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TRAJECTORY PARAMETERS FOR AS-504 - TYPE MISSIONS

VOLUME I
EARTH PARKING ORBIT PHASE

By Edward M. Jiongo
Mission Analysis Branch

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PROJECT APOLLO

TRAJECTORY PARAMETERS FOR AS-504-TYPE MISSIONS
VOLUME I - EARTH PARKING ORBIT PHASE

By Edward M. Jiongo
Mission Analysis Branch

July 24, 1967

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

Approved: M P Frank
M. P. Frank III, Chief
Mission Analysis Branch

Approved: John P. Mayer
John P. Mayer, Chief
Mission Planning and Analysis Division

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TRAJECTORY PARAMETERS FOR AS-504-TYPE MISSIONS

VOLUME I - EARTH PARKING ORBIT PHASE

By Edward M. Jiongo

SUMMARY AND INTRODUCTION

A study to provide information required primarily for the flight control and flight crew personnel to support an AS-504-type mission for any launch opportunity during a monthly launch window is being made.

Volume I provides figures of trajectory parameters describing the earth parking orbit phase. It describes the S-IVB earth orbit insertion conditions, the coast in earth parking orbit, and radar tracking from earth orbit insertion to 4.5 hours after lift-off. The data is independent of launch date and is presented as a function of launch azimuth. Venting in earth parking orbit was not simulated. While venting will perturb the trajectory, it is not expected to change the data presented significantly. Spacecraft time in earth shadow was not included since the study is not associated with any specific launch opportunity and the time spent in earth shadow is dependent upon the position of the sun, earth, and the moon at the time of launch. (The latest shadow information now available is contained in reference 1.)

~~Three~~ TWO additional volumes will be published. Volume II will describe in detail each phase of the first lunar mission in the monthly launch window. The characteristics of each phase will be common to the same phase for any launch opportunity in the monthly window. Only Volume II will present detailed time histories of all pertinent trajectory parameters. The information will be in similar format to that in the AS-504 Preliminary Spacecraft Reference Trajectory (ref. 2).

Because of significant changes in the mission profile resulting from a change in launch date from one day to the next, Volume III will summarize a mission for the first injection opportunity of each launch day in the monthly window. The information will be less detailed than that in Volume II, but the format will also be similar to that in reference 2.

Volume ~~IV~~ III will summarize how pertinent trajectory parameters vary throughout each daily launch window. It will present the variation of mission parameters with launch azimuth for each launch date in the window.

DISCUSSION OF FIGURES

S-IVB Earth Orbit Insertion Conditions

The earth parking orbit insertion conditions are summarized in table I (ref. 3 and 4) and figures 1 and 2. Table I shows the actual insertion conditions obtained from Marshal Space Flight Center used to generate the ground tracks shown in figures 3 and 4. The various parameters, such as time, latitude, and longitude, are shown as a function of launch azimuth. For launch azimuths other than the 72°, 78°, 84°, 90°, 96°, 102°, and 108° shown in table I, refer to figure 1. The data in the figure was obtained by a least squares curve fit of the data in table I. Figure 2(a) shows the groundtracks for launch azimuth of 72°, 78°, 84°, 90°, 96°, 102°, and 108° from earth orbit insertion to 3 minutes past earth orbit insertion. Total tracking time from insertion for land stations and various ships may be compared in figure 2(b).

Earth Parking Orbit Phase

The earth parking orbit phase is summarized in figures 3, 4, and 5. It was generated using the ARMP program (ref. 5). Figure 3(a) through (c) shows the groundtrack on a 90°-to-90° map for launch azimuths of 72°, 78°, 84°, 90°, 96°, 102°, and 108° with 100-n. mi., 5°-tracking circles included. Figure 3(a) shows the groundtracks for the aforementioned launch azimuth for the first revolution; figure 3(b), the second revolution; and figure 3(c), the third revolution. The launch azimuth spread covers the present range safety restricitons of 72° through 108°. For launch azimuths between 72° through 108°, other than those specifically shown, a linear interpolation can be performed. Figure 4(a) through (c) is identical to figure 3(a) through (c) except that it is on a 180°-to-180° map to allow more detail and clarity if the region of interest is near 90° E or 90° W longitude. For more detailed groundtracks and translunar injection burn contours, see reference 6.

Figure 5 shows latitude in earth parking orbit as a function of g.e.t. Since the approximate latitude of ignition of a translunar injection burn is the negative of the moon's declination at time of pericynthion passage, figure 5 provides a close approximation of the time of coast in earth parking orbit for a proposed lunar mission.

Radar Tracking Information for Earth Parking Orbit

The radar tracking data is summarized in table II, and figures 5 through 24. This data was also generated using the ARMP program. Table II lists the available land-based radar stations, their three letter code names, and their geodetic location (ref. 7). Tracking ships were not

included as their locations depend almost entirely on a specific mission and launch date.

Figure 5 shows which station will be tracking, duration of pass, and tracking overlap for the maximum earth parking orbit coast time of 4.5 hr. It gives a complete history for the launch azimuth from 72° through 108° in increments of 2°.

Individual station histories are shown in figures 6 through 24. As a typical example, figure 11 provides a detailed history for Carnarvon. Figure 11(a) shows g.e.t. for 3° elevation at acquisition and termination versus launch azimuth for each revolution that the station tracks. Figure 11(b) shows duration of pass above 3° elevation versus launch azimuth. Figure 11(c) shows azimuth of acquisition at 0° elevation versus launch azimuth for each revolution the station tracks. By showing azimuth of acquisition at 0° elevation a radar station can lock-on the spacecraft at the earliest opportunity, although the data may not be usable until some minimum elevation, such as 3° is obtained. The time of acquisition for the 0° lock-on will always be approximately 15 to 20 seconds previous to the time of acquisition shown in figures 6(a) through 24(a).

TABLE I.- PARKING ORBIT INSERTION CONDITIONS

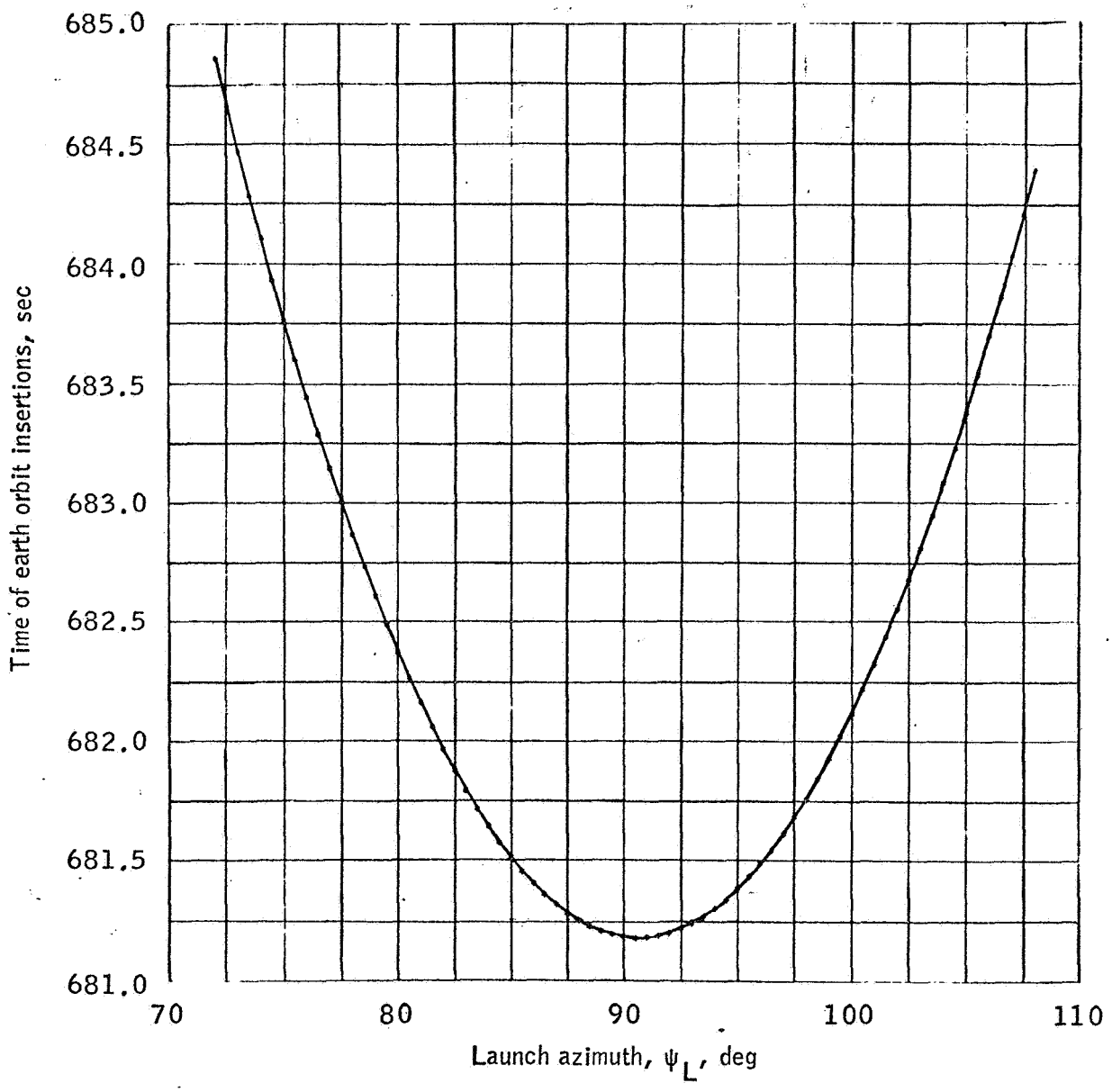
Launch azimuth, deg	Ground elapsed time at insertion, sec	Geocentric latitude, deg	Longitude, deg	Radius, n. mi.	Inertial velocity, deg	Inertial flight-path angle, deg	Inertial azimuth, deg	Inclination, deg	Weight at earth parking orbit insertion, lb
72	684.854	32.4827	54.5062	3543.9342	25 573.9679	-0.0025	87.7212	32.5538	297 892.2
78	682.872	30.1538	54.6232	3543.9343	25 573.9679	-0.0007	92.8774	30.2779	298 844.0
84	681.642	27.8492	54.9354	3543.9344	25 573.9679	-0.0008	97.9427	28.8723	299 434.3
90	681.179	25.5758	55.4276	3543.9345	25 573.6979	-0.0009	102.9381	28.4642	299 656.8
96	681.487	23.3399	56.0887	3543.9345	25 573.6979	-0.0010	107.8823	29.0951	299 508.9
102	682.561	21.1478	56.9110	3543.9345	25 573.6979	-0.0009	112.7910	30.7019	298 993.4
108	684.391	19.0045	57.8901	3543.9344	25 573.9645	-0.0009	117.6799	33.1452	298 114.7

TABLE II.- TRACKING STATIONS

Call letters	Station name	Radar equipment	Geodetic latitude, deg	Geodetic longitude, deg	Height above mean sea level, n. mi.
HAW	Hawaii	Unified S-band (30' dish)	22.12807249	-159.66722638	0.61388228
PAT	Patrick	C-band	28.22655278	-80.59929166	0.00809892
GST	Goldstone	Unified S-band (85' dish)	35.34169500	-116.87328833	0.52145788
GYM	Guaymas	Unified S-band (30' dish)	27.96320610	-110.72084916	0.01048596
PRE	Pretoria	C-band	-25.94372222	28.35850000	0.00809892
TEX	Corpus	Unified S-band (30' dish)	27.65361111	-97.37833333	0.00000000
WHS	White Sands	C-band	32.35822222	-106.36956389	0.66630728
MLA	Merritt Island	Unified S-band (30' dish)	28.50827222	-80.52674611	0.00672786
GBI	Grand Bahama	Unified S-band (30' dish)	26.65416666	-78.15277778	0.00000000
BDA	Bermuda	Unified S-band (30' dish)	32.35128694	-64.65818111	0.01133909
ANT	Antigua	Unified S-band (30' dish)	17.01944444	-61.75000000	0.00000000
ASC	Ascension	Unified S-band (30' dish)	-7.95523416	-14.32757889	0.30302375
MAD	Madrid	Unified S-band (85' dish)	40.45535833	-4.16739555	0.44559935
CRO	Carnarvon	Unified S-band (30' dish)	-24.90756278	113.72424722	0.03099352

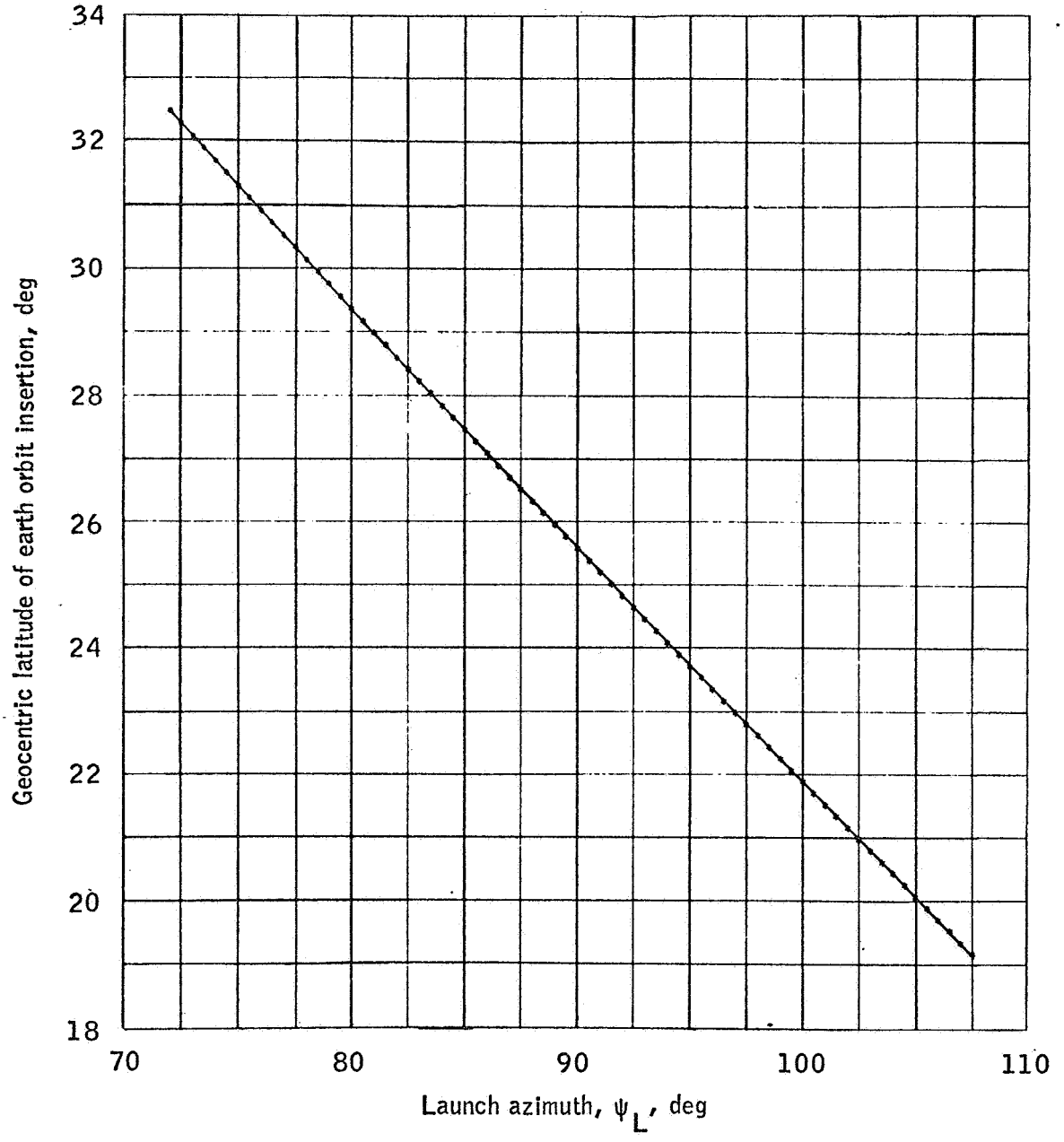
TABLE II.- TRACKING STATIONS - Concluded

Call letters	Station name	Radar equipment	Geodetic latitude, deg	Geodetic longitude, deg	Height above mean sea level, n. mi.
GUA	Guam	Unified S-band (30' dish)	13.30823555	144.73441361	0.06916846
CNB	Canberra	Unified S-band (30' dish)	-35.59722222	148.97916666	0.00000000
CYI	Grand Canary	Unified S-band (85' dish)	27.74027777	-15.60416666	0.00000000
EGL	Eglin	C-band	30.42176666	-86.79811388	0.01511821
GTI	Grand Turk	C-band	21.46290833	-71.13204444	0.01943840



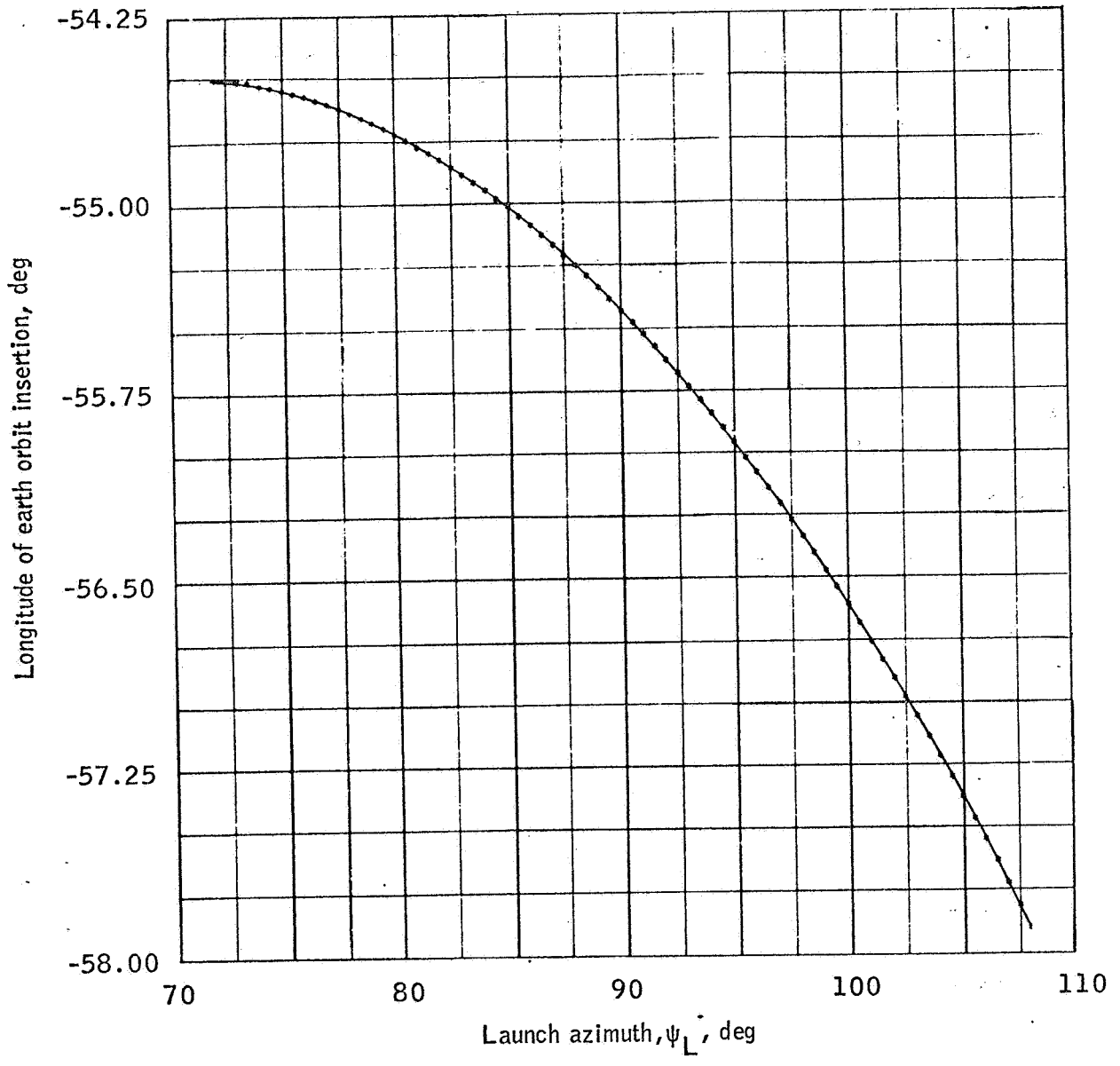
(a) Time of earth orbit insertion as a function of launch azimuth.

Figure 1.- Earth orbit insertion conditions.



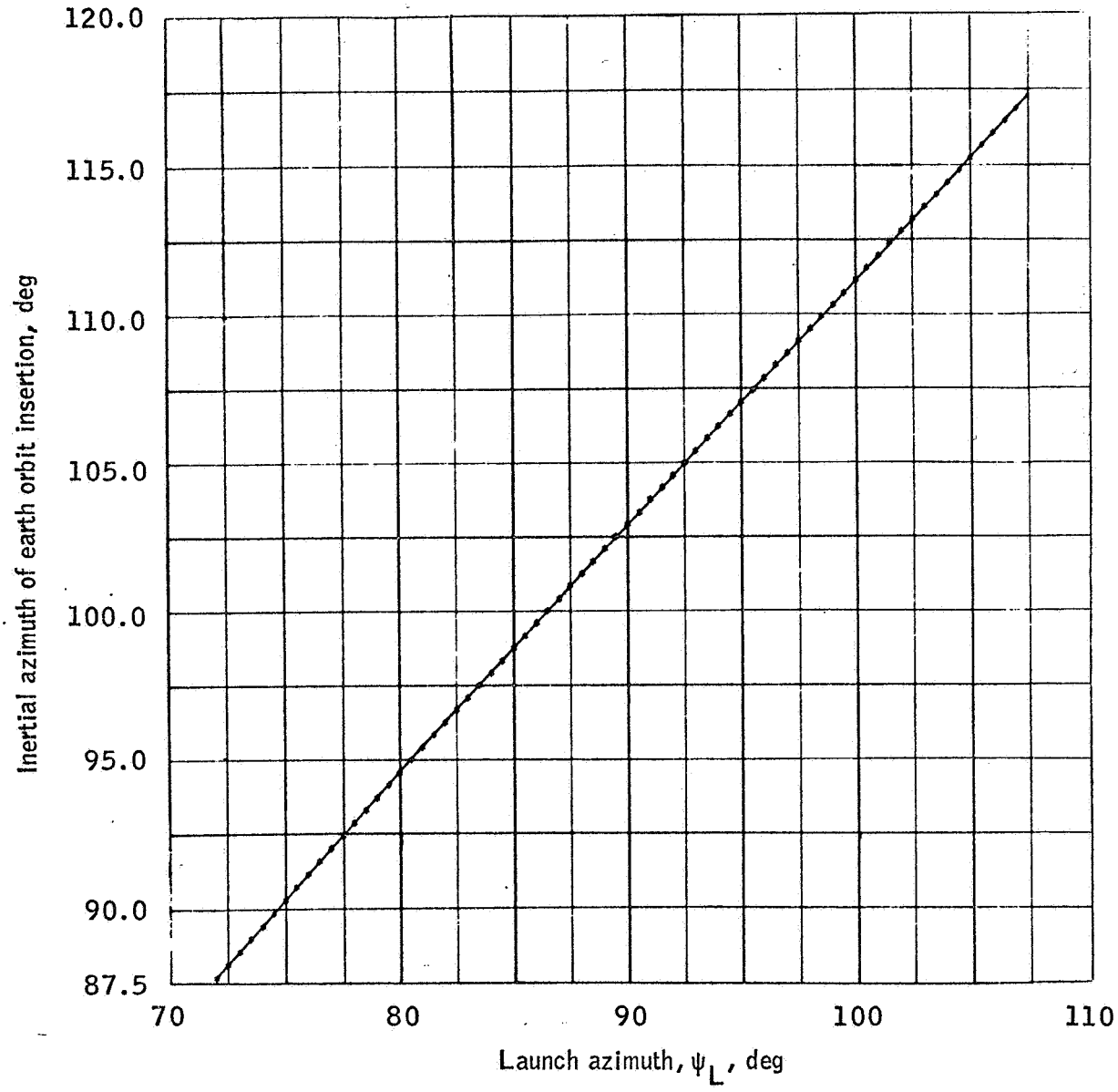
(b) Geocentric latitude of earth orbit insertion as a function of launch azimuth.

Figure 1.- Continued.



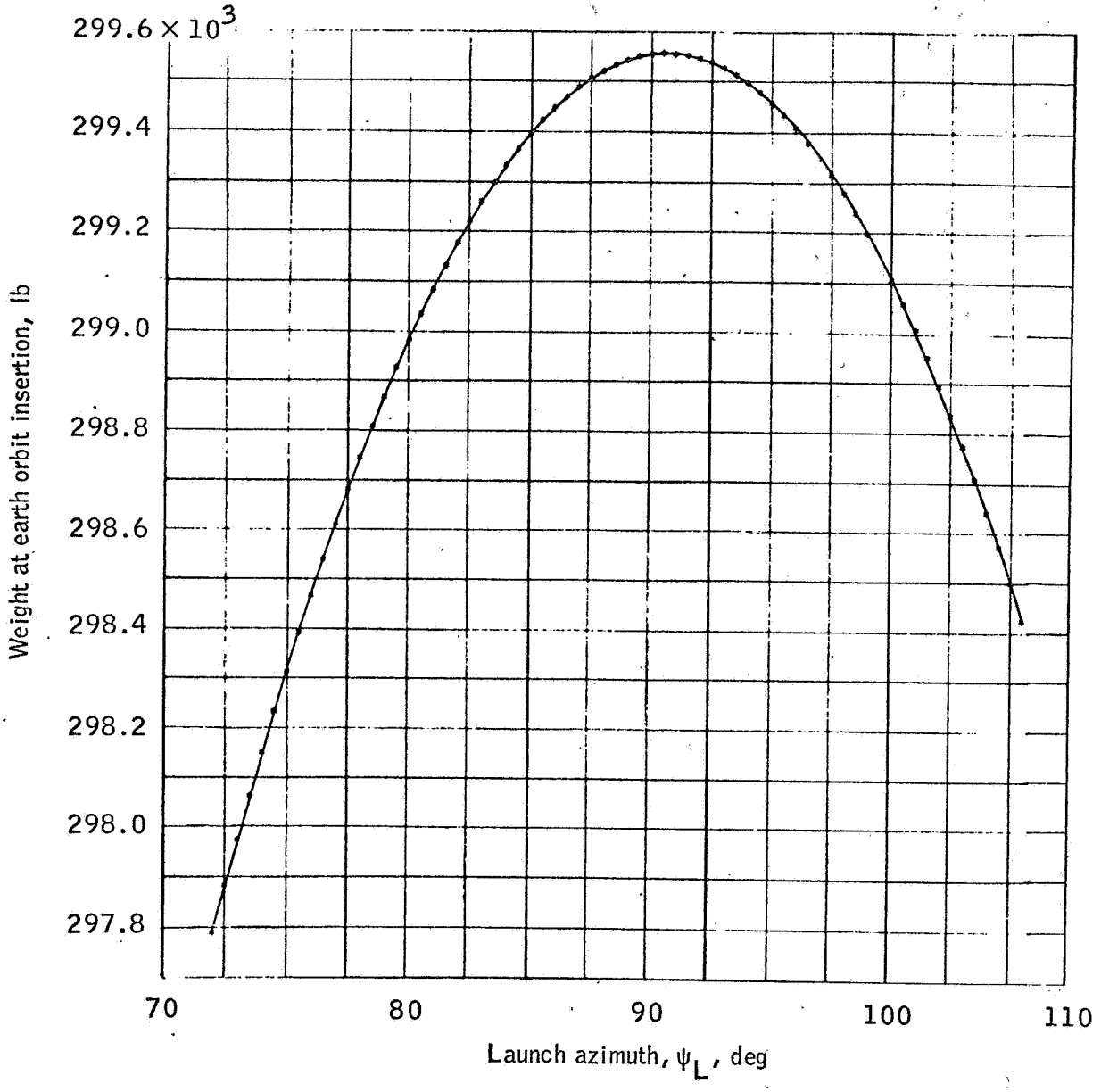
(c) Longitude of earth orbit insertion as a function of launch azimuth.

Figure 1.- Continued.



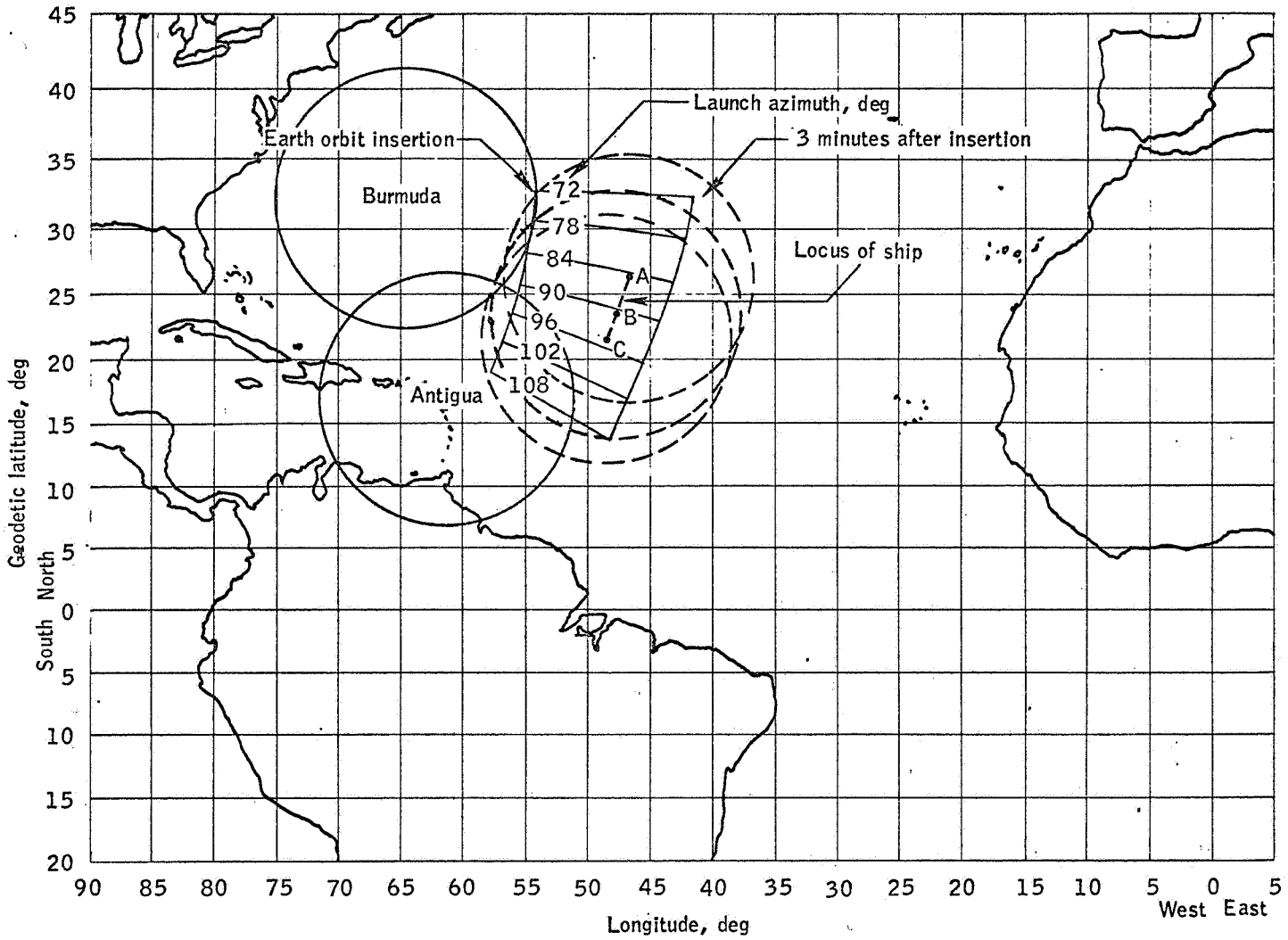
(d) Inertial azimuth of earth orbit insertion as a function of launch azimuth.

Figure 1.- Continued.



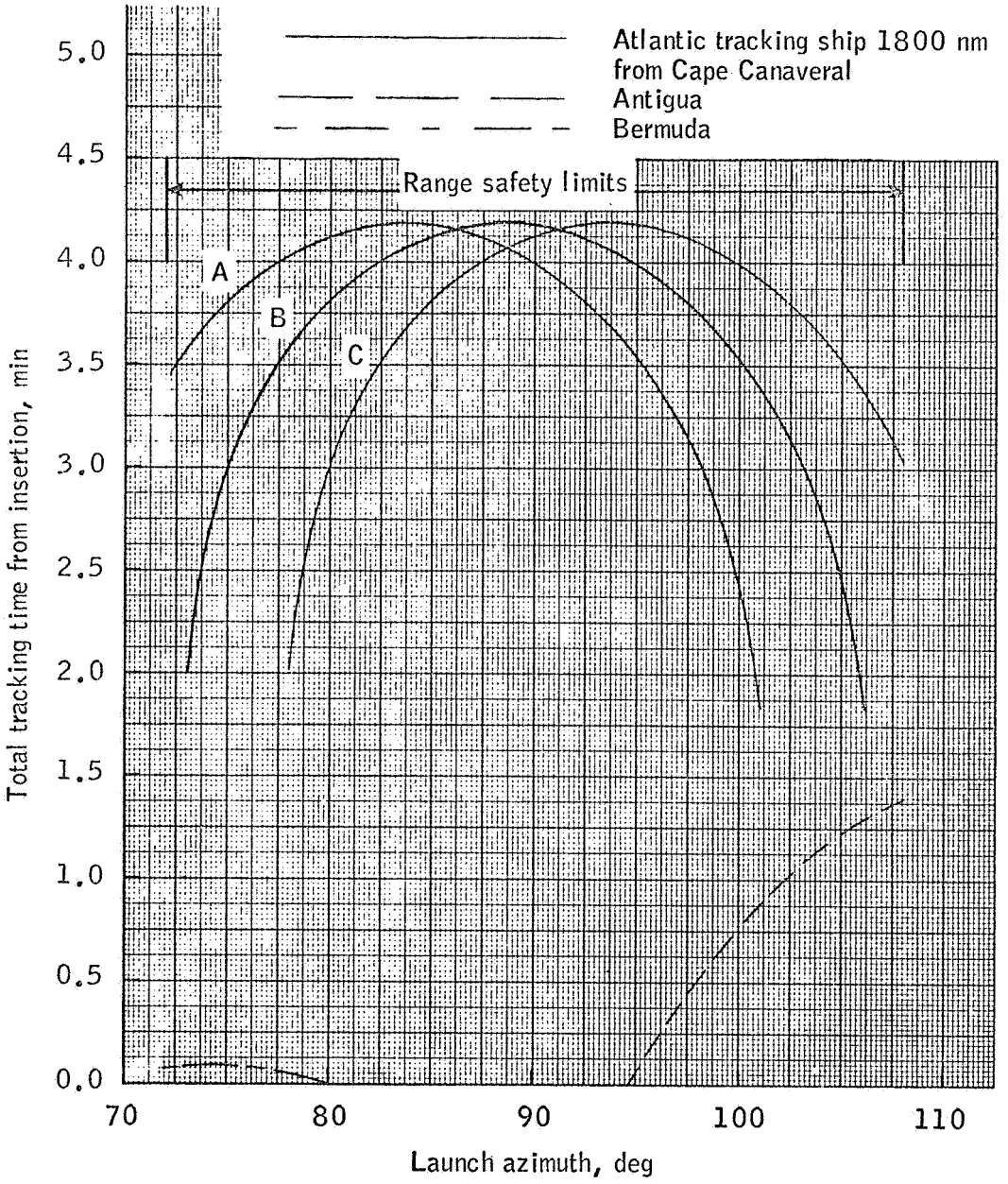
(e) Weight at earth orbit insertion as a function of launch azimuth.

Figure 1.- Concluded.



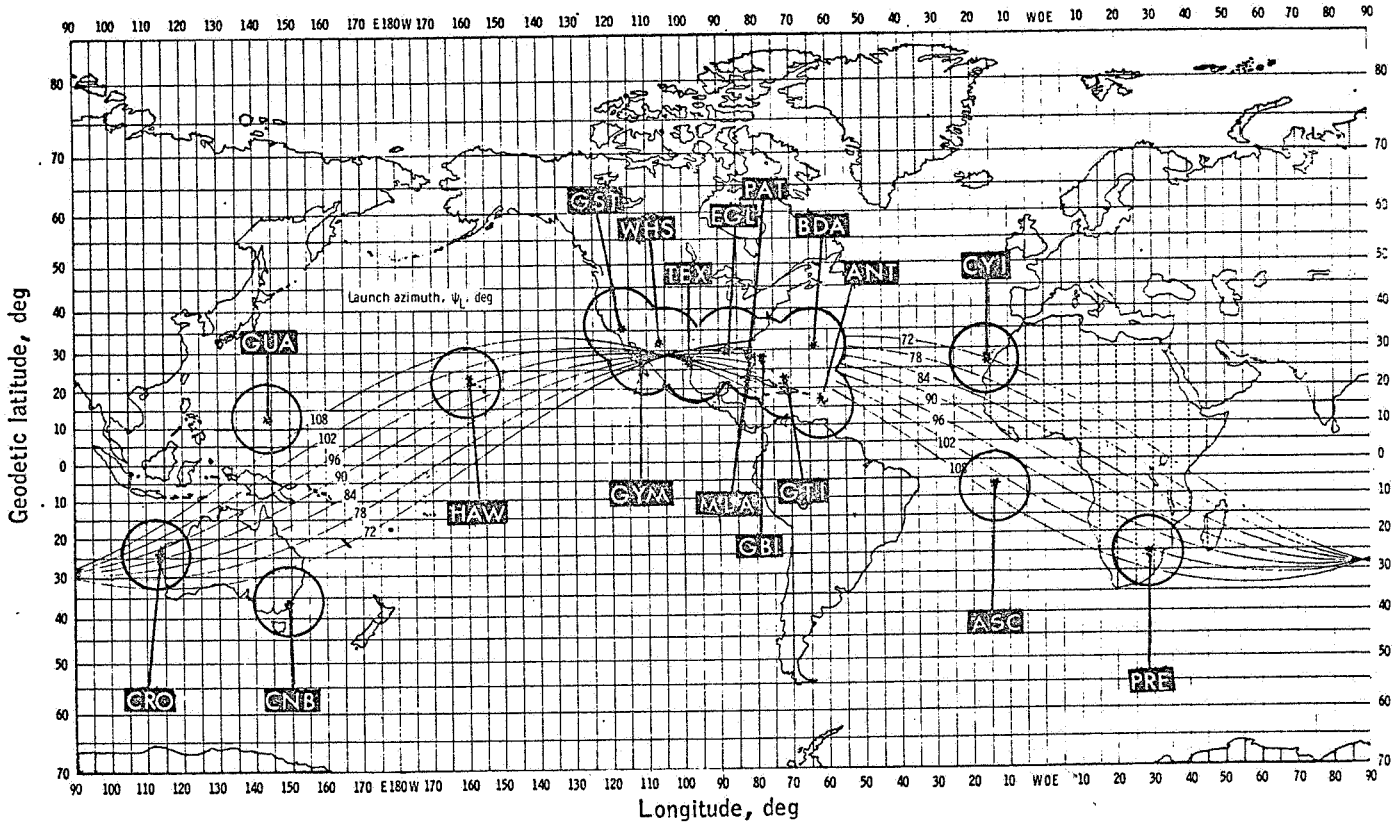
(a) Groundtracks from earth orbit insertion until three minutes later.

Figure 2.- The earth orbit insertion area for an AS-504-type mission.



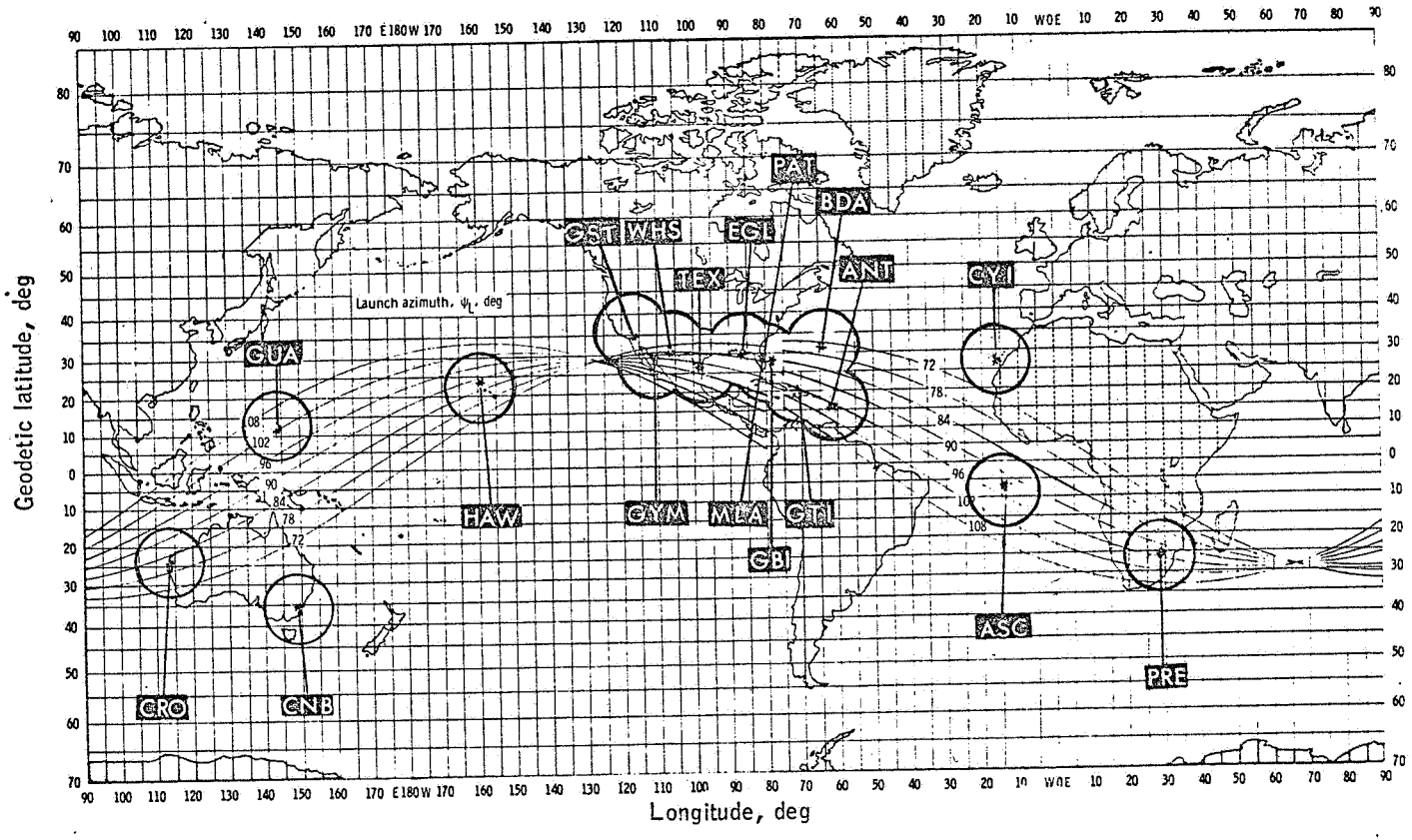
(b) Comparison of land stations and various ship locations (A, B, and C).

Figure 2.- Concluded.



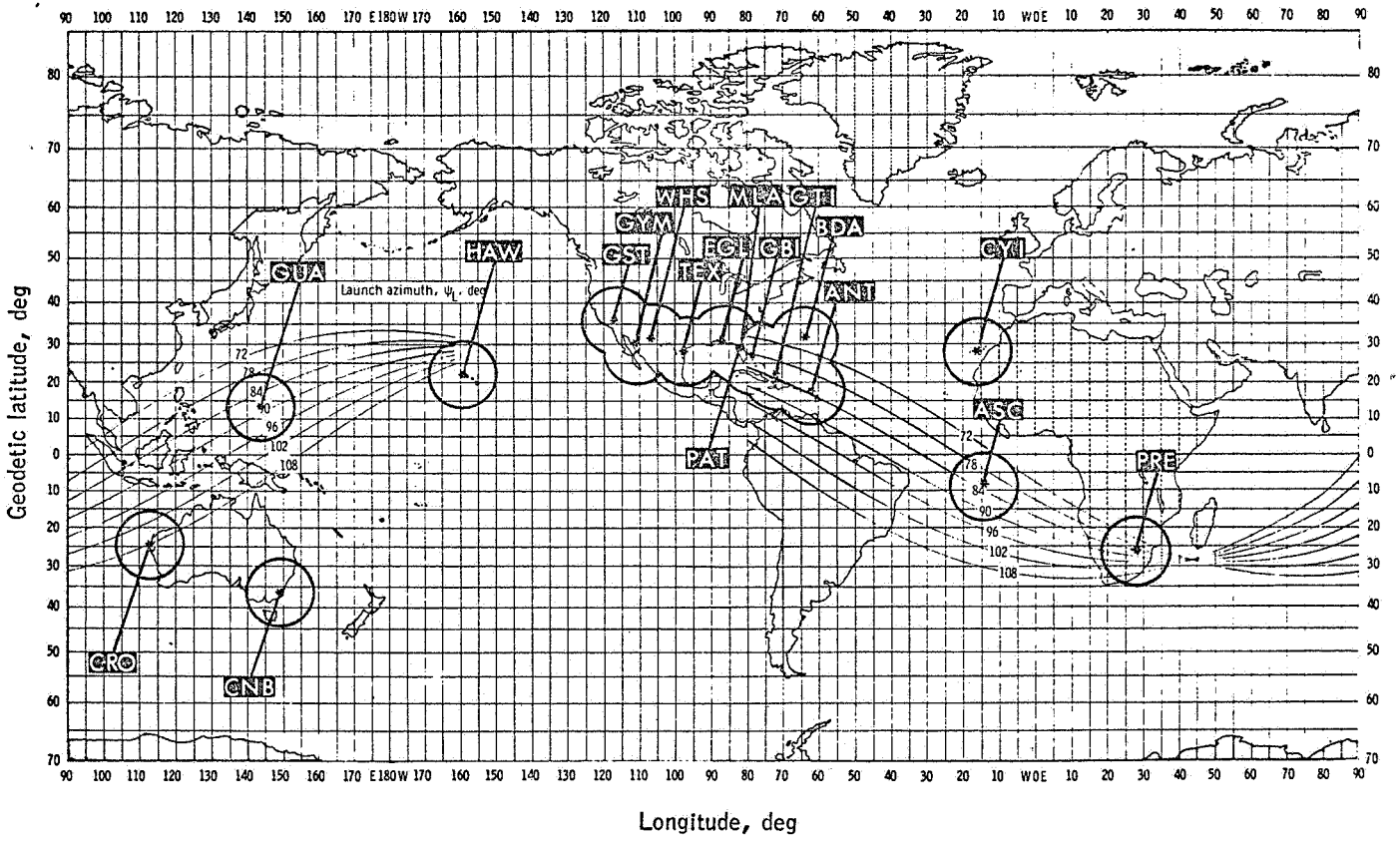
(a) First revolution.

Figure 3.- Earth parking orbit for launch azimuth 72 degrees through 108 degrees (90 degrees to 90 degrees map).



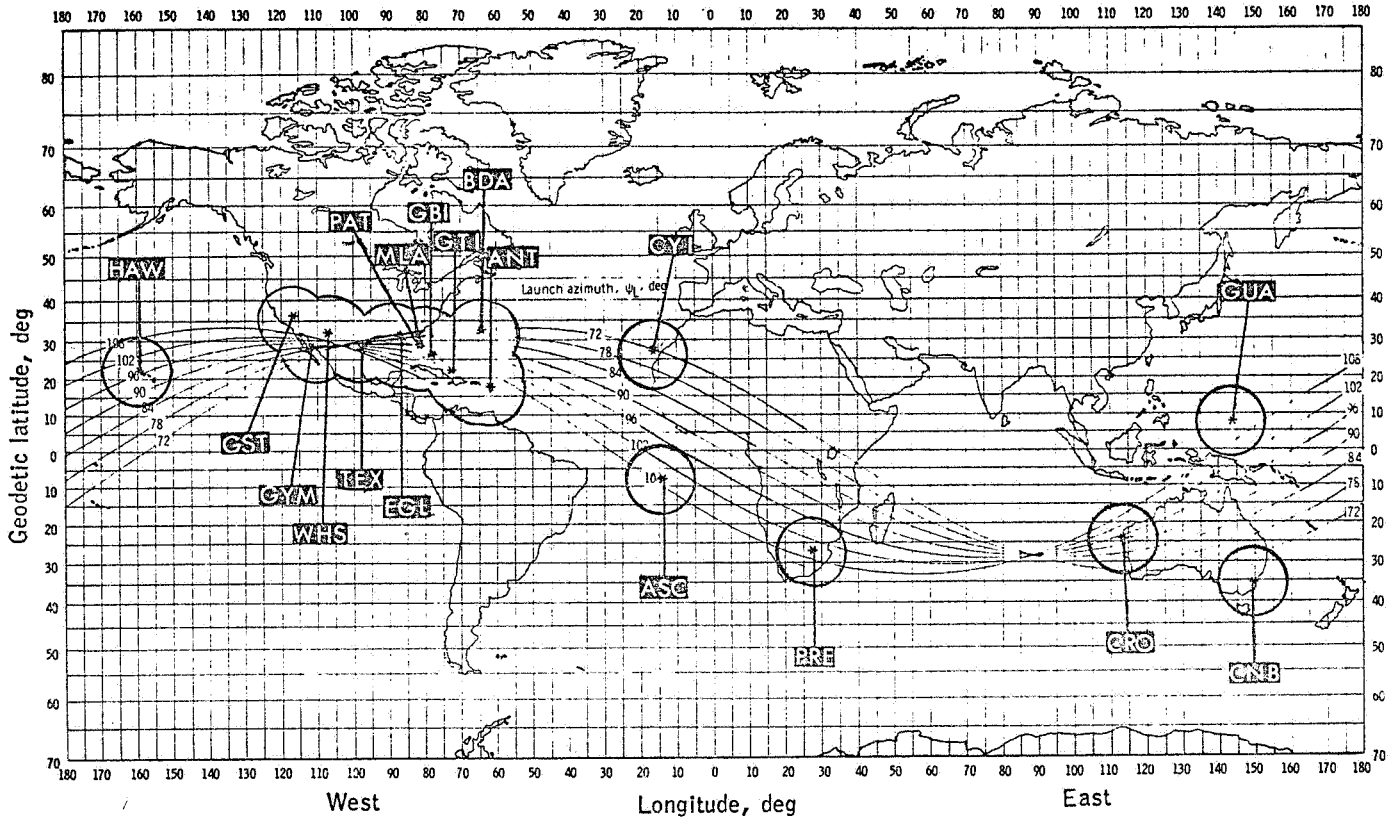
(b) Second revolution.

Figure 3.- Continued.



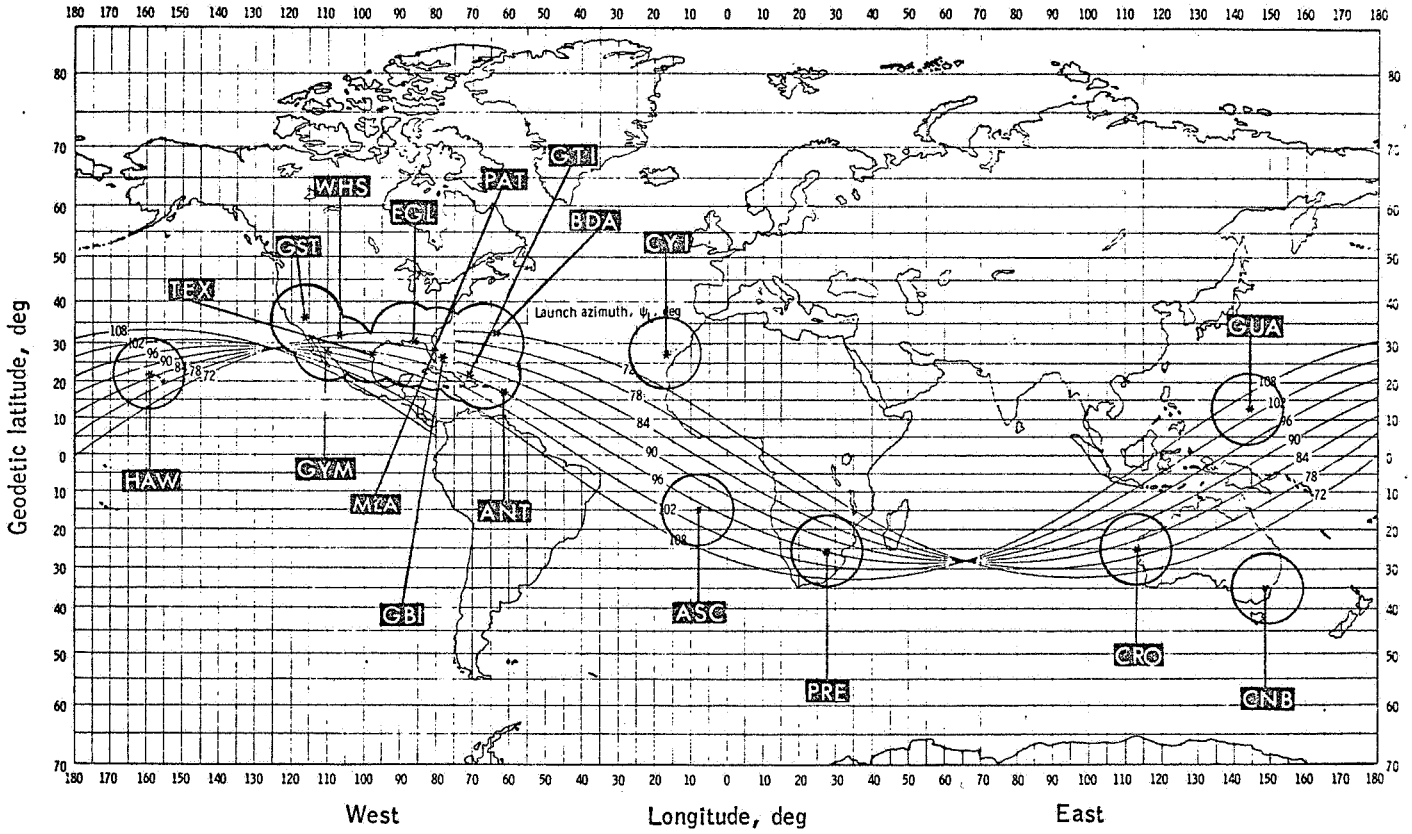
(c) Third revolution.

Figure 3.- Concluded.



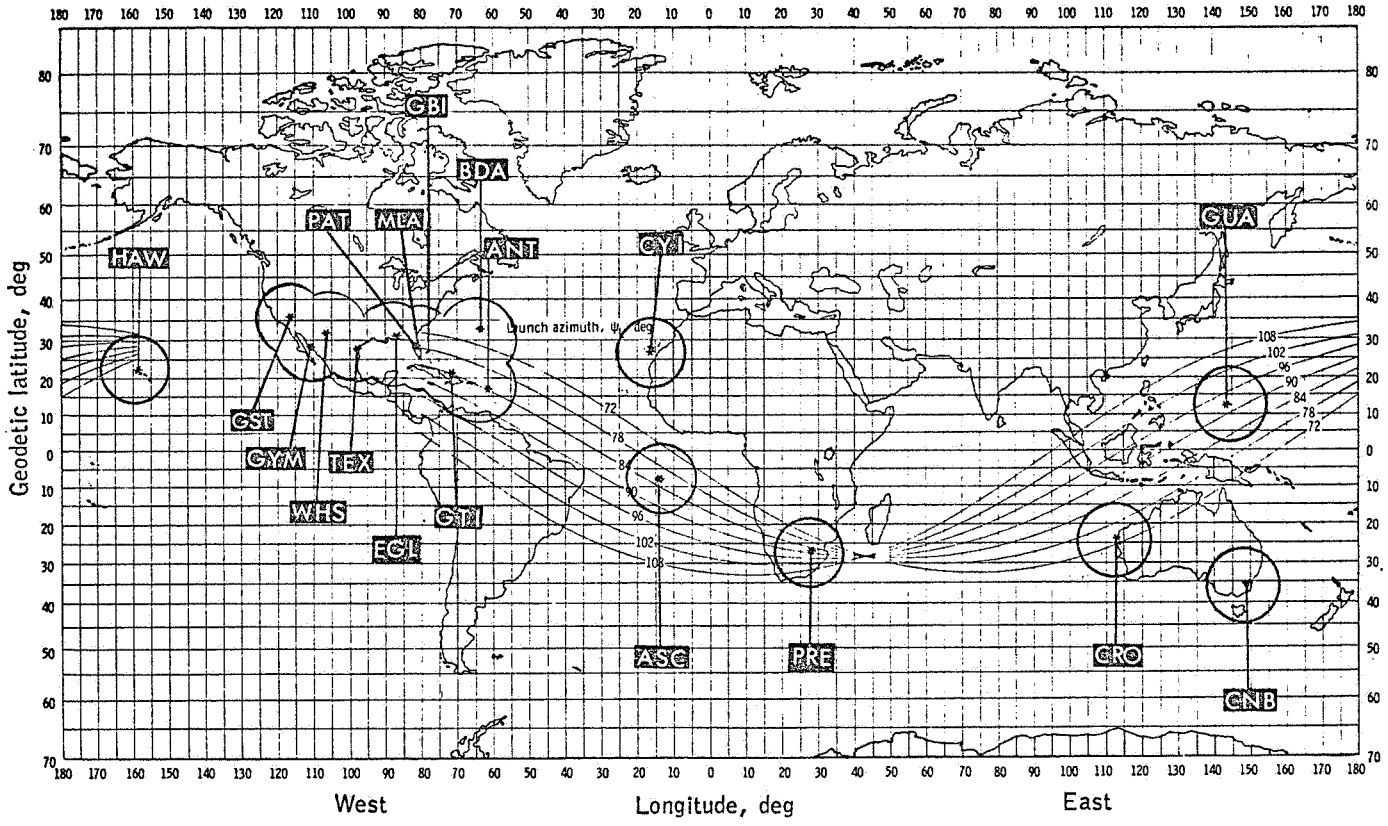
(a) First revolution.

Figure 4.- Earth parking orbit for launch azimuth 72 degrees through 108 degrees (180 degrees to 180 degrees map).



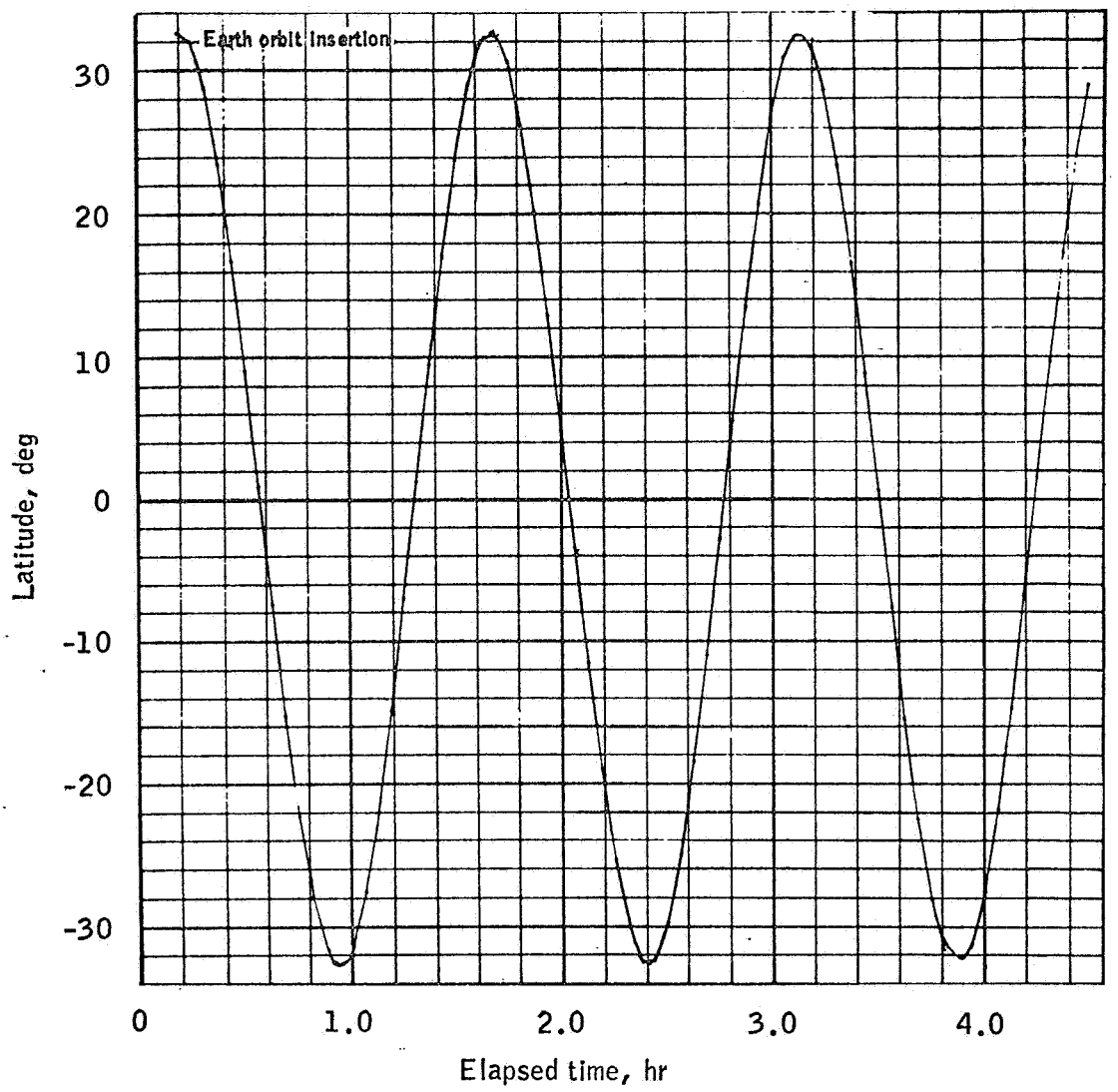
(b) Second revolution.

Figure 4.- Continued.



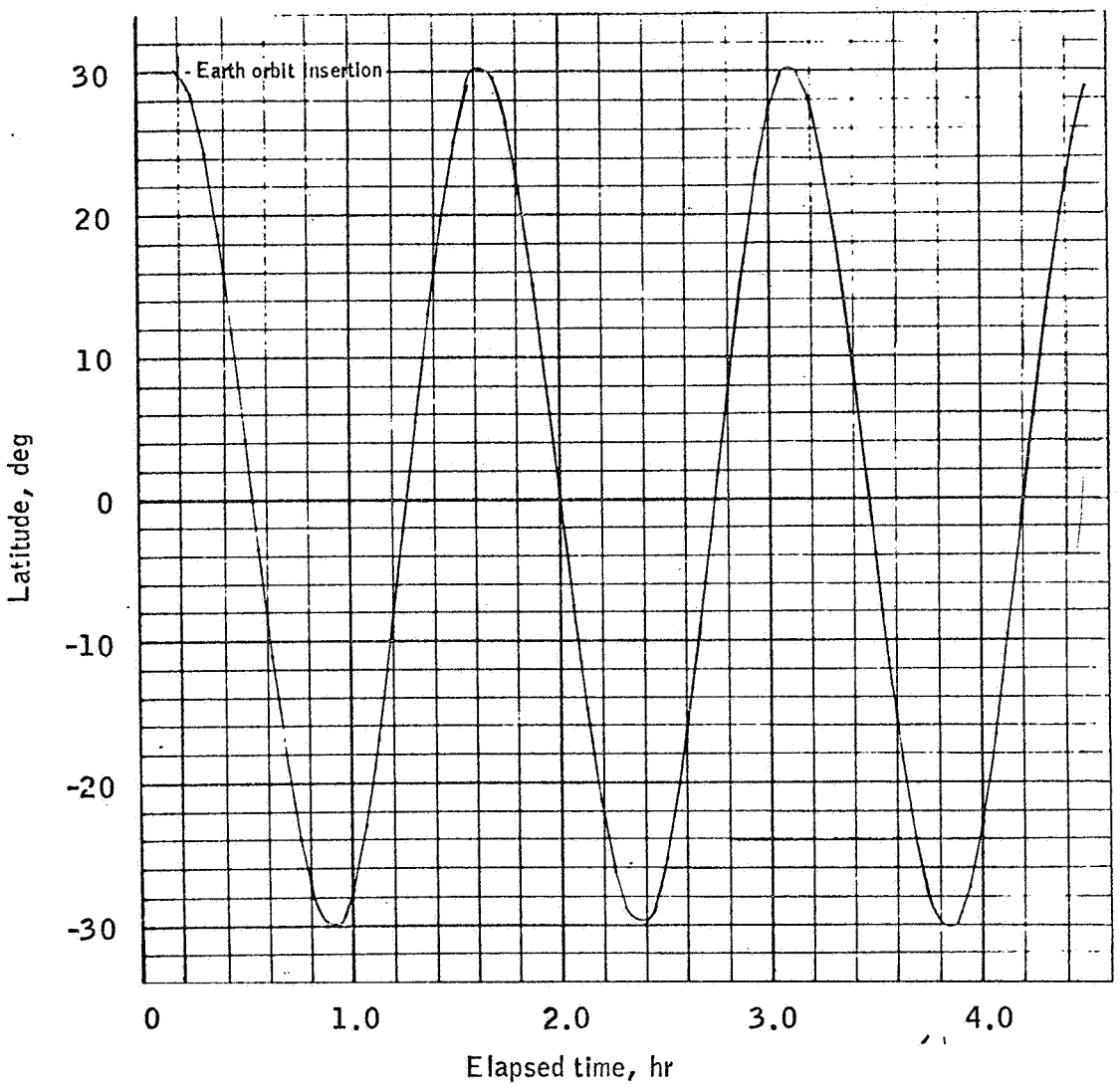
(c) Third revolution.

Figure 4.- Concluded.



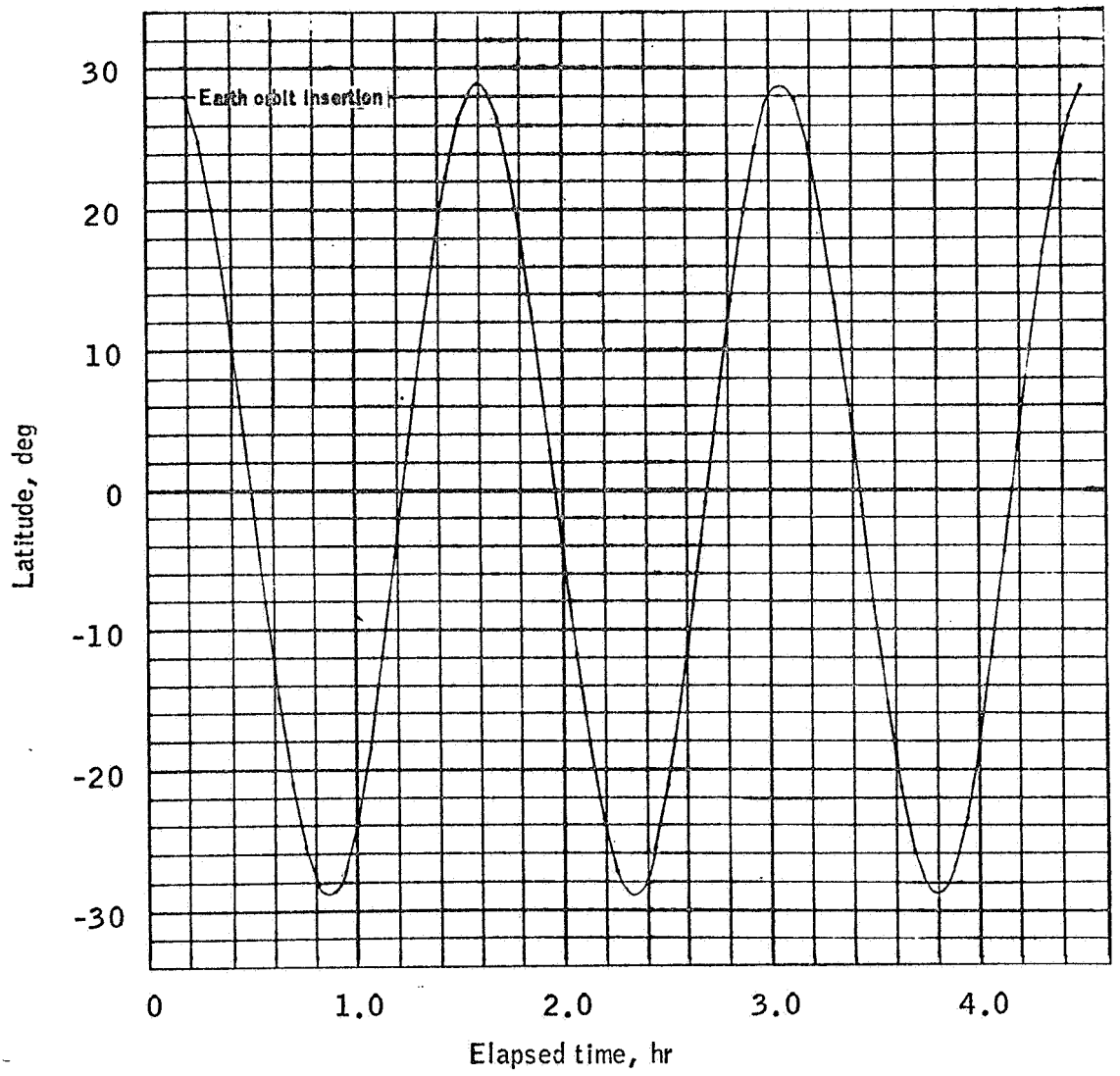
(a) 72-degree launch azimuth.

Figure 5.- Elapsed time from launch versus latitude for launch azimuth 72 degrees through 108 degrees, (100-nautical mile altitude earth parking orbit).



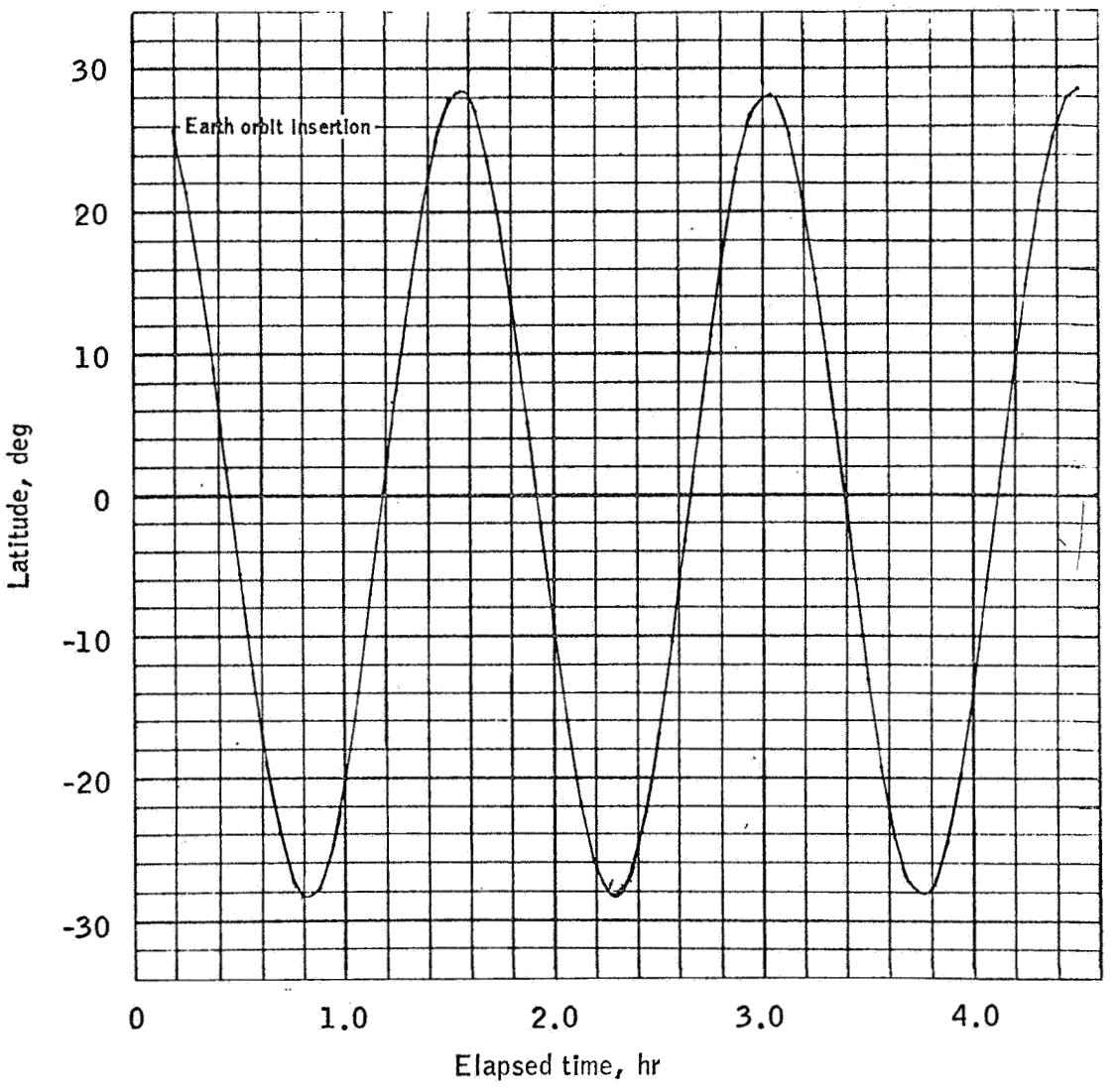
(b) 78-degree launch azimuth.

Figure 5.- Continued.



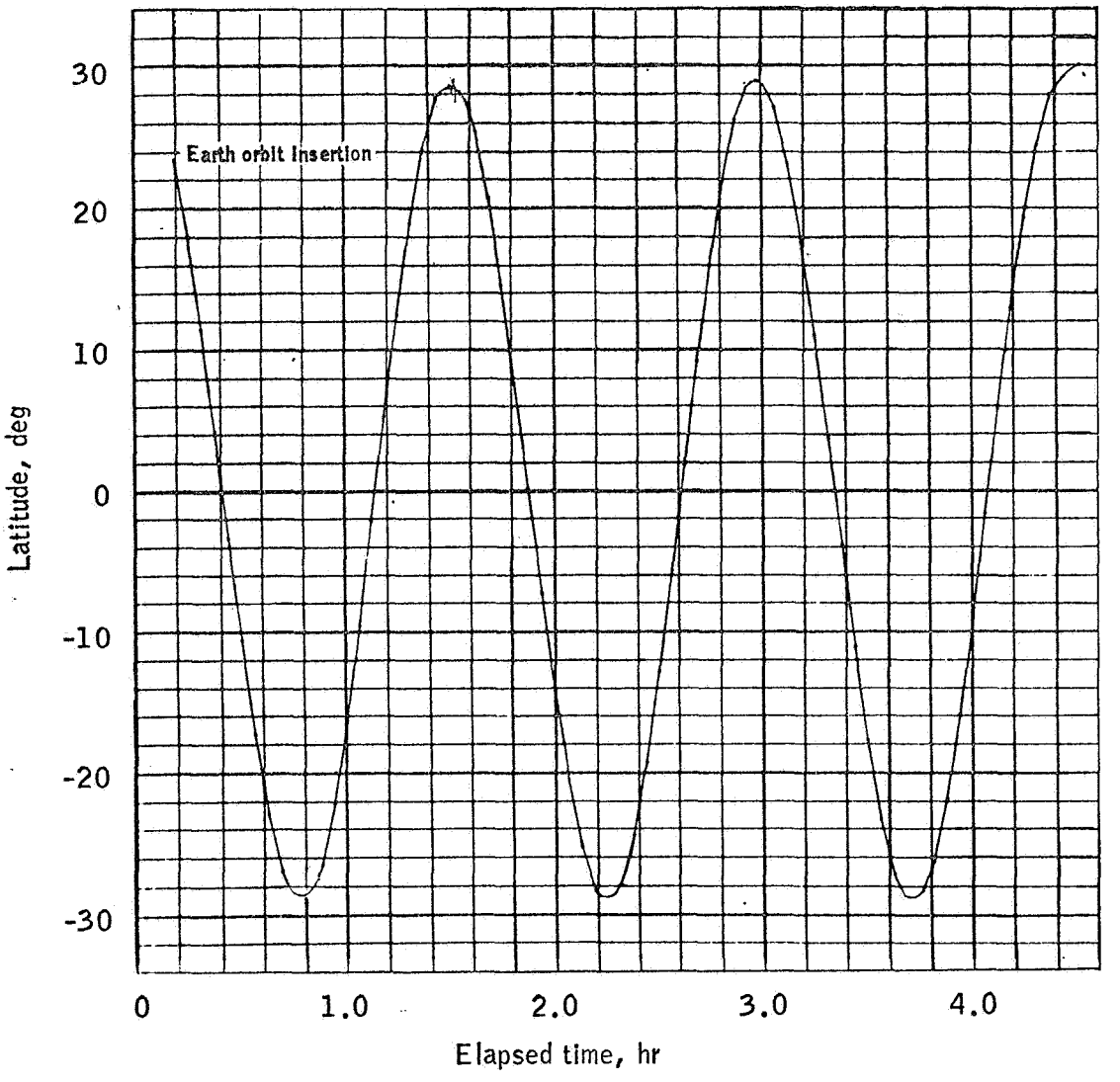
(c) 84-degree launch azimuth.

Figure 5.- Continued.



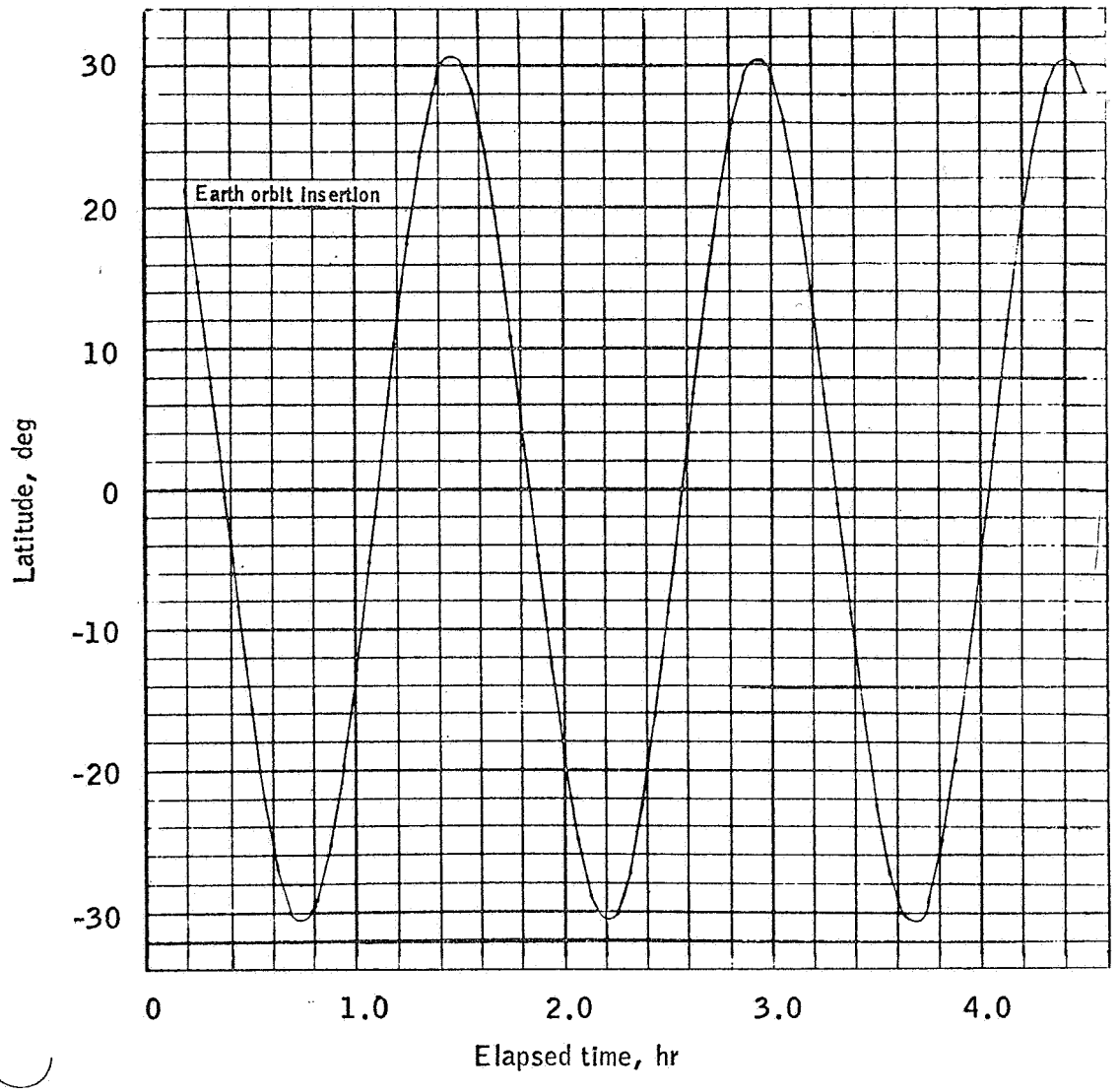
(d) 90-degree launch azimuth.

Figure 5.- Continued.



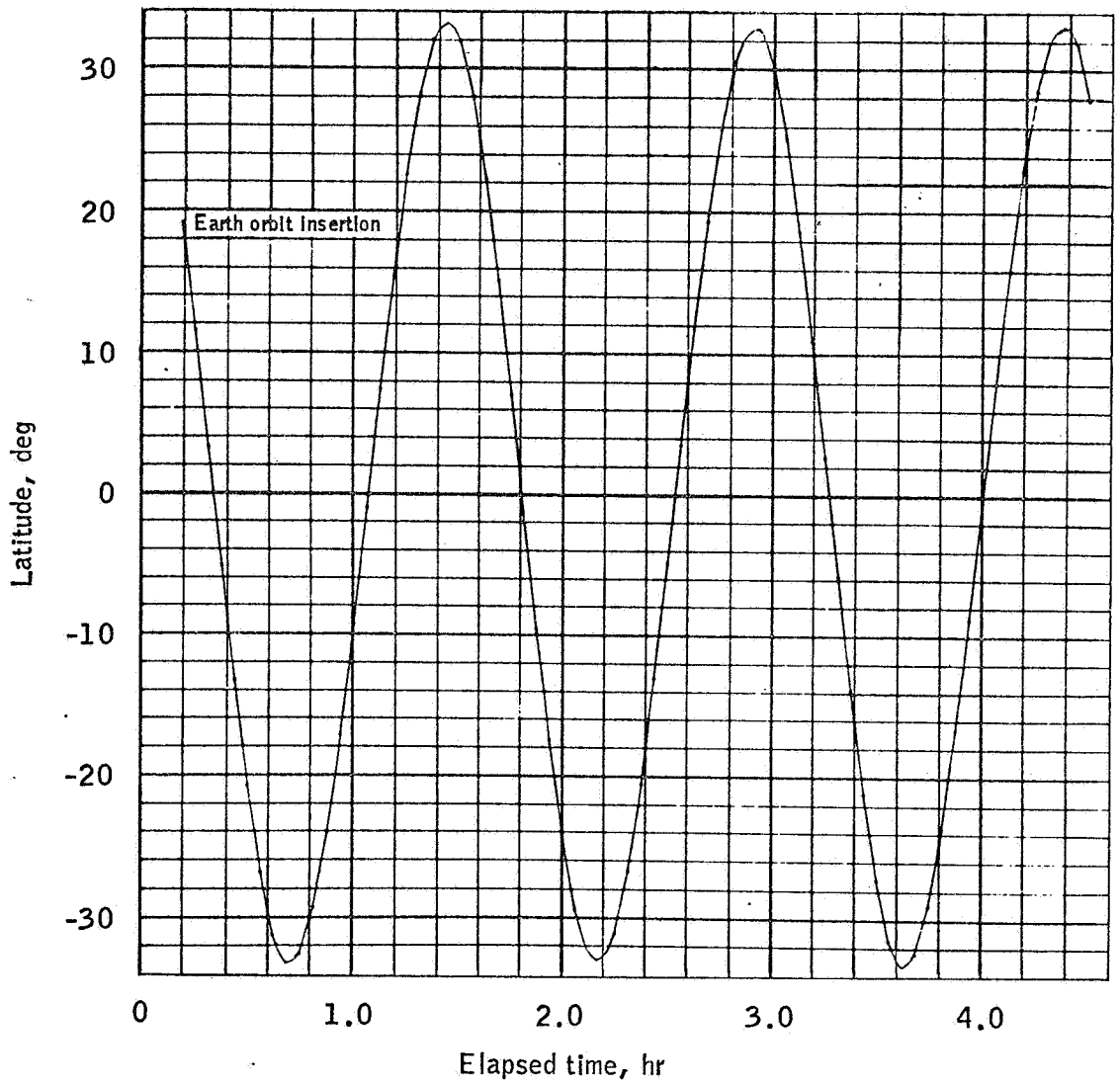
(e) 96-degree launch azimuth.

Figure 5.- Continued.



(f) 102-degree launch azimuth.

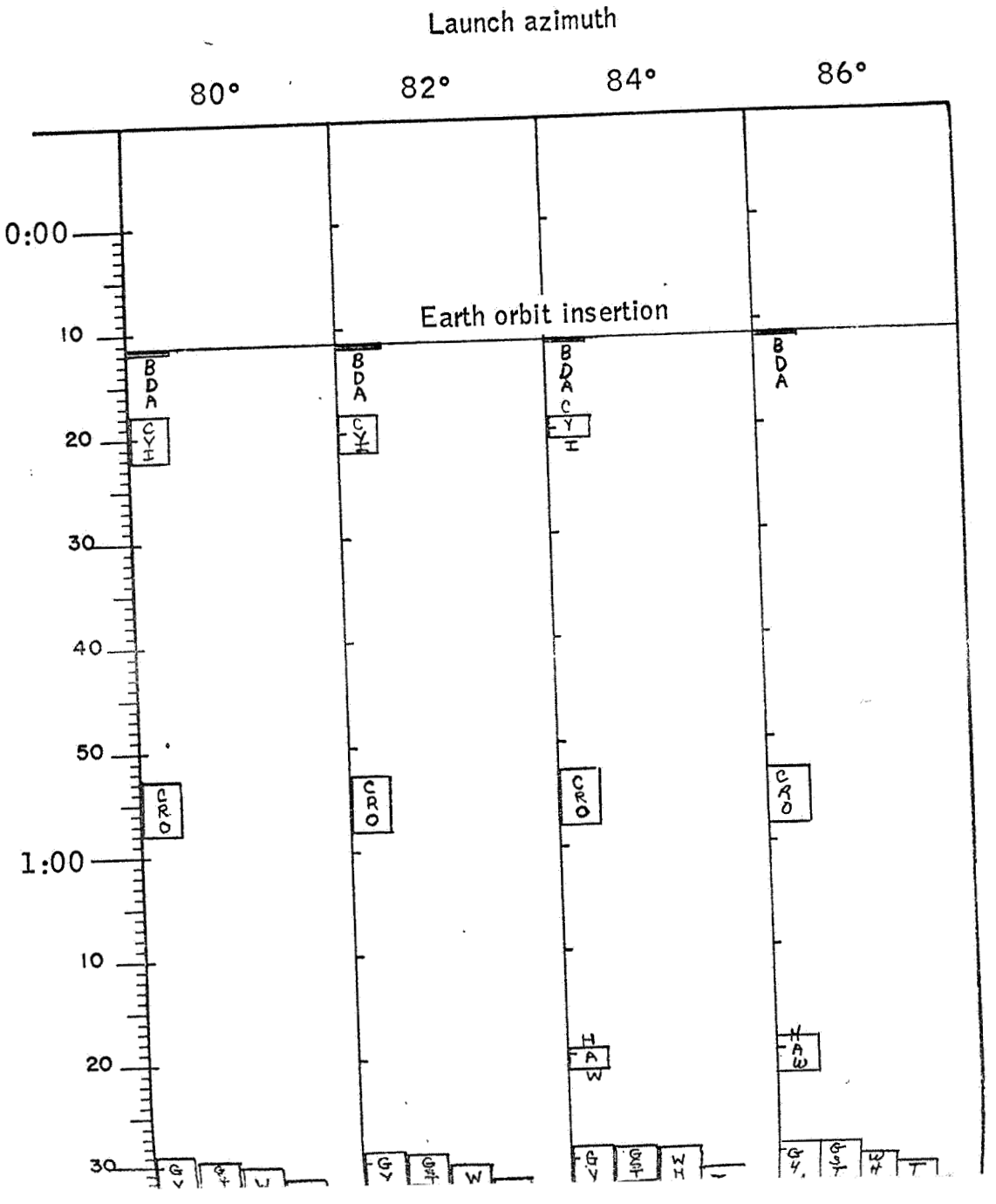
Figure 5.- Continued.



(g) 108-degree launch azimuth.

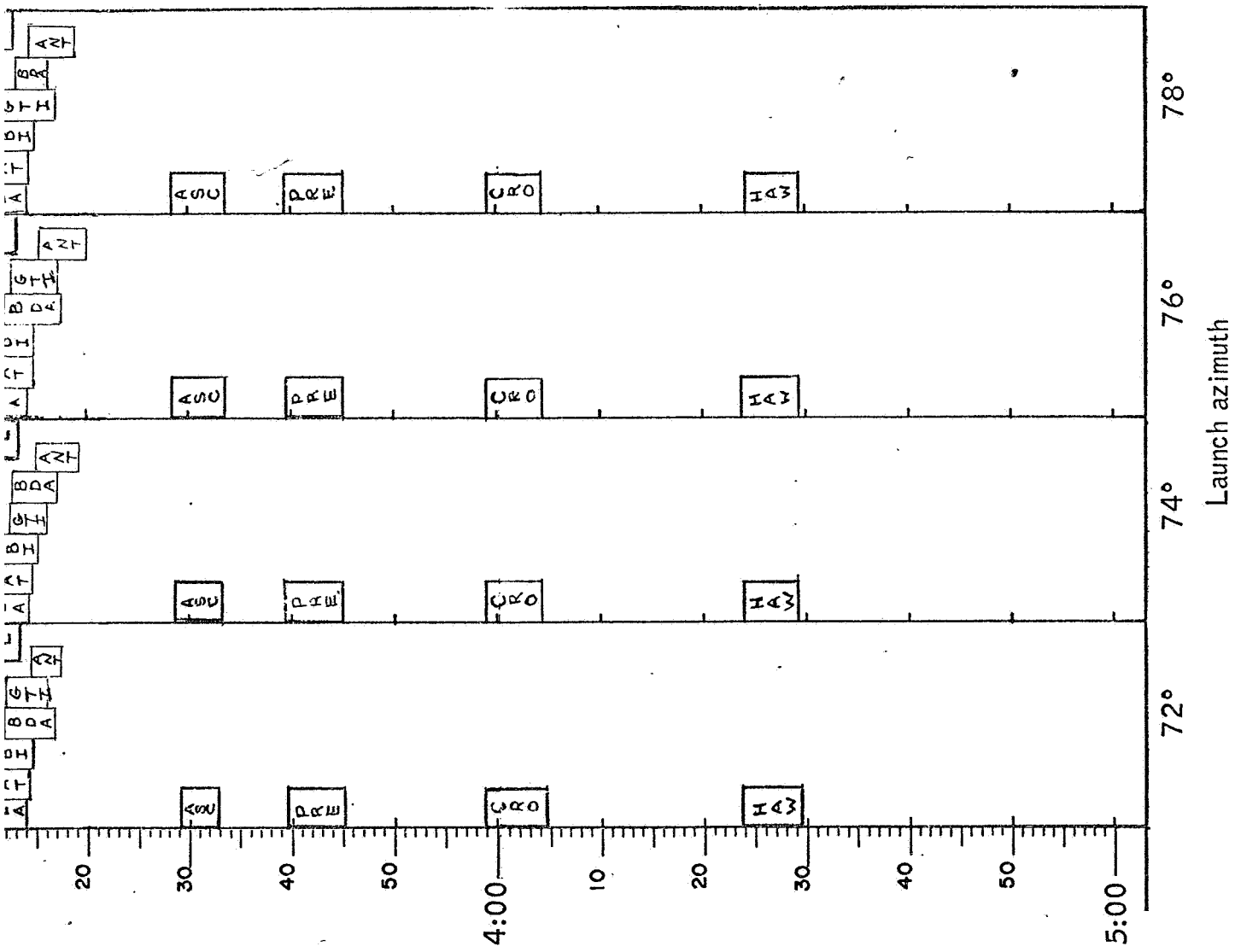
Figure 5.- Concluded.

#1


Launch azimuth
80°
82°
84°
86°
Earth orbit insertion
0:00
10
20
30
40
50
1:00
10
20
30
BDA
CYH
CRO
HAW
GY
GST
W
WH
T

Ground elapsed time, g.e.t., hr:min
2:00
3:00
30
40
50
10
20
30
40
50
10
20

2#

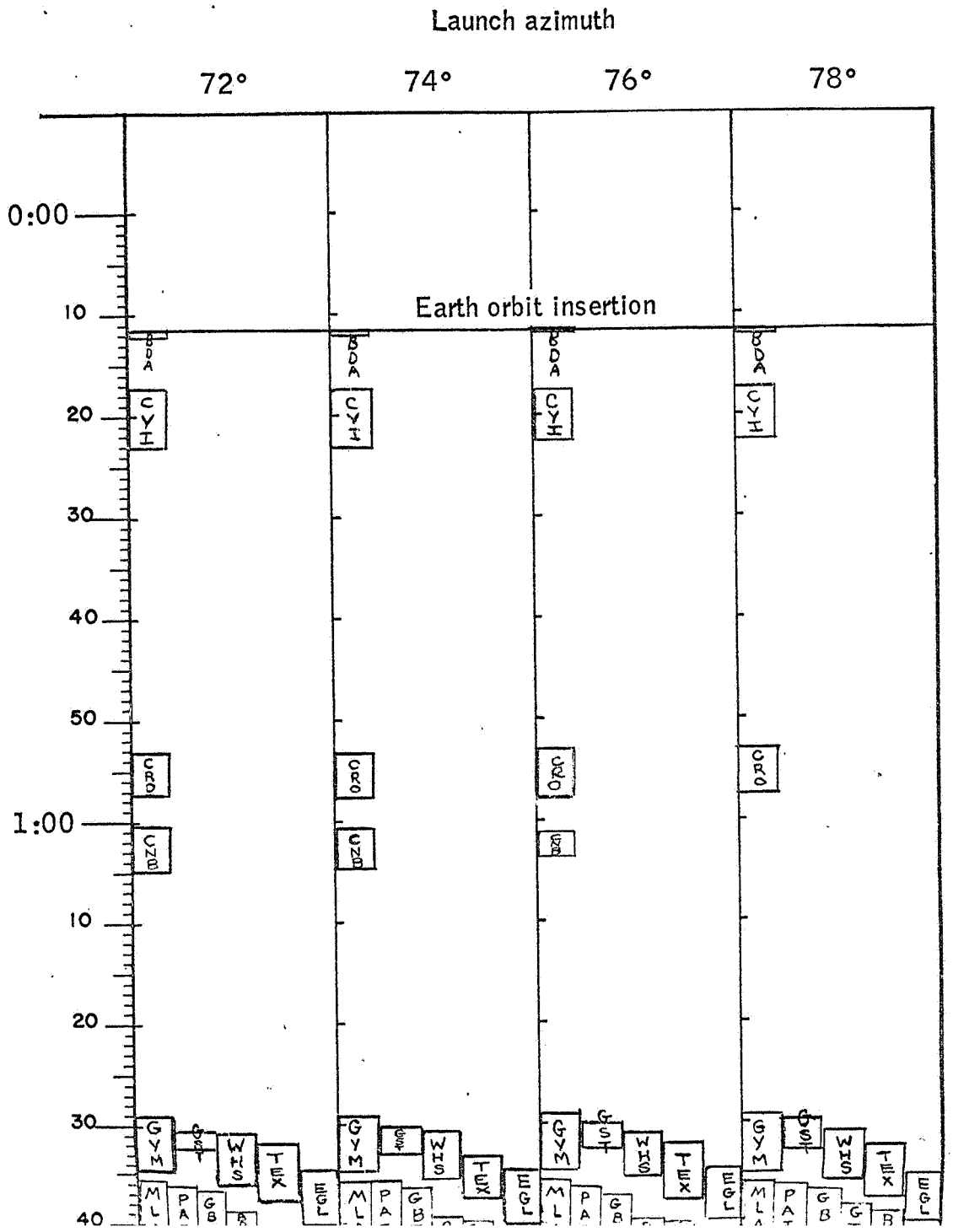


(a) 72-degree through 78-degree launch azimuths.

Figure 6.- Tracking history for various launch azimuths.

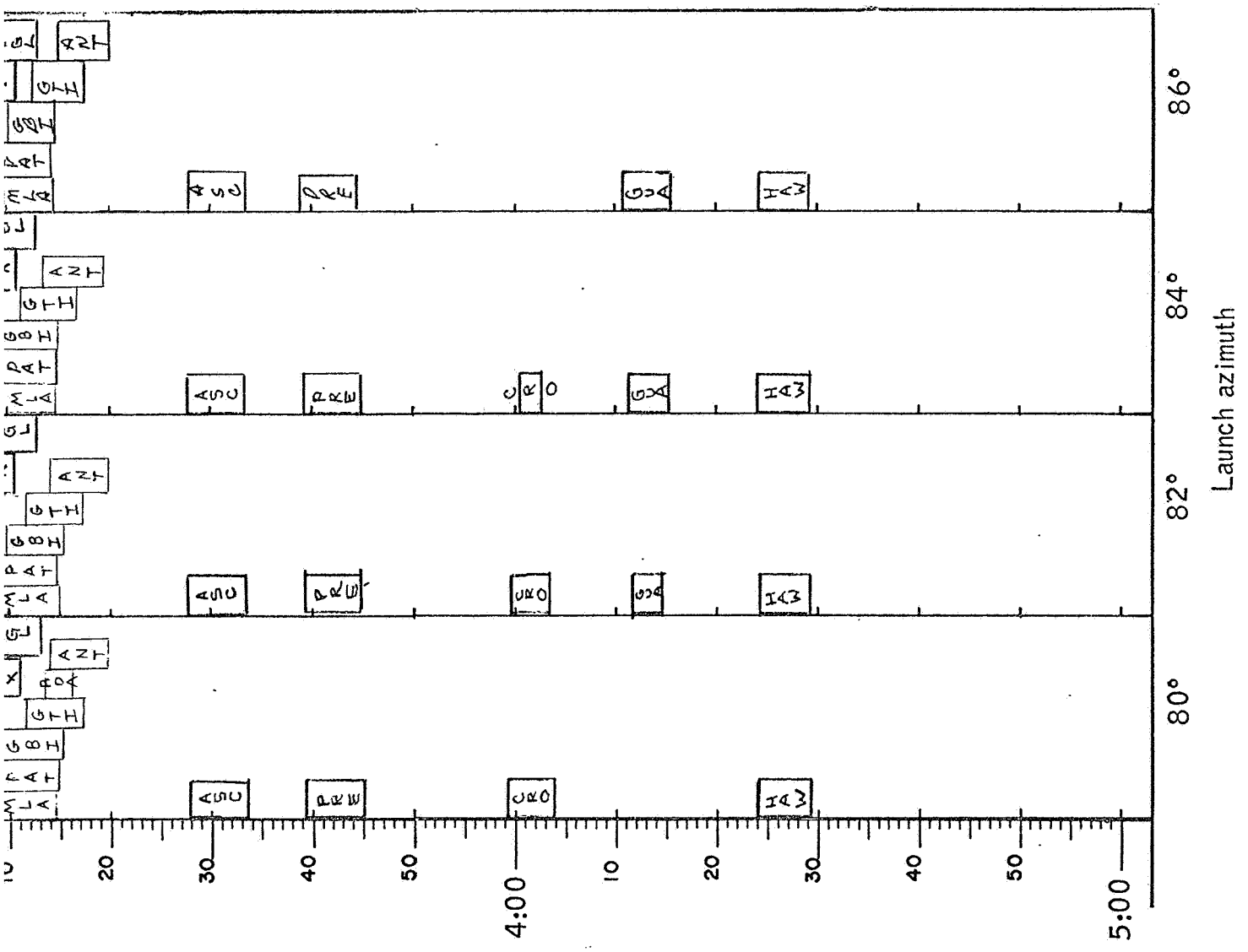
#3

#1


Launch azimuth
72°
74°
76°
78°
Earth orbit insertion
0:00
10
20
30
40
50
1:00
10
20
30
40
BDA
CYH
CRO
CZB
GYM
WHS
TEX
EGL
MLA
PAT
GB

Ground elapsed time, g.e.t, hr:min
2:00
3:00
30
40
50
10
20
30
40
50
10
20
30

#2

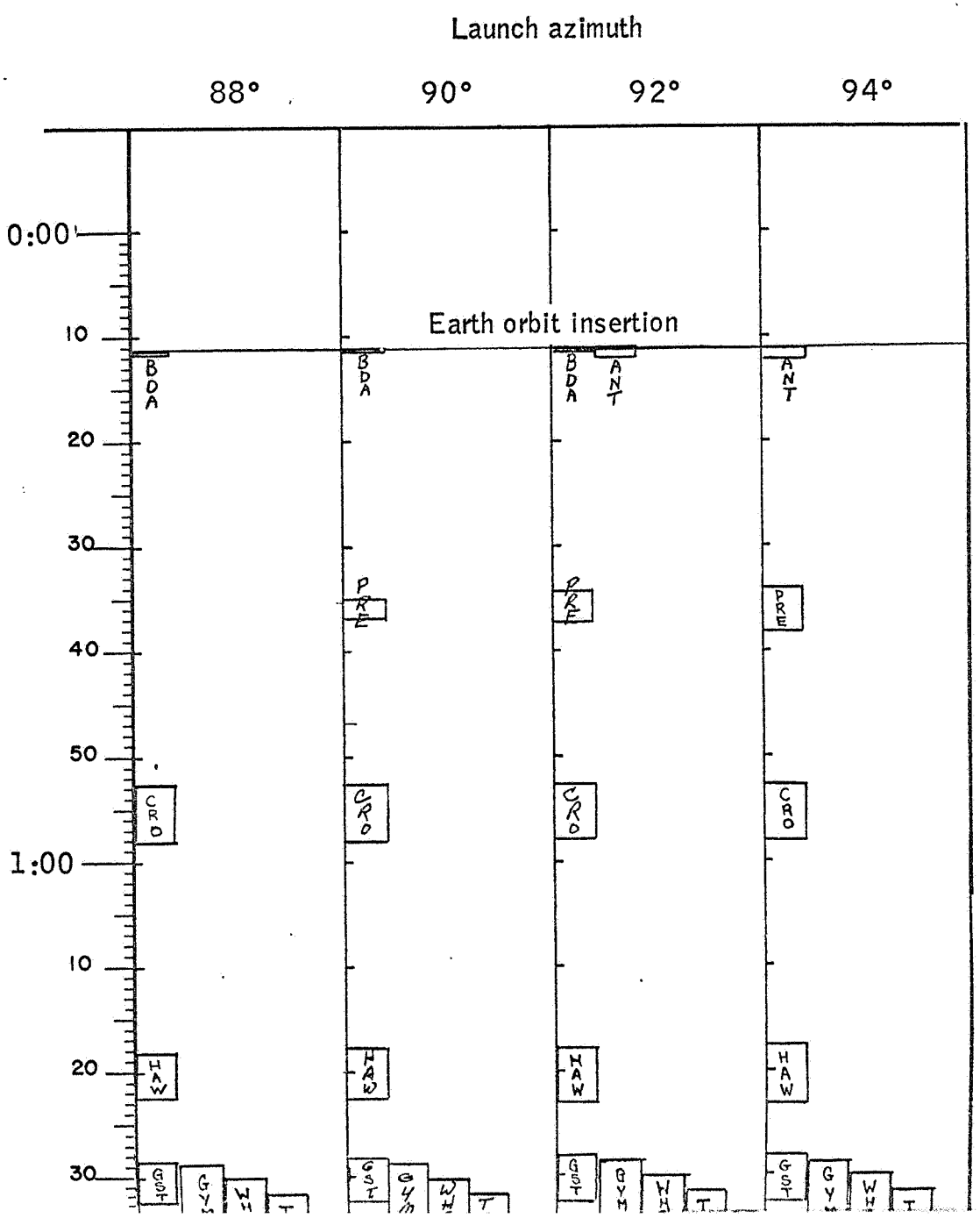


(b) 80-degree through 86-degree launch azimuths.

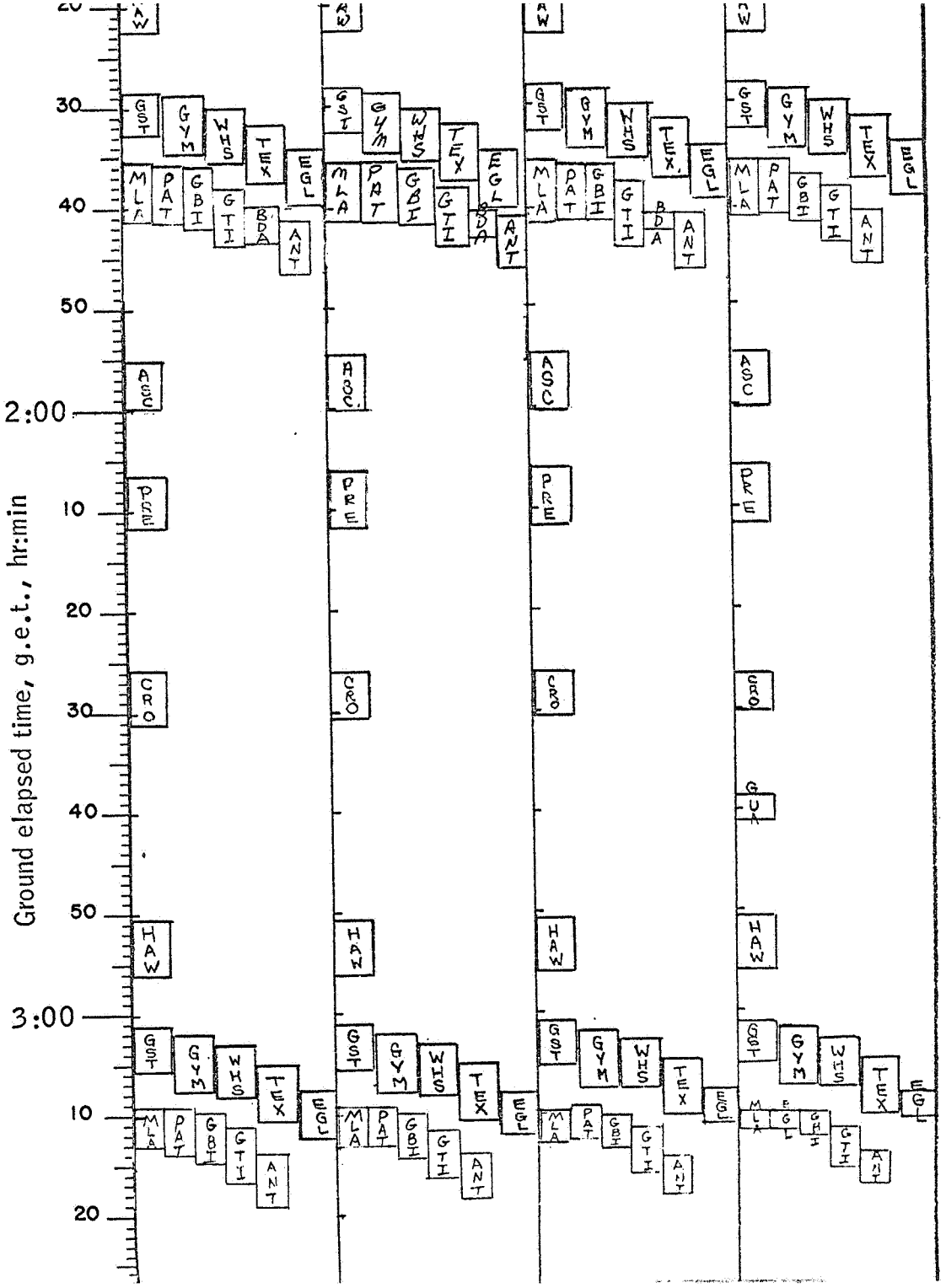
Figure 6.- Continued.

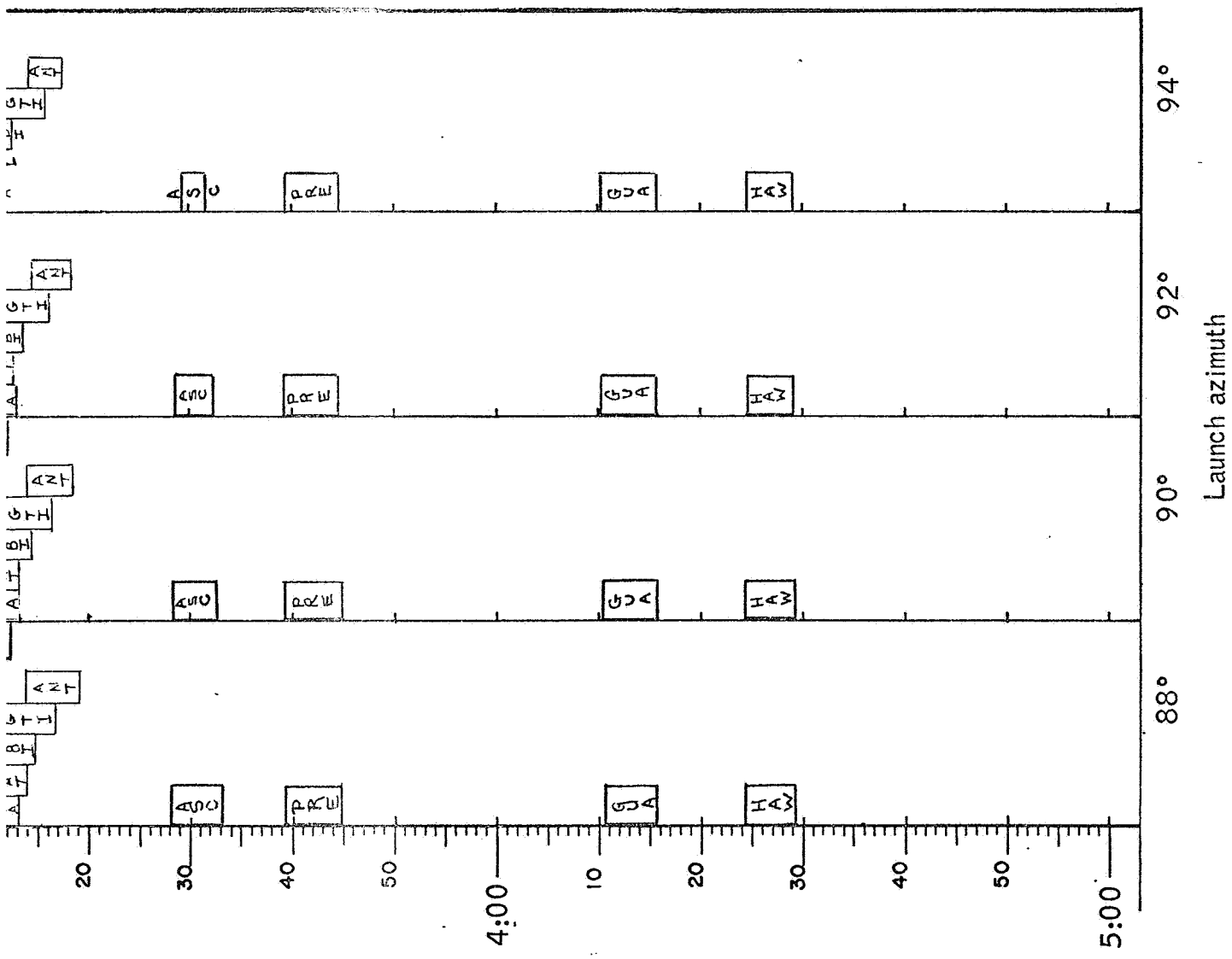
#3

#1


Launch azimuth
88°
90°
92°
94°
0:00
10
20
30
40
50
1:00
10
20
30
Earth orbit insertion
BDA
ANT
PRE
CRO
HAW
GST
GYM
WH
T

#2

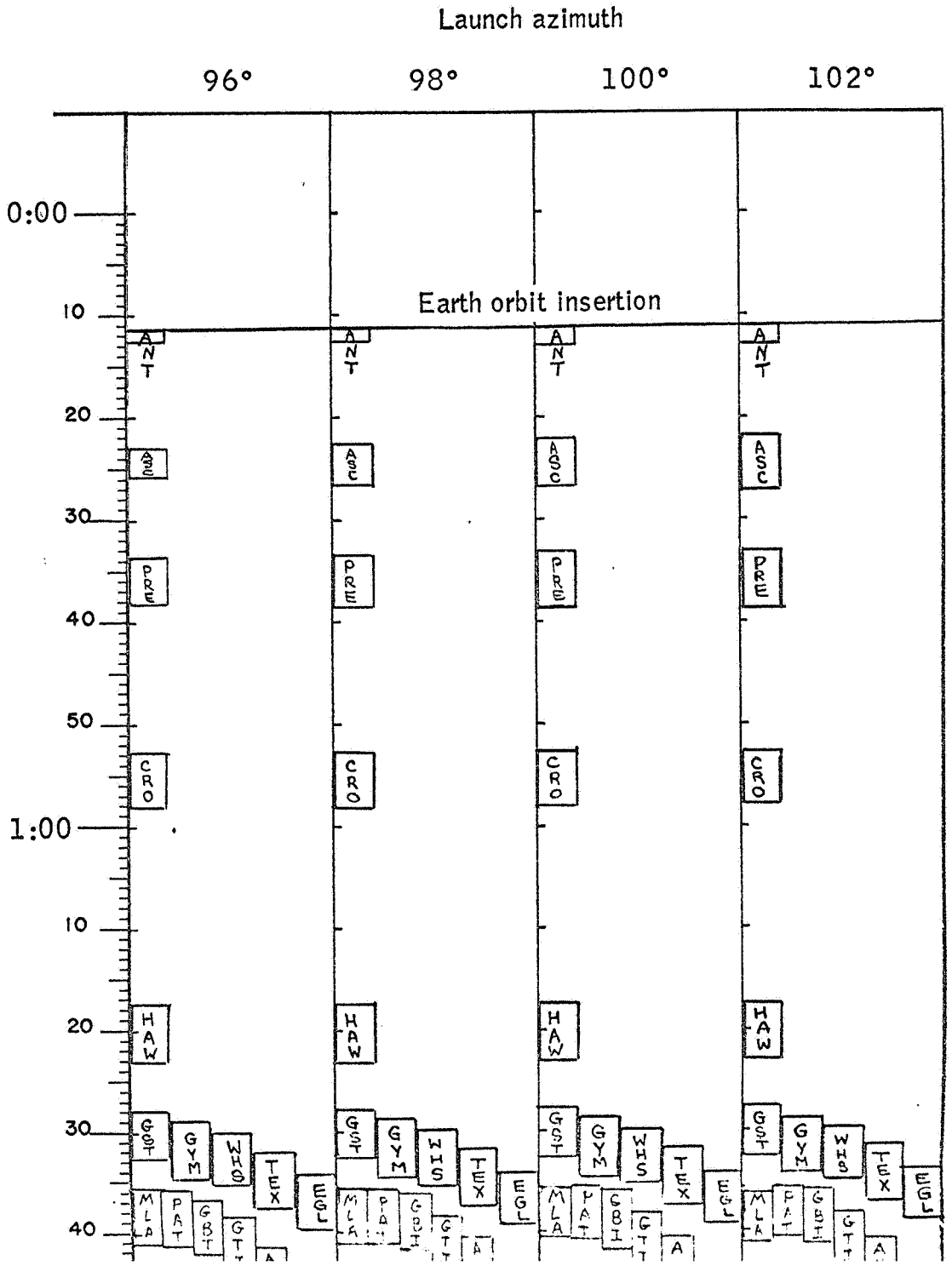

Ground elapsed time, g.e.t., hr:min
2:00
3:00
10
20
30
40
50
AW
GST
GYM
WHS
TEX
EGL
MLA
PAT
GBI
GTI
BDA
ANT
ASC
PRE
CRO
GUA
HAW



(c) 88-degree through 94-degree launch azimuths.

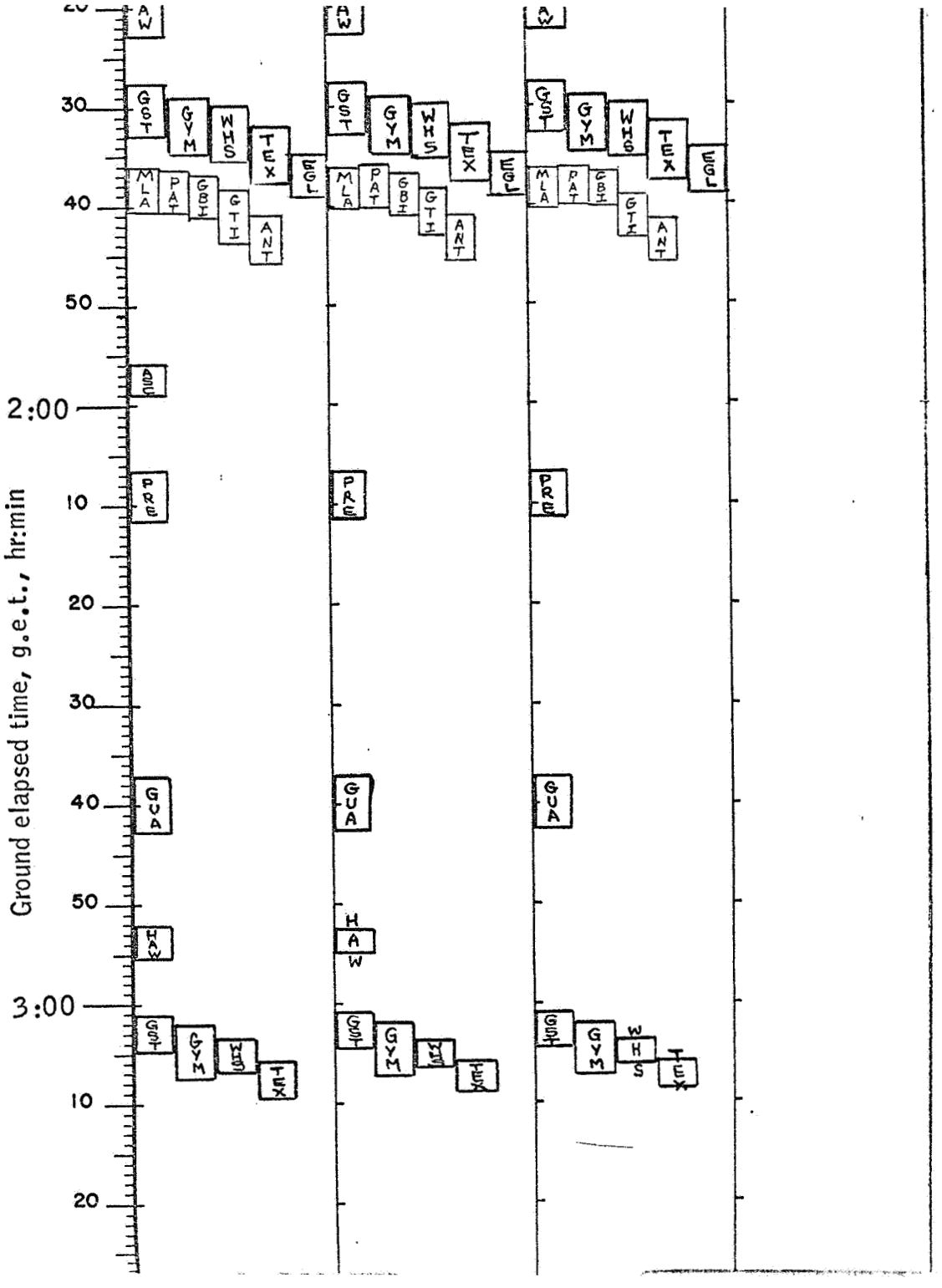
Figure 6.- Continued.

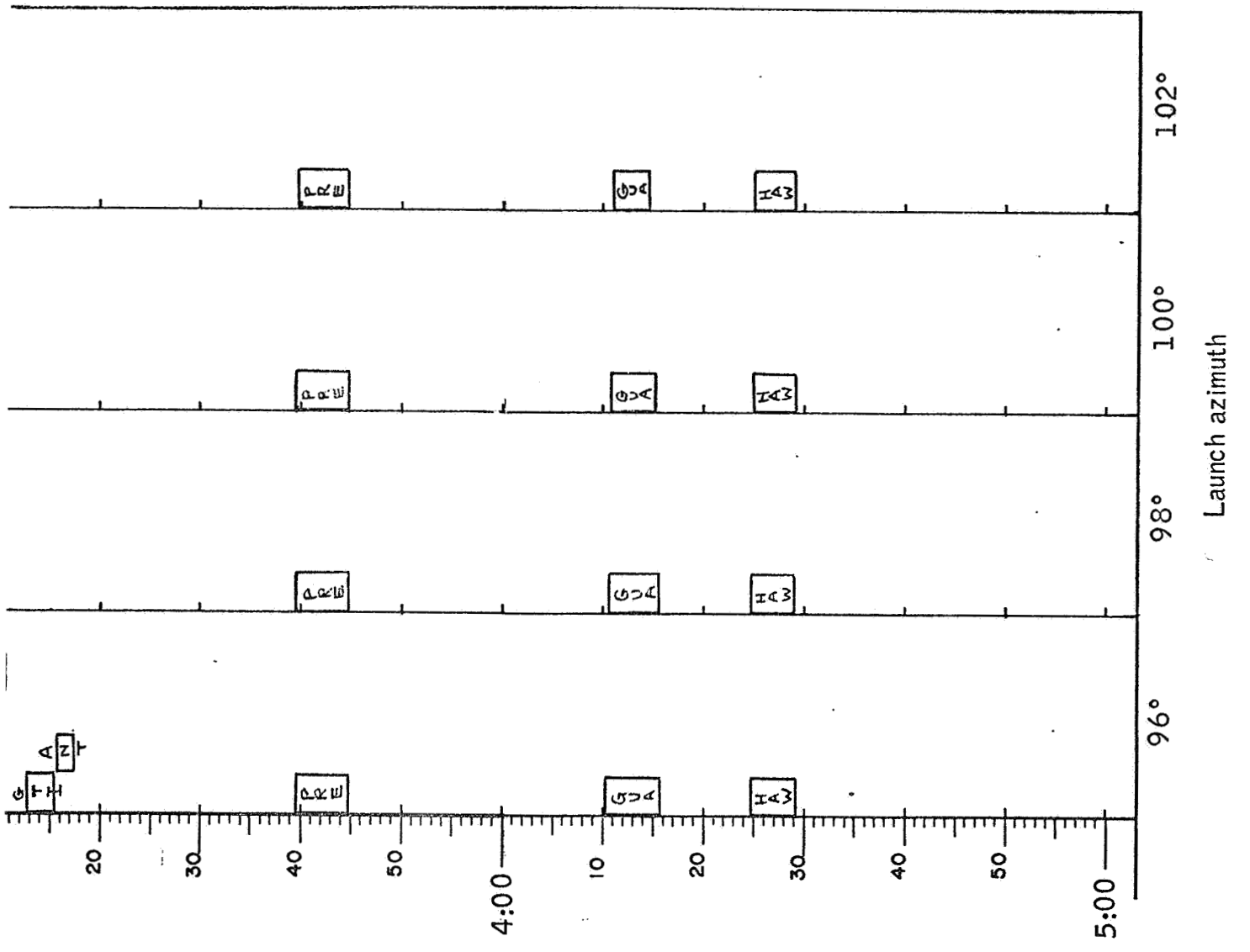
#3


Launch azimuth
96°
98°
100°
102°
0:00
10
20
30
40
50
1:00
10
20
30
40
Earth orbit insertion
ANT
ASC
PRE
CRO
HAW
GST
GYM
WHS
TEX
EGL
MLA
PAT
GBT
GBI
GTT
A

#1

#2


Ground elapsed time, g.e.t., hr:min
2:00
3:00
AW
GST
GYM
WHS
TEX
EGL
MLA
PAT
GBI
GTI
ANT
PRE
GUA
HAW

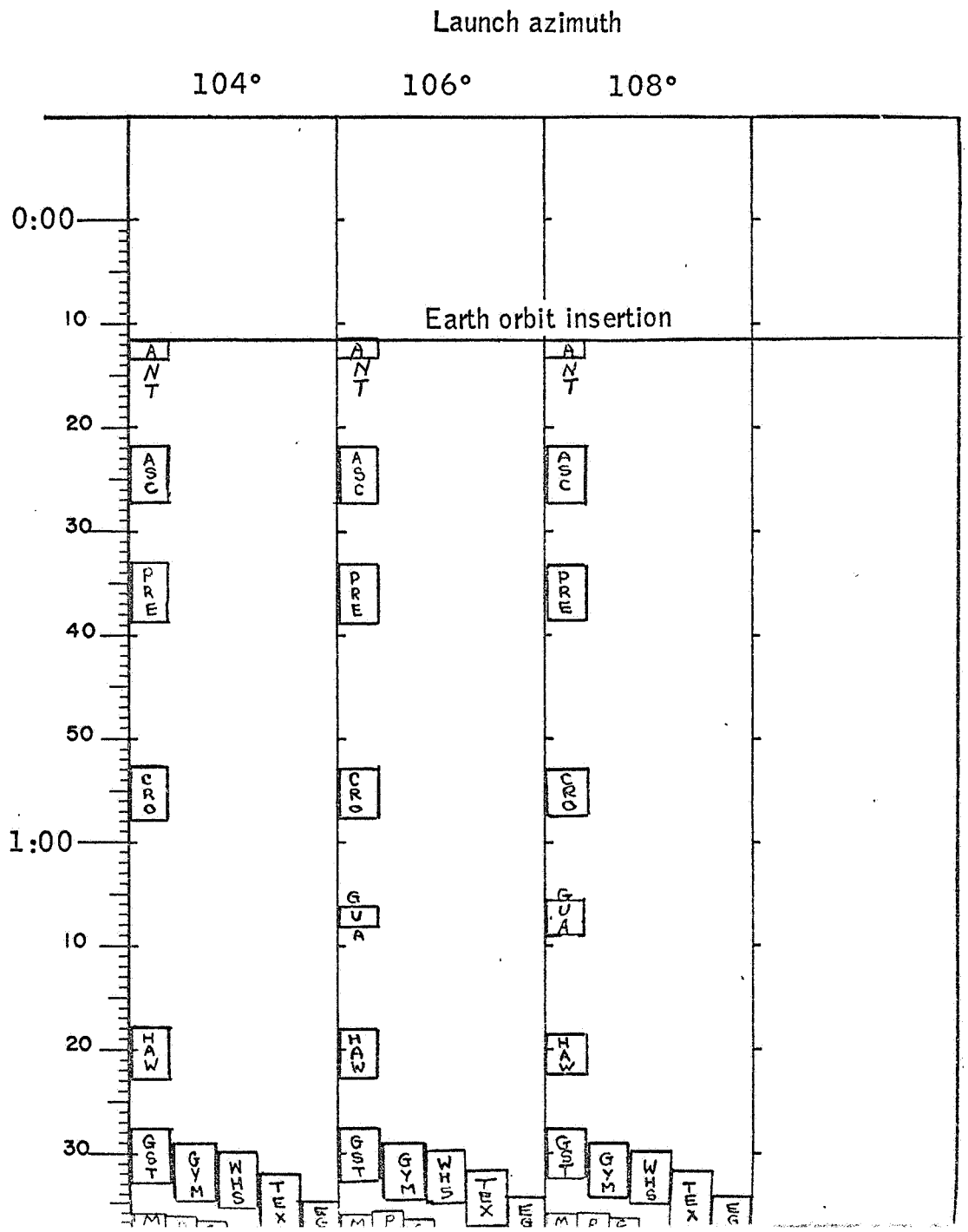


(d) 96-degree through 102-degree launch azimuths.

Figure 6.- Continued.

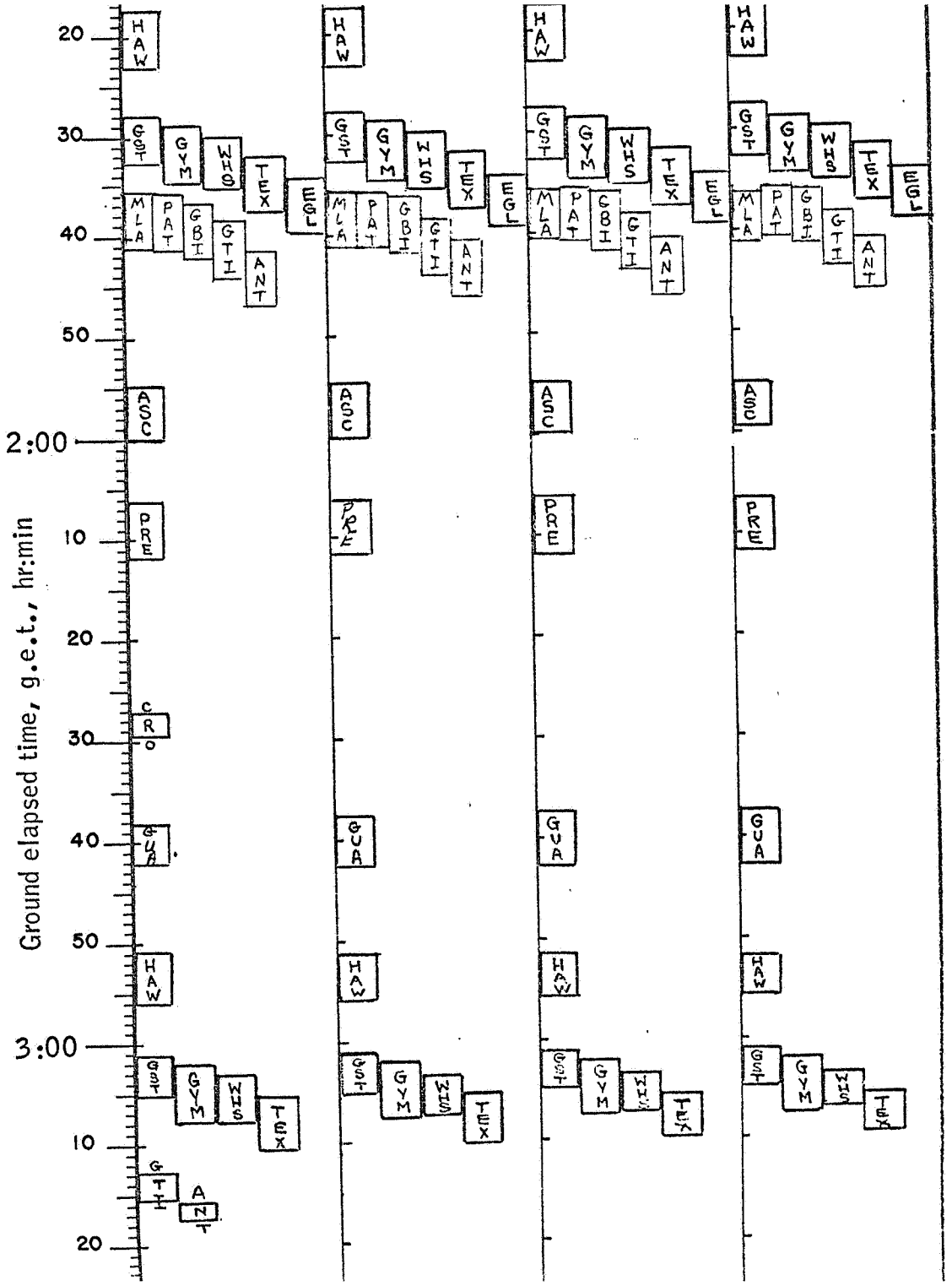
#3

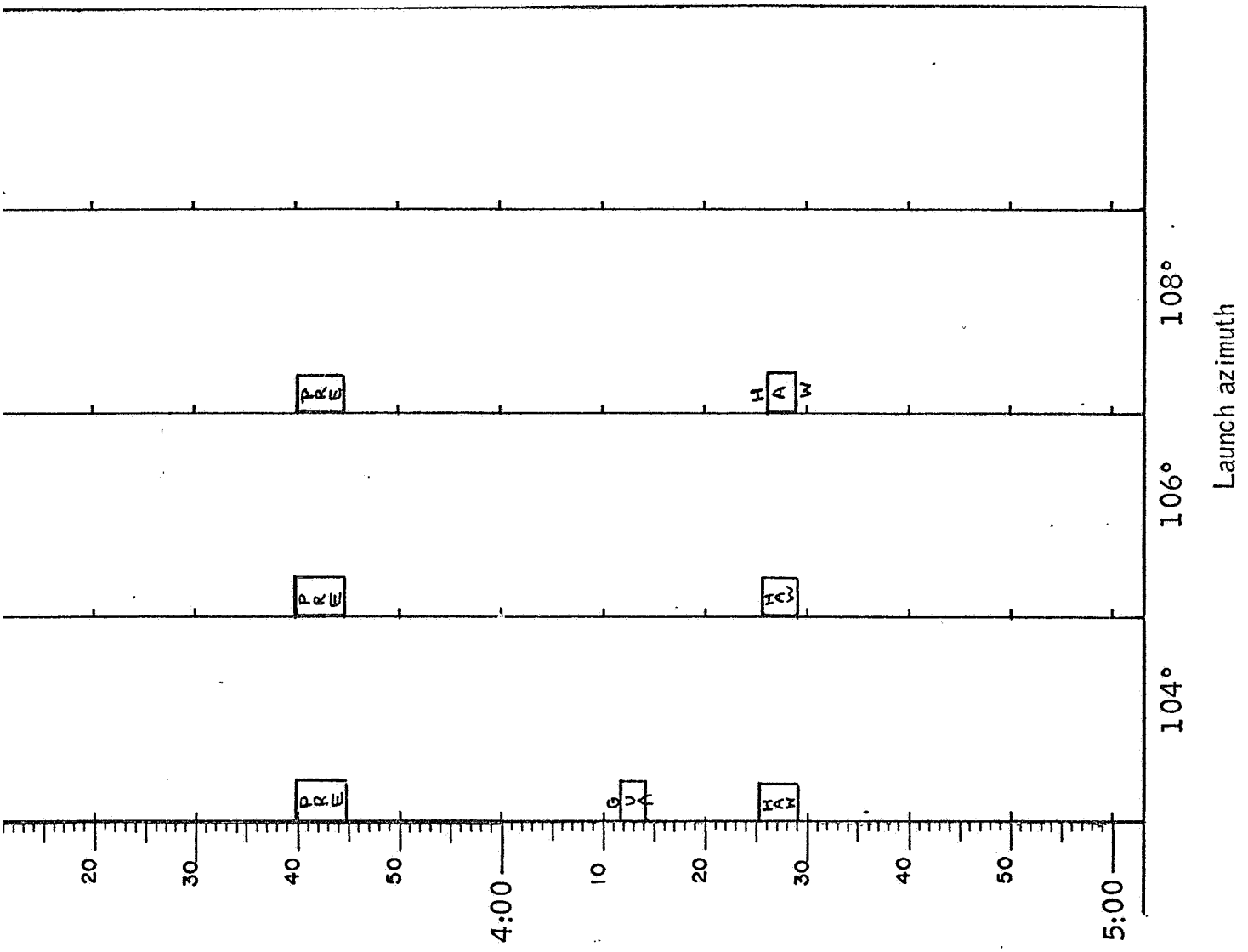
#1



Launch azimuth
104°
106°
108°
0:00
10
20
30
40
50
1:00
10
20
30
Earth orbit insertion
ANT
ASC
PRE
CRO
GUA
HAW
GST
GYM
WHS
TEX

#2


HAW
GST
GYM
WHS
TEX
EGL
MLA
PAT
GBI
GTI
ANT
ASC
PRE
CRO
GUA
Ground elapsed time, g.e.t., hr:min
20
30
40
50
2:00
10
20
30
40
50
3:00
10
20

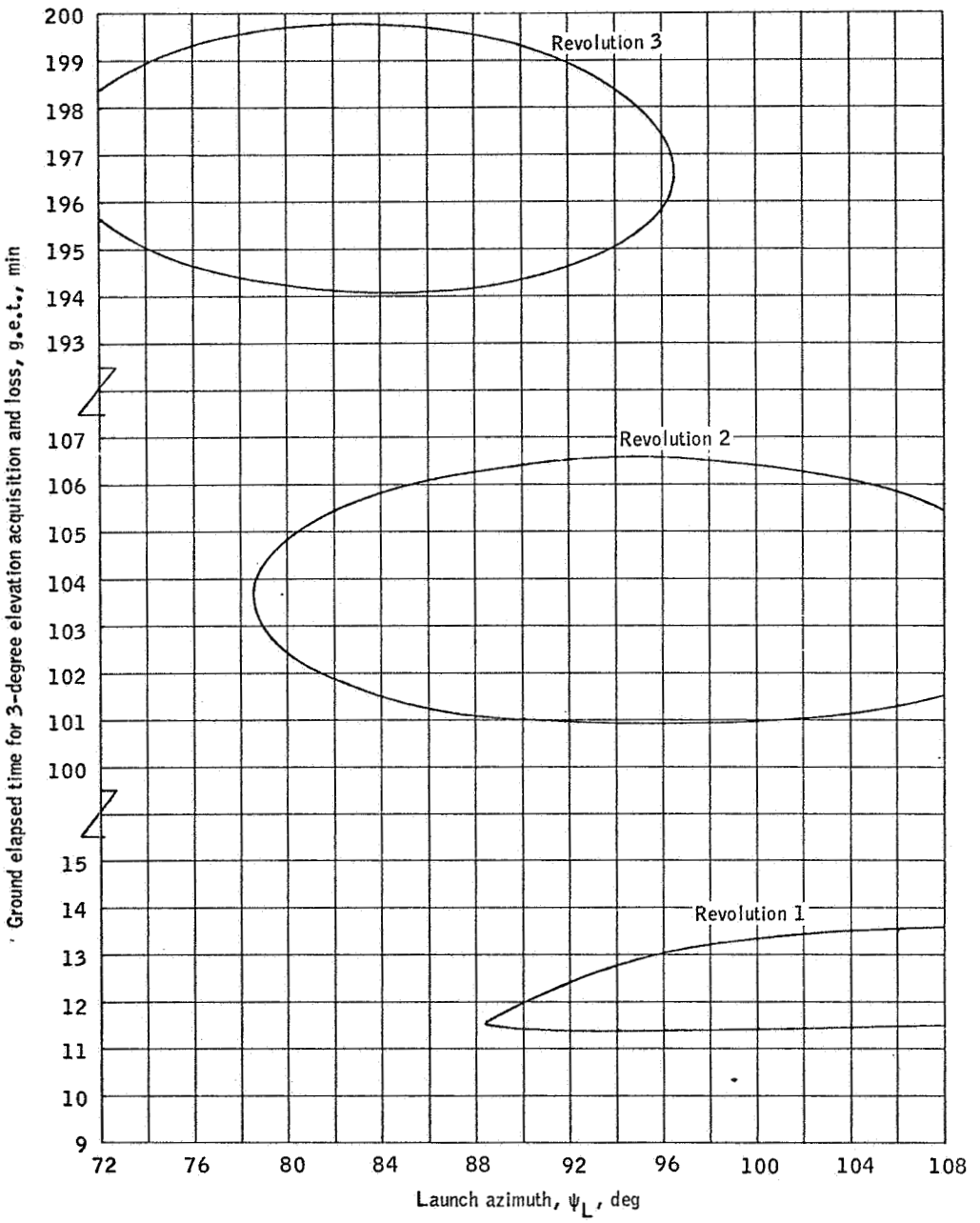


(e) 104-degree through 108-degree launch azimuths.

Figure 6.- Concluded.

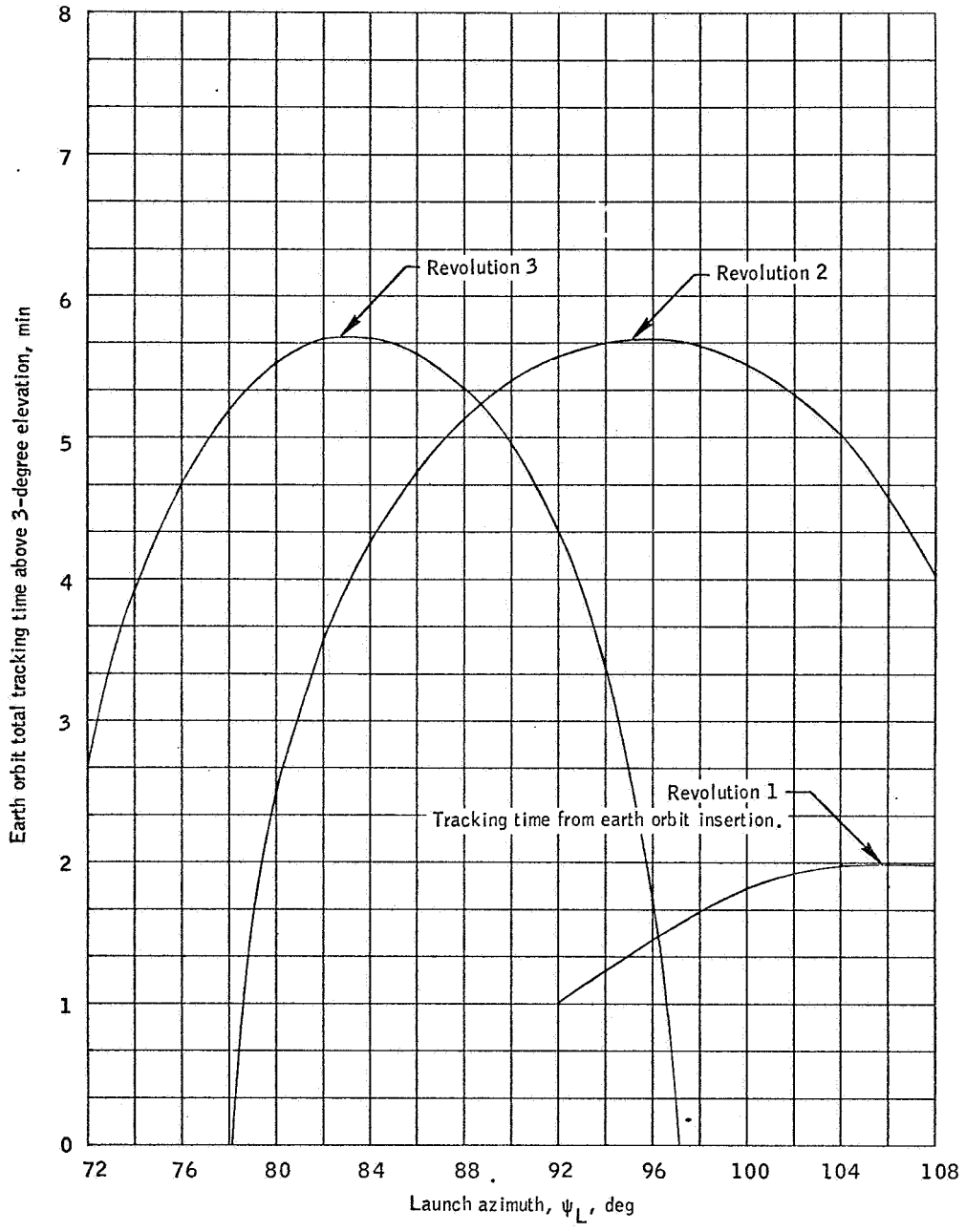
#3

MSC 687-68



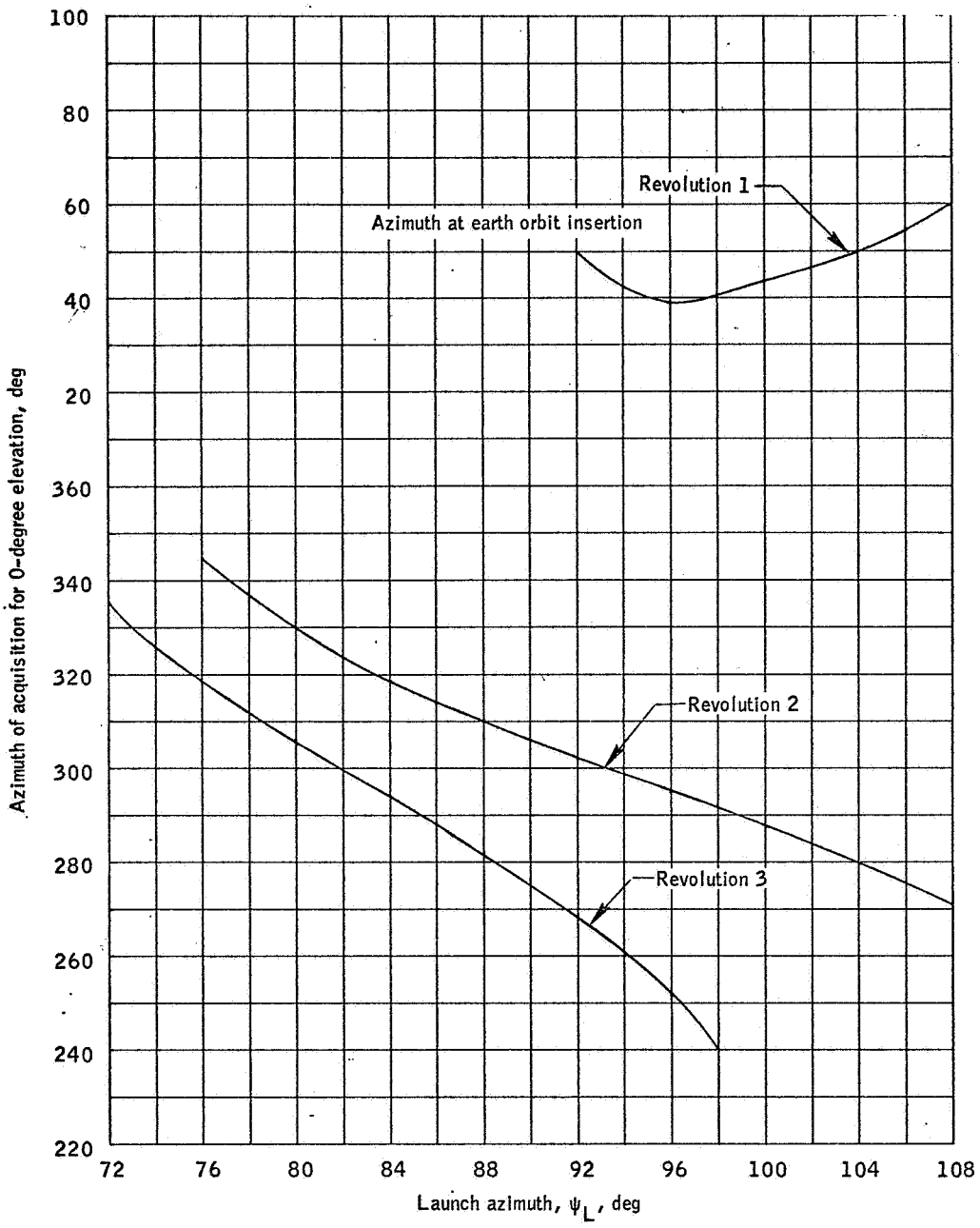
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 7.- Antigua radar tracking information for the first three revolutions as a function of launch azimuth.



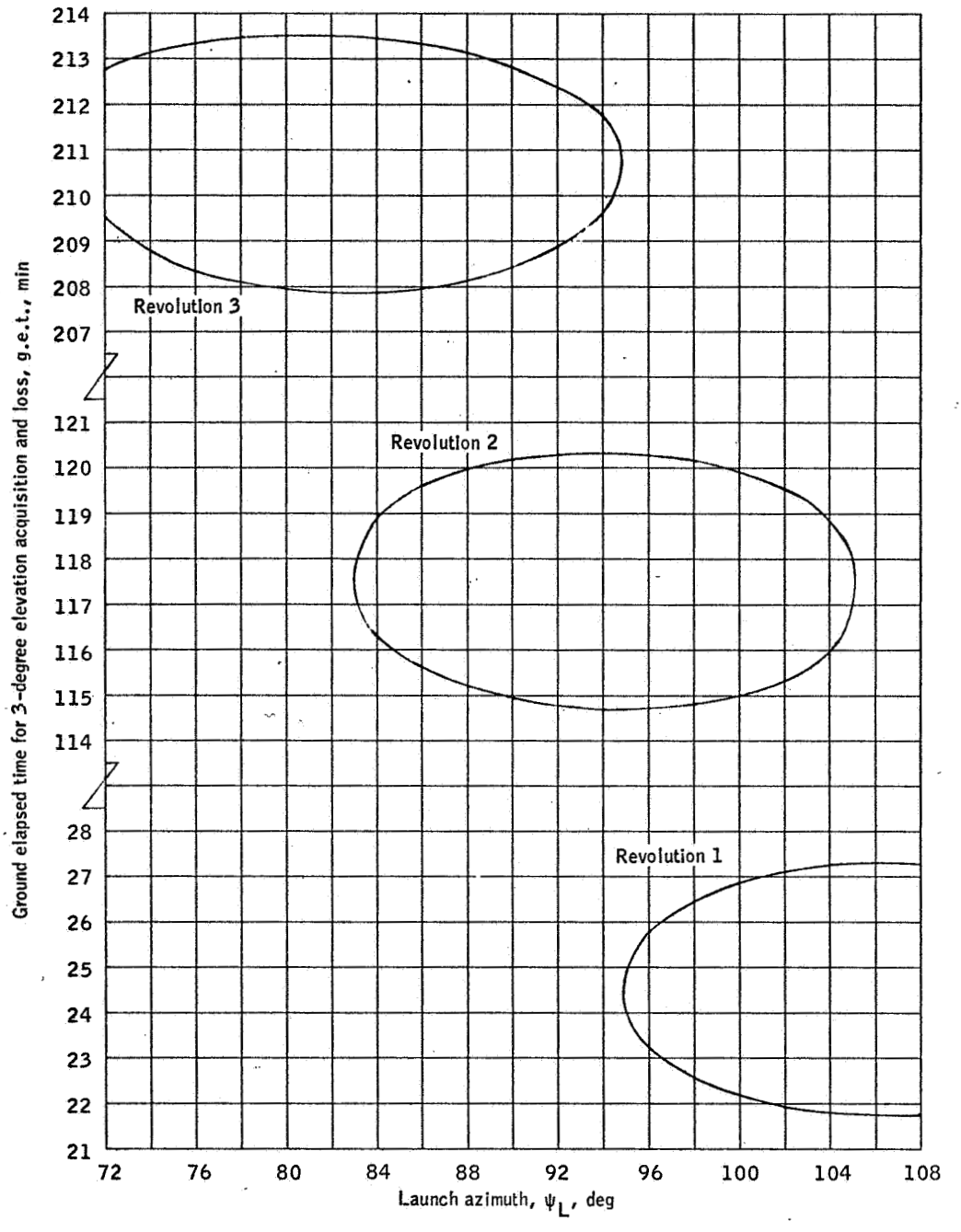
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 7.- Continued.



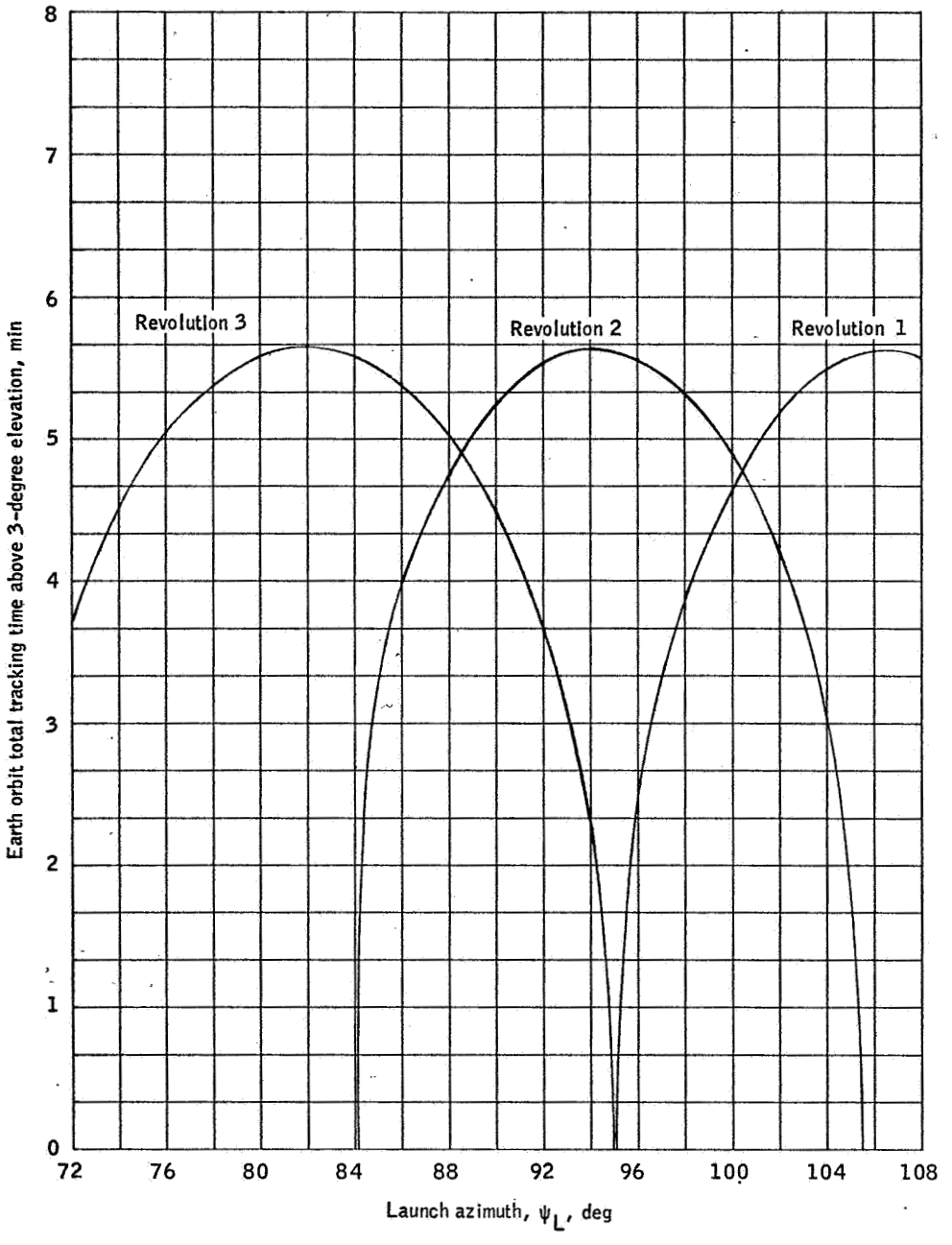
(c) Azimuth of acquisition for 0-degree elevation.

Figure 7.- Concluded.



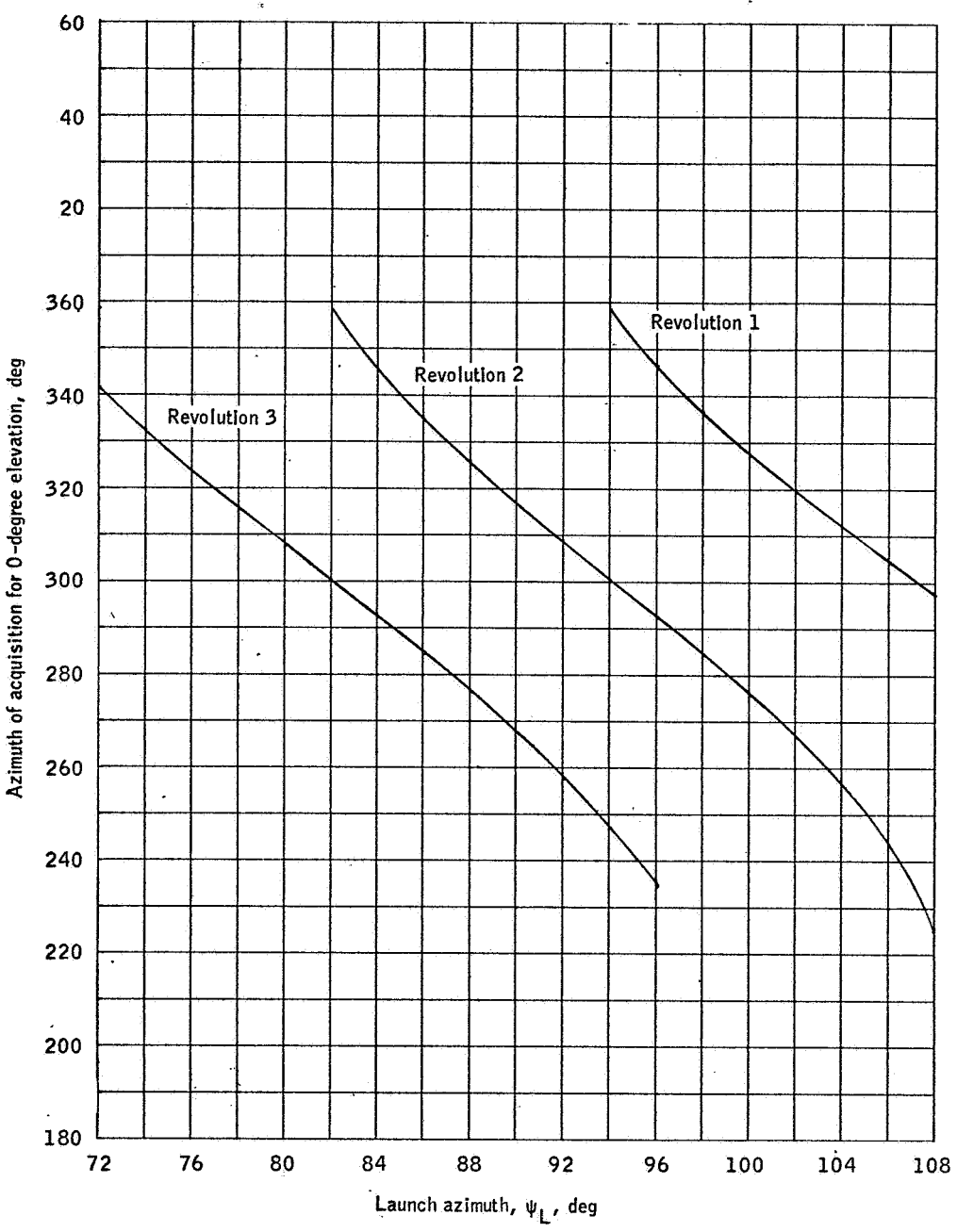
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 8.- Ascension radar tracking information for the first three revolutions as a function of launch azimuth.



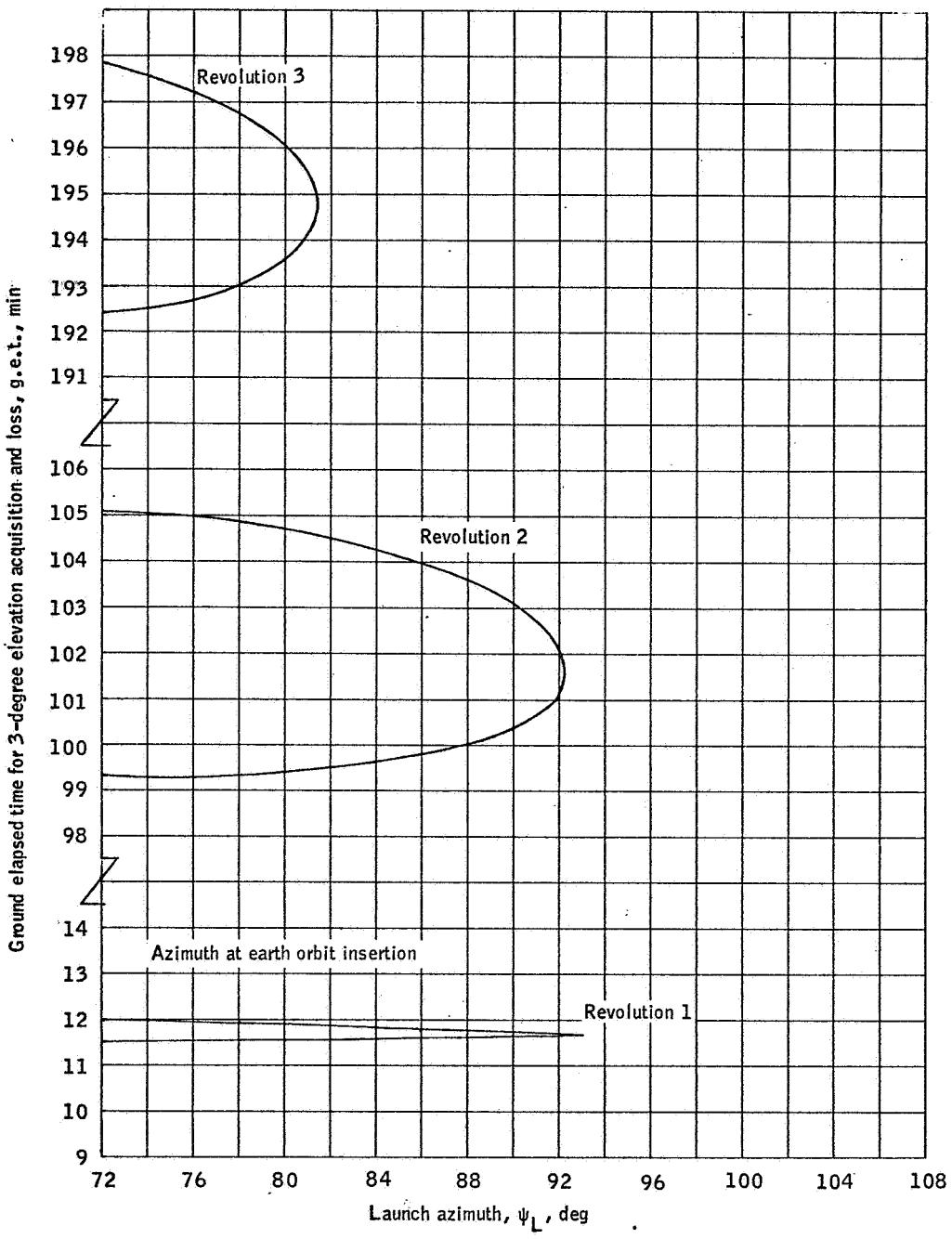
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 8.- Continued.



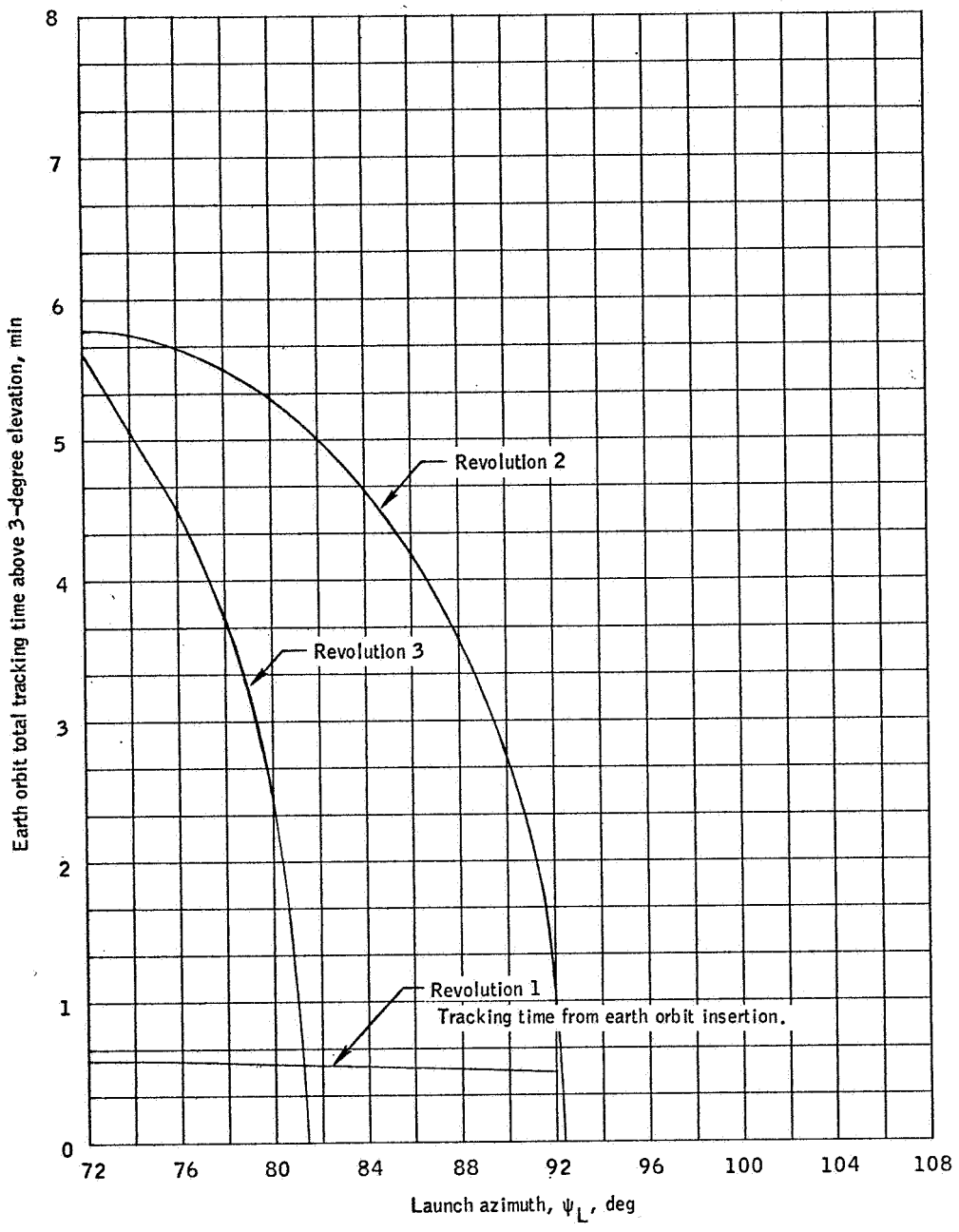
(c) Azimuth of acquisition for 0-degree elevation.

Figure 8.- Concluded.



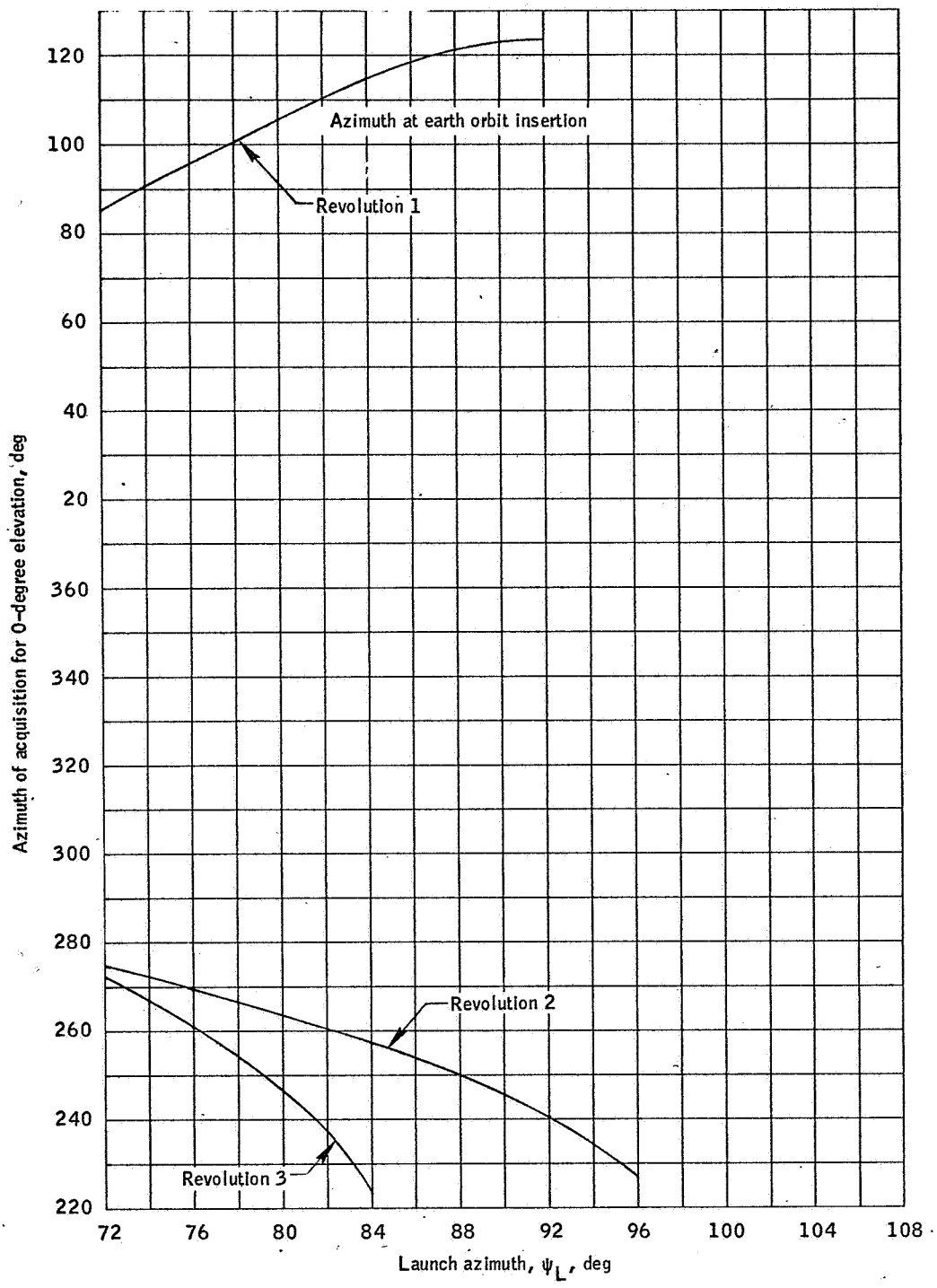
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 9.- Bermuda radar tracking information for the first three revolutions as a function of launch azimuth.



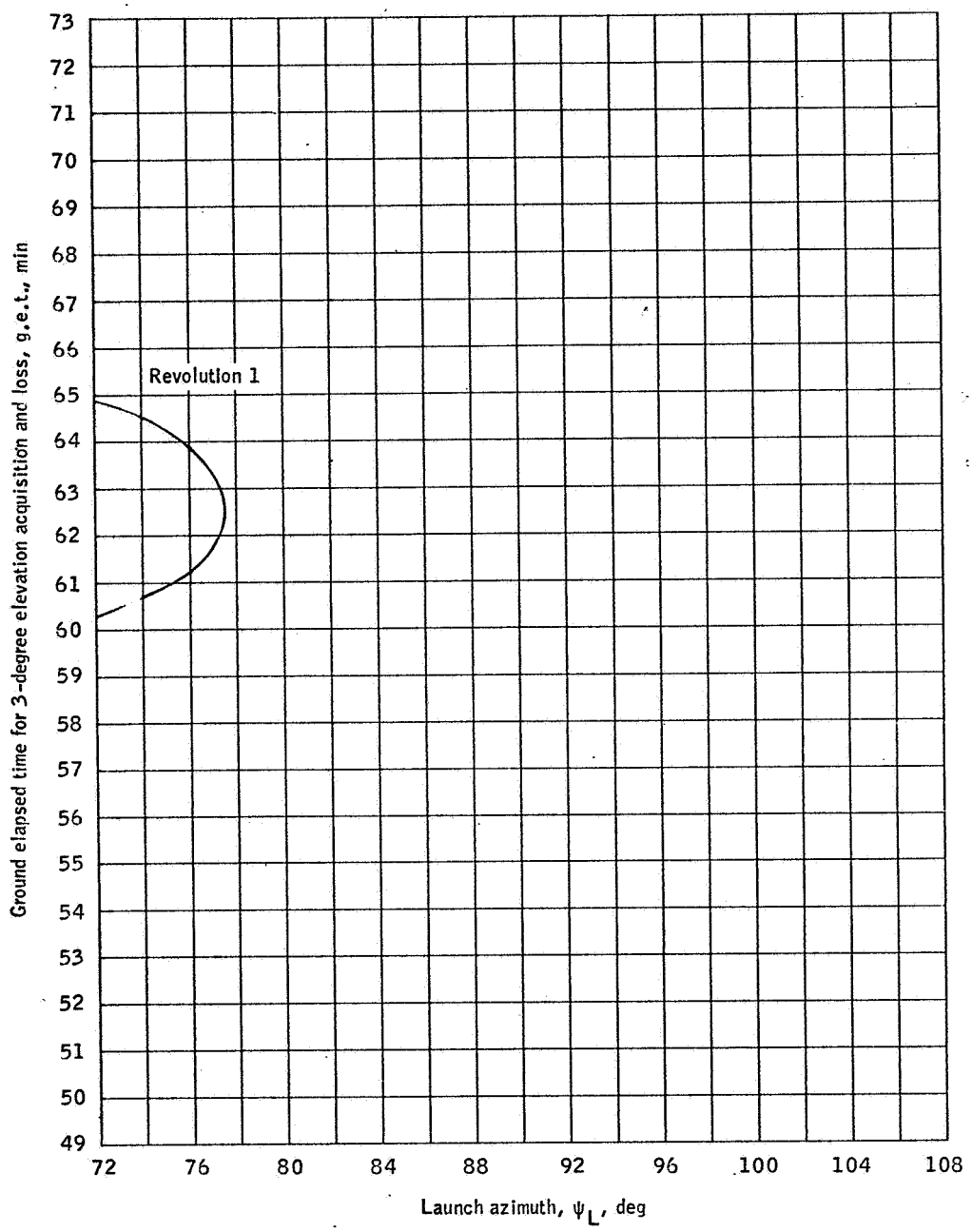
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 9.- Continued.



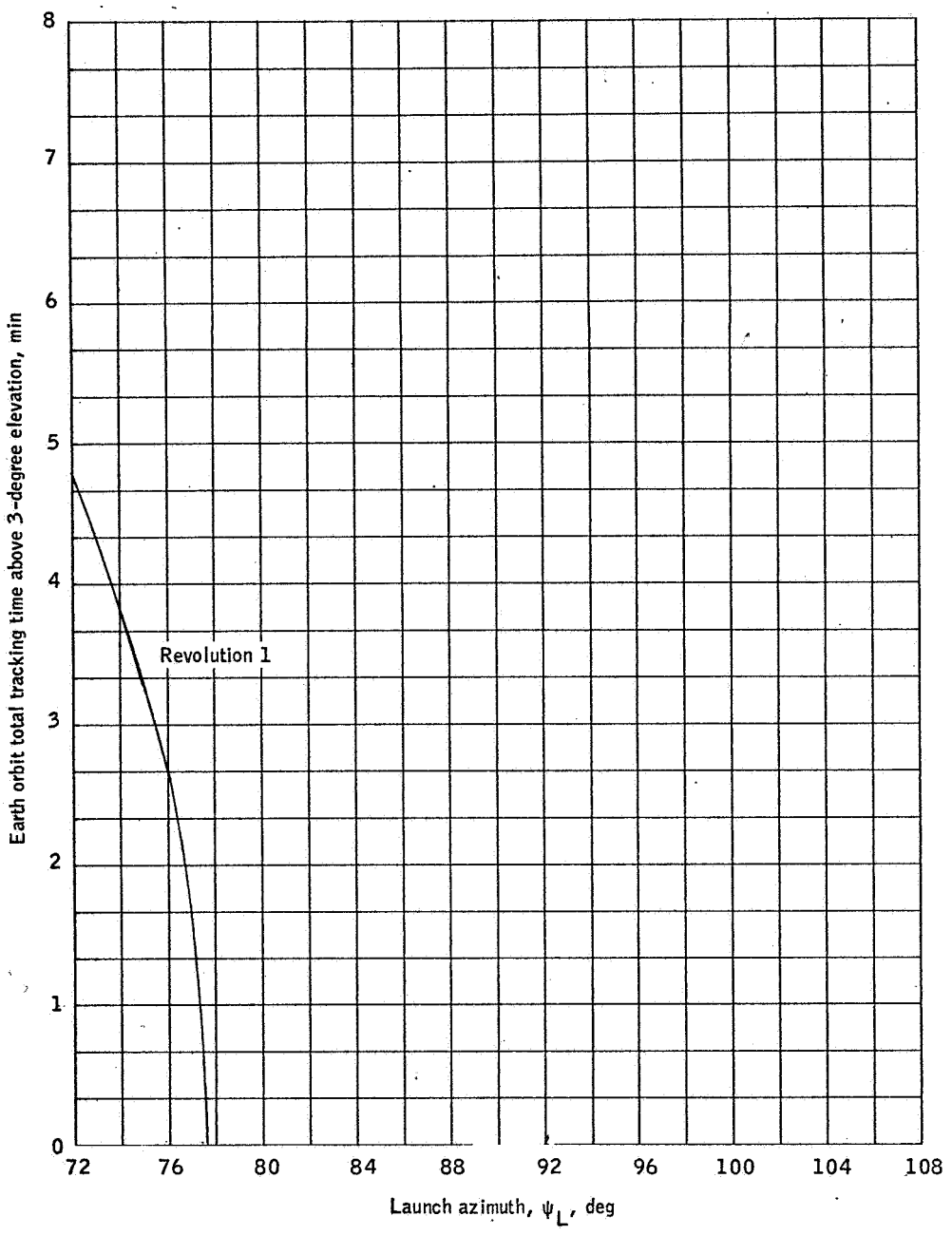
(c) Azimuth of acquisition for 0-degree elevation.

Figure 9.- Concluded.



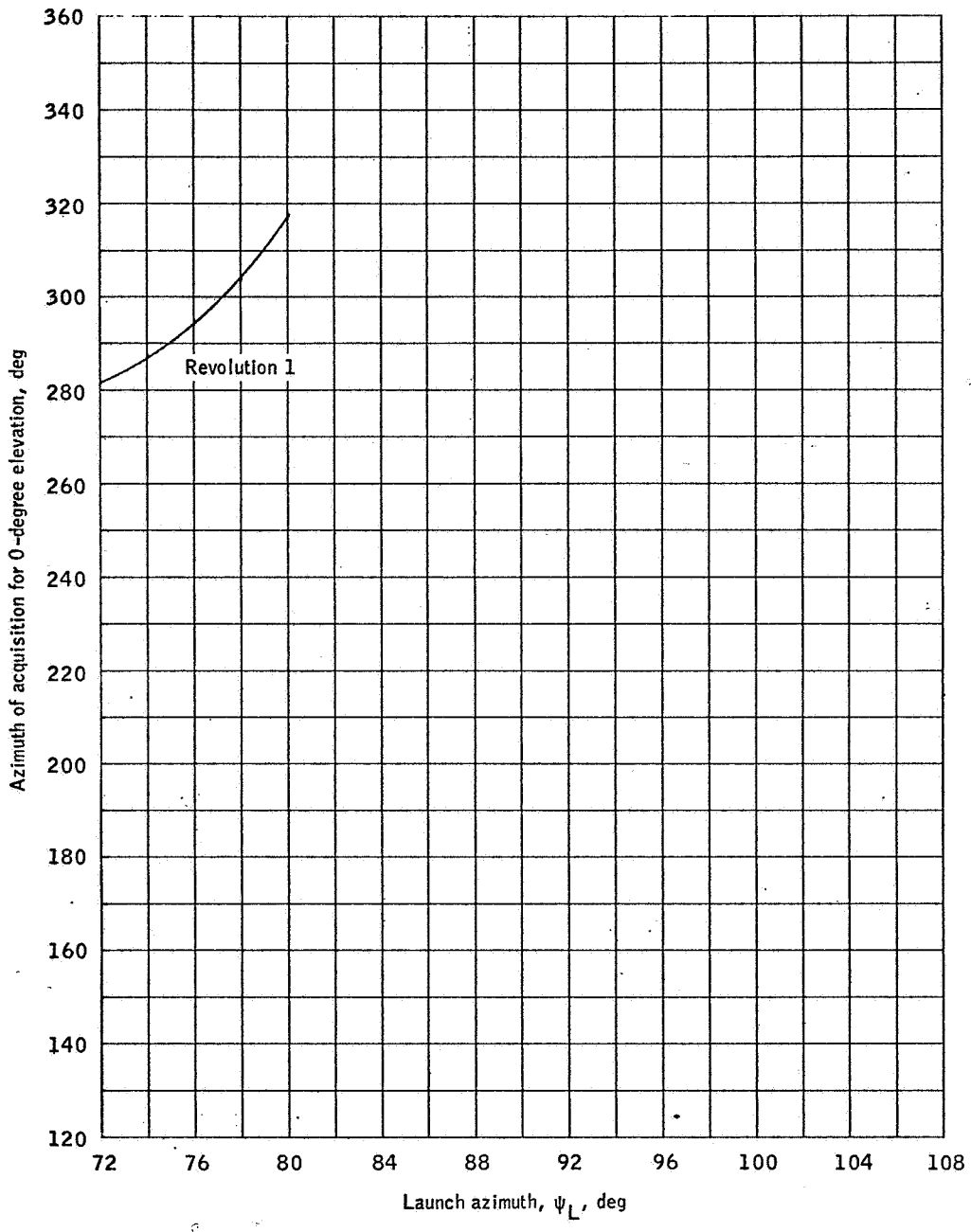
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 10.- Canberra radar tracking information for the first three revolutions as a function of launch azimuth.



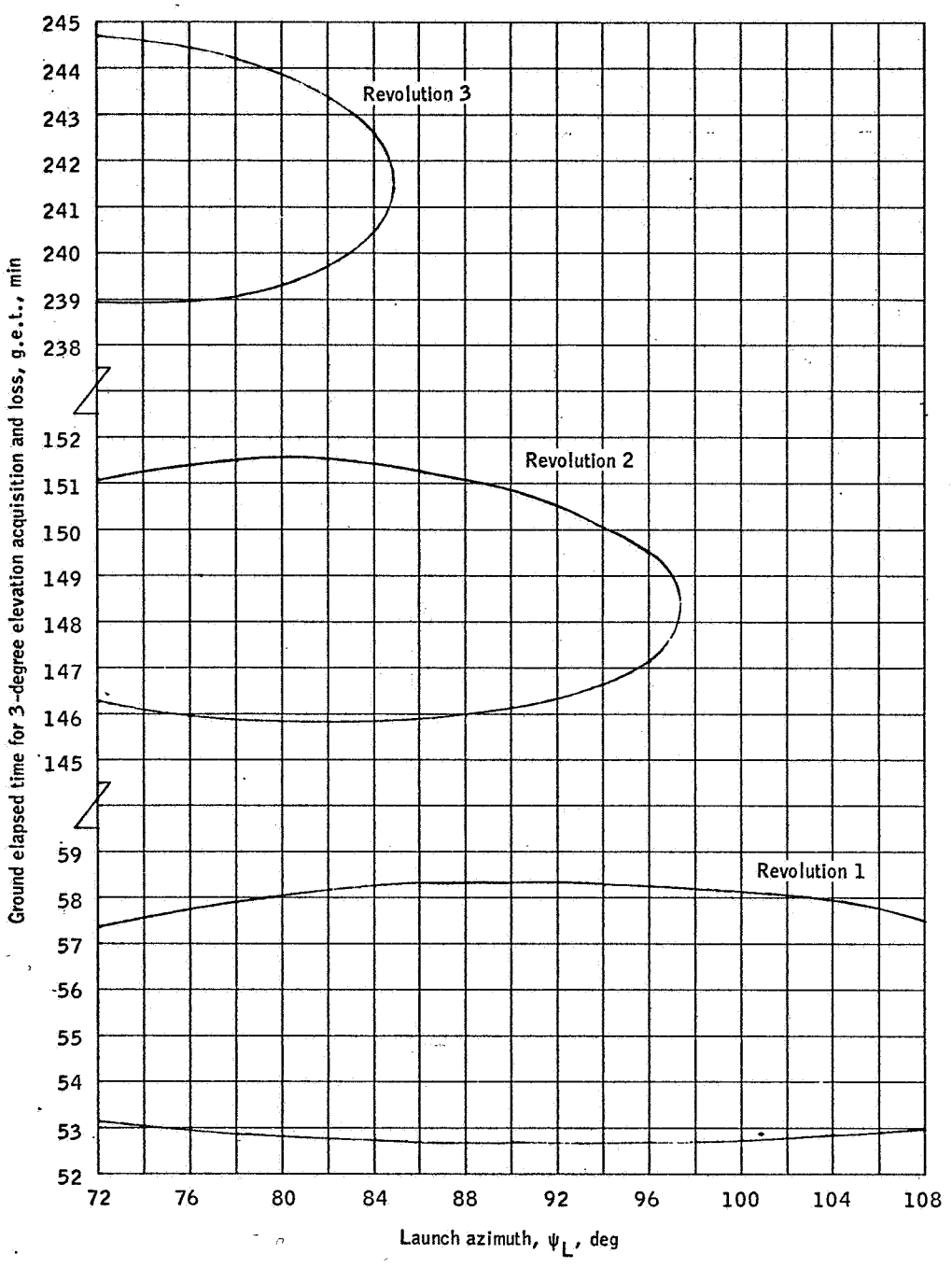
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 10.- Continued.



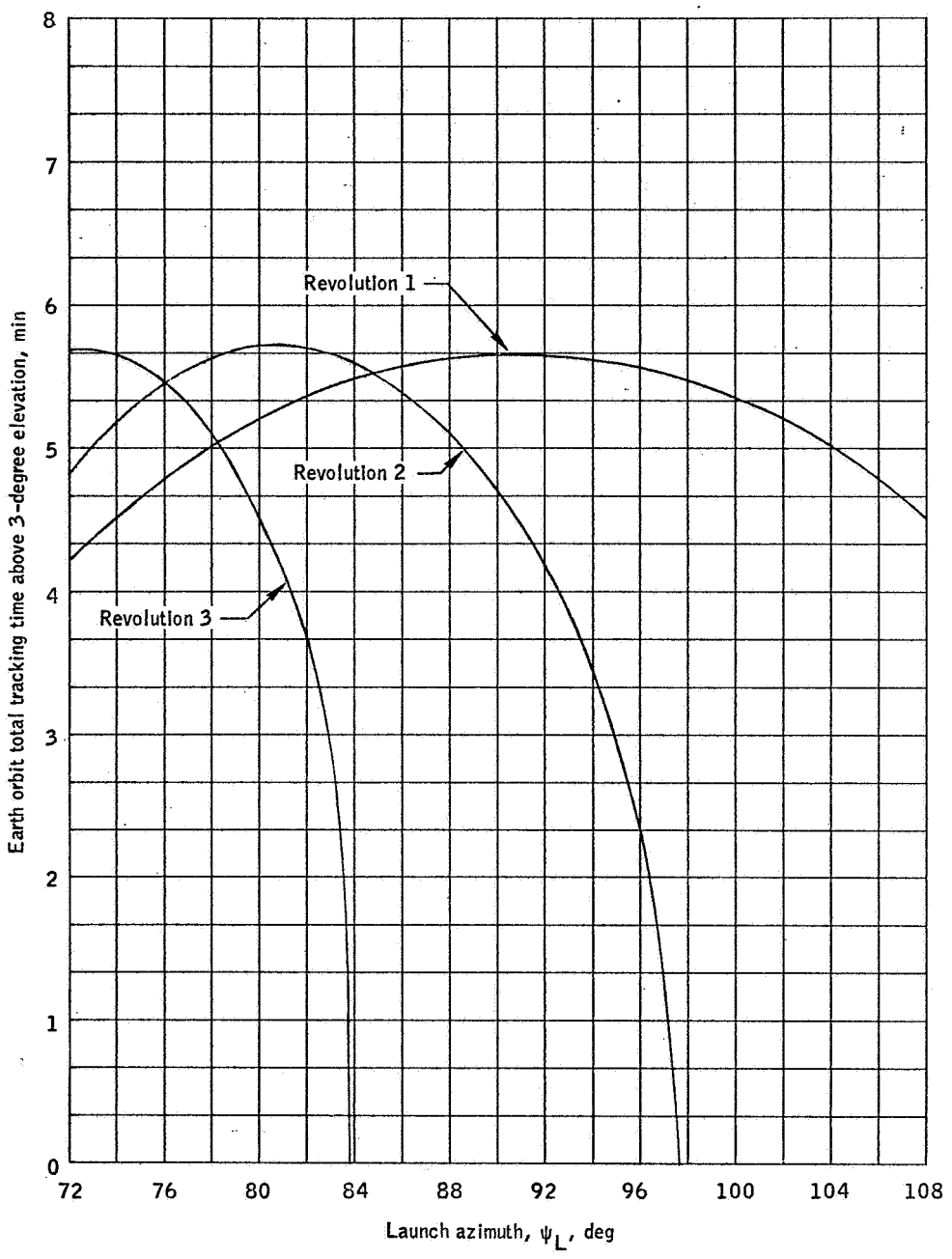
(c) Azimuth of acquisition for 0-degree elevation.

Figure 10.- Concluded.



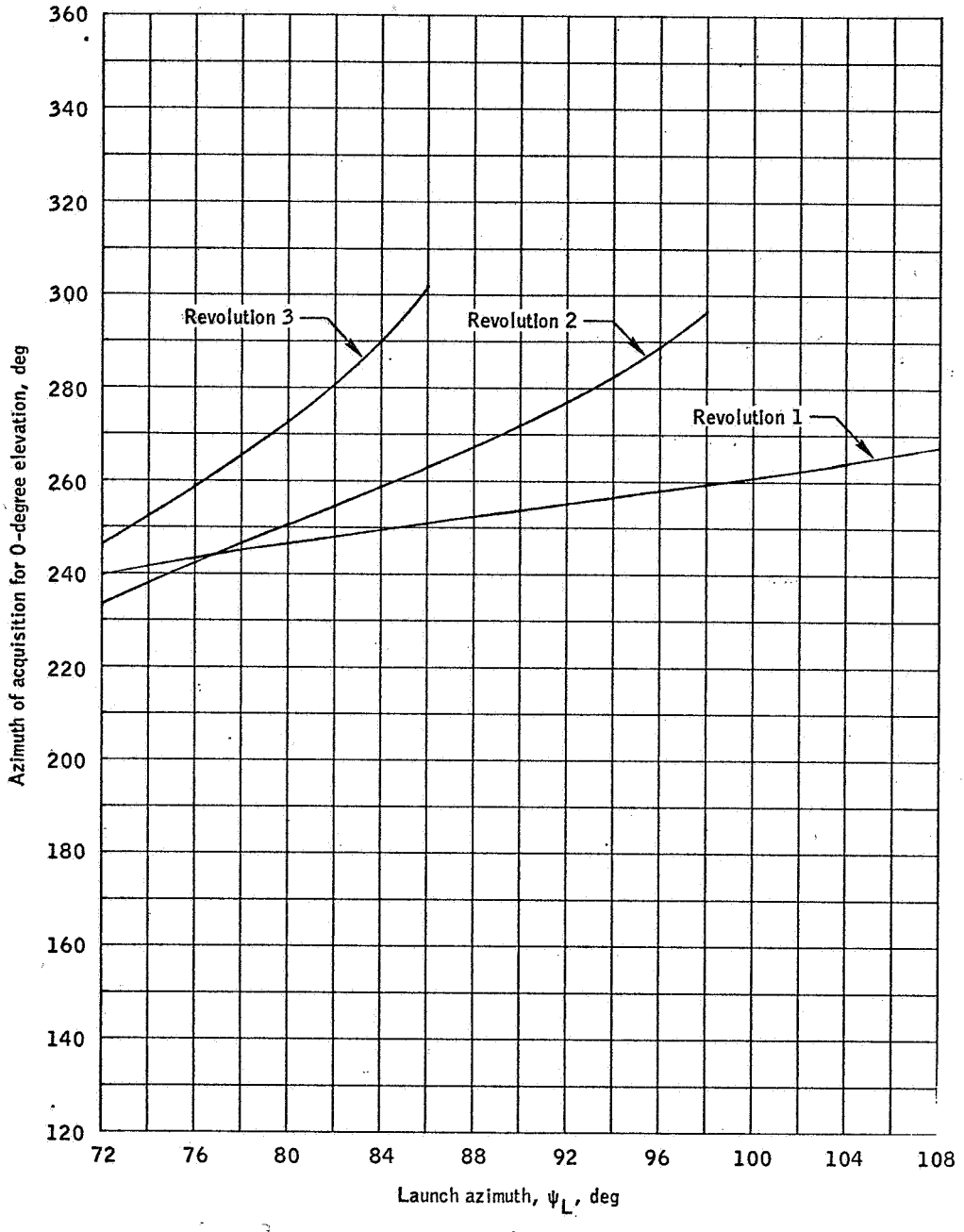
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 11.- Carnarvon radar tracking information for the first three revolutions as a function of launch azimuth.



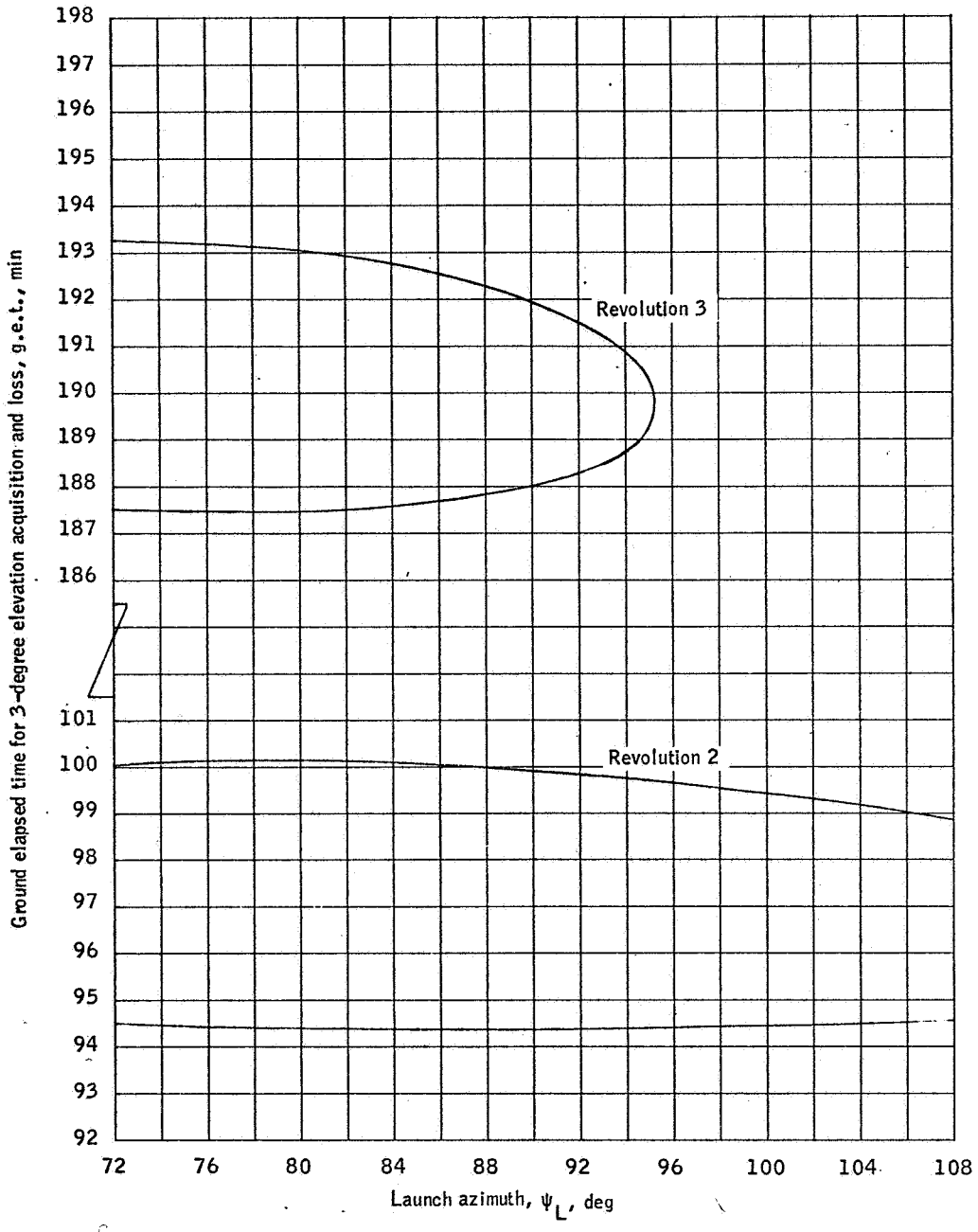
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 11.- Continued.



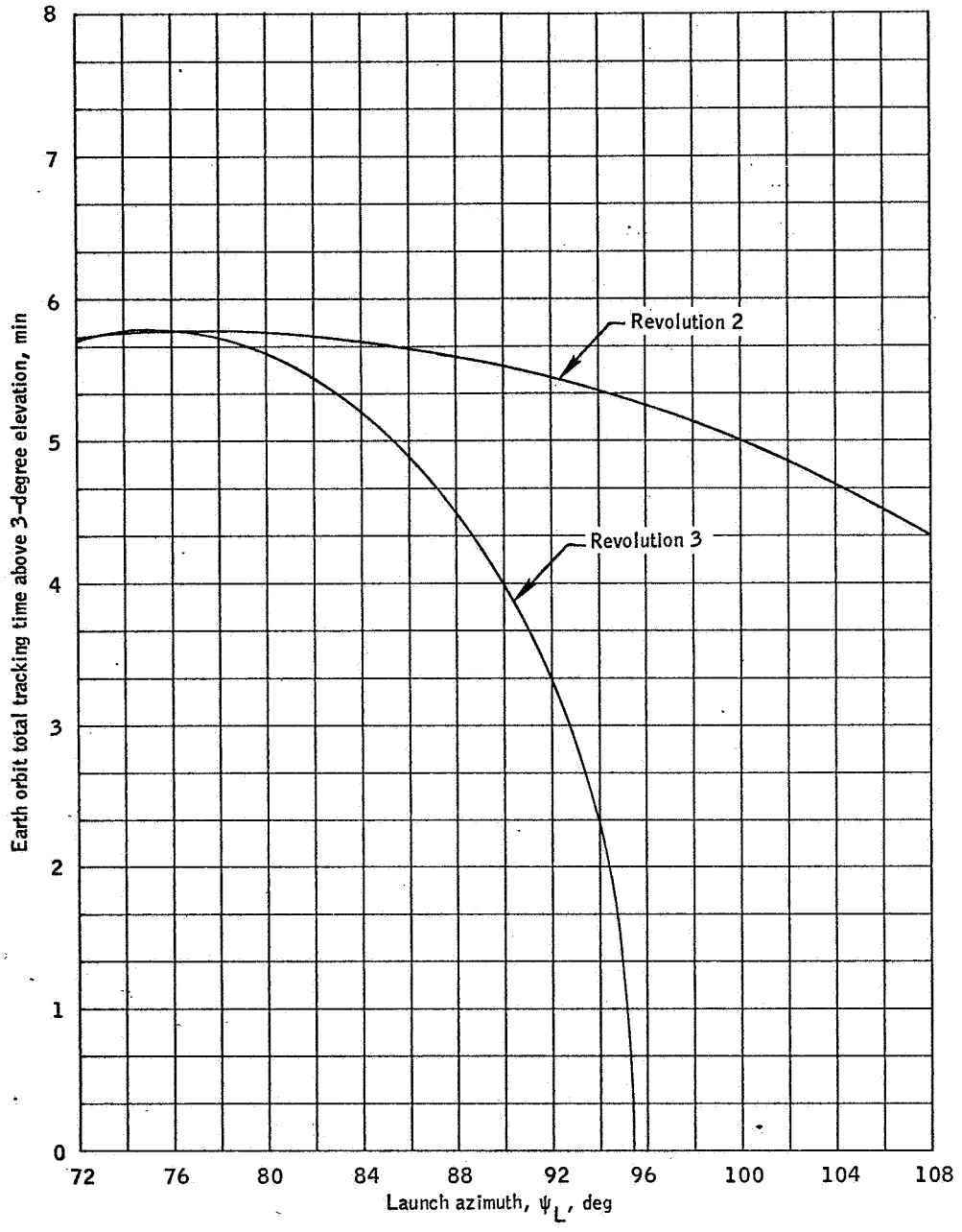
(c) Azimuth of acquisition for 0-degree elevation.

Figure 11.- Concluded.



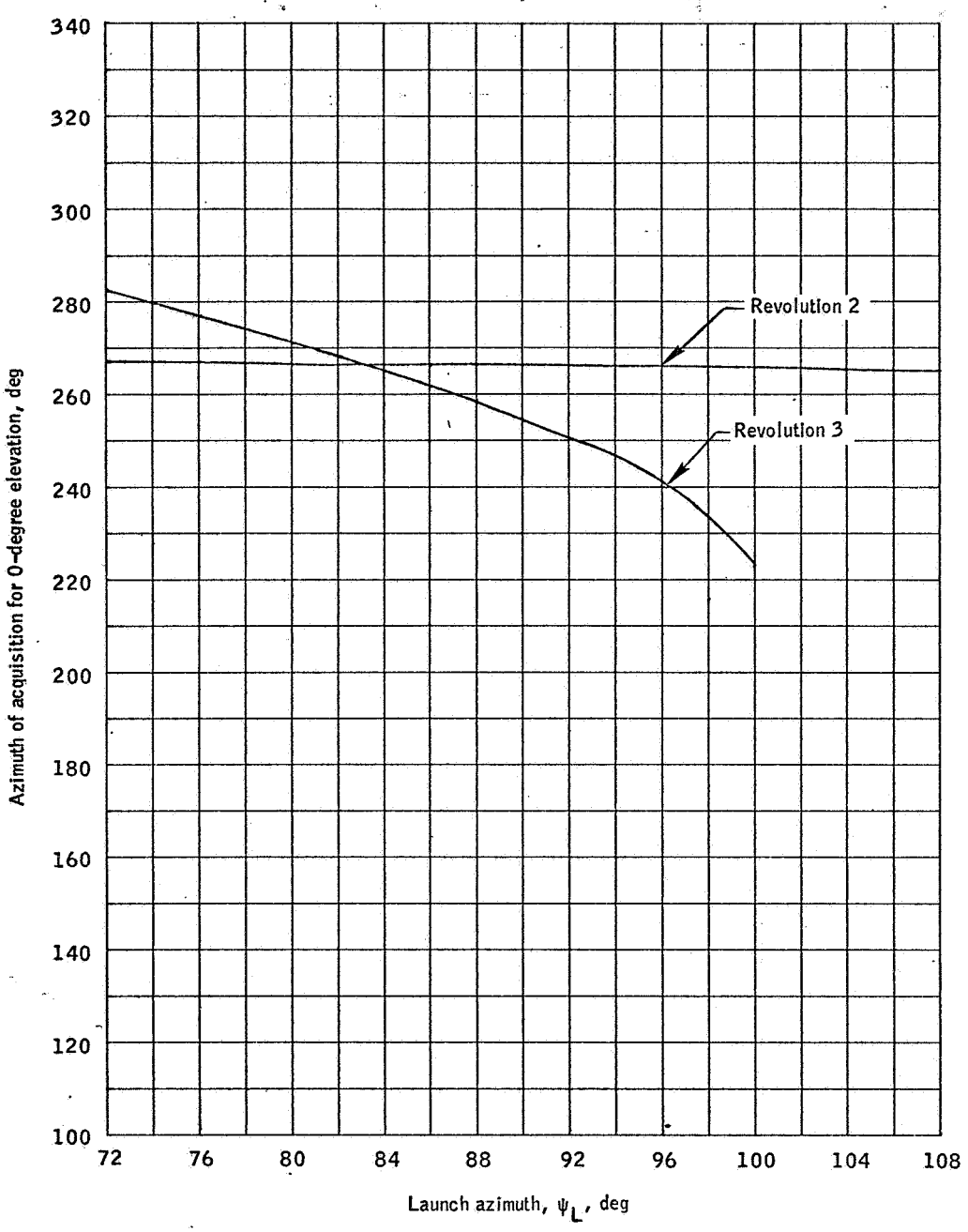
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 12.-Eglin radar tracking information for the first three revolutions as a function of launch azimuth.



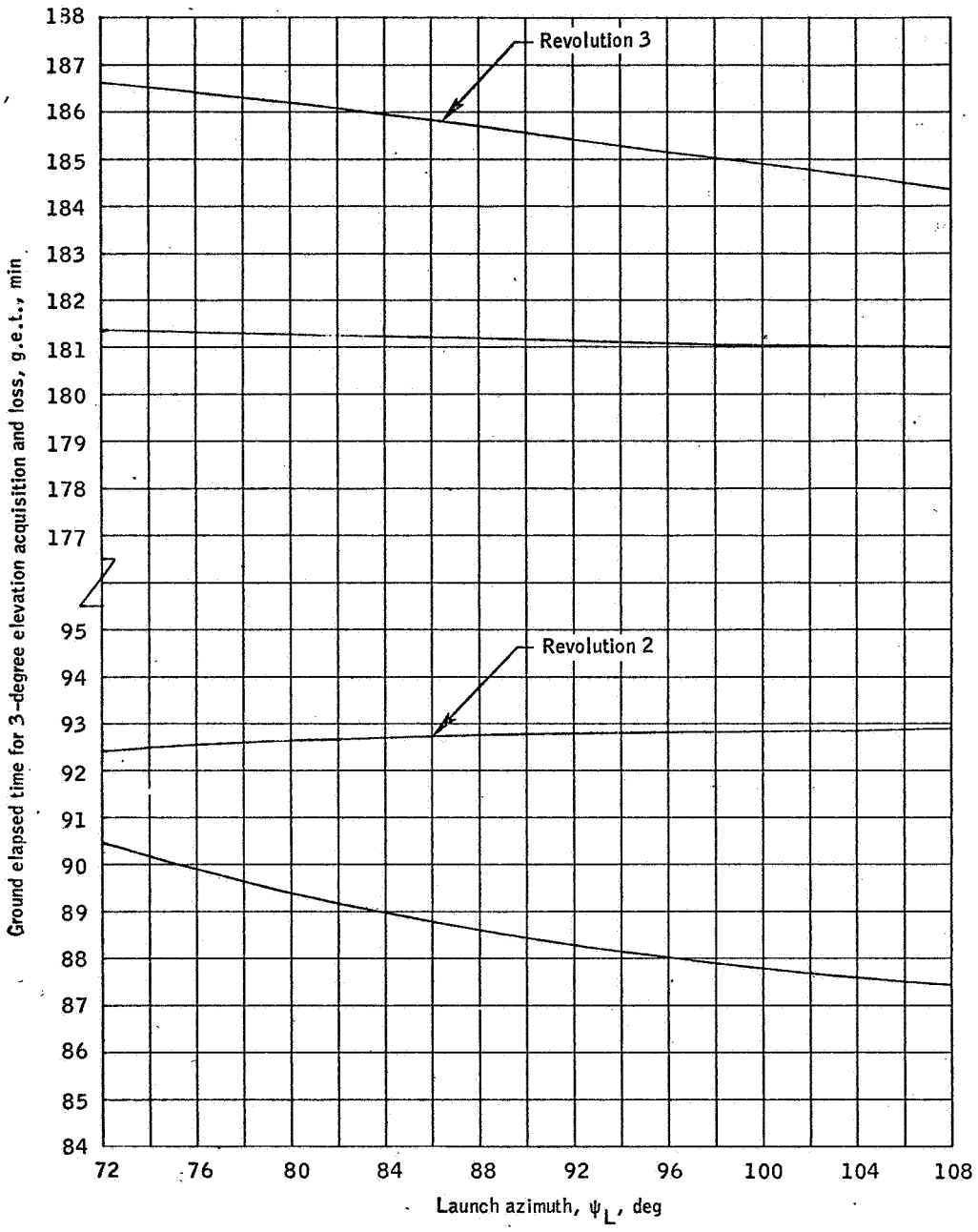
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 12.- Continued.



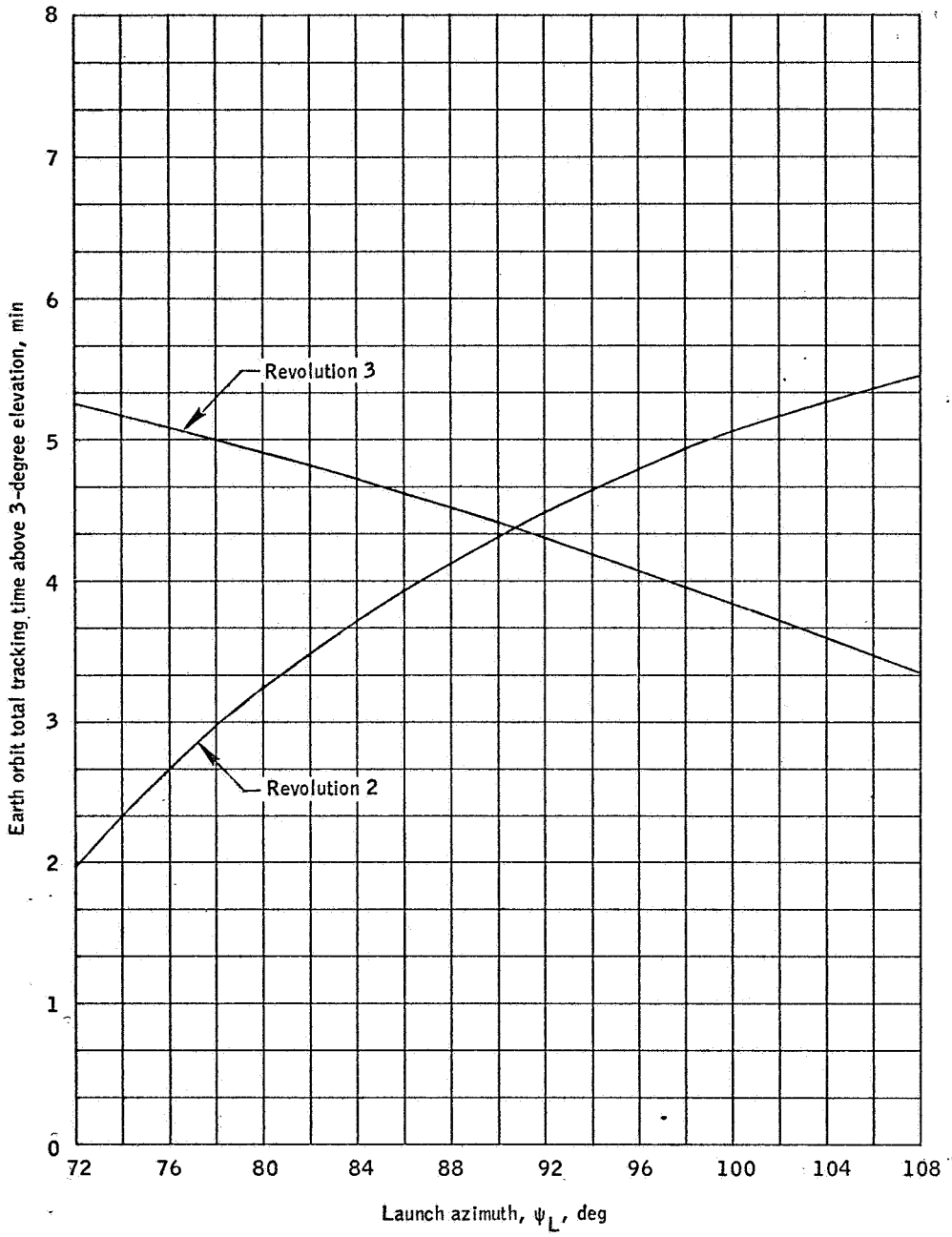
(c) Azimuth of acquisition for 0-degree elevation.

Figure 12.- Concluded.



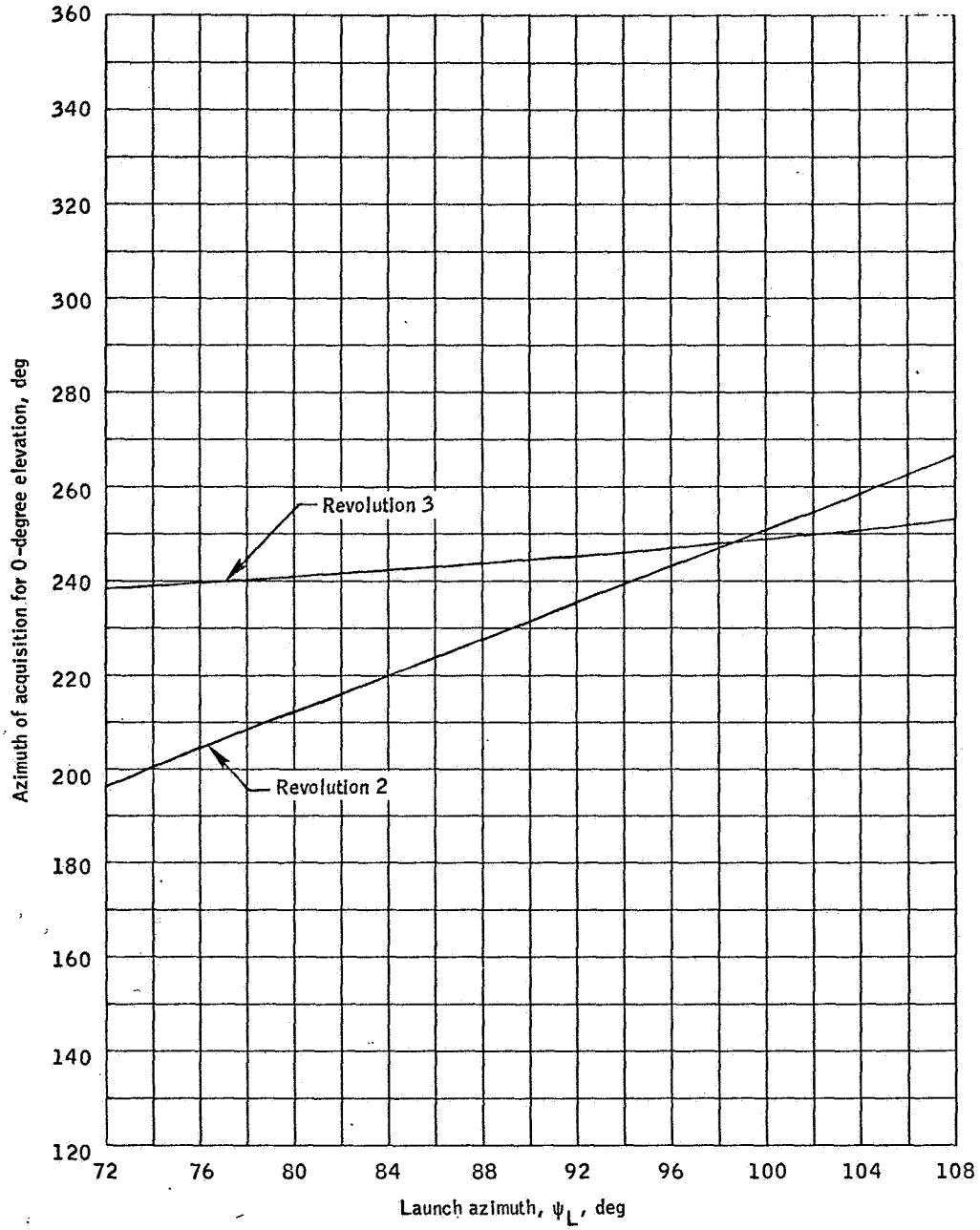
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 13.-Goldstone radar tracking information for the first three revolutions as a function of launch azimuth.



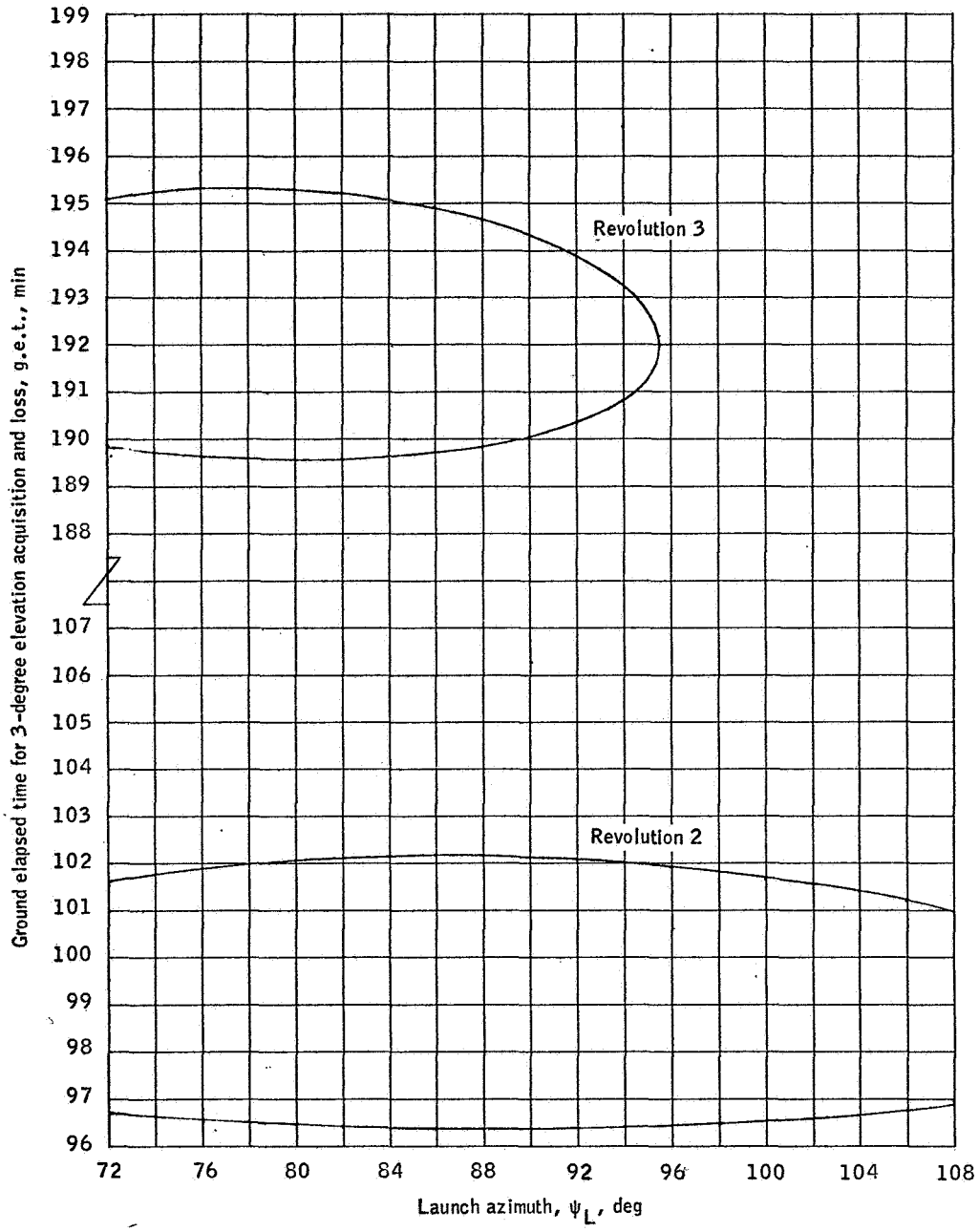
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 13.- Continued.



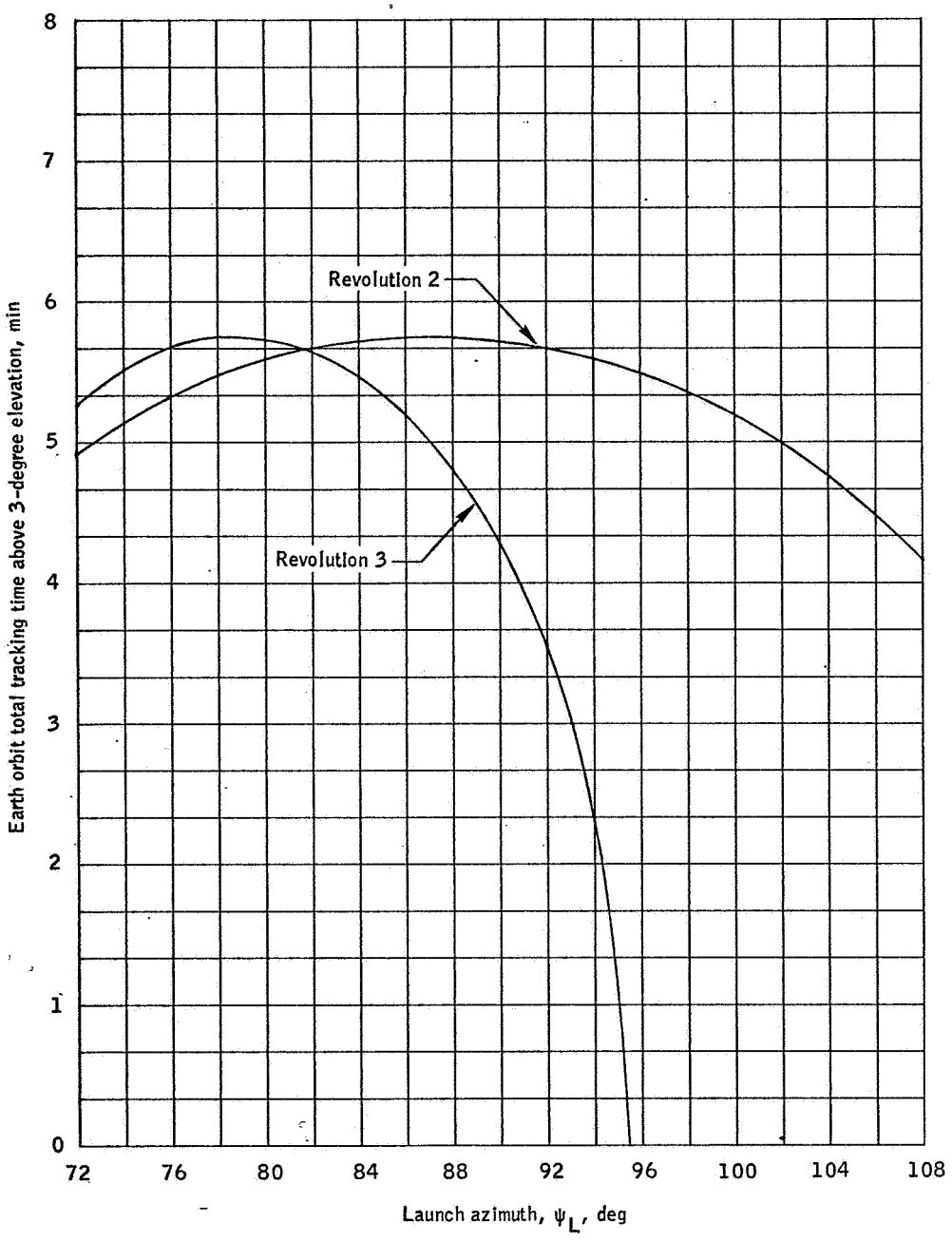
(c) Azimuth of acquisition for 0-degree elevation.

Figure 13.-Concluded.



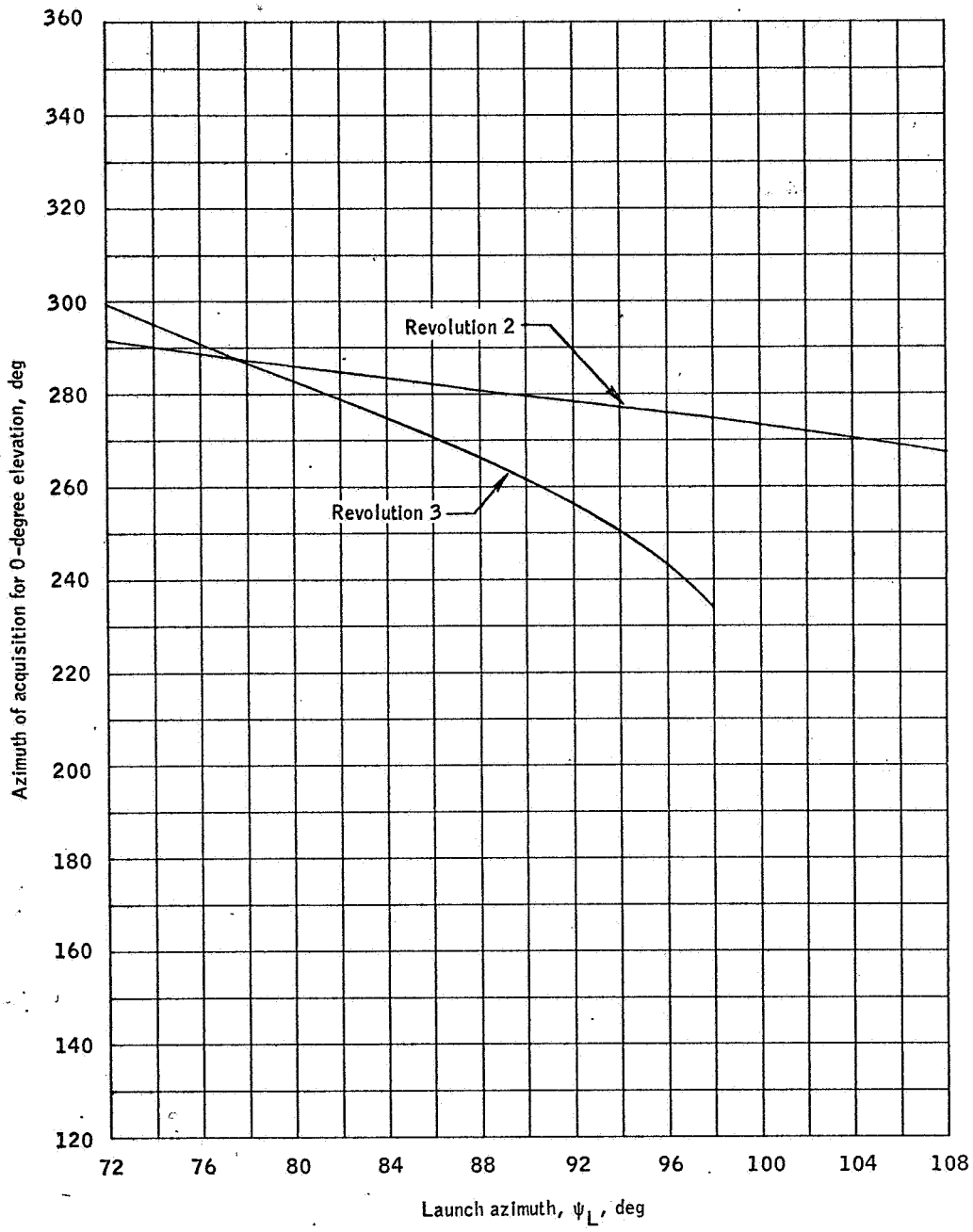
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 14.- Grand Bahama Island radar tracking information for the first three revolutions as a function of launch azimuth.



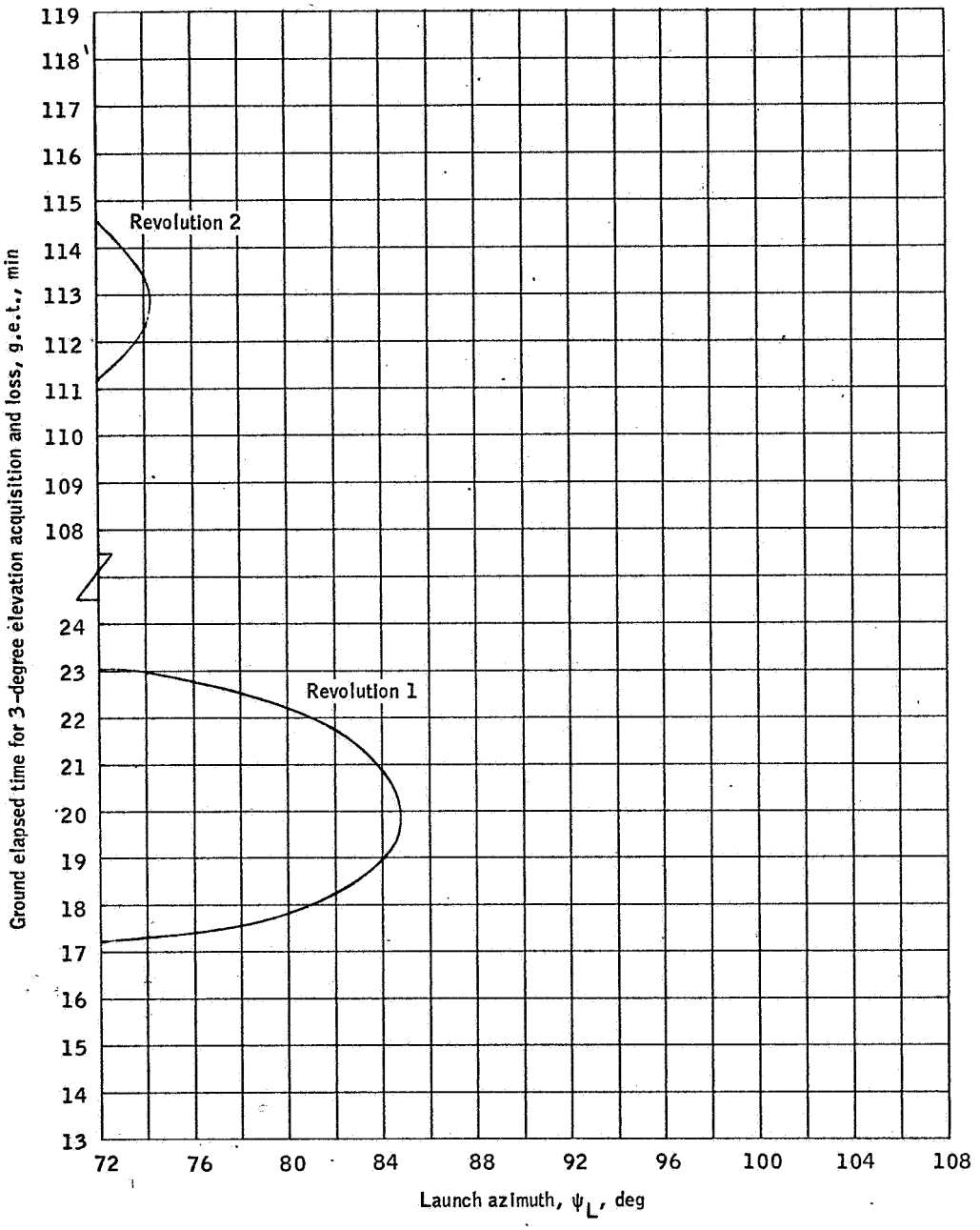
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 14.- Continued.



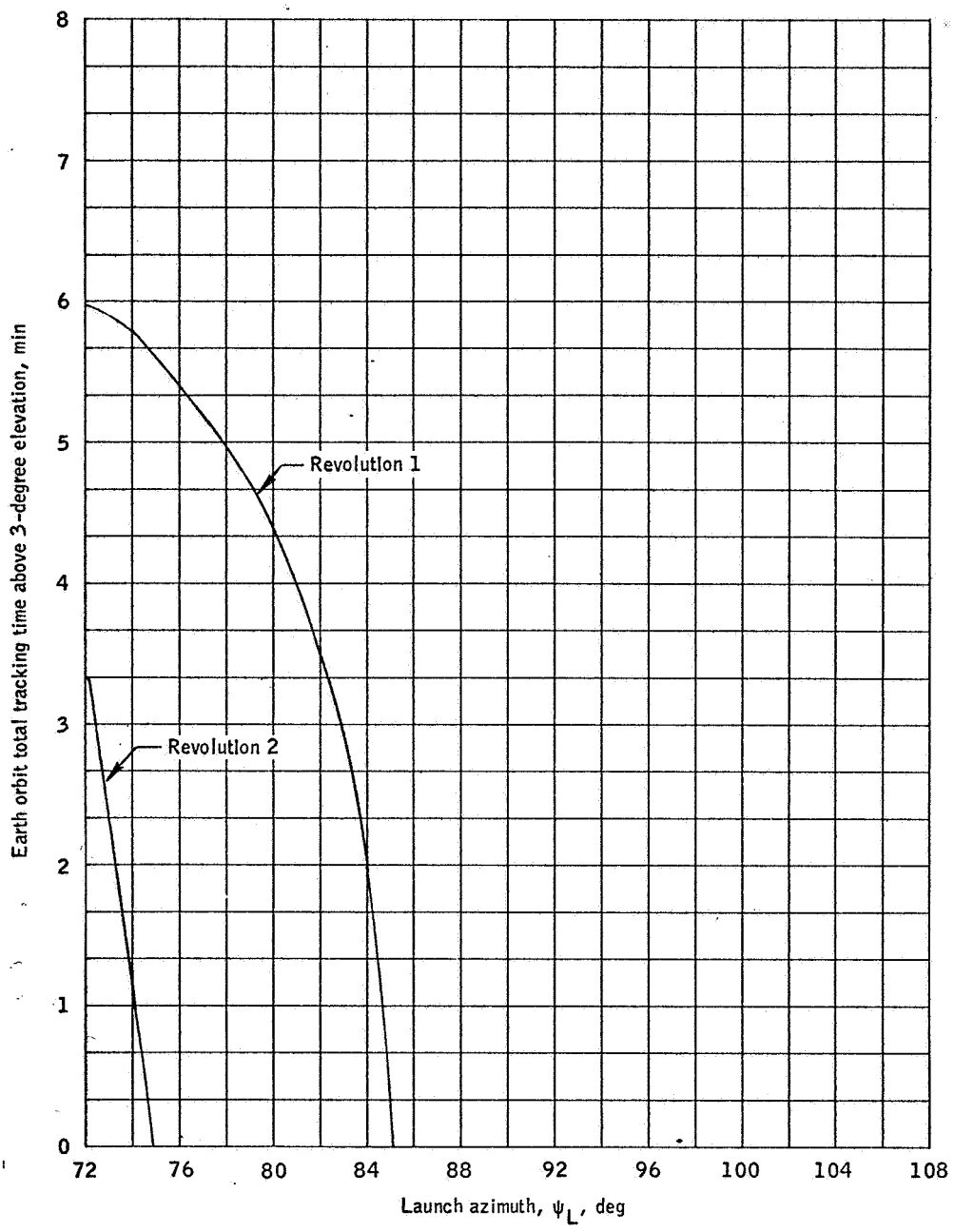
(c) Azimuth of acquisition for 0-degree elevation.

Figure 14.- Concluded.



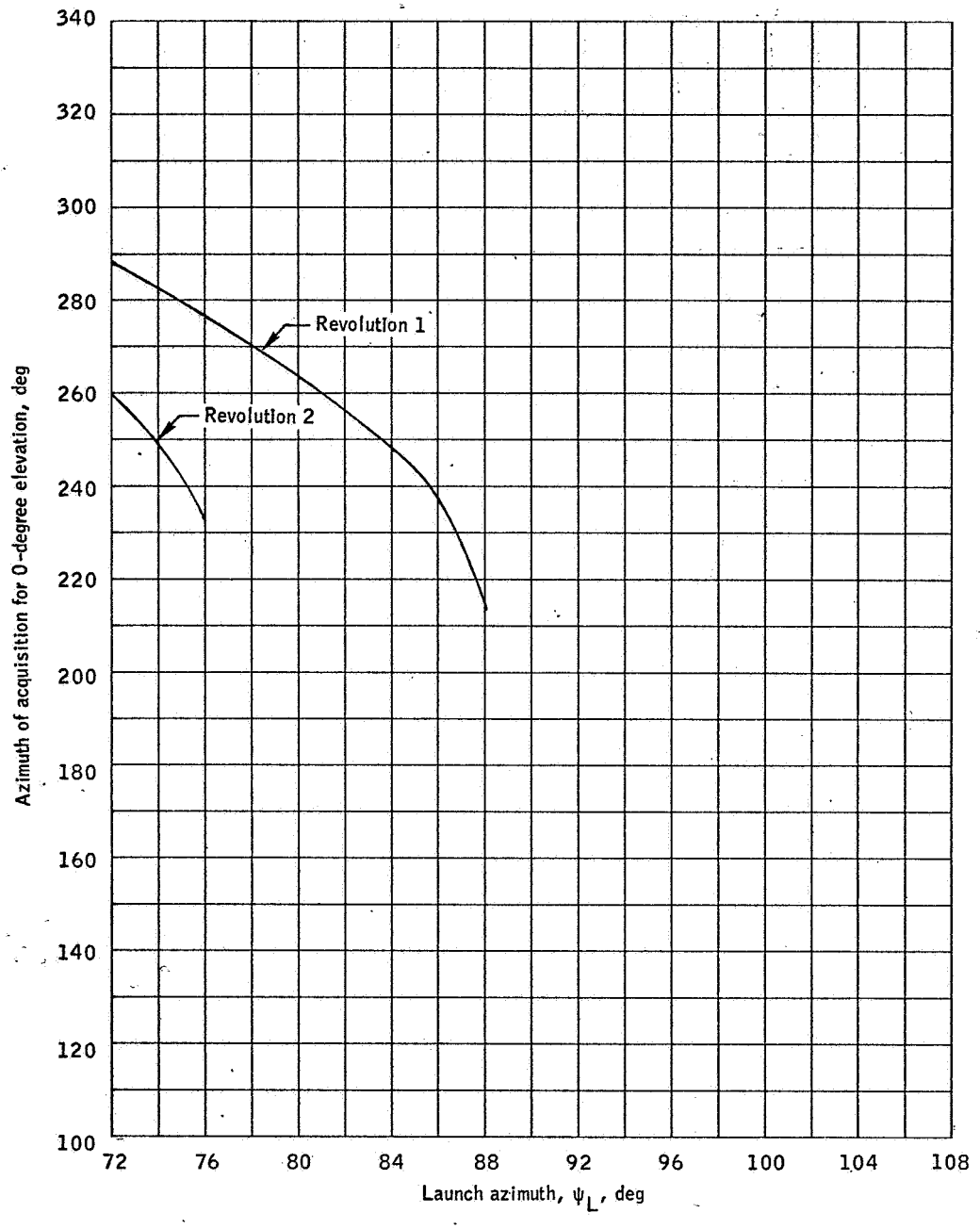
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 15.- Grand Canary Island radar tracking information for the first three revolutions as a function of launch azimuth.



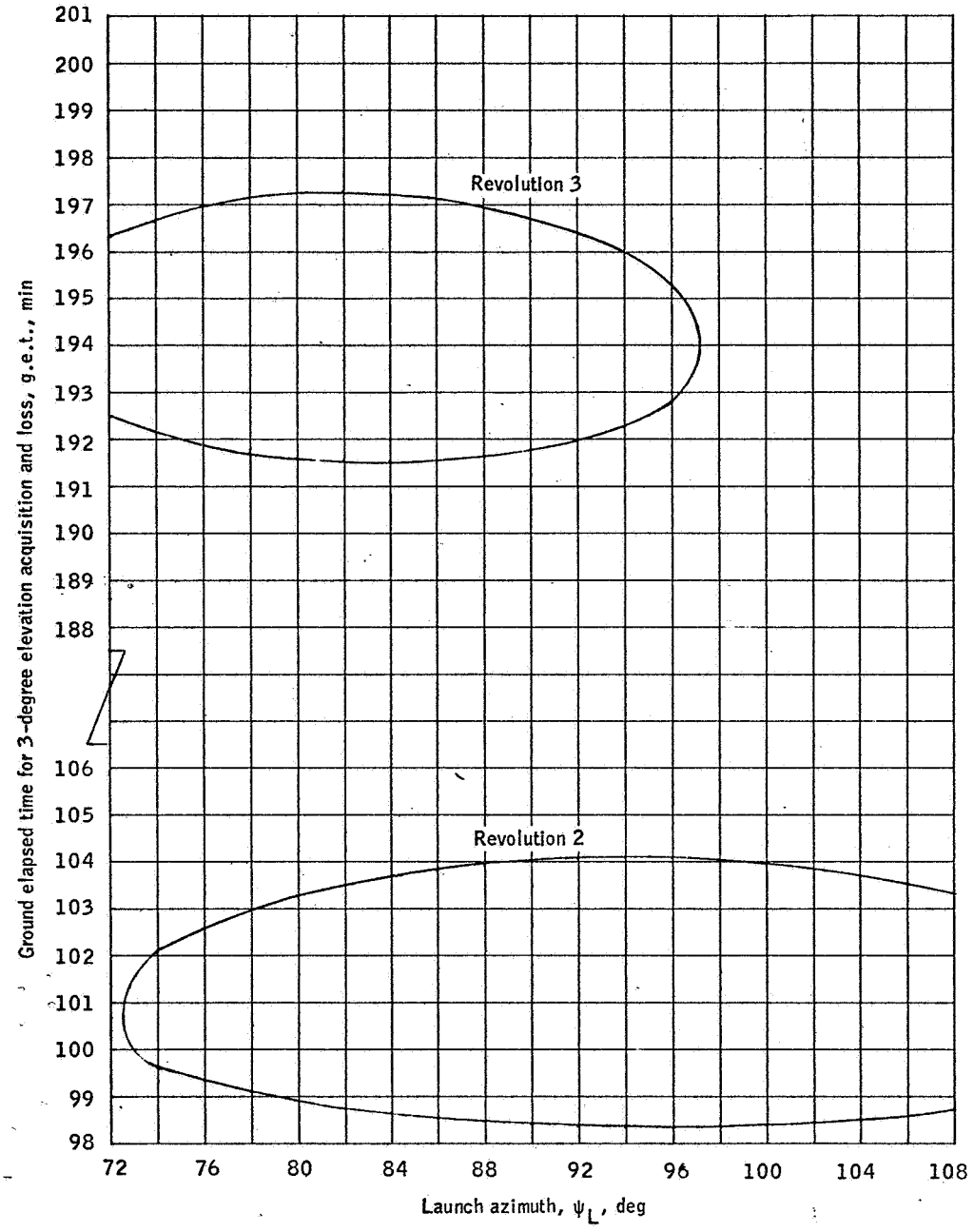
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 15.- Continued.



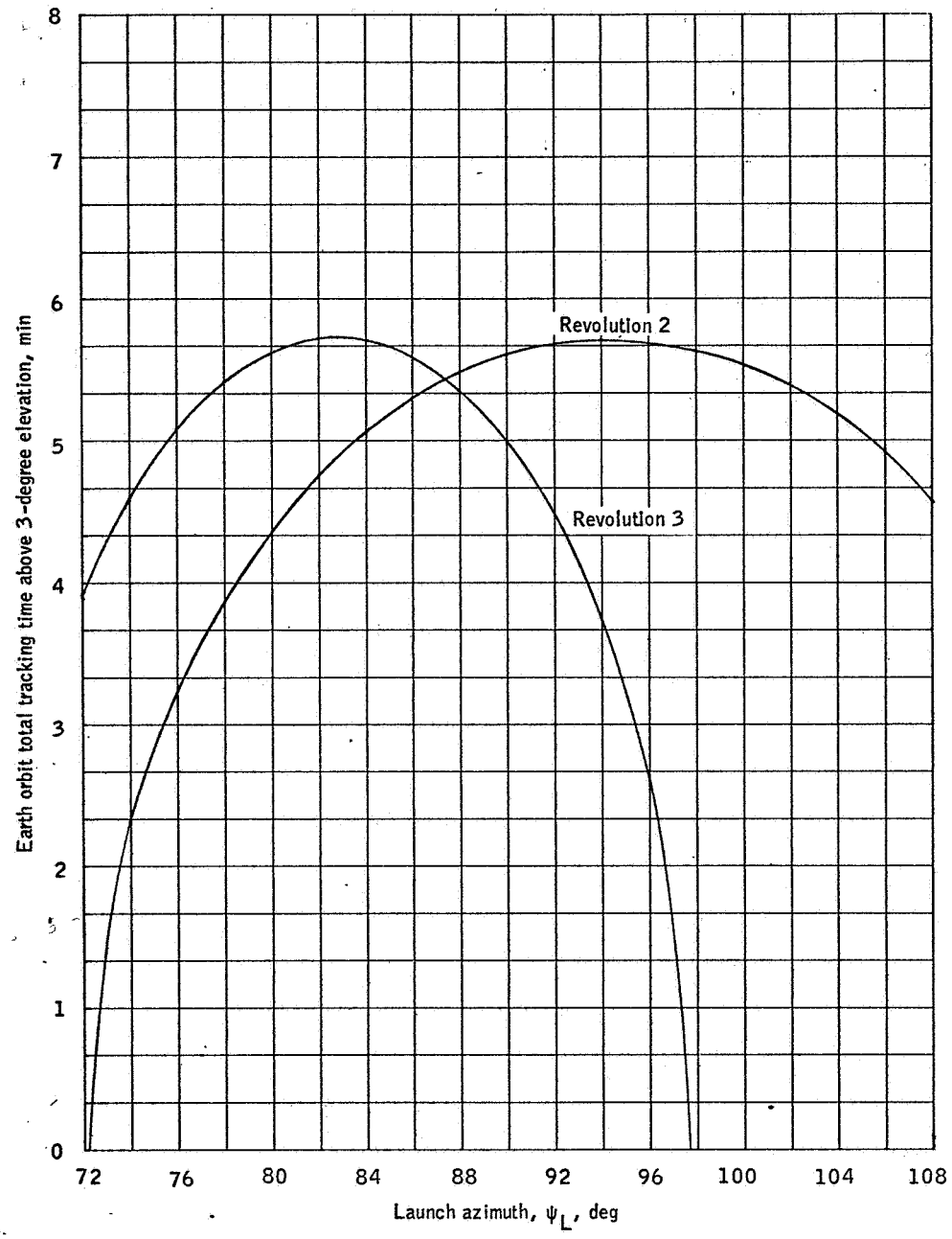
(c) Azimuth of acquisition for 0-degree elevation.

Figure 15.- Concluded.



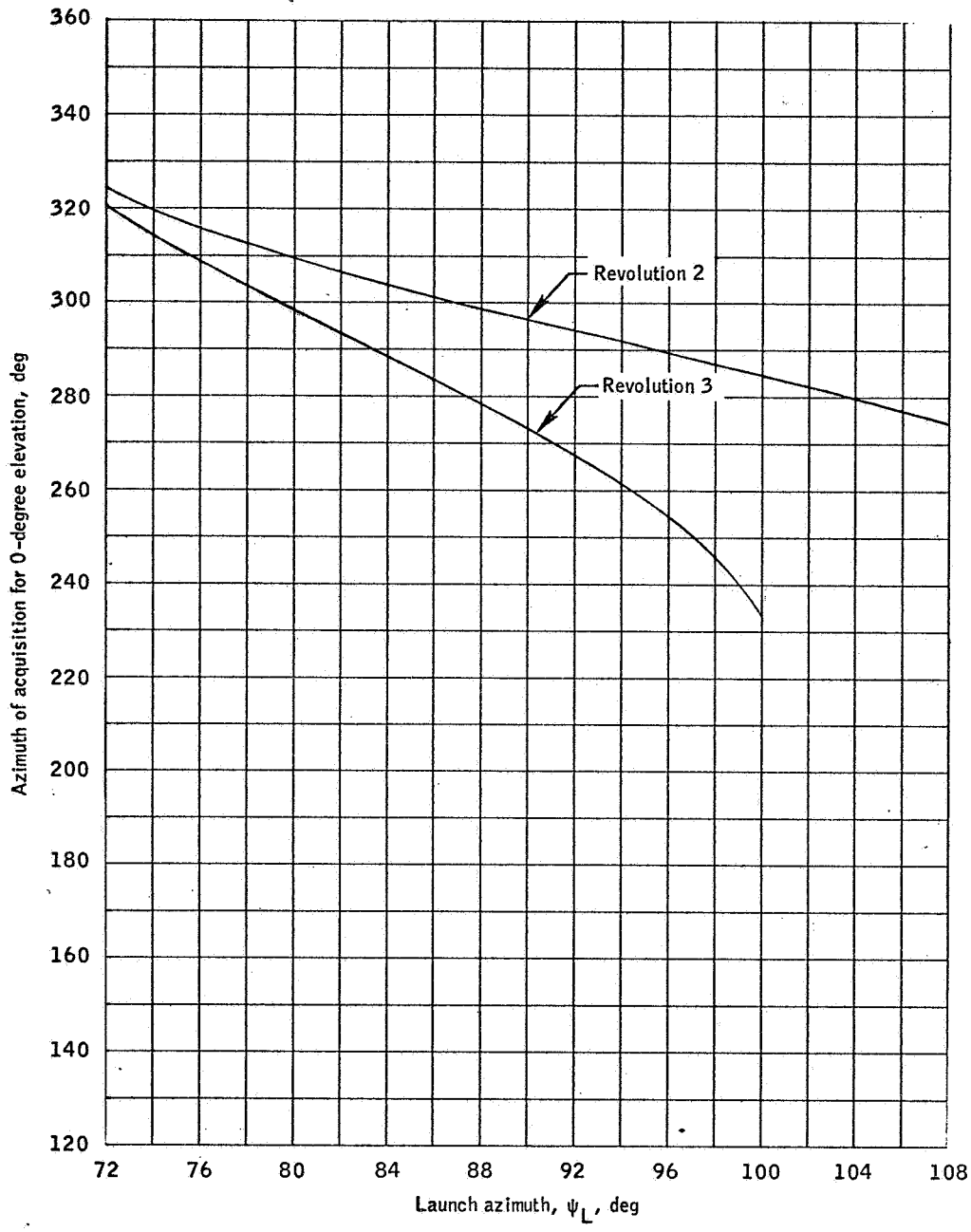
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 16.- Grand Turk Island radar tracking information for the first three revolutions as a function of launch azimuth.



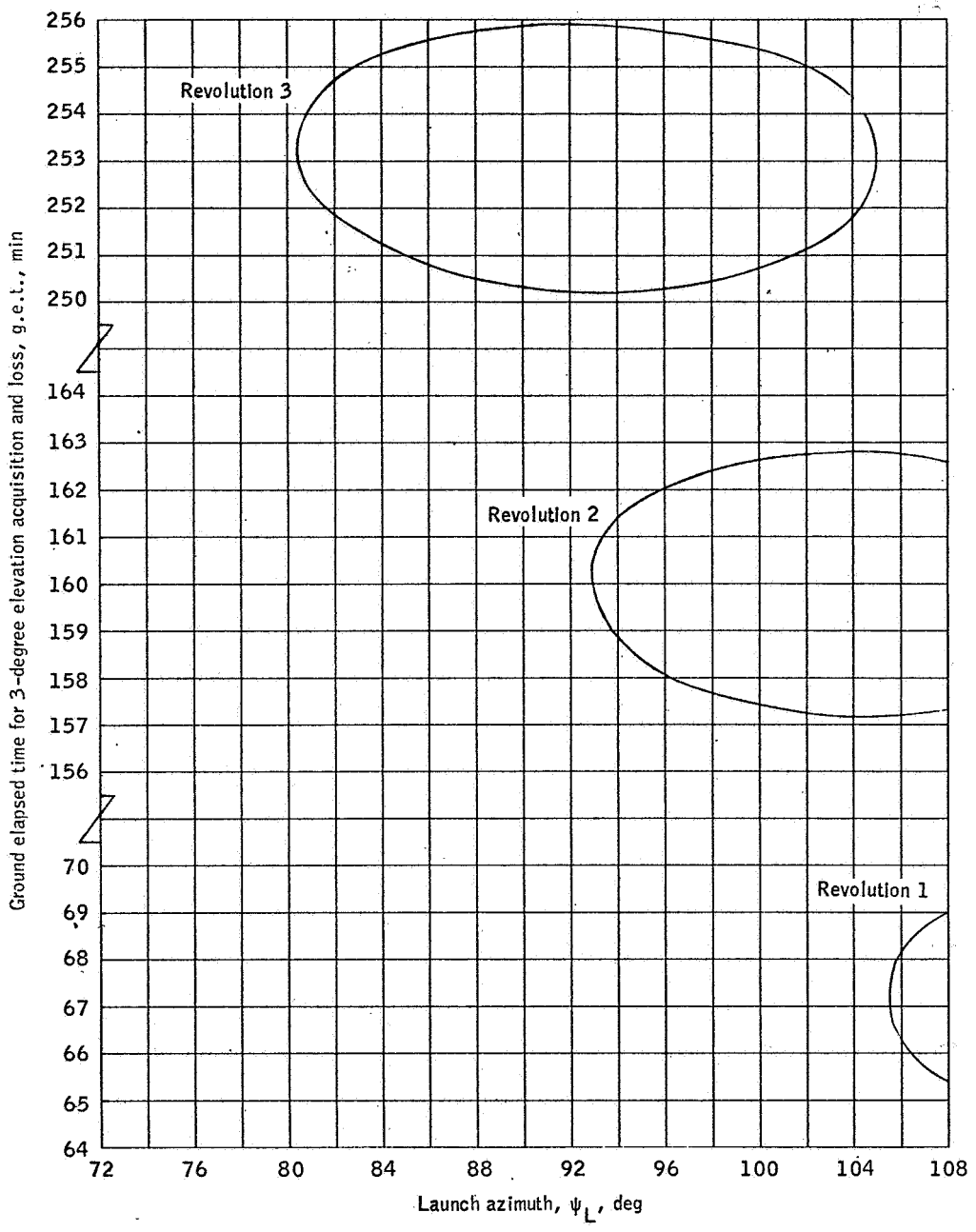
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 16.- Continued.



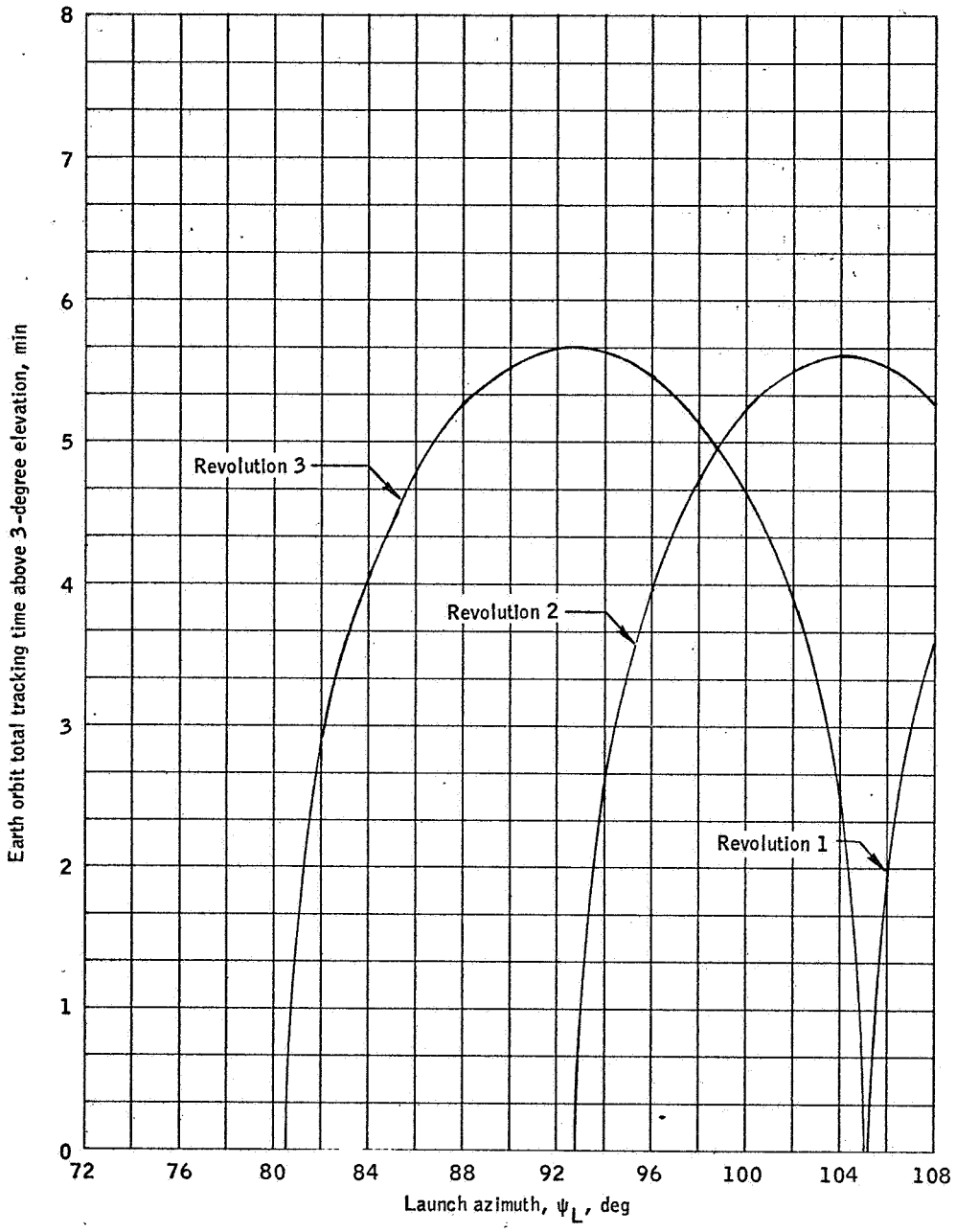
(c) Azimuth of acquisition for 0-degree elevation.

Figure 16.- Concluded.



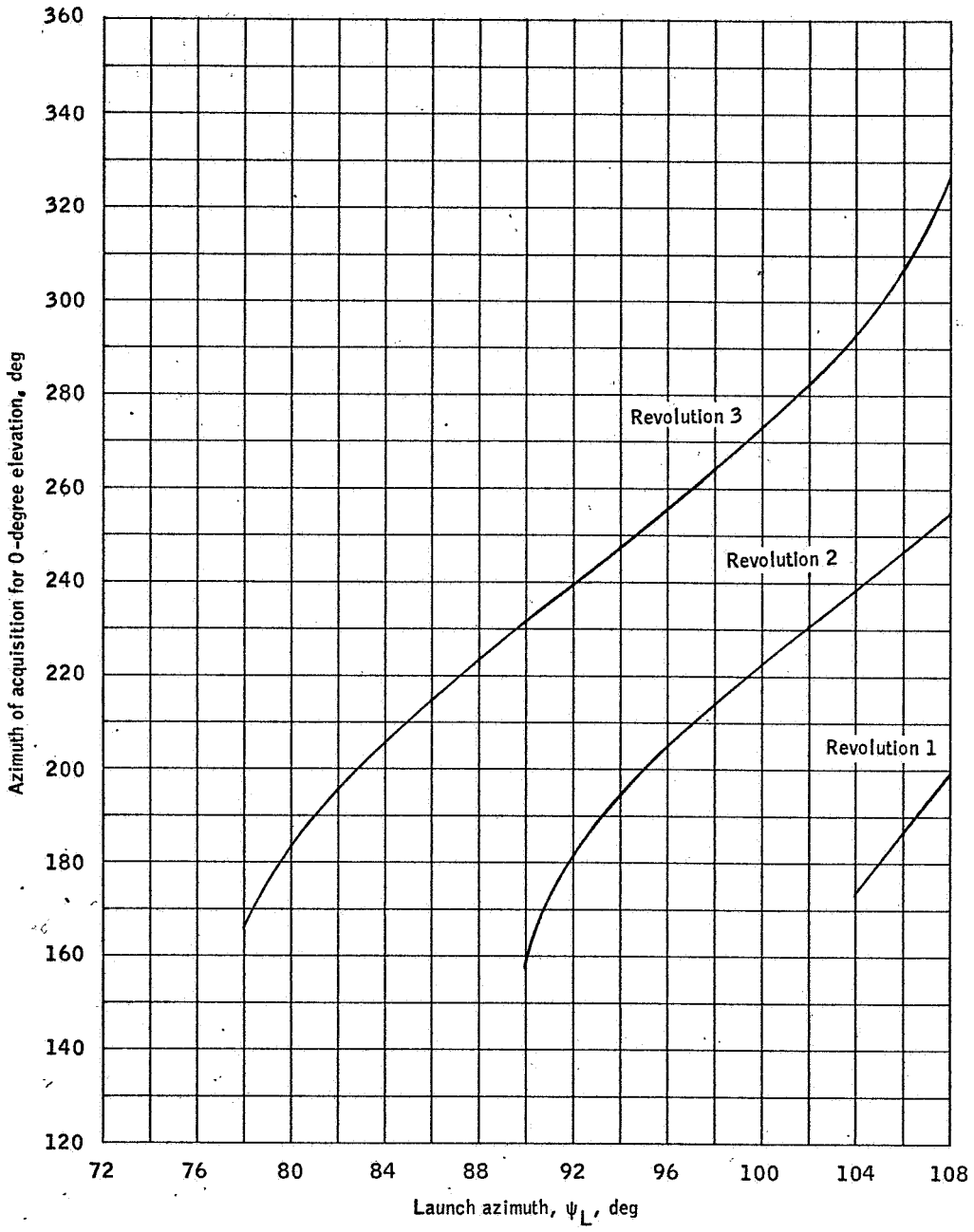
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 17.- Guam radar tracking information for the first three revolutions as a function of launch azimuth.



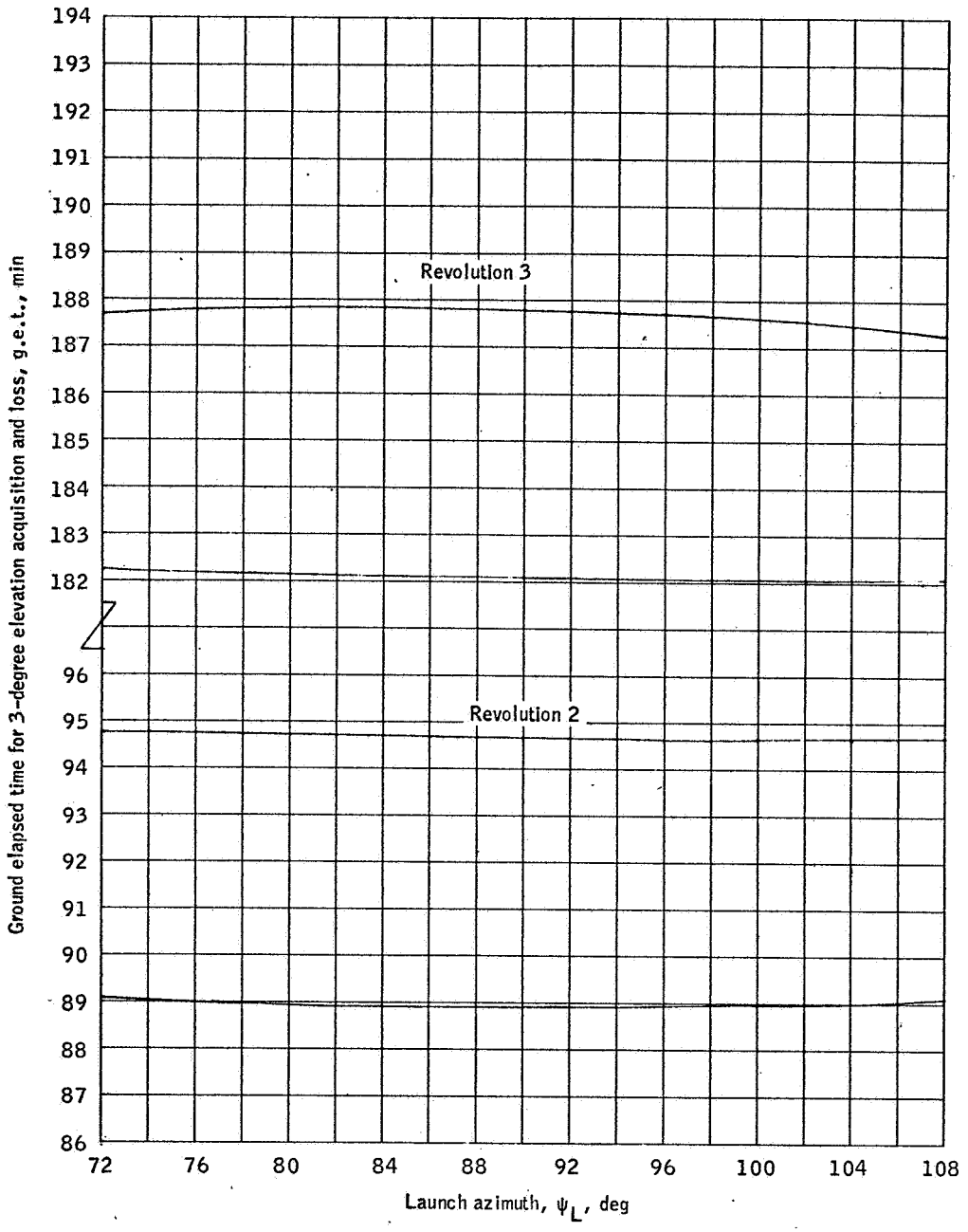
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 17.- Continued.



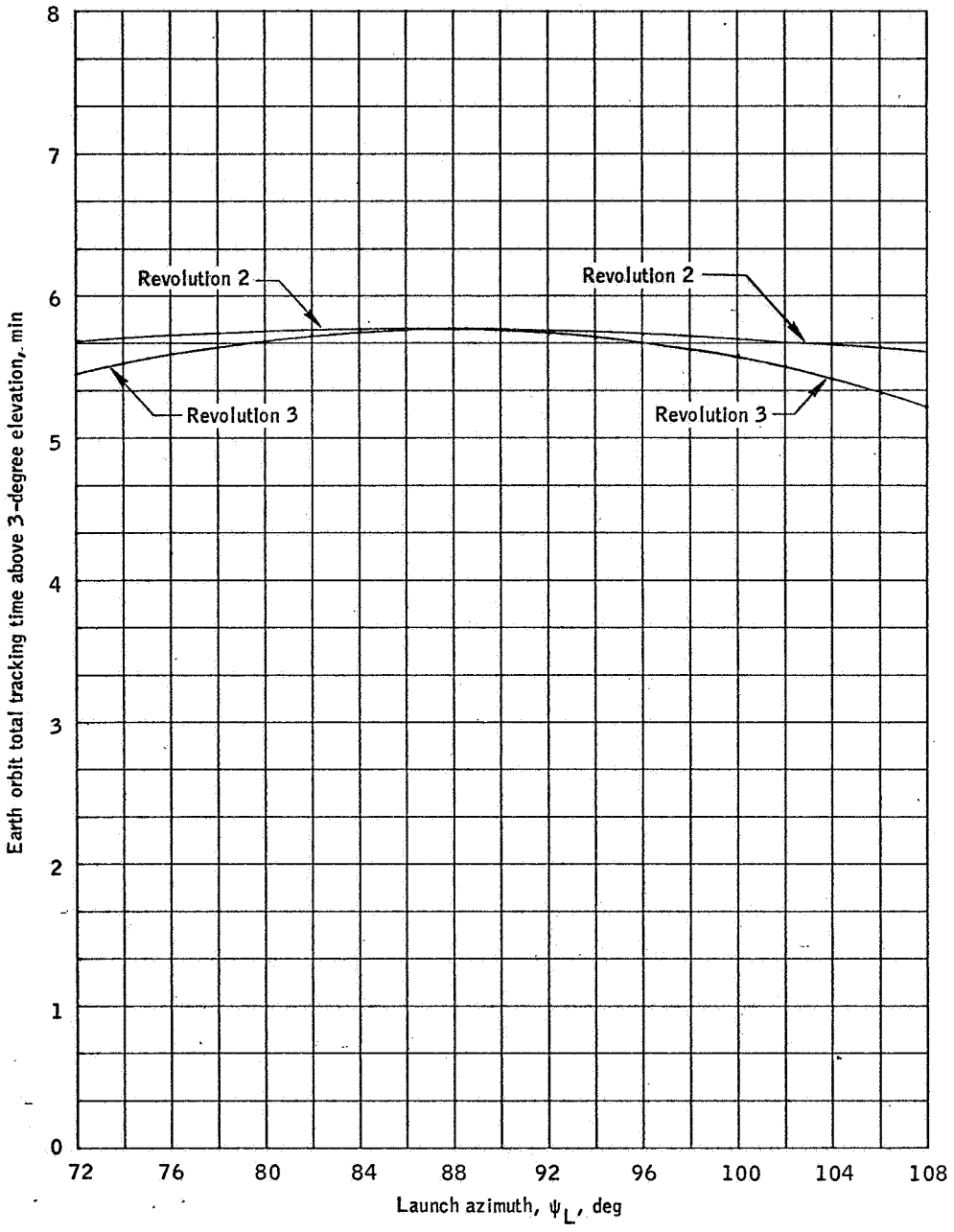
(c) Azimuth of acquisition for 0-degree elevation.

Figure 17.- Concluded.



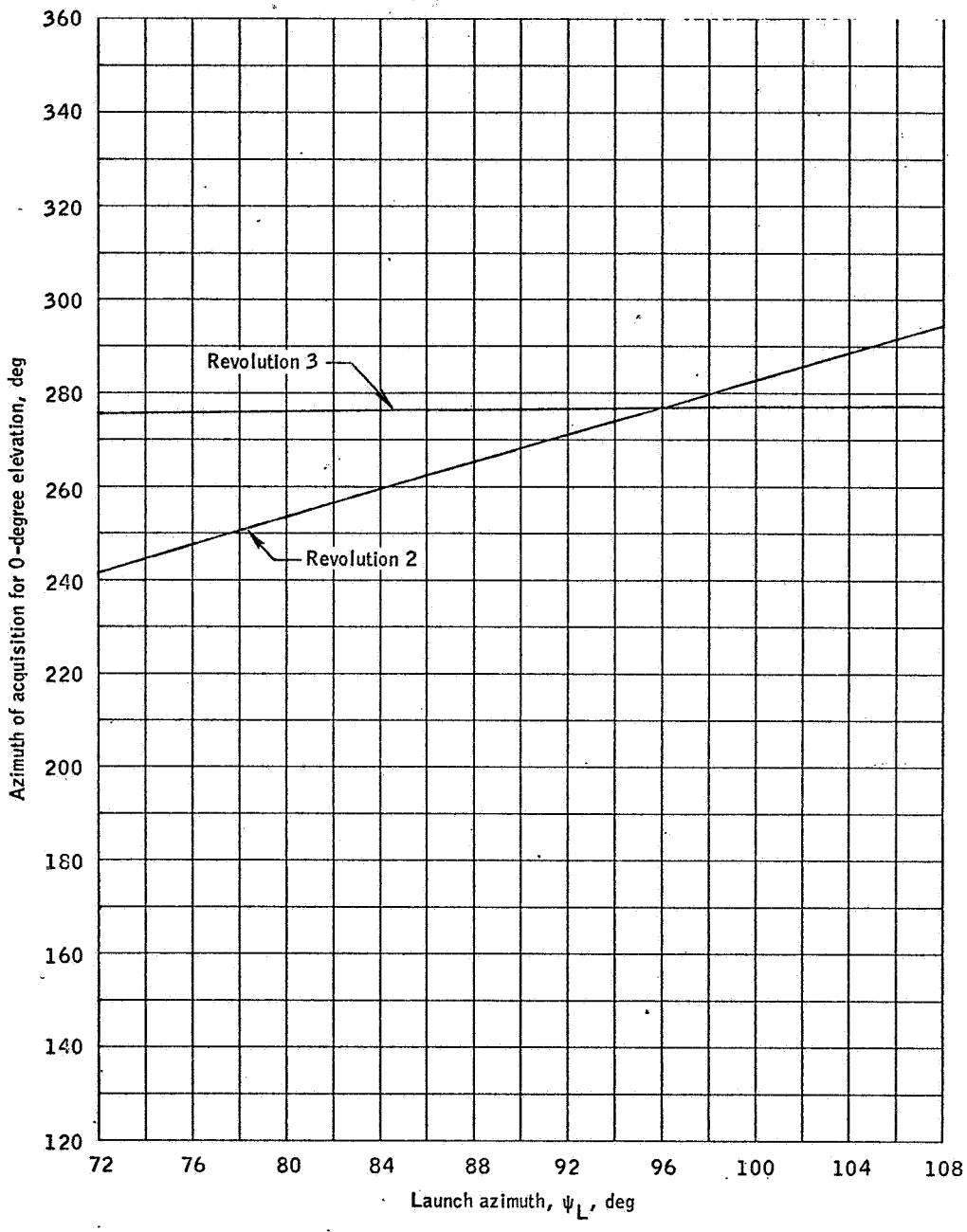
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 18.- Guaymas radar tracking information for the first three revolutions as a function of launch azimuth.



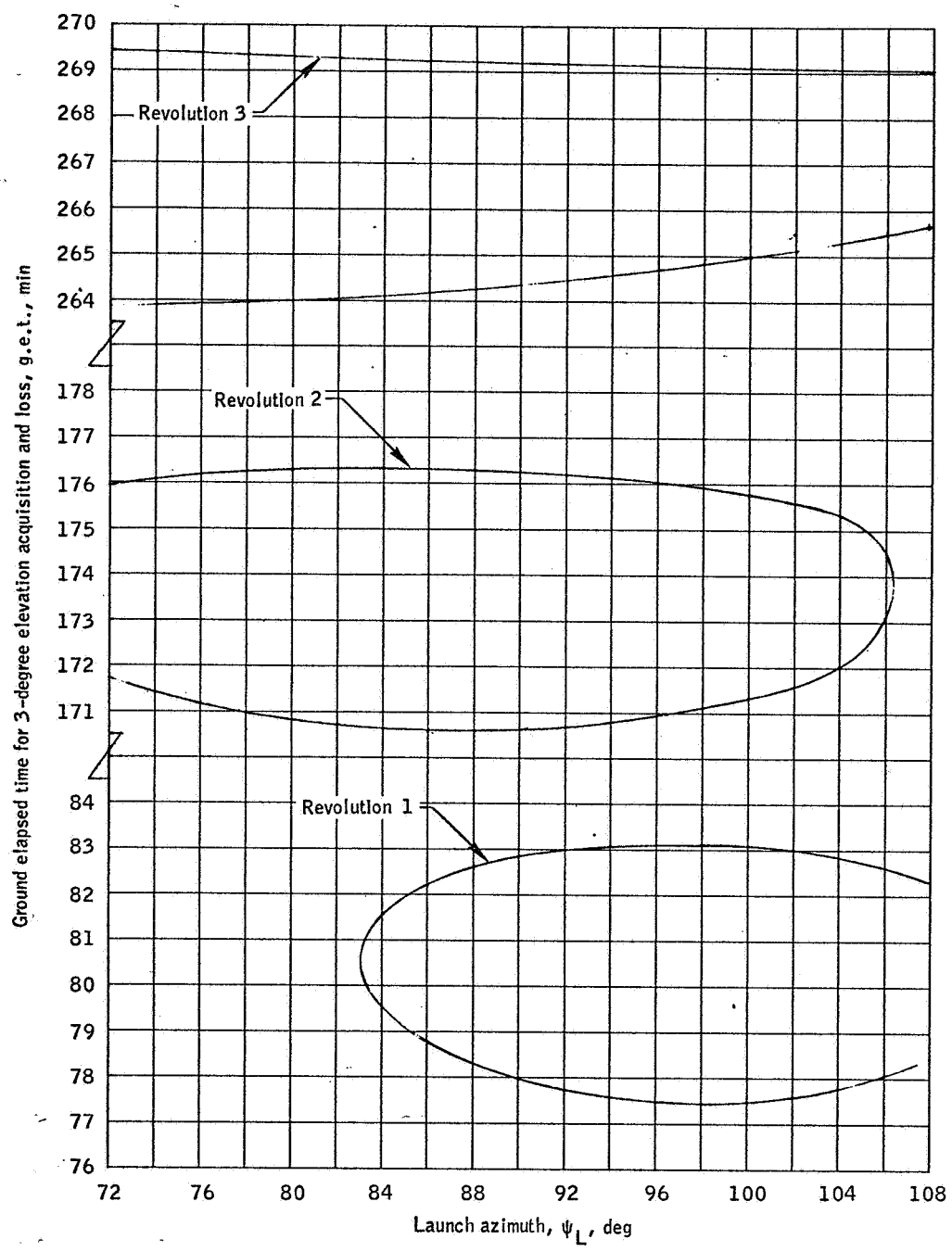
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 18.- Continued.



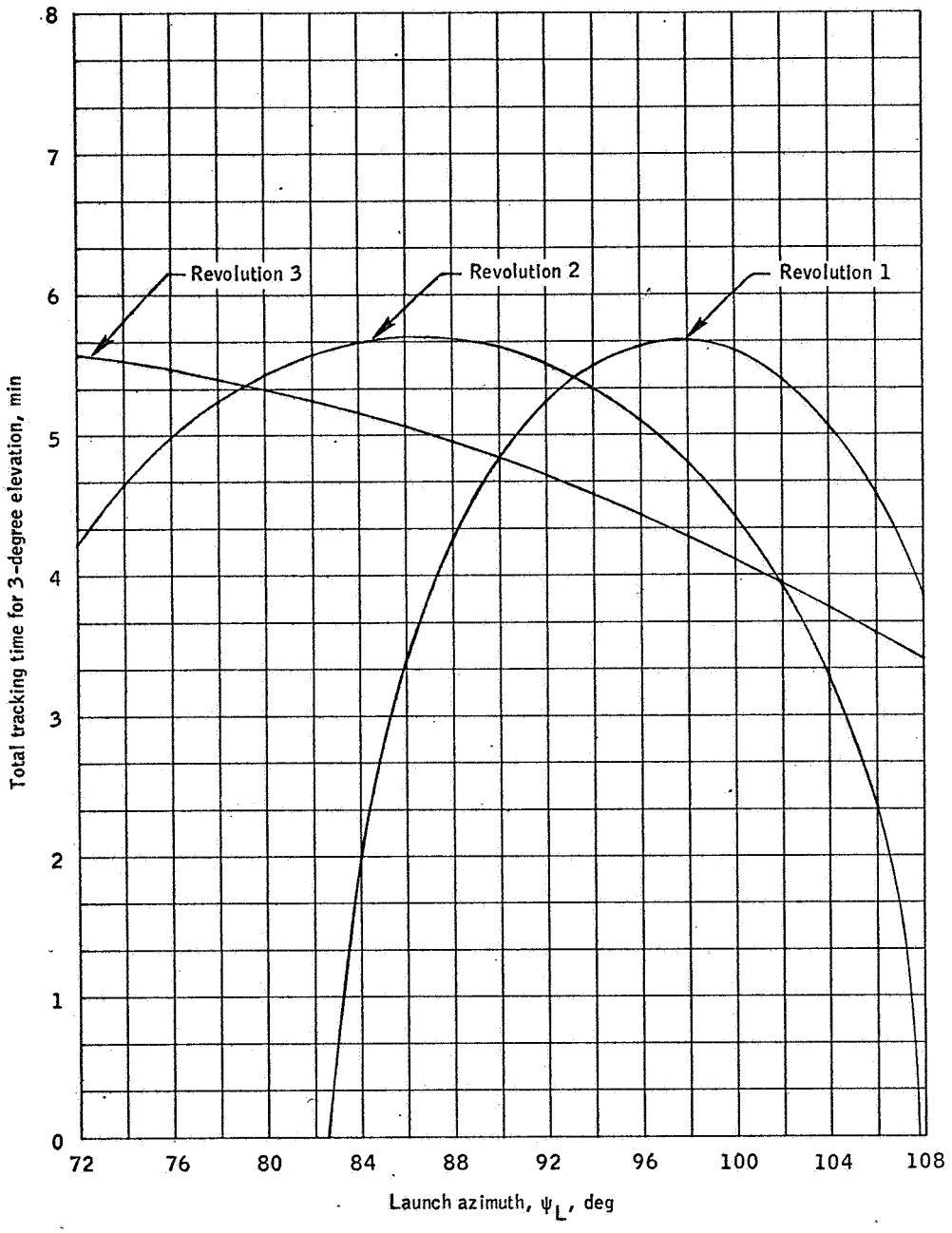
(c) Azimuth of acquisition for 0-degree elevation.

Figure 18.- Concluded.



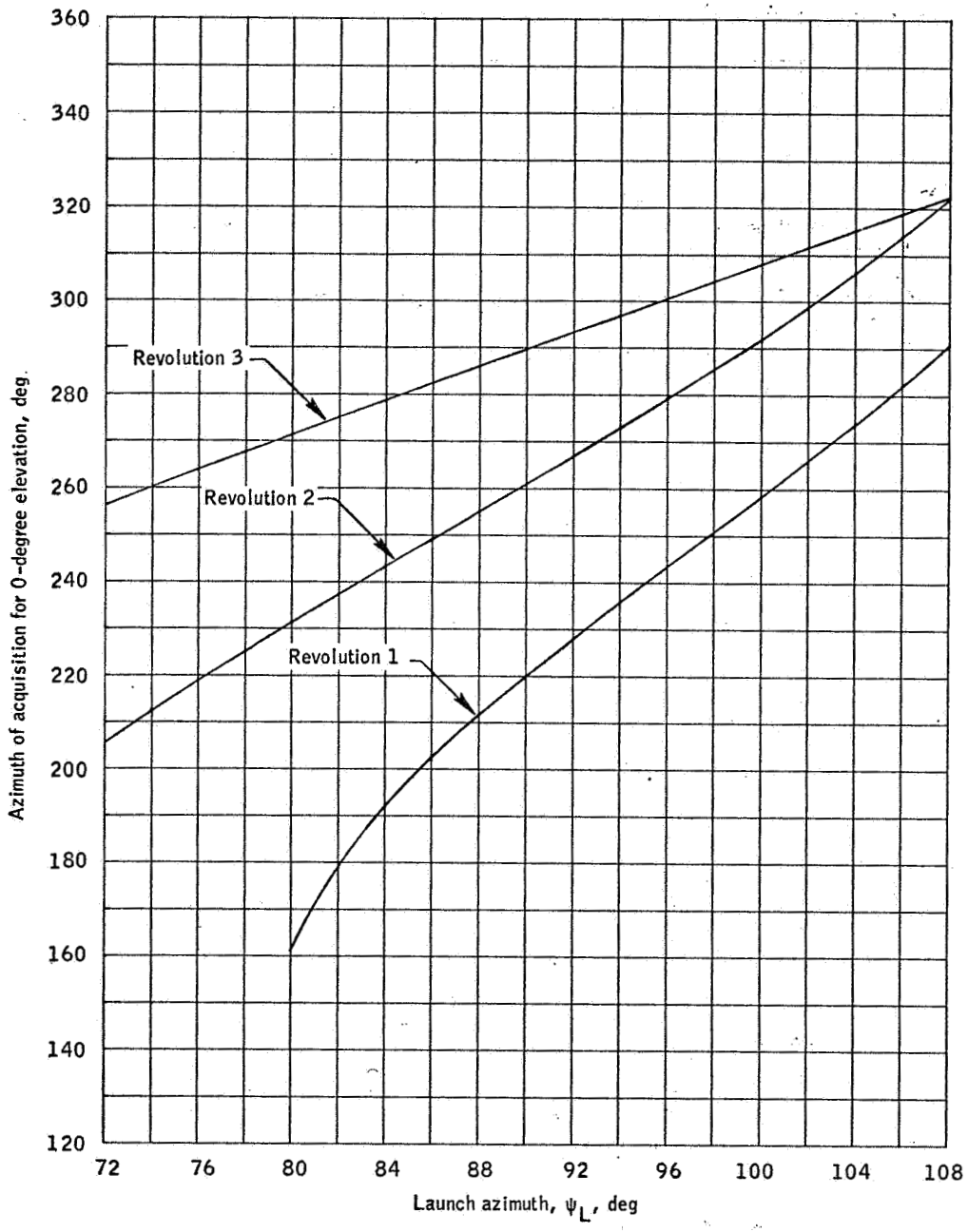
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 19.- Hawaii radar tracking information for the first three revolutions as a function of launch azimuth.



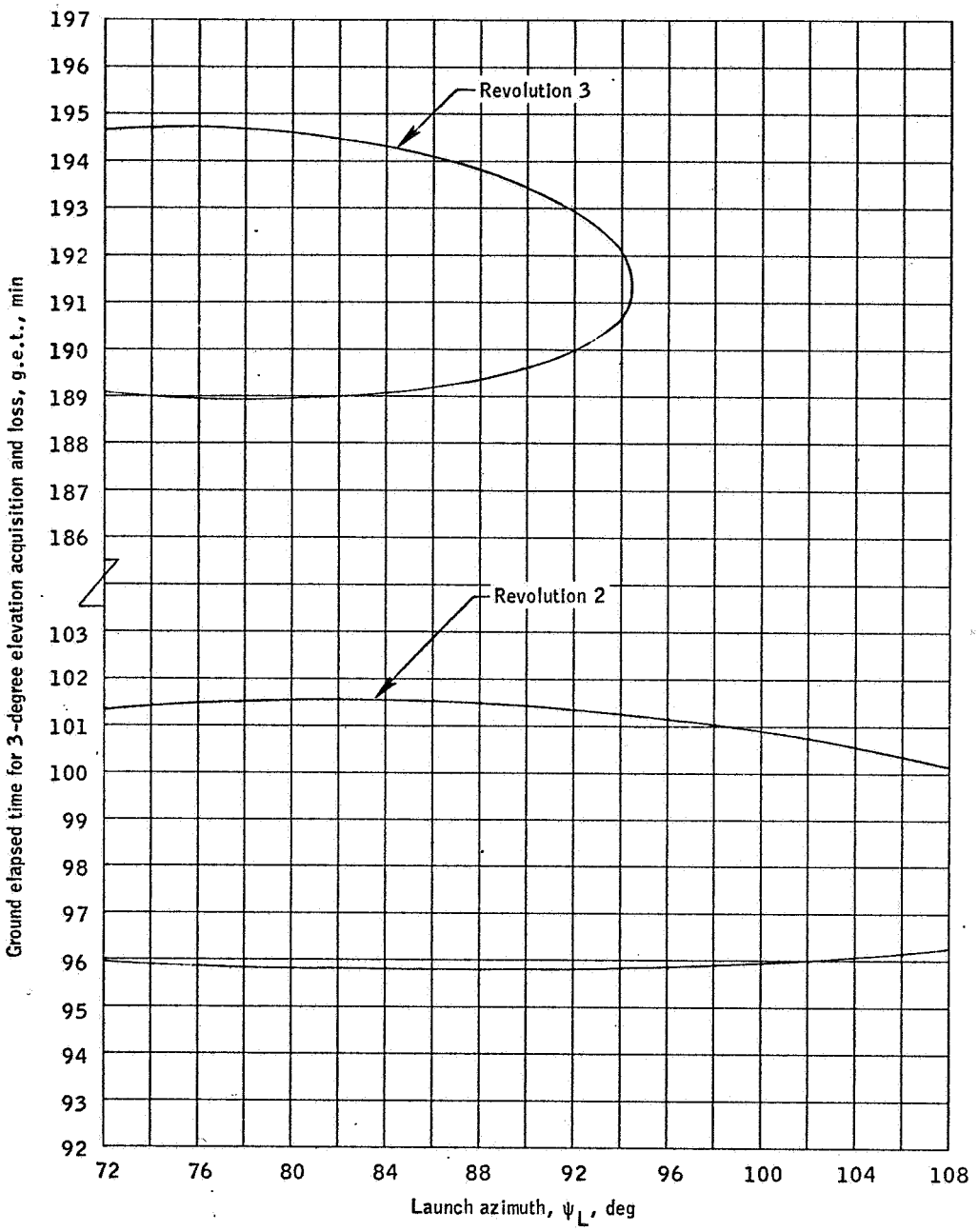
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 19.- Continued.



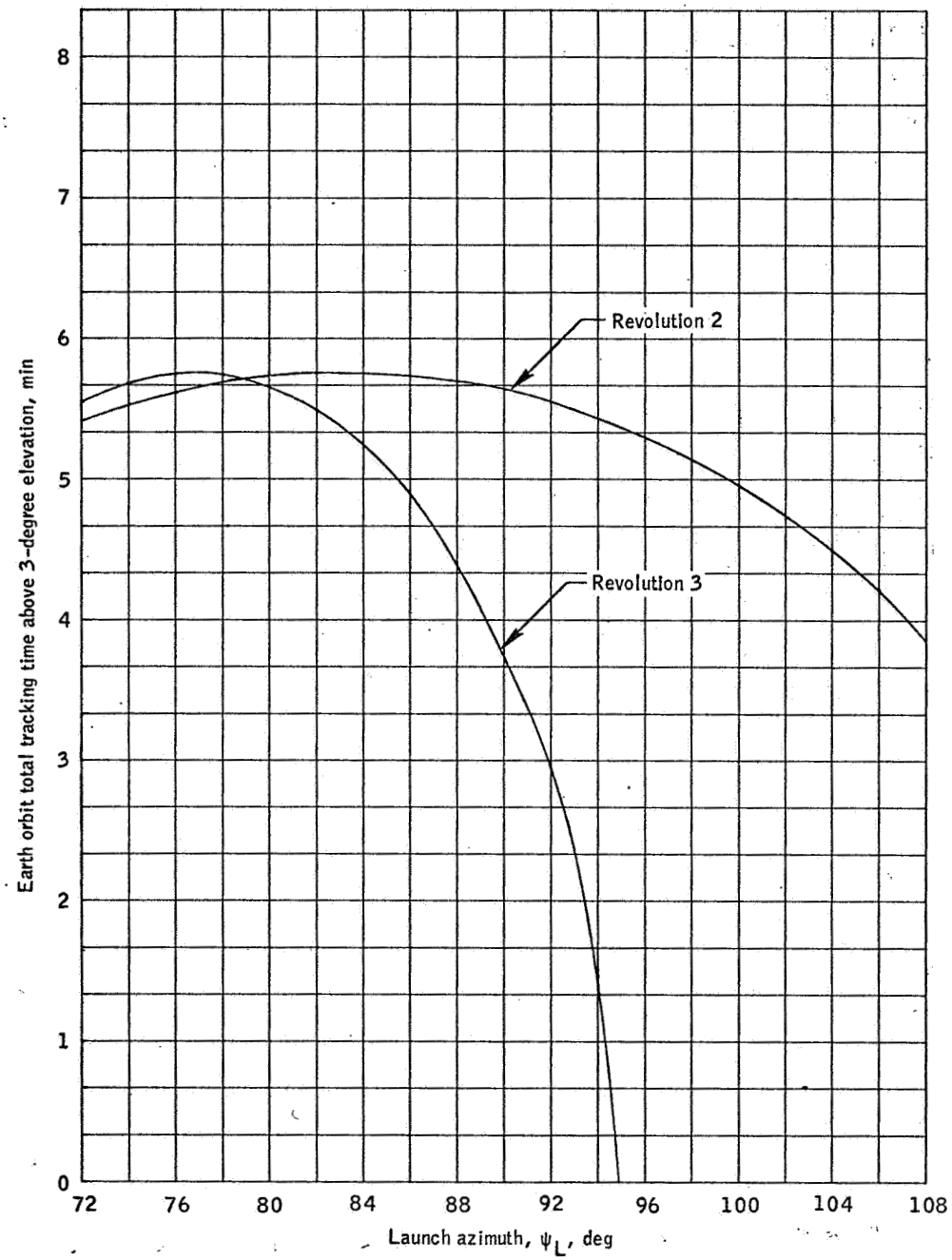
(c) Azimuth of acquisition for 0-degree elevation.

Figure 19. - Concluded.



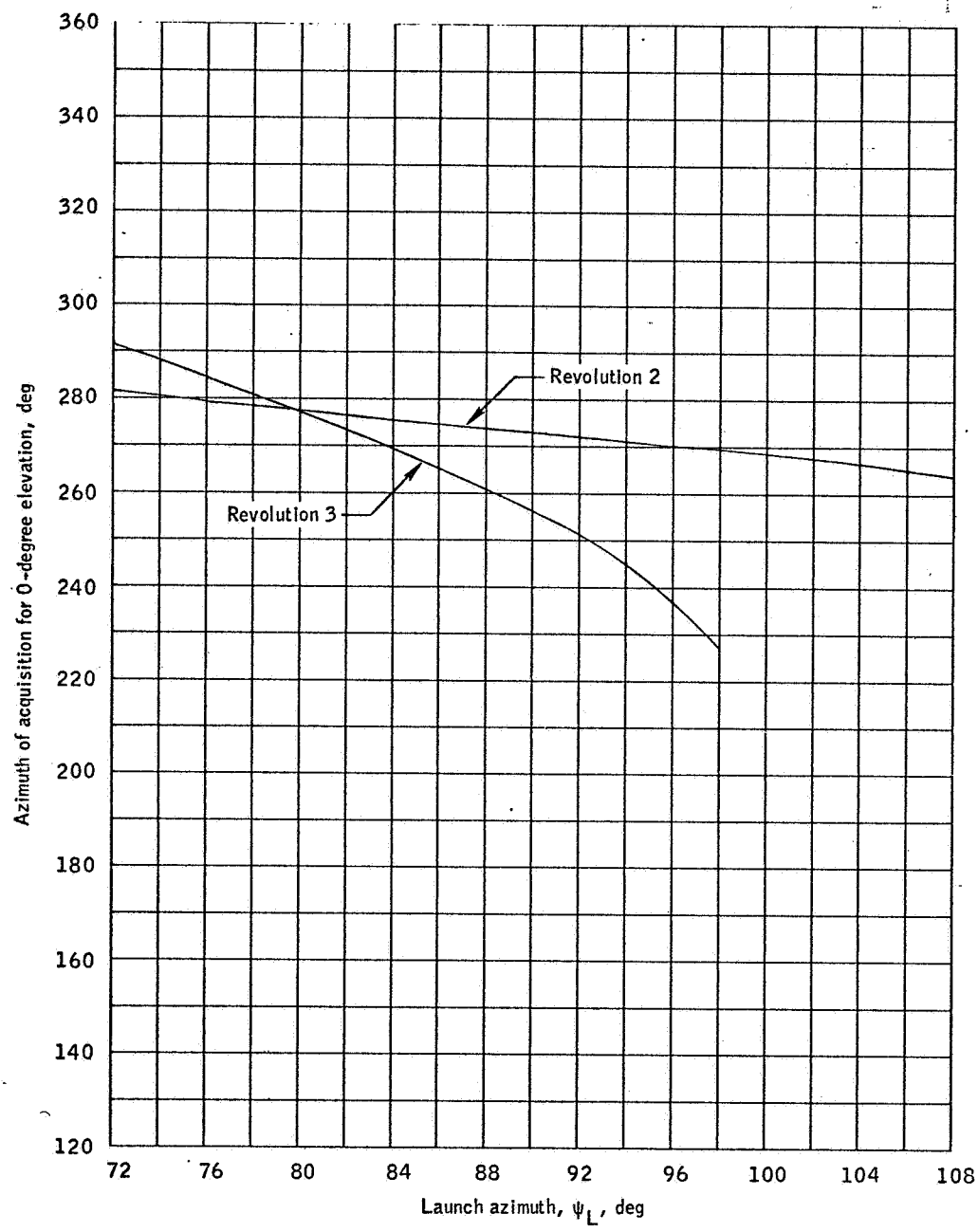
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 20.- Merritt Island radar tracking information for the first three revolutions as a function of launch azimuth.



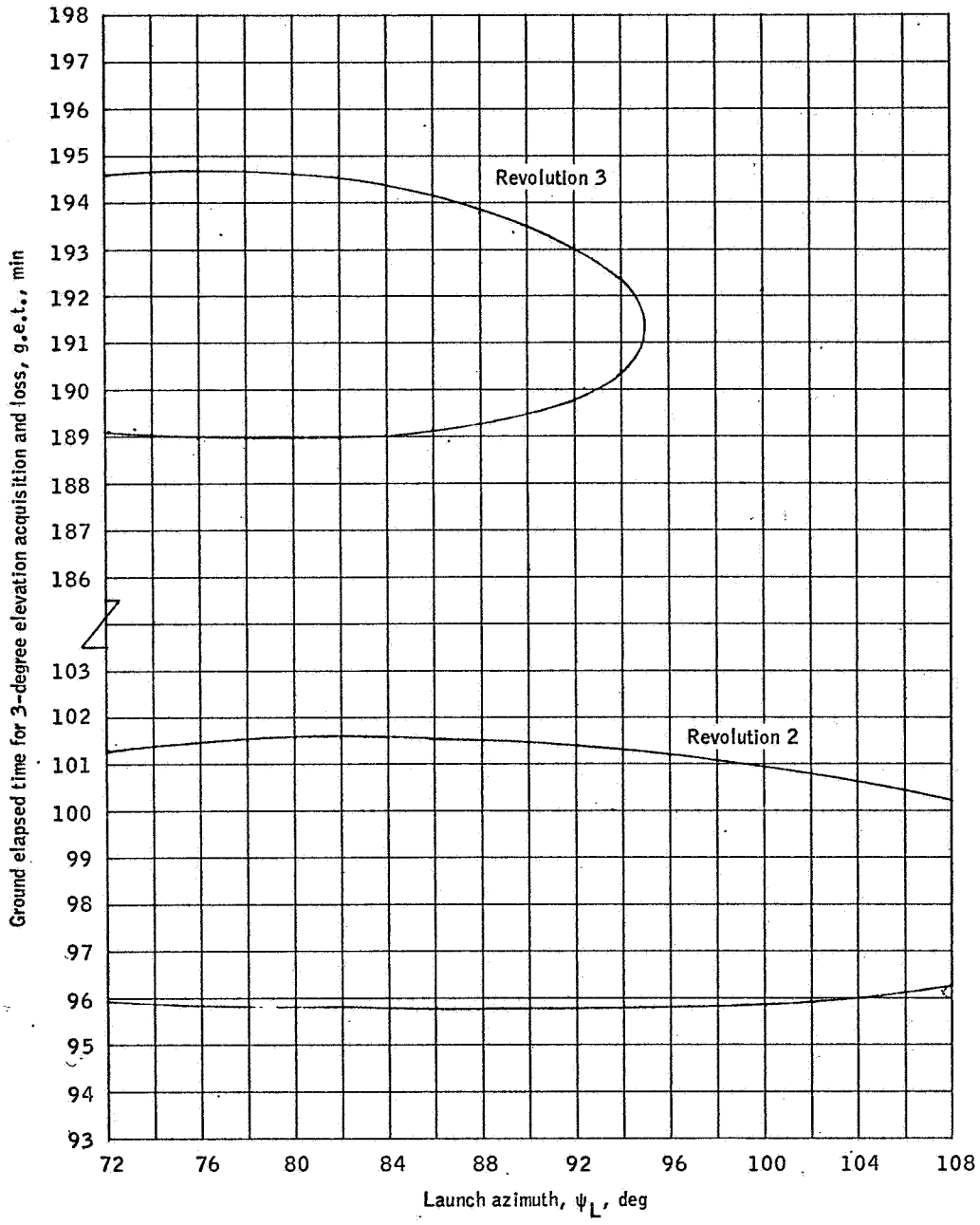
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 20.- Continued.



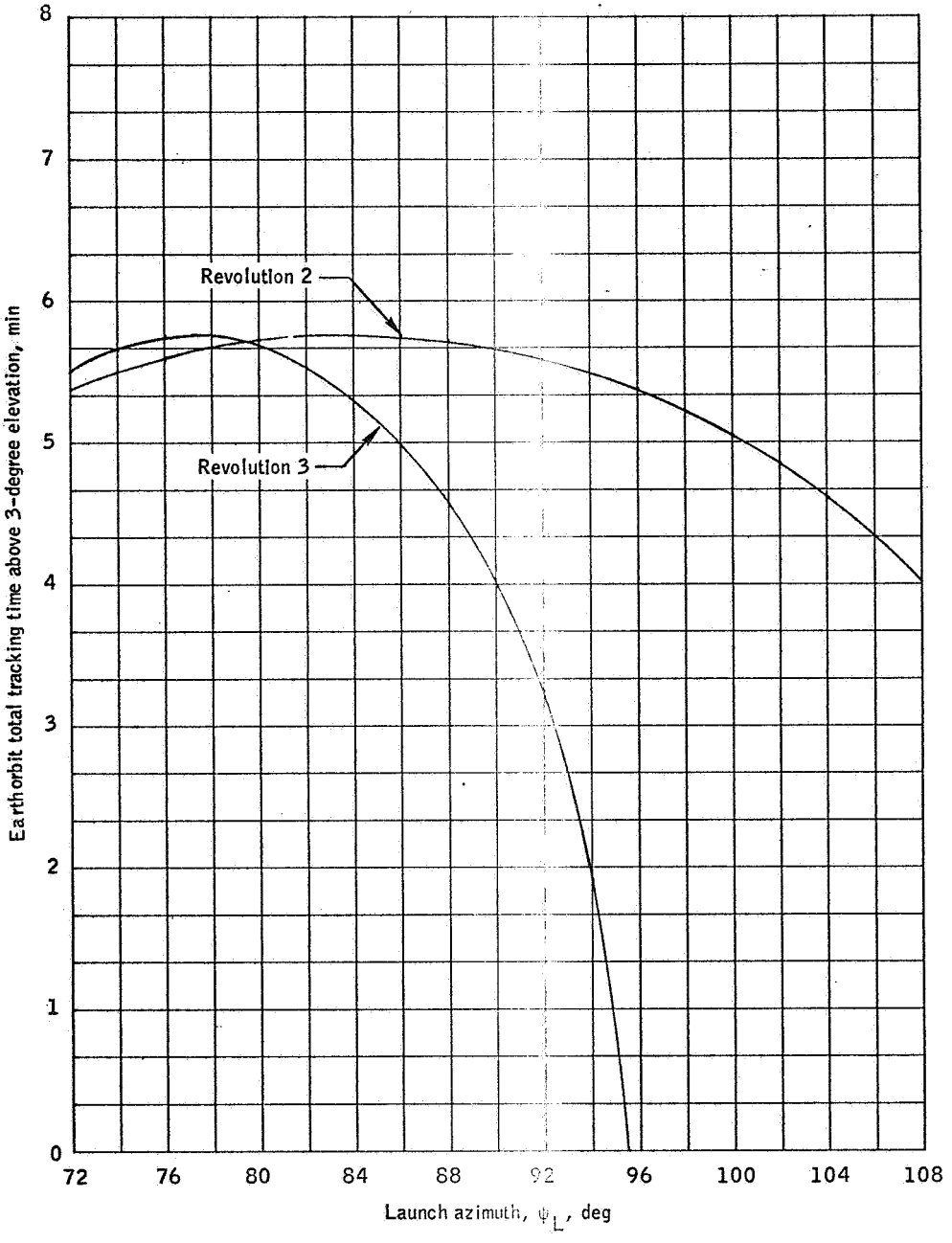
(c) Azimuth of acquisition for 0-degree elevation.

Figure 20.- Concluded.



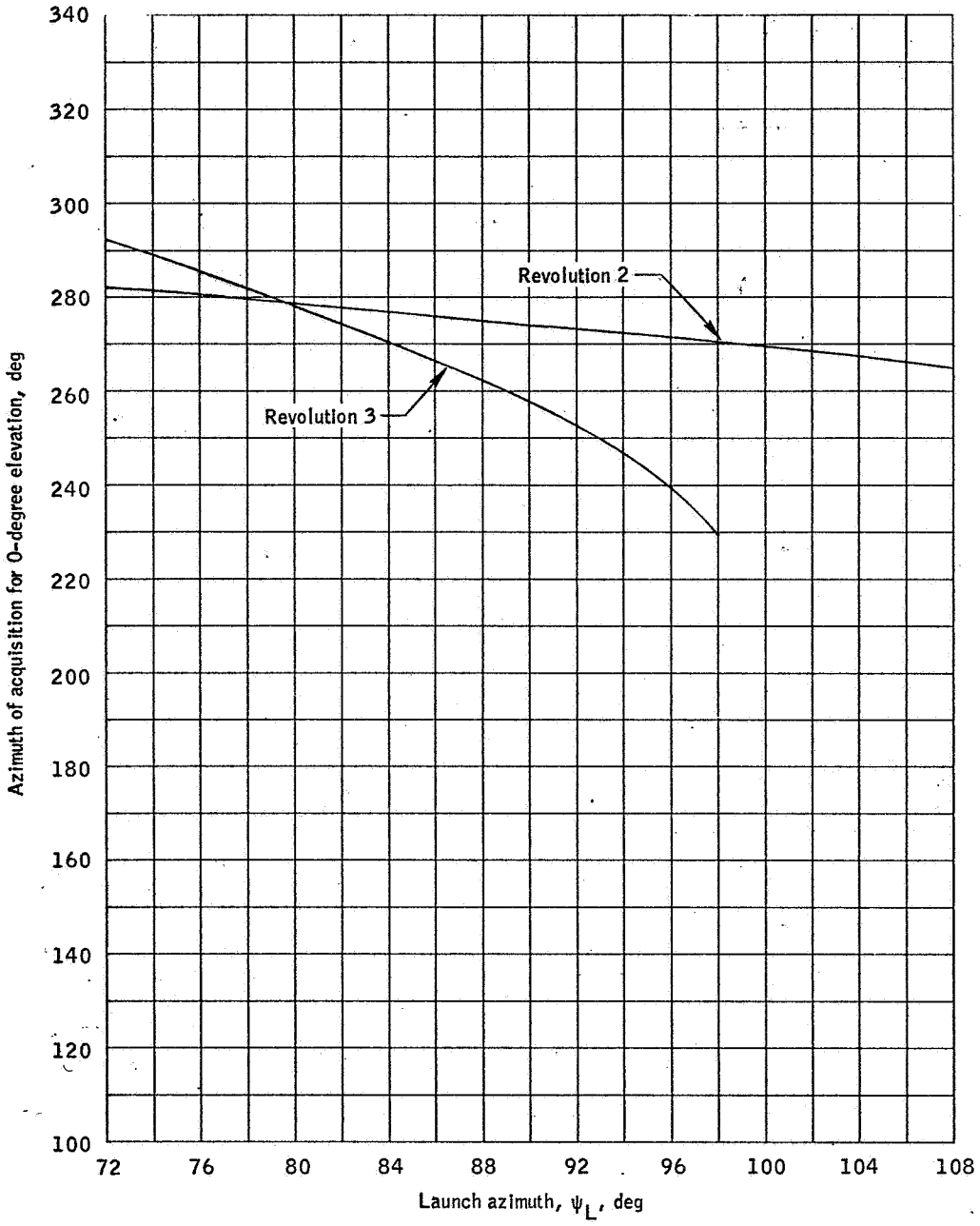
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 21.- Patrick radar tracking information for the first three revolutions as a function of launch azimuth.



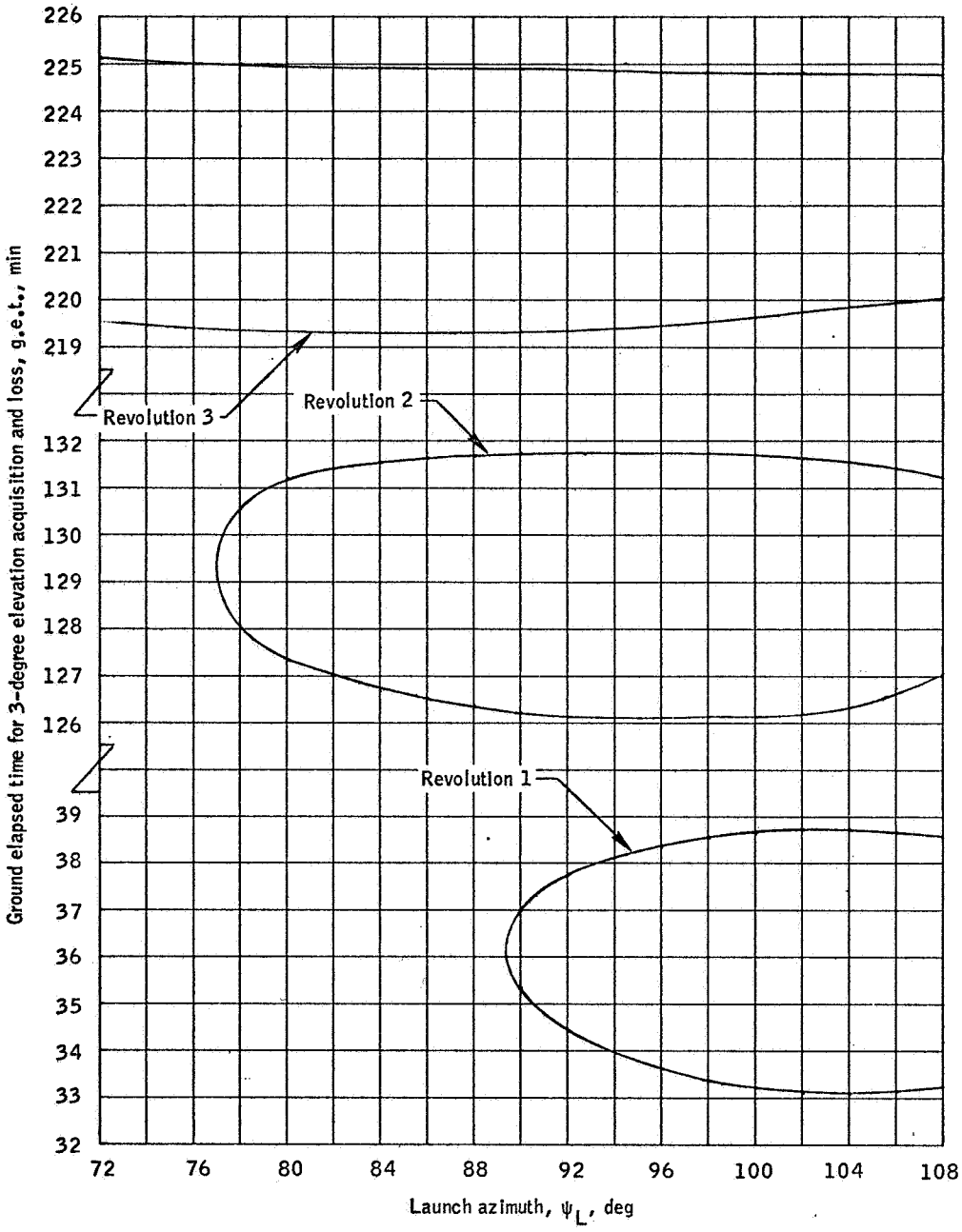
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 21.- Continued.



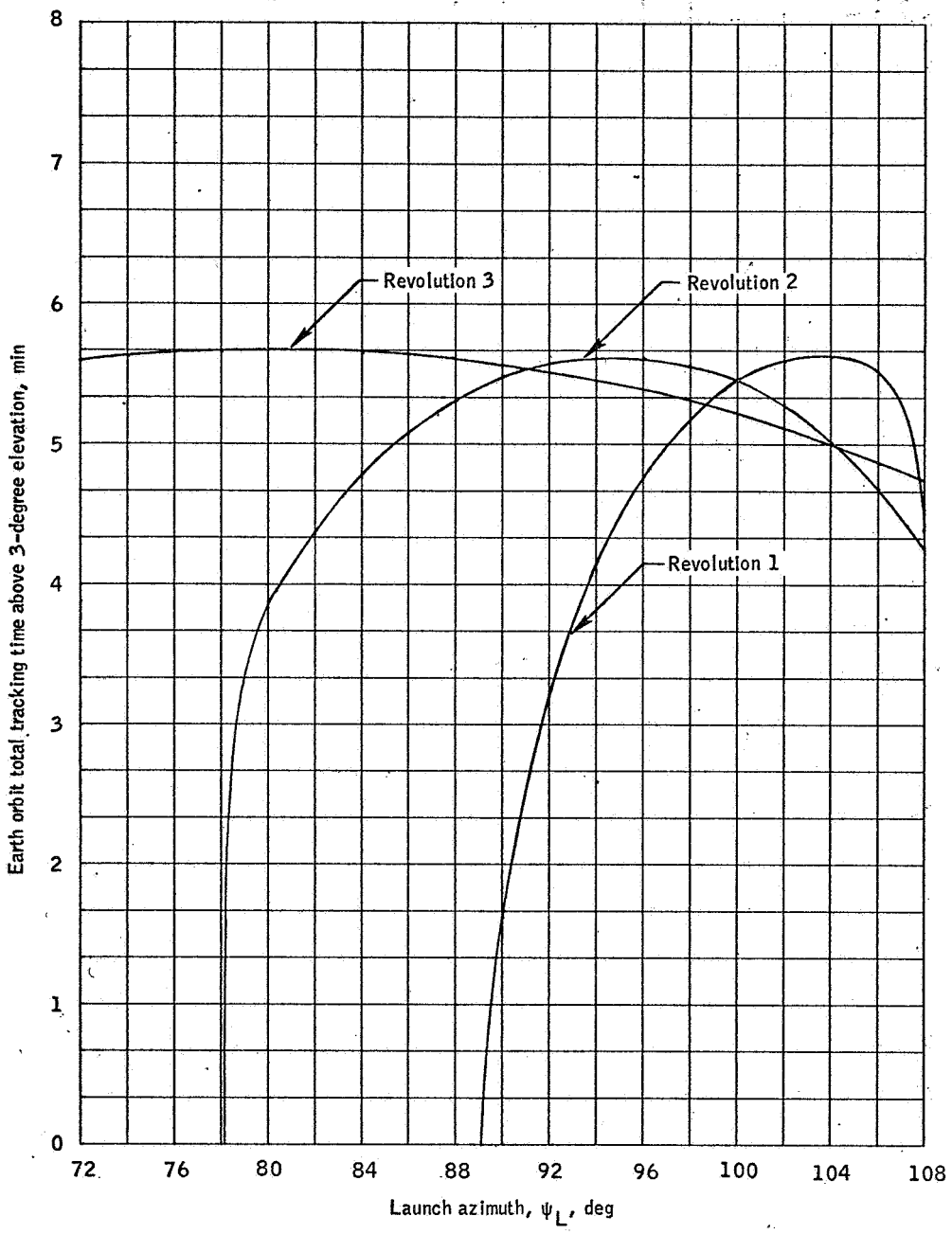
(c) Azimuth of acquisition for 0-degree elevation.

Figure 21.- Concluded.



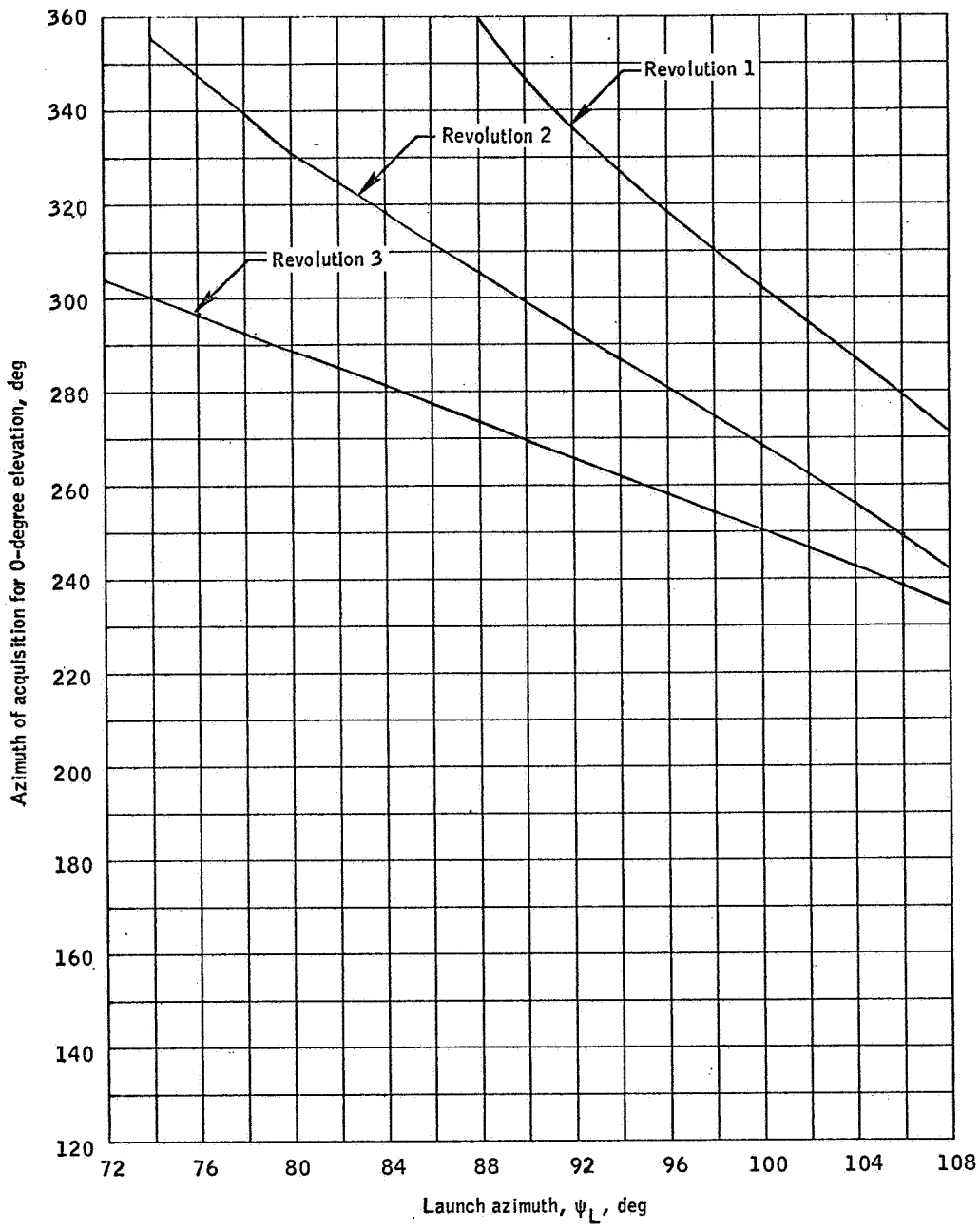
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 22.- Pretoria radar tracking information for the first three revolutions as a function of launch azimuth.



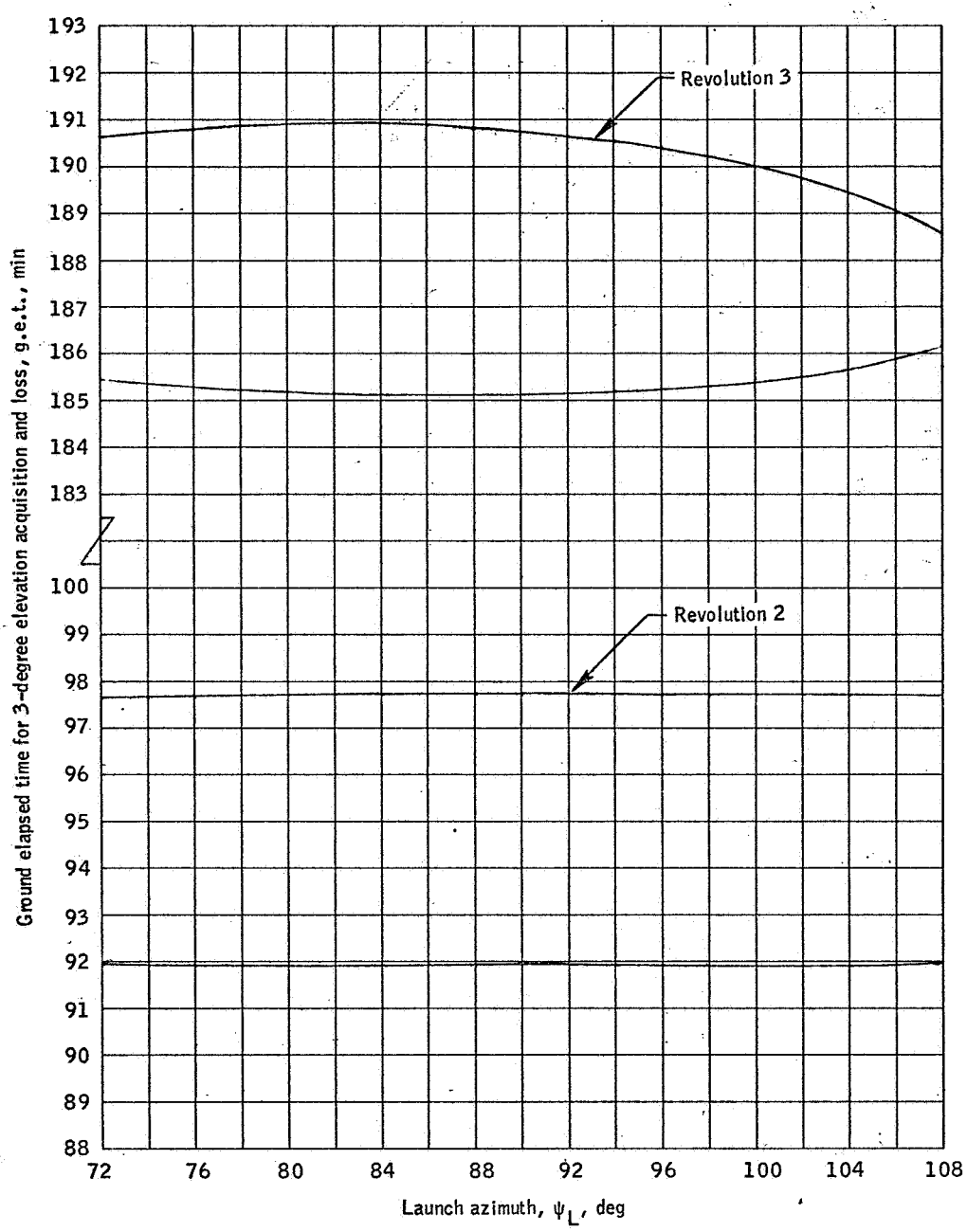
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 22.- Continued.



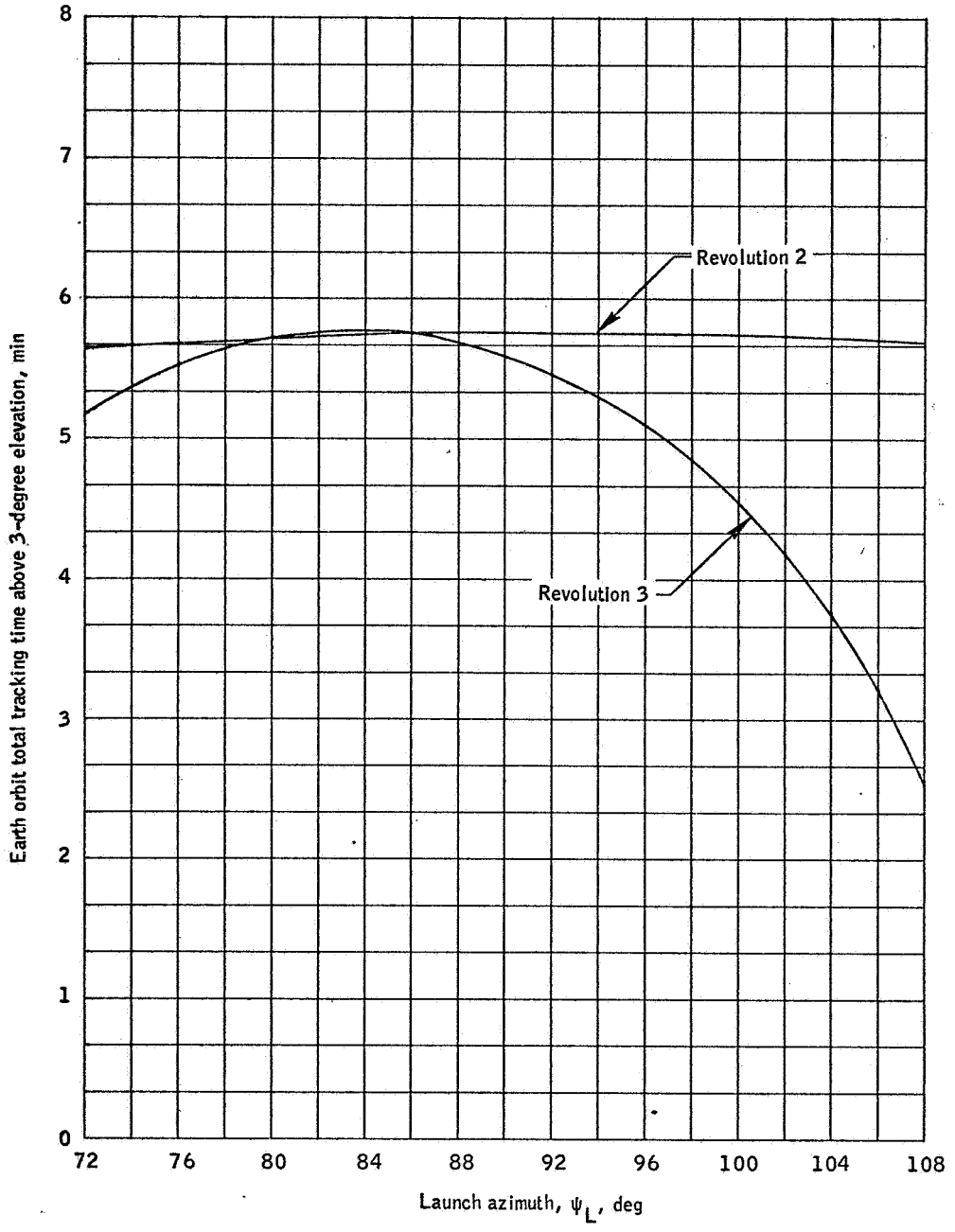
(c) Azimuth of acquisition for 0-degree elevation.

Figure 22.- Concluded.



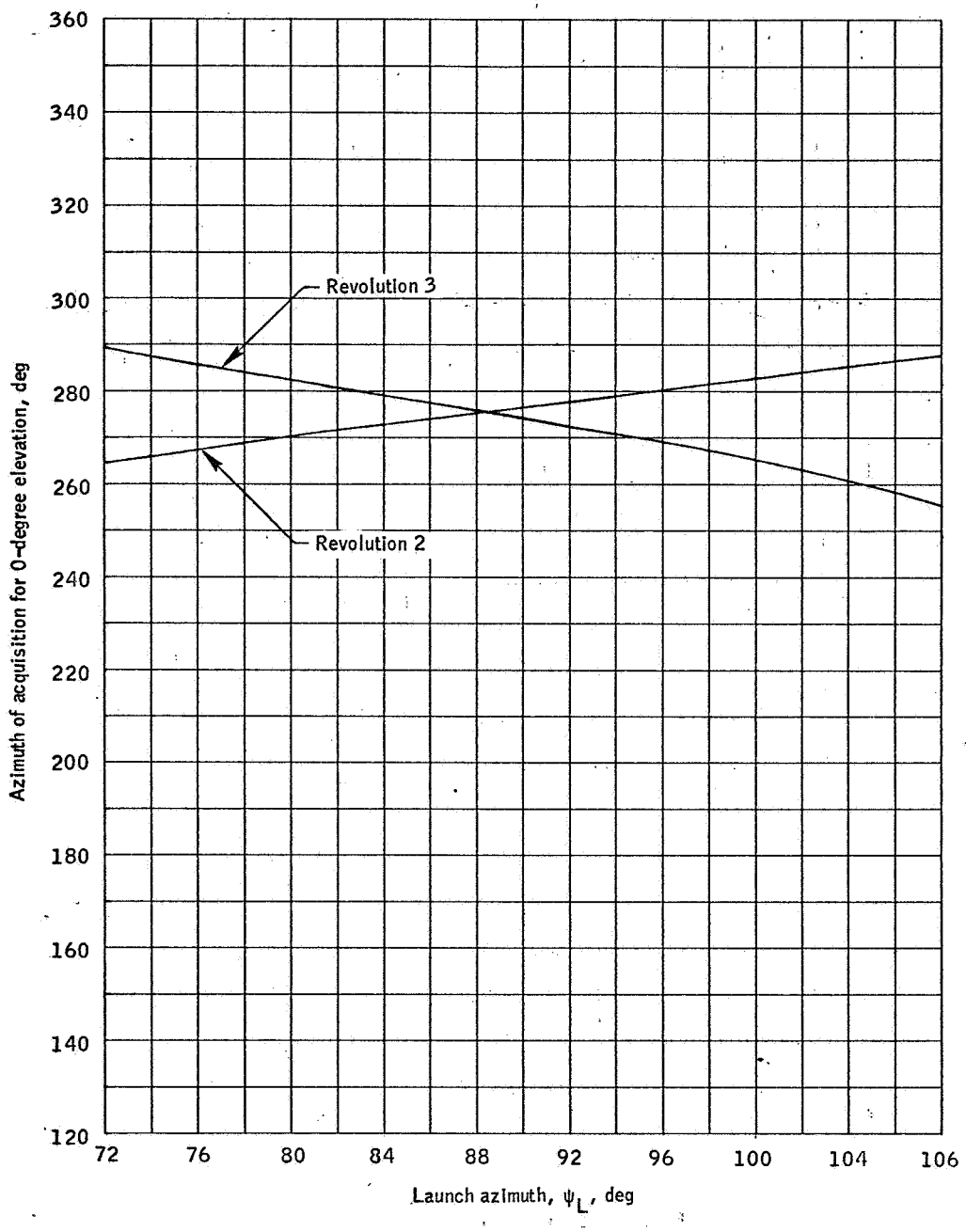
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 23.- Texas radar tracking information for the first three revolutions as a function of launch azimuth.



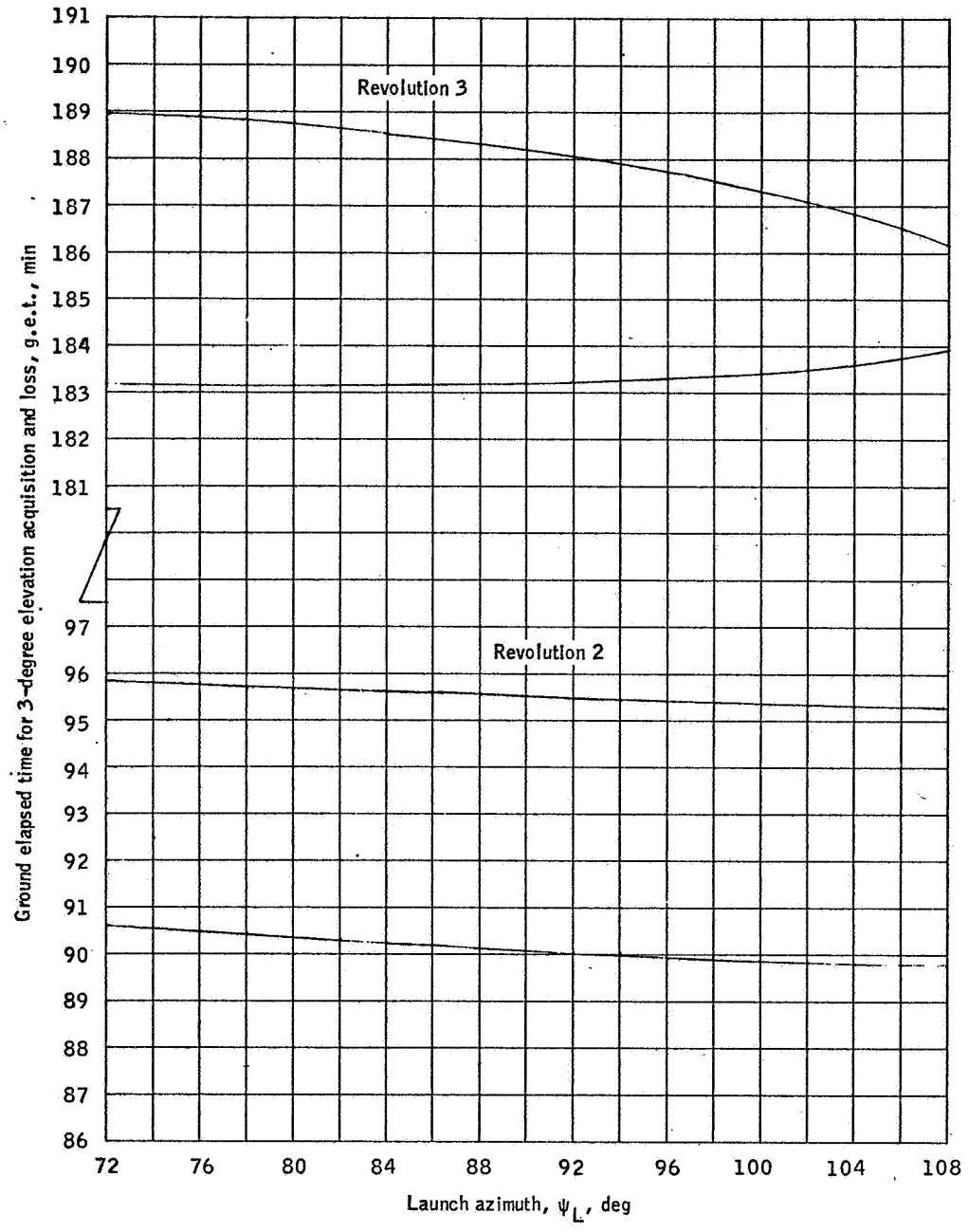
(b) Earth orbit total tracking time above 3-degree elevation.

Figure 23.- Continued.



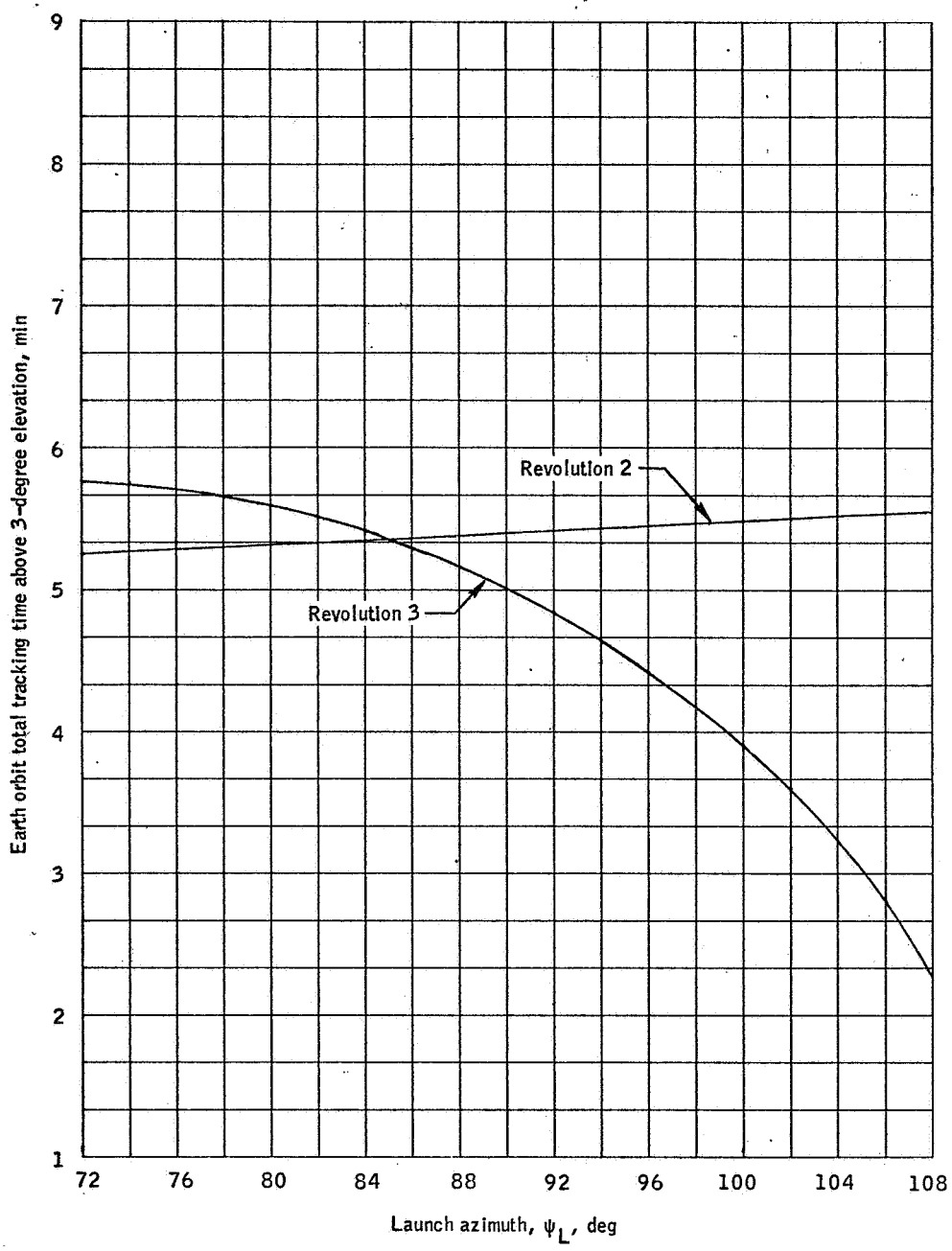
(c) Azimuth of acquisition for 0-degree elevation.

Figure 23.- Concluded.



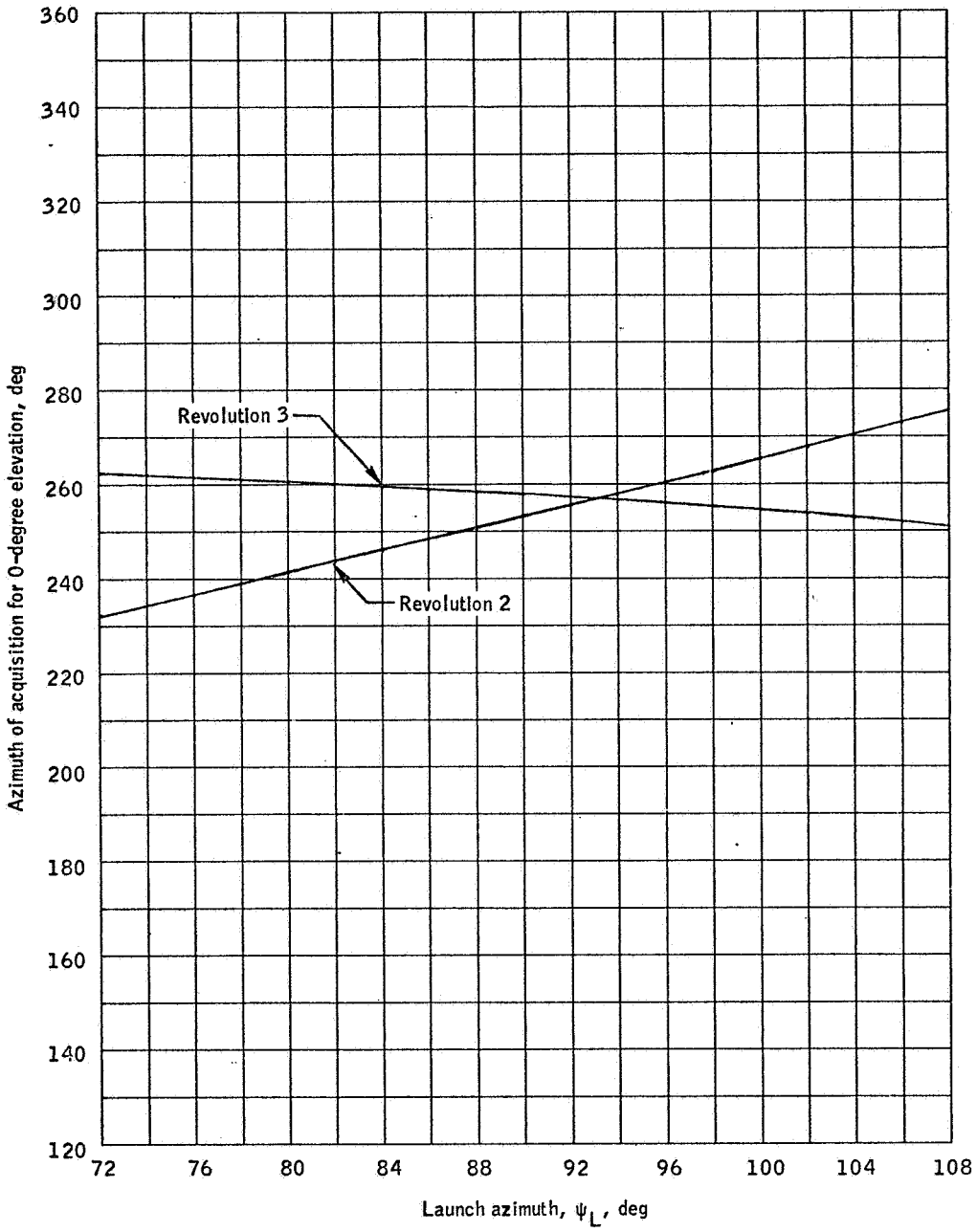
(a) Ground elapsed time for 3-degree elevation acquisition and loss.

Figure 24.- White Sands radar tracking information for the first three revolutions as a function of launch azimuth.



(b) Earth orbit total tracking time above 3-degree elevation.

Figure 24.- Continued.



(c) Azimuth of acquisition for 0-degree elevation.

Figure 24.- Concluded.

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