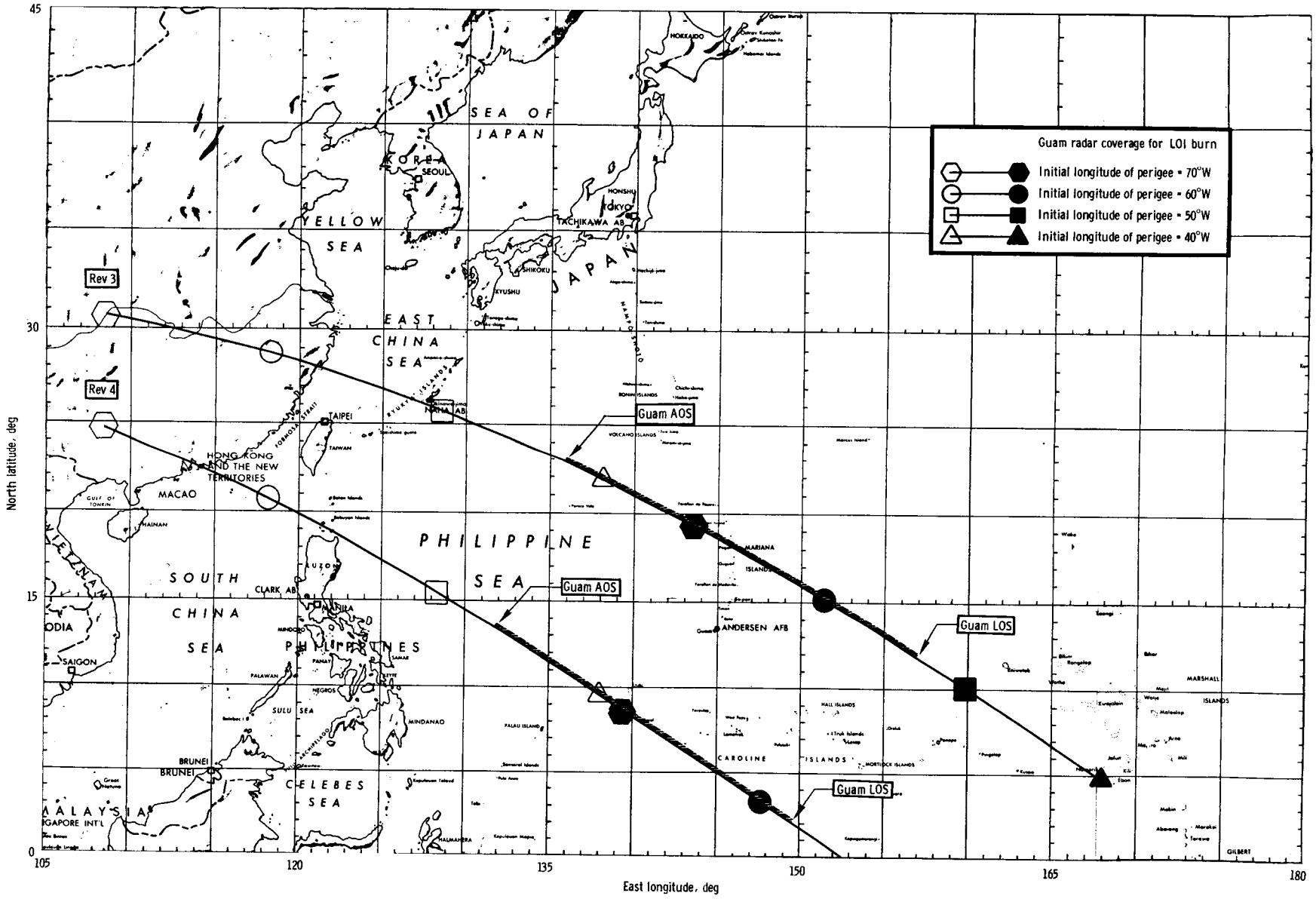


Figure 2.- Ground elapsed time of S-IVB ignition as a function of launch azimuth.



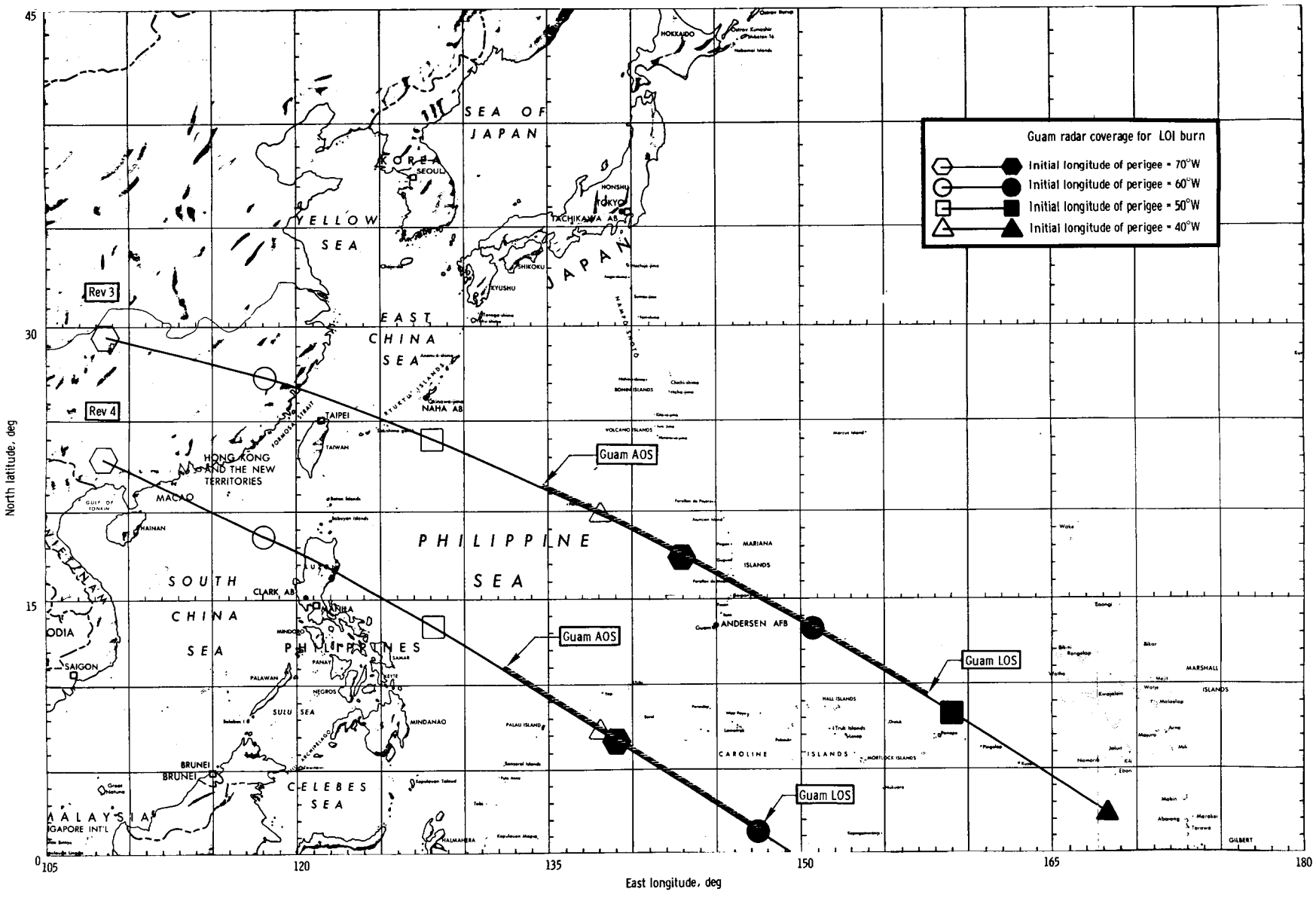
(a) Launch azimuth = 70°; altitude of perigee = 150 nautical miles.

Figure 3. - Ground track of LOI burn occurring in second, third or fourth revolution with various longitudes of initial perigee.



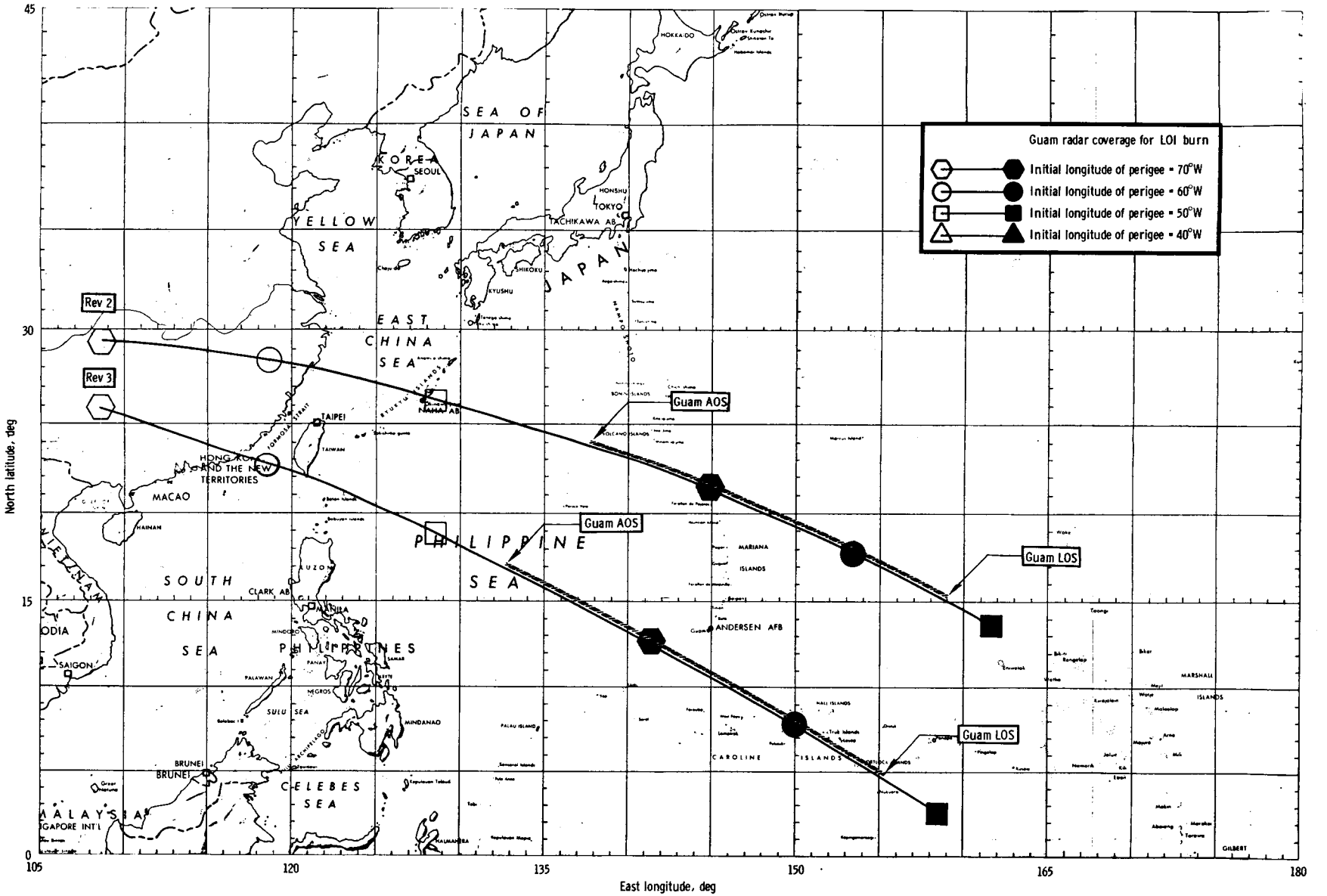
(b) Launch azimuth = 72°; altitude of perigee = 150 nautical miles.

Figure 3. - Continued.



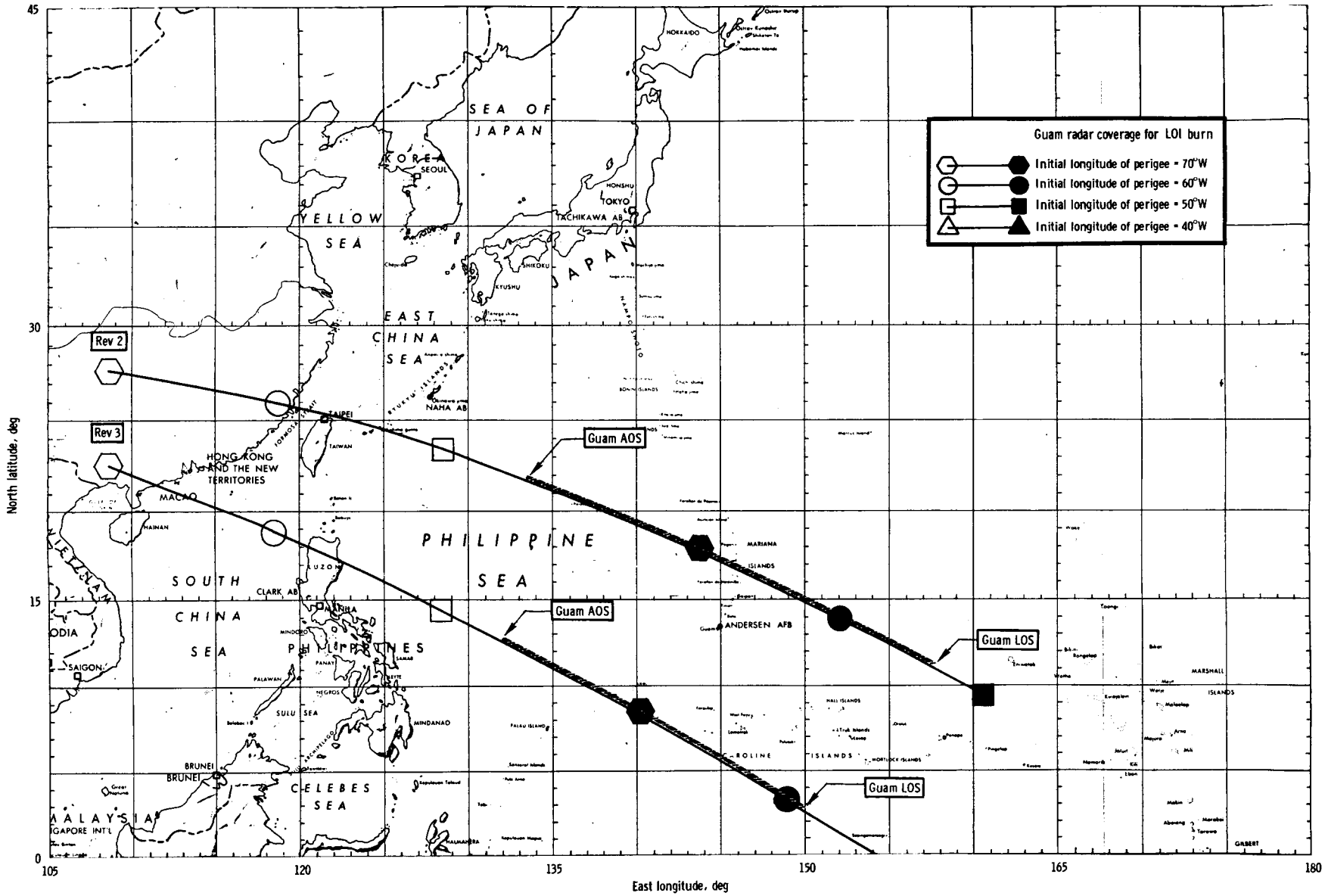
(c) Launch azimuth = 74°; altitude of perigee = 150 nautical miles.

Figure 3. - Continued.



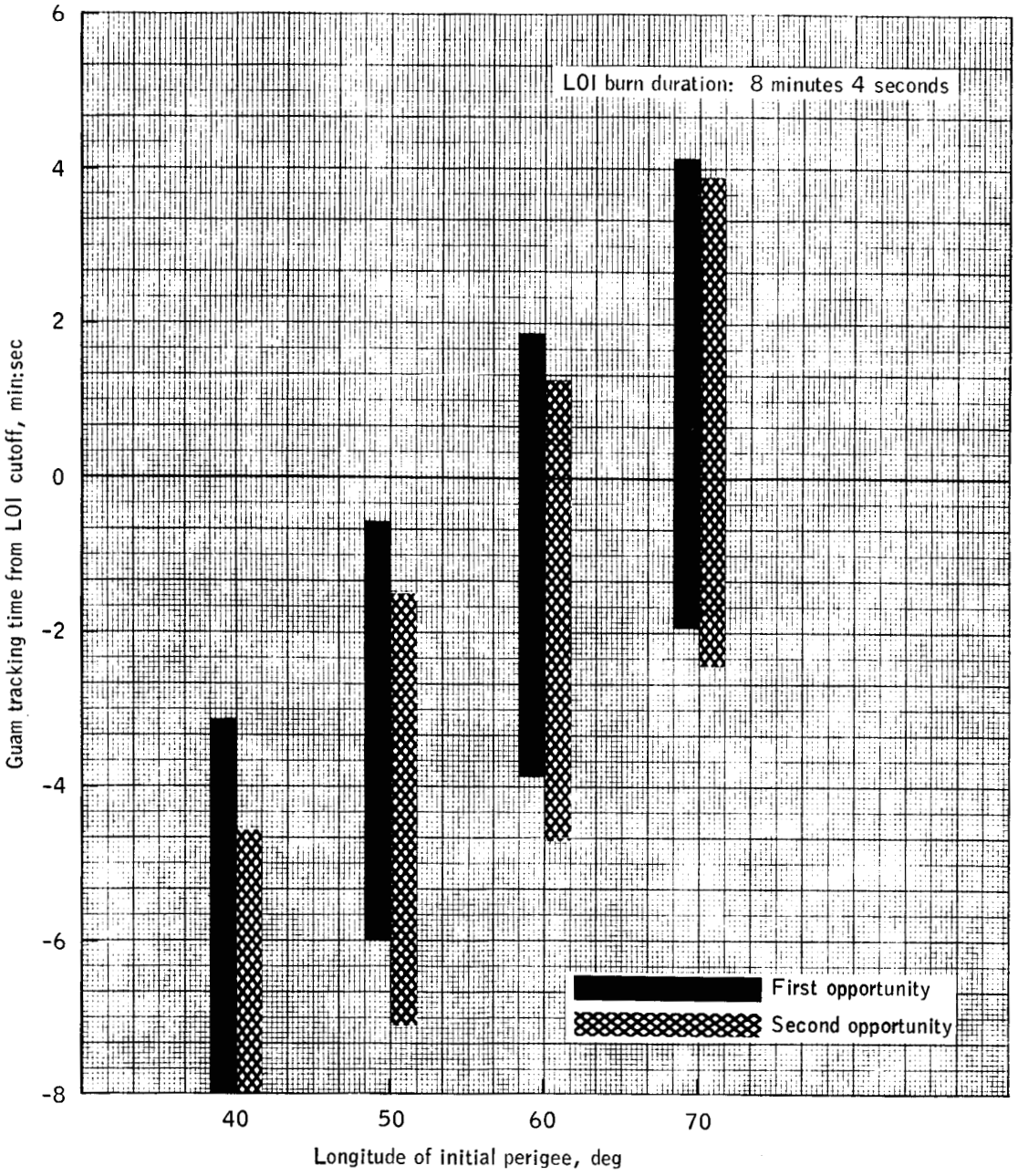
(d) Launch azimuth = 80°; altitude of perigee = 150 nautical miles.

Figure 3. - Continued.



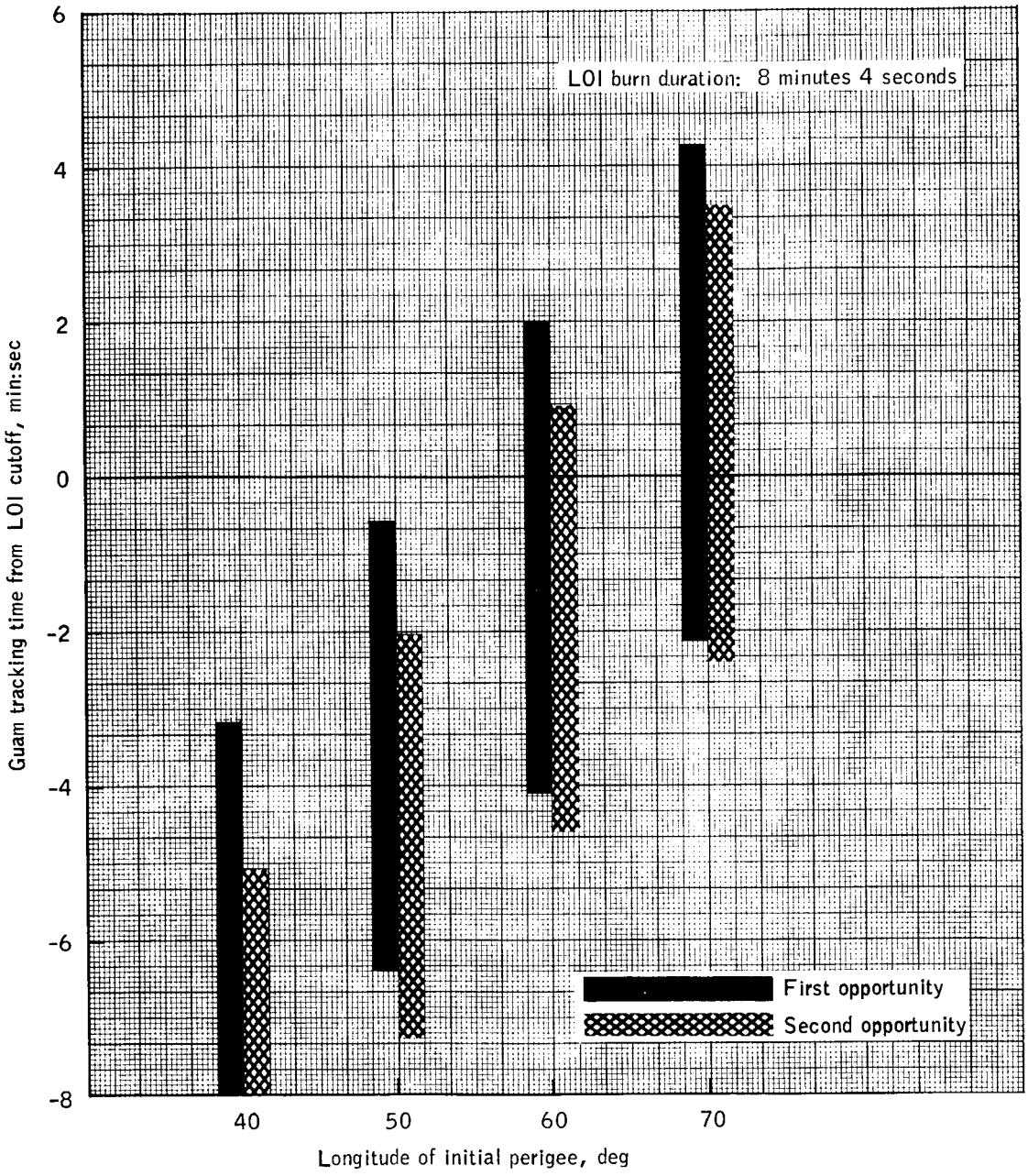
(e) Launch azimuth = 85°; altitude of perigee = 150 nautical miles.

Figure 3. - Continued.



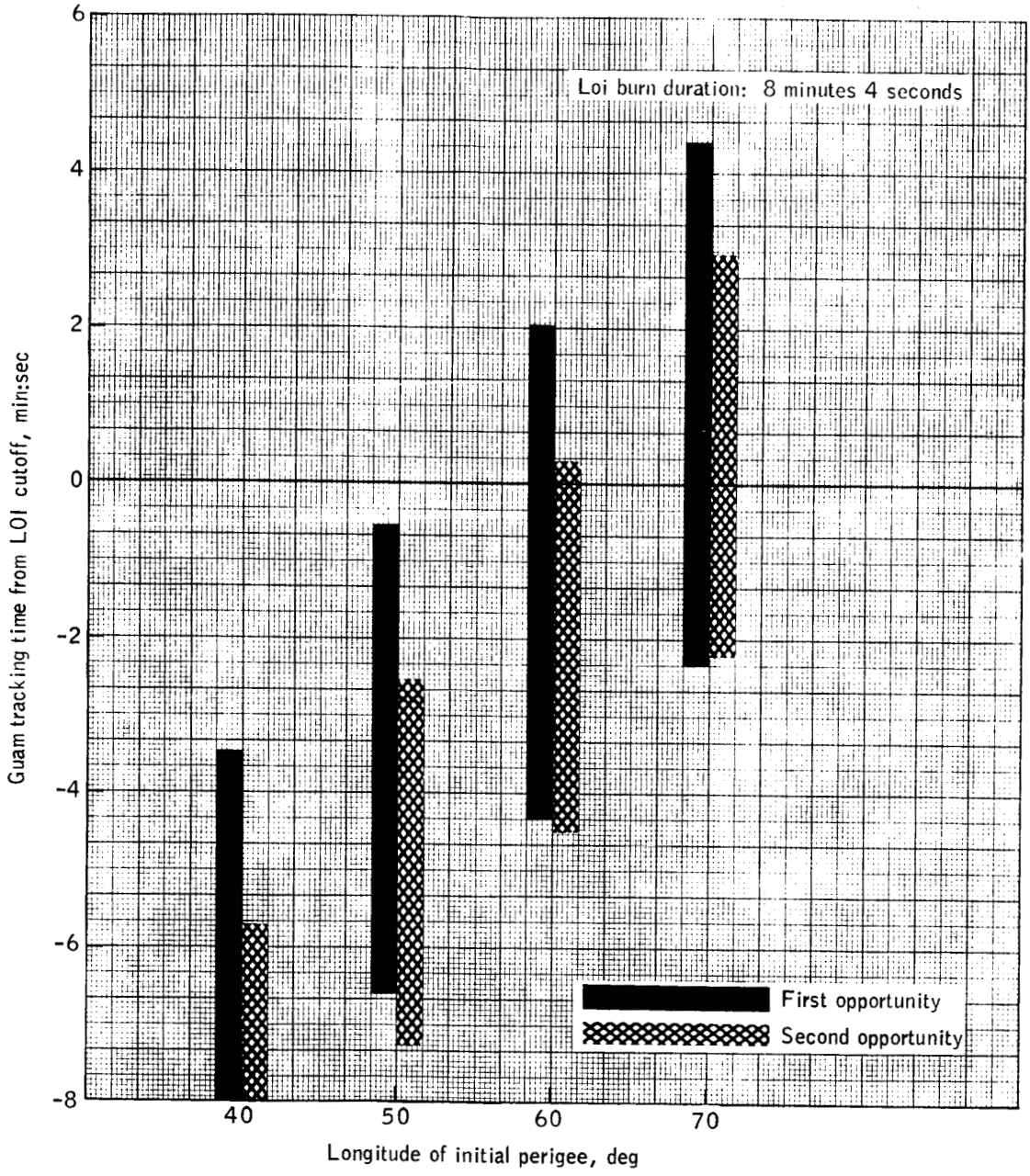
(a) Launch azimuth 70°.

Figure 4.- LOI burn tracking by Guam using various launch azimuths and a perigee altitude of 150 nautical miles.



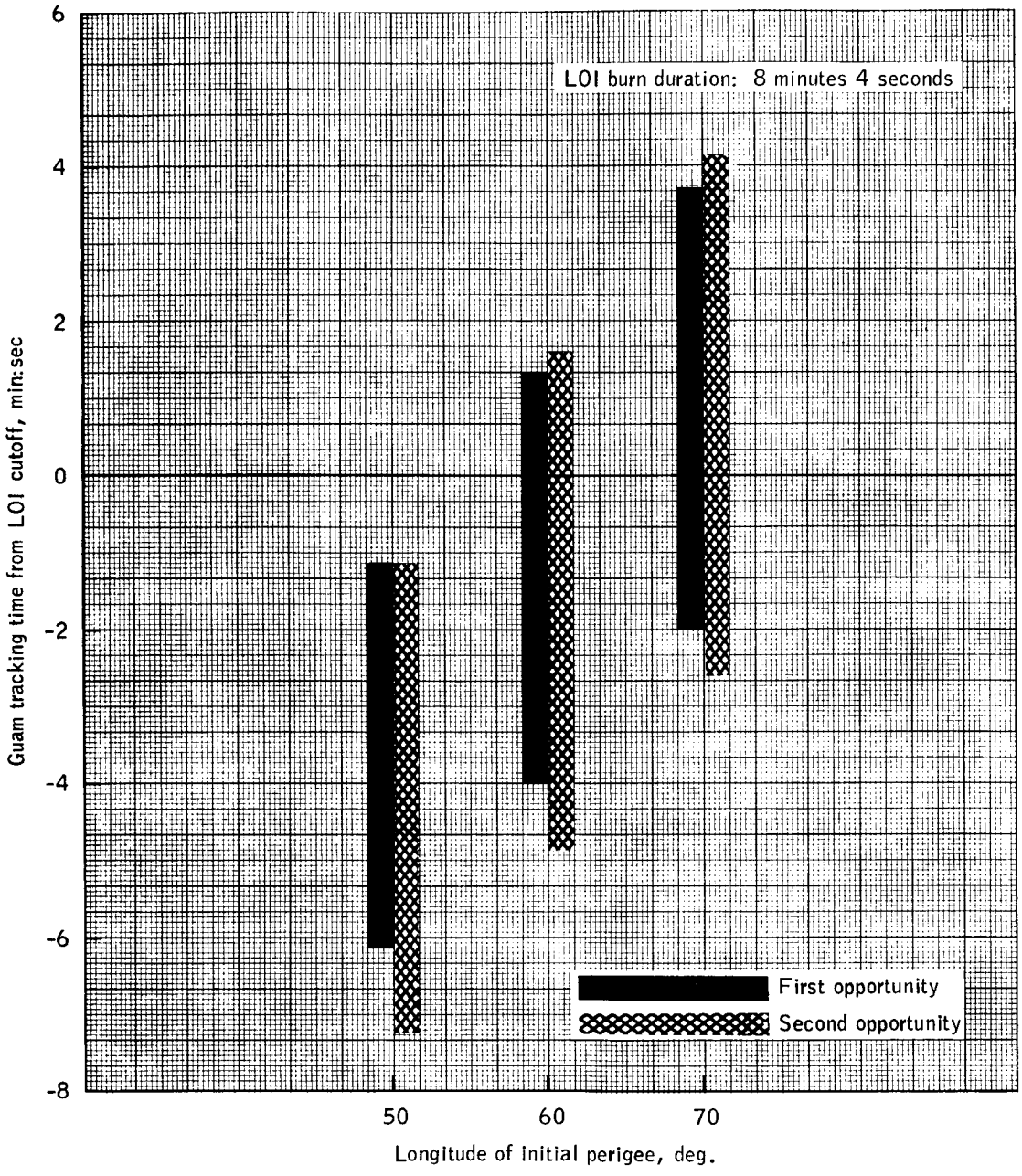
(b) Launch azimuth 72°.

Figure 4.- Continued.



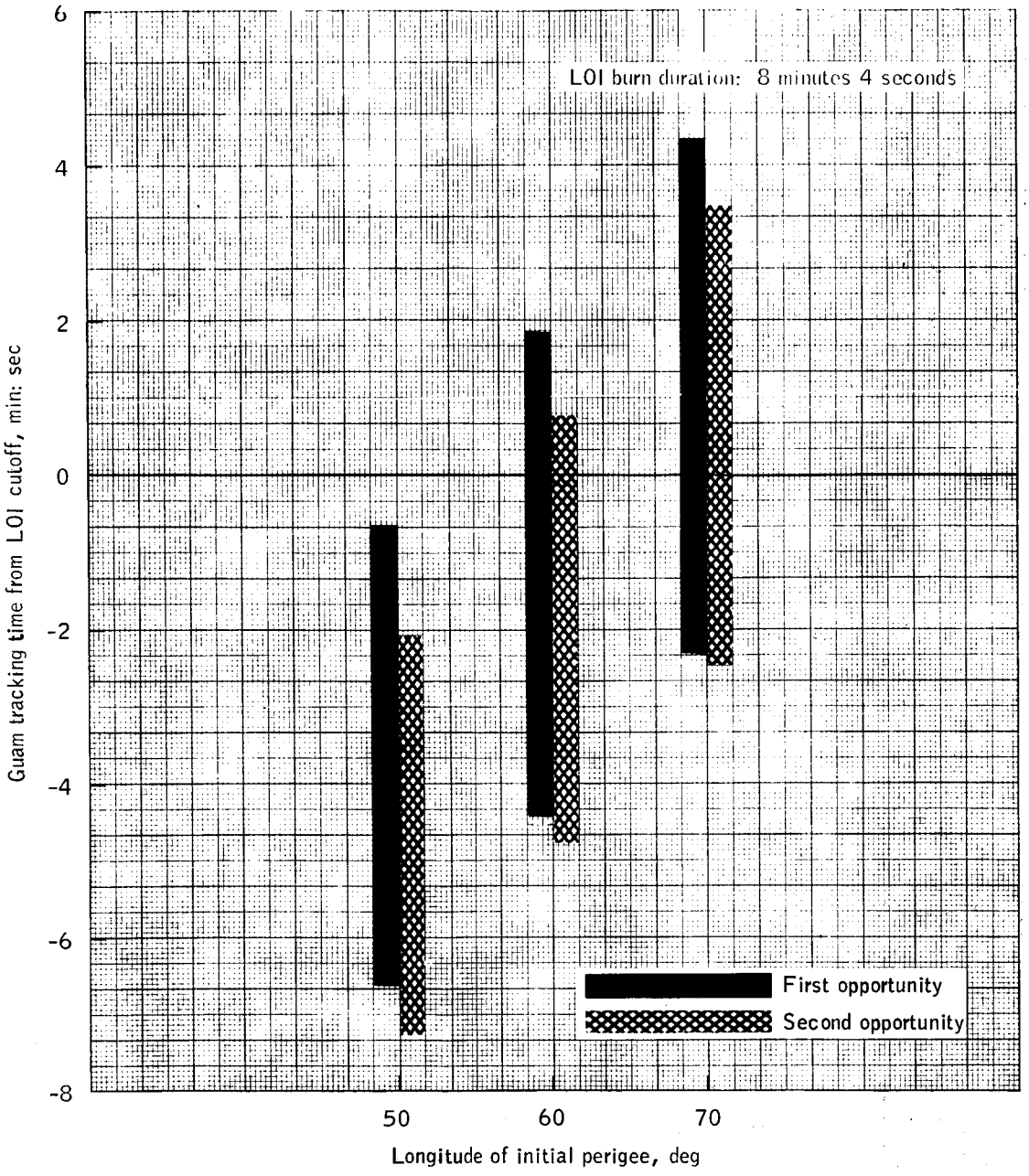
(c) Launch azimuth 74°.

Figure 4.- Continued.



(d) Launch azimuth 80°.

Figure 4.- Continued.



(e) Launch azimuth 85°.

Figure 4.- Concluded.

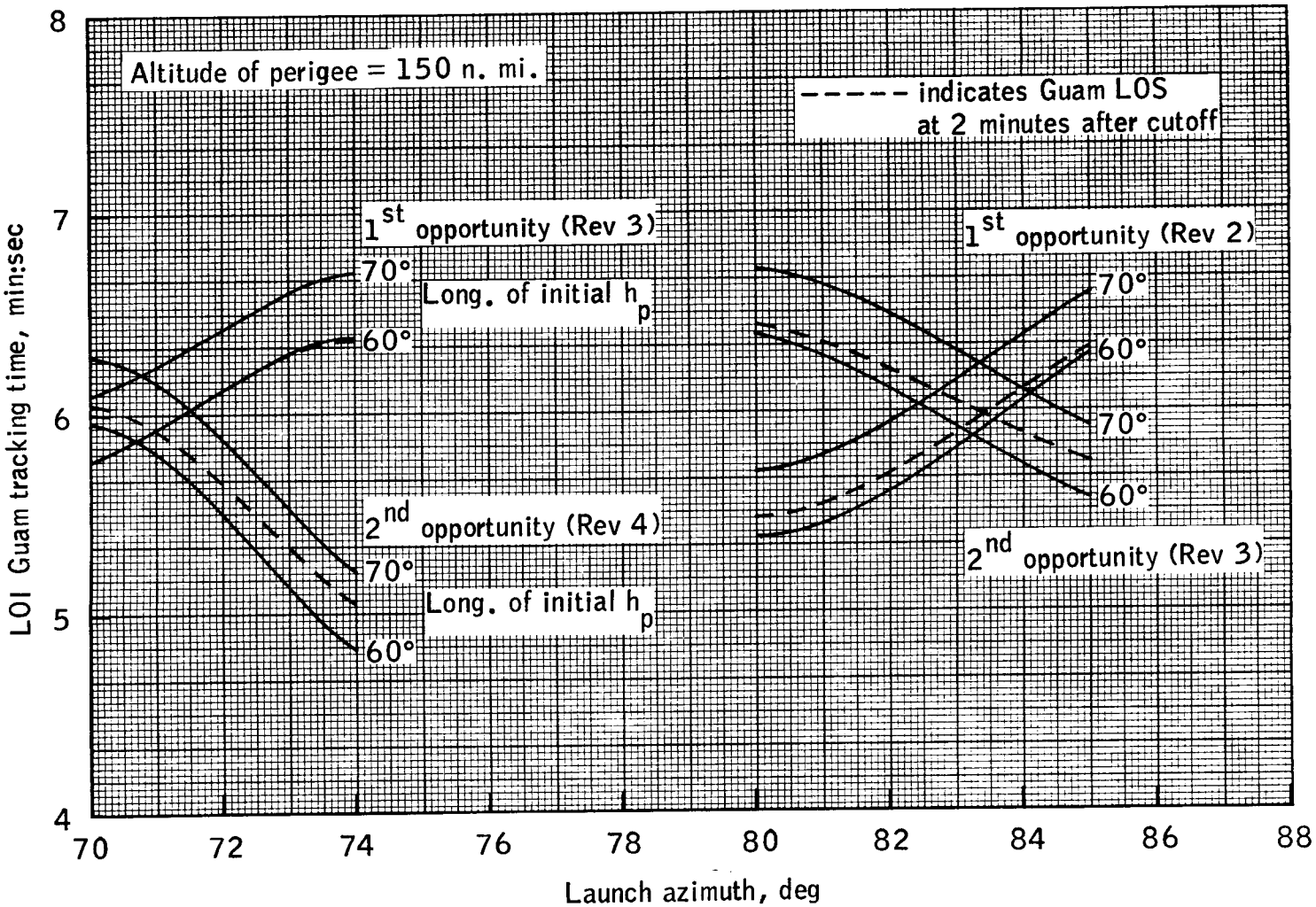


Figure 5.- Total tracking time by Guam as a function of launch azimuths for two injection opportunities and two longitudes of initial perigee.

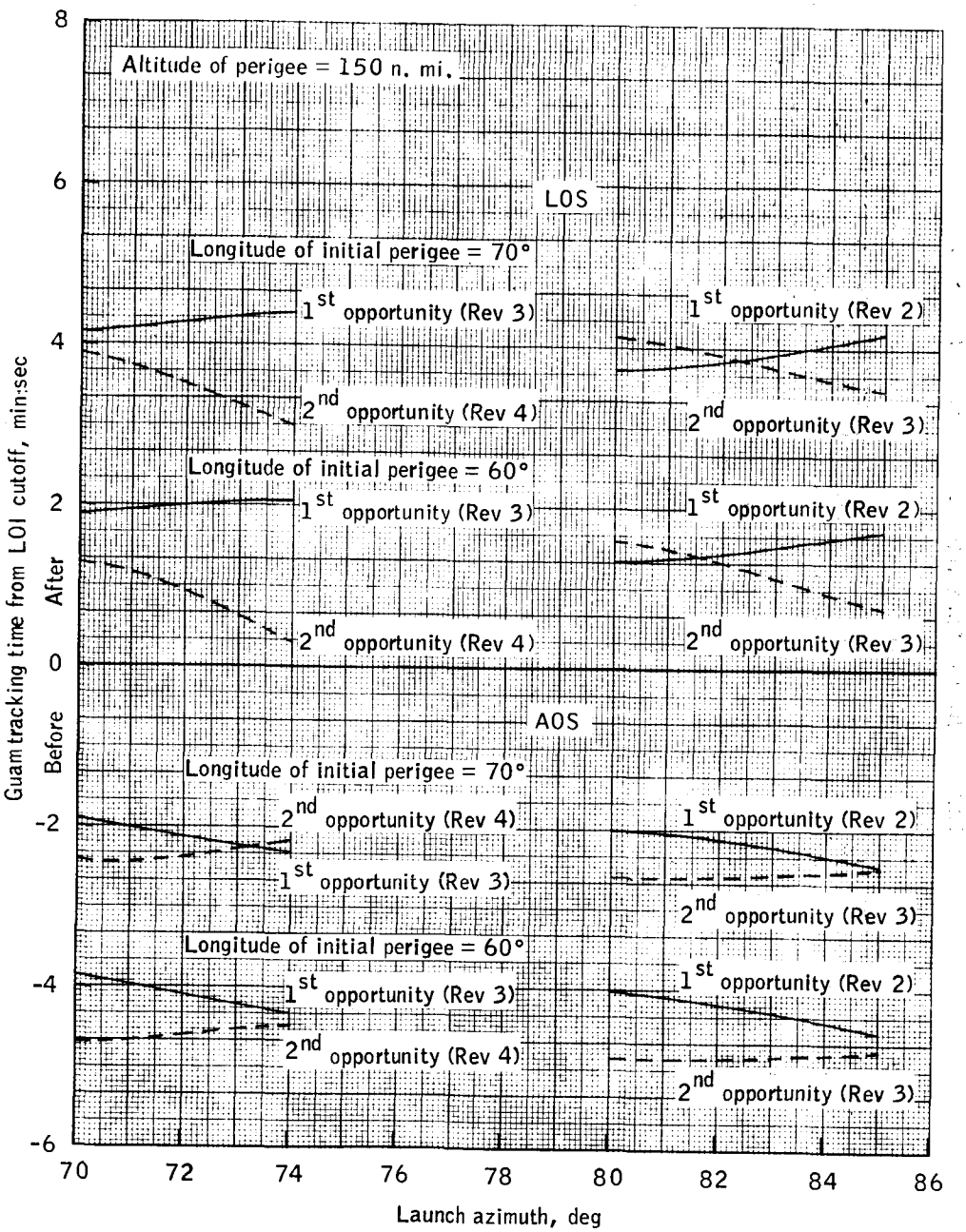
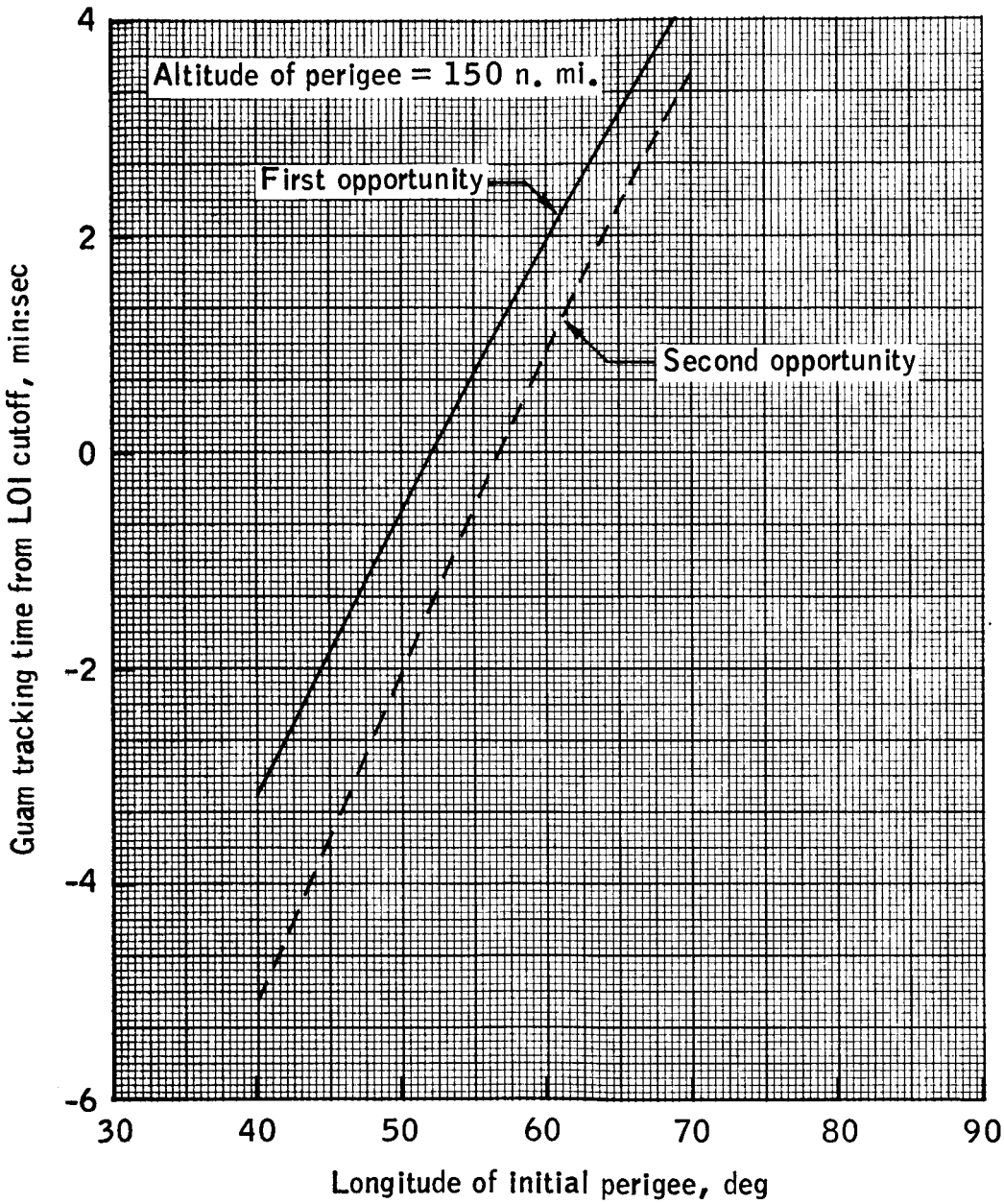
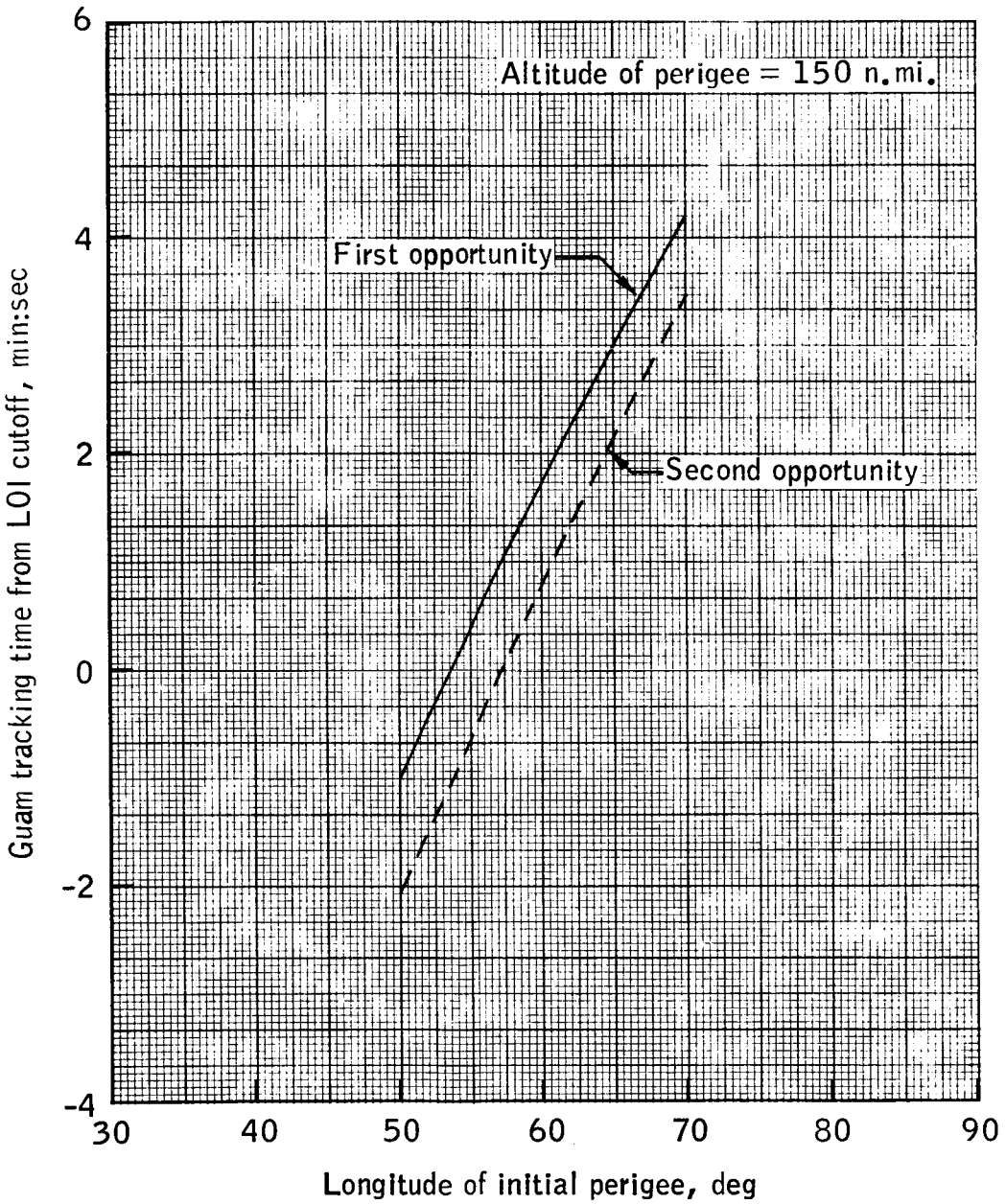


Figure 6.- Guam tracking from LOI cutoff as a function of launch azimuth for two injection opportunities and two longitudes of initial perigee.



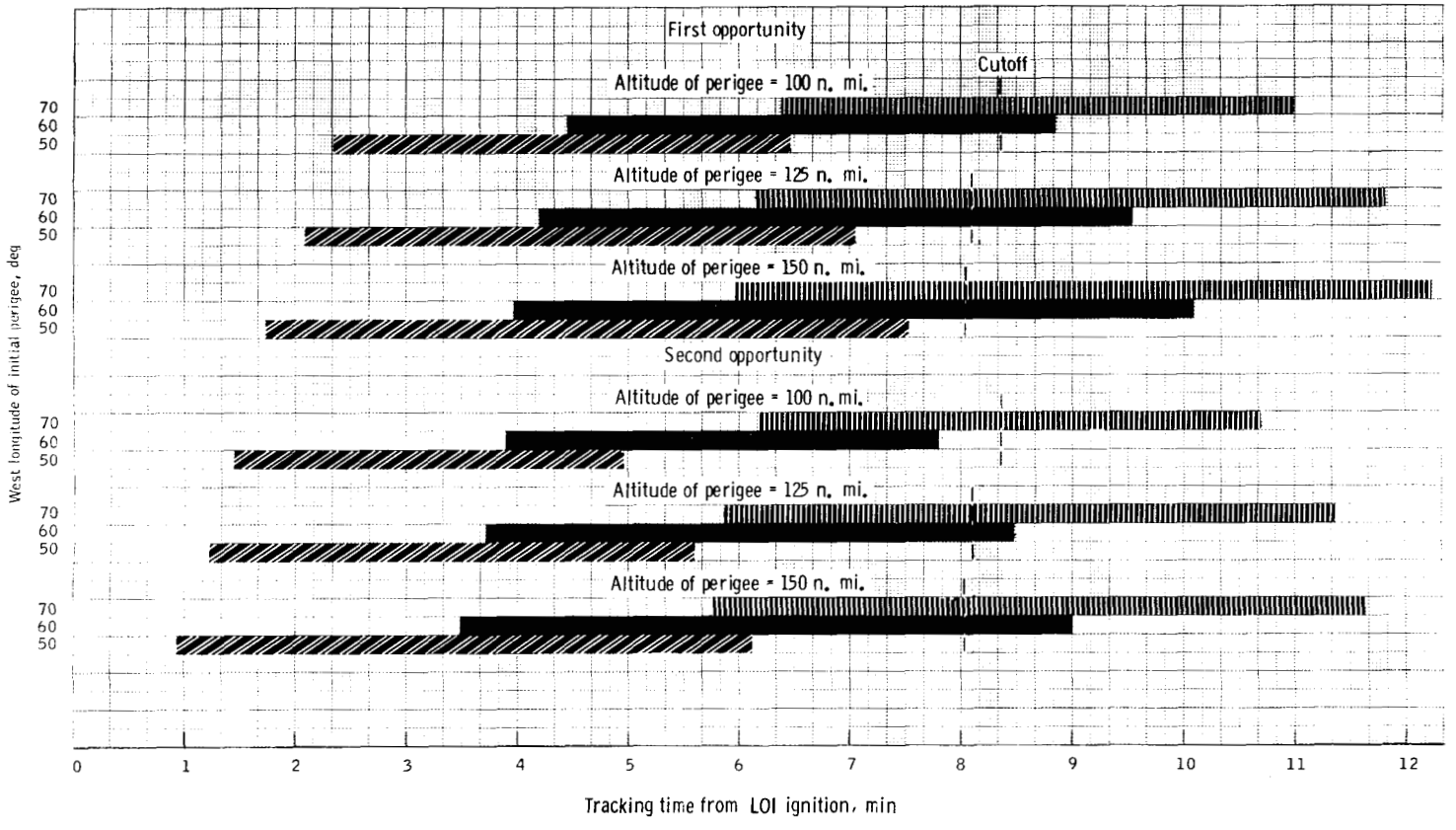
(a) 72° launch azimuth.

Figure 7.- Time of Guam LOS after LOI cutoff for different longitudes of initial perigee.



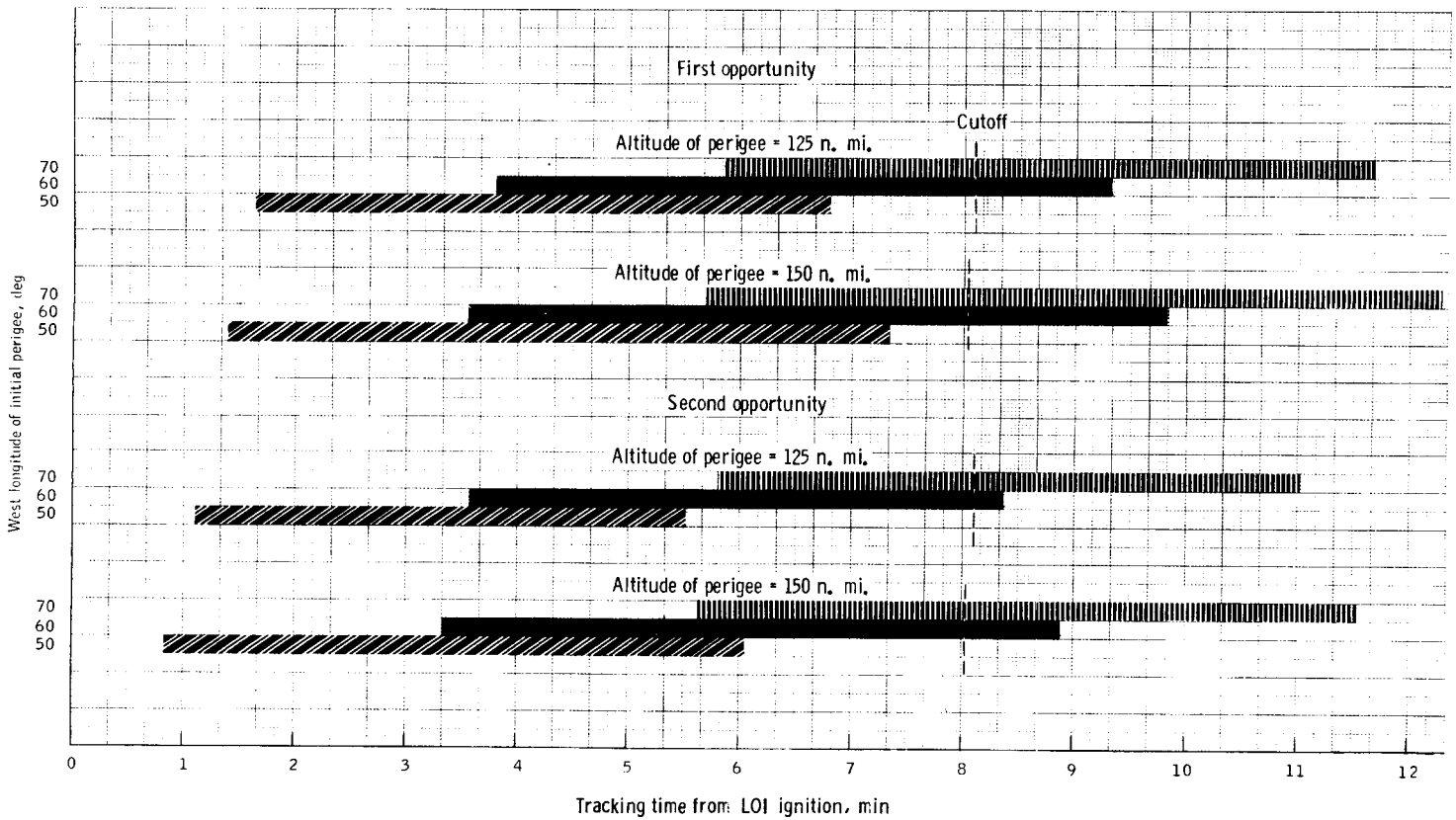
(b) 85° launch azimuth.

Figure 7.- Concluded.



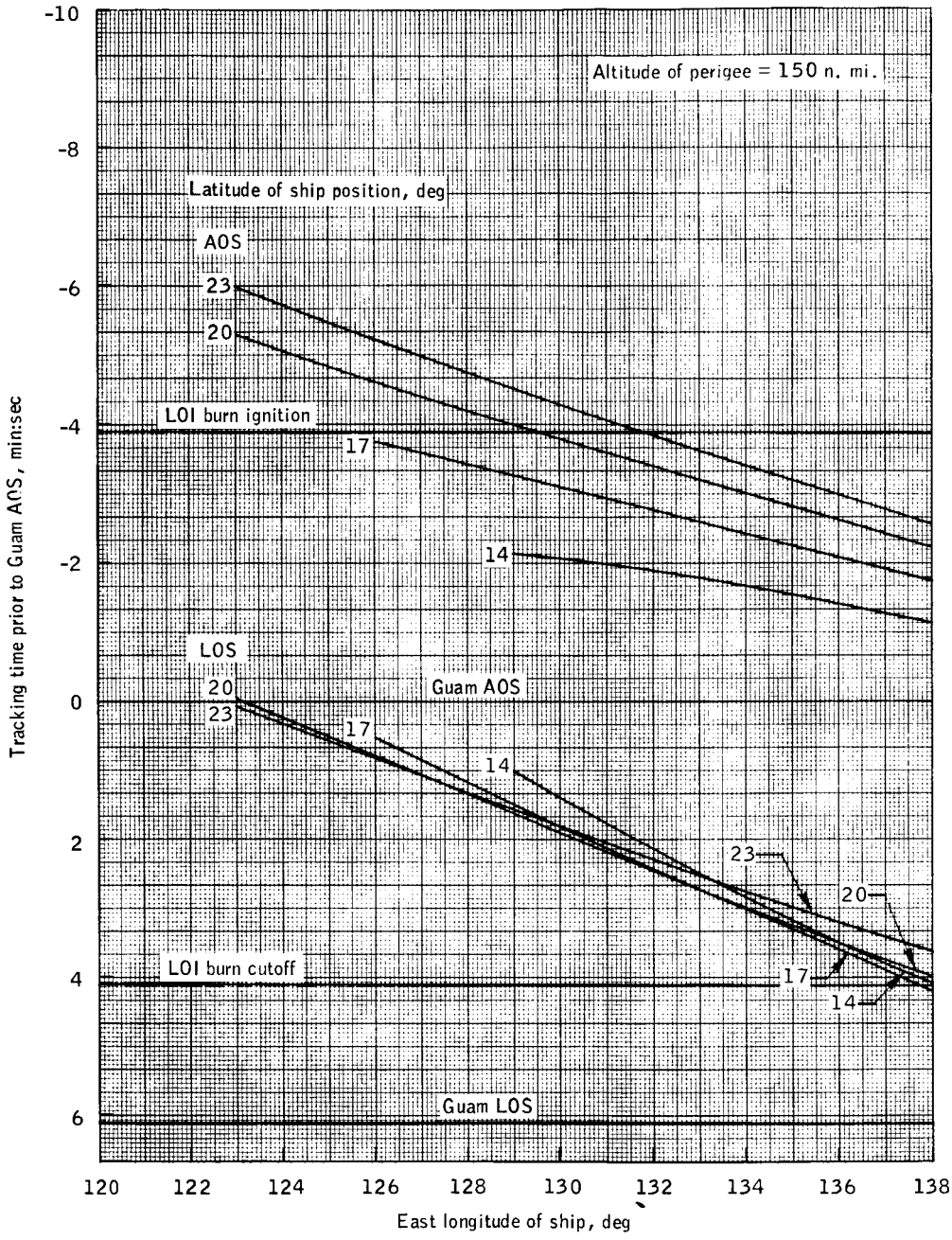
(a) 72° launch azimuth.

Figure 8. - Guam tracking at various longitudes of initial perigee and different perigee altitudes.



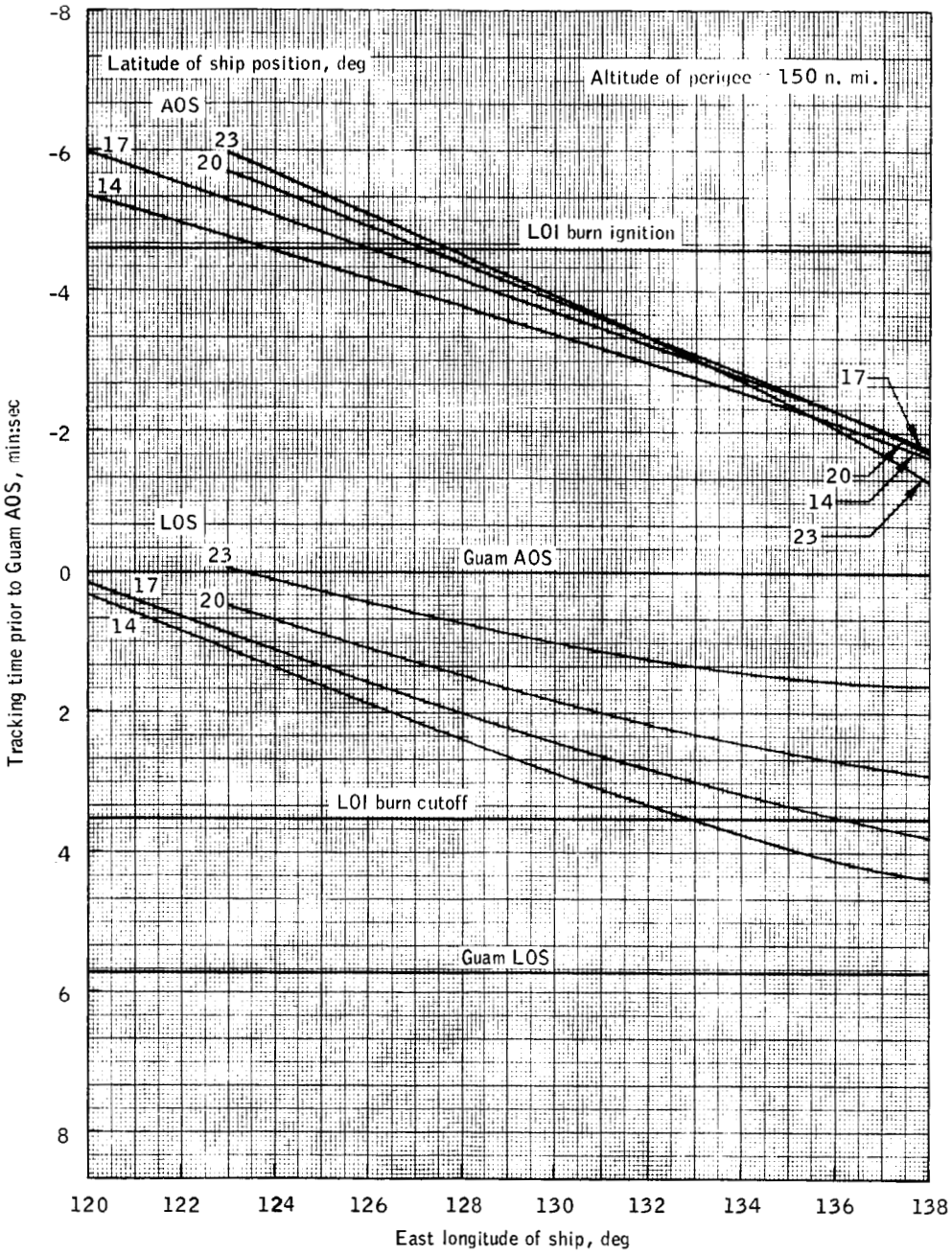
(b) 85° launch azimuth.

Figure 8. - Concluded.



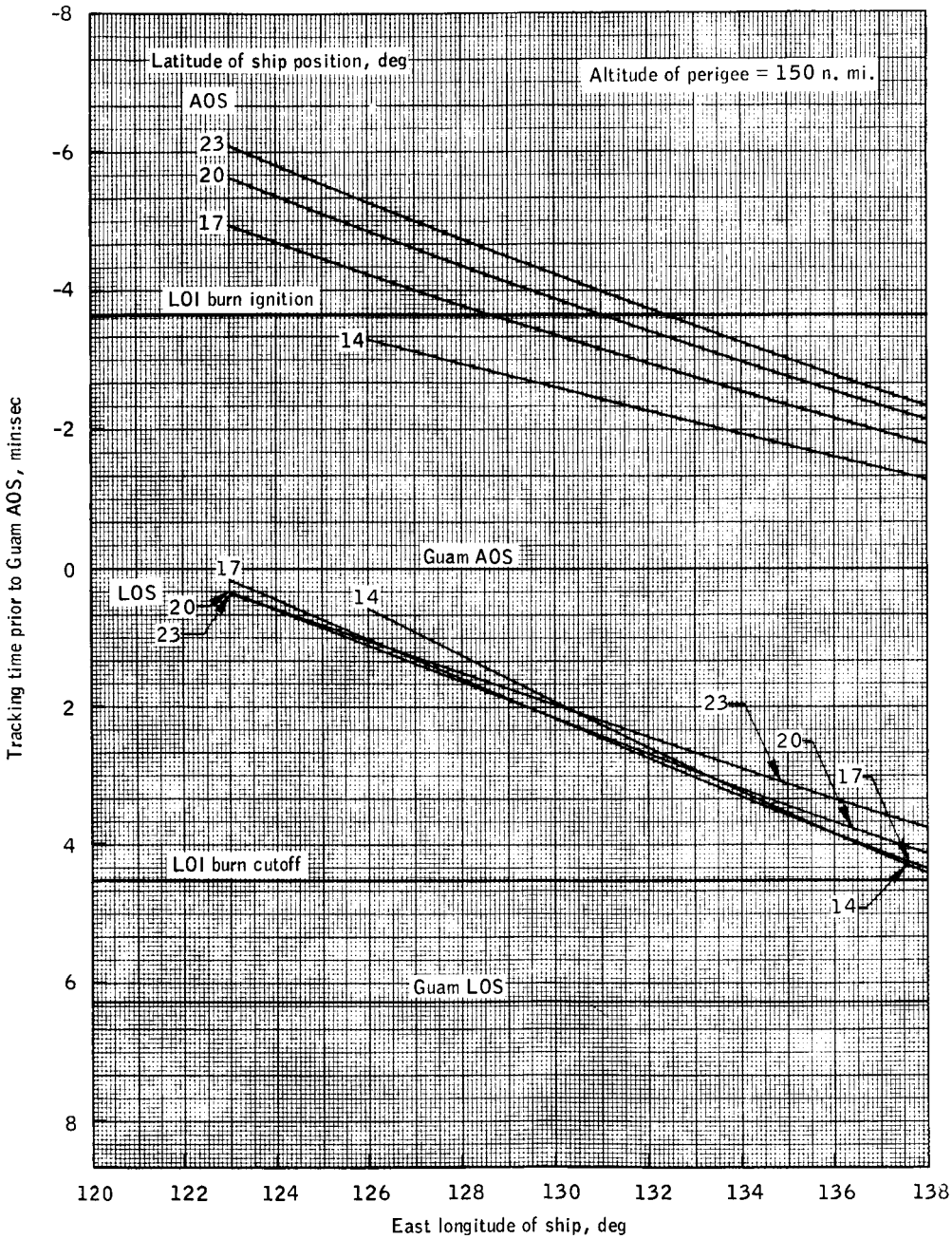
(a) 72° launch azimuth; 60° longitude of initial perigee.

Figure 9.- Ship tracking time prior to Guam AOS for different ship positions.



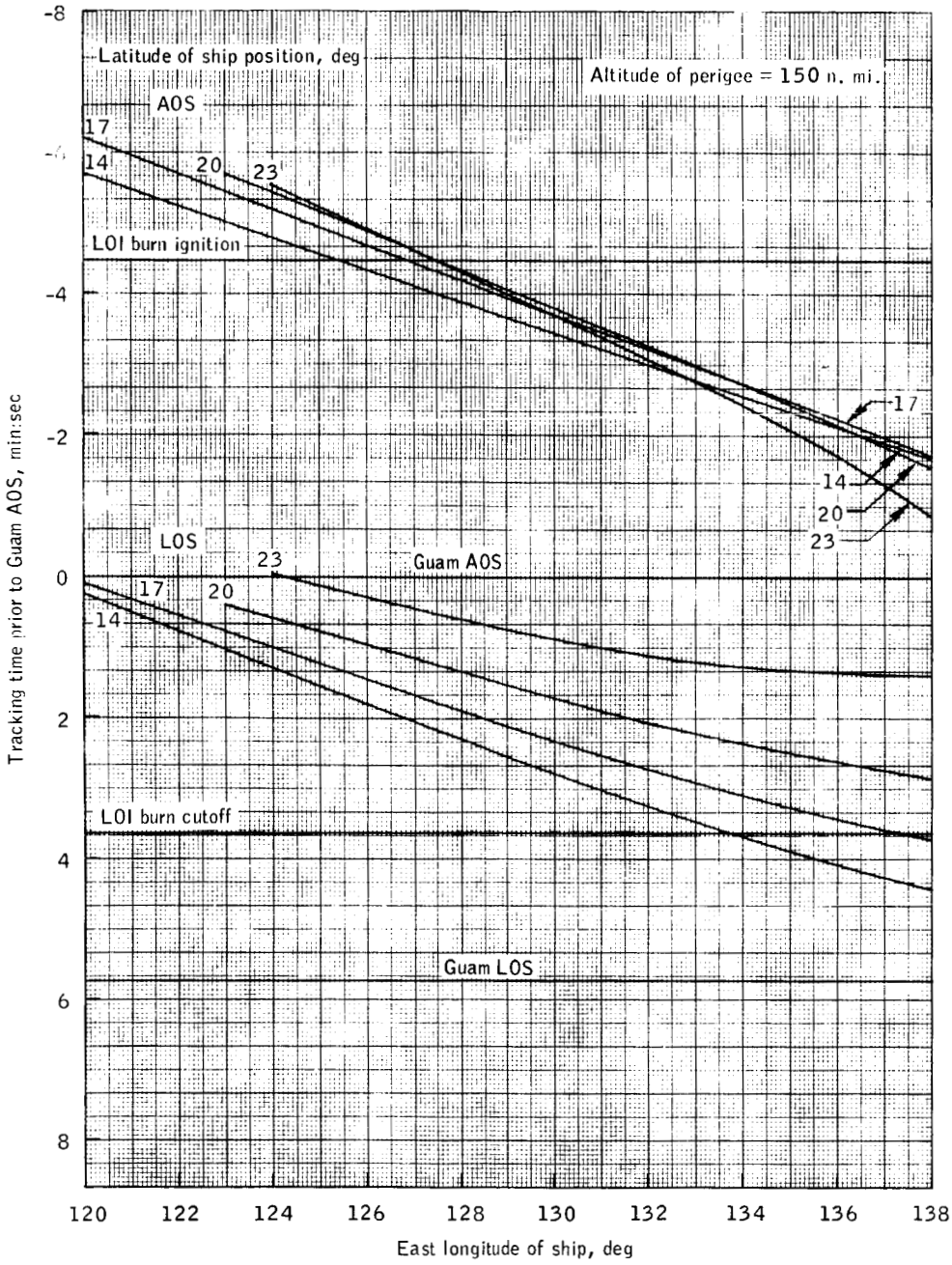
(b) 72° launch azimuth; 65° longitude of initial perigee.

Figure 9.- Continued.



(c) 85° launch azimuth; 60° longitude of intitial perigee.

Figure 9.- Continued.



(d) 85° launch azimuth; 65° longitude of initial perigee.

Figure 9.- Concluded.

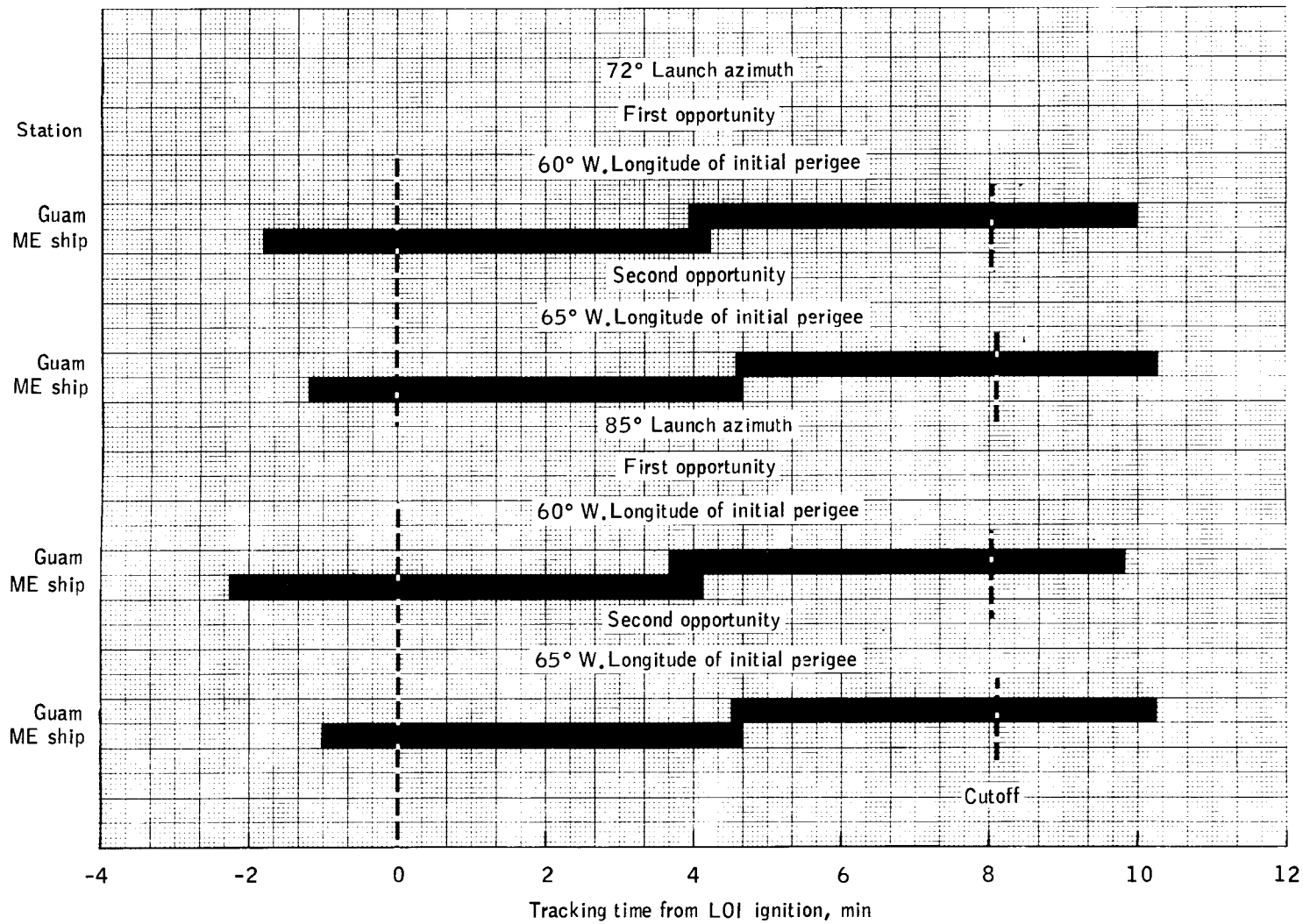


Figure 10.- LOI burn coverage using optimum ship location and Guam.

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2. TRW Systems: Orbital Insertion Parameters for Saturn V Launch Trajectories with Flight Azimuths From 60 to 90 Degrees. TRW memorandum 3423.6-172, March 6, 1967