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ATM STAR TRACKER VEHICLE STRUCTURE OCCULTATION STUDY

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16. Abstract

A computer study has been performed to evaluate the vehicle occultation of the ATM star tracker. Reference stars Canopus, Achernar, and Alpha Crux have been selected for the ATM star tracker.

The criteria used in selecting these stars were based on the mission requirements, position of the stars, characteristics of the stars, and the tracker design. This study has considered the "worst case" constraints: a 35 ±2 degrees orbital inclination angle; a ±7.5 degrees orbital plane — principal axis misalignment of the spacecraft; a docking misalignment of ±10 degrees; and a reflection zone of 15 degrees around the orbital workshop solar array.

Occultation graphs indicate the necessity for three reference stars to reduce the possibility of simultaneous occultation. The graphs also indicate that 2- to 3-day periods of vehicle occultation could occur (depending on the launch hour and day) if the docking error exceeds ±5 degrees.

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SUMMARY

A computer study has been performed to evaluate the vehicle occultation of the ATM star tracker. Reference stars Canopus, Achernar, and Alpha Crux have been selected for the ATM star tracker.

The criteria used in selecting these stars were based on the mission requirements, position of the stars, characteristics of the stars, and the tracker design. This study has considered the "worst case" constraints: a 35 ± 2 degrees orbital inclination angle; a ± 7.5 degrees orbital plane — principal axis misalignment of the spacecraft; a docking misalignment of ± 10 degrees; and a reflection zone of 15 degrees around the orbital workshop solar array.

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INTRODUCTION

Utilization of the ATM star tracker position signals to calculate the vehicle roll reference depends upon having an unobstructed view of a reference star. During the ATM mission, it is possible for parts of the vehicle to intermittently obstruct the star line-of-sight. Reference stars Canopus, Achernar, and Alpha Crux have been selected to minimize this occultation. Their approximate separation of 90 degrees in right ascension enhances the possibility that at least one of the stars will not be occulted by the vehicle structure at all times. Computer studies are summarized on the occultation graphs. These graphs permit the launch time and mission period to be chosen to minimize or avoid star tracker occultation problems.

STUDY CONSIDERATIONS

Vehicle structure occultations of the ATM star tracker are caused by obstructions from the solar arrays and support structures. The star tracker is located on the -Z axis (rack coordinates) at the top of the rack. The tracker's outer gimbal is oriented along the sun line, with its inner gimbal orthogonal to this axis. This position offers less interference and provides the most suitable tracking window for the reference stars. Light reflecting surfaces in the star tracker line-of-sight are also considered as obstructions, because the telescope protective shutter will automatically close when the pointing direction is within 5 degrees of the earth albedo or 45 degrees of the sun (or an equivalent reflective light).

This study has considered the selection of reference stars, the design characteristics and limitations of the star tracker, and the mission parameters. Each of the possible obstructions and reflective surfaces in the tracker field of view has also been considered.

SELECTION OF REFERENCE STARS

Limitations for tracking a given star are dependent upon the hardware and functional requirements of the mission. The ATM star tracker position on the rack defines a target area in the south declination on the star chart. No single target star is visible to the star tracker at all times; therefore, multiple reference stars are chosen. Criteria for selecting reference stars are as follows:

ATM Mission Requirements

The positions of the reference stars with respect to the spacecraft are dependent upon the orbital parameters, the launch time (hour and day), and the time of year. Therefore, reference stars are chosen with these considerations to provide little or no interruptions of star tracker position information.

Star Tracker Design Requirements

Reference stars are selected to be compatible with the electronic, optical, and mechanical design of the star tracker. The photomultiplier tube characteristics and gain parameters are also prime considerations.

Position of Reference Stars

The selected position of reference stars is south of the ecliptic plane and as near as possible to the south ecliptic pole. This position provides the most suitable loci of gimbal angular motion to track the reference stars, and there is no interference from the direct sun or planets which are in the ecliptic plane. Hour angle separation between reference stars is chosen to be near 90 degrees. This provides different tracking patterns for each of the reference stars and, hence, less possibilities of simultaneous occultations.

Reference Star Magnitudes

Target stars selected are of first magnitude or greater (as referenced to the S-20 phototube). This is necessary to achieve an acceptable signal-to-noise output and to provide a good target for acquisition and tracking.

Reference Star Isolation

The magnitudes of other stars in the regions of Canopus and Achernar are below the acquisition threshold of the star tracker. The possibility of acquiring an ambiguous star in these regions and within the coarse search pattern (± 15 degrees) is nil. However, several stars in the vicinity of Alpha Crux could be acquired when searching for Alpha Crux. *

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*Alpha Crux is not anticipated to be the target star during the initial phases of the mission. After the vehicle position has been established in orbit, the location of Alpha Crux will be known to be less than 2 degrees.

It will be necessary to position the star tracker within the fine search pattern (± 2 degrees) of Alpha Crux and than perform a position analysis to determine if an erroneous star has been acquired.

STUDY CONSTRAINTS

Data displayed on the occultation graphs were obtained by programing a digital computer to simulate the star tracker gimbal motions and to trace the positions of the stars in the tracker window. A number of constraints are considered in ascertaining the occultation periods. These constraints are as follows:

Orbital Inclination Angle

The inclination angle of the orbit with respect to the earth equator was considered to be 35 ± 2 degrees. The effect of the constraint is a shift of the star position pattern about the outer gimbal axis in the tracker window. This necessitates an increase in the outer gimbal angle limits to track the target star, Canopus.

Orbital Plane Misalignment

The "worst case" effects of gravity gradient torques on the ATM could create an orbital plane to principal axis misalignment of ±7.5 degrees. The effect of this constraint is the same as that of the inclination angle.

Docking Misalignment

The maximum allowable errors for docking the ATM-LM to the multiple docking adapter is ± 10 degrees. The effect of the constraint is also star position pattern shift about the outer gimbal axis in the tracker window, but with respect to the ATM only. The star position will not change with respect to the Orbital Workshop.

Reflection Angles

The orbital workshop solar array in the star tracker window area will be exposed to the sun. The reflection from this surface is expected to restrict the star tracking capabilities to 15 degrees around this solar array. All other structures and the backs of the ATM solar arrays in the star tracker window will be painted flat black. The star tracker is expected to track a star within 2 degrees of these surfaces.

SUMMARY OF RESULTS

The star tracker window is shown in Figure 1, which indicates the obstructions that are seen by the star tracker while tracking the reference star. Loci of gimbal angular motion for reference stars Canopus, Achernar, and Alpha Crux are shown in Figures 2, 3, and 4. The occultation patterns for a docking error of 0 degrees are shown in Figures 5, 6, and 7. Similarly, Figures 8 through 13 show the occultation regions for a docking error of ± 10 degrees. Simultaneous occultations do not occur for a 0-degree docking error, but they do occur for ± 10 degrees and are shown in Figures 14 and 15.

Graphs of Occultation Periods

Occultation periods (Figs. 5 through 15) are plotted as a function of the day of the year and launch hour. By inclining the day of the year axis to the launch hour axis to account for orbital regression, a direct plot of occultation intervals is recorded.

Graph Interpretation

Occultation periods are determined as follows:

1. The point on the graph where the launch hour intersects the launch day at right angles is located.

2. The mission line at this intersection is followed for the length of the mission.

3. The occultations (clear areas) that appear on the mission line represent that period of time during which the reference stars will be obstructed by the vehicle structure or reflective surfaces of the structure. The numbered occultation areas correspond to the areas in the star tracker window (Fig. 1).

CONCLUSIONS

The occultation graphs indicate a star, or combination of stars, that may be selected to provide a reference for the ATM star tracker. This study has considered the "worst case" conditions for all possible constraints. If docking errors are held to ± 5 degrees or less, there will be no simultaneous occultation of all three reference stars. However, if the docking errors are greater than ±5 degrees, there will be 2- to 3-day occultation periods (Figs. 14 and 15).

The reflection zone around the orbital workshop solar array has been estimated to be 15 degrees for the worst case. This is the angle limit for the star tracker to operate near the solar array. Laboratory tests are being conducted to determine the validity of the 15-degree limit. If this angle is reduced to 5 degrees, occultation area (1) will be eliminated in Figures 8 through 11 and reduced in Figures 9, 10, 12, and 13.

The graphs show that occultation zones may be circumvented if the launch hour or launch dates are slightly altered. Thus, a computer program can be generated from these graphs to select the most suitable launch and mission times.

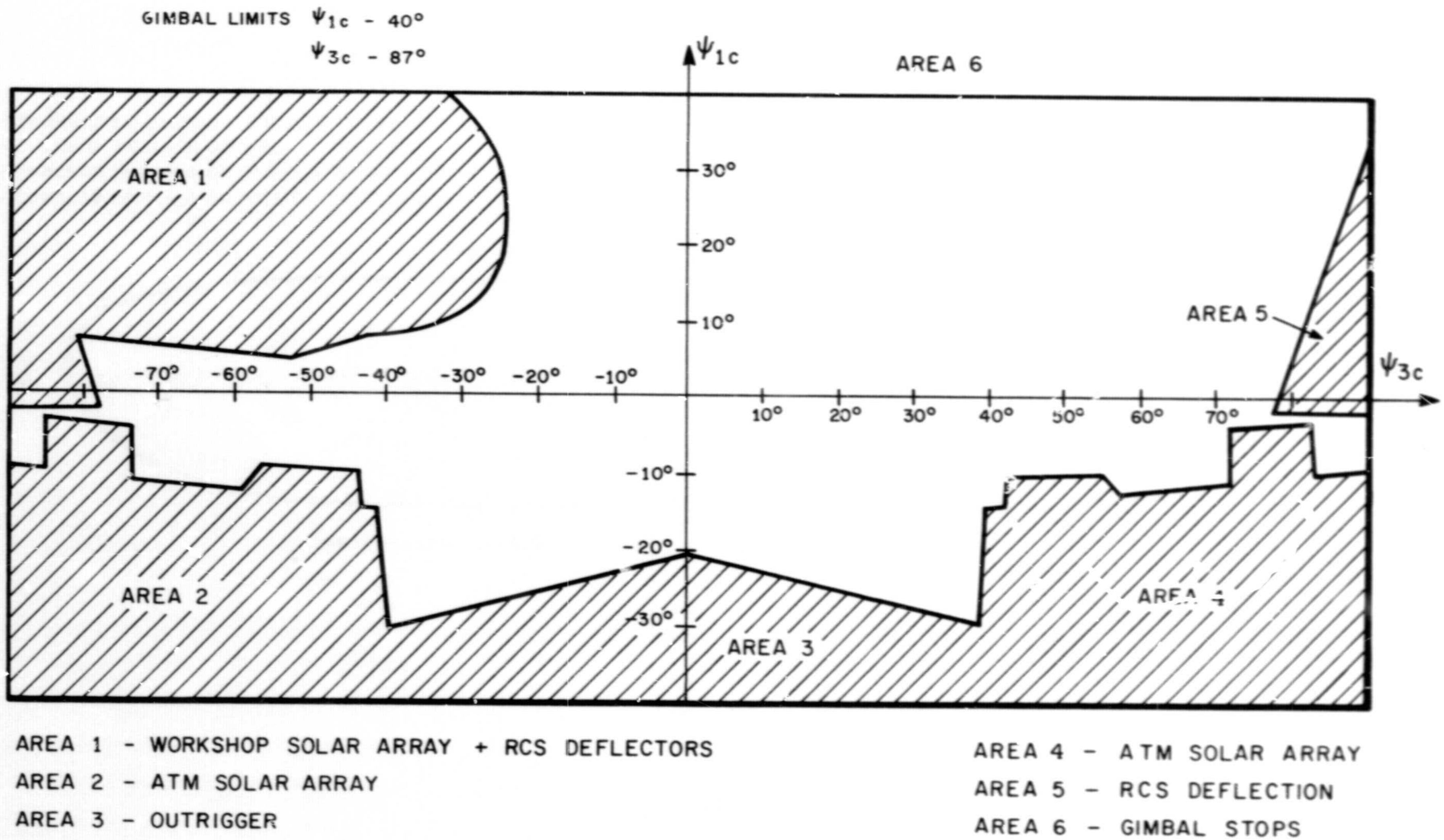


FIGURE 1. STAR TRACKER WINDOW

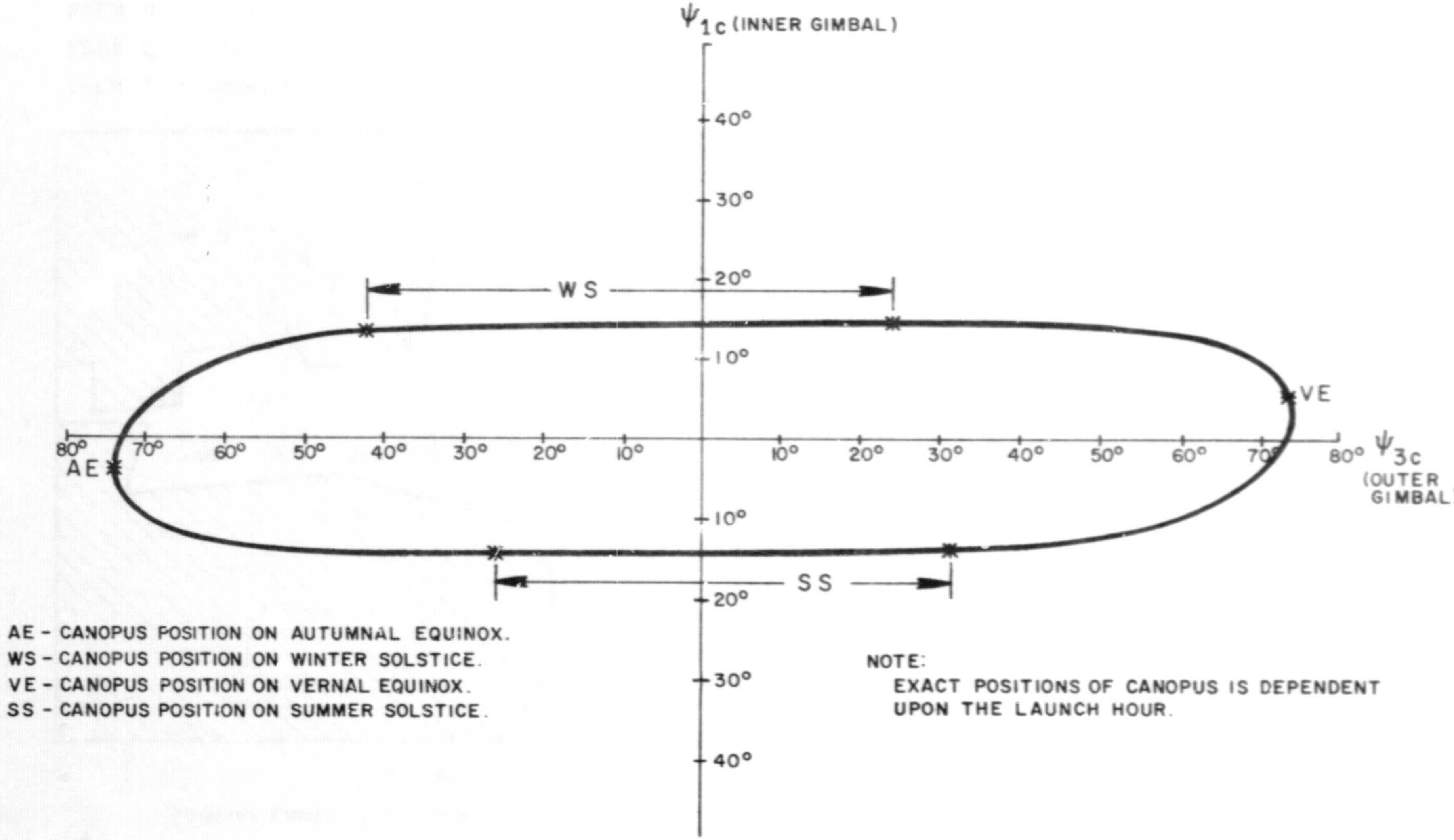


FIGURE 2. LOCI OF GIMBAL ANGULAR MOTION FOR CANOPUS

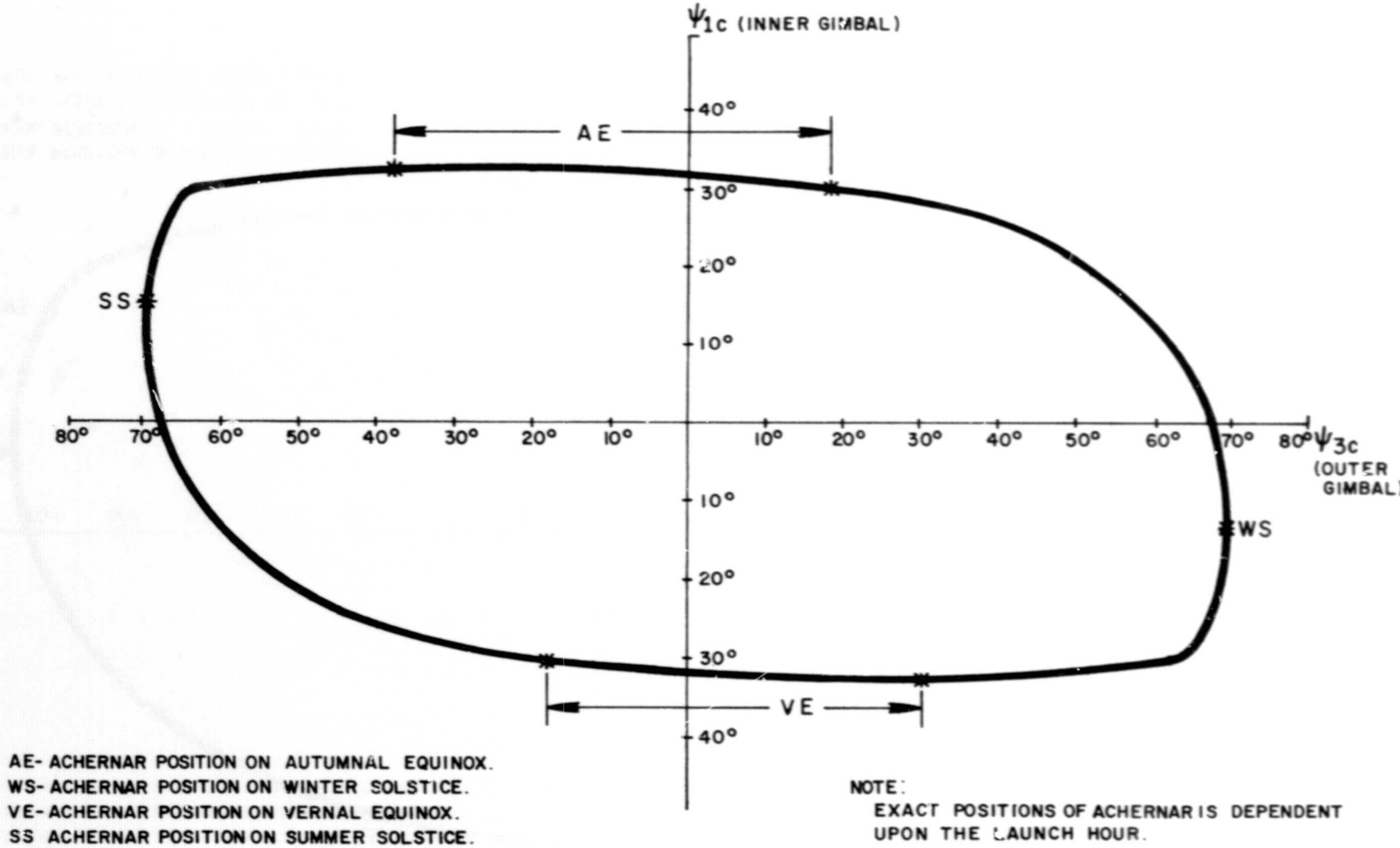
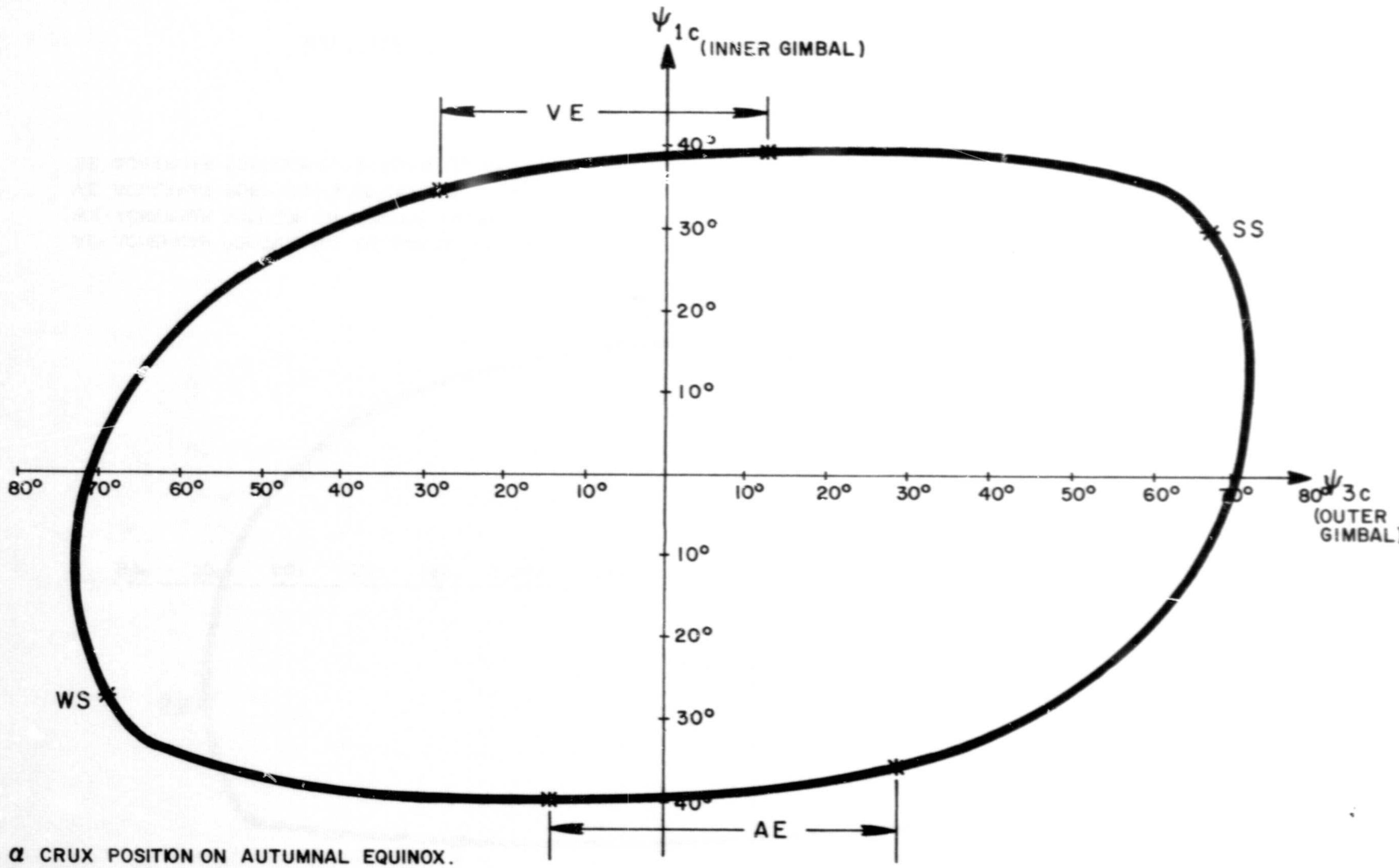


FIGURE 3. LOCI OF GIMBAL ANGULAR MOTION FOR ACHERNAR



AE - α CRUX POSITION ON AUTUMNAL EQUINOX.
WS - α CRUX POSITION ON WINTER SOLSTICE.
VE - α CRUX POSITION ON VERNAL EQUINOX.
SS - α CRUX POSITION ON SUMMER SOLSTICE.

NOTE:
EXACT POSITIONS OF α CRUX IS DEPENDENT UPON THE LAUNCH HOUR.

FIGURE 4. LOCI OF GIMBAL ANGULAR MOTION FOR ALPHA CRUX

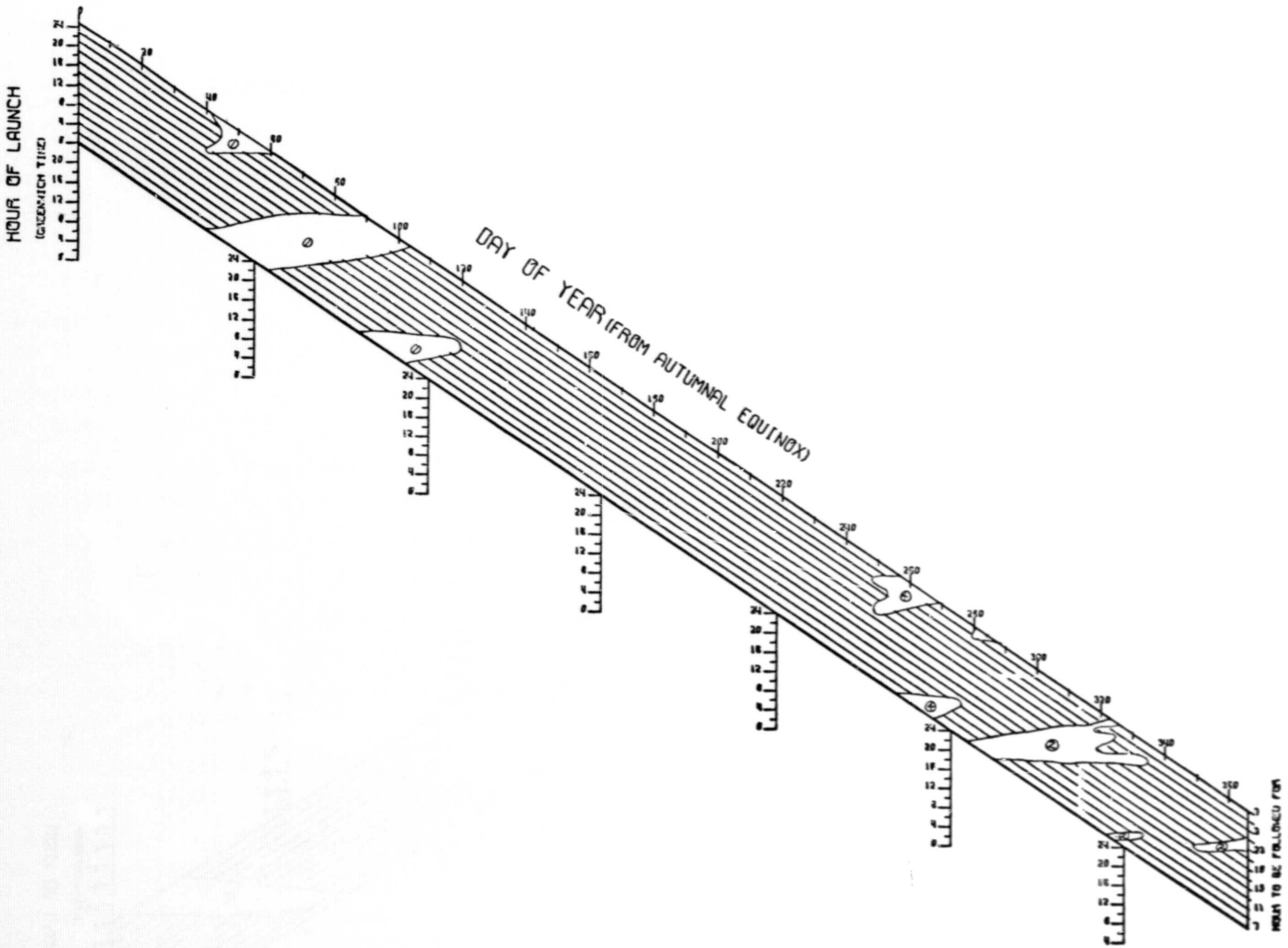


FIGURE 5. OCCULTATION OF CANOPUS (0° ATM DOCKING MISALIGNMENT)

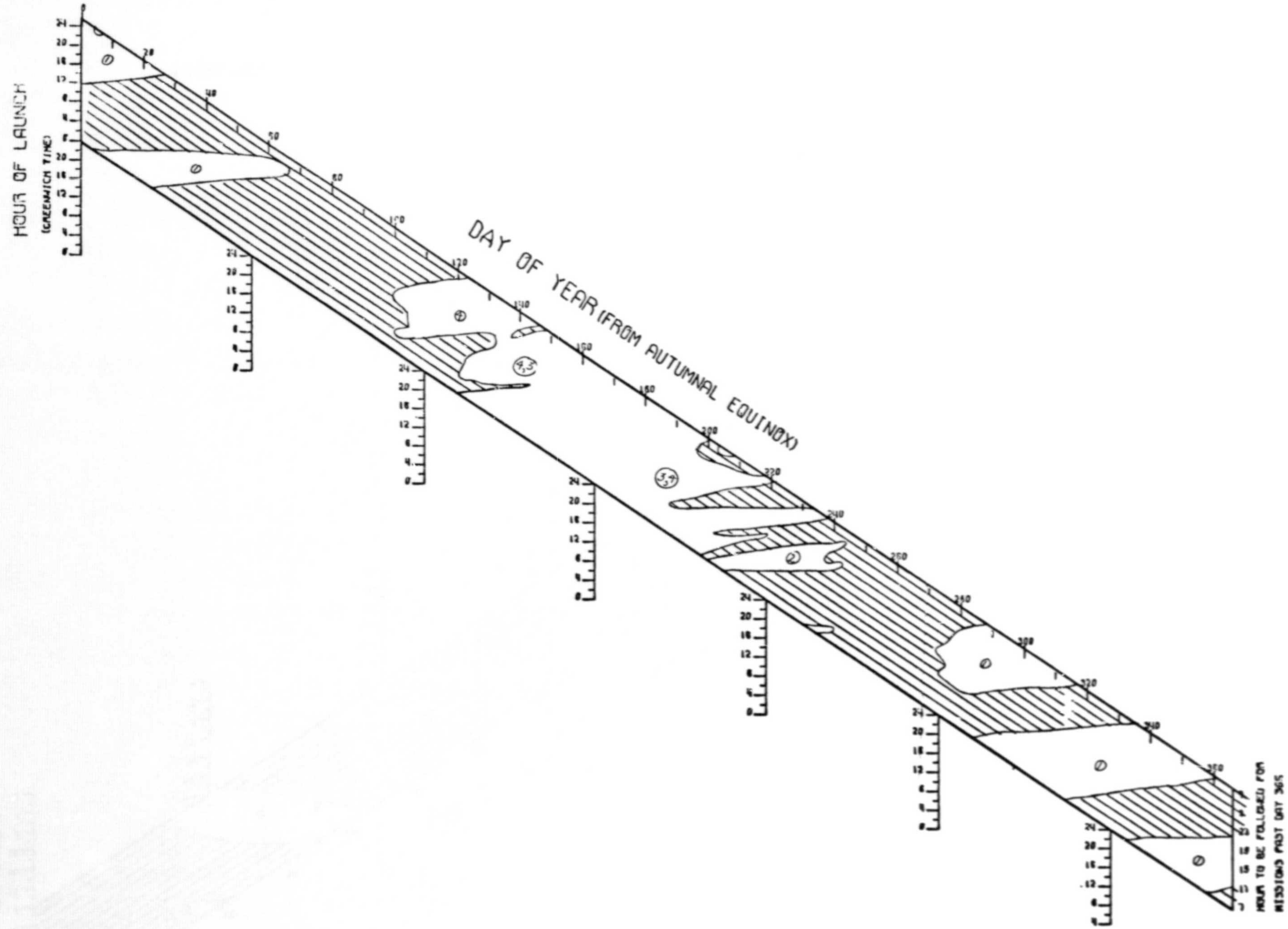


FIGURE 6. OCCULTATION OF ACHERNAR (0° ATM DOCKING MISALIGNMENT)

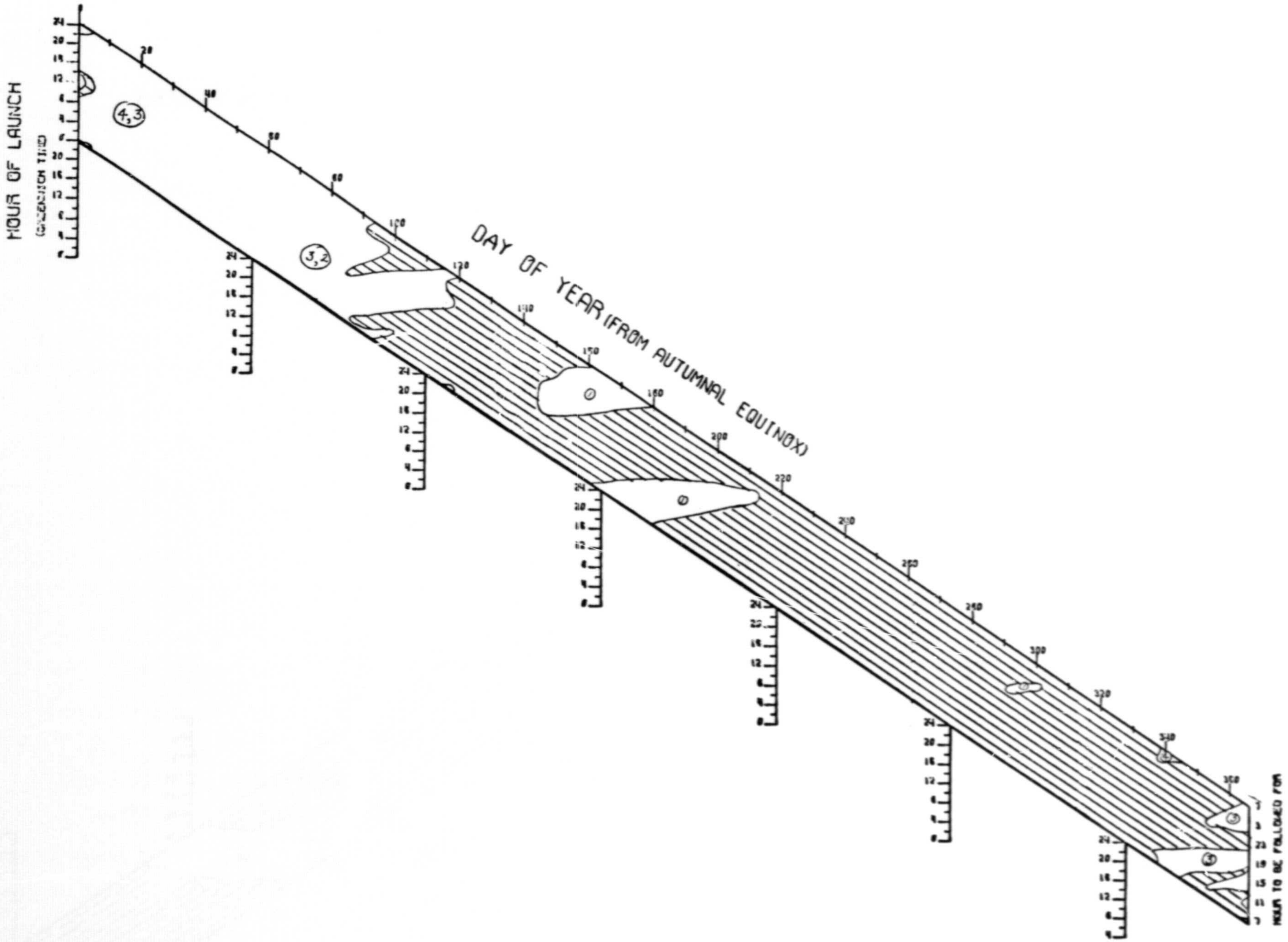


FIGURE 7. OCCULTATION OF ALPHA CRUX (0° ATM DOCKING MISALIGNMENT)

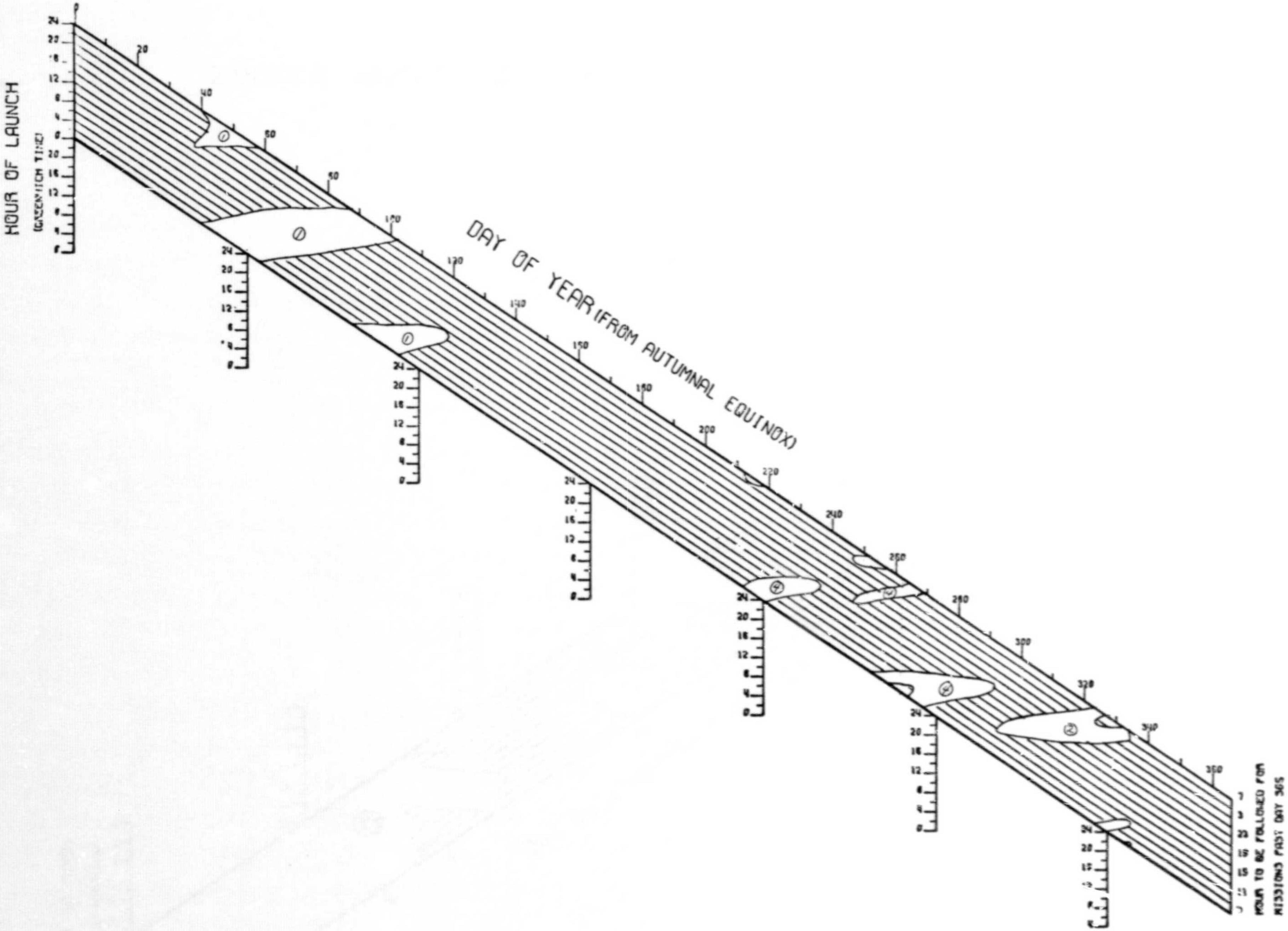


FIGURE 8. OCCULTATION OF CANOPUS (+10° ATM DOCKING MISALIGNMENT)

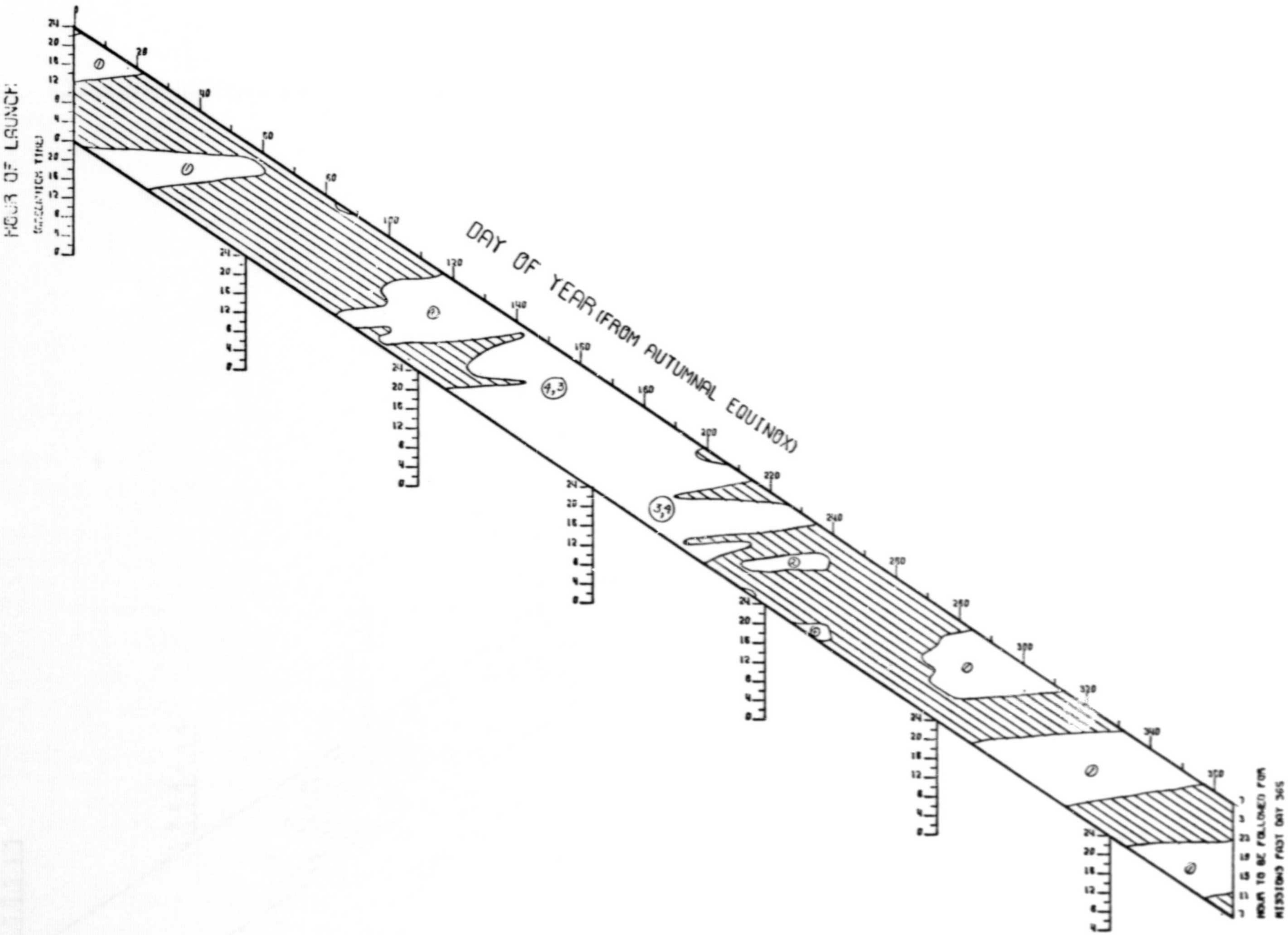


FIGURE 9. OCCULTATION OF ACHERNAR (+10° ATM DOCKING MISALIGNMENT)

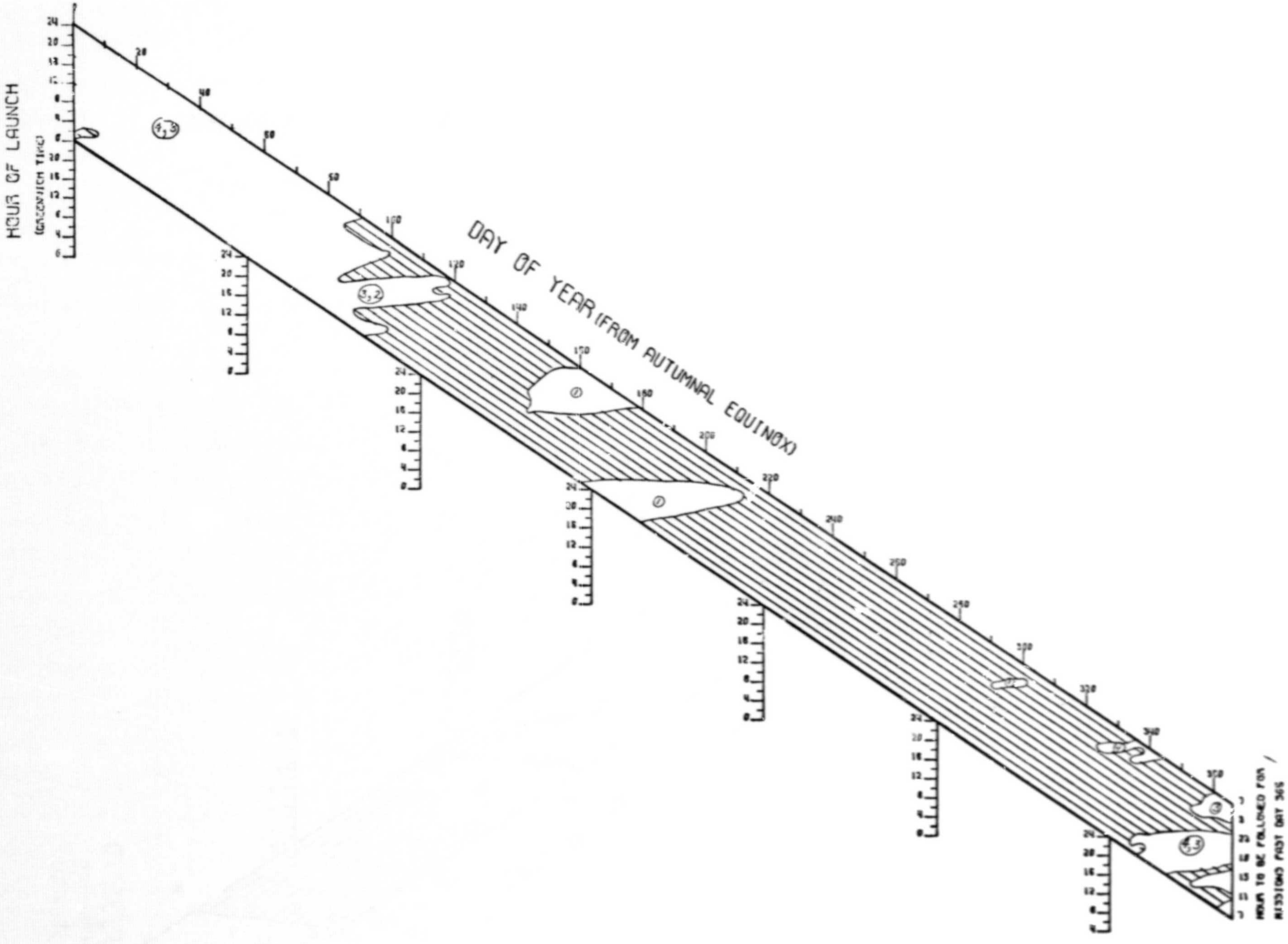


FIGURE 10. OCCULTATION OF ALPHA CRUX (+10° ATM DOCKING MISALIGNMENT)

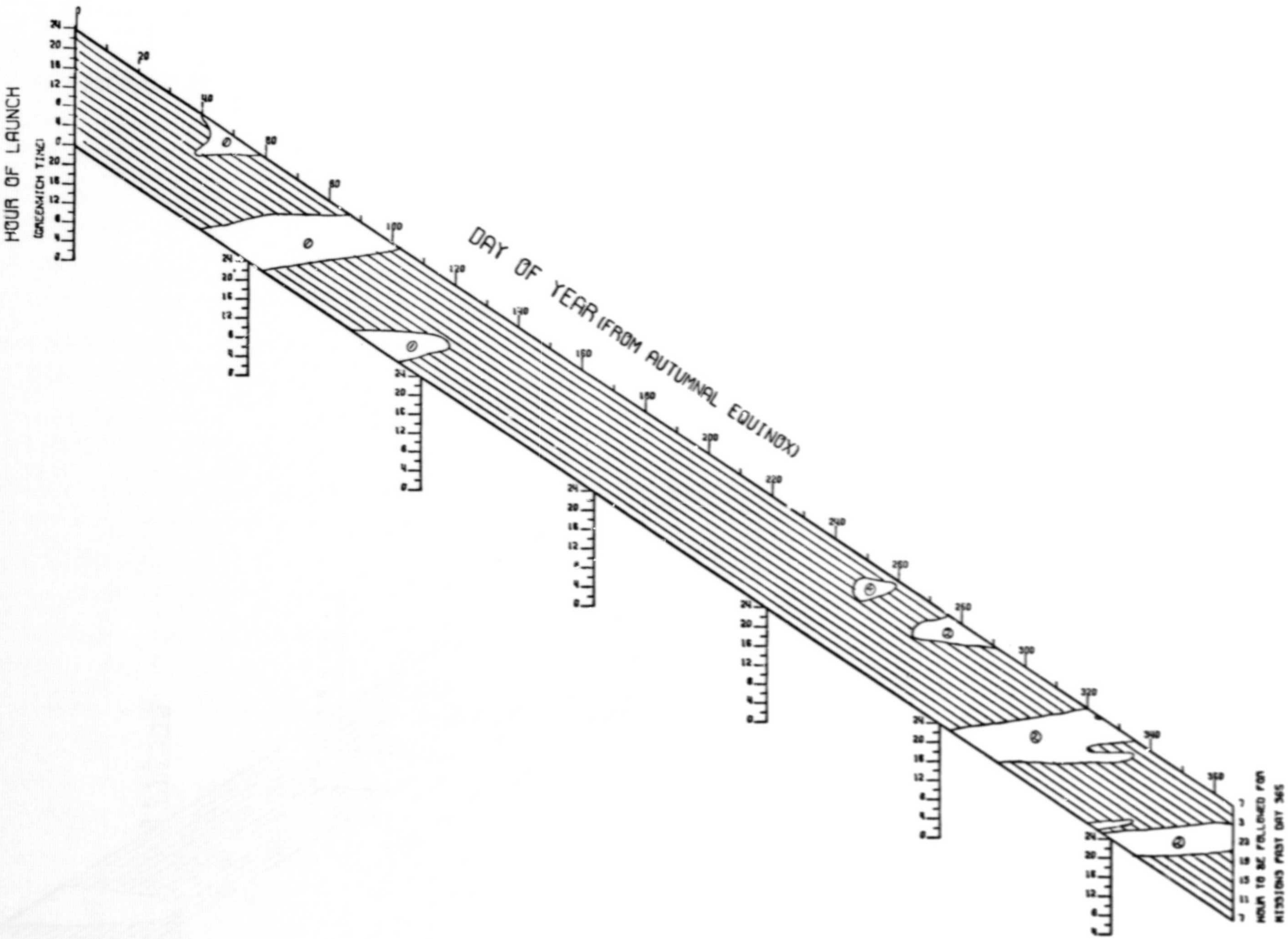


FIGURE 11. OCCULTATION OF CANOPUS (-10° ATM DOCKING MISALIGNMENT)

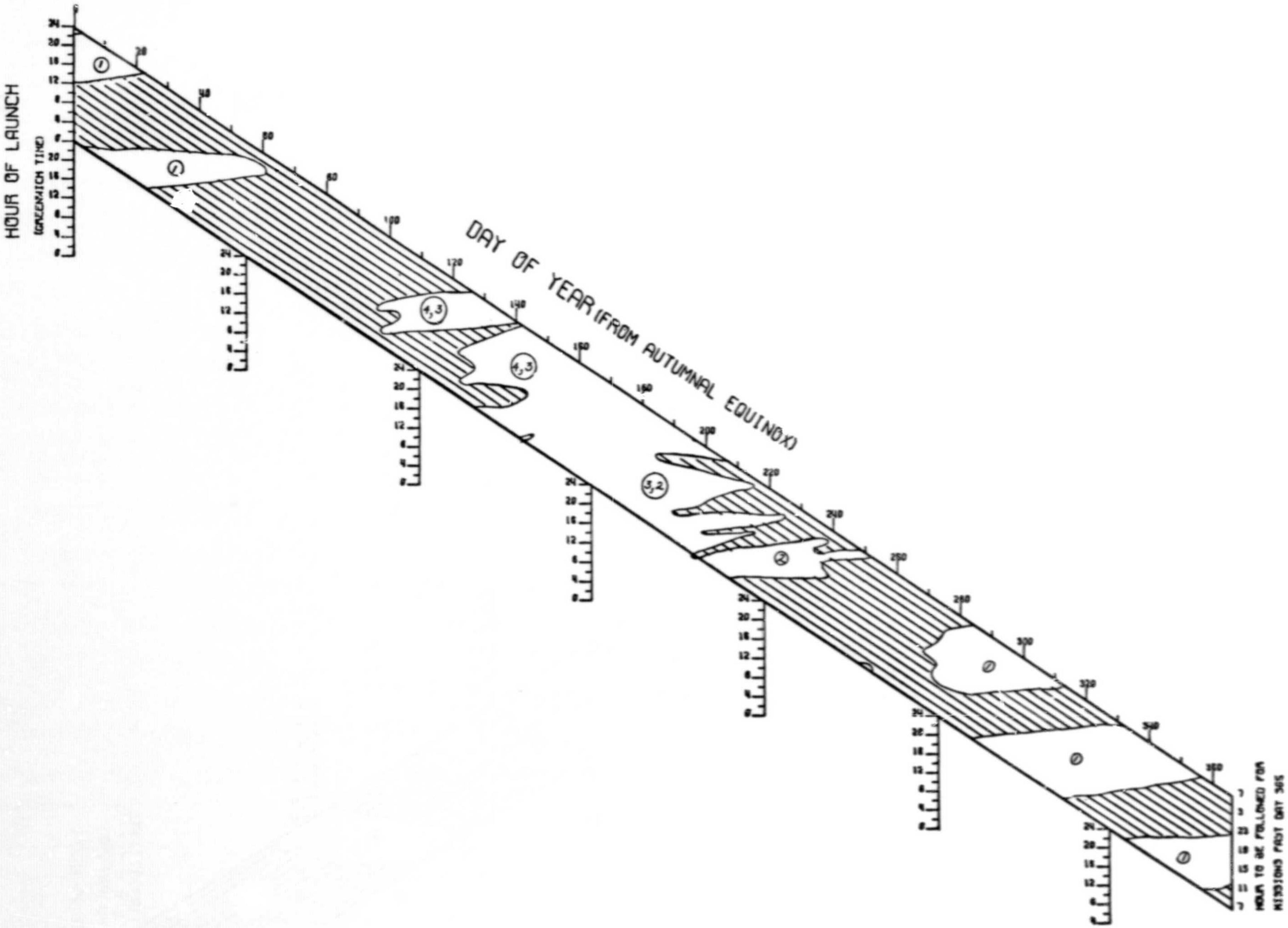


FIGURE 12. OCCULTATION OF ACHERNAR (-10° ATM DOCKING MISALIGNMENT)

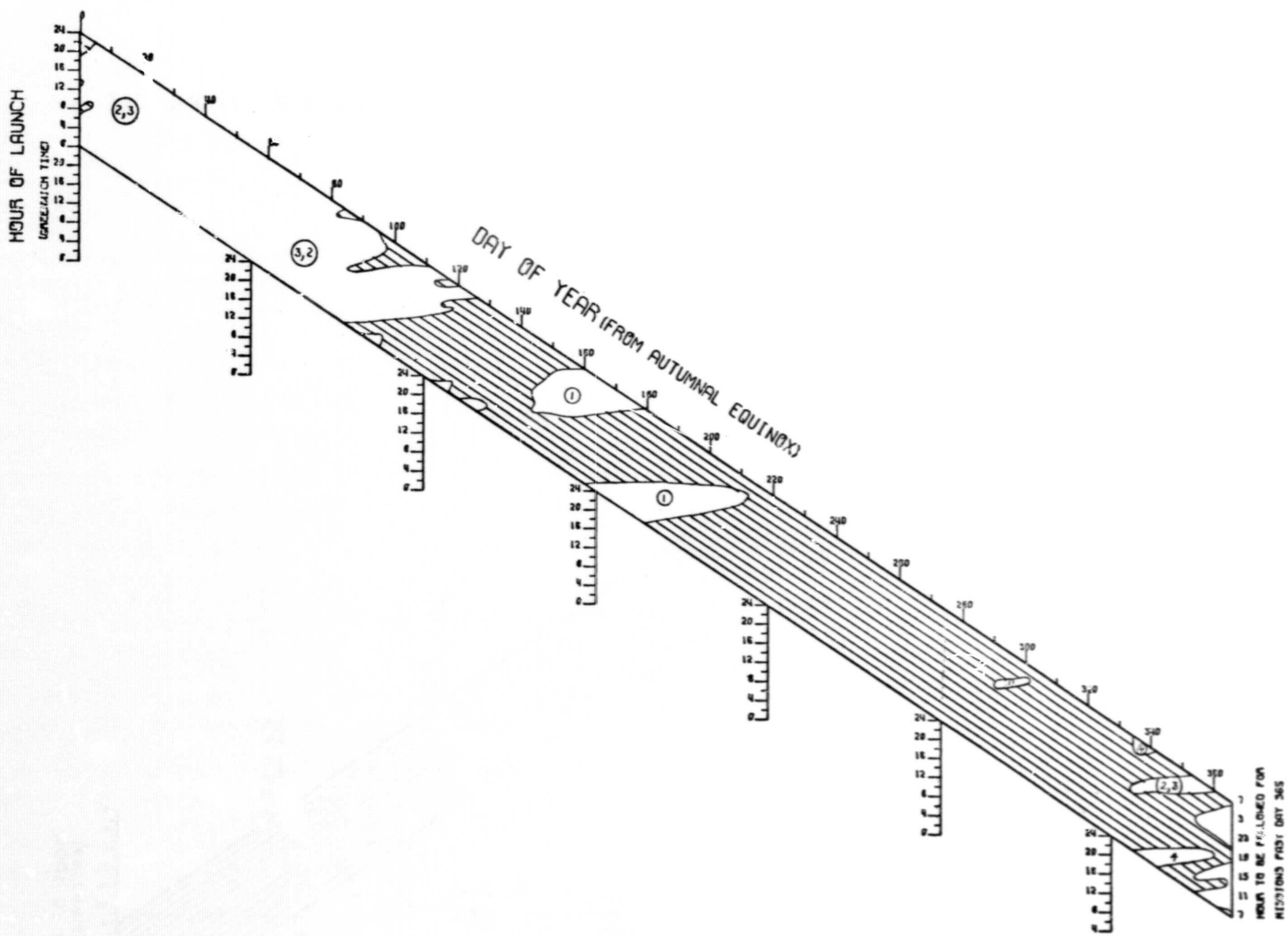


FIGURE 13. OCCULTATION OF ALPHA CRUX (-10° ATM DOCKING MISALIGNMENT)

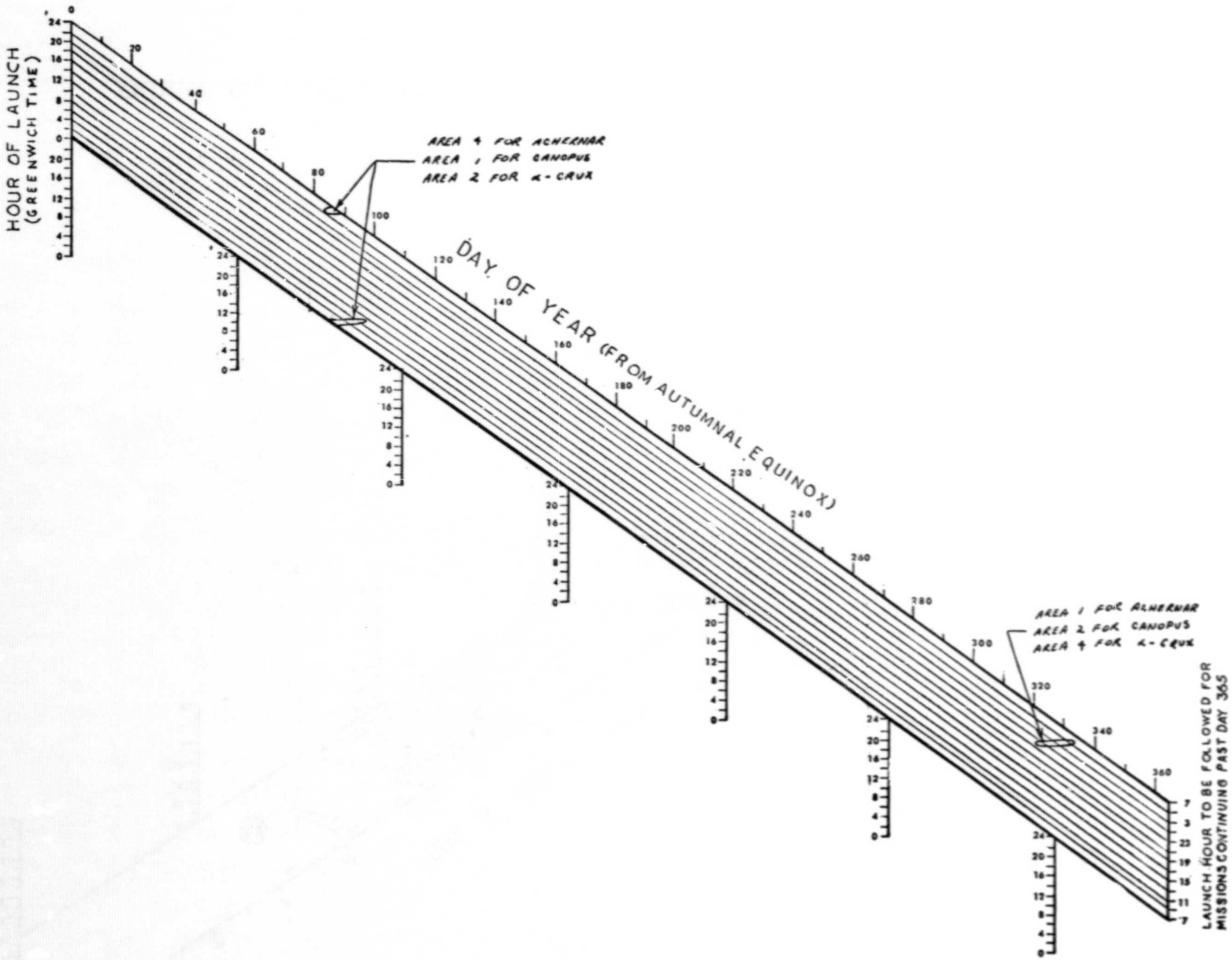


FIGURE 14. SIMULTANEOUS OCCULTATION OF CANOPUS, ACHERNAR, ALPHA CRUX
(+10° ATM DOCKING MISALIGNMENT)

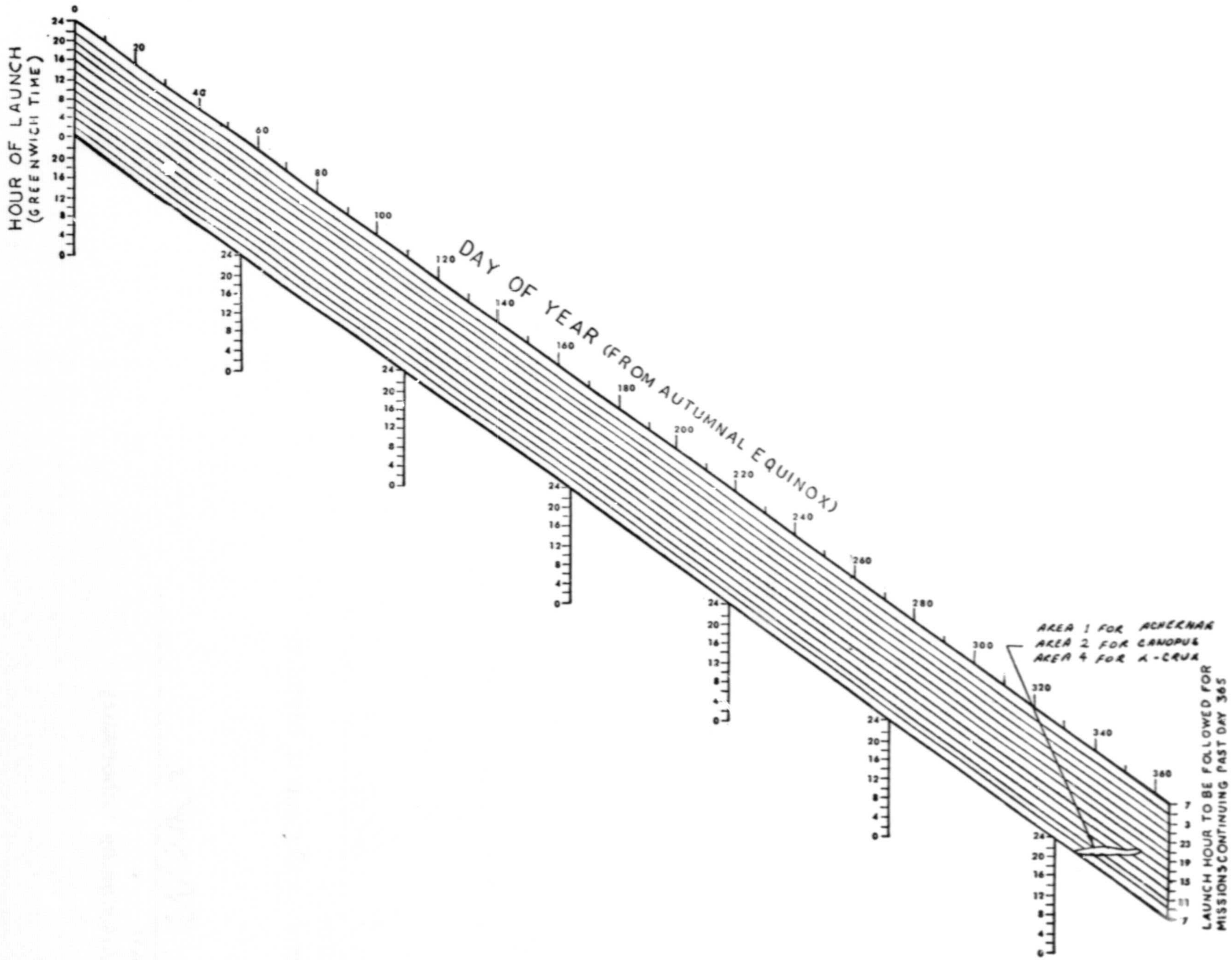


FIGURE 15. SIMULTANEOUS OCCULTATION OF CANOPUS, ACHERNAR, ALPHA CRUX
(-10° ATM DOCKING MISALIGNMENT)

APPROVAL

TM X-53836

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By C. E. Lee

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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