C.J. Elvey

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Number 7
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IGY WORLD DATA CENTER A

Rockets and Satellites

NATIONAL ACADEMY OF SCIENCES

SIMPLIFIED SATELLITE PREDICTION FROM MODIFIED ORBITAL ELEMENTS

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SIMPLIFIED SATELLITE PREDICTION FROM MODIFIED ORBITAL ELEMENTS

LEONARD N. CORMIER
NORTON GOODWIN
REGINALD K. SQUIRES

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IGY WORLD DATA CENTER A
ROCKETS AND SATELLITES

First Limited Draft Edition 29 August 1958
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PREFACE

This second draft of "Simplified Satellite Prediction from Modified Orbital Elements" is now included in the IGY World Data Center "A" Satellite Report Series. Only minor modifications from the first draft edition have been incorporated into the text, the most significant change being the addition of Appendix 2, which outlines the arrangements for communicating modified orbital elements.

The word "simplified", as it appears in the title deserves some explanation. To persons not familiar with the complexities of reducing more conventional satellite orbital elements to local observation times and angles, the method described may hardly appear simplified. In fact, many observers who have attempted to make predictions either from fundamental or from incomplete data report the method to be simpler than other generally used methods.

The manual, together with its tables and charts may be thought of as a complete computation program for pencil and paper, as opposed to a deck of punch-cards for programming an electronic data computer. Nevertheless, persons not necessarily familiar with celestial mechanics can compute from modified orbital element all data needed for local observations. Many of the tables are directly applicable in connection with other prediction methods. The modified elements, of course, may be used as input data for any appropriate computation program.

Many simplifications, shortcuts and other suggestions will present themselves to users of the booklet after computing a few actual predictions. The authors themselves have found a number of shortcuts to the method and, by way of example, Appendix 3 includes several such shortcuts and other notes.

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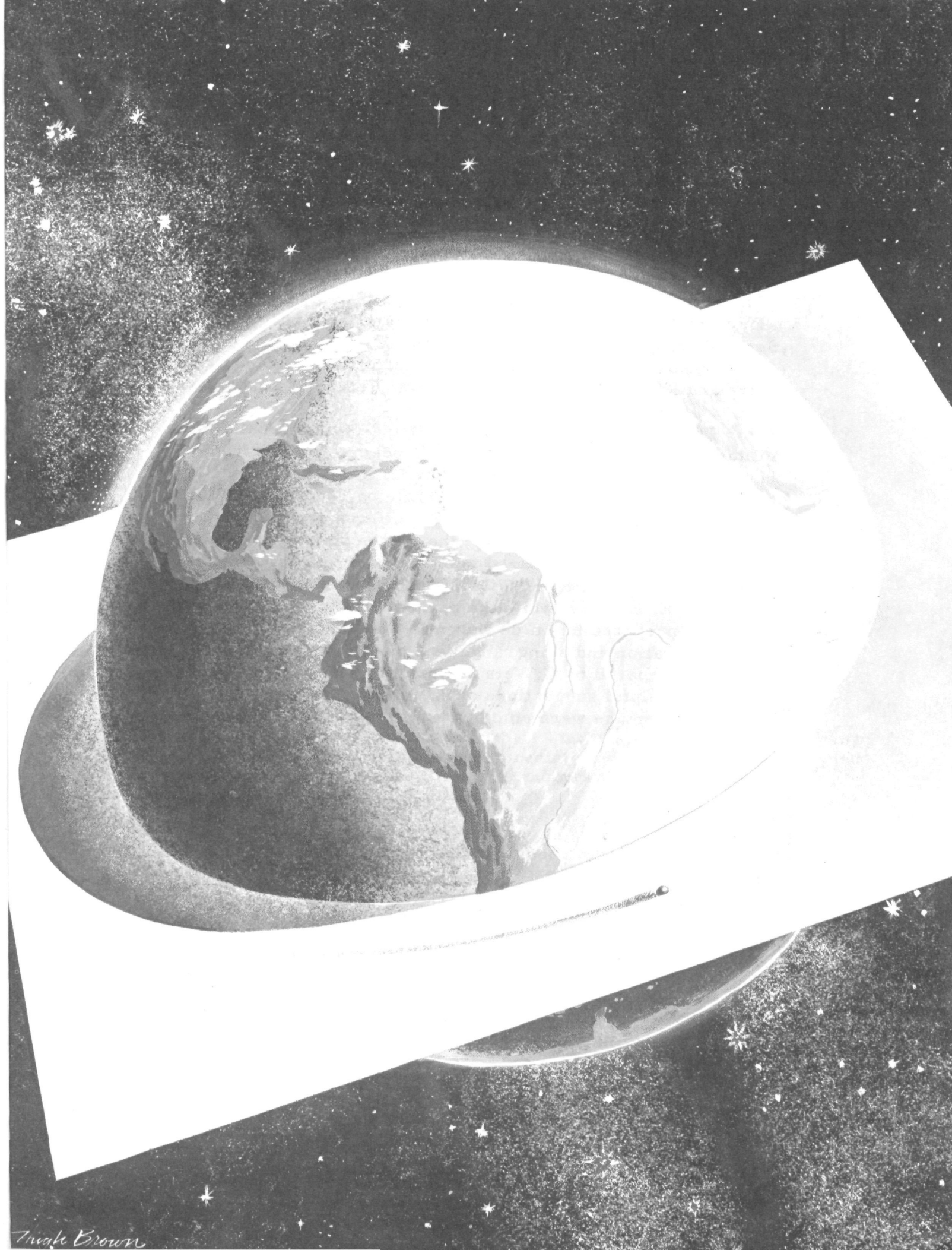
Trudy Brown

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The preparations of Tables I, II and IV was greatly facilitated by free use of a Burroughs Model E-102 electronic computer. Table III was prepared by G. H. Conant, Jr, using free time on the Massachusetts Institute of Technology's IBM Model 704 electronic computer. Table V was provided by the Naval Research Laboratory; the part of this up to 40° latitude has previously appeared in chart form in NRL Report #5066 by J. W. Siry, R. H. Wilson, Jr., M. de Novens, M. P. Hann, and E. L. Lady, while the part for 45° to 85° latitudes was later prepared by M. de Novens. The chart for determining elevation and slant range is a modification of a similar chart prepared by G. Veis and drawn by R. Atkinson. A number of helpful suggestions of S. W. Henricksen of the Army Map Service were employed in preparation of the plotting grids.

SIMPLIFIED SATELLITE PREDICTION FROM MODIFIED ORBITAL ELEMENTS

L. N. Cormier[1/], N. Goodwin[2/], and R. K. Squires[3/]

ABSTRACT: The problem of supplying prediction data for IGY satellite observers is discussed in terms of the need for providing a large number of stations with "fresh" data in a useful form. A straightforward method is given whereby an observer can: (a) Eliminate all but potentially significant observation periods; (b) For any such period, determine the precise time when the satellite will cross (or approach) his latitude circle, the longitude of the crossing (or approach), and the satellite height; and (c) Derive from such crossing (or approach) data the azimuth, elevation and slant range to the satellite for one or more optical observations, or comparable data for radio observations.

The method is specifically designed to direct primary consideration to the times when the orbit plane (without regard to the satellite position) passes through a selected point on the observer's meridian. Modification of the orbital elements permits direct application of the observer's geographical coordinates for first determining the times of approach of the orbit plane, and for then determining the relative position of the satellite.

Prepared message forms, computation forms, tables and charts that may be used for graphic solutions are given.

PURPOSE

Individual observers require predictions as to when and where IGY satellites may be expected to pass near their stations. To be useful for many types of observation programming, such prediction data may have to be based upon up-to-date information as to the whereabouts of a particular satellite, and the rates of its changes of position.

Some artificial earth satellites may be in such stable orbits to permit calculation of satisfactory predictions for considerably more than one week beyond current orbital information. For close-in orbits, predictions based upon week-old elements may prove of questionable value. During the terminal phase of a satellite's life, it may not be possible to make satisfactory projections of future position for more than half a day. Communications considerations, therefore, will influence the form in which data is transmitted from the computing centers to the observer.

1/ National Academy of Sciences - National Research Council, USNC-IGY Staff
2/ Director, Phototrack Program
3/ Naval Research Laboratory, (currently at National Aeronautics and Space Administration)

Computation and communication of satellite prediction data may take several forms. For example, the computation centers may provide predictions tailored for specific stations. Practice has shown that if an attempt is made to provide such specialized service to more than a limited number of stations the overload on computation and communication facilities may result in delays and errors. A more general and practical procedure is to compute and to communicate schedules of predicted satellite sub-points: e.g., longitudes where, and times when the satellite crosses over the equator or specified parallels of latitude. Such schedules require not inconsiderable computation effort on the part of the observer, and yet central computation and communication facilities may nevertheless become overloaded when several satellites are in orbit at the same time. From a communications standpoint, such prediction schedules are excessively redundant, in many cases representing mere interpolation between two sets of "orbital elements", each completely describing the positions of the orbit plane, and of the satellite within the orbit plane, at particular times.

The practical usefulness of data based upon interpolation suggests a third form for supplying prediction data in terms of the orbital elements themselves. From computation and communications standpoints, the transmission of orbital elements offers the simplest and most concise solution to supplying observers with the necessary data. Disadvantages to the observer include: (a) The fact that many observers are not familiar with orbital elements; and, (b) The computation effort required on the part of the observer, even when he does know how to use the elements for prediction purposes. The chief advantage in transmitting orbital elements to the observer is that he is more likely to receive up-to-date information in sufficient time to be conveniently useful.

The purpose of this paper is to describe a prediction system which is in keeping with a practical computation and communication effort and which will at the same time provide good service to the observer. The approach is to minimize the disadvantages of using orbital elements for prediction purposes.

MODIFICATION OF ORBITAL ELEMENTS

The form in which orbital elements are traditionally given for stating the positions of the planets has been modified to eliminate unnecessary computations. For example, the position of the orbit plane is given in terms of geographic longitude, rather than "celestial longitude" or "right ascension". Such modification avoids a number of confusing computations and references to almanacs. Similarly, the practice of giving the time of an actual observation as reference time (or "epoch"), rather than a time when the satellite is at perigee, has the effect of transferring to the observer a computation which could be better accomplished at the issuing computing center. By choosing the reference time at an instant when the satellite is at perigee, one measure serves to fix the positions of both the "ellipse" in which the satellite travels and the position of the satellite within the ellipse.

COMPUTATION FORMS, TABLES AND CHARTS

The observer's computations can be simplified not only by modifying the traditional orbital elements, but also by solving beforehand, and in a general way, many of the problems of converting the information contained in the elements into values referred to his station. These general solutions have been reduced to computation forms, tables, and charts. The computations are explicit, straightforward, and involve no operation more complicated than long division.

BASIC ASSUMPTIONS

The modified orbital elements described below and the method of satellite prediction through their use are based upon certain fundamental assumptions; an understanding of these assumptions is not a prerequisite to use of the method. The assumptions are as follows:

(a) That the satellite moves around the center of the earth in an elliptical orbit of constant eccentricity, all the points of which lie within a plane whose inclination to the earth's equator is constant;

(b) That the orbit plane rotates at a constant rate around the earth's polar axis;

(c) That within the orbit plane, the elliptical orbit itself rotates around the center of the earth at a constant rate; and,

(d) That the satellite within its orbit will sweep out equal areas in equal intervals of time.

(e) That the decrease in period due to drag can be represented on a plot by a straight line over intervals of about one week.

The foregoing assumptions are not altogether valid, because the earth is not a perfectly uniform sphere, and because of other factors influencing the satellite's motion. Nevertheless, computations based on such assumptions will yield prediction data of sufficient accuracy for most observational purposes, provided the data on which they are based are sufficiently "fresh".

DESCRIPTION OF THE METHOD

Using orbital elements given in the prescribed form, initial times are computed which place the orbit plane through a point on the observers meridian at the intersection of a nearby reference latitude. Subsequent times when the orbit plane sweeps through such reference point are then determined, from which the observer may select an appropriate sweep time for further computation to determine when and where the satellite will cross reference latitude. Additional optional calculations permit determination of times when the satellite will make its closest approach to the observer and will cross specific bearings. Azimuth, elevation, slant range, visibility and apparent angular motion for such times may also be determined.

Printed forms, tables and plotting grids supplied herein, a pencil, protractor and some long division are all that are required in applying the method.

By reducing interpolation errors, extension of the tables would improve the precision of the method. Such extension might be justified in cases where the behavior of satellite period could be predicted with sufficient accuracy.

EXAMPLE

An example is given below of the method of simplified satellite prediction from modified orbital elements. The example is based upon the orbital elements for earth satellite 1958 Epsilon which were issued 13 August 1958 by the United States Naval Research Laboratory and which were modified to conform to the prediction methods employed. The example shows how, through use of prepared computation forms, charts and tables, orbital elements referred to 8 August 1958 were used in predicting the time when earth satellite 1958 Epsilon could be expected to make a meridian pass near Lima, Peru on 16 August 1958. It will be noted, in following through the example given below, that the computation forms are intended to give explicit instructions. Long division is the most complicated mathematical operation involved.

Form for Logging Given Information and for Locating Orbit Plane Relative to Observer

MODIFIED ORBITAL ELEMENTS

FOR EARTH SATELLITE 1958 - EPSILON

GIVEN ON 13 AUG 1958 (date)

BY NAVAL RESEARCH LABORATORY

Reference time (Greenwich Mean Time = GMT, UT or Z)	1958 ^{y} 8 ^{mo} 8 ^{d} 16 ^{h} 49 ^{m} 16 GMT
Reference time (Station Time = GMT) N (−) 5 ^{h}	1958 ^{y} 8 ^{mo} 8 ^{d} 11 ^{h} 49 ^{m} 16 ST
Orbit inclination	+~~N~~ 50°29
Longitude of northbound node at reference time	192°69 West of Greenwich
Prime sweep interval:	1421 ^{m} 91
or 1440 ^{m} 00 (1 day), N (−)	18 ^{m} 09
Perigee and satellite position at reference time (measured in degrees of arc from northbound node and in direction of satellite's motion)	85°45
Change in perigee position per period	+~~N~~ 0°22274 /period
Perigee-to-perigee period at reference time	109 ^{m} 887
Per period change in perigee-to-perigee period	−0 ^{m} 00225 /period
Eccentricity of orbit	0.12678
Estimated correction to crossing times (not always given)	~~EARLY (LATE)~~
Radial distance of satellite from center of earth at perigee	4123.6 statute miles
Radio transmission frequencies	107 997 Mc
	108 03 Mc
	.... Mc

1 Statute mile = 1.609 kilometers; 1 kilometer = 0.6214 mile; 5 miles are approximately 8 kilometers

The modified orbital elements given above are largely self-explanatory.

Reference time is the particular time when the satellite, its orbit, and its orbital plane were all in the precise positions defined by the orbital elements that follow. Reference time is given in Greenwich Mean Time (GMT). In the line immediately following, there is provision for converting such reference time into station time (ST).

(Reference time differs from the more conventional "epoch" only in that it is a particular "epoch" at which the satellite happens to be passing through perigee.)

Station time (ST) is the standard or daylight time normally used by the observer in scheduling his daily activities.

Orbit inclination defines the space angle formed by the orbit plane as it intersects the earth's equatorial plane. It is given as negative if the satellite motion is from east to west.

Longitude of the northbound node at reference time defines the position of the orbit plane in geographical coordinates. There are two nodes or points at which the orbit plane intersects the earth's equator. One can be distinguished from the other by the direction in which the satellite travels when passing overhead. The northbound node is defined as the node over which the satellite will pass with a northerly heading. The longitude of the northbound node is expressed in degrees west of Greenwich.

> (The Northbound node differs from the "ascending node" of conventional orbital elements in that the longitude of the "ascending node" is conventionally measured eastward from the vernal equinox.)

Prime sweep interval is determined by the combined motions of the orbit plane and the earth. It may be considered as the length of time it apparently takes the orbit plane to sweep completely around the earth. The interval differs by a small amount from one mean solar day. In computing the times when the orbit plane will sweep through a specified meridian point, as is done in Schedule C, below, it is convenient to think of the prime sweep interval as one day plus or minus so-many minutes.

Perigee and satellite positions at reference time are identical because of the way reference time has been defined. Perigee is defined as the orbit point closest to the center of the earth. The position of perigee is defined by an angle (at the center of the earth) measured from the northbound node to the perigee location in the direction of the satellite's travel.

Change in perigee position per period defines the motion of the elliptical orbit during the time interval between successive passes of the satellite through any specified orbit point. The change is given as positive if the motion is in the same direction as that of the satellite.

Perigee-to-perigee period at reference time is the interval between successive passes of the satellite through any specified orbit point.

> (Perigee-to-perigee period is by definition identical to the "anomalistic period" of conventional orbital elements.)

Per period change in perigee-to-perigee period gives the amount by which the satellite's period grows shorter per period. Per period change, times number of periods since reference time, plus period at reference time yields current perigee-to-perigee period. Over an interval, the average between current period and period at reference time is used to determine the current position of the satellite.

Eccentricity of orbit defines the shape of the elliptical orbit and conforms to the normal definition of the term.

Estimated correction to crossing times may sometimes be given.

Perigee-to perigee period is the most perishable of all the orbital elements and the most difficult to project for an extended period of time. During the terminal phase of a satellite's life, perigee-to-perigee period can be expected to change rapidly and erratically. Communication of current orbital information to observers at such times becomes increasingly difficult. By issuing corrections to crossing times computed from published orbital elements, communications effort can be kept at a minimum. Such corrections will also permit the observer to adjust completed predictions based on "old" orbital elements. Correction estimates based on observations can also be applied in the same way.

Radial distance of satellite from center of earth at perigee together with eccentricity defines the size of the orbit, and also the radial distances of all points in the orbit. It is given in statute miles.

Radio transmission frequencies will be needed both for radio tracking and for telemetry. The frequencies are given in megacycles.

Schedule A: To Find Longitudes of Northbound Node at Sweep Times and Specific Central Angles Between Equator and Reference Latitude

(Compute ONLY ONCE for given station and inclination)

	PRIME SWEEP	RETURN SWEEP
0. From part of Table I showing given orbit inclination, SELECT reference latitude closest to station latitude		10°00 (S)
1. STRIKE OUT ALL of line *a* or *b* whichever contains a false statement:		
a. Reference latitude is *South*	180°00	360°00
~~b. Reference latitude is North~~	~~0°00~~	~~180°00~~
2. ENTER: Minimum longitude of northbound node west of meridian point at sweep times (from Table I) and ADD and SUBTRACT as indicated	+ 8°4 W	− 8°4 W
3. Specific longitudes of northbound node west of meridian point at sweep times	188°4 W	351°6 W
4. ENTER: Longitude of station's meridian *west* of Greenwich (360° LESS *east* longitude) and ADD	+ 077°2 W	+ 077°2 W
5. Longitudes of northbound node at sweep times	265°6 W	068°8 W

(*Note: If the orbit inclination is negative, STRIKE OUT ALL of line* a *or* b *above, whichever contains a* true *statement, and in entering results in Item 3, above, TRANSPOSE to opposite column.*)

6. STRIKE OUT ALL of line *a* or *b* below, whichever contains a false statement:		
a. Reference latitude is *South*	180°00	360°00
~~b. Reference latitude is North~~	~~0°00~~	~~180°00~~
7. ENTER: Initial central angle between equator and reference latitude (from Table II) and ADD and SUBTRACT as indicated.	+ 13°0	− 13°0
8. Specific central angles between equator and reference latitude	193°0	347°0

In the instant example, the coordinates of a station at Lima, Peru are used: Station latitude 11°78 S., longitude is 77°15 W., and the station is about 3963 miles from the center of the earth. It is important to note that Schedule A provides two different sets of answers, one under a column marked "Prime sweep" and the other under a column marked "Return sweep". Two sets of answers are required because two different parts of the orbit plane of 1958 Epsilon sweep through Lima, Peru, and it is important to distinguish between them.

The part of the orbit plane through which a satellite passes from equator to pole (whether North or South) is always identified with prime sweep, and the part through which a satellite passes in returning from pole to equator is always identified with return sweeps of the orbit plane through any specified meridian point. The distinction between prime and return sweeps disappears for meridian points whose latitude is numerically equal to orbit inclination -- a fact that simplifies computation in Schedule A for observers whose latitude is numerically close to or greater than the orbit inclination.

Schedule A need only be computed once for a given station and orbit inclination.

A 10° S reference latitude was selected because it is the reference latitude nearest to the station's latitude for which data on the given orbit inclination is computed in Tables I, II and IV. The intersection between the station's meridian and reference latitude (10° S) defines the meridian point for which sweep times are computed in Part I, below.

Schedule A can be used for either southern or northern latitudes, and covers the possibility of a negative orbit inclination. Tables I and II are used in the same way whether the latitude is north or south, and whether the orbit inclination is positive or negative.

PART I — TO LOCATE ORBIT PLANE

Schedule B: To Find Orbit Plane's Relative Westward Motion

1. Degrees of longitude between successive prime sweeps	360°00
2. DIVIDE BY: Prime sweep interval in minutes (given)	÷ 1421m91
3. Orbit plane's relative westward motion (degrees of arc per minute)	0°.2532/m

Schedule C: To Find Times When Orbit Plane Sweeps Through Meridian Point

	PRIME SWEEP	RETURN SWEEP
1. Longitudes of northbound node at sweep times (Schedule A, Item 5)	265°.6 W	068°.8 W 428.8
2. SUBTRACT: Longitude of northbound node at reference time (given) *(ADD: 360° if needed to avoid negative balance)*	− 192°.7 W	− 192°.7 W
3. Longitude to be traversed before first sweeps after reference time	072°.9 W	236°.1 W
4. DIVIDE BY: Orbit plane's relative westward motion (Schedule B, Item 3)	÷ 0°.2532/m	÷ 0°.2532/m
5. Equivalent times in minutes before first sweeps	287m.9	932m.3
6. CONVERT: Item 5, above, to hours and minutes	4h 47m.9	15h 32m.3
7. ADD: Reference time (from given data)	+ 8mo 8d 11h 49m.16 ST	+ 8d 11h 49m.16 ST
8. Times of first sweeps after reference time	8mo 8d 16h 37m.06 ST	9d 03h 21m.46 ST

8. Times of first sweeps after reference time	8 mo 8 d 16 h 37 m 06 ST	9 d 03 h 21 m 46 ST
9. ADD: Prime sweep interval (given)	+1 d 4 (−) 18 m 09	+1 d 4 (−) 18 m 09
10. Times of SECOND sweeps	8 mo 9 d 16 h 18 m 97 ST	10 d 03 h 03 m 37 ST
11. ADD: Prime sweep interval	+1 d 4 (−) 18 m 09	+1 d 4 (−) 18 m 09
12. Times of THIRD sweeps	8 mo 10 d 16 h 00 m 88 ST	11 d 02 h 45 m 28 ST
13. ADD: Prime sweep interval	+1 d 4 (−) 18 m 09	+1 d 4 (−) 18 m 09
14. Times of FOURTH sweeps	8 mo 11 d 15 h 42 m 79 ST	12 d 02 h 27 m 19 ST
15. ADD: Prime sweep interval	+1 d 4 (−) 18 m 09	+1 d 4 (−) 18 m 09
16. Times of FIFTH sweeps	8 mo 12 d 15 h 24 m 70 ST	13 d 02 h 09 m 10 ST
17. ADD: Prime sweep interval	+1 d 4 (−) 18 m 09	+1 d 4 (−) 18 m 09
18. Times of SIXTH sweeps	8 mo 13 d 15 h 06 m 61 ST	14 d 01 h 51 m 01 ST
19. ADD: Prime sweep interval	+1 d 4 (−) 18 m 09	+1 d 4 (−) 18 m 09
20. Times of SEVENTH sweeps	8 mo 14 d 14 h 48 m 52 ST	15 d 01 h 32 m 92 ST
21. ADD: Prime sweep interval	+1 d 4 (−) 18 m 09	+1 d 4 (−) 18 m 09
22. Times of EIGHTH sweeps	8 mo 15 d 14 h 30 m 43 ST	16 d 01 h 14 m 83 ST
23. ADD: Prime sweep interval	+1 d 4 (−) 18 m 09	+1 d 4 (−) 18 m 09
24. Times of NINTH sweeps	8 mo 16 d 14 h 12 m 34 ST	17 d 00 h 56 m 74 ST
25. ADD: Prime sweep interval	+1 d 4 (−) 18 m 09	+1 d 4 (−) 18 m 09
26. Times of TENTH sweeps	8 mo 17 d 13 h 54 m 25 ST	18 d 00 h 38 m 65 ST
27. ADD: Prime sweep interval	+1 d + (−) m	+1 d + (−) m
28. Times of ELEVENTH sweeps	mo d h m ST	d h m ST

Part I is self-explanatory. The purpose in finding out when the orbit plane sweeps through the selected meridian point will be apparent when it is realized that satellite 1958 Epsilon must pass closest to the meridian point within 55 minutes of sweep time. As a general rule, the time when any IGY satellite passes closest to any point on the earth's surface is bound to be within half a period of the time the orbit plane itself sweeps through or closest to such point.

It will be noted in the above example that the sweep times keep changing. The time limits within which the satellite will pass closest to the observer are also changing in a like manner because of the general rule mentioned above.

Without further computation an observer can inspect a filled-in Schedule C to determine which of the close passes for the ensuing week will occur at inopportune times. He can determine without further ado which passes are obviously going to occur at the wrong time of day for visual sighting. He can also pick out a sweep time that seems favorable, and using that sweep time, work out a detailed prediction with the help of a form for locating the satellite -- first within the orbit plane, then relative to the observer, as is shown below.

PART II—TO FIND WHEN AND WHERE SATELLITE 1958 - EPSILON CROSSES REFERENCE LATITUDE ON 8 mo 16 d, 1958

Schedule D. To Find Minutes Elapsed between Reference Time and a Selected Sweep Time

1. Selected sweep time (from Schedule C, above)	8 mo 16 d 14 h 12.34 m ST
2. SUBTRACT: Reference time (from given data)	− 8 mo 8 d 11 h 49.16 m ST
3. Elapsed time from reference time to selected sweep time	8 d 02 h 23.2 m
4. ENTER: Minutes from Item 3 (above)	23.2 m
5. ENTER: Hours from Item 3 (above) MULTIPLIED BY 60	120.00 m
6. ENTER: Days from Item 3 (above) MULTIPLIED BY 1,440, and ADD: Items 4, 5 & 6	+ 11520.00 m
7. Time in minutes elapsed since reference time	11663.2 m

The computations involved in Schedule D, above, are self-explanatory.

Schedule E. To Find Time when Satellite is Last at Perigee prior to Selected Sweep Time

1. Time in minutes elapsed since reference time (Schedule D, Item 7)	11663.2 m
2. DIVIDE BY: *Average** perigee-to-perigee period	÷ 109.768 m
3. ENTER: *Quotient* (number of periods completed since reference time)	106
and	
4. ENTER: *Remainder* in minutes	27.8 m
5. ENTER: Selected sweep time (Schedule D, Item 1) and SUBTRACT Item 4 from Item 5:	8 mo 16 d 14 h 12.34 m ST
6. Time when satellite is last at perigee prior to selected sweep time	8 mo 16 d 13 h 44.5 m ST

*In predicting satellite positions for only one or two days from given reference time, the small changes in period that occur during the interval may normally be disregarded. Substantial errors in crossing times will result if changes in period are not taken into account in predicting for more than one or two days from reference time. The difference between period at reference time and the period current at the time for which prediction is being made can be determined as follows:

$$\text{APPROXIMATE number of whole periods completed} = \frac{\text{elapsed time}}{\text{given period (rounded off)}} =$$

$$\frac{11663^m.2}{109^m.9/\text{period}} = \underline{106 \text{ periods}} \qquad \text{(slide rule accuracy is sufficient)}$$

$$\text{CURRENT period} = 109^m.887 - 106 \text{ periods}(0^m.00225/\text{given period})$$

$$= 109^m.887 - 0^m.239 = \underline{109^m.648} \qquad \text{(used in Schedule F, Item 9)}$$

$$\text{AVERAGE period} = 109^m.887 - \frac{0^m.239}{2} = \underline{109^m.768}$$

In determing the Remainder (Schedule E, Item 4), it is essential to compute as precise a value as possible for the AVERAGE period and to carry out the division completely. Equivalent precision can be obtained by multiplying the precise AVERAGE period by an approximate number of whole periods and subtracting the product from the total elapsed time.

Elapsed Time	$11663^m.2$
Less: 106 x $169^m.768$	$11635^m.4$
Remainder	$27^m.8$

If the Remainder is negative, add whole average periods; if it exceeds one period, subtract.

Schedule F. To Find Time when Satellite Crosses Reference Latitude

1. Number of whole periods completed since reference time (Schedule E, Item 3)		106
2. MULTIPLY BY: Change in perigee position per period (given)	× +(-)	0°.22274 /period
3. Change in perigee position since reference time	+(-)	23°.61
4. ADD: Perigee position at reference time (given)	+	85°.45
5. Current perigee position relative to northbound node		109°.06
6. ENTER: Appropriate central angle between equator and reference latitude, (from Schedule A, Item 8) and SUBTRACT: Item 5 from Item 6, *adding 360° to item 6 if necessary*		193°.0
7. Perigee distance from crossing point, measured within orbit plane		83°.9
8. ENTER: Equivalent fraction-of-period for given orbit eccentricity (from Table III)		0.194
9. MULTIPLY BY: *Current** perigee-to-perigee period	×	109m.6
10. Time required for satellite to travel from current perigee position to crossing point.		21m.3
11. CONVERT above to hours and minutes		0h 21m.3
12. ADD: Time when satellite is last at perigee (Schedule E, Item 6)	+	13h 44m.5 ST
13. Time when satellite crosses reference latitude	....h ....m ....ST	14h 05m.8 ST

NOTE: If time computed in item 13 differs from selected sweep time by more than one-half perigee-to-perigee period, then determine alternative time as shown below:

14. ADD (SUBTRACT) as appropriate: One whole perigee-to-perigee period (given)		....h ....m
15. Alternative time when satellite crosses reference latitude	....h ....m ....ST	....h ....m ST

To BRING ABOVE UP-TO-DATE, Determine from the most recent data that the satellite will cross reference latitudes ....m.... minutes early, SUBTRACT this amount from Item 13 or 15, and ENTER corrected time in appropriate box. (If satellite is late—ADD)

If the time when the satellite crosses reference latitude found in Item 13, Schedule F, differs from selected sweep time by more than one-half period, the crossing that occurs one whole period earlier (or later, as the case may be) will actually constitute a closer approach. In such case, it will be sufficient to add or subtract one whole period, whichever reduces the difference between crossing time and sweep time, as indicated in Item 14, Schedule F.

In the case of satellites passing high near the station, it may be possible to observe the satellite as it crosses reference latitude one whole period after or before the crossing closest to sweep time. The times of such crossings are found by adding or subtracting one whole period, as indicated in the form.

How predictions can be brought up-to-date with estimated or subsequently issued correction data is explained at the foot of Schedule F, above, and at the foot of Schedule G, below.

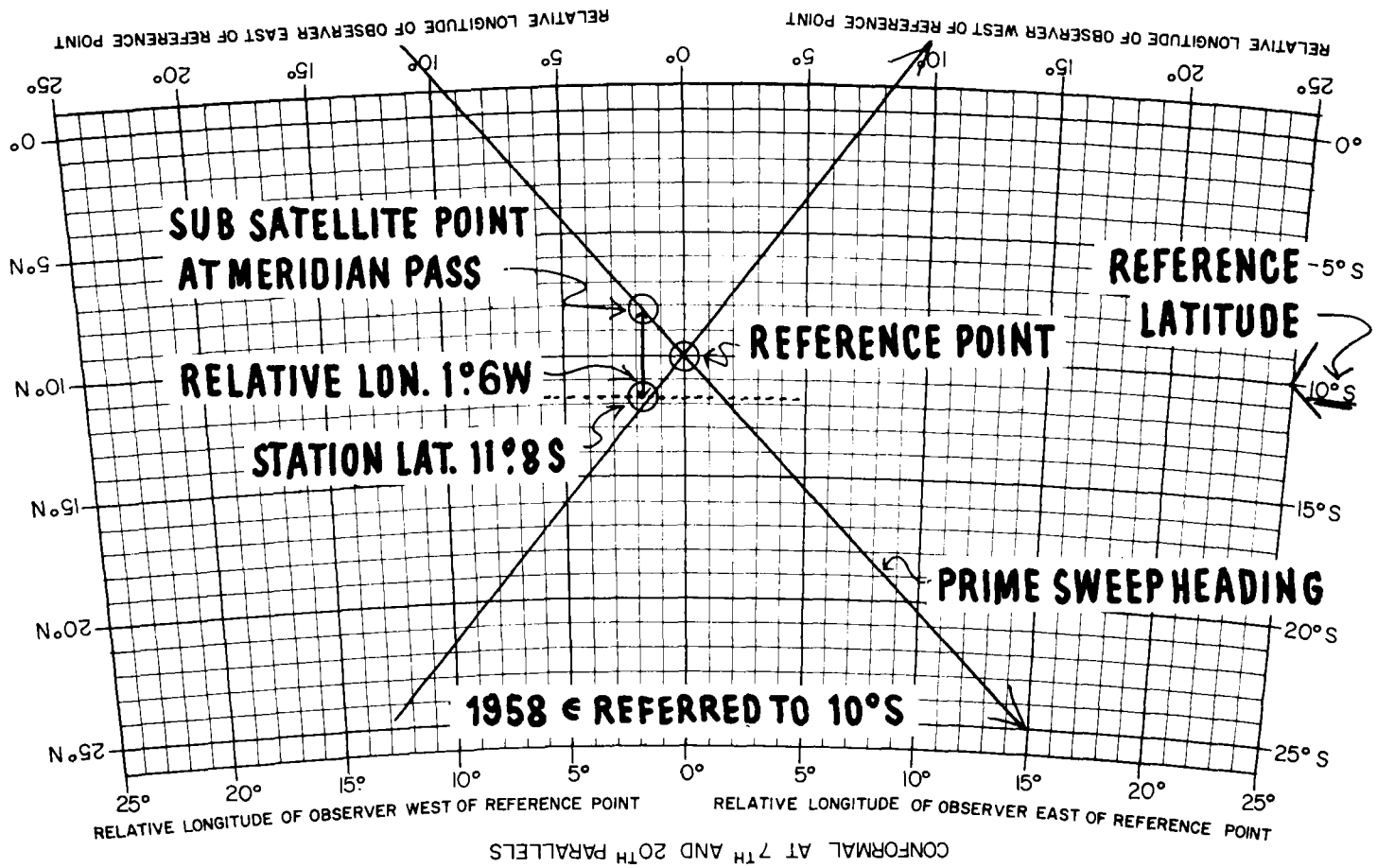
Schedule G. To Find Relative Longitude of Point Where Satellite Crosses Reference Latitude

1. Time when satellite crosses reference latitude (From schedule F, Item 13 or 15 uncorrected):	8 mo 16 d 14 h 05 m 8	ST
2. SUBTRACT: Selected sweep time	− 8 mo 16 d 14 h 12 m 3	ST
3. Time difference (note whether plus or minus)	±(−) h 6 m 5	
4. CONVERT above to minutes	+(−) m	±(−) 6 m 5
5. MULTIPLY BY: Rate of orbit plane's relative westward motion (Schedule B, Item 3)		×0°.2532 /min.
6. Relative longitude of point where satellite crosses reference latitude. (If time difference in Item 3 is *positive*, the observer's station will be *East*; of crossing point.	+(−) °	±(−) 1 ° 6

To BRING ABOVE UP-TO-DATE, SUBTRACT from time given in Item 4, the correction used in bringing Schedule F up-to-date, and ENTER result in Box. MULTIPLY corrected time by Item 5, and ENTER product in box opposite Item 6.

The orbit plane apparently sweeps from east to west. Thus a crossing that occurs before sweep time will occur when the plane is to the east of the observer's meridian. The computation in Schedule G, above, is obvious.

Normally, an observer will not be directly interested in merely observing the satellite when it passes across reference latitude; he will probably want to know when and where to look to observe the satellite as it passes nearest his station or directly across his meridian. Information of this type was in the instant example derived through use of a plotting grid as shown below.



The grid was prepared in accordance with the following instructions appearing at the beginning of the third and last part of the computation forms. In preparing the plotting grid it should be remembered that a straight line represents the satellite track for only a short segment near the reference point. If it is desired to use the grid for drawing a longer portion of the satellite track, points may be plotted by means of Tables I and II, by assuming a mean angular velocity for the satellite (as seen from the center of the earth) and by making the corresponding correction for the relative westward motion of the orbit plane.

PART III—OPTIONAL ADDITIONAL DETERMINATIONS

Preliminary Preparation of Plotting Grid (for use with any Pass of a given Satellite near Observer's Station)

1. SELECT a plotting grid showing latitude both of observer's station and of reference latitude used in Part II.
2. LOCATE Reference latitude used in Part II on central meridian (0° relative longitude). *This is reference point.*
3. ENTER Heading along satellite track for given orbit inclination and reference latitude (from Table IV) 37.3
4. ALSO ENTER: 180° *less* Item 3, above 142.7
5. DRAW straight line(s) through reference point on heading(s) (measured clockwise from North) shown above. EXTEND the resulting satellite track(s) on both sides of the reference point and MARK satellite direction(s) with arrowhead(s).

In the example given above, the grid appears to be upside-down. Inspection will show, however, that the latitudes along the right-hand margin are correct for a station that is south of the equator. Note that both arrows point to the east. The grid for a westward-moving satellite (negative orbit inclination) would be plotted in a similar way. Table IV should not be used for deriving the heading of satellites having negative inclination, since correction for the observer's motion has been subtracted from rather than added to the east-west component of the satellite's motion. The line that points away from the equator and toward the pole will in either event represent the path of the satellite at prime sweep times. Where reference latitude is numerically equal to orbit inclination, there is only one heading, and only one line crossing the central meridian at 90°.

The satellite tracks for 1958 Epsilon may be used for any pass of the satellite near Lima, Peru. The additional marks on the grid shown above are pertinent only to the specific pass under consideration. It is suggested that observers mark specific positions for a specific pass described in a Schedule H computation with a grease pencil on a transparent overlay. In this way, one grid may be used again and again for a given satellite and station location. How the grid is used is illustrated in the following:

Schedule H—To Obtain Azimuth, Elevation, Slant Range and Passage Times

1. LOCATE Observer's relative position on plotting grid using station latitude (given) and relative longitude (from Schedule G, Item 6).
2. SELECT Point(s) of observational interest along satellite track
3. DRAW LINE(S) from observer's relative position to selected point(s)
4. MEASURE clockwise from North the angular distances(s) from observer's position to point(s) of interest, and ENTER as **Azimuth**
5. MEASURE distance(s) from observer's position to point(s) of interest, SCALE OFF on meridian to read in degrees of arc and ENTER as **Distance(s) from observer in degrees**
6. MEASURE along satellite track from reference point to point(s) of interest, SCALE OFF on meridian to read in degrees of arc and ENTER as **adjustment(s) to position**
7. ADD Current perigee distance (from Schedule F, Item 7)
8. **Perigee distance(s) relative to points of interest**

   TURN TO Table III opposite *perigee position(s)* found in Item 8 (above) and under given orbit eccentricity, FIND and ENTER:
9. **Equivalent fraction(s) of period**
10. **Radial distance factor(s)**
11. MULTIPLY radial distance factor (Item 10, above) by radial distance at perigee (given)
12. **Radial distance(s) of satellite from center of the earth**
13. SUBTRACT Mean radius of Earth (3959 mi.) or radius at station

    Satellite height(s) above point(s) of interest
14. USING Satellite heights (from Item 13, above) and distance(s) from observer in degrees (from Item 5, above) ENTER "Chart for Determining Elevation and Slant Range" to OBTAIN **Elevation(s)** / **Slant range(s)**
15. MULTIPLY **Equivalent fraction of period** (Item 9, above) by 109 m 6 (*Current* perigee-to-perigee period) and ENTER
16. SUBTRACT Time required for satellite to travel from current perigee position to reference point (Schedule F, Item 10)
17. Time interval(s) between satellite passage over point(s) of interest and satellite passage over reference point
18. ADD Time when satellite passes over reference latitude (from Schedule F. Item 13 or 15)
19. Time(s) of satellite passage over point(s) of interest
20. Satellite in sunlight (from Table V)
21. Sky Dark at station (from Table VI)

	Sub-Satellite Point(s) of Observational Interest			
	Point of Nearest Approach	Meridian Passage	Alt #1	Alt #2
4. Azimuth	°	000° or ~~180°~~	°	°
5. Distance(s) from observer in degrees	°	3.4	°	°
6. Adjustment(s) to position	+(−) °	−(−) 2.3	+(−) °	+(−) °
7. Current perigee distance	+ °	+ 83.9	+ °	+ °
8. Perigee distance(s) relative to points of interest	°	81.6	°	°
9. Equivalent fraction(s) of period	0.	0. 187	0.	0.
10. Radial distance factor(s)	.	1.106	.	.
11. Radial distance at perigee (given)	× mi	× 4123.6 mi	× mi	× mi
12. Radial distance(s) of satellite from center of the earth	mi	4561 mi	mi	mi
13. Mean radius of Earth (3959 mi.) or radius at station	− mi	− 3963 mi	− mi	− mi
Satellite height(s) above point(s) of interest	mi	598 mi	mi	mi
14. Elevation(s)	°	65.0	°	°
Slant range(s)	mi	640 mi	mi	mi
15. Equivalent fraction of period (Item 9) by 109 m 6 (*Current* perigee-to-perigee period)	m	20 m 5	m	m
16. Time required for satellite to travel from current perigee position to reference point (Schedule F, Item 10)	− m	− 21 m 3	− m	− m
17. Time interval(s) between satellite passage over point(s) of interest and satellite passage over reference point	+(−) m	−(−) 0 m 8	+(−) m	+(−) m
18. Time when satellite passes over reference latitude (from Schedule F. Item 13 or 15)	+ h m	+ 14 h 05 m 8	+ h m	+ h m
19. Time(s) of satellite passage over point(s) of interest	h m	14 h 05 m 0	h m	h m
20. Satellite in sunlight (from Table V)	Yes No	(Yes) No	Yes No	Yes No
21. Sky Dark at station (from Table VI)		Yes (No)		

Item 19 of Schedule H, above indicates that the satellite was predicted to pass across the station's meridian at $14^h\ 05^m.0$, station time. The station time of the pass as actually observed at Lima, Peru was $14^h\ 04^m.4$.

Items 20 and 21 of Schedule H, above, are of interest only to persons making photographic or visual sightings. Although the tables are extensive, the answers required are of the yes-no type. The sky is either dark enough to make an observation or it isn't. In general, the sky will be too bright after the end of nautical twilight in the morning, and before the beginning of nautical twilight in the evening. These times may be found in Table VI.

Similarly, the satellite will not be visible (unless it is self-luminous because of friction or for other reasons) except when the sun is shining at the latitude and height through which the satellite is traveling.

The longitude of the satellite is taken into account in determining local mean time for Table V. The longitude of the station is taken into account in determining local mean time for Table VI.

In the example shown, the local mean time of the subsatellite point of interest was identical to the local mean time of the observer. Local mean time varies uniformly, increasing four minutes of time for every degree of easterly longitude; but in the example given, both the observer and the subsatellite point of interest were on the same meridian.

The relation between station time and local mean time of the observer was found through the following generalized formula:

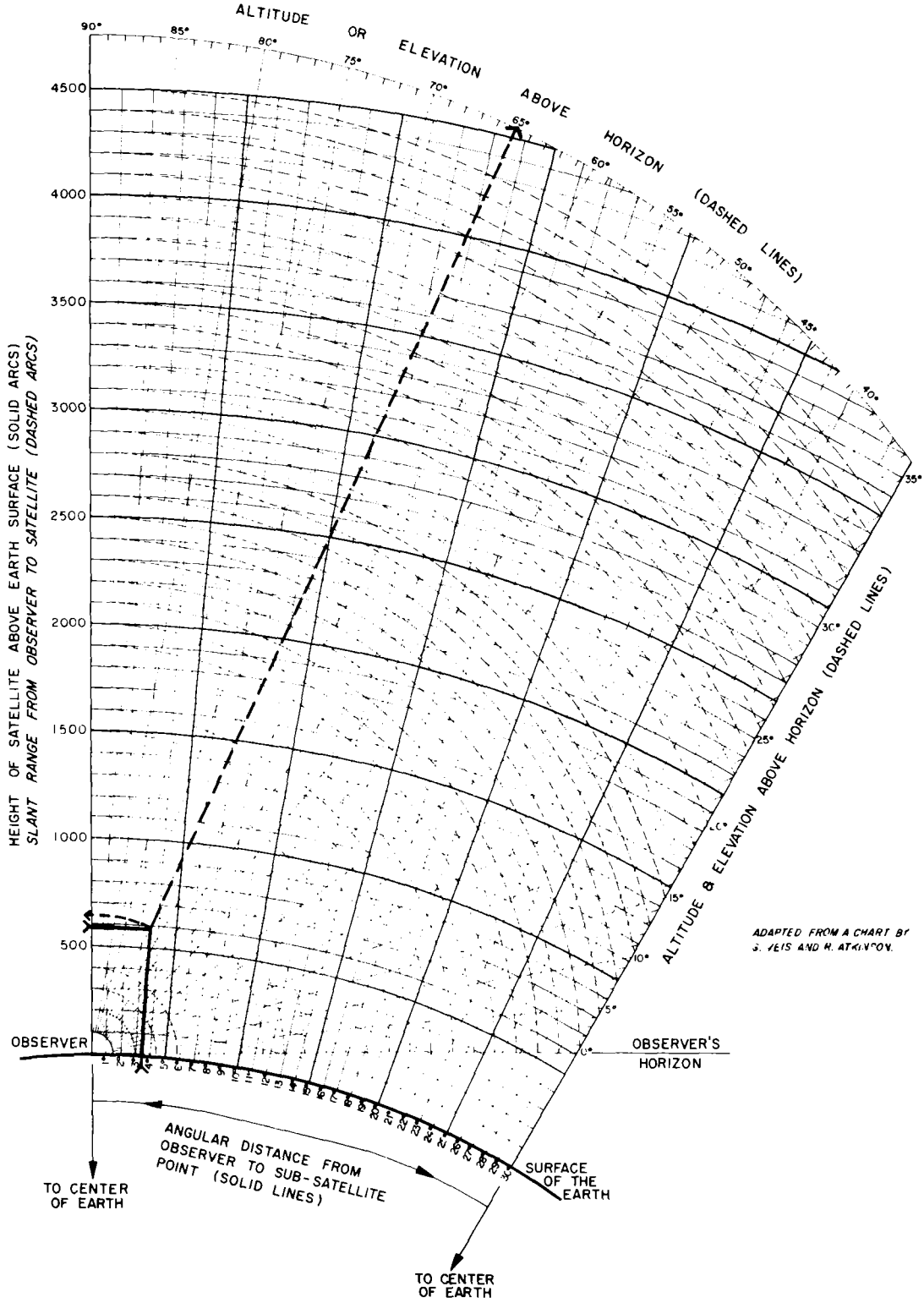
TO FIND RELATION OF LOCAL MEAN TIME OF OBSERVER TO STATION TIME (ST)

1. ENTER: Number of hours Greenwich mean time is ahead of station time (ST)		$+\ 05^h.00$
2. MULTIPLY above by		15°/hour
3. Longitude of central meridian of station time zone		$75^\circ.00$ W
4. SUBTRACT station longitude		$-\ 77^\circ.15$ W
5. Longitude of station east of central meridian	(-)	$2^\circ.15$ E
6. MULTIPLY above by		$4^m.00/^\circ$
7. Local mean time of observer EQUALS station time (ST)	(-)	$8^m.6$

The plotting grid will always show on its face how far the observer is expected to be east or west of subsatellite points of interest. If the observer is N degrees east of a subsatellite point of interest, then the local mean time of that subsatellite point is (4 TIMES N) minutes earlier than the local mean time of the observer. Similarly, if the observer is N degrees west of a subsatellite point of interest, then the local mean time of that subsatellite point is (4 TIMES N) minutes later than the local mean time of the observer.

CHART FOR DETERMINING ELEVATION & SLANT RANGE OF SATELLITE

ALL DISTANCES ARE IN STATUTE MILES - 5 STATUTE MILES EQUAL APPROXIMATELY 8 KILOMETERS.



The above reproduction illustrates how the computed height of 590 miles (Item 13) and the measured angular distance from observer to the subsatellite point of interest of $3.^{\circ}4$ (Item 5) were used in finding that the satellite would appear at an elevation of $65.^{\circ}0$ above the observer's horizon, and would be at a slant range distance of 630 statute miles from the observer. The resulting information was entered in Item 14.

TABLE I
MINIMUM LONGITUDE OF NORTHBOUND NODE WEST OF MERIDIAN POINT AT SWEEP TIMES
FOR ORBIT INCLINATIONS OF 1° TO 45° AND 46° TO 90°

ORBIT INCLI-NATION	REFERENCE LATITUDE 0°	2°.5	5°	7°.5	10°	12°.5	15°	17°.5	20°	22°.5	25°	27°.5	30°	32°.5	35°	37°.5	40°	42°.5	45° or > 45°
1°	00.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
2°	00.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
3°	00.0	56.4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4°	00.0	38.6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5°	00.0	29.9	90.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6°	00.0	24.5	56.6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
7°	00.0	20.8	45.4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
8°	00.0	18.1	38.5	70.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
9°	00.0	16.0	33.5	56.5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
10°	00.0	14.3	29.7	48.5	90.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*
11°	00.0	13.1	26.7	42.8	65.3	*	*	*	*	*	*	*	*	*	*	*	*	*	*
12°	00.0	11.9	24.7	38.4	56.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*
13°	00.0	10.9	22.3	34.8	49.8	73.8	*	*	*	*	*	*	*	*	*	*	*	*	*
14°	00.0	10.1	20.5	31.9	45.2	62.8	*	*	*	*	*	*	*	*	*	*	*	*	*
15°	00.0	9.4	19.1	29.5	41.2	55.8	90.0	*	*	*	*	*	*	*	*	*	*	*	*
16°	00.0	8.9	17.8	27.4	38.0	50.6	68.9	*	*	*	*	*	*	*	*	*	*	*	*
17°	00.0	8.4	16.6	25.6	35.2	46.5	61.2	*	*	*	*	*	*	*	*	*	*	*	*
18°	00.0	7.9	15.6	23.9	32.8	43.1	55.5	76.0	*	*	*	*	*	*	*	*	*	*	*
19°	00.0	7.4	14.7	22.5	30.8	40.2	51.1	66.4	*	*	*	*	*	*	*	*	*	*	*
20°	00.0	6.9	13.9	21.2	29.0	37.6	47.3	60.0	90.0	*	*	*	*	*	*	*	*	*	*
21°	00.0	6.5	13.2	20.1	27.4	35.2	44.3	55.3	71.7	*	*	*	*	*	*	*	*	*	*
22°	00.0	6.2	12.5	19.0	25.9	33.3	41.5	51.3	64.3	*	*	*	*	*	*	*	*	*	*
23°	00.0	5.9	11.9	18.1	24.6	31.6	39.2	48.0	59.2	77.6	*	*	*	*	*	*	*	*	*
24°	00.0	5.6	11.3	17.2	23.4	29.8	36.9	45.1	55.0	68.7	*	*	*	*	*	*	*	*	*
25°	00.0	5.4	10.8	16.4	22.2	28.4	35.0	42.6	51.3	62.8	90.0	*	*	*	*	*	*	*	*
26°	00.0	5.1	10.3	15.7	21.2	27.0	33.3	40.3	48.3	58.3	73.3	*	*	*	*	*	*	*	*
27°	00.0	4.9	9.9	15.0	20.3	25.8	31.7	38.2	45.7	54.4	64.8	*	*	*	*	*	*	*	*
28°	00.0	4.7	9.5	14.3	19.4	24.7	30.3	36.4	43.2	51.2	61.7	78.5	*	*	*	*	*	*	*
29°	00.0	4.5	9.1	13.7	18.6	23.7	28.9	34.6	41.1	48.3	57.5	70.4	*	*	*	*	*	*	*
30°	00.0	4.3	8.7	13.2	17.8	22.6	27.6	33.1	39.1	45.9	53.9	64.7	90.0	*	*	*	*	*	*
31°	00.0	4.2	8.3	12.7	17.1	21.6	26.5	31.7	37.3	43.7	51.2	59.4	74.1	*	*	*	*	*	*
32°	00.0	4.0	8.0	12.2	16.4	20.8	25.4	30.3	35.7	41.6	48.4	56.7	67.8	*	*	*	*	*	*
33°	00.0	3.9	7.7	11.7	15.8	20.0	24.4	29.1	34.2	39.7	46.1	53.4	63.0	80.0	*	*	*	*	*
34°	00.0	3.7	7.5	11.3	15.1	19.2	23.4	27.9	32.7	37.9	43.8	50.7	59.2	71.7	*	*	*	*	*
35°	00.0	3.6	7.2	10.9	14.6	18.5	22.5	26.8	31.4	36.3	41.8	48.2	55.8	66.2	90.0	*	*	*	*
36°	00.0	3.4	6.9	10.4	14.0	17.8	21.6	25.7	30.2	34.8	40.0	45.9	52.8	61.8	74.7	*	*	*	*
37°	00.0	3.3	6.7	10.0	13.6	17.1	20.8	24.7	29.0	33.4	38.3	43.8	50.3	58.1	68.6	*	*	*	*
38°	00.0	3.2	6.4	9.7	13.1	16.5	20.0	23.8	27.8	32.1	36.7	41.9	47.8	54.8	63.9	79.7	*	*	*
39°	00.0	3.1	6.2	9.4	12.6	15.9	19.3	22.9	26.7	30.8	35.2	40.2	45.7	52.2	60.0	71.7	*	*	*
40°	00.0	3.0	6.0	9.0	12.1	15.3	18.6	22.1	25.7	29.6	33.8	38.5	43.7	49.8	56.7	66.3	90.0	*	*
41°	00.0	2.9	5.8	8.7	11.7	14.8	17.9	21.3	24.8	28.5	32.5	36.8	41.7	47.4	53.8	62.3	74.9	*	*
42°	00.0	2.8	5.6	8.4	11.3	14.3	17.3	20.5	23.9	27.4	31.2	35.4	40.0	45.3	51.2	58.7	68.8	*	*
43°	00.0	2.7	5.4	8.1	10.9	13.8	16.7	19.8	23.0	26.4	30.1	34.0	38.4	43.3	48.8	55.4	64.3	79.5	*
44°	00.0	2.6	5.2	7.8	10.5	13.3	16.1	19.1	22.2	25.4	29.0	32.7	36.8	41.5	46.6	52.7	60.4	71.6	*
45°	00.0	2.5	5.0	7.6	10.2	12.8	15.6	18.4	21.4	24.5	27.8	31.4	35.3	39.6	44.5	50.2	57.1	66.4	90.0

TABLE I (Continued)

ORBIT INCLI-NATION	REFERENCE LATITUDE																		
	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
46°	00.0	4.8	9.8	15.0	20.6	26.8	33.9	42.6	54.3	75.0	*	*	*	*	*	*	*	*	*
47°	00.0	4.6	9.4	14.5	19.9	25.8	32.5	40.7	51.6	68.9	*	*	*	*	*	*	*	*	*
48°	00.0	4.5	9.1	14.0	19.2	24.9	31.2	39.1	49.2	64.3	*	*	*	*	*	*	*	*	*
49°	00.0	4.3	8.8	13.5	18.5	23.9	30.0	37.4	46.9	60.4	*	*	*	*	*	*	*	*	*
50°	00.0	4.2	8.5	13.0	17.8	23.0	28.9	36.0	44.7	57.1	90.0	*	*	*	*	*	*	*	*
51°	00.0	4.0	8.2	12.5	17.1	22.2	27.8	34.5	42.8	54.2	75.5	*	*	*	*	*	*	*	*
52°	00.0	3.9	7.9	12.1	16.5	21.4	26.8	33.2	41.0	51.5	68.9	*	*	*	*	*	*	*	*
53°	00.0	3.7	7.6	11.6	15.9	20.6	25.7	31.9	39.3	48.9	64.2	*	*	*	*	*	*	*	*
54°	00.0	3.6	7.4	11.2	15.3	19.8	24.7	30.6	37.6	46.6	60.3	*	*	*	*	*	*	*	*
55°	00.0	3.4	7.1	10.8	14.7	19.1	23.8	29.4	36.0	44.5	56.7	90.0	*	*	*	*	*	*	*
56°	00.0	3.3	6.8	10.4	14.2	18.4	22.9	28.2	34.5	42.4	53.7	74.8	*	*	*	*	*	*	*
57°	00.0	3.2	6.5	10.0	13.7	17.7	22.0	27.0	13.1	40.5	50.8	68.3	*	*	*	*	*	*	*
58°	00.0	3.1	6.3	9.6	13.2	17.0	21.1	25.9	31.7	38.7	48.2	63.4	*	*	*	*	*	*	*
59°	00.0	3.0	6.0	9.2	12.7	16.3	20.2	24.9	30.4	36.9	45.8	59.3	*	*	*	*	*	*	*
60°	00.0	2.9	5.8	8.9	12.2	15.7	19.4	23.9	29.1	35.3	43.6	55.7	90.0	*	*	*	*	*	*
61°	00.0	2.8	5.6	8.5	11.7	15.0	18.6	22.9	27.8	33.7	41.4	52.5	74.3	*	*	*	*	*	*
62°	00.0	2.7	5.4	8.2	11.2	14.4	17.8	21.9	26.5	32.2	39.4	49.5	67.3	*	*	*	*	*	*
63°	00.0	2.5	5.1	7.8	10.7	13.8	17.0	20.9	25.3	30.7	37.4	46.8	62.2	*	*	*	*	*	*
64°	00.0	2.4	4.9	7.5	10.2	13.2	16.3	20.0	24.2	29.2	35.6	44.2	57.8	*	*	*	*	*	*
65°	00.0	2.3	4.7	7.2	9.7	12.6	15.6	19.1	23.1	27.8	33.8	41.9	53.9	90.0	*	*	*	*	*
66°	00.0	2.2	4.5	6.9	9.3	12.0	14.9	18.2	22.0	26.5	32.2	39.6	50.6	72.9	*	*	*	*	*
67°	00.0	2.1	4.3	6.5	8.8	11.4	14.2	17.3	20.9	25.2	30.4	37.3	47.4	65.9	*	*	*	*	*
68°	00.0	2.0	4.1	6.2	8.4	10.9	13.5	16.5	19.9	23.8	28.8	35.3	44.5	60.3	*	*	*	*	*
69°	00.0	1.9	3.9	5.9	8.0	10.3	12.8	15.6	18.8	22.6	27.3	33.3	41.8	55.6	*	*	*	*	*
70°	00.0	1.8	3.7	5.6	7.6	9.8	12.1	14.8	17.8	21.4	25.7	31.3	39.2	51.4	90.0	*	*	*	*
71°	00.0	1.7	3.5	5.3	7.2	9.2	11.4	14.0	16.8	20.1	24.2	29.5	36.7	47.7	71.6	*	*	*	*
72°	00.0	1.6	3.3	5.0	6.8	8.7	10.8	13.2	15.8	19.0	22.8	27.7	34.3	44.2	63.5	*	*	*	*
73°	00.0	1.5	3.1	4.7	6.4	8.2	10.1	12.4	14.8	17.8	21.4	25.9	32.1	41.0	57.3	*	*	*	*
74°	00.0	1.4	2.9	4.4	6.0	7.7	9.5	11.6	13.9	16.7	20.0	24.2	29.8	38.0	52.2	*	*	*	*
75°	00.0	1.3	2.7	4.1	5.6	7.2	8.8	10.8	13.0	15.5	18.6	22.5	27.7	35.2	45.4	90.0	*	*	*
76°	00.0	1.2	2.5	3.8	5.2	6.7	8.2	10.1	12.1	14.4	17.3	20.9	25.6	32.3	43.3	68.8	*	*	*
77°	00.0	1.1	2.3	3.5	4.8	6.2	7.6	9.3	11.2	13.4	16.0	19.3	23.6	29.7	39.5	59.7	*	*	*
78°	00.0	1.1	2.2	3.3	4.4	5.7	7.0	8.6	10.3	12.3	14.7	17.7	21.6	27.2	35.8	52.7	*	*	*
79°	00.0	1.0	2.0	3.0	4.0	5.2	6.4	7.8	9.4	11.2	13.4	16.2	19.7	24.7	32.3	46.6	*	*	*
80°	00.0	0.9	1.8	2.7	3.6	4.7	5.8	7.1	8.5	10.2	12.1	14.6	17.8	22.3	29.1	41.3	90.0	*	*
81°	00.0	0.8	1.6	2.4	3.2	4.2	5.2	6.3	7.6	9.1	10.9	13.1	15.9	19.9	25.8	36.3	64.3	*	*
82°	00.0	0.7	1.4	2.2	2.9	3.8	4.6	5.6	6.8	8.1	9.7	11.6	14.1	17.6	22.8	31.7	54.3	*	*
83°	00.0	0.6	1.2	1.9	2.5	3.3	4.0	4.8	5.9	7.1	8.4	10.1	12.3	15.3	19.7	27.3	44.2	*	*
84°	00.0	0.5	1.0	1.6	2.2	2.8	3.4	4.1	5.1	6.0	7.2	8.7	10.5	13.0	16.8	23.2	36.7	*	*
85°	00.0	0.4	0.8	1.3	1.8	2.3	2.8	3.4	4.2	5.0	6.0	7.2	8.7	10.8	13.9	19.0	29.7	90.0	*
86°	00.0	0.3	0.6	1.1	1.5	1.9	2.3	2.8	3.4	4.0	4.8	5.7	6.9	8.6	11.1	15.1	23.4	53.4	*
87°	00.0	0.2	0.4	0.8	1.1	1.4	1.7	2.1	2.5	3.0	3.6	4.3	5.2	6.4	8.3	11.3	17.3	37.0	*
88°	00.0	0.1	0.2	0.5	0.7	0.9	1.2	1.4	1.7	2.0	2.4	2.9	3.5	4.3	5.5	7.5	11.4	23.6	*
89°	00.0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.7	2.1	2.8	3.7	5.7	11.6	*
90°	00.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	00.0	-

* Where reference latitude is numerically equal to orbit inclination angle, minimum longitude of northbound node west of meridian point is 90°0 at sweep times, and return sweeps may be considered merged with and indistinguishable from prime sweeps. For stations at latitudes numerically close to or higher than orbit inclination angle, considerable computation effort can be saved by making use of this fact.

TABLE II

INITIAL CENTRAL ANGLE WITHIN ORBIT PLANE BETWEEN EQUATOR AND REFERENCE LATITUDE MEASURED IN DEGREES FOR ORBIT INCLINATIONS OF 1° TO 45° AND 46° TO 90°

ORBIT INCLI-NATION	REFERENCE LATITUDE																		45° or > 45°
	0°	2°5	5°	7°5	10°	12°5	15°	17°5	20°	22°5	25°	27°5	30°	32°5	35°	37°5	40°	42°5	
1°	00.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
2°	00.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
3°	00.0	56.5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4°	00.0	38.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5°	00.0	30.0	90.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6°	00.0	24.7	56.5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
7°	00.0	21.0	45.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
8°	00.0	18.3	38.8	69.5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
9°	00.0	16.2	33.9	56.6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
10°	00.0	14.5	30.1	48.7	90.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*
11°	00.0	13.2	27.2	43.2	65.5	*	*	*	*	*	*	*	*	*	*	*	*	*	*
12°	00.0	12.1	24.8	38.9	56.6	*	*	*	*	*	*	*	*	*	*	*	*	*	*
13°	00.0	11.2	22.8	35.5	50.5	74.2	*	*	*	*	*	*	*	*	*	*	*	*	*
14°	00.0	10.4	21.1	32.7	45.9	63.5	*	*	*	*	*	*	*	*	*	*	*	*	*
15°	00.0	9.7	19.7	30.3	42.6	56.7	90.0	*	*	*	*	*	*	*	*	*	*	*	*
16°	00.0	9.1	18.4	28.3	39.0	51.7	69.9	*	*	*	*	*	*	*	*	*	*	*	*
17°	00.0	8.6	17.3	26.4	36.4	47.8	62.3	*	*	*	*	*	*	*	*	*	*	*	*
18°	00.0	8.1	16.4	25.0	34.2	44.5	56.9	76.7	*	*	*	*	*	*	*	*	*	*	*
19°	00.0	7.7	15.5	23.6	32.2	41.7	52.7	67.5	*	*	*	*	*	*	*	*	*	*	*
20°	00.0	7.3	14.8	22.4	30.5	39.3	49.2	61.5	90.0	*	*	*	*	*	*	*	*	*	*
21°	00.0	7.0	14.1	21.4	29.0	37.2	46.2	57.0	72.6	*	*	*	*	*	*	*	*	*	*
22°	00.0	6.7	13.5	20.4	27.6	35.2	43.7	53.4	65.9	*	*	*	*	*	*	*	*	*	*
23°	00.0	6.4	12.9	19.5	26.4	33.6	41.5	50.3	61.1	78.4	*	*	*	*	*	*	*	*	*
24°	00.0	6.2	12.4	18.7	25.3	32.1	39.5	47.7	57.2	70.2	*	*	*	*	*	*	*	*	*
25°	00.0	5.9	11.9	18.0	24.3	30.8	37.8	45.4	54.0	64.9	90.0	*	*	*	*	*	*	*	*
26°	00.0	5.7	11.5	17.3	23.3	29.6	36.2	43.3	51.3	60.8	74.6	*	*	*	*	*	*	*	*
27°	00.0	5.5	11.1	16.7	22.5	28.5	34.8	41.5	48.9	57.5	68.6	*	*	*	*	*	*	*	*
28°	00.0	5.3	10.7	16.1	21.7	27.5	33.5	39.8	46.8	54.6	64.2	79.6	*	*	*	*	*	*	*
29°	00.0	5.2	10.4	15.6	21.0	26.5	32.3	38.4	44.9	52.1	60.7	72.3	*	*	*	*	*	*	*
30°	00.0	5.0	10.0	15.1	20.3	25.7	31.2	37.0	43.2	49.9	57.7	67.4	90.0	*	*	*	*	*	*
31°	00.0	4.9	9.7	14.7	19.7	24.9	30.2	35.7	41.6	48.0	55.1	63.7	76.1	*	*	*	*	*	*
32°	00.0	4.7	9.5	14.3	19.1	24.1	29.2	34.6	40.2	46.2	52.9	60.6	70.7	*	*	*	*	*	*
33°	00.0	4.6	9.2	13.9	18.6	23.4	28.4	33.5	38.9	44.6	50.9	58.0	66.6	80.6	*	*	*	*	*
34°	00.0	4.5	9.0	13.5	18.1	22.8	27.6	32.5	37.7	43.2	49.1	55.7	63.4	73.9	*	*	*	*	*
35°	00.0	4.4	8.7	13.2	17.6	22.2	26.8	31.6	36.6	41.9	47.5	53.6	60.7	69.5	90.0	*	*	*	*
36°	00.0	4.3	8.5	12.8	17.2	21.6	26.1	30.8	35.6	40.6	46.0	51.8	58.3	66.1	77.4	*	*	*	*
37°	00.0	4.2	8.3	12.5	16.8	21.1	25.5	30.0	34.6	39.5	44.6	50.1	56.2	63.2	72.4	*	*	*	*
38°	00.0	4.1	8.1	12.2	16.4	20.6	24.9	29.2	33.7	38.4	43.3	48.6	54.3	60.8	68.7	81.4	*	*	*
39°	00.0	4.0	8.0	12.0	16.0	20.1	24.3	28.5	32.9	37.5	42.2	47.2	52.6	58.6	65.7	75.3	*	*	*
40°	00.0	3.9	7.8	11.7	15.7	19.7	23.7	27.9	32.1	36.5	41.1	45.9	51.1	56.7	63.2	71.3	90.0	*	*
41°	00.0	3.8	7.6	11.5	15.3	19.3	23.2	27.3	31.4	35.7	40.1	44.7	49.7	55.0	61.0	68.1	78.5	*	*
42°	00.0	3.7	7.5	11.2	15.0	18.9	22.8	26.7	30.7	34.9	39.2	43.6	48.4	53.4	59.0	65.5	73.9	*	*
43°	00.0	3.7	7.3	11.0	14.8	18.5	22.3	26.2	30.1	34.1	38.3	42.6	47.1	52.0	57.2	63.2	70.5	82.1	*
44°	00.0	3.6	7.2	10.8	14.5	18.2	21.9	25.7	29.5	33.4	37.5	41.7	46.0	50.7	55.7	61.2	67.7	76.5	*
45°	00.0	3.5	7.1	10.6	14.2	17.8	21.5	25.2	28.9	32.8	36.7	40.8	45.0	49.5	54.2	59.4	65.4	72.8	90.0

TABLE II (Continued)

ORBIT INCLI-NATION	REFERENCE LATITUDES																		
	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
46°	00.0	7.0	14.0	21.1	28.4	36.0	44.0	52.9	63.3	79.4	*	*	*	*	*	*	*	*	*
47°	00.0	6.8	13.7	20.7	27.9	35.3	43.1	51.7	61.5	75.2	*	*	*	*	*	*	*	*	*
48°	00.0	6.7	13.5	20.4	27.4	34.7	42.3	50.5	59.9	72.1	*	*	*	*	*	*	*	*	*
49°	00.0	6.6	13.3	20.1	26.9	34.1	41.5	49.5	58.4	69.5	*	*	*	*	*	*	*	*	*
50°	00.0	6.5	13.1	19.7	26.5	33.5	40.7	48.5	57.0	67.4	90.0	*	*	*	*	*	*	*	*
51°	00.0	6.4	12.9	19.5	26.1	32.9	40.0	47.6	55.8	65.5	80.3	*	*	*	*	*	*	*	*
52°	00.0	6.4	12.7	19.2	25.7	32.1	39.4	46.7	54.7	63.8	76.4	*	*	*	*	*	*	*	*
53°	00.0	6.3	12.6	18.9	25.4	31.9	38.8	45.9	53.6	62.3	73.6	*	*	*	*	*	*	*	*
54°	00.0	6.2	12.4	18.7	25.0	31.5	38.2	45.2	52.6	60.9	71.2	*	*	*	*	*	*	*	*
55°	00.0	6.1	12.2	18.4	24.6	31.1	37.6	44.4	51.7	59.7	69.3	90.0	*	*	*	*	*	*	*
56°	00.0	6.0	12.0	18.2	24.3	30.7	37.1	43.8	50.8	58.5	67.5	81.1	*	*	*	*	*	*	*
57°	00.0	6.0	11.8	18.0	24.0	30.3	36.6	43.2	50.0	57.5	66.0	77.6	*	*	*	*	*	*	*
58°	00.0	5.9	11.6	17.8	23.7	29.9	36.1	42.6	49.3	56.5	64.6	75.0	*	*	*	*	*	*	*
59°	00.0	5.8	11.4	17.6	23.5	29.5	35.7	42.0	48.6	55.6	63.3	72.9	*	*	*	*	*	*	*
60°	00.0	5.8	11.3	17.4	23.3	29.2	35.3	41.5	47.9	54.7	62.2	71.1	90.0	*	*	*	*	*	*
61°	00.0	5.7	11.2	17.2	23.2	28.9	34.9	41.0	47.2	54.0	61.1	69.5	82.0	*	*	*	*	*	*
62°	00.0	5.7	11.2	17.0	23.1	28.6	34.5	40.5	47.7	53.3	60.2	68.1	78.8	*	*	*	*	*	*
63°	00.0	5.6	11.1	16.8	23.0	28.3	34.1	40.1	46.2	52.6	59.3	66.8	76.4	*	*	*	*	*	*
64°	00.0	5.6	11.1	16.7	22.9	28.0	33.8	39.7	45.7	51.9	58.5	65.7	74.5	*	*	*	*	*	*
65°	00.0	5.5	11.0	16.6	22.8	27.8	33.5	39.3	45.2	51.3	57.7	64.7	72.9	90.0	*	*	*	*	*
66°	00.0	5.5	11.0	16.4	22.5	27.5	33.2	38.9	44.8	50.8	56.7	63.7	71.4	82.8	*	*	*	*	*
67°	00.0	5.4	10.9	16.3	22.2	27.3	32.9	38.5	44.4	50.3	56.3	62.9	70.2	79.9	*	*	*	*	*
68°	00.0	5.4	10.8	16.2	21.9	27.1	32.6	38.2	44.0	49.8	55.7	62.1	69.1	77.8	*	*	*	*	*
69°	00.0	5.4	10.7	16.1	21.6	26.9	32.3	37.9	43.6	49.3	55.1	61.3	68.1	76.1	*	*	*	*	*
70°	00.0	5.3	10.6	16.0	21.3	26.7	32.1	37.6	43.2	48.8	54.6	60.7	67.2	74.7	90.0	*	*	*	*
71°	00.0	5.3	10.5	15.9	21.1	26.5	31.9	37.3	42.9	48.4	54.1	60.0	66.3	73.4	83.6	*	*	*	*
72°	00.0	5.3	10.5	15.8	21.0	26.3	31.7	37.0	42.6	48.0	53.7	59.5	65.6	72.4	81.1	*	*	*	*
73°	00.0	5.3	10.4	15.7	20.9	26.1	31.5	36.8	42.3	47.7	53.2	58.9	64.9	71.4	79.3	*	*	*	*
74°	00.0	5.2	10.4	15.6	20.8	26.0	31.3	36.6	42.0	47.4	52.8	58.4	64.3	70.5	77.8	*	*	*	*
75°	00.0	5.2	10.4	15.5	20.7	25.9	31.2	36.4	41.7	47.1	52.5	58.0	63.7	69.8	76.6	90.0	*	*	*
76°	00.0	5.2	10.3	15.4	20.6	25.8	31.0	36.2	41.5	46.7	52.1	57.6	63.2	69.1	75.6	84.6	*	*	*
77°	00.0	5.2	10.3	15.3	20.5	25.7	30.8	36.0	41.3	46.5	51.8	57.2	62.7	68.5	74.7	82.5	*	*	*
78°	00.0	5.1	10.2	15.3	20.4	25.6	30.7	35.8	41.1	46.3	51.6	56.9	62.3	67.9	73.9	80.6	*	*	*
79°	00.0	5.1	10.2	15.2	20.3	25.5	30.6	35.7	40.9	46.1	51.3	56.6	61.9	67.4	73.2	79.7	*	*	*
80°	00.0	5.1	10.2	15.2	20.3	25.4	30.5	35.6	40.7	45.9	51.1	56.3	61.6	67.0	72.6	78.8	90.0	*	*
81°	00.0	5.1	10.1	15.2	20.3	25.3	30.4	35.5	40.6	45.7	50.9	56.1	61.3	66.6	72.1	77.9	85.6	*	*
82°	00.0	5.0	10.1	15.1	20.2	25.2	30.3	35.4	40.5	45.5	50.7	55.9	61.0	66.2	71.6	77.3	84.0	*	*
83°	00.0	5.0	10.1	15.1	20.2	25.2	30.2	35.3	40.4	45.4	50.5	55.7	60.8	65.9	71.2	76.7	82.8	*	*
84°	00.0	5.0	10.1	15.1	20.2	25.1	30.1	35.2	40.3	45.3	50.4	55.5	60.6	65.7	70.9	76.2	82.0	*	*
85°	00.0	5.0	10.0	15.1	20.1	25.1	30.1	35.2	40.2	45.2	50.3	55.3	60.4	65.5	70.6	75.8	81.3	90.0	*
86°	00.0	5.0	10.0	15.0	20.1	25.1	30.1	35.1	40.1	45.1	50.2	55.2	60.3	65.3	70.4	75.5	80.8	87.0	*
87°	00.0	5.0	10.0	15.0	20.1	25.0	30.0	35.1	40.1	45.1	50.1	55.1	60.2	65.2	70.2	75.3	80.5	86.0	*
88°	00.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.1	60.1	65.1	70.1	75.1	80.2	85.4	*
89°	00.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.1	*
90°	00.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0

* Where reference latitude is numerically equal to orbit inclination angle, initial central angle within orbit plane between equator and reference latitude is 90.0, and return sweeps may be considered merged with and indistinguishable from prime sweeps. For stations at latitudes numerically close to or higher than orbit inclination angle, considerable computation effort may be saved by making use of this fact.

TABLE III - A
FRACTIONS OF PERIOD
EQUIVALENT TO ANGULAR DISTANCES OF 2° TO 180°* FROM PERIGEE (MEASURED AT THE CENTER OF THE EARTH)
FOR ORBIT ECCENTRICITIES OF FROM 0.020 TO 0.320

PERIGEE DISTANCE	0.020	0.040	0.060	0.080	0.100	0.120	0.140	0.160	0.180	0.200	0.220	0.240	0.260	0.280	0.300	0.320
2°	0.005	0.005	0.005	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003
4°	0.011	0.010	0.010	0.009	0.009	0.009	0.008	0.008	0.008	0.007	0.007	0.007	0.006	0.006	0.006	0.005
6°	0.016	0.015	0.015	0.014	0.014	0.013	0.012	0.012	0.011	0.011	0.010	0.010	0.009	0.009	0.009	0.008
8°	0.021	0.021	0.020	0.019	0.018	0.017	0.017	0.016	0.015	0.015	0.014	0.013	0.013	0.012	0.011	0.011
10°	0.027	0.026	0.025	0.024	0.023	0.022	0.021	0.020	0.019	0.018	0.017	0.017	0.016	0.015	0.014	0.014
12°	0.032	0.031	0.030	0.028	0.027	0.026	0.025	0.024	0.023	0.022	0.021	0.020	0.019	0.018	0.017	0.016
14°	0.037	0.036	0.034	0.033	0.032	0.030	0.029	0.028	0.027	0.025	0.024	0.023	0.022	0.021	0.020	0.019
16°	0.043	0.041	0.039	0.038	0.036	0.035	0.033	0.032	0.031	0.029	0.028	0.027	0.025	0.024	0.023	0.022
18°	0.048	0.046	0.044	0.043	0.041	0.039	0.037	0.036	0.034	0.033	0.031	0.030	0.029	0.027	0.026	0.025
20°	0.053	0.051	0.049	0.047	0.045	0.044	0.042	0.040	0.038	0.037	0.035	0.033	0.032	0.030	0.029	0.027
22°	0.059	0.056	0.054	0.052	0.050	0.048	0.046	0.044	0.042	0.040	0.038	0.037	0.035	0.033	0.032	0.030
24°	0.064	0.062	0.059	0.057	0.055	0.052	0.050	0.048	0.046	0.044	0.042	0.040	0.038	0.036	0.035	0.033
26°	0.069	0.067	0.064	0.062	0.059	0.057	0.054	0.052	0.050	0.048	0.046	0.044	0.042	0.040	0.038	0.036
28°	0.075	0.072	0.069	0.066	0.064	0.061	0.059	0.056	0.054	0.051	0.049	0.047	0.045	0.043	0.041	0.039
30°	0.080	0.077	0.074	0.071	0.068	0.066	0.063	0.060	0.058	0.055	0.053	0.050	0.048	0.046	0.044	0.042
32°	0.086	0.082	0.079	0.076	0.073	0.070	0.067	0.064	0.062	0.059	0.056	0.054	0.052	0.049	0.047	0.044
34°	0.091	0.087	0.084	0.081	0.078	0.075	0.072	0.069	0.066	0.063	0.060	0.057	0.055	0.052	0.050	0.047
36°	0.096	0.093	0.089	0.086	0.082	0.079	0.076	0.073	0.070	0.067	0.064	0.061	0.058	0.056	0.053	0.050
38°	0.102	0.098	0.094	0.091	0.087	0.084	0.080	0.077	0.074	0.071	0.068	0.065	0.062	0.059	0.056	0.053
40°	0.107	0.103	0.099	0.095	0.092	0.088	0.085	0.081	0.078	0.075	0.071	0.068	0.065	0.062	0.059	0.056
42°	0.112	0.108	0.104	0.100	0.097	0.093	0.089	0.085	0.082	0.079	0.075	0.072	0.069	0.066	0.062	0.059
44°	0.118	0.114	0.109	0.105	0.101	0.097	0.094	0.090	0.086	0.082	0.079	0.076	0.072	0.069	0.066	0.063
46°	0.123	0.119	0.114	0.110	0.106	0.102	0.098	0.094	0.090	0.086	0.083	0.079	0.076	0.072	0.069	0.066
48°	0.129	0.124	0.120	0.115	0.111	0.107	0.102	0.098	0.094	0.091	0.087	0.083	0.079	0.076	0.072	0.069
50°	0.134	0.129	0.125	0.120	0.116	0.111	0.107	0.103	0.099	0.095	0.091	0.087	0.083	0.079	0.076	0.072
52°	0.139	0.135	0.130	0.125	0.120	0.116	0.112	0.107	0.103	0.099	0.095	0.091	0.087	0.083	0.079	0.075
54°	0.145	0.140	0.135	0.130	0.125	0.121	0.116	0.112	0.107	0.103	0.099	0.095	0.090	0.086	0.083	0.079
56°	0.150	0.145	0.140	0.135	0.130	0.125	0.121	0.116	0.112	0.107	0.103	0.098	0.094	0.090	0.086	0.082
58°	0.156	0.150	0.145	0.140	0.135	0.130	0.125	0.121	0.116	0.111	0.107	0.102	0.098	0.094	0.090	0.086
60°	0.161	0.156	0.150	0.145	0.140	0.135	0.130	0.125	0.120	0.116	0.111	0.106	0.102	0.098	0.093	0.089
62°	0.167	0.161	0.156	0.150	0.145	0.140	0.135	0.130	0.125	0.120	0.115	0.111	0.106	0.101	0.097	0.093
64°	0.172	0.166	0.161	0.155	0.150	0.145	0.140	0.134	0.129	0.124	0.119	0.115	0.110	0.105	0.101	0.096
66°	0.178	0.172	0.166	0.161	0.155	0.150	0.144	0.139	0.134	0.129	0.124	0.119	0.114	0.109	0.104	0.100
68°	0.183	0.177	0.171	0.166	0.160	0.155	0.149	0.144	0.139	0.133	0.128	0.123	0.118	0.113	0.108	0.104
70°	0.188	0.183	0.177	0.171	0.165	0.160	0.154	0.149	0.143	0.138	0.133	0.127	0.122	0.117	0.112	0.107
72°	0.194	0.188	0.182	0.176	0.170	0.165	0.159	0.153	0.148	0.142	0.137	0.132	0.127	0.121	0.116	0.111
74°	0.199	0.193	0.187	0.181	0.176	0.170	0.164	0.158	0.153	0.147	0.142	0.136	0.131	0.126	0.120	0.115
76°	0.205	0.199	0.193	0.187	0.181	0.175	0.169	0.163	0.158	0.152	0.146	0.141	0.135	0.130	0.124	0.119
78°	0.210	0.204	0.198	0.192	0.186	0.180	0.174	0.168	0.162	0.157	0.151	0.145	0.140	0.134	0.129	0.123
80°	0.216	0.210	0.204	0.197	0.191	0.185	0.179	0.173	0.167	0.162	0.156	0.150	0.144	0.139	0.133	0.128

PERIGEE DISTANCE	0.020	0.040	0.060	0.080	0.100	0.120	0.140	0.160	0.180	0.200	0.220	0.240	0.260	0.280	0.300	0.320
82°	0.221	0.215	0.209	0.203	0.197	0.191	0.184	0.178	0.172	0.166	0.161	0.155	0.149	0.143	0.137	0.132
84°	0.227	0.221	0.214	0.208	0.202	0.196	0.190	0.184	0.177	0.171	0.165	0.159	0.154	0.148	0.142	0.136
86°	0.233	0.226	0.220	0.214	0.207	0.201	0.195	0.189	0.183	0.176	0.170	0.164	0.158	0.152	0.147	0.141
88°	0.238	0.232	0.225	0.219	0.213	0.206	0.200	0.194	0.188	0.182	0.175	0.169	0.163	0.157	0.151	0.145
90°	0.244	0.237	0.231	0.225	0.218	0.212	0.206	0.199	0.193	0.187	0.181	0.174	0.168	0.162	0.156	0.150
92°	0.249	0.243	0.236	0.230	0.224	0.217	0.211	0.205	0.198	0.192	0.186	0.179	0.173	0.167	0.161	0.155
94°	0.255	0.248	0.242	0.236	0.229	0.223	0.216	0.210	0.204	0.197	0.191	0.185	0.178	0.172	0.166	0.160
96°	0.260	0.254	0.248	0.241	0.235	0.228	0.222	0.216	0.209	0.203	0.196	0.190	0.184	0.177	0.171	0.165
98°	0.266	0.260	0.253	0.247	0.240	0.234	0.228	0.221	0.215	0.208	0.202	0.195	0.189	0.183	0.176	0.170
100°	0.271	0.265	0.259	0.252	0.246	0.240	0.233	0.227	0.220	0.214	0.207	0.201	0.194	0.188	0.181	0.175
102°	0.277	0.271	0.264	0.258	0.252	0.245	0.239	0.232	0.226	0.219	0.213	0.206	0.200	0.193	0.187	0.180
104°	0.283	0.276	0.270	0.264	0.257	0.251	0.245	0.238	0.232	0.225	0.219	0.212	0.206	0.199	0.192	0.186
106°	0.288	0.282	0.276	0.270	0.263	0.257	0.250	0.244	0.238	0.231	0.224	0.218	0.211	0.205	0.198	0.191
108°	0.294	0.288	0.282	0.275	0.269	0.263	0.256	0.250	0.243	0.237	0.230	0.224	0.217	0.211	0.204	0.197
110°	0.300	0.293	0.287	0.281	0.275	0.269	0.262	0.256	0.249	0.243	0.236	0.230	0.223	0.216	0.210	0.203
112°	0.305	0.299	0.293	0.287	0.281	0.275	0.268	0.262	0.255	0.249	0.242	0.236	0.229	0.223	0.216	0.209
114°	0.311	0.305	0.299	0.293	0.287	0.281	0.274	0.268	0.262	0.255	0.249	0.242	0.235	0.229	0.222	0.215
116°	0.316	0.311	0.305	0.299	0.293	0.287	0.280	0.274	0.268	0.261	0.255	0.248	0.242	0.235	0.228	0.222
118°	0.322	0.316	0.311	0.305	0.299	0.293	0.287	0.280	0.274	0.268	0.261	0.255	0.248	0.242	0.235	0.228
120°	0.328	0.322	0.316	0.311	0.305	0.299	0.293	0.287	0.280	0.274	0.268	0.261	0.255	0.248	0.241	0.235
122°	0.333	0.328	0.322	0.317	0.311	0.305	0.299	0.293	0.287	0.281	0.274	0.268	0.261	0.255	0.248	0.241
124°	0.339	0.334	0.328	0.323	0.317	0.311	0.305	0.299	0.293	0.287	0.281	0.275	0.268	0.262	0.255	0.248
126°	0.345	0.340	0.334	0.329	0.323	0.317	0.312	0.306	0.300	0.294	0.288	0.281	0.275	0.269	0.262	0.255
128°	0.350	0.345	0.340	0.335	0.329	0.324	0.318	0.312	0.307	0.301	0.295	0.288	0.282	0.276	0.269	0.263
130°	0.356	0.351	0.346	0.341	0.336	0.330	0.325	0.319	0.313	0.307	0.301	0.295	0.289	0.283	0.277	0.270
132°	0.362	0.357	0.352	0.347	0.342	0.337	0.331	0.326	0.320	0.314	0.309	0.303	0.297	0.290	0.284	0.278
134°	0.368	0.363	0.358	0.353	0.348	0.343	0.338	0.332	0.327	0.321	0.316	0.310	0.304	0.298	0.292	0.285
136°	0.373	0.369	0.364	0.359	0.354	0.349	0.344	0.339	0.334	0.328	0.323	0.317	0.311	0.306	0.299	0.293
138°	0.379	0.375	0.370	0.366	0.361	0.356	0.351	0.346	0.341	0.336	0.330	0.325	0.319	0.313	0.307	0.301
140°	0.385	0.381	0.376	0.372	0.367	0.363	0.358	0.353	0.348	0.343	0.338	0.332	0.327	0.321	0.315	0.310
142°	0.390	0.386	0.382	0.378	0.374	0.369	0.365	0.360	0.355	0.350	0.345	0.340	0.335	0.329	0.324	0.318
144°	0.396	0.392	0.388	0.384	0.380	0.376	0.371	0.367	0.362	0.358	0.353	0.348	0.343	0.337	0.332	0.326
146°	0.402	0.398	0.394	0.391	0.387	0.383	0.378	0.374	0.370	0.365	0.360	0.356	0.351	0.346	0.340	0.335
148°	0.408	0.404	0.401	0.397	0.393	0.389	0.385	0.381	0.377	0.373	0.368	0.364	0.359	0.354	0.349	0.344
150°	0.413	0.410	0.407	0.403	0.400	0.396	0.392	0.388	0.384	0.380	0.376	0.372	0.367	0.363	0.358	0.353
152°	0.419	0.416	0.413	0.410	0.406	0.403	0.399	0.396	0.392	0.388	0.384	0.380	0.376	0.371	0.367	0.362
154°	0.425	0.422	0.419	0.416	0.413	0.410	0.406	0.403	0.399	0.396	0.392	0.388	0.384	0.380	0.376	0.371
156°	0.431	0.428	0.425	0.422	0.419	0.416	0.413	0.410	0.407	0.403	0.400	0.396	0.393	0.389	0.385	0.381
158°	0.436	0.434	0.431	0.429	0.426	0.423	0.420	0.417	0.414	0.411	0.408	0.405	0.401	0.398	0.394	0.390
160°	0.442	0.440	0.438	0.435	0.433	0.430	0.428	0.425	0.422	0.419	0.416	0.413	0.410	0.407	0.403	0.400
162°	0.448	0.446	0.444	0.442	0.439	0.437	0.435	0.432	0.430	0.427	0.424	0.422	0.419	0.416	0.413	0.409
164°	0.454	0.452	0.450	0.448	0.446	0.444	0.442	0.440	0.437	0.435	0.433	0.430	0.428	0.425	0.422	0.419
166°	0.460	0.458	0.456	0.455	0.453	0.451	0.449	0.447	0.445	0.443	0.441	0.439	0.437	0.434	0.432	0.429
168°	0.465	0.464	0.463	0.461	0.460	0.458	0.456	0.455	0.453	0.451	0.449	0.447	0.445	0.443	0.441	0.439
170°	0.471	0.470	0.469	0.468	0.466	0.465	0.464	0.462	0.461	0.459	0.458	0.456	0.454	0.453	0.451	0.449
172°	0.477	0.476	0.475	0.474	0.473	0.472	0.471	0.470	0.469	0.467	0.466	0.465	0.464	0.462	0.461	0.459
174°	0.483	0.482	0.481	0.481	0.480	0.479	0.478	0.477	0.476	0.476	0.475	0.474	0.473	0.472	0.471	0.469
176°	0.488	0.488	0.487	0.487	0.486	0.486	0.485	0.485	0.484	0.484	0.483	0.482	0.482	0.481	0.480	0.480
178°	0.494	0.494	0.494	0.493	0.493	0.493	0.493	0.492	0.492	0.492	0.492	0.491	0.491	0.491	0.490	0.490
180°	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500

* Where the angular distance is greater than 180°, FIND fraction of period for 360° LESS given angular distance, AND SUBTRACT same from 1.000. The fraction of period for N, where N is greater than 180°, is equal to 1.000 LESS the fraction of period for (360° LESS N).

TABLE III - B
RADIAL DISTANCE FACTORS
FOR ANGULAR DISTANCES OF 2° TO 180°* FROM PERIGEE (MEASURED AT THE CENTER OF THE EARTH)
FOR ORBIT ECCENTRICITIES OF FROM 0.020 TO 0.320

PERIGEE DISTANCE	0.020	0.040	0.060	0.080	0.100	0.120	0.140	0.160	0.180	0.200	0.220	0.240	0.260	0.280	0.300	0.320
2°	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4°	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.001	1.001	1.001	1.001
6°	1.000	1.000	1.000	1.000	1.000	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.001
8°	1.000	1.000	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.002	1.002	1.002	1.002	1.002	1.002	1.002
10°	1.000	1.001	1.001	1.001	1.001	1.002	1.002	1.002	1.002	1.003	1.003	1.003	1.003	1.003	1.004	1.004
12°	1.000	1.001	1.001	1.002	1.002	1.002	1.003	1.003	1.003	1.004	1.004	1.004	1.005	1.005	1.005	1.005
14°	1.001	1.001	1.002	1.002	1.003	1.003	1.004	1.004	1.005	1.005	1.005	1.006	1.006	1.007	1.007	1.007
16°	1.001	1.001	1.002	1.003	1.004	1.004	1.005	1.005	1.006	1.006	1.007	1.008	1.008	1.009	1.009	1.009
18°	1.001	1.002	1.003	1.004	1.004	1.005	1.006	1.007	1.008	1.008	1.009	1.010	1.010	1.011	1.011	1.012
20°	1.001	1.002	1.003	1.004	1.006	1.007	1.007	1.008	1.009	1.010	1.011	1.012	1.013	1.013	1.014	1.015
22°	1.001	1.003	1.004	1.005	1.007	1.008	1.009	1.010	1.011	1.012	1.013	1.014	1.015	1.016	1.017	1.018
24°	1.002	1.003	1.005	1.006	1.008	1.009	1.011	1.012	1.013	1.015	1.016	1.017	1.018	1.019	1.020	1.021
26°	1.002	1.004	1.006	1.008	1.009	1.011	1.013	1.014	1.016	1.017	1.019	1.020	1.021	1.023	1.024	1.025
28°	1.002	1.005	1.007	1.009	1.011	1.013	1.015	1.016	1.018	1.020	1.022	1.023	1.025	1.026	1.028	1.029
30°	1.003	1.005	1.008	1.010	1.012	1.015	1.017	1.019	1.021	1.023	1.025	1.027	1.028	1.030	1.032	1.034
32°	1.003	1.006	1.009	1.011	1.014	1.017	1.019	1.021	1.024	1.026	1.028	1.030	1.032	1.034	1.036	1.038
34°	1.003	1.007	1.010	1.013	1.016	1.019	1.021	1.024	1.027	1.029	1.032	1.034	1.037	1.039	1.041	1.043
36°	1.004	1.007	1.011	1.014	1.018	1.021	1.024	1.027	1.030	1.033	1.036	1.038	1.041	1.044	1.046	1.049
38°	1.004	1.008	1.012	1.016	1.020	1.023	1.027	1.030	1.033	1.037	1.040	1.043	1.046	1.049	1.051	1.054
40°	1.005	1.009	1.013	1.018	1.022	1.026	1.030	1.033	1.037	1.041	1.044	1.047	1.051	1.054	1.057	1.060
42°	1.005	1.010	1.015	1.019	1.024	1.028	1.033	1.037	1.041	1.045	1.049	1.052	1.056	1.060	1.063	1.066
44°	1.006	1.011	1.016	1.021	1.026	1.031	1.036	1.040	1.045	1.049	1.053	1.057	1.061	1.065	1.069	1.073
46°	1.006	1.012	1.018	1.023	1.029	1.034	1.039	1.044	1.049	1.054	1.058	1.063	1.067	1.072	1.076	1.080
48°	1.007	1.013	1.019	1.025	1.031	1.037	1.042	1.048	1.053	1.058	1.063	1.068	1.073	1.078	1.083	1.087
50°	1.007	1.014	1.021	1.027	1.034	1.040	1.046	1.052	1.058	1.063	1.069	1.074	1.080	1.085	1.090	1.095
52°	1.008	1.015	1.022	1.029	1.036	1.043	1.050	1.056	1.062	1.068	1.074	1.080	1.086	1.092	1.097	1.103
54°	1.008	1.016	1.024	1.031	1.039	1.046	1.053	1.060	1.067	1.074	1.080	1.087	1.093	1.099	1.105	1.111
56°	1.009	1.017	1.026	1.034	1.042	1.050	1.057	1.065	1.072	1.079	1.086	1.093	1.100	1.107	1.113	1.120
58°	1.009	1.018	1.027	1.036	1.045	1.053	1.061	1.069	1.077	1.085	1.093	1.100	1.107	1.115	1.122	1.129
60°	1.010	1.020	1.029	1.038	1.048	1.057	1.065	1.074	1.083	1.091	1.099	1.107	1.115	1.123	1.130	1.138
62°	1.011	1.021	1.031	1.041	1.051	1.060	1.070	1.079	1.088	1.097	1.106	1.114	1.123	1.131	1.140	1.148
64°	1.011	1.022	1.033	1.043	1.054	1.064	1.074	1.084	1.094	1.103	1.113	1.122	1.131	1.140	1.149	1.158
66°	1.012	1.023	1.035	1.046	1.057	1.068	1.079	1.089	1.100	1.110	1.120	1.130	1.139	1.149	1.159	1.168
68°	1.012	1.025	1.037	1.049	1.060	1.072	1.083	1.094	1.105	1.116	1.127	1.138	1.148	1.158	1.169	1.179
70°	1.013	1.026	1.039	1.051	1.064	1.076	1.088	1.100	1.112	1.123	1.135	1.146	1.157	1.168	1.179	1.190
72°	1.014	1.027	1.041	1.054	1.067	1.080	1.093	1.105	1.118	1.130	1.142	1.154	1.166	1.178	1.190	1.201
74°	1.014	1.029	1.043	1.057	1.070	1.084	1.098	1.111	1.124	1.137	1.150	1.163	1.176	1.188	1.201	1.213
76°	1.015	1.030	1.045	1.059	1.074	1.088	1.103	1.117	1.131	1.145	1.158	1.172	1.185	1.199	1.212	1.225
78°	1.016	1.031	1.047	1.062	1.078	1.093	1.108	1.123	1.137	1.152	1.167	1.181	1.195	1.210	1.224	1.238
80°	1.016	1.033	1.049	1.065	1.081	1.097	1.113	1.129	1.144	1.160	1.175	1.190	1.206	1.221	1.236	1.251

PERIGEE DISTANCE	0.020	0.040	0.060	0.080	0.100	0.120	0.140	0.160	0.180	0.200	0.220	0.240	0.260	0.280	0.300	0.320
82°	1.017	1.034	1.051	1.068	1.085	1.102	1.118	1.135	1.151	1.168	1.184	1.200	1.216	1.232	1.248	1.264
84°	1.018	1.036	1.053	1.071	1.089	1.106	1.124	1.141	1.158	1.175	1.193	1.210	1.227	1.244	1.260	1.277
86°	1.019	1.037	1.056	1.074	1.092	1.111	1.129	1.147	1.165	1.183	1.202	1.220	1.238	1.255	1.273	1.291
88°	1.019	1.039	1.058	1.077	1.096	1.115	1.134	1.154	1.173	1.192	1.211	1.230	1.249	1.268	1.287	1.305
90°	1.020	1.040	1.060	1.080	1.100	1.120	1.140	1.160	1.180	1.200	1.220	1.240	1.260	1.280	1.300	1.320
92°	1.021	1.041	1.062	1.083	1.104	1.125	1.146	1.167	1.187	1.208	1.229	1.250	1.272	1.293	1.314	1.335
94°	1.021	1.043	1.064	1.086	1.108	1.129	1.151	1.173	1.195	1.217	1.239	1.261	1.283	1.305	1.328	1.350
96°	1.022	1.044	1.067	1.089	1.112	1.134	1.157	1.180	1.203	1.226	1.249	1.272	1.295	1.319	1.342	1.366
98°	1.023	1.046	1.069	1.092	1.116	1.139	1.163	1.186	1.210	1.234	1.259	1.283	1.307	1.332	1.357	1.382
100°	1.024	1.047	1.071	1.095	1.119	1.144	1.168	1.193	1.218	1.243	1.268	1.294	1.320	1.345	1.371	1.398
102°	1.024	1.049	1.073	1.098	1.123	1.149	1.174	1.200	1.226	1.252	1.278	1.305	1.332	1.359	1.386	1.414
104°	1.025	1.050	1.076	1.101	1.127	1.153	1.180	1.207	1.234	1.261	1.289	1.316	1.345	1.373	1.402	1.431
106°	1.026	1.052	1.078	1.104	1.131	1.158	1.186	1.214	1.242	1.270	1.299	1.328	1.357	1.387	1.417	1.448
108°	1.026	1.053	1.080	1.107	1.135	1.163	1.192	1.220	1.250	1.279	1.309	1.339	1.370	1.401	1.433	1.465
110°	1.027	1.054	1.082	1.110	1.139	1.168	1.197	1.227	1.257	1.288	1.319	1.351	1.383	1.416	1.449	1.482
112°	1.028	1.056	1.084	1.113	1.143	1.173	1.203	1.234	1.265	1.297	1.330	1.362	1.396	1.430	1.465	1.500
114°	1.028	1.057	1.087	1.116	1.147	1.177	1.209	1.241	1.273	1.306	1.340	1.374	1.409	1.445	1.481	1.518
116°	1.029	1.059	1.089	1.119	1.150	1.182	1.215	1.247	1.281	1.315	1.350	1.386	1.422	1.459	1.497	1.535
118°	1.030	1.060	1.091	1.122	1.154	1.187	1.220	1.254	1.289	1.324	1.361	1.397	1.435	1.474	1.513	1.553
120°	1.030	1.061	1.093	1.125	1.158	1.191	1.226	1.261	1.297	1.333	1.371	1.409	1.448	1.488	1.529	1.571
122°	1.031	1.063	1.095	1.128	1.162	1.196	1.231	1.267	1.304	1.342	1.381	1.421	1.461	1.503	1.546	1.590
124°	1.032	1.064	1.097	1.131	1.165	1.201	1.237	1.274	1.312	1.351	1.391	1.432	1.474	1.518	1.562	1.608
126°	1.032	1.065	1.099	1.133	1.169	1.205	1.242	1.280	1.320	1.360	1.401	1.444	1.487	1.532	1.578	1.626
128°	1.033	1.066	1.101	1.136	1.172	1.209	1.248	1.287	1.327	1.369	1.411	1.455	1.500	1.547	1.595	1.644
130°	1.033	1.067	1.103	1.139	1.176	1.214	1.253	1.293	1.334	1.377	1.421	1.466	1.513	1.561	1.611	1.662
132°	1.034	1.069	1.104	1.141	1.179	1.218	1.258	1.299	1.342	1.385	1.431	1.477	1.525	1.575	1.627	1.680
134°	1.034	1.070	1.106	1.144	1.182	1.222	1.263	1.305	1.349	1.394	1.440	1.488	1.538	1.589	1.642	1.697
136°	1.035	1.071	1.108	1.146	1.185	1.226	1.268	1.311	1.356	1.402	1.449	1.499	1.550	1.603	1.658	1.715
138°	1.035	1.072	1.109	1.148	1.188	1.230	1.272	1.317	1.362	1.409	1.458	1.509	1.562	1.616	1.673	1.732
140°	1.036	1.073	1.111	1.151	1.191	1.233	1.277	1.322	1.369	1.417	1.467	1.519	1.573	1.630	1.688	1.749
142°	1.036	1.074	1.113	1.153	1.194	1.237	1.281	1.327	1.375	1.425	1.476	1.529	1.585	1.642	1.702	1.765
144°	1.037	1.075	1.114	1.155	1.197	1.240	1.286	1.332	1.381	1.432	1.484	1.539	1.596	1.655	1.717	1.781
146°	1.037	1.076	1.115	1.157	1.199	1.244	1.290	1.337	1.387	1.439	1.492	1.548	1.606	1.667	1.730	1.797
148°	1.038	1.077	1.117	1.159	1.202	1.247	1.294	1.342	1.393	1.445	1.500	1.557	1.616	1.679	1.744	1.812
150°	1.038	1.077	1.118	1.160	1.204	1.250	1.297	1.347	1.398	1.451	1.507	1.565	1.626	1.690	1.756	1.826
152°	1.038	1.078	1.119	1.162	1.207	1.253	1.301	1.351	1.403	1.457	1.514	1.573	1.635	1.700	1.768	1.840
154°	1.039	1.079	1.120	1.164	1.209	1.255	1.304	1.355	1.408	1.463	1.521	1.581	1.644	1.710	1.780	1.853
156°	1.039	1.079	1.121	1.165	1.211	1.258	1.307	1.359	1.412	1.468	1.527	1.588	1.653	1.720	1.791	1.865
158°	1.039	1.080	1.122	1.167	1.212	1.260	1.310	1.362	1.416	1.473	1.533	1.595	1.660	1.729	1.801	1.877
160°	1.040	1.081	1.123	1.168	1.214	1.262	1.313	1.365	1.420	1.478	1.538	1.601	1.667	1.737	1.810	1.888
162°	1.040	1.081	1.124	1.169	1.216	1.264	1.315	1.368	1.424	1.482	1.543	1.607	1.674	1.745	1.819	1.897
164°	1.040	1.082	1.125	1.170	1.217	1.266	1.317	1.371	1.427	1.486	1.547	1.612	1.680	1.751	1.827	1.906
166°	1.040	1.082	1.126	1.171	1.218	1.268	1.319	1.373	1.430	1.489	1.551	1.616	1.685	1.757	1.834	1.914
168°	1.040	1.082	1.126	1.172	1.219	1.269	1.321	1.375	1.432	1.492	1.555	1.620	1.690	1.763	1.840	1.921
170°	1.040	1.083	1.127	1.172	1.220	1.270	1.322	1.377	1.434	1.494	1.557	1.624	1.694	1.767	1.845	1.927
172°	1.041	1.083	1.127	1.173	1.221	1.271	1.323	1.378	1.436	1.496	1.560	1.627	1.697	1.771	1.849	1.932
174°	1.041	1.083	1.127	1.173	1.221	1.272	1.324	1.380	1.437	1.498	1.562	1.629	1.699	1.774	1.853	1.936
176°	1.041	1.083	1.127	1.174	1.222	1.272	1.325	1.380	1.438	1.499	1.563	1.630	1.701	1.776	1.855	1.939
178°	1.041	1.083	1.128	1.174	1.222	1.273	1.325	1.381	1.439	1.500	1.564	1.631	1.702	1.777	1.857	1.941
180°	1.041	1.083	1.128	1.174	1.222	1.273	1.326	1.381	1.439	1.500	1.564	1.632	1.703	1.778	1.857	1.941

* Where the angular distance is greater than 180°, USE radial distance factor for 360° LESS given angular distance
The radial distance factors for N and for (360° LESS N) are equal.

TABLE IV
HEADING ALONG SATELLITE TRACK
FOR SPECIFIED ORBIT INCLINATIONS AT SPECIFIED LATITUDES
MEASURED CLOCKWISE IN DEGREES FROM TRUE NORTH FOR VARIOUS LATITUDES AND ORBIT INCLINATIONS

ORBIT INCLI-NATION	REFERENCE LATITUDES																		45° or > 45°
	0°	2°5	5°	7°5	10°	12°5	15°	17°5	20°	22°5	25°	27°5	30°	32°5	35°	37°5	40°	42°5	
1°	88.9	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
2°	87.9	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
3°	86.8	88.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4°	85.7	86.6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5°	84.6	85.3	90.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6°	83.5	84.1	86.4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
7°	82.5	83.0	84.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
8°	81.4	81.8	83.2	87.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
9°	80.3	80.7	81.9	84.6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
10°	79.2	79.6	80.7	83.1	90.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*
11°	78.2	78.5	79.5	81.3	85.1	*	*	*	*	*	*	*	*	*	*	*	*	*	*
12°	77.1	77.4	78.3	79.9	82.8	*	*	*	*	*	*	*	*	*	*	*	*	*	*
13°	76.0	76.3	77.1	78.6	81.0	86.2	*	*	*	*	*	*	*	*	*	*	*	*	*
14°	75.0	75.2	75.9	77.3	79.4	83.2	*	*	*	*	*	*	*	*	*	*	*	*	*
15°	73.9	74.1	74.8	76.0	77.9	81.0	90.0	*	*	*	*	*	*	*	*	*	*	*	*
16°	72.9	73.0	73.6	74.8	76.5	79.2	84.0	*	*	*	*	*	*	*	*	*	*	*	*
17°	71.8	71.9	72.5	73.6	75.2	77.5	81.3	*	*	*	*	*	*	*	*	*	*	*	*
18°	70.8	70.8	71.4	72.4	73.8	76.0	79.2	85.4	*	*	*	*	*	*	*	*	*	*	*
19°	69.7	69.8	70.3	71.2	72.6	74.5	77.3	81.9	*	*	*	*	*	*	*	*	*	*	*
20°	68.7	68.7	69.2	70.0	71.3	73.1	75.7	79.5	90.0	*	*	*	*	*	*	*	*	*	*
21°	67.6	67.6	68.1	68.9	70.1	71.8	74.1	77.4	83.0	*	*	*	*	*	*	*	*	*	*
22°	66.6	66.5	67.0	67.7	68.9	70.4	72.5	75.5	80.0	*	*	*	*	*	*	*	*	*	*
23°	65.5	65.5	65.9	66.6	67.7	69.1	71.1	73.8	77.6	84.8	*	*	*	*	*	*	*	*	*
24°	64.4	64.4	64.8	65.5	66.5	67.9	69.7	72.1	75.5	80.8	*	*	*	*	*	*	*	*	*
25°	63.3	63.3	63.7	64.4	65.3	66.6	68.3	70.6	73.6	78.0	90.0	*	*	*	*	*	*	*	*
26°	62.3	62.2	62.6	63.2	64.1	65.4	67.0	69.1	71.8	75.7	82.1	*	*	*	*	*	*	*	*
27°	61.2	61.2	61.5	62.1	63.0	64.1	65.8	67.6	70.2	73.6	78.7	*	*	*	*	*	*	*	*
28°	60.2	60.1	60.4	61.0	61.8	62.9	64.4	66.2	68.6	71.7	76.1	84.1	*	*	*	*	*	*	*
29°	59.1	59.0	59.3	59.9	60.7	61.7	63.1	64.9	67.1	69.9	73.8	79.8	*	*	*	*	*	*	*
30°	58.0	57.9	58.3	58.8	59.5	60.6	61.9	63.5	65.6	68.2	71.7	76.7	90.0	*	*	*	*	*	*
31°	57.0	56.9	57.2	57.7	58.4	59.4	60.6	62.2	64.1	66.6	69.8	74.1	81.3	*	*	*	*	*	*
32°	55.9	55.8	56.1	56.6	57.3	58.2	59.4	60.9	62.7	65.0	68.0	71.8	77.5	*	*	*	*	*	*
33°	54.8	54.7	55.0	55.	56.2	57.1	58.2	59.6	61.4	63.5	66.2	69.8	74.6	83.6	*	*	*	*	*
34°	53.7	53.7	53.9	54.4	55.0	55.9	57.0	58.3	60.0	62.1	64.6	67.8	72.1	78.7	*	*	*	*	*
35°	52.6	52.6	52.9	53.3	53.9	54.7	55.8	57.1	58.7	60.6	63.0	66.0	69.9	75.4	90.0	*	*	*	*
36°	51.6	51.5	51.8	52.2	52.8	53.6	54.6	55.9	57.4	59.2	61.4	64.2	67.8	72.6	80.4	*	*	*	*
37°	50.5	50.5	50.7	51.1	51.7	52.5	53.4	54.6	56.1	57.8	59.1	62.5	65.8	70.1	76.4	*	*	*	*
38°	49.4	49.4	49.7	50.0	50.6	51.3	52.3	53.4	54.8	56.5	58.5	60.9	63.9	67.8	73.2	82.9	*	*	*
39°	48.3	48.4	48.6	49.0	49.5	50.2	51.1	52.2	53.5	55.1	57.0	59.3	62.2	65.7	70.5	77.7	*	*	*
40°	47.2	47.3	47.5	47.9	48.8	49.1	49.8	51.0	52.3	53.8	55.6	57.8	60.5	63.8	68.0	74.0	90.0	*	*
41°	46.2	46.2	46.5	46.8	47.2	48.0	48.8	49.8	51.0	52.5	54.2	56.3	58.8	61.9	65.8	71.0	79.6	*	*
42°	45.1	45.2	45.4	45.7	46.2	46.9	47.6	48.6	49.8	51.2	52.9	54.8	57.2	60.1	63.6	68.3	75.2	*	*
43°	44.0	44.1	44.3	44.7	45.1	45.7	46.5	47.4	48.6	49.9	51.5	53.4	55.6	58.3	61.6	65.9	71.7	82.3	
44°	42.9	43.1	43.3	43.6	44.0	44.6	45.4	46.3	47.4	48.6	50.2	52.0	54.1	56.6	59.7	63.6	68.8	76.6	*
45°	41.9	42.0	42.2	42.5	42.9	43.5	44.2	45.1	46.2	47.4	49.5	50.6	52.6	55.0	57.9	61.5	66.1	72.7	90.0

NOTE: Table IV is computed on the basis of a 105 minute period, but will serve quite well for satellites having moderate eccentricities and periods of one and a half to two hours. The error in heading for satellites having a circular orbit and a period of 2 hours and 15 minutes will not exceed 1°2.

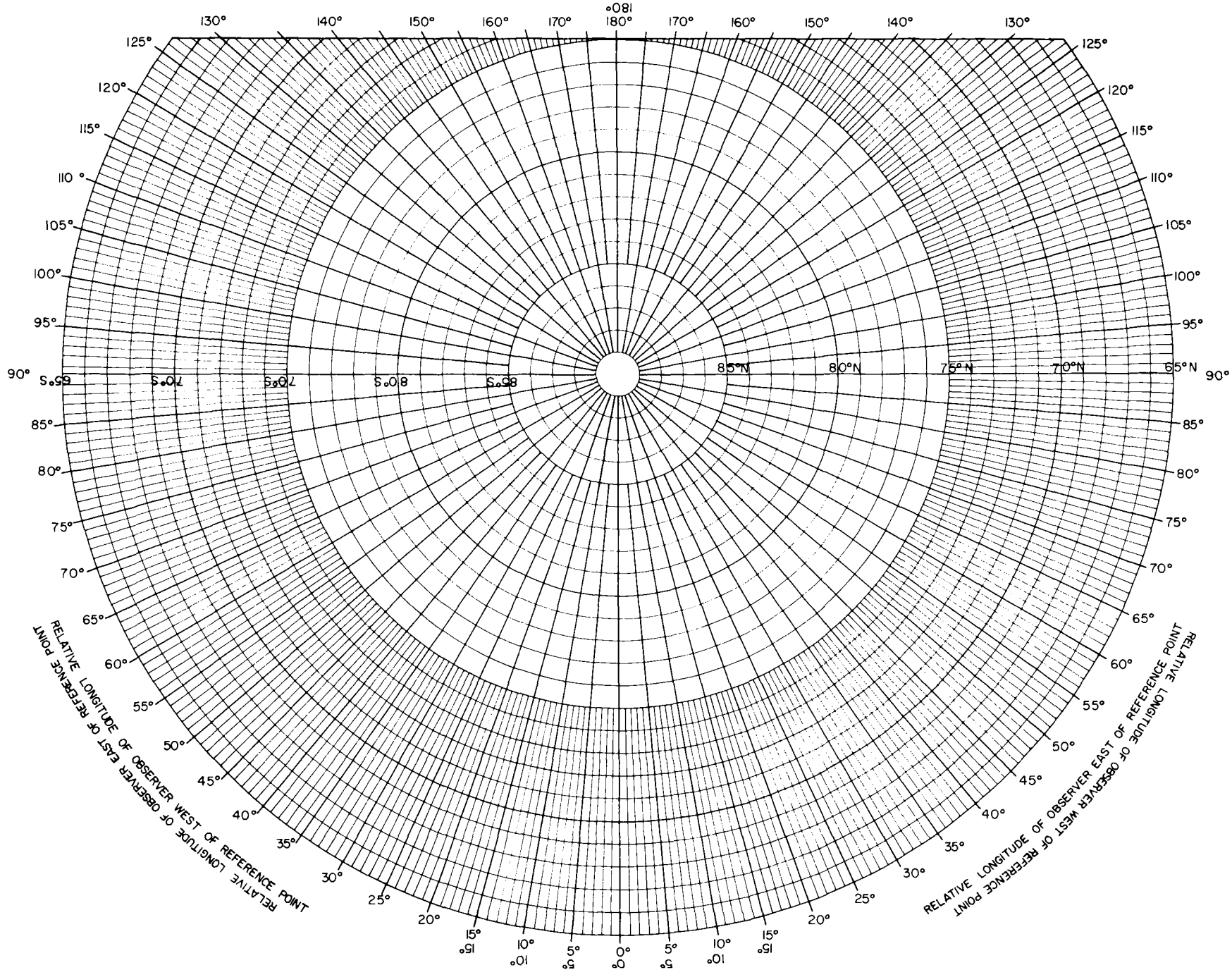
TABLE IV (Continued)

ORBIT INCLINATION	REFERENCE LATITUDES																		
	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
46°	40.8	41.1	41.9	43.1	45.0	47.5	51.1	56.1	63.7	78.7	*	*	*	*	*	*	*	*	*
47°	39.8	40.1	40.8	42.0	43.8	46.2	49.7	54.4	61.4	73.9	*	*	*	*	*	*	*	*	*
48°	38.7	39.0	39.7	40.9	42.6	45.0	48.2	52.7	59.3	70.2	*	*	*	*	*	*	*	*	*
49°	37.7	38.0	38.6	39.7	41.4	43.7	46.8	51.1	57.2	67.0	*	*	*	*	*	*	*	*	*
50°	36.7	36.9	37.6	38.6	40.2	42.4	45.4	49.5	55.3	64.0	90.0	*	*	*	*	*	*	*	*
51°	35.6	35.9	36.5	37.5	39.1	41.2	44.1	48.0	53.4	61.5	77.7	*	*	*	*	*	*	*	*
52°	34.6	34.8	35.4	36.4	37.9	39.9	42.7	46.4	51.5	59.0	72.5	*	*	*	*	*	*	*	*
53°	33.5	33.8	34.4	35.3	36.7	38.7	41.4	44.4	49.8	56.7	68.5	*	*	*	*	*	*	*	*
54°	32.5	32.7	33.3	34.2	35.6	37.5	40.0	43.4	48.0	54.5	65.0	*	*	*	*	*	*	*	*
55°	31.5	31.7	32.2	33.1	34.4	36.3	38.7	41.9	46.3	52.4	61.9	90.0	*	*	*	*	*	*	*
56°	30.4	30.6	31.1	32.0	33.3	35.1	37.4	40.5	44.7	50.4	59.1	76.6	*	*	*	*	*	*	*
57°	29.4	29.6	30.1	30.9	32.2	33.8	36.1	39.1	43.0	48.5	56.5	71.0	*	*	*	*	*	*	*
58°	28.3	28.5	29.0	29.8	31.0	32.6	34.8	37.6	41.4	46.5	54.0	66.6	*	*	*	*	*	*	*
59°	27.3	27.5	28.0	28.7	29.9	31.5	33.5	36.2	39.8	44.7	51.6	62.8	*	*	*	*	*	*	*
60°	26.3	26.5	26.9	27.7	28.8	30.3	32.3	34.9	38.3	42.9	49.3	59.5	90.0	*	*	*	*	*	*
61°	25.2	25.4	25.9	26.6	27.6	29.1	31.0	33.5	36.7	41.1	47.2	56.4	75.3	*	*	*	*	*	*
62°	24.2	24.4	24.8	25.5	26.5	27.9	29.7	32.1	35.2	39.4	45.1	53.5	69.1	*	*	*	*	*	*
63°	23.2	23.4	23.7	24.4	25.4	26.7	28.5	30.8	33.7	37.6	43.0	50.8	64.3	*	*	*	*	*	*
64°	22.1	22.3	22.7	23.3	24.3	25.6	27.2	29.4	32.2	36.0	41.0	48.3	60.2	*	*	*	*	*	*
65°	21.1	21.3	21.6	22.3	23.2	24.4	26.0	28.1	30.8	34.3	39.1	45.8	56.6	90.0	*	*	*	*	*
66°	20.1	20.2	20.6	21.2	22.1	23.2	24.8	26.8	29.3	32.7	37.1	43.4	53.2	73.7	*	*	*	*	*
67°	19.1	19.2	19.5	20.1	20.9	22.1	23.5	25.4	27.9	31.0	35.3	41.2	50.1	66.9	*	*	*	*	*
68°	18.0	18.2	18.5	19.0	19.8	20.9	22.3	24.1	26.4	29.4	33.4	38.9	47.1	61.6	*	*	*	*	*
69°	17.0	17.1	17.5	18.0	18.7	19.8	21.1	22.1	25.0	27.9	31.6	36.8	44.3	57.0	*	*	*	*	*
70°	16.0	16.1	16.4	16.9	17.6	18.6	19.9	21.5	23.6	26.3	29.8	34.7	41.6	53.0	90.0	*	*	*	*
71°	15.0	15.1	15.4	15.8	16.5	17.5	18.7	20.2	22.2	24.8	28.1	32.6	39.0	49.2	71.7	*	*	*	*
72°	13.9	14.1	14.3	14.8	15.4	16.3	17.5	19.0	20.8	23.2	26.4	30.6	36.5	45.8	63.9	*	*	*	*
73°	12.9	13.0	13.3	13.7	14.4	15.2	16.3	17.7	19.4	21.7	24.6	28.6	34.1	42.5	58.2	*	*	*	*
74°	11.9	12.0	12.3	12.7	13.3	14.1	15.1	16.4	18.1	20.2	22.9	26.6	31.7	39.4	52.8	*	*	*	*
75°	10.9	11.0	11.2	11.6	12.2	12.9	13.9	15.1	16.7	18.7	21.3	24.7	29.4	36.4	48.2	90.0	*	*	*
76°	9.9	10.0	10.2	10.5	11.1	11.8	12.7	13.9	15.3	17.2	19.6	22.8	27.1	33.5	44.0	68.8	*	*	*
77°	8.9	9.0	9.2	9.5	10.0	10.7	11.5	12.6	14.0	15.7	17.9	20.9	24.9	30.7	40.0	59.8	*	*	*
78°	7.9	7.9	8.1	8.5	8.9	9.5	10.3	11.4	12.6	14.3	16.3	19.0	22.7	27.9	36.2	52.8	*	*	*
79°	6.9	6.9	7.1	7.4	7.8	8.4	9.2	10.1	11.3	12.8	14.7	17.2	20.5	25.2	32.7	46.8	*	*	*
80°	5.9	5.9	6.1	6.4	6.8	7.3	8.0	8.9	10.0	11.3	13.1	15.3	18.4	22.6	29.4	41.3	90.0	*	*
81°	4.9	4.9	5.1	5.3	5.7	6.2	6.8	7.6	8.6	9.9	11.5	13.5	16.2	20.1	26.1	36.3	64.0	*	*
82°	3.9	3.9	4.0	4.3	4.6	5.1	5.7	6.3	7.3	8.4	9.9	11.7	14.1	17.6	22.9	31.6	52.8	*	*
83°	2.9	2.9	3.0	3.2	3.5	4.0	4.5	5.2	6.0	7.0	8.3	9.9	12.1	15.1	19.7	27.1	44.1	*	*
84°	1.9	1.9	2.0	2.2	2.5	2.8	3.3	3.9	4.7	5.6	6.7	8.2	10.0	12.6	16.5	22.8	36.4	*	*
85°	0.9	0.9	1.0	1.1	1.4	1.7	2.2	2.7	3.3	4.1	5.1	6.4	8.0	10.1	13.4	18.7	29.5	90.0	*
86°	359.9	359.8	359.9	0.1	0.3	0.6	1.0	1.5	2.0	2.7	3.6	4.6	5.9	7.8	10.4	14.6	23.0	52.9	*
87°	358.9	358.8	358.9	359.1	359.3	359.5	359.8	0.2	0.7	1.3	2.0	2.8	3.9	5.4	7.4	10.6	16.8	36.6	*
88°	357.8	357.8	357.9	358.0	358.2	358.4	358.7	359.0	359.4	359.9	0.4	1.1	1.9	3.0	4.4	6.7	10.9	23.3	*
89°	356.8	356.8	356.9	357.0	357.1	357.3	357.5	357.8	358.1	358.5	358.4	359.3	359.9	0.6	1.4	2.8	5.0	11.2	*
90°	355.8	355.8	355.9	356.0	356.1	356.2	356.4	356.6	356.8	357.0	357.3	357.6	357.9	358.2	358.5	358.9	359.3	359.6	-

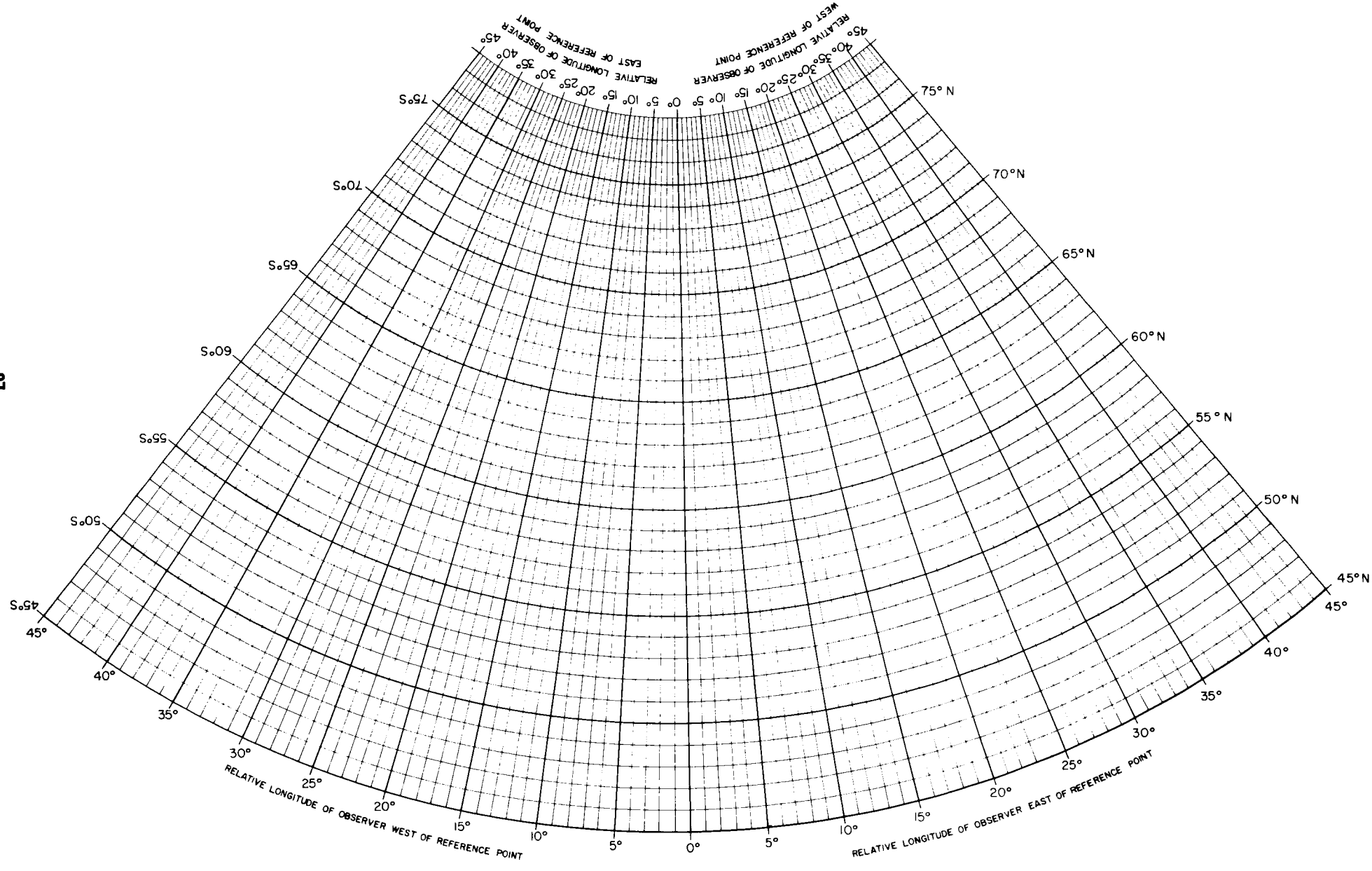
* Where reference latitude is numerically equal to orbit inclination angle, heading will be $90^{o}0$

POLAR GRID FOR PLOTTING POSITION OF OBSERVER RELATIVE TO SATELLITE TRACK

POLAR STEREOGRAPHIC PROJECTION

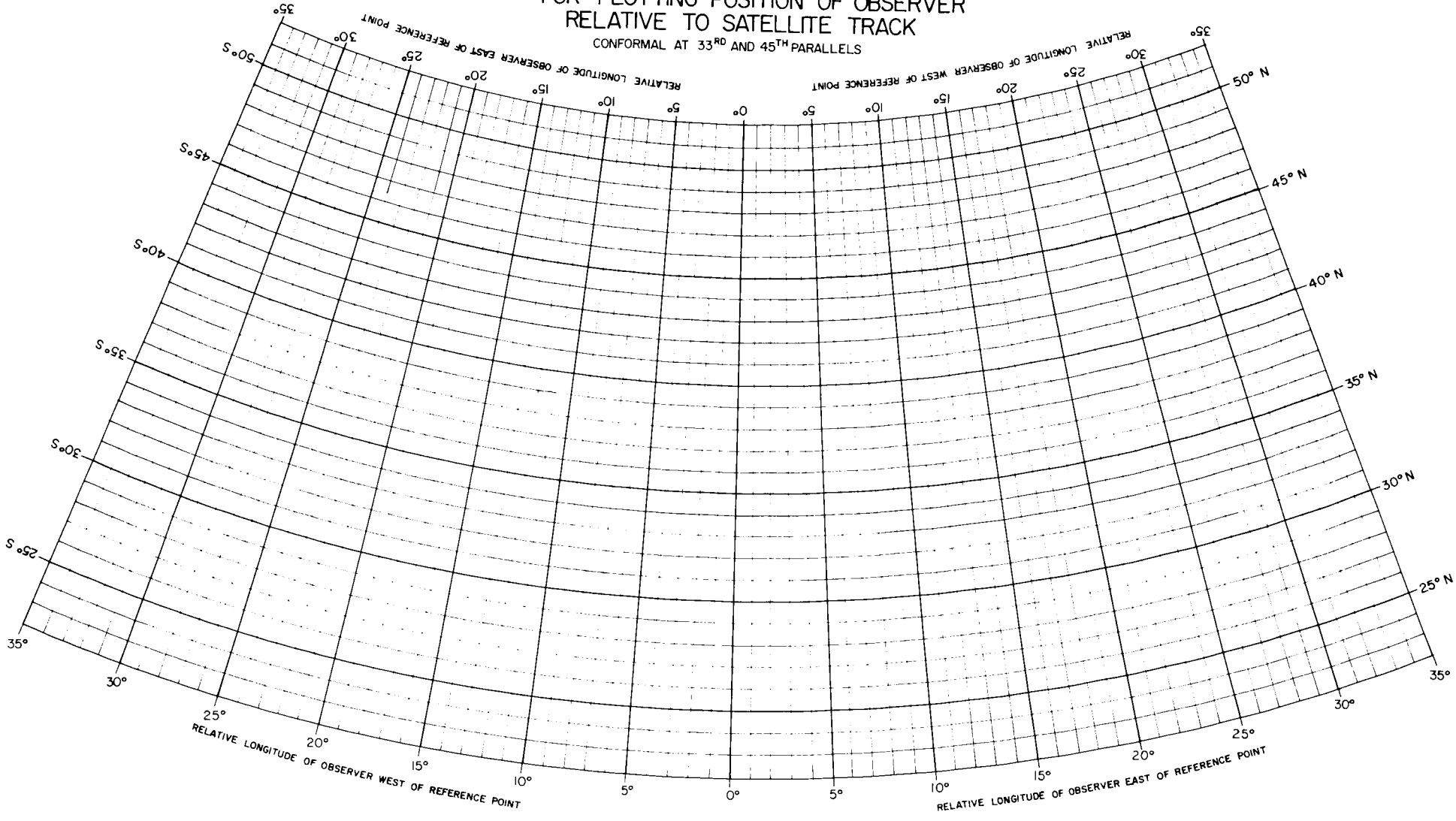


SUB-POLAR GRID
FOR PLOTTING POSITION OF OBSERVER RELATIVE TO SATELLITE TRACK
CONFORMAL AT 55TH AND 65TH PARALLELS



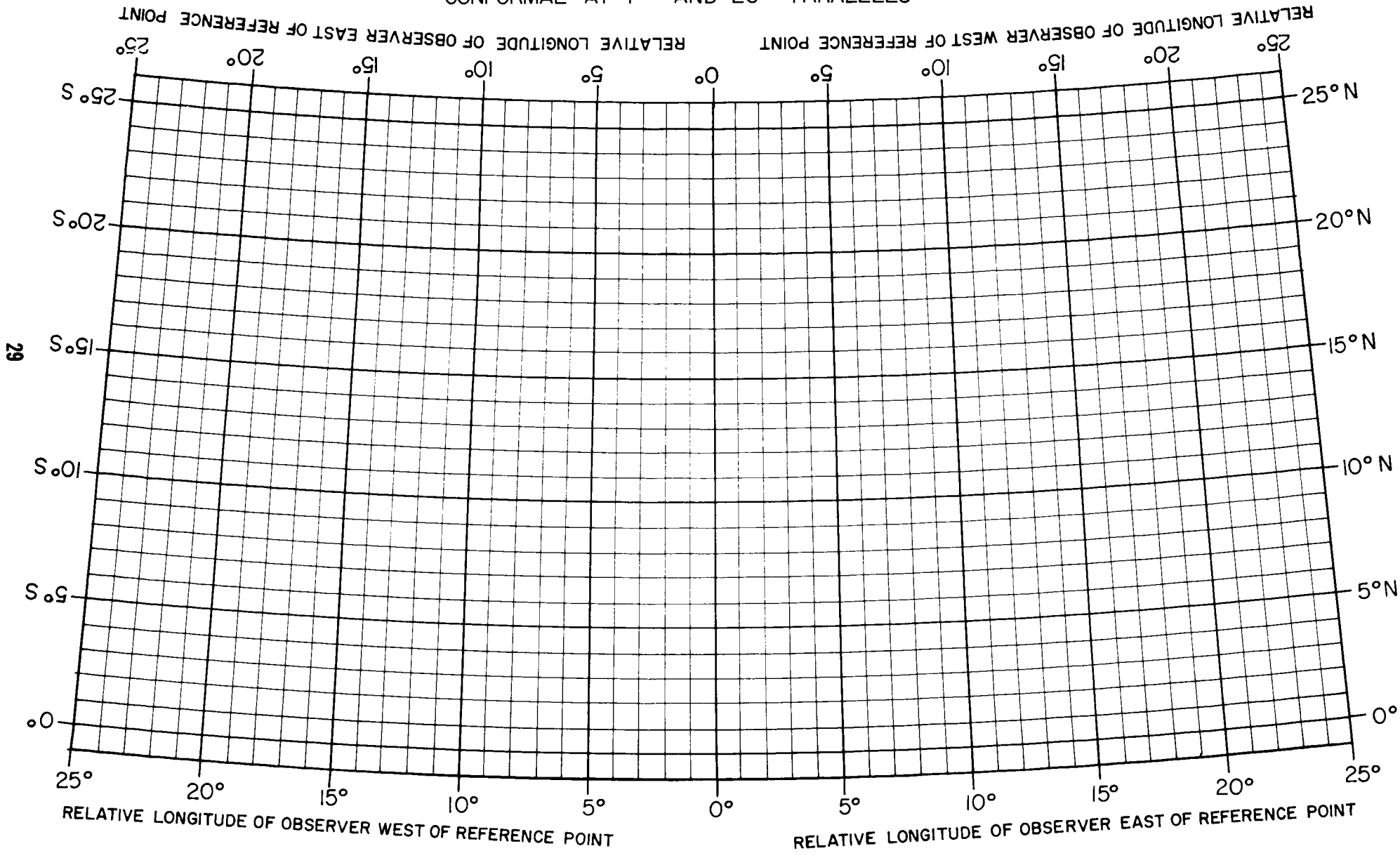
MID-LATITUDE GRID
FOR PLOTTING POSITION OF OBSERVER RELATIVE TO SATELLITE TRACK

CONFORMAL AT 33RD AND 45TH PARALLELS



SUB-EQUATORIAL GRID
FOR PLOTTING POSITION OF OBSERVER RELATIVE TO SATELLITE TRACK

CONFORMAL AT 7TH AND 20TH PARALLELS



EQUATORIAL GRID FOR PLOTTING POSITION OF OBSERVER RELATIVE TO SATELLITE TRACK

MERCATOR PROJECTION

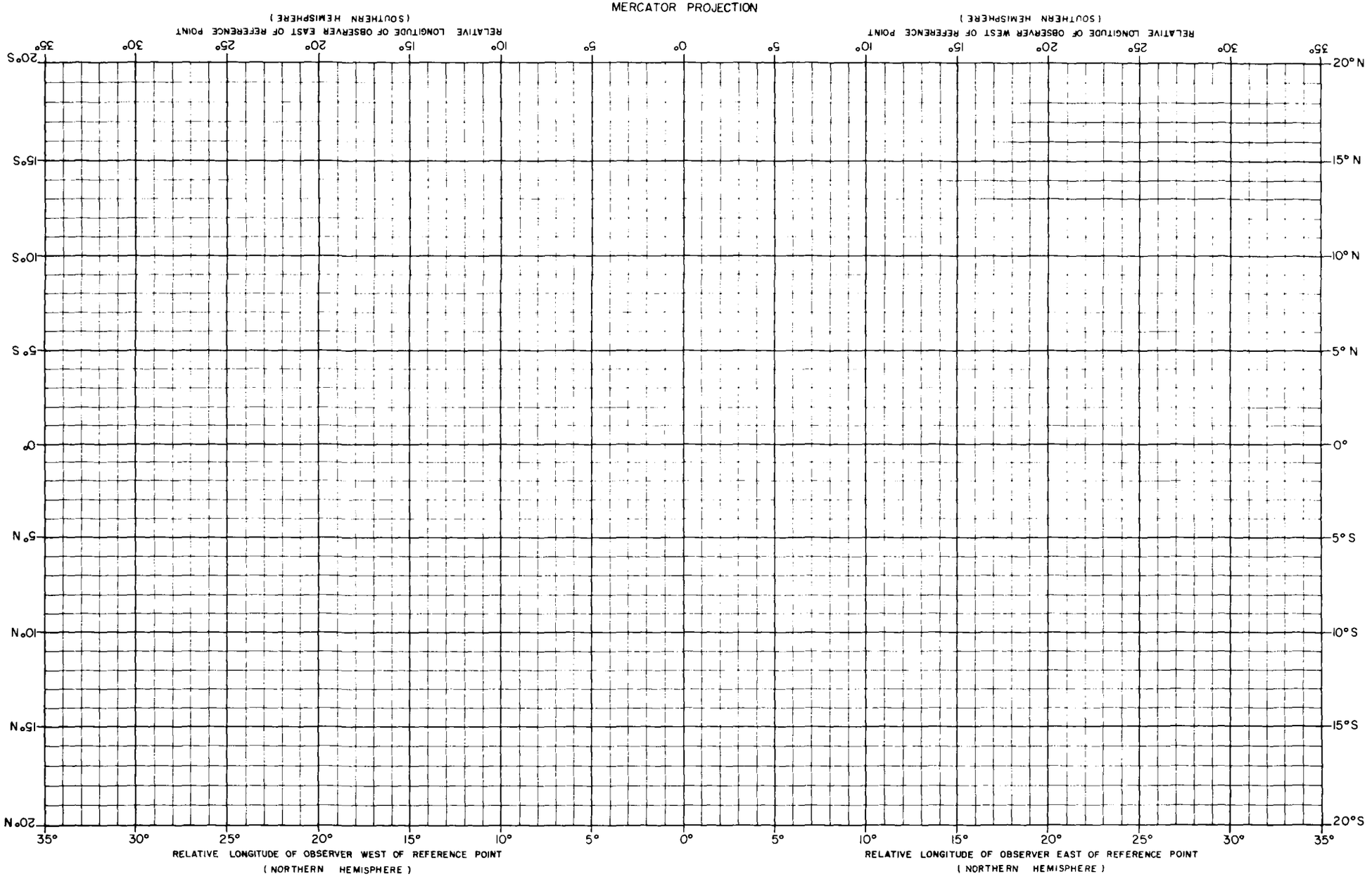


TABLE V — 0° LATITUDE
LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 0° LATITUDE

SUNRISE (0° Lat.)

Satellite Heights	JAN 19	FEB 22	MAR 21	APR 16	MAY 21	JUN 22	JUL 24	AUG 28	SEP 24	OCT 20	NOV 22	DEC 22
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
200 mi	04 54	05 01	04 55	04 47	04 40	04 42	04 49	04 48	04 40	04 32	04 29	04 39
300 mi	04 39	04 46	04 42	04 32	04 24	04 27	04 34	04 33	04 26	04 17	04 14	04 23
400 mi	04 25	04 34	04 29	04 20	04 10	04 14	04 20	04 21	04 13	04 05	04 00	04 10
500 mi	04 14	04 23	04 18	04 09	03 59	03 58	04 09	04 10	04 02	03 54	03 49	03 58
600 mi	04 03	04 11	04 09	03 59	03 48	03 51	03 58	04 00	03 53	03 42	03 38	03 47
700 mi	03 55	04 04	04 01	03 50	03 40	03 42	03 50	03 51	03 45	03 35	03 30	03 38
800 mi	03 46	03 57	03 53	03 43	03 31	03 33	03 41	03 44	03 37	03 28	03 21	03 29
900 mi	03 39	03 50	03 46	03 36	03 24	03 25	03 34	03 37	03 30	03 21	03 14	03 21
1000 mi	03 31	03 43	03 40	03 29	03 16	03 18	03 26	03 30	03 24	03 14	03 06	03 14
1100 mi	03 25	03 38	03 34	03 24	03 10	03 11	03 20	03 25	03 18	03 09	03 00	03 07
1200 mi	03 19	03 32	03 28	03 18	03 04	03 04	03 14	03 19	03 12	03 03	02 54	03 00
1300 mi	03 13	03 26	03 23	03 12	02 58	02 58	03 08	03 13	03 07	02 57	02 48	02 54
1400 mi	03 08	03 21	03 18	03 10	02 53	02 53	03 03	03 11	03 02	02 52	02 43	02 49
1500 mi	03 03	03 17	03 14	03 03	02 48	02 47	02 58	03 04	02 58	02 48	02 38	02 43

SUNSET (0° Lat.)

Satellite Heights	JAN 19	FEB 22	MAR 21	APR 16	MAY 21	JUN 22	JUL 24	AUG 28	SEP 24	OCT 20	NOV 22	DEC 22
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
200 mi	19 28	19 27	19 20	19 13	19 13	19 20	19 23	19 15	19 04	18 58	19 03	19 17
300 mi	19 43	19 42	19 34	19 28	19 28	19 37	19 38	19 29	19 18	19 13	19 18	19 33
400 mi	19 57	19 54	19 47	19 40	19 44	19 50	19 52	19 41	19 31	19 25	19 32	19 46
500 mi	20 08	20 05	19 58	19 51	19 53	20 02	20 03	19 52	19 42	19 36	19 43	20 02
600 mi	20 19	20 15	20 07	20 03	20 04	20 13	20 14	20 04	19 51	19 46	19 54	20 09
700 mi	20 27	20 24	20 15	20 10	20 14	20 22	20 22	20 11	19 59	19 55	20 02	20 18
800 mi	20 36	20 41	20 23	20 17	20 21	20 31	20 31	20 18	20 07	20 02	20 11	20 27
900 mi	20 43	20 38	20 30	20 24	20 28	20 39	20 38	20 25	20 14	20 09	20 18	20 35
1000 mi	20 51	20 45	20 36	20 31	20 36	20 46	20 46	20 32	20 20	20 16	20 26	20 42
1100 mi	20 57	20 50	20 42	20 36	20 42	20 53	20 52	20 37	20 26	20 21	20 32	20 49
1200 mi	21 03	20 56	20 48	20 42	20 48	21 00	20 58	20 43	20 32	20 27	20 38	20 56
1300 mi	21 09	21 02	20 53	20 48	20 54	21 06	21 04	20 49	20 37	20 33	20 44	21 02
1400 mi	21 14	21 04	20 58	20 53	20 59	21 11	21 19	20 54	20 42	20 35	20 49	21 07
1500 mi	21 19	21 11	21 02	20 57	21 04	21 17	21 14	20 58	20 46	20 42	20 54	21 13

*For local mean time of satellite, SUBTRACT from local mean time of observer $4^{m}/^{o}$ that observer is EAST.

TABLE V — 10° NORTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 10° NORTH LATITUDE

SUNRISE (10° N)

Satellite Heights	JAN 19 h m	FEB 22 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	05 08	05 01	04 54	04 47	04 40	04 22	04 32	04 40	04 39	04 39	04 43	04 39
300 mi	04 54	04 52	04 40	04 23	04 06	04 06	04 16	04 24	04 24	04 23	04 29	04 40
400 mi	04 40	04 40	04 27	04 10	03 52	03 51	04 02	04 11	04 11	04 11	04 15	04 27
500 mi	04 29	04 29	04 17	03 58	03 40	03 38	03 50	03 59	04 01	04 00	04 04	04 16
600 mi	04 18	04 19	04 07	03 48	03 28	03 27	03 38	03 49	03 51	03 50	03 53	04 05
700 mi	04 09	04 11	03 59	03 40	03 19	03 17	03 29	03 41	03 43	03 42	03 44	03 56
800 mi	04 01	04 03	03 51	03 32	03 10	03 07	03 20	03 33	03 35	03 34	03 36	03 48
900 mi	03 54	03 56	03 44	03 24	03 01	02 58	03 11	03 25	03 28	03 27	03 29	03 40
1000 mi	03 47	03 49	03 37	03 17	02 54	02 50	03 04	03 18	03 21	03 20	03 22	03 33
1100 mi	03 41	03 44	03 31	03 11	02 46	02 42	02 56	03 12	03 15	03 15	03 16	03 27
1200 mi	03 35	03 38	03 26	03 05	02 39	02 34	02 49	03 06	03 10	03 09	03 10	03 21
1300 mi	03 29	03 32	03 20	02 59	02 32	02 27	02 42	03 00	03 04	03 03	03 04	03 15
1400 mi	03 25	03 28	03 15	02 54	02 26	02 20	02 36	02 55	02 59	02 59	03 00	03 10
1500 mi	03 20	03 23	03 10	02 49	02 20	02 14	02 30	02 50	02 54	02 54	02 55	03 05

SUNSET (10° N)

Satellite Heights	JAN 19 h m	FEB 22 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	19 14	19 20	19 21	19 23	19 31	19 41	19 40	19 23	19 05	18 51	18 48	18 59
300 mi	19 31	19 31	19 28	19 33	19 52	20 02	19 56	19 38	19 12	19 07	19 03	19 16
400 mi	19 42	19 48	19 49	19 50	20 00	20 13	20 10	19 51	19 33	19 19	19 17	19 29
500 mi	19 53	19 59	19 59	20 02	20 12	20 26	20 22	20 03	19 43	19 30	19 28	19 40
600 mi	20 04	20 09	20 09	20 12	20 24	20 37	20 34	20 13	19 53	19 40	19 39	19 51
700 mi	20 13	20 17	20 17	20 20	20 33	20 47	20 43	20 21	20 01	19 48	19 48	20 00
800 mi	20 21	20 25	20 25	20 28	20 42	20 57	20 52	20 29	20 09	19 56	19 56	20 08
900 mi	20 28	20 32	20 32	20 36	20 51	21 06	21 01	20 37	20 16	20 03	20 03	20 16
1000 mi	20 35	20 39	20 39	20 43	20 58	21 14	21 08	20 44	20 23	20 10	20 10	20 23
1100 mi	20 41	20 44	20 45	20 49	21 06	21 22	21 16	20 50	20 29	20 15	20 16	20 29
1200 mi	20 47	20 50	20 50	20 55	21 13	21 30	21 23	20 56	20 34	20 21	20 22	20 35
1300 mi	20 53	20 56	20 56	21 01	21 20	21 37	21 30	21 02	20 40	20 27	20 28	20 41
1400 mi	20 57	21 00	21 01	21 06	21 26	21 44	21 36	21 07	20 45	20 31	20 32	20 46
1500 mi	21 02	21 05	21 06	21 11	21 32	21 50	21 42	21 12	20 50	20 36	20 37	20 51

TABLE V — 10° SOUTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 10° SOUTH LATITUDE

SUNRISE (10° S)

Satellite Heights	JAN 19 h m	FEB 22 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	04 36	04 52	04 54	04 54	04 53	05 00	05 03	04 55	04 40	04 19	04 13	04 20
300 mi	04 21	04 37	04 40	04 38	04 39	04 44	04 49	04 39	04 24	04 08	03 56	04 02
400 mi	04 07	04 24	04 27	04 26	04 25	04 31	04 35	04 27	04 11	03 55	03 42	03 47
500 mi	03 55	04 12	04 17	04 15	04 14	04 20	04 24	04 16	04 01	03 43	03 30	03 34
600 mi	03 43	04 02	04 07	04 05	04 03	04 09	04 13	04 06	03 51	03 33	03 18	03 23
700 mi	03 34	03 54	03 59	03 57	03 54	04 00	04 04	03 58	03 43	03 25	03 09	03 13
800 mi	03 25	03 46	03 51	03 49	03 46	03 52	03 56	03 50	03 35	03 17	03 00	03 03
900 mi	03 16	03 38	03 44	03 42	03 39	03 44	03 49	03 43	03 28	03 09	02 51	02 54
1000 mi	03 09	03 31	03 37	03 35	03 32	03 37	03 42	03 36	03 21	03 02	02 44	02 46
1100 mi	03 01	03 25	03 31	03 30	03 26	03 31	03 36	03 31	03 15	02 56	02 36	02 38
1200 mi	02 54	03 19	03 26	03 24	03 20	03 25	03 30	03 25	03 10	02 50	02 29	02 30
1300 mi	02 47	03 13	03 20	03 18	03 14	03 19	03 24	03 19	03 04	02 44	02 22	02 23
1400 mi	02 41	03 08	03 15	03 14	03 10	03 14	03 20	03 15	02 59	02 39	02 16	02 16
1500 mi	02 35	03 03	03 10	03 09	03 05	03 09	03 15	03 10	02 54	02 34	02 10	02 11

SUNSET (10° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	19 45	19 35	19 21	19 05	18 58	19 03	18 59	19 08	19 06	19 08	19 21	19 38
300 mi	20 01	19 51	19 36	19 22	19 13	19 16	19 17	19 23	19 20	19 22	19 36	19 54
400 mi	20 15	20 04	19 49	19 34	19 27	19 33	19 31	19 35	19 33	19 35	19 50	20 09
500 mi	20 27	20 16	19 59	19 45	19 38	19 44	19 48	19 46	19 43	19 47	20 02	20 22
600 mi	20 39	20 26	20 09	19 55	19 49	19 55	19 59	19 56	19 53	19 57	20 14	20 33
700 mi	20 48	20 34	20 17	20 03	19 58	20 04	20 08	20 04	20 01	20 05	20 23	20 43
800 mi	20 57	20 42	20 25	20 11	20 06	20 12	20 16	20 12	20 09	20 13	20 32	20 53
900 mi	21 06	20 50	20 32	20 18	20 13	20 20	20 23	20 19	20 16	20 21	20 41	21 02
1000 mi	21 13	20 57	20 39	20 25	20 20	20 27	20 30	20 26	20 23	20 28	20 48	21 10
1100 mi	21 21	21 03	20 45	20 30	20 26	20 33	20 36	20 31	20 29	20 34	20 56	21 18
1200 mi	21 28	21 09	20 50	20 36	20 32	20 39	20 42	20 37	20 34	20 40	21 03	21 26
1300 mi	21 35	21 15	20 56	20 42	20 38	20 45	20 48	20 43	20 40	20 46	21 10	21 33
1400 mi	21 41	21 20	21 01	20 46	20 42	20 50	20 53	20 45	20 45	20 51	21 16	21 42
1500 mi	21 47	21 25	21 06	20 51	20 47	20 55	20 58	20 59	20 50	20 56	21 22	21 46

*For local mean time of satellite, SUBTRACT from local mean time of observer $4^{m}/^{\circ}$ that observer is EAST.

TABLE V — 20° NORTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 20° NORTH LATITUDE

SUNRISE (20° N)

Satellite Heights	JAN 19 h m	FEB 22 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	05 21	05 12	04 52	04 27	04 02	03 58	04 11	04 28	04 36	04 42	04 56	05 11
300 mi	05 05	04 56	04 36	04 10	03 43	03 38	03 53	04 11	04 20	04 27	04 40	04 56
400 mi	04 51	04 43	04 22	03 56	03 27	03 22	03 37	03 57	04 06	04 14	04 26	04 42
500 mi	04 39	04 31	04 11	03 49	03 13	03 06	03 23	03 45	03 55	04 02	04 14	04 30
600 mi	04 29	04 21	04 00	03 32	03 00	02 53	03 10	03 33	03 44	03 52	04 04	04 20
700 mi	04 20	04 12	03 52	03 23	02 48	02 41	02 58	03 24	03 36	03 43	03 55	04 10
800 mi	04 12	04 05	03 43	03 14	02 37	02 29	02 47	03 15	03 27	03 36	03 47	04 02
900 mi	04 05	03 57	03 36	03 05	02 28	02 17	02 38	03 06	03 20	03 28	03 40	03 54
1000 mi	03 58	03 50	03 29	02 58	02 18	02 06	02 28	02 59	03 13	03 21	03 33	03 47
1100 mi	03 51	03 44	03 22	02 50	02 08	01 55	02 18	02 51	03 06	03 15	03 26	03 41
1200 mi	03 45	03 38	03 16	02 43	02 00	01 44	02 10	02 44	03 00	03 09	03 20	03 34
1300 mi	03 40	03 32	03 10	02 36	01 50	01 33	02 00	02 37	02 54	03 03	03 15	03 29
1400 mi	03 35	03 28	03 05	02 30	01 42	01 22	01 52	02 31	02 49	02 59	03 10	03 24
1500 mi	03 29	03 23	03 00	02 24	01 33	01 10	01 43	02 26	02 44	02 54	03 04	03 19

SUNSET (20° N)

Satellite Heights	JAN 19 h m	FEB 22 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	19 00	19 16	19 24	19 34	19 53	20 06	20 06	19 34	19 08	18 47	18 36	18 45
300 mi	19 17	19 32	19 40	19 50	20 09	20 26	20 19	19 51	19 24	19 03	18 52	19 00
400 mi	19 31	19 45	19 54	20 04	20 25	20 42	20 35	20 05	19 38	19 16	19 06	19 14
500 mi	19 43	19 57	20 05	20 16	20 39	20 58	20 49	20 17	19 49	19 28	19 18	19 26
600 mi	19 53	20 07	20 16	20 28	20 52	21 11	21 02	20 29	20 00	19 38	19 28	19 36
700 mi	20 02	20 16	20 24	20 37	21 04	21 23	21 14	20 38	20 08	19 47	19 37	19 46
800 mi	20 10	20 23	20 33	20 46	21 15	21 35	21 25	20 47	20 17	19 54	19 45	19 54
900 mi	20 17	20 31	20 40	20 55	21 24	21 47	21 34	20 56	20 24	20 02	19 52	20 02
1000 mi	20 24	20 38	20 47	21 02	21 34	21 58	21 44	21 03	20 31	20 09	19 59	20 09
1100 mi	20 31	20 44	20 54	21 10	21 44	22 09	21 54	21 11	20 38	20 15	20 06	20 15
1200 mi	20 37	20 50	21 00	21 17	21 52	22 20	22 02	21 18	20 44	20 21	20 12	20 22
1300 mi	20 42	20 56	21 06	21 24	22 02	22 31	22 12	21 25	20 50	20 27	20 17	20 27
1400 mi	20 47	21 00	21 11	21 30	22 10	22 42	22 20	21 31	20 55	20 31	20 22	20 32
1500 mi	20 53	21 05	21 16	21 36	22 19	22 54	22 29	21 37	21 00	20 36	20 28	20 37

TABLE V — 20° SOUTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 20° SOUTH LATITUDE

SUNRISE (20° S)

Satellite Heights	JAN 19 h m	FEB 22 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	04 14	04 40	04 50	04 57	05 06	05 14	05 16	05 00	04 36	04 05	03 52	03 54
300 mi	03 58	04 24	04 36	04 42	04 50	05 00	05 00	04 43	04 20	03 55	03 33	03 34
400 mi	03 42	04 10	04 22	04 29	04 36	04 46	04 46	04 30	04 06	03 41	03 17	03 18
500 mi	03 28	03 58	04 11	04 17	04 24	04 34	04 34	04 18	03 55	03 29	03 03	03 02
600 mi	03 15	03 46	04 00	04 07	04 14	04 24	04 24	04 08	03 44	03 17	02 50	02 49
700 mi	03 03	03 37	03 52	03 58	04 05	04 14	04 15	03 59	03 36	03 08	02 38	02 37
800 mi	02 52	03 28	03 43	03 51	03 57	04 06	04 07	03 52	03 27	02 59	02 27	02 25
900 mi	02 43	03 19	03 36	03 43	03 50	03 58	04 00	03 44	03 20	02 50	02 18	02 13
1000 mi	02 33	03 12	03 29	03 36	03 43	03 51	03 53	03 37	03 13	02 43	02 08	02 02
1100 mi	02 23	03 04	03 22	03 30	03 36	03 45	03 46	03 31	03 06	02 35	01 58	01 51
1200 mi	02 15	02 57	03 16	03 24	03 30	03 38	03 40	03 25	03 00	02 28	01 50	01 40
1300 mi	02 05	02 50	03 10	03 18	03 25	03 33	03 35	03 19	02 54	02 21	01 40	01 29
1400 mi	01 57	02 44	03 05	03 14	03 20	03 28	03 30	03 15	02 49	02 15	01 32	01 18
1500 mi	01 48	02 38	03 00	03 09	03 14	03 23	03 24	03 10	02 44	02 09	01 23	01 06

SUNSET (20° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	20 07	19 46	19 23	19 03	18 55	18 48	18 56	19 08	19 13	19 20	19 43	19 56
300 mi	20 24	20 04	19 40	19 18	19 02	19 04	19 12	19 19	19 24	19 35	19 59	20 22
400 mi	20 40	20 18	19 54	19 31	19 16	19 18	19 26	19 32	19 38	19 49	20 15	20 38
500 mi	20 54	20 30	20 05	19 43	19 28	19 30	19 38	19 44	19 49	20 01	20 29	20 54
600 mi	21 07	20 42	20 16	19 53	19 38	19 40	19 48	19 54	20 00	20 13	20 42	21 07
700 mi	21 19	20 51	20 24	20 02	19 47	19 50	19 57	20 03	20 08	20 22	20 54	21 19
800 mi	21 30	21 00	20 33	20 19	19 55	19 58	20 05	20 10	20 17	20 31	21 05	21 31
900 mi	21 39	21 09	20 40	20 17	20 02	20 06	20 12	20 18	20 24	20 40	21 14	21 43
1000 mi	21 49	21 16	20 47	20 24	20 09	20 13	20 19	20 25	20 31	20 47	21 24	21 54
1100 mi	21 59	21 24	20 54	20 30	20 16	20 19	20 26	20 31	20 38	20 55	21 34	22 05
1200 mi	22 07	21 31	21 00	20 36	20 22	20 26	20 32	20 37	20 44	21 02	21 42	22 16
1300 mi	22 17	21 38	21 06	20 42	20 37	20 31	20 37	20 43	20 50	21 09	21 52	22 27
1400 mi	22 25	21 44	21 11	20 46	20 42	20 36	20 42	20 47	20 55	21 15	22 00	22 38
1500 mi	22 34	21 50	21 16	20 51	20 48	20 41	20 48	20 52	21 00	21 21	22 09	22 50

*For local mean time of satellite, SUBTRACT from local mean time of observer $4^{m}/^{\circ}$ that observer is EAST.

TABLE V — 30° NORTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 30° NORTH LATITUDE

SUNRISE (30° N)

Satellite Heights	JAN 19	FEB 23	MAR 21	APR 16	MAY 21	JUN 22	JUL 24	AUG 28	SEP 24	OCT 20	NOV 22	DEC 22
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
200 mi	05 32	05 15	04 45	04 10	03 32	03 23	03 41	04 11	04 29	04 44	05 04	05 25
300 mi	05 15	04 57	04 27	03 51	03 10	02 59	03 20	03 52	04 11	04 28	04 50	05 07
400 mi	05 00	04 42	04 12	03 35	02 50	02 38	03 00	03 36	03 56	04 13	04 35	04 54
500 mi	04 48	04 30	04 00	03 20	02 33	02 17	02 43	03 21	03 44	04 01	04 23	04 41
600 mi	04 37	04 19	03 48	03 08	02 16	01 58	02 26	03 09	03 32	03 50	04 12	04 30
700 mi	04 27	04 10	03 38	02 56	02 00	01 37	02 10	02 57	03 22	03 41	04 02	04 20
800 mi	04 18	04 01	03 28	02 45	01 43	01 15	01 53	02 46	03 12	03 32	03 53	04 12
900 mi	04 10	03 53	03 20	02 34	01 27	00 47	01 37	02 35	03 04	03 24	03 45	04 04
1000 mi	04 03	03 45	03 12	02 24	01 08	///	01 18	02 25	02 56	03 16	03 38	03 56
1100 mi	03 58	03 38	03 04	02 15	00 48	///	00 58	02 16	02 48	03 09	03 33	03 49
1200 mi	03 50	03 32	02 57	02 06	00 11	///	00 21	02 07	02 41	03 03	03 24	03 43
1300 mi	03 44	03 26	02 50	01 56	///	///	///	01 57	02 34	02 57	03 19	03 37
1400 mi	03 38	03 20	02 44	01 48	///	///	///	01 49	02 28	02 51	03 13	03 31
1500 mi	03 33	03 14	02 37	01 38	///	///	///	01 39	02 21	02 45	03 08	03 26

SUNSET (30° N)

Satellite Heights	JAN 19	FEB 22	MAR 21	APR 16	MAY 21	JUN 22	JUL 24	AUG 28	SEP 24	OCT 20	NOV 22	DEC 22
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
200 mi	18 49	19 14	19 32	19 50	20 22	20 40	20 30	19 51	19 15	18 45	18 26	18 30
300 mi	19 07	19 31	19 49	20 09	20 42	21 05	20 52	20 10	19 33	19 02	18 42	18 49
400 mi	19 22	19 46	20 04	20 25	21 02	21 26	21 12	20 26	19 48	19 17	18 57	19 02
500 mi	19 34	19 58	20 16	20 40	21 19	21 47	21 29	20 41	20 00	19 29	19 09	19 15
600 mi	19 45	20 09	20 28	20 52	21 36	22 06	21 46	20 53	20 12	19 40	19 20	19 26
700 mi	19 55	20 18	20 38	21 04	21 52	22 27	22 02	21 05	20 22	19 49	19 30	19 36
800 mi	20 04	20 27	20 48	21 15	22 09	22 51	22 19	21 16	20 32	19 58	19 39	19 44
900 mi	20 12	20 35	20 56	21 26	22 25	23 17	22 35	21 27	20 40	20 06	19 47	19 52
1000 mi	20 19	20 43	21 04	21 36	22 44	///	22 54	21 37	20 48	20 14	19 54	20 00
1100 mi	20 24	20 50	21 12	21 45	23 04	///	23 14	21 46	20 56	20 21	19 59	20 07
1200 mi	20 32	20 56	21 19	21 54	23 41	///	23 51	21 55	21 03	20 27	20 07	20 13
1300 mi	20 38	21 02	21 26	22 04	///	///	///	22 05	21 10	20 33	20 13	20 19
1400 mi	20 44	21 08	21 32	22 12	///	///	///	22 13	21 16	20 39	20 19	20 25
1500 mi	20 49	21 14	21 39	22 22	///	///	///	22 23	21 23	20 45	20 24	20 30

TABLE V — 30° SOUTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 30° SOUTH LATITUDE

SUNRISE (30° S)

Satellite Heights	JAN 19	FEB 22	MAR 21	APR 16	MAY 21	JUN 22	JUL 24	AUG 28	SEP 24	OCT 20	NOV 22	DEC 22
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
200 mi	03 44	04 22	04 41	04 58	05 16	05 28	05 27	05 02	04 31	03 46	03 22	03 20
300 mi	03 25	04 05	04 27	04 43	05 00	05 11	05 10	04 44	04 11	03 36	03 00	02 55
400 mi	03 05	03 49	04 12	04 28	04 45	04 58	04 54	04 24	03 56	03 20	02 40	02 34
500 mi	02 48	03 34	04 00	04 16	04 33	04 45	04 43	04 17	03 44	03 05	02 23	02 13
600 mi	02 31	03 22	03 48	04 05	04 22	04 34	04 32	04 06	03 32	02 53	02 06	01 54
700 mi	02 15	03 10	03 38	03 56	04 12	04 24	04 22	03 57	03 22	02 41	01 50	01 33
800 mi	01 58	02 59	03 28	03 47	04 03	04 16	04 13	03 48	03 12	02 30	01 33	01 11
900 mi	01 42	02 48	03 20	03 39	03 55	04 08	04 05	03 40	03 04	02 19	01 17	00 43
1000 mi	01 23	02 38	03 12	03 31	03 48	04 00	03 58	03 32	02 56	02 09	00 58	///
1100 mi	01 03	02 29	03 04	03 24	03 43	03 53	03 53	03 25	02 48	02 00	00 38	///
1200 mi	00 26	02 20	02 57	03 18	03 35	03 47	03 45	03 19	02 41	01 51	00 01	///
1300 mi	///	02 10	02 50	03 12	03 29	03 41	03 39	03 13	02 34	01 41	///	///
1400 mi	///	02 02	02 44	03 06	03 23	03 35	03 33	03 07	02 26	01 33	///	///
1500 mi	///	01 52	02 37	03 00	03 18	03 30	03 28	03 01	02 21	01 23	///	///

SUNSET (30° S)

Satellite Heights	JAN 19	FEB 23	MAR 21	APR 16	MAY 21	JUN 22	JUL 24	AUG 28	SEP 24	OCT 20	NOV 22	DEC 22
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
200 mi	20 41	20 03	19 31	19 01	18 27	18 33	18 46	19 03	19 18	19 36	20 12	20 37
300 mi	20 57	20 23	19 49	19 17	18 52	18 53	19 02	19 18	19 33	19 54	20 32	21 01
400 mi	21 17	20 39	20 04	19 32	19 07	19 06	19 17	19 33	19 52	20 10	20 52	21 22
500 mi	21 34	20 54	20 16	19 44	19 19	19 19	19 29	19 45	20 00	20 25	21 19	21 43
600 mi	21 51	21 06	20 28	19 55	19 30	19 30	19 40	19 56	20 12	20 37	21 26	22 02
700 mi	22 07	21 18	20 38	20 04	19 40	19 41	19 50	20 05	20 22	20 49	21 42	22 23
800 mi	22 34	21 29	20 48	20 13	19 45	19 48	19 59	20 14	20 32	21 00	21 59	22 45
900 mi	22 40	21 40	20 56	20 21	19 57	19 56	20 07	20 23	20 40	21 11	22 15	23 13
1000 mi	22 59	21 50	21 04	20 29	20 04	20 04	20 14	20 30	20 48	21 25	22 34	///
1100 mi	23 19	21 59	21 12	20 36	20 09	20 11	20 19	20 37	20 56	21 30	22 54	///
1200 mi	23 56	22 08	21 19	20 42	20 17	20 17	20 27	20 43	21 03	21 39	23 31	///
1300 mi	///	22 18	21 26	20 48	20 23	20 23	20 33	20 49	21 10	21 49	///	///
1400 mi	///	22 26	21 32	20 54	20 29	20 29	20 39	20 55	21 16	21 57	///	///
1500 mi	///	22 36	21 39	21 00	20 34	20 34	20 44	21 01	21 23	22 22	///	///

*For local mean time of satellite, SUBTRACT from local mean time of observer $4^{m}/^{\circ}$ that observer is EAST.

TABLE V — 35° NORTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 35° NORTH LATITUDE

SUNRISE (35° N)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	05 38	05 15	04 39	04 00	03 13	02 56	03 22	03 59	04 24	04 45	05 12	05 33
300 mi	05 19	04 56	04 21	03 38	02 47	02 31	02 57	03 39	04 05	04 27	04 54	05 16
400 mi	05 04	04 41	04 05	03 20	02 24	02 04	02 34	03 21	03 49	04 12	04 39	04 59
500 mi	04 51	04 28	03 51	03 04	02 02	01 36	02 12	03 05	03 35	03 59	04 26	04 46
600 mi	04 39	04 16	03 39	02 50	01 40	01 03	01 50	02 51	03 23	03 47	04 14	04 34
700 mi	04 29	04 06	03 28	02 36	01 16	///	01 26	02 37	03 12	03 37	04 04	04 24
800 mi	04 20	03 56	03 17	02 23	00 47	///	00 57	02 24	03 01	03 27	03 55	04 15
900 mi	04 12	03 47	03 08	02 10	///	///	///	02 11	02 52	03 18	03 47	04 06
1000 mi	04 04	03 40	02 59	01 58	///	///	///	01 59	02 43	03 11	03 39	03 59
1100 mi	03 57	03 32	02 50	01 46	///	///	///	01 47	02 34	03 03	03 32	03 52
1200 mi	03 50	03 25	02 42	01 33	///	///	///	01 34	02 26	02 56	03 25	03 41
1300 mi	03 43	03 19	02 34	01 20	///	///	///	01 21	02 18	02 50	03 18	03 38
1400 mi	03 37	03 12	02 26	01 10	///	///	///	01 11	02 10	02 43	03 12	03 33
1500 mi	03 32	03 06	02 19	00 49	///	///	///	00 50	02 03	02 37	03 07	03 27

SUNSET (35° N)

Satellite Heights	JAN 19 h m	FEB 22 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	18 43	19 14	19 37	20 02	20 42	21 04	20 50	20 02	19 16	18 44	18 20	18 24
300 mi	19 03	19 32	19 55	20 22	21 05	21 33	21 15	20 23	19 39	19 03	18 38	18 40
400 mi	19 18	19 47	20 11	20 40	21 28	22 00	21 38	20 41	19 55	19 18	18 53	18 57
500 mi	19 31	20 00	20 25	20 56	21 50	22 28	22 00	20 57	20 09	19 31	19 06	19 10
600 mi	19 43	20 12	20 37	21 10	22 12	23 01	22 22	21 11	20 21	19 43	19 18	19 22
700 mi	19 53	20 22	20 48	21 24	22 36	///	22 46	21 26	20 32	19 53	19 28	19 32
800 mi	20 02	20 32	20 59	21 37	23 05	///	23 15	21 38	20 43	20 03	19 37	19 41
900 mi	20 10	20 41	21 08	21 50	///	///	///	21 51	20 52	20 12	19 45	19 50
1000 mi	20 18	20 48	21 17	22 02	///	///	///	22 03	21 01	20 19	19 53	19 57
1100 mi	20 25	20 56	21 26	22 14	///	///	///	22 15	21 10	20 27	20 00	20 04
1200 mi	20 32	21 03	21 34	22 27	///	///	///	22 28	21 18	20 34	20 07	20 15
1300 mi	20 39	21 09	21 42	22 40	///	///	///	22 41	21 26	20 40	20 14	20 18
1400 mi	20 45	21 16	21 50	22 50	///	///	///	22 51	21 34	20 47	20 20	20 23
1500 mi	20 50	21 22	21 57	23 11	///	///	///	23 13	21 41	20 53	20 25	20 29

TABLE V — 35° SOUTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 35° SOUTH LATITUDE

SUNRISE (35° S)

Satellite Heights	JAN 19 h m	FEB 22 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	03 24	04 10	04 38	04 59	05 22	05 36	05 33	05 02	04 23	03 42	03 03	02 57
300 mi	03 02	03 52	04 21	04 42	05 04	05 20	05 14	04 43	04 05	03 23	02 37	02 27
400 mi	02 39	03 34	04 05	04 27	04 49	05 03	04 59	04 28	03 49	03 05	02 14	02 00
500 mi	02 17	03 18	03 51	04 14	04 36	04 50	04 46	04 15	03 35	02 49	01 52	01 32
600 mi	01 55	03 04	03 39	04 02	04 24	04 38	04 34	04 03	03 23	02 35	01 30	00 59
700 mi	01 31	02 50	03 28	03 52	04 14	04 28	04 24	03 53	03 12	02 21	01 06	///
800 mi	01 02	02 37	03 17	03 42	04 05	04 19	04 15	03 43	03 01	02 08	00 37	///
900 mi	///	02 24	03 08	03 33	03 57	04 10	04 07	03 34	02 52	01 55	///	///
1000 mi	///	02 12	02 59	03 26	03 49	04 03	03 59	03 27	02 43	01 43	///	///
1100 mi	///	02 00	02 50	03 18	03 42	03 56	03 52	03 19	02 34	01 31	///	///
1200 mi	///	01 47	02 42	03 11	03 35	03 45	03 45	03 12	02 26	01 18	///	///
1300 mi	///	01 34	02 34	03 05	03 28	03 42	03 38	03 06	02 18	01 05	///	///
1400 mi	///	01 24	02 26	02 58	03 22	03 37	03 32	02 59	02 10	00 55	///	///
1500 mi	///	01 03	02 19	02 52	03 17	03 31	03 27	02 53	02 03	00 34	///	///

SUNSET (35° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	20 56	20 14	19 41	19 00	18 30	18 26	18 42	19 03	19 23	19 48	20 30	21 01
300 mi	21 20	20 36	19 55	19 18	18 48	18 44	18 58	19 19	19 37	20 07	20 55	21 29
400 mi	21 43	20 54	20 11	19 33	19 03	19 01	19 13	19 34	19 55	20 25	21 18	21 56
500 mi	22 05	21 10	20 15	19 46	19 16	19 14	19 26	19 47	20 08	20 41	21 40	22 24
600 mi	22 27	21 24	20 37	19 58	19 28	19 26	19 38	19 59	20 21	20 55	22 02	22 57
700 mi	22 51	21 38	20 48	20 08	19 38	19 36	19 48	20 09	20 32	21 09	22 26	///
800 mi	23 20	21 51	20 59	20 18	19 47	19 45	19 57	20 19	20 43	21 22	22 55	///
900 mi	///	22 04	21 08	20 27	19 55	19 54	20 05	20 28	20 52	21 35	///	///
1000 mi	///	22 16	21 17	20 34	20 03	20 01	20 13	20 35	21 01	21 47	///	///
1100 mi	///	22 28	21 26	20 42	20 08	20 08	20 20	20 43	21 10	21 59	///	///
1200 mi	///	22 41	21 34	20 49	20 17	20 19	20 27	20 50	21 18	22 12	///	///
1300 mi	///	22 54	21 42	20 55	20 24	20 22	20 34	20 56	21 26	22 25	///	///
1400 mi	///	23 04	21 40	21 02	20 30	20 27	20 40	21 03	21 34	22 50	///	///
1500 mi	///	23 25	21 57	21 08	20 35	20 33	20 45	21 09	21 42	22 56	///	///

*For local mean time of satellite, SUBTRACT from local mean time of observer $4^{m}/^{\circ}$ that observer is EAST.

TABLE V — 40° NORTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 40° NORTH LATITUDE

SUNRISE (40° N)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	05 44	05 14	04 33	03 32	02 48	02 28	02 56	03 45	04 17	04 44	05 17	05 40
300 mi	05 23	04 54	04 13	03 22	02 17	01 51	02 27	03 23	03 57	04 25	04 58	05 21
400 mi	05 07	04 38	03 56	03 01	01 46	01 05	01 56	03 02	03 40	04 09	04 42	05 05
500 mi	04 53	04 24	03 40	02 43	01 13	///	01 23	02 44	03 24	03 55	04 28	04 50
600 mi	04 43	04 11	03 26	02 25	00 20	///	00 30	02 26	03 10	03 42	04 18	04 38
700 mi	04 30	04 00	03 14	02 08	///	///	///	02 09	02 58	03 31	04 05	04 29
800 mi	04 20	03 50	03 02	01 52	///	///	///	01 53	02 46	03 21	03 55	04 17
900 mi	04 11	03 41	02 51	01 34	///	///	///	01 35	02 35	03 12	03 46	04 08
1000 mi	04 03	03 32	02 41	01 16	///	///	///	01 17	02 25	03 03	03 38	04 00
1100 mi	03 55	03 24	02 30	00 54	///	///	///	00 55	02 14	02 55	03 30	03 52
1200 mi	03 48	03 16	02 21	///	///	///	///	///	02 05	02 47	03 23	03 45
1300 mi	03 41	03 08	02 11	///	///	///	///	///	01 57	02 39	03 16	03 38
1400 mi	03 35	03 01	02 02	///	///	///	///	///	01 46	02 32	03 10	03 32
1500 mi	03 29	02 54	01 52	///	///	///	///	///	01 36	02 25	03 04	03 26

SUNSET (40° N)

Satellite Heights	JAN 19 h m	FEB 22 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	18 39	19 12	19 44	20 16	21 06	21 35	21 14	20 16	19 26	18 44	18 14	18 16
300 mi	18 59	19 34	20 03	20 38	21 35	22 11	21 45	20 39	19 47	19 05	18 34	18 35
400 mi	19 75	19 50	20 20	20 59	22 06	22 59	22 16	21 00	20 04	19 21	18 50	18 51
500 mi	19 29	20 04	20 36	21 17	22 39	///	22 49	21 18	20 20	19 35	19 04	19 06
600 mi	19 39	20 17	20 50	21 35	23 32	///	23 42	21 36	20 34	19 48	19 14	19 18
700 mi	19 52	20 28	21 02	21 52	///	///	///	21 53	20 46	19 59	19 27	19 27
800 mi	20 02	20 38	21 14	22 08	///	///	///	22 09	20 58	20 09	19 37	19 39
900 mi	20 11	20 47	21 25	22 26	///	///	///	22 27	21 09	20 18	19 46	19 48
1000 mi	20 19	20 56	21 35	22 44	///	///	///	22 45	21 19	20 27	19 54	19 56
1100 mi	20 27	21 04	21 46	23 06	///	///	///	23 17	21 30	20 35	20 02	20 04
1200 mi	20 34	21 12	21 55	///	///	///	///	///	21 39	20 43	20 09	20 11
1300 mi	20 41	21 20	22 05	///	///	///	///	///	21 49	20 51	20 16	20 18
1400 mi	20 47	21 27	22 14	///	///	///	///	///	21 58	20 58	20 22	20 24
1500 mi	20 53	21 34	22 24	///	///	///	///	///	22 08	21 05	20 28	20 30

TABLE V — 40° SOUTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 40° SOUTH LATITUDE

SUNRISE (40° S)

Satellite Heights	JAN 19 h m	FEB 22 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	02 58	03 56	04 31	04 58	05 27	05 43	05 39	05 03	04 17	03 33	02 38	02 25
300 mi	02 32	03 36	04 13	04 40	05 04	05 25	05 18	04 41	04 05	03 07	02 07	01 47
400 mi	02 01	03 15	03 56	04 24	04 52	05 09	05 02	04 25	03 48	02 46	01 36	01 01
500 mi	01 28	02 57	03 40	04 10	04 38	04 54	04 48	04 11	03 32	02 28	01 03	///
600 mi	00 35	02 39	03 26	03 57	04 28	04 42	04 38	03 58	03 18	02 10	00 10	///
700 mi	///	02 22	03 14	03 46	04 15	04 33	04 25	03 47	03 06	01 53	///	///
800 mi	///	02 06	03 02	03 36	04 05	04 21	04 15	03 37	02 54	01 37	///	///
900 mi	///	01 48	02 51	03 27	03 56	04 12	04 06	03 28	02 43	01 19	///	///
1000 mi	///	01 30	02 41	03 18	03 48	04 04	03 58	03 19	02 33	01 01	///	///
1100 mi	///	01 08	02 30	03 10	03 40	03 56	03 50	03 11	02 22	00 39	///	///
1200 mi	///	///	02 21	03 02	03 33	03 49	03 43	03 03	02 13	///	///	///
1300 mi	///	///	02 11	02 54	03 26	03 42	03 36	02 55	02 03	///	///	///
1400 mi	///	///	02 02	02 47	03 20	03 36	03 30	02 48	01 54	///	///	///
1500 mi	///	///	01 52	02 40	03 14	03 30	03 24	02 41	01 48	///	///	///

SUNSET (40° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	21 22	20 28	19 39	18 65	18 25	18 20	18 29	19 06	19 35	20 13	20 56	21 38
300 mi	21 50	20 52	20 03	19 20	18 44	18 39	18 54	19 21	19 47	20 23	21 25	22 09
400 mi	22 21	21 13	20 20	19 36	19 00	18 55	19 10	19 37	20 04	20 44	21 56	22 55
500 mi	22 54	21 31	20 36	19 50	19 14	19 20	19 24	19 51	20 20	21 02	22 29	///
600 mi	23 47	21 49	20 50	20 03	19 24	19 22	19 34	20 04	20 38	21 20	23 22	///
700 mi	///	22 06	21 02	20 14	19 37	19 31	19 47	20 15	20 46	21 37	///	///
800 mi	///	22 22	21 14	20 24	19 47	19 43	19 57	20 25	20 58	21 53	///	///
900 mi	///	22 40	21 25	20 33	19 56	19 52	20 06	20 34	21 09	22 11	///	///
1000 mi	///	22 58	21 35	20 42	20 04	20 00	20 14	20 43	21 19	22 29	///	///
1100 mi	///	23 20	21 46	20 50	20 12	20 08	20 22	20 51	21 30	22 51	///	///
1200 mi	///	///	21 53	20 58	20 19	20 15	20 29	20 59	21 37	///	///	///
1300 mi	///	///	22 05	21 06	20 26	20 22	20 36	21 07	21 49	///	///	///
1400 mi	///	///	22 14	21 13	20 32	20 28	20 42	21 14	21 58	///	///	///
1500 mi	///	///	22 24	21 20	20 38	20 34	20 48	21 21	22 08	///	///	///

*For local mean time of satellite, SUBTRACT from local mean time of observer $4^{m}/^{\circ}$ that observer is EAST.

TABLE V — 45° NORTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 45° NORTH LATITUDE

SUNRISE (45° N)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	05 49	05 13	04 25	03 28	02 13	01 40	02 22	03 27	04 09	04 42	05 22	05 46
300 mi	05 27	04 51	04 02	03 00	01 29	///	01 39	03 01	03 46	04 22	05 02	05 27
400 mi	05 09	04 34	03 43	02 36	00 22	///	00 32	02 37	03 27	04 05	04 44	05 10
500 mi	04 54	04 18	03 26	02 13	///	///	///	02 14	03 10	03 49	04 29	04 54
600 mi	04 41	04 04	03 10	01 49	///	///	///	01 50	02 54	03 35	04 16	04 41
700 mi	04 29	03 52	02 55	01 24	///	///	///	01 25	02 39	03 23	04 04	04 29
800 mi	04 19	03 40	02 41	00 53	///	///	///	00 54	02 25	03 11	03 54	04 18
900 mi	04 09	03 30	02 28	///	///	///	///	///	02 12	03 01	03 44	04 09
1000 mi	04 00	03 20	02 14	///	///	///	///	///	01 58	02 51	03 35	04 00
1100 mi	03 51	03 11	02 01	///	///	///	///	///	01 45	02 42	03 26	03 51
1200 mi	03 43	03 02	01 48	///	///	///	///	///	01 32	02 33	03 18	03 44
1300 mi	03 36	02 53	01 34	///	///	///	///	///	01 18	02 24	03 11	03 36
1400 mi	03 29	02 45	01 18	///	///	///	///	///	01 02	02 16	03 04	03 29
1500 mi	03 22	02 37	01 01	///	///	///	///	///	00 45	02 08	02 57	03 23

SUNSET (45° N)

Satellite Heights	JAN 19 h m	FEB 22 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	18 32	19 15	19 52	20 34	21 42	22 23	21 48	20 32	19 33	18 46	18 09	18 09
300 mi	18 55	19 37	20 14	21 00	22 23	///	22 33	21 01	19 58	19 08	18 30	18 29
400 mi	19 13	19 54	20 33	21 24	23 30	///	23 40	21 25	20 17	19 25	18 48	18 46
500 mi	19 28	20 10	20 50	21 47	///	///	///	21 48	20 34	19 41	19 03	19 02
600 mi	19 41	20 24	21 06	22 11	///	///	///	22 12	20 50	19 55	19 16	19 15
700 mi	19 53	20 36	21 21	22 36	///	///	///	22 37	21 05	20 07	19 28	19 27
800 mi	20 03	20 48	21 35	23 07	///	///	///	23 08	21 19	20 19	19 38	19 38
900 mi	20 13	20 58	21 48	///	///	///	///	///	21 32	20 29	19 48	19 47
1000 mi	20 22	21 08	22 02	///	///	///	///	///	21 46	20 39	19 57	19 56
1100 mi	20 31	21 17	21 15	///	///	///	///	///	21 59	20 48	20 06	20 05
1200 mi	20 39	21 26	22 28	///	///	///	///	///	22 12	20 57	20 14	20 12
1300 mi	20 46	21 35	22 42	///	///	///	///	///	22 26	21 06	20 21	20 20
1400 mi	20 53	21 43	22 58	///	///	///	///	///	22 42	21 14	20 28	20 27
1500 mi	21 00	21 51	23 15	///	///	///	///	///	22 59	21 22	20 35	20 33

TABLE V — 45° SOUTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 45° SOUTH LATITUDE

SUNRISE (45° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	02 22	03 39	04 24	04 57	05 32	05 49	05 45	05 01	04 10	03 13	02 03	01 37
300 mi	01 44	03 14	04 02	04 37	05 12	05 31	05 22	04 38	03 46	02 45	01 19	///
400 mi	00 37	02 50	03 43	04 20	04 54	05 14	05 04	04 21	03 27	02 21	00 12	///
500 mi	///	02 27	03 26	04 04	04 39	04 58	04 49	04 05	03 10	01 58	///	///
600 mi	///	02 00	03 10	03 50	04 26	04 45	04 36	03 51	02 54	01 34	///	///
700 mi	///	01 38	02 55	03 38	04 14	04 33	04 24	03 39	02 39	01 09	///	///
800 mi	///	01 07	02 41	03 26	04 04	04 22	04 14	03 27	02 25	00 38	///	///
900 mi	///	///	02 28	03 16	03 54	04 13	04 04	03 17	02 12	///	///	///
1000 mi	///	///	02 14	03 06	03 45	04 04	03 55	03 07	01 58	///	///	///
1100 mi	///	///	02 01	02 57	03 36	03 55	03 46	02 58	01 45	///	///	///
1200 mi	///	///	01 48	02 48	03 28	03 48	03 38	02 49	01 32	///	///	///
1300 mi	///	///	01 34	02 39	03 21	03 40	03 31	02 40	01 18	///	///	///
1400 mi	///	///	01 18	02 31	03 14	03 33	03 24	02 32	01 02	///	///	///
1500 mi	///	///	01 01	02 23	03 07	03 27	03 17	02 24	00 45	///	///	///

SUNSET (45° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	21 57	20 44	19 48	19 01	18 29	18 12	18 29	19 03	19 37	20 19	21 32	22 20
300 mi	22 38	21 14	20 14	19 23	18 40	18 33	18 50	19 24	19 58	20 45	22 13	///
400 mi	23 45	21 38	20 33	19 40	18 58	18 50	19 08	19 41	20 17	21 09	23 20	///
500 mi	///	22 01	20 50	19 04	19 13	19 06	19 23	19 57	20 34	21 32	///	///
600 mi	///	21 28	21 06	20 10	19 26	19 19	19 36	20 11	20 50	21 56	///	///
700 mi	///	22 50	21 21	20 22	19 38	19 31	19 48	20 23	21 05	22 21	///	///
800 mi	///	23 21	21 35	20 34	19 48	19 42	19 58	20 35	21 19	22 52	///	///
900 mi	///	///	21 48	20 44	19 58	19 51	20 04	20 45	21 32	///	///	///
1000 mi	///	///	22 02	20 06	20 07	20 00	20 17	20 55	21 46	///	///	///
1100 mi	///	///	22 15	21 03	20 16	20 09	20 26	21 04	21 59	///	///	///
1200 mi	///	///	22 28	21 12	20 24	20 16	20 34	21 13	22 12	///	///	///
1300 mi	///	///	22 42	21 21	20 31	20 24	20 41	21 22	22 26	///	///	///
1400 mi	///	///	22 58	21 29	20 38	20 31	20 48	21 30	22 42	///	///	///
1500 mi	///	///	23 15	21 37	20 45	20 37	20 55	21 38	22 59	///	///	///

*For local mean time of satellite, SUBTRACT from local mean time of observer $4^{m}/^{o}$ that observer is EAST.

TABLE V — 50° NORTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 50° NORTH LATITUDE

SUNRISE (50° N)

Satellite Heights	JAN 19 h m	FEB 22 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	05 55	05 10	04 14	03 05	01 11	///	01 20	03 04	03 57	04 40	05 27	05 56
300 mi	05 31	04 47	03 48	02 30	///	///	///	02 31	03 32	04 18	05 06	05 34
400 mi	05 11	04 27	03 26	01 58	///	///	///	01 59	03 10	03 58	04 46	05 14
500 mi	04 55	04 10	03 05	01 22	///	///	///	01 23	02 49	03 41	04 30	04 57
600 mi	04 40	03 54	02 46	00 26	///	///	///	00 27	02 30	03 25	04 15	04 42
700 mi	04 27	03 40	02 28	///	///	///	///	///	02 12	03 11	04 02	04 30
800 mi	04 15	03 27	02 09	///	///	///	///	///	01 53	02 58	03 50	04 18
900 mi	04 04	03 14	01 50	///	///	///	///	///	01 34	02 45	03 39	04 07
1000 mi	03 54	02 58	01 30	///	///	///	///	///	01 14	02 29	03 29	03 57
1100 mi	03 45	02 52	01 06	///	///	///	///	///	00 50	02 23	03 20	03 48
1200 mi	03 35	02 40	00 25	///	///	///	///	///	00 09	02 11	03 10	03 39
1300 mi	03 27	02 30	///	///	///	///	///	///	///	02 01	03 02	03 35
1400 mi	03 19	02 19	///	///	///	///	///	///	///	01 50	02 54	03 23
1500 mi	03 11	02 09	///	///	///	///	///	///	///	01 40	02 46	03 16

SUNSET (50° N)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	18 28	19 19	20 04	20 58	22 47	///	22 48	20 55	19 44	18 48	18 04	18 00
300 mi	18 51	19 41	20 28	21 30	///	///	///	21 30	20 12	19 12	18 26	18 22
400 mi	19 11	20 01	20 50	22 02	///	///	///	22 02	20 34	19 32	18 46	18 42
500 mi	19 27	20 18	21 11	22 38	///	///	///	22 38	20 55	19 49	19 02	18 59
600 mi	19 42	20 34	21 30	23 34	///	///	///	23 34	21 14	20 05	19 17	19 14
700 mi	19 55	20 48	21 48	///	///	///	///	///	21 32	20 19	19 30	19 26
800 mi	20 07	21 01	22 07	///	///	///	///	///	21 51	20 32	19 42	19 38
900 mi	20 18	21 14	22 26	///	///	///	///	///	22 10	20 45	19 53	19 49
1000 mi	20 28	21 30	22 46	///	///	///	///	///	22 30	21 01	20 03	19 59
1100 mi	20 37	21 36	23 10	///	///	///	///	///	22 54	21 07	20 12	20 08
1200 mi	20 47	21 48	23 51	///	///	///	///	///	23 35	21 19	20 22	20 17
1300 mi	20 55	21 58	///	///	///	///	///	///	///	21 29	20 30	20 21
1400 mi	21 03	22 09	///	///	///	///	///	///	///	21 40	20 38	20 33
1500 mi	21 11	22 19	///	///	///	///	///	///	///	21 50	20 46	20 40

TABLE V — 50° SOUTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 50° SOUTH LATITUDE

SUNRISE (50° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	01 16	03 16	04 10	04 54	05 37	05 59	05 49	04 58	04 56	02 53	01 01	///
300 mi	///	02 44	03 48	04 33	05 16	05 38	05 26	04 34	03 32	02 15	///	///
400 mi	///	02 12	03 26	04 13	04 56	05 18	05 06	04 14	03 10	01 43	///	///
500 mi	///	01 36	03 05	03 56	04 40	05 01	04 50	03 57	02 49	01 07	///	///
600 mi	///	00 40	02 46	03 40	04 25	04 46	04 35	03 41	02 30	00 11	///	///
700 mi	///	///	02 28	03 26	04 12	04 34	04 22	03 27	02 12	///	///	///
800 mi	///	///	02 09	03 13	04 00	04 22	04 10	03 14	01 53	///	///	///
900 mi	///	///	01 50	03 00	03 49	04 11	03 59	03 01	01 34	///	///	///
1000 mi	///	///	01 30	02 44	03 39	04 01	03 49	02 45	01 14	///	///	///
1100 mi	///	///	01 06	02 38	03 30	03 52	03 40	02 39	00 50	///	///	///
1200 mi	///	///	00 25	02 26	03 20	03 43	03 30	02 27	00 09	///	///	///
1300 mi	///	///	///	02 16	03 12	03 39	03 22	02 17	///	///	///	///
1400 mi	///	///	///	02 05	03 04	03 27	03 14	02 06	///	///	///	///
1500 mi	///	///	///	01 55	02 56	03 20	03 06	01 56	///	///	///	///

SUNSET (50° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	23 00	21 07	20 01	19 05	18 14	18 03	18 25	19 07	19 51	20 51	22 37	///
300 mi	///	21 44	20 28	19 27	18 36	18 26	18 46	19 28	20 12	21 15	///	///
400 mi	///	22 16	20 50	19 47	18 56	18 46	19 06	19 48	20 34	21 47	///	///
500 mi	///	22 52	21 11	20 04	19 12	19 03	19 22	20 05	20 55	22 23	///	///
600 mi	///	23 48	21 30	20 20	19 27	19 18	19 37	20 21	21 14	23 19	///	///
700 mi	///	///	21 48	20 34	19 40	19 30	19 50	20 35	21 32	///	///	///
800 mi	///	///	22 07	20 47	19 52	19 42	20 02	20 48	21 51	///	///	///
900 mi	///	///	22 26	21 00	20 03	19 53	20 13	21 01	22 10	///	///	///
1000 mi	///	///	22 46	21 16	20 13	20 03	20 23	21 17	22 30	///	///	///
1100 mi	///	///	23 10	21 22	20 22	20 12	20 32	21 23	22 54	///	///	///
1200 mi	///	///	23 51	21 34	20 32	20 21	20 42	21 35	23 35	///	///	///
1300 mi	///	///	///	21 44	20 40	20 25	20 50	21 45	///	///	///	///
1400 mi	///	///	///	21 55	20 48	20 37	20 58	21 56	///	///	///	///
1500 mi	///	///	///	22 05	20 56	20 44	21 06	22 06	///	///	///	///

*For local mean time of satellite, SUBTRACT from local mean time of observer $4^{m}/^{\circ}$ that observer is EAST.

TABLE V – 55° NORTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 55° NORTH LATITUDE

SUNRISE (55° N)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	06 01	05 07	04 00	02 30	///	///	///	02 28	03 37	04 35	05 32	06 05
300 mi	05 33	04 40	03 28	01 41	///	///	///	01 42	03 12	04 11	05 08	05 40
400 mi	05 11	04 17	03 01	00 28	///	///	///	00 29	02 45	03 48	04 46	05 18
500 mi	04 53	03 57	02 35	///	///	///	///	///	02 19	03 28	04 28	04 59
600 mi	04 37	03 39	02 08	///	///	///	///	///	01 52	03 10	04 12	04 43
700 mi	04 22	03 22	01 41	///	///	///	///	///	01 25	02 53	03 57	04 28
800 mi	04 09	03 06	01 07	///	///	///	///	///	00 51	02 37	03 44	04 15
900 mi	03 56	02 51	///	///	///	///	///	///	///	02 22	03 31	04 05
1000 mi	03 44	02 36	///	///	///	///	///	///	///	02 07	03 19	03 52
1100 mi	03 33	02 21	///	///	///	///	///	///	///	01 52	03 08	03 41
1200 mi	03 23	02 06	///	///	///	///	///	///	///	01 37	02 58	03 31
1300 mi	03 13	01 50	///	///	///	///	///	///	///	01 21	02 48	03 22
1400 mi	03 03	01 33	///	///	///	///	///	///	///	01 04	02 38	03 13
1500 mi	02 54	01 13	///	///	///	///	///	///	///	00 44	02 29	03 04

SUNSET (55° N)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	18 22	19 24	20 20	21 36	///	///	///	21 30	20 00	18 52	17 58	17 52
300 mi	18 49	19 48	20 48	22 19	///	///	///	22 20	20 32	19 19	18 24	18 16
400 mi	19 11	20 11	21 15	23 32	///	///	///	23 33	20 59	19 42	18 46	18 38
500 mi	19 29	20 31	21 41	///	///	///	///	///	21 25	20 02	19 04	18 57
600 mi	19 45	20 49	22 08	///	///	///	///	///	21 52	20 20	19 20	19 13
700 mi	20 00	21 06	22 35	///	///	///	///	///	22 19	20 37	19 35	19 28
800 mi	20 13	21 22	23 09	///	///	///	///	///	22 53	20 53	19 48	19 41
900 mi	20 26	21 37	///	///	///	///	///	///	///	21 08	20 01	19 51
1000 mi	20 38	21 52	///	///	///	///	///	///	///	21 23	20 13	20 04
1100 mi	20 49	22 07	///	///	///	///	///	///	///	21 38	20 24	20 15
1200 mi	20 59	22 22	///	///	///	///	///	///	///	21 53	20 34	20 25
1300 mi	21 09	22 38	///	///	///	///	///	///	///	22 09	20 44	20 34
1400 mi	21 19	22 55	///	///	///	///	///	///	///	22 26	20 54	20 43
1500 mi	21 28	23 15	///	///	///	///	///	///	///	22 46	21 03	20 52

TABLE V – 55° SOUTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 55° SOUTH LATITUDE

SUNRISE (55° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	///	02 40	03 54	04 48	05 42	06 08	05 55	04 55	03 52	02 24	///	///
300 mi	///	01 55	03 28	04 26	05 18	05 44	05 28	04 27	03 12	01 26	///	///
400 mi	///	00 42	03 01	04 03	04 56	05 22	05 06	04 04	02 45	00 13	///	///
500 mi	///	///	02 35	03 43	04 38	05 03	04 48	03 44	02 19	///	///	///
600 mi	///	///	02 08	03 25	04 22	04 47	04 32	03 26	01 52	///	///	///
700 mi	///	///	01 41	03 08	04 07	04 32	04 17	03 09	01 25	///	///	///
800 mi	///	///	01 07	02 52	03 54	04 19	04 04	02 53	00 51	///	///	///
900 mi	///	///	///	02 37	03 41	04 09	03 51	02 38	///	///	///	///
1000 mi	///	///	///	02 22	03 29	03 56	03 39	02 23	///	///	///	///
1100 mi	///	///	///	02 07	03 18	03 45	03 28	02 08	///	///	///	///
1200 mi	///	///	///	01 52	03 08	03 35	03 18	01 53	///	///	///	///
1300 mi	///	///	///	01 36	02 58	03 26	03 08	01 37	///	///	///	///
1400 mi	///	///	///	01 19	02 48	03 17	02 58	01 20	///	///	///	///
1500 mi	///	///	///	00 59	02 39	03 08	02 49	01 00	///	///	///	///

SUNSET (55° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	///	21 42	20 18	19 09	18 08	17 60	18 20	19 12	20 08	21 17	///	///
300 mi	///	22 33	20 48	19 34	18 34	18 20	18 44	19 35	20 32	22 04	///	///
400 mi	///	23 46	21 15	19 57	18 56	18 42	19 06	19 58	20 59	23 17	///	///
500 mi	///	///	21 41	20 17	19 14	19 01	19 24	20 18	21 25	///	///	///
600 mi	///	///	22 08	20 35	19 30	19 17	19 40	20 36	21 52	///	///	///
700 mi	///	///	22 35	20 52	19 45	19 32	19 55	20 53	22 19	///	///	///
800 mi	///	///	23 09	21 08	19 58	19 45	20 08	21 09	22 53	///	///	///
900 mi	///	///	///	21 23	20 11	19 55	20 21	21 24	///	///	///	///
1000 mi	///	///	///	21 38	20 23	20 08	20 33	21 39	///	///	///	///
1100 mi	///	///	///	21 53	20 34	20 19	20 46	21 54	///	///	///	///
1200 mi	///	///	///	22 08	20 44	20 29	20 54	22 09	///	///	///	///
1300 mi	///	///	///	22 24	20 54	20 38	21 04	22 25	///	///	///	///
1400 mi	///	///	///	22 41	21 04	20 47	21 14	22 42	///	///	///	///
1500 mi	///	///	///	23 01	21 13	20 56	21 23	23 02	///	///	///	///

*For local mean time of satellite, SUBTRACT from local mean time of observer $4^{m}/^{o}$ that observer is EAST.

TABLE V — 60° NORTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 60° NORTH LATITUDE

SUNRISE (60° N)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	06 08	05 00	03 37	01 22	///	///	///	01 25	03 19	04 29	05 38	06 15
300 mi	05 36	04 29	02 58	///	///	///	///	///	02 42	04 00	05 11	05 46
400 mi	05 11	04 02	02 21	///	///	///	///	///	02 05	03 33	04 46	05 21
500 mi	04 49	03 29	01 40	///	///	///	///	///	01 24	03 00	04 24	05 00
600 mi	04 30	03 16	00 37	///	///	///	///	///	00 21	02 47	04 05	04 41
700 mi	04 13	02 54	///	///	///	///	///	///	///	02 25	03 48	04 24
800 mi	03 57	02 33	///	///	///	///	///	///	///	02 04	03 32	04 09
900 mi	03 43	02 11	///	///	///	///	///	///	///	01 42	03 18	03 55
1000 mi	03 29	01 48	///	///	///	///	///	///	///	01 19	03 04	03 42
1100 mi	03 15	01 20	///	///	///	///	///	///	///	00 51	02 50	03 29
1200 mi	03 02	00 34	///	///	///	///	///	///	///	00 05	02 37	03 17
1300 mi	02 49	///	///	///	///	///	///	///	///	///	02 24	03 06
1400 mi	02 37	///	///	///	///	///	///	///	///	///	02 12	02 55
1500 mi	02 25	///	///	///	///	///	///	///	///	///	02 00	02 44

SUNSET (60° N)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	18 15	19 30	20 43	22 51	///	///	///	22 29	20 21	18 58	17 54	17 41
300 mi	18 46	19 59	21 18	///	///	///	///	///	21 02	19 30	18 21	18 10
400 mi	19 11	20 26	21 55	///	///	///	///	///	21 39	19 57	18 46	18 35
500 mi	19 33	20 59	22 36	///	///	///	///	///	22 20	20 30	19 08	18 56
600 mi	19 52	21 12	23 39	///	///	///	///	///	23 23	20 43	19 27	19 15
700 mi	20 09	21 34	///	///	///	///	///	///	///	21 05	19 44	19 32
800 mi	20 25	21 55	///	///	///	///	///	///	///	21 26	20 00	19 47
900 mi	20 39	22 17	///	///	///	///	///	///	///	21 48	20 14	20 01
1000 mi	20 53	22 40	///	///	///	///	///	///	///	22 11	20 28	20 14
1100 mi	21 07	23 08	///	///	///	///	///	///	///	22 39	20 42	20 27
1200 mi	21 20	23 54	///	///	///	///	///	///	///	23 25	20 55	20 39
1300 mi	21 33	///	///	///	///	///	///	///	///	///	21 08	20 50
1400 mi	21 45	///	///	///	///	///	///	///	///	///	21 20	21 01
1500 mi	21 57	///	///	///	///	///	///	///	///	///	21 32	21 12

TABLE V — 60° SOUTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 60° SOUTH LATITUDE

SUNRISE (60° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	///	01 37	03 31	04 42	05 48	06 18	06 01	04 48	03 18	01 15	///	///
300 mi	///	///	02 58	04 15	05 21	05 50	05 31	04 16	02 42	///	///	///
400 mi	///	///	02 21	03 48	04 56	05 25	05 06	03 49	02 05	///	///	///
500 mi	///	///	01 40	03 15	04 34	05 04	04 44	03 16	01 24	///	///	///
600 mi	///	///	00 37	03 02	04 15	04 45	04 25	03 03	00 21	///	///	///
700 mi	///	///	///	02 40	03 58	04 28	04 08	02 41	///	///	///	///
800 mi	///	///	///	02 19	03 42	04 13	03 52	02 20	///	///	///	///
900 mi	///	///	///	01 57	03 28	03 59	03 38	01 58	///	///	///	///
1000 mi	///	///	///	01 34	03 14	03 46	03 24	01 35	///	///	///	///
1100 mi	///	///	///	01 06	03 00	03 33	03 10	01 07	///	///	///	///
1200 mi	///	///	///	00 20	02 47	03 21	02 57	00 21	///	///	///	///
1300 mi	///	///	///	///	02 34	03 10	02 44	///	///	///	///	///
1400 mi	///	///	///	///	02 22	02 59	02 32	///	///	///	///	///
1500 mi	///	///	///	///	02 10	02 48	02 20	///	///	///	///	///

SUNSET (60° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	///	22 41	20 40	19 16	18 04	17 51	18 14	19 18	20 32	22 28	///	///
300 mi	///	///	21 18	19 45	18 31	18 14	18 41	19 46	21 02	///	///	///
400 mi	///	///	21 55	20 12	18 56	18 39	19 06	20 13	21 39	///	///	///
500 mi	///	///	22 36	20 45	19 18	19 00	19 28	20 46	22 20	///	///	///
600 mi	///	///	23 39	20 58	19 37	19 19	19 47	20 59	23 23	///	///	///
700 mi	///	///	///	21 20	19 54	19 36	20 04	21 21	///	///	///	///
800 mi	///	///	///	21 41	20 10	19 51	20 20	21 42	///	///	///	///
900 mi	///	///	///	22 03	20 24	20 05	20 34	22 04	///	///	///	///
1000 mi	///	///	///	22 26	20 38	20 18	20 48	22 27	///	///	///	///
1100 mi	///	///	///	22 54	20 52	20 31	21 02	22 55	///	///	///	///
1200 mi	///	///	///	23 40	21 05	20 43	21 15	23 41	///	///	///	///
1300 mi	///	///	///	///	21 18	20 54	21 28	///	///	///	///	///
1400 mi	///	///	///	///	21 30	21 05	21 40	///	///	///	///	///
1500 mi	///	///	///	///	21 42	21 16	21 52	///	///	///	///	///

*For local mean time of satellite, SUBTRACT from local mean time of observer $4^{m/o}$ that observer is EAST.

TABLE V — 65° NORTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 65° NORTH LATITUDE

SUNRISE (65° N)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	06 11	04 48	03 00	///	///	///	///	///	02 44	04 19	05 46	06 29
300 mi	05 37	04 12	02 05	///	///	///	///	///	01 49	03 43	05 12	05 54
400 mi	05 08	03 39	00 40	///	///	///	///	///	00 24	03 10	04 43	05 24
500 mi	04 42	03 08	///	///	///	///	///	///	///	02 39	04 17	04 59
600 mi	04 19	02 36	///	///	///	///	///	///	///	02 07	03 54	04 37
700 mi	03 58	02 03	///	///	///	///	///	///	///	01 34	03 33	04 17
800 mi	03 39	01 23	///	///	///	///	///	///	///	00 54	03 14	03 58
900 mi	03 20	///	///	///	///	///	///	///	///	///	02 55	03 41
1000 mi	03 02	///	///	///	///	///	///	///	///	///	02 37	03 24
1100 mi	02 43	///	///	///	///	///	///	///	///	///	02 18	03 09
1200 mi	02 24	///	///	///	///	///	///	///	///	///	01 59	02 55
1300 mi	02 06	///	///	///	///	///	///	///	///	///	01 41	02 38
1400 mi	01 44	///	///	///	///	///	///	///	///	///	01 19	02 23
1500 mi	01 21	///	///	///	///	///	///	///	///	///	00 56	02 08

SUNSET (65° N)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	18 11	19 40	21 16	///	///	///	///	///	21 00	19 11	17 46	17 27
300 mi	18 45	20 16	22 11	///	///	///	///	///	21 55	19 47	18 20	18 02
400 mi	19 14	20 49	23 36	///	///	///	///	///	23 20	20 20	18 49	18 32
500 mi	19 40	21 20	///	///	///	///	///	///	///	20 51	19 15	18 57
600 mi	20 03	21 52	///	///	///	///	///	///	///	21 23	19 38	19 19
700 mi	20 24	22 25	///	///	///	///	///	///	///	21 56	19 59	19 39
800 mi	20 43	23 05	///	///	///	///	///	///	///	22 36	20 18	19 58
900 mi	21 02	///	///	///	///	///	///	///	///	///	20 37	20 15
1000 mi	21 20	///	///	///	///	///	///	///	///	///	20 55	20 32
1100 mi	21 39	///	///	///	///	///	///	///	///	///	21 14	20 47
1200 mi	21 58	///	///	///	///	///	///	///	///	///	21 33	21 01
1300 mi	22 16	///	///	///	///	///	///	///	///	///	21 51	21 18
1400 mi	22 38	///	///	///	///	///	///	///	///	///	22 13	21 33
1500 mi	23 01	///	///	///	///	///	///	///	///	///	22 36	21 48

TABLE V — 65° SOUTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 65° SOUTH LATITUDE

SUNRISE (65° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	///	///	02 60	04 34	05 56	06 33	06 06	04 35	02 44	///	///	///
300 mi	///	///	02 05	03 58	05 22	05 58	05 32	03 59	01 49	///	///	///
400 mi	///	///	00 40	03 25	04 53	05 28	05 03	03 26	00 24	///	///	///
500 mi	///	///	///	02 54	04 27	05 03	04 37	02 55	///	///	///	///
600 mi	///	///	///	02 22	04 04	04 41	04 14	02 23	///	///	///	///
700 mi	///	///	///	01 49	03 43	04 21	03 53	01 50	///	///	///	///
800 mi	///	///	///	01 09	03 24	04 02	03 34	01 10	///	///	///	///
900 mi	///	///	///	///	03 05	03 45	03 15	///	///	///	///	///
1000 mi	///	///	///	///	02 47	03 28	02 57	///	///	///	///	///
1100 mi	///	///	///	///	02 28	03 13	02 38	///	///	///	///	///
1200 mi	///	///	///	///	02 09	02 59	02 19	///	///	///	///	///
1300 mi	///	///	///	///	01 51	02 42	02 01	///	///	///	///	///
1400 mi	///	///	///	///	01 29	02 27	01 39	///	///	///	///	///
1500 mi	///	///	///	///	01 06	02 12	01 16	///	///	///	///	///

SUNSET (65° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	///	///	21 16	19 26	17 56	17 31	18 06	19 27	21 00	///	///	///
300 mi	///	///	22 11	20 02	18 30	18 06	18 40	20 03	21 55	///	///	///
400 mi	///	///	23 36	20 35	18 59	18 36	19 09	20 36	23 20	///	///	///
500 mi	///	///	///	21 06	19 25	19 01	19 35	21 07	///	///	///	///
600 mi	///	///	///	21 38	19 48	19 23	19 58	21 39	///	///	///	///
700 mi	///	///	///	22 11	20 09	19 43	20 19	22 12	///	///	///	///
800 mi	///	///	///	22 51	20 28	20 02	20 38	22 52	///	///	///	///
900 mi	///	///	///	///	20 47	20 19	20 57	///	///	///	///	///
1000 mi	///	///	///	///	21 05	20 36	21 15	///	///	///	///	///
1100 mi	///	///	///	///	21 24	20 51	21 34	///	///	///	///	///
1200 mi	///	///	///	///	21 43	21 05	21 53	///	///	///	///	///
1300 mi	///	///	///	///	22 01	21 22	22 11	///	///	///	///	///
1400 mi	///	///	///	///	22 23	21 37	22 33	///	///	///	///	///
1500 mi	///	///	///	///	22 46	21 52	22 56	///	///	///	///	///

*For local mean time of satellite, SUBTRACT from local mean time of observer $4^{m}/^{\circ}$ that observer is EAST.

TABLE V — 70° NORTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 70° NORTH LATITUDE

SUNRISE (70° N)

SATELLITE HEIGHTS	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	06 20	04 31	01 50	///	///	///	///	///	01 34	04 02	05 55	06 46
300 mi	05 37	03 44	///	///	///	///	///	///	///	03 15	05 12	06 03
400 mi	05 01	02 54	///	///	///	///	///	///	///	02 25	04 36	05 26
500 mi	04 29	02 07	///	///	///	///	///	///	///	01 38	04 04	04 55
600 mi	03 59	00 53	///	///	///	///	///	///	///	00 24	03 34	04 27
700 mi	03 32	///	///	///	///	///	///	///	///	///	03 07	04 02
800 mi	03 05	///	///	///	///	///	///	///	///	///	02 40	03 38
900 mi	02 37	///	///	///	///	///	///	///	///	///	02 12	03 15
1000 mi	02 08	///	///	///	///	///	///	///	///	///	01 43	02 52
1100 mi	01 33	///	///	///	///	///	///	///	///	///	01 08	02 30
1200 mi	00 35	///	///	///	///	///	///	///	///	///	00 10	02 10
1300 mi	///	///	///	///	///	///	///	///	///	///	///	01 39
1400 mi	///	///	///	///	///	///	///	///	///	///	///	01 08
1500 mi	///	///	///	///	///	///	///	///	///	///	///	23 58

SUNSET (70° N)

SATELLITE HEIGHTS	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	18 02	19 57	22 26	///	///	///	///	///	22 10	19 28	17 37	17 10
300 mi	18 45	20 44	///	///	///	///	///	///	///	20 15	18 20	17 53
400 mi	19 21	21 54	///	///	///	///	///	///	///	21 05	18 56	18 30
500 mi	19 53	22 21	///	///	///	///	///	///	///	21 52	19 28	19 01
600 mi	20 23	23 35	///	///	///	///	///	///	///	23 06	19 58	19 29
700 mi	20 50	///	///	///	///	///	///	///	///	///	20 25	19 54
800 mi	21 17	///	///	///	///	///	///	///	///	///	20 52	20 18
900 mi	21 45	///	///	///	///	///	///	///	///	///	21 20	20 41
1000 mi	22 14	///	///	///	///	///	///	///	///	///	21 49	21 04
1100 mi	22 49	///	///	///	///	///	///	///	///	///	22 24	21 26
1200 mi	23 47	///	///	///	///	///	///	///	///	///	23 50	21 46
1300 mi	///	///	///	///	///	///	///	///	///	///	///	22 17
1400 mi	///	///	///	///	///	///	///	///	///	///	///	22 48
1500 mi	///	///	///	///	///	///	///	///	///	///	///	23 58

TABLE V — 70° SOUTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 70° SOUTH LATITUDE

SUNRISE (70° S)

SATELLITE HEIGHTS	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	///	///	01 50	04 17	06 05	06 50	06 15	04 18	01 34	///	///	///
300 mi	///	///	///	03 30	05 21	06 07	05 31	03 31	///	///	///	///
400 mi	///	///	///	02 40	04 46	05 30	04 56	02 41	///	///	///	///
500 mi	///	///	///	01 53	04 14	04 59	04 24	01 54	///	///	///	///
600 mi	///	///	///	00 39	03 44	04 31	03 54	00 40	///	///	///	///
700 mi	///	///	///	///	03 17	04 06	03 27	///	///	///	///	///
800 mi	///	///	///	///	02 50	03 42	03 00	///	///	///	///	///
900 mi	///	///	///	///	02 22	03 19	02 32	///	///	///	///	///
1000 mi	///	///	///	///	01 53	02 56	02 03	///	///	///	///	///
1100 mi	///	///	///	///	01 18	02 34	01 28	///	///	///	///	///
1200 mi	///	///	///	///	00 20	02 14	00 30	///	///	///	///	///
1300 mi	///	///	///	///	///	01 43	///	///	///	///	///	///
1400 mi	///	///	///	///	///	01 12	///	///	///	///	///	///
1500 mi	///	///	///	///	///	00 02	///	///	///	///	///	///

SUNSET (70° S)

SATELLITE HEIGHTS	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	///	///	22 26	19 43	17 47	17 14	17 57	19 44	22 10	///	///	///
300 mi	///	///	///	20 30	18 30	17 57	18 40	20 31	///	///	///	///
400 mi	///	///	///	21 20	19 06	18 34	19 16	21 21	///	///	///	///
500 mi	///	///	///	22 07	19 38	19 05	19 48	22 08	///	///	///	///
600 mi	///	///	///	23 21	20 08	19 33	20 18	23 22	///	///	///	///
700 mi	///	///	///	///	20 35	19 58	20 45	///	///	///	///	///
800 mi	///	///	///	///	21 02	20 22	21 12	///	///	///	///	///
900 mi	///	///	///	///	21 30	20 45	21 40	///	///	///	///	///
1000 mi	///	///	///	///	21 59	21 08	22 09	///	///	///	///	///
1100 mi	///	///	///	///	22 34	21 30	22 44	///	///	///	///	///
1200 mi	///	///	///	///	23 32	21 50	23 42	///	///	///	///	///
1300 mi	///	///	///	///	///	22 21	///	///	///	///	///	///
1400 mi	///	///	///	///	///	22 52	///	///	///	///	///	///
1500 mi	///	///	///	///	///	00 02	///	///	///	///	///	///

*For local mean time of satellite, SUBTRACT from local mean time of observer $4^m/^\circ$ that observer is EAST.

TABLE V — 80° NORTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 80° NORTH LATITUDE

SUNRISE (80° N)

SATELLITE HEIGHTS	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	06 50	02 39	///	///	///	///	///	///	///	02 10	06 25	08 05
300 mi	05 26	///	///	///	///	///	///	///	///	///	05 01	06 33
400 mi	04 11	///	///	///	///	///	///	///	///	///	03 46	05 21
500 mi	02 55	///	///	///	///	///	///	///	///	///	02 30	04 18
600 mi	01 02	///	///	///	///	///	///	///	///	///	00 37	03 16
700 mi	///	///	///	///	///	///	///	///	///	///	///	02 08
800 mi	///	///	///	///	///	///	///	///	///	///	///	///
900 mi	///	///	///	///	///	///	///	///	///	///	///	///
1000 mi	///	///	///	///	///	///	///	///	///	///	///	///
1100 mi	///	///	///	///	///	///	///	///	///	///	///	///
1200 mi	///	///	///	///	///	///	///	///	///	///	///	///
1300 mi	///	///	///	///	///	///	///	///	///	///	///	///
1400 mi	///	///	///	///	///	///	///	///	///	///	///	///
1500 mi	///	///	///	///	///	///	///	///	///	///	///	///

SUNSET (80° N)

SATELLITE HEIGHTS	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	17 32	21 49	///	///	///	///	///	///	///	21 20	17 07	15 51
300 mi	18 56	///	///	///	///	///	///	///	///	///	18 31	17 23
400 mi	19 11	///	///	///	///	///	///	///	///	///	19 46	18 35
500 mi	21 27	///	///	///	///	///	///	///	///	///	21 02	19 38
600 mi	23 20	///	///	///	///	///	///	///	///	///	22 55	20 40
700 mi	///	///	///	///	///	///	///	///	///	///	///	21 48
800 mi	///	///	///	///	///	///	///	///	///	///	///	///
900 mi	///	///	///	///	///	///	///	///	///	///	///	///
1000 mi	///	///	///	///	///	///	///	///	///	///	///	///
1100 mi	///	///	///	///	///	///	///	///	///	///	///	///
1200 mi	///	///	///	///	///	///	///	///	///	///	///	///
1300 mi	///	///	///	///	///	///	///	///	///	///	///	///
1400 mi	///	///	///	///	///	///	///	///	///	///	///	///
1500 mi	///	///	///	///	///	///	///	///	///	///	///	///

TABLE V — 80° SOUTH

LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 80° SOUTH LATITUDE

SUNRISE (80° S)

SATELLITE HEIGHTS	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	///	///	///	02 25	06 35	08 09	06 45	02 26	///	///	///	///
300 mi	///	///	///	///	05 11	06 37	05 21	///	///	///	///	///
400 mi	///	///	///	///	03 56	05 25	04 06	///	///	///	///	///
500 mi	///	///	///	///	02 40	04 22	02 50	///	///	///	///	///
600 mi	///	///	///	///	00 47	03 20	00 57	///	///	///	///	///
700 mi	///	///	///	///	///	02 12	///	///	///	///	///	///
800 mi	///	///	///	///	///	///	///	///	///	///	///	///
900 mi	///	///	///	///	///	///	///	///	///	///	///	///
1000 mi	///	///	///	///	///	///	///	///	///	///	///	///
1100 mi	///	///	///	///	///	///	///	///	///	///	///	///
1200 mi	///	///	///	///	///	///	///	///	///	///	///	///
1300 mi	///	///	///	///	///	///	///	///	///	///	///	///
1400 mi	///	///	///	///	///	///	///	///	///	///	///	///
1500 mi	///	///	///	///	///	///	///	///	///	///	///	///

SUNSET (80° S)

SATELLITE HEIGHTS	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	///	///	///	21 35	17 17	15 55	17 27	21 36	///	///	///	///
300 mi	///	///	///	///	18 41	17 27	18 51	///	///	///	///	///
400 mi	///	///	///	///	19 56	18 39	20 06	///	///	///	///	///
500 mi	///	///	///	///	21 12	19 42	21 22	///	///	///	///	///
600 mi	///	///	///	///	23 05	20 44	23 15	///	///	///	///	///
700 mi	///	///	///	///	///	21 52	///	///	///	///	///	///
800 mi	///	///	///	///	///	///	///	///	///	///	///	///
900 mi	///	///	///	///	///	///	///	///	///	///	///	///
1000 mi	///	///	///	///	///	///	///	///	///	///	///	///
1100 mi	///	///	///	///	///	///	///	///	///	///	///	///
1200 mi	///	///	///	///	///	///	///	///	///	///	///	///
1300 mi	///	///	///	///	///	///	///	///	///	///	///	///
1400 mi	///	///	///	///	///	///	///	///	///	///	///	///
1500 mi	///	///	///	///	///	///	///	///	///	///	///	///

*For local mean time of satellite, SUBTRACT from local mean time of observer $4^{m}/^{\circ}$ that observer is EAST.

TABLE V — 85° NORTH
LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 85° NORTH LATITUDE

SUNRISE (85° N)

SATELLITE HEIGHTS	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	7 42	///	///	///	///	///	///	///	///	///	7 17	#
300 mi	4 52	///	///	///	///	///	///	///	///	///	4 27	7 18
400 mi	1 25	///	///	///	///	///	///	///	///	///	7 00	4 56
500 mi	///	///	///	///	///	///	///	///	///	///	///	2 31
600 mi	///	///	///	///	///	///	///	///	///	///	///	///
700 mi	///	///	///	///	///	///	///	///	///	///	///	///
800 mi	///	///	///	///	///	///	///	///	///	///	///	///
900 mi	///	///	///	///	///	///	///	///	///	///	///	///
1000 mi	///	///	///	///	///	///	///	///	///	///	///	///
1100 mi	///	///	///	///	///	///	///	///	///	///	///	///
1200 mi	///	///	///	///	///	///	///	///	///	///	///	///
1300 mi	///	///	///	///	///	///	///	///	///	///	///	///
1400 mi	///	///	///	///	///	///	///	///	///	///	///	///
1500 mi	///	///	///	///	///	///	///	///	///	///	///	///

SUNSET (85° N)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	16 40	///	///	///	///	///	///	///	///	///	16 15	#
300 mi	19 30	///	///	///	///	///	///	///	///	///	19 05	16 38
400 mi	22 57	///	///	///	///	///	///	///	///	///	22 32	19 00
500 mi	///	///	///	///	///	///	///	///	///	///	///	21 25
600 mi	///	///	///	///	///	///	///	///	///	///	///	///
700 mi	///	///	///	///	///	///	///	///	///	///	///	///
800 mi	///	///	///	///	///	///	///	///	///	///	///	///
900 mi	///	///	///	///	///	///	///	///	///	///	///	///
1000 mi	///	///	///	///	///	///	///	///	///	///	///	///
1100 mi	///	///	///	///	///	///	///	///	///	///	///	///
1200 mi	///	///	///	///	///	///	///	///	///	///	///	///
1300 mi	///	///	///	///	///	///	///	///	///	///	///	///
1400 mi	///	///	///	///	///	///	///	///	///	///	///	///
1500 mi	///	///	///	///	///	///	///	///	///	///	///	///

TABLE V — 85° SOUTH
LOCAL MEAN TIMES* OF SUNRISE AND SUNSET AT VARIOUS SATELLITE HEIGHTS ON SELECTED DATES FOR 85° SOUTH LATITUDE

SUNRISE (10° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	///	///	///	///	7 27	#	7 37	///	///	///	///	///
300 mi	///	///	///	///	4 37	7 22	4 47	///	///	///	///	///
400 mi	///	///	///	///	1 10	5 00	1 20	///	///	///	///	///
500 mi	///	///	///	///	///	2 35	///	///	///	///	///	///
600 mi	///	///	///	///	///	///	///	///	///	///	///	///
700 mi	///	///	///	///	///	///	///	///	///	///	///	///
800 mi	///	///	///	///	///	///	///	///	///	///	///	///
900 mi	///	///	///	///	///	///	///	///	///	///	///	///
1000 mi	///	///	///	///	///	///	///	///	///	///	///	///
1100 mi	///	///	///	///	///	///	///	///	///	///	///	///
1200 mi	///	///	///	///	///	///	///	///	///	///	///	///
1300 mi	///	///	///	///	///	///	///	///	///	///	///	///
1400 mi	///	///	///	///	///	///	///	///	///	///	///	///
1500 mi	///	///	///	///	///	///	///	///	///	///	///	///

SUNSET (85° S)

Satellite Heights	JAN 19 h m	FEB 23 h m	MAR 21 h m	APR 16 h m	MAY 21 h m	JUN 22 h m	JUL 24 h m	AUG 28 h m	SEP 24 h m	OCT 20 h m	NOV 22 h m	DEC 22 h m
200 mi	///	///	///	///	16 25	#	16 35	///	///	///	///	///
300 mi	///	///	///	///	19 15	16 42	19 25	///	///	///	///	///
400 mi	///	///	///	///	22 42	19 04	22 52	///	///	///	///	///
500 mi	///	///	///	///	///	21 29	///	///	///	///	///	///
600 mi	///	///	///	///	///	///	///	///	///	///	///	///
700 mi	///	///	///	///	///	///	///	///	///	///	///	///
800 mi	///	///	///	///	///	///	///	///	///	///	///	///
900 mi	///	///	///	///	///	///	///	///	///	///	///	///
1000 mi	///	///	///	///	///	///	///	///	///	///	///	///
1100 mi	///	///	///	///	///	///	///	///	///	///	///	///
1200 mi	///	///	///	///	///	///	///	///	///	///	///	///
1300 mi	///	///	///	///	///	///	///	///	///	///	///	///
1400 mi	///	///	///	///	///	///	///	///	///	///	///	///
1500 mi	///	///	///	///	///	///	///	///	///	///	///	///

*For local mean time of satellite, SUBTRACT from local mean time of observer $4^{m/o}$ that observer is EAST.

#Never Sunlit.

CHART FOR DETERMINING ELEVATION & SLANT RANGE OF SATELLITE

ALL DISTANCES ARE IN STATUTE MILES - 5 STATUTE MILES EQUAL APPROXIMATELY 8 KILOMETERS.

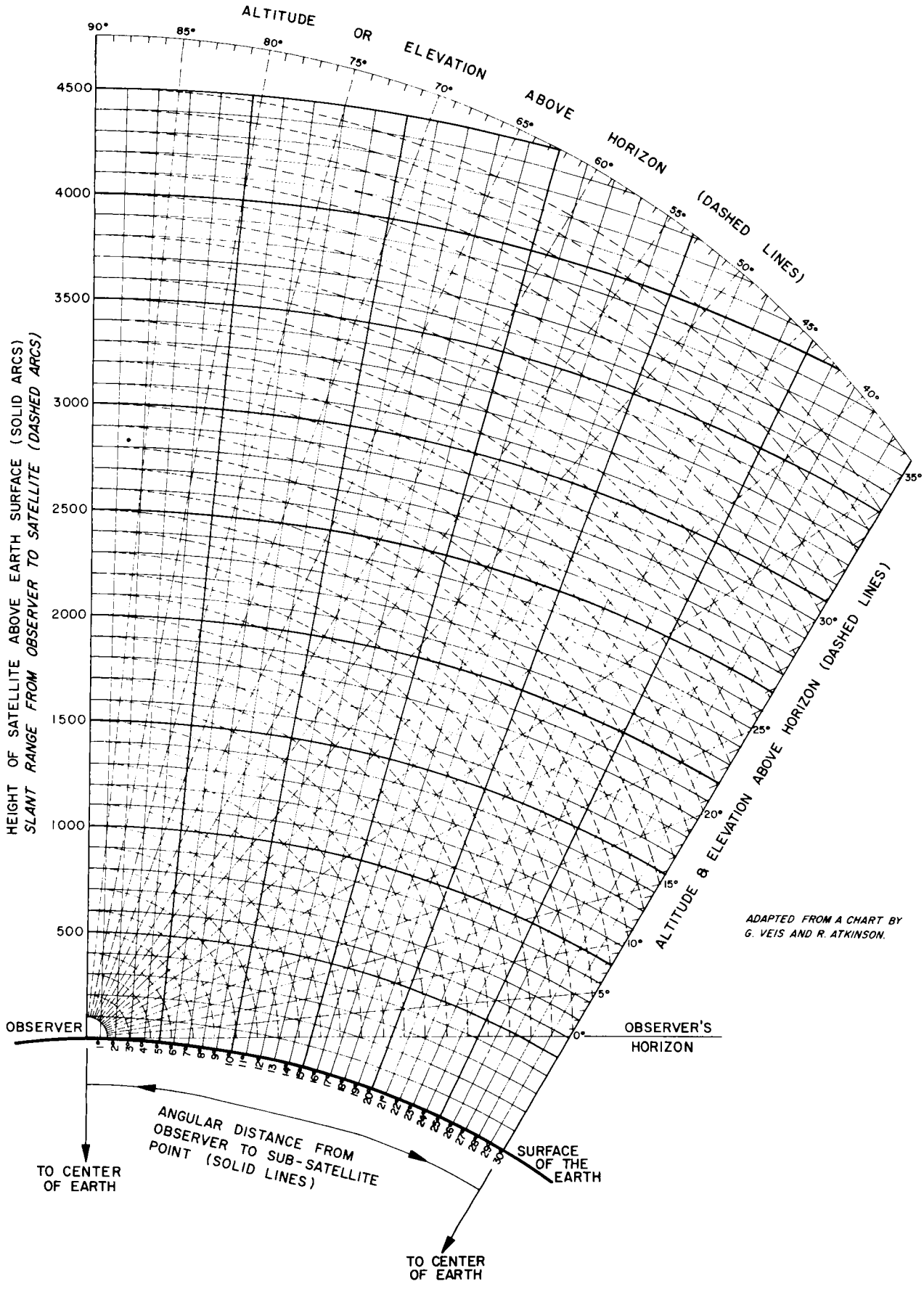


TABLE VI — NORTH

LOCAL MEAN TIMES* OF END AND OF BEGINNING OF NAUTICAL TWILIGHT ON SELECTED DATES AT STATIONS FROM 0° TO 64° NORTH LATITUDE

NAUTICAL TWILIGHT ENDS

	STATION LATITUDE															
	0°	10°	20°	30°	35°	40°	45°	50°	52°	54°	56°	58°	60°	62°	64°
DATE	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
JAN 19	05 20	05 34	05 47	06 01	06 08	06 15	06 23	06 32	06 36	06 41	06 45	06 50	06 56	07 02	07 08
FEB 22	05 25	05 32	05 37	05 42	05 44	05 45	05 47	05 48	05 49	05 49	05 49	05 49	05 49	05 49	05 49
MAR 21	05 19	05 19	05 16	05 12	05 08	05 04	04 59	04 52	04 48	04 45	04 40	04 35	04 29	04 22	04 14
APR 16	05 11	05 03	04 52	04 38	04 29	04 18	04 05	03 48	03 39	03 30	03 19	03 06	02 50	02 31	02 06
MAY 21	05 05	04 49	04 30	04 06	03 50	03 31	03 07	02 33	02 16	01 53	01 22	00 21	///	///	///
JUN 22	05 09	04 50	04 28	03 59	03 40	03 17	02 46	02 00	01 34	00 45	///	///	///	///	///
JUL 24	05 15	05 00	04 41	04 16	04 01	03 42	03 18	02 44	02 26	02 04	01 34	00 34	///	///	///
AUG 28	05 13	05 05	04 54	04 40	04 31	04 21	04 07	03 50	03 41	03 32	03 21	03 08	02 52	02 33	02 07
SEP 24	05 05	05 04	05 01	04 57	04 53	04 49	04 44	04 37	04 33	04 29	04 25	04 20	04 14	04 07	03 58
OCT 20	04 56	05 03	05 08	05 13	05 15	05 16	05 18	05 19	05 19	05 19	05 20	05 20	05 20	05 19	05 19
NOV 22	04 55	05 09	05 22	05 36	05 43	05 50	05 58	06 07	06 11	06 15	06 19	06 24	06 30	06 35	06 42
DEC 22	05 06	05 23	05 39	05 56	06 04	06 14	06 24	06 36	06 41	06 47	06 53	07 00	07 07	07 16	07 25

NAUTICAL TWILIGHT BEGINS

	STATION LATITUDE															
	0°	10°	20°	30°	35°	40°	45°	50°	52°	54°	56°	58°	60°	62°	64°
DATE	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
JAN 19	19 02	18 48	18 35	18 21	18 14	18 07	17 59	17 50	17 46	17 42	17 37	17 32	17 27	17 21	17 14
FEB 22	19 02	18 56	18 50	18 46	18 44	18 42	18 41	18 40	18 40	18 40	18 39	18 39	18 39	18 40	18 40
MAR 21	18 55	18 56	18 59	19 03	19 07	19 11	19 17	19 24	19 28	19 32	19 37	19 42	19 48	19 55	20 04
APR 16	18 48	18 57	19 08	19 22	19 31	19 42	19 56	20 13	20 22	20 32	20 43	20 57	21 13	21 33	21 59
MAY 21	18 48	19 09	19 23	19 48	20 03	20 22	20 47	21 21	21 39	22 02	22 34	///	///	///	///
JUN 22	18 54	19 13	19 36	20 05	20 29	20 47	21 18	22 03	22 31	23 11	///	///	///	///	///
JUL 24	18 57	19 13	19 32	19 56	20 12	20 30	20 54	21 27	21 45	22 06	22 36	23 28	///	///	///
AUG 28	18 50	18 58	19 09	19 22	19 31	19 42	19 55	20 12	20 20	20 30	20 41	20 53	21 08	21 27	21 51
SEP 24	18 40	18 41	18 43	18 48	18 51	18 55	19 00	19 07	19 11	19 15	19 19	19 24	19 30	19 37	19 45
OCT 20	18 34	18 27	18 21	18 17	18 15	18 13	18 11	18 10	18 10	18 10	18 09	18 09	18 09	18 09	18 10
NOV 22	18 37	18 23	18 10	17 56	17 49	17 42	17 34	17 25	17 21	17 17	17 12	17 07	17 02	16 56	16 49
DEC 22	18 51	18 34	18 18	18 01	17 52	17 43	17 33	17 21	17 16	17 09	17 03	16 56	16 49	16 41	16 31

Compiled from the American Nautical Almanac for the year 1958.

*For local mean time of observer, SUBTRACT from station time (ST) $4^{m}/^{\circ}$ that observer is WEST of central meridian of station time zone. If station time (ST) is N hours earlier than Greenwich Mean Time, the central meridian is (15° TIMES N) WEST of Greenwich.

TABLE VI — SOUTH

LOCAL MEAN TIMES* OF END AND OF BEGINNING OF NAUTICAL TWILIGHT ON SELECTED DATES AT STATIONS FROM 0° TO 60° SOUTH LATITUDE

NAUTICAL TWILIGHT ENDS

	STATION LATITUDES												
	0°	10°	20°	30°	35°	40°	45°	50°	52°	54°	56°	58°	60°
DATE	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
JAN 19	05 20	05 03	04 44	04 19	04 03	03 44	03 19	02 44	02 25	02 02	01 28	///	///
FEB 22	05 25	05 16	05 06	04 52	04 43	04 32	04 18	04 01	03 52	03 43	03 32	03 18	03 03
MAR 21	05 19	05 19	05 16	05 12	05 09	05 05	04 59	04 52	04 49	04 45	04 41	04 36	04 30
APR 16	05 11	05 18	05 23	05 28	05 30	05 31	05 33	05 34	05 34	05 35	05 35	05 35	05 35
MAY 21	05 05	05 19	05 33	05 46	05 53	06 00	06 08	06 16	06 20	06 24	06 29	06 34	06 39
JUN 22	05 09	05 26	05 43	05 59	06 08	06 17	06 28	06 40	06 45	06 50	06 57	07 03	07 11
JUL 24	05 15	05 29	05 42	05 56	06 02	06 09	06 17	06 26	06 30	06 34	06 38	06 43	06 48
AUG 28	05 13	05 20	05 25	05 29	05 31	05 33	05 34	05 36	05 36	05 36	05 37	05 37	05 37
SEP 24	05 05	05 04	05 02	04 57	04 54	04 50	04 45	04 38	04 34	04 31	04 26	04 21	04 15
OCT 20	04 56	04 48	04 38	04 24	04 15	04 04	03 51	03 34	03 25	03 16	03 05	02 52	02 37
NOV 22	04 55	04 39	04 20	03 55	03 39	03 20	02 56	02 22	02 03	01 41	01 09	///	///
DEC 22	05 06	04 47	04 24	03 55	03 37	03 13	02 43	01 57	01 29	00 41	///	///	///

NAUTICAL TWILIGHT BEGINS

	STATION LATITUDES												
	0°	10°	20°	30°	35°	40°	45°	50°	52°	54°	56°	58°	60°
DATE	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
JAN 19	19 02	19 18	19 38	20 02	20 18	20 37	21 02	21 36	21 54	21 17	22 49	///	///
FEB 22	19 02	19 11	19 21	19 35	19 44	19 54	20 08	20 25	20 33	20 43	20 54	21 06	21 22
MAR 21	18 55	18 56	18 58	19 02	19 05	19 09	19 14	19 21	19 25	19 29	19 33	19 38	19 44
APR 16	18 48	18 41	18 36	18 31	18 29	18 27	18 26	18 24	18 24	18 24	18 23	18 23	18 23
MAY 21	18 48	18 33	18 20	18 07	18 00	17 53	17 45	17 36	17 32	17 28	17 23	17 19	17 13
JUN 22	18 54	18 37	18 21	18 04	17 56	17 46	17 36	17 24	17 19	17 13	17 07	17 00	16 52
JUL 24	18 57	18 44	18 31	18 18	18 11	18 04	17 56	17 48	17 44	17 40	17 35	17 31	17 26
AUG 28	18 50	18 44	18 38	18 34	18 32	18 31	18 29	18 28	18 28	18 28	18 28	18 28	18 28
SEP 24	18 40	18 41	18 44	18 48	18 52	18 56	19 01	19 08	19 12	19 16	19 21	19 26	19 32
OCT 20	18 34	18 42	18 53	19 07	19 16	19 27	19 40	19 58	20 06	20 06	20 27	20 40	20 56
NOV 22	18 37	18 53	19 13	19 38	19 53	20 13	20 38	21 12	21 31	21 54	22 27	///	///
DEC 22	18 51	19 10	19 33	20 02	20 20	20 44	21 14	22 00	22 28	23 15	///	///	///

Compiled from the American Nautical Almanac for the year 1958.

*For local mean time of observer, SUBTRACT from station time (ST) $4^m/^\circ$ that observer is WEST of central meridian of station time zone. If station time (ST) is N hours earlier than Greenwich Mean Time, the central meridian is (15° TIMES N) WEST of Greenwich.

APPENDIX 1 - Formulas Used In Preparing Tables

Table I: $\lambda = \arcsin(\tan \phi / \tan i)$;

Table II: $\alpha = \arcsin(\sin \phi / \sin i)$; and,

Table III a: $EPP = \frac{t}{T} = \frac{M}{2\pi} = \frac{E - e \sin E}{2\pi}$

Table III b: $RDF = r_v / r_p = \frac{1 + e}{1 + e \cos v}$

Table IV*: $\gamma = \arcsin\left(\frac{1440 \cos i - T \cos^2 \phi}{1440 \cos \phi - T \cos i \cos \phi}\right)$

Where: λ is minimum longitude of northbound node measured westward from foot of observer's meridian on the equator;

ϕ is latitude of meridian point;

i is orbit inclination;

α is initial central angle within orbit plane between equator and reference latitude;

EPP is equivalent percent of period;

t is time in minutes since perigee;

T is period in minutes;

M is mean anomaly measured in radians;

E is eccentric anomaly;

e is eccentricity.

RDF is radial distance factor.

r_v is radial distance of satellite at v.

r_p is radial distance of satellite at perigee.

γ is heading along satellite track.

v is true anomaly: the current position of satellite within orbit plane measured at the center of the earth from perigee in the direction of the satellite's motion and is related to E as follows:

$$\tan \frac{E}{2} = \left(\frac{1 - e}{1 + e}\right)^{\frac{1}{2}} \tan \frac{v}{2}$$

*Table IV is computed for a 105 minute period; note that the formula does not take into account the effect of precession of the orbit plane, which would not significantly affect the accuracy of the table.

APPENDIX 2 - Communication of Modified Orbital Elements

A. SUMMARY -- Modified orbital elements are communicated by radio and by mail. The world-wide radio teletype channel is the IGY World Warning Agency. Data are sent over this channel in the SATOR code explained below in section B. Within the United States (including Alaska), Hawaii, Puerto Rico and adjacent portions of Canada and Mexico, the radio channel is the Civil Air Patrol voice communications network, which broadcasts modified elements in uncoded form (see section C). In addition to these radio services, many volunteer participants receive modified elements by mail from the appropriate volunteer headquarters (see section D). Section E explains the relationship between modified orbital elements and a more traditional form.

B. IGY WORLD WARNING AGENCY: WORLD-WIDE RADIO TELETYPE SERVICE TO REGIONAL IGY WARNING CENTERS — This communication channel carries various types of IGY information, e.g. solar activity. The Comité Special Année Géophysique Internationale (CSAGI) has issued a new code which is specially designed for transmission of modified orbital elements. The code was drafted by the USNC-IGY and edited by the CSAGI Reporter. It was issued as the Fifth Supplement to the Draft Manual for World Days and Communications, compiled and produced at the Central Radio Propagation Laboratory, National Bureau of Standards, Boulder, Colorado, U.S.A. As with other codes in the Draft Manual, it must be replaced with the final, corrected version when available. This code is reproduced below for the convenience of users of this prediction booklet.

SATOR (Modified Orbital Elements for Prediction Purposes)

Code word: SATOR

Symbolic form:							
	SATOR	aabbc	deeff	ggggZ	hhhhX	NOWES	iiiii
	jkkkk	ARPER	11111	mnnnX		PERIOD	ooooo
	ppppp	ECCEN	qqqqq	PERRA		rrrrr	RAFRE
	sssss	(sssss repeated as necessary)				RADEG	ttttt

Key:

aa = last two digits of year satellite launched
bb = Greek letter designation, 01 = Alpha, 02 = Beta, etc.
c = component
d = reference time (epoch): last digit of numerical notation for month; i.e. 1 = January or November, 2 = February or December, 3 = March, etc.
ee = reference time (epoch): date
ff = reference time (epoch): hour
gggg = reference time (epoch): minutes and hundredths of minutes
Z = Universal time, Greenwich Mean Time
hhhh = inclination in degrees and hundredths of degrees. If the orbit inclination is negative (satellite fired westward) group is preceded by NEGAT
X = always an X
NOWES = sub-indicator for geographical longitude of northbound node west of Greenwich at reference time
iiiii = longitude of northbound node in degrees and hundredths of degrees
j = 1 if plus: when the "prime sweep interval" is one day plus a certain number of minutes
2 if minus: when the "prime sweep interval" is one day minus a certain number of minutes
This is equivalent to saying that the same portion of the orbit plane will reappear at the same location a certain number of minutes earlier each day.
kkkk = number of minutes and hundredths of minutes by which "prime sweep interval" differs from one day or 1440 minutes. This is another way of expressing the relative "westward motion" of the orbit plane.
ARPER = sub-indicator (argument of perigee) angular distance of perigee from node at reference time. For modified orbital elements, this is also the position of the satellite in the ellipse at reference time (mean anomaly at epoch is always equal to zero in this system)
11111 = angular distance of perigee and satellite from northbound node, measured in the direction of satellite travel in degrees and hundredths of degrees
m = 1 for plus, if perigee moves in the same direction as satellite travel
2 for minus, if perigee moves in the direction opposite to satellite travel
nnn = average decimal fraction of a degree which perigee moves per period, measured in thousandths of a degree
X = always an X
PERIOD = sub-indicator for perigee-to-perigee period (anomalistic period)

ooooo = perigee-to-perigee period (anomalistic period) in minutes and thousandths of a minute. If first two digits are less than 85 it should be understood that 100 should be added in order to arrive at the correct period (period cannot be less than about 88 minutes). Should the period be greater than 185 minutes a special notation will be made in the message.

ppppp = average per period change in perigee-to-perigee period, measured as a decimal fraction in one hundred thousandths of a minute

ECCEN = sub-indicator for eccentricity

ggggg = eccentricity, measured as a decimal fraction in one hundred thousandths

PERRA = sub-indicator for radial distance of satellite from center of earth at perigee

rrrrr = radial distance of satellite from center of earth at perigee, measured in miles and tenths of miles

RAFRE = sub-indicator for radio frequencies currently being transmitted from satellite

sssss = radio frequency in megacycles and hundredths of megacycles

RADEG = sub-indicator for right ascension of the ascending node expressed in degrees and hundredths of degrees in order that this message may also serve the needs of those who prefer traditional orbital elements (Note that this sub-indicator and the following code group represent a revision of the code appearing in the Fifth Supplement to the Draft Manual)

ttttt = degrees and hundredths of degrees of right ascension (Note that right ascension is given in degrees and hundredths of degrees rather than hours and minutes)

[Since all of the above quantities have sub-indicators, a message need only include those quantities which have changed since the last reference time (epoch)]

Example: (modified orbital elements used in example in booklet): SATOR 58051

80816	4916Z	5029X	NOWES	19269	21809	ARPER	08545
0223X	PERIOD	09887	00225	ECCEN	12678	PERRA	41236
RAFRE	10800	10803	RADEG	XXXXX			

* * * * *

It may sometimes be advantageous to up date a set of modified orbital elements by giving an estimated correction to crossing time, since the most perishable information is the satellite position in the ellipse at any given time.

Code word: ESTCO

Symbolic form: ESTCO XuuvX EARLY or LATEX xyyzz

ESTCO = sub-indicator for estimated correction to crossing times

X = always an X; gives group distinctive appearance

uu = minutes by which satellite is expected to early or late

v = tenths of minutes by which satellite is expected to be early or late

X = always an X

EARLY = if satellite is estimated to be early

LATEX = if satellite is estimated to be late

x = time for which correction is computed: last digit of month

yy = time for which correction is computed: date

zz = time for which correction is computed: hour

Example: SATOR 58051 80816 4916Z ESTCO X054X EARLY 81116

Translation: On the third day after reference time, satellite 58 epsilon is estimated to be 5.4 minutes earlier than the position computed on the basis of modified orbital elements having a reference time of August 8 at 1649.16Z

C. CIVIL AIR PATROL (CAP)--Radio broadcasts of modified orbital elements within the United States (including Alaska), Hawaii, Puerto Rico and adjacent portions of Canada and Mexico. A sample message form for modified orbital elements, and origins, frequencies and times of broadcasts are given below:

MODIFIED ORBITAL ELEMENTS FOR 195P DELTA-2
From SMITHSONIAN ASTROPHYSICAL OBSERVATORY
Reference time 02 DEC at 23 hours 47.33 minutes Zebra;
Orbit inclination 65.33 degrees;
Longitude of northbound node 219.23 degrees west of Greenwich;
Prime sweep interval one day MINUS 14.49 minutes;
Perigee and satellite position 342.83 degrees, MINUS 0.03002 degrees per period;
Perigee-to-perigee period 102.634 minutes, minus 0.00153 minutes per period;
Eccentricity 0.09246;
Radial distance of perigee 4094.8 statute miles;
Radio frequencies 20.005, 40.009, megacycles;
(Alt. position of node) Right Ascension 209.82 degrees.

Regular broadcasts* are scheduled for Tuesday and Friday evenings as follows:

Station	Frequency	Time
VP0, Hq. CAP, Bolling AFB, Washington 25, D. C.	4275 Kc	1900 EST & 2000 EST
VP01, Box 105, Mitchell AFB, N. Y.	2374 Kc or 4585 Kc	2030 EST
VP02, Shaw AFB, Sumter, S. C.	4467.5 Kc	2030 EST
VP03, Old Adm. Bldg., Detroit-Wayne Metro. Airport, Inkster, Mich.	4507.5 Kc	2030 EST
VP04, Dept. of Commerce Bldg., Berry Field, Nashville 10, Tenn.	4467.5 Kc	2030 CST
VP05, Bldg. T384, Minn.-St. Paul International Airport, Minneapolis, Minn.	2374 Kc	2030 CST
VP06, 102 Walnut Hill Village, Dallas 20, Texas	4507.5 Kc	2030 CST
VP07, Bldg. 471, Lowry AFB, Colo.	4507.5 Kc or 4585 Kc	2030 MST
VP08, Bldg. T-235, Presidio of San Francisco, San Francisco, Calif.	4585 Kc	2030 PST

*Special broadcasts will be made nightly (seven nights a week) on the above schedule in the event of a Satellite with rapidly changing elements.

D. SPECIAL MAIL SERVICE TO PARTICIPATING VOLUNTEER OBSERVERS--When feasible, modified orbital elements are mailed to participating volunteer observers. Moonwatch (volunteer visual observer) teams receive modified orbital elements as part of a general information sheet. Inquiries from Moonwatch teams should be addressed to Smithsonian Astrophysical Observatory, Moonwatch Headquarters, 60 Garden St., Cambridge 38, Mass. Moonbeam (radio tracking) and Phototrack (photographic tracking) groups receive airmail announcement cards similar to the sample message form shown above in section C. Inquiries from the latter groups should be addressed to 826 Connecticut Avenue, Washington 6, D. C.

E. RELATIONSHIP BETWEEN MODIFIED ORBITAL ELEMENTS AND MORE TRADITIONAL FORM.

Modified Form	More Traditional Form Used by NRL	Relationship
(1) Reference time	(1) Epoch	(1) Identical
(2) Inclination	(2) Inclination	(2) Identical
(3) Geographic longitude of northbound node west of Greenwich	(3) Celestial longitude of ascending node east of vernal equinox (in plane of celestial equator, not eliptic)	(3) Equivalent but complex therefore both forms given
(4) Prime sweep interval	(4) Westward motion of node	(4) Equivalent; one easily derivable from the other
(5) Position of perigee	(5) Argument of perigee	(5) Identical
(6) Position of satellite	(6) Mean anomaly at epoch	(6) Reference time always chosen to make mean anomaly = zero; i.e., when satellite is at perigee
(7) Perigee-to-perigee period	(7) Anomalistic period	(7) Identical
(8) Average change in period, per period	(8) Given in different forms or sometimes not at all	(8)
(9) Eccentricity	(9) Eccentricity	(9) Identical
(10) Radial distance of satellite from center of earth at perigee	(10) Perigee (measured from mean surface of earth	(10) Differ only by mean radius of earth

A. SHORTCUTS PERMITTING SLIDE-RULE DIVISION--Where a desk calculator is not available, the long divisions indicated in Schedule B, and in Schedule C, Item 4 can be reduced to slide rule problems of sufficient accuracy as follows:

1. To find westward motion from prime sweep interval:

Average westward motion due to earth's rotation	$\frac{360^\circ}{1440 \text{ min}} = 0^\circ.2500/\text{min}$
Adjustment for precession of orbit plane and equation of time	$\frac{\Lambda I}{5760} = \frac{18.07}{5760} = +\ 0^\circ.00315/\text{min}^*$
Westward motion	$0^\circ.2532/\text{min}$

Where: ΛI is the amount, in minutes, by which the prime sweep interval differs from one day. Justification for ignoring the quadratic and higher terms in cases where ΛI does not exceed about 20 minutes can be found in the following:

$$\text{Westward motion} = \frac{360^\circ}{\text{prime sweep interval}} = \frac{360^\circ}{(1440 - \Delta I)\text{min}} =$$

$$\frac{360}{1440}\left[1 + \frac{\Delta I}{1440} + \left(\frac{\Delta I}{1440}\right)^2 + \ldots\right]^\circ/\text{min} \approx \frac{360}{1440}\left[1 + \frac{\Delta I}{1440}\right]^\circ/\text{min}$$

$$\text{(where } \Delta I \text{ is small compared to 1440)} = \left(0.2500 + \frac{I\Lambda}{5760}\right)^\circ/\text{min}$$

Note that for negative orbit inclinations, prime sweep interval will be equal to one day plus ΔI, and the adjustment must be subtracted.

2. To find time equivalent of longitude to be swept by orbit plane:

Time required for earth to rotate $72^\circ.9$ at 4 min/$^\circ$	291.6 min
LESS: Adjustment for precession of orbit plane and equation of time during above interval.. = 291.6 min x $0^\circ.0032$/min* x 4 min/$^\circ$	- 3.7 min
Time equivalent of longitude to be swept by orbit plane	287.9 min

*0.0032 is the Adjustment found in Shortcut #1 (above).

Justification:

$$\text{Equivalent time} = \frac{072^\circ.9}{0^\circ.2532/\text{min}} = \frac{072^\circ.9}{(0^\circ.2500 + 0^\circ.0032)/\text{min}}$$

$$\approx 4 \times 72.9\ [1 - 4(0.0032)] = 291.6 - 291.6 \times (4) \times 0.0032 = 287.9 \text{ min.}$$

B. PLOTS—If predictions are made quite regularly, Dr. Erwin Schroader of Applied Physics Laboratory points out that it is worthwhile to construct plots of (1) westward motion as a function of ΔI (amount by which prime sweep interval differs from one day); (2) time equivalent of longitude for various values of westward motions, and (3) current perigee-to-perigee period as a function of time elapsed since reference time, for various values of change in period per period. Also, the series of additions and subtractions in Schedule C can be computed graphically by means of a finely-divided clock face or compass rose and a pair of dividers. Finally, it is possible to devise extrapolation formulas to eliminate part of the work involved in Part II, when predictions are being made for several successive days.

C. CORRECTIONS FROM LOCAL OBSERVATIONS—An observer may use his own observations to correct already computed predictions. For example, if a satellite appears 3 minutes early and 2^{o} of longitude east of predicted position, this information may be entered in the appropriate boxes in Schedule F, item 13 or 15 and Schedule G, item 4 or 6.

D. USE OF OVERLAYS—Tracing paper or clear plastic is useful for marking the observer's position on the plotting grids or for making computations in the event of a temporary shortage of computation forms.

E. SUNSET TIMES AT 88 MILES FROM TABLE VI—Table V is used for determining whether the sun is shining at satellite altitude for various satellite longitudes, latitudes and local times. Table VI is used for determining whether the sun is less than or more than 12^{o} below the horizon at various observer longitudes, latitudes at various local times. However, Dr. R. H. Wilson of the Naval Research Laboratory points out that the information contained in Table VI essentially gives the sunrise and sunset times for a point 88 miles above the earth, and thus is useful for the critical satellite heights between 88 and 200 miles. When Table VI is used in this way, care must be taken to enter table with satellite latitude, longitude and local time rather than observer's latitude, longitude and local time. For latitudes greater than 50^{o} interpolation between Tables V and VI is inconvenient since the latitude entries for the two tables are not identical.

F. PREDICTIONS FROM INCOMPLETE LAUNCH DATA--------The prediction system outlined in this booklet can be adapted to making predictions based on the type of information often given at the time of launching a new satellite. Since it is normal to launch a satellite with a velocity in excess of that needed for a circular orbit, the best guess is to assume that perigee is at the launching point, i.e. that there are no launching angle errors. With this assumption, and the time of satellite passage over any given geographic location, it is possible to work backward with the aid of Tables II, III-A and I to construct modified orbital elements, provided inclination, approximate eccentricity, perigee-to-perigee period and perigee distance are known. The prime sweep interval and change in perigee-to-perigee period may be inferred from previous experience.

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NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA.
FOUNDED 1863.

MODIFIED ORBITAL ELEMENTS

FOR EARTH SATELLITE 19....-....

GIVEN ON ..... (date)

BY.....

Reference time (Greenwich Mean Time = GMT, UT or Z)	19.....^{y} .....^{m} o .....^{d} .....^{h} .....^{m}..... GMT
Reference time (Station Time = GMT) + (−) .....^{h})	19.....^{y} .....^{m} o .....^{d} .....^{h} .....^{m}..... ST
Orbit inclination	+ (−) .....°.....
Longitude of northbound node at reference time	.....°.....West of Greenwich
Prime sweep interval:	.....^{m}.....
or 1440^{m}00 (1 day), + (−)	.....^{m}.....
Perigee and satellite position at reference time (measured in degrees of arc from northbound node and in direction of satellite's motion)	.....°.....
Change in perigee position per period	+(−) ....°...../period
Perigee-to-perigee period at reference time	.....^{m}.....
Per period change in perigee-to-perigee period	−0^{m}...../period
Eccentricity of orbit	0.....
Estimated correction to crossing times (not always given)	.....^{m}.....EARLY (LATE)
Radial distance of satellite from center of earth at perigee	..... statute miles
Radio transmission frequencies	.... Mc
	.... Mc
	.... Mc

1 Statute mile = 1.609 kilometers; 1 kilometer = 0.6214 mile; 5 miles are approximately 8 kilometers

Schedule A: To Find Longitudes of Northbound Node at Sweep Times and Specific Central Angles Between Equator and Reference Latitude

(Compute ONLY ONCE for given station and inclination)

	PRIME SWEEP	.....°.... N(S) RETURN SWEEP
0. From part of Table I showing given orbit inclination, SELECT reference latitude closest to station latitude		
1. STRIKE OUT ALL of line *a* or *b* whichever contains a false statement:		
a. Reference latitude is *South*	180°00	360°00
b. Reference latitude is *North*	0°00	180°00
2. ENTER: Minimum longitude of northbound node west of meridian point at sweep times (from Table I) and ADD and SUBTRACT as indicated	+ .....°..... W	− .....°..... W
3. Specific longitudes of northbound node west of meridian point at sweep times	.....°..... W	.....°..... W
4. ENTER: Longitude of station's meridian *west* of Greenwich (360° LESS *east* longitude) and ADD	+ .....°..... W	+ .....°..... W
5. Longitudes of northbound node at sweep times	.....°..... W	.....°..... W

(*Note: If the orbit inclination is negative, STRIKE OUT ALL of line* a *or* b *above, whichever contains a* true *statement, and in entering results in Item 3, above, TRANSPOSE to opposite column.*)

6. STRIKE OUT ALL of line *a* or *b* below, whichever contains a false statement:		
a. Reference latitude is *South*	180°00	360°00
b. Reference latitude is *North*	0°00	180°00
7. ENTER: Initial central angle between equator and reference latitude (from Table II) and ADD and SUBTRACT as indicated.	+ .....°.....	− .....°.....
8. Specific central angles between equator and reference latitude	.....°.....	.....°.....

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(*over*)

PART I — TO LOCATE ORBIT PLANE

Schedule B: To Find Orbit Plane's Relative Westward Motion

1. Degrees of longitude between successive prime sweeps	360°00
2. DIVIDE BY: Prime sweep interval in minutes (given)	÷ ....m....
3. Orbit plane's relative westward motion (degrees of arc per minute)	0°...../m

Schedule C: To Find Times When Orbit Plane Sweeps Through Meridian Point

	PRIME SWEEP	RETURN SWEEP
1. Longitudes of northbound node at sweep times (Schedule A, Item 5)	....°.... W	....°.... W
2. SUBTRACT: Longitude of northbound node at reference time (given) *(ADD: 360° if needed to avoid negative balance)*	− ....°.... W	− ....°.... W
3. Longitude to be traversed before first sweeps after reference time	....°.... W	....°.... W
4. DIVIDE BY: Orbit plane's relative westward motion (Schedule B, Item 3)	÷ 0°...../m	÷ 0°...../m
5. Equivalent times in minutes before first sweeps	....m....	....m....
6. CONVERT: Item 5, above, to hours and minutes	....h ....m....	....h ....m....
7. ADD: Reference time (from given data)	+....mo....d....h....m.... ST	+....d....h....m.... ST
8. Times of first sweeps after reference time	....mo....d....h....m.... ST	....d....h....m.... ST
9. ADD: Prime sweep interval (given)	+1d+(−)....m....	+1d+(−)....m....
10. Times of SECOND sweeps	....mo....d....h....m.... ST	....d....h....m.... ST
11. ADD: Prime sweep interval	+1d+(−)....m....	+1d+(−)....m....
12. Times of THIRD sweeps	....mo....d....h....m.... ST	....d....h....m.... ST
13. ADD: Prime sweep interval	+1d+(−)....m....	+1d+(−)....m....
14. Times of FOURTH sweeps	....mo....d....h....m.... ST	....d....h....m.... ST
15. ADD: Prime sweep interval	+1d+(−)....m....	+1d+(−)....m....
16. Times of FIFTH sweeps	....mo....d....h....m.... ST	....d....h....m.... ST
17. ADD: Prime sweep interval	+1d+(−)....m....	+1d+(−)....m....
18. Times of SIXTH sweeps	....mo....d....h....m.... ST	....d....h....m.... ST
19. ADD: Prime sweep interval	+1d+(−)....m....	+1d+(−)....m....
20. Times of SEVENTH sweeps	....mo....d....h....m.... ST	....d....h....m.... ST
21. ADD: Prime sweep interval	+1d+(−)....m....	+1d+(−)....m....
22. Times of EIGHTH sweeps	....mo....d....h....m.... ST	....d....h....m.... ST
23. ADD: Prime sweep interval	+1d+(−)....m....	+1d+(−)....m....
24. Times of NINTH sweeps	....mo....d....h....m.... ST	....d....h....m.... ST
25. ADD: Prime sweep interval	+1d+(−)....m....	+1d+(−)....m....
26. Times of TENTH sweeps	....mo....d....h....m.... ST	....d....h....m.... ST
27. ADD: Prime sweep interval	+1d+(−)....m....	+1d+(−)....m....
28. Times of ELEVENTH sweeps	....mo....d....h....m.... ST	....d....h....m.... ST

MODIFIED ORBITAL ELEMENTS

FOR EARTH SATELLITE 19....-....

GIVEN ON ..... (date)

BY.....

Reference time (Greenwich Mean Time = GMT, UT or Z)	19....^{y} ....^{mo} ....^{d} ....^{h} ....^{m}.... GMT
Reference time (Station Time = GMT) + (−) ....^{h})	19....^{y} ....^{mo} ....^{d} ....^{h} ....^{m}.... ST
Orbit inclination	+ (−) ....°....
Longitude of northbound node at reference time	....°....West of Greenwich
Prime sweep interval:	....^{m}....
	or 1440^{m}00 (1 day), + (−) ....^{m}....
Perigee and satellite position at reference time (measured in degrees of arc from northbound node and in direction of satellite's motion)	....°....
Change in perigee position per period	+(−) ....°..../period
Perigee-to-perigee period at reference time	....^{m}....
Per period change in perigee-to-perigee period	−0^{m}..../period
Eccentricity of orbit	0.....
Estimated correction to crossing times (not always given)	....^{m}....EARLY (LATE)
Radial distance of satellite from center of earth at perigee	..... statute miles
Radio transmission frequencies	.... Mc
	.... Mc
	.... Mc

1 Statute mile = 1.609 kilometers; 1 kilometer = 0.6214 mile; 5 miles are approximately 8 kilometers

Schedule A: To Find Longitudes of Northbound Node at Sweep Times and Specific Central Angles Between Equator and Reference Latitude

(Compute ONLY ONCE for given station and inclination)

	PRIME SWEEP	....° .... N(S) RETURN SWEEP
0. From part of Table I showing given orbit inclination, SELECT reference latitude closest to station latitude		
1. STRIKE OUT ALL of line *a* or *b* whichever contains a false statement:		
a. Reference latitude is *South*	180°00	360°00
b. Reference latitude is *North*	0°00	180°00
2. ENTER: Minimum longitude of northbound node west of meridian point at sweep times (from Table I) and ADD and SUBTRACT as indicated	+ ....°.... W	− ....°.... W
3. Specific longitudes of northbound node west of meridian point at sweep times	....°.... W	....°.... W
4. ENTER: Longitude of station's meridian *west* of Greenwich (360° LESS *east* longitude) and ADD	+ ....°.... W	+ ....°.... W
5. Longitudes of northbound node at sweep times	....°.... W	....°.... W

(Note: If the orbit inclination is negative, STRIKE OUT ALL of line a *or* b *above, whichever contains a* true *statement, and in entering results in Item 3, above, TRANSPOSE to opposite column.)*

6. STRIKE OUT ALL of line *a* or *b* below, whichever contains a false statement:		
a. Reference latitude is *South*	180°00	360°00
b. Reference latitude is *North*	0°00	180°00
7. ENTER: Initial central angle between equator and reference latitude (from Table II) and ADD and SUBTRACT as indicated.	+ ....°....	− ....°....
8. Specific central angles between equator and reference latitude	....°....	....°....

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PART I — TO LOCATE ORBIT PLANE

Schedule B: To Find Orbit Plane's Relative Westward Motion

1. Degrees of longitude between successive prime sweeps	360°00
2. DIVIDE BY: Prime sweep interval in minutes (given)	÷ ....m....
3. Orbit plane's relative westward motion (degrees of arc per minute)	0°...../m

Schedule C: To Find Times When Orbit Plane Sweeps Through Meridian Point

	PRIME SWEEP	RETURN SWEEP
1. Longitudes of northbound node at sweep times (Schedule A, Item 5)	....°.... W	....°.... W
2. SUBTRACT: Longitude of northbound node at reference time (given) *(ADD: 360° if needed to avoid negative balance)*	− ....°.... W	− ....°.... W
3. Longitude to be traversed before first sweeps after reference time	....°.... W	....°.... W
4. DIVIDE BY: Orbit plane's relative westward motion (Schedule B, Item 3)	÷ 0°...../m	÷ 0°...../m
5. Equivalent times in minutes before first sweeps	....m....	....m....
6. CONVERT: Item 5, above, to hours and minutes	....h ....m....	....h ....m....
7. ADD: Reference time (from given data)	+ ....mo ....d ....h ....m.... ST	+ ....d ....h ....m.... ST
8. Times of first sweeps after reference time	....mo ....d ....h ....m.... ST	....d ....h ....m.... ST
9. ADD: Prime sweep interval (given)	+1d+(−) ....m....	+1d+(−) ....m....
10. Times of SECOND sweeps	....mo ....d ....h ....m.... ST	....d ....h ....m.... ST
11. ADD: Prime sweep interval	+1d+(−) ....m....	+1d+(−) ....m....
12. Times of THIRD sweeps	....mo ....d ....h ....m.... ST	....d ....h ....m.... ST
13. ADD: Prime sweep interval	+1d+(−) ....m....	+1d+(−) ....m....
14. Times of FOURTH sweeps	....mo ....d ....h ....m.... ST	....d ....h ....m.... ST
15. ADD: Prime sweep interval	+1d+(−) ....m....	+1d+(−) ....m....
16. Times of FIFTH sweeps	....mo ....d ....h ....m.... ST	....d ....h ....m.... ST
17. ADD: Prime sweep interval	+1d+(−) ....m....	+1d+(−) ....m....
18. Times of SIXTH sweeps	....mo ....d ....h ....m.... ST	....d ....h ....m.... ST
19. ADD: Prime sweep interval	+1d+(−) ....m....	+1d+(−) ....m....
20. Times of SEVENTH sweeps	....mo ....d ....h ....m.... ST	....d ....h ....m.... ST
21. ADD: Prime sweep interval	+1d+(−) ....m....	+1d+(−) ....m....
22. Times of EIGHTH sweeps	....mo ....d ....h ....m.... ST	....d ....h ....m.... ST
23. ADD: Prime sweep interval	+1d+(−) ....m....	+1d+(−) ....m....
24. Times of NINTH sweeps	....mo ....d ....h ....m.... ST	....d ....h ....m.... ST
25. ADD: Prime sweep interval	+1d+(−) ....m....	+1d+(−) ....m....
26. Times of TENTH sweeps	....mo ....d ....h ....m.... ST	....d ....h ....m.... ST
27. ADD: Prime sweep interval	+1d+(−) ....m....	+1d+(−) ....m....
28. Times of ELEVENTH sweeps	....mo ....d ....h ....m.... ST	....d ....h ....m.... ST

Form for locating satellite—first within the orbit plane, then relative to observer.

PART II—TO FIND WHEN AND WHERE SATELLITE 19..... - ..... CROSSES REFERENCE LATITUDE ON .....mo .....d, 19.....

Schedule D. To Find Minutes Elapsed between Reference Time and a Selected Sweep Time

1. Selected sweep time (from Schedule C, above)	.....mo .....d .....h .....m.....	ST
2. SUBTRACT: Reference time (from given data)	− .....mo .....d .....h .....m.....	ST
3. Elapsed time from reference time to selected sweep time	.....d .....h .....m.....	
4. ENTER: Minutes from Item 3 (above)	.....m.....	
5. ENTER: Hours from Item 3 (above) MULTIPLIED BY 60	.....m00	
6. ENTER: Days from Item 3 (above) MULTIPLIED BY 1,440, and ADD: Items 4, 5 & 6	+.....m00	
7. Time in minutes elapsed since reference time	.....m.....	

Schedule E. To Find Time when Satellite is Last at Perigee prior to Selected Sweep Time

1. Time in minutes elapsed since reference time (Schedule D, Item 7)	.....m.....	
2. DIVIDE BY: *Average** perigee-to-perigee period	÷ .....m.....	
3. ENTER: *Quotient* (number of periods completed since reference time) *and*	.....	
4. ENTER: *Remainder* in minutes	.....m.....	
5. ENTER: Selected sweep time (Schedule D, Item 1) and SUBTRACT Item 4 from Item 5:	.....mo .....d .....h .....m.....	ST
6. Time when satellite is last at perigee prior to selected sweep time	.....mo .....d .....h .....m.....	ST

Schedule F. To Find Time when Satellite Crosses Reference Latitude

1. Number of whole periods completed since reference time (Schedule E, Item 3)	.....	
2. MULTIPLY BY: Change in perigee position per period (given)	× +(−) .....°...../period	
3. Change in perigee position since reference time	+(−) .....°.....	
4. ADD: Perigee position at reference time (given)	+ .....°.....	
5. Current perigee position relative to northbound node	.....°.....	
6. ENTER: Appropriate central angle between equator and reference latitude, (from Schedule A, Item 8) and SUBTRACT: Item 5 from Item 6, *adding 360° to item 6 if necessary*	.....°.....	
7. Perigee distance from crossing point, measured within orbit plane	.....°.....	
8. ENTER: Equivalent fraction-of-period for given orbit eccentricity (from Table III)	.....	
9. MULTIPLY BY: *Current** perigee-to-perigee period	× .....m.....	
10. Time required for satellite to travel from current perigee position to crossing point.	.....m.....	
11. CONVERT above to hours and minutes	.....h .....m.....	
12. ADD: Time when satellite is last at perigee (Schedule E, Item 6)	+.....h .....m.....	ST
13. Time when satellite crosses reference latitude	.....h .....m..... ST	.....h .....m..... ST

NOTE: If time computed in item 13 differs from selected sweep time by more than one-half perigee-to-perigee period, then determine alternative time as shown below:

14. ADD (SUBTRACT) as appropriate: One whole perigee-to-perigee period (given)	.....h .....m.....	
15. Alternative time when satellite crosses reference latitude	.....h .....m..... ST	.....h .....m..... ST

To BRING ABOVE UP-TO-DATE, Determine from the most recent data that the satellite will cross reference latitudes .....m..... minutes early, SUBTRACT this amount from Item 13 or 15, and ENTER corrected time in appropriate box. (If satellite is late—ADD)

Schedule G. To Find Relative Longitude of Point Where Satellite Crosses Reference Latitude

1. Time when satellite crosses reference latitude (From schedule F, Item 13 or 15 uncorrected):	.....mo .....d .....h .....m.....	ST
2. SUBTRACT: Selected sweep time	− .....mo .....d .....h .....m.....	ST
3. Time difference (note whether plus or minus)	+(−) .....h .....m.....	
4. CONVERT above to minutes	+(−) .....m.....	+(−) .....m.....
5. MULTIPLY BY: Rate of orbit plane's relative westward motion (Schedule B, Item 3)		×0°...../min.
6. Relative longitude of point where satellite crosses reference latitude. (If time difference in Item 3 is *positive*, the observer's station will be *East;* of crossing point.	+(−) .....°.....	+(−) .....°.....

To BRING ABOVE UP-TO-DATE, SUBTRACT from time given in Item 4, the correction used in bringing Schedule F up-to-date, and ENTER result in Box. MULTIPLY corrected time by Item 5, and ENTER product in box opposite Item 6.

*See p.9 of text.

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PART III—OPTIONAL ADDITIONAL DETERMINATIONS

Preliminary Preparation of Plotting Grid (for use with any Pass of a given Satellite near Observer's Station)

1. SELECT a plotting grid showing latitude both of observer's station and of reference latitude used in Part II.
2. LOCATE Reference latitude used in Part II on central meridian (0° relative longitude). *This is reference point.*
3. ENTER Heading along satellite track for given orbit inclination and reference latitude (from Table IV) ..... °
4. ALSO ENTER: 180° *less* Item 3, above ..... °
5. DRAW straight line(s) through reference point on heading(s) (measured clockwise from North) shown above. EXTEND the resulting satellite track(s) on both sides of the reference point and MARK satellite direction(s) with arrowhead(s).

Schedule H—To Obtain Azimuth, Elevation, Slant Range and Passage Times

1. LOCATE Observer's relative position on plotting grid using station latitude (given) and relative longitude (from Schedule G, Item 6).
2. SELECT Point(s) of observational interest along satellite track
3. DRAW LINE(S) from observer's relative position to selected point(s)
4. MEASURE clockwise from North the angular distances(s) from observer's position to point(s) of interest, and ENTER as **Azimuth**
5. MEASURE distance(s) from observer's position to point(s) of interest, SCALE OFF on meridian to read in degrees of arc and ENTER as **Distance(s) from observer in degrees**
6. MEASURE along satellite track from reference point to point(s) of interest, SCALE OFF on meridian to read in degrees of arc and ENTER as **adjustment(s) to position**
7. ADD Current perigee distance (from Schedule F, Item 7)
8. **Perigee distance(s) relative to points of interest**
   TURN TO Table III opposite *perigee position*(s) found in Item 8 (above) and under given orbit eccentricity, FIND and ENTER:
9. **Equivalent fraction(s) of period**
10. **Radial distance factor**(s)
11. MULTIPLY radial distance factor (Item 10, above) by radial distance at perigee (given)
12. **Radial distance**(s) **of satellite from center of the earth**
13. SUBTRACT Mean radius of Earth (3959 mi.) or radius at station
    Satellite height(s) *above point*(s) *of interest*
14. USING Satellite heights (from Item 13, above) and distance(s) from observer in degrees (from Item 5, above) ENTER "Chart for Determining Elevation and Slant Range" to OBTAIN { **Elevation**(s) / **Slant range**(s)
15. MULTIPLY **Equivalent fraction of period** (Item 9, above) by ..... m (*Current* perigee-to-perigee period) and ENTER
16. SUBTRACT Time required for satellite to travel from current perigee position to reference point (Schedule F, Item 10)
17. Time interval(s) between satellite passage over point(s) of interest and satellite passage over reference point
18. ADD Time when satellite passes over reference latitude (from Schedule F. Item 13 or 15)
19. Time(s) of satellite passage over point(s) of interest
20. Satellite in sunlight (from Table V)
21. Sky Dark at station (from Table VI)

	Sub-Satellite Point(s) of Observational Interest			
	Point of Nearest Approach	Meridian Passage	Alt #1	Alt #2
4.	..°	000° or 180°	..°	..°
5.	..°..	..°..	..°..	..°..
6.	+(−) ..°..	+(−) ..°..	+(−) ..°..	+(−) ..°..
7.	+..°..	+..°..	+..°..	+..°..
8.	..°..	..°..	..°..	..°..
9.	0....	0....	0....	0....
10.	....	....	....	....
11.	× .. mi	× .. mi	× .. mi	× .. mi
12.	.. mi	.. mi	.. mi	.. mi
13.	− .. mi	− .. mi	− .. mi	− .. mi
	.. mi	.. mi	.. mi	.. mi
14.	..°	..°	..°	..°
	.. mi	.. mi	.. mi	.. mi
15.	.. m	.. m	.. m	.. m
16.	− .. m	− .. m	− .. m	− .. m
17.	+(−) .. m	+(−) .. m	+(−) .. m	+(−) .. m
18.	+ .. h .. m	+ .. h .. m	+ .. h .. m	+ .. h .. m
19.	.. h .. m	.. h .. m	.. h .. m	.. h .. m
20.	Yes No	Yes No	Yes No	Yes No
21.		Yes No		

Form for locating satellite—first within the orbit plane, then relative to observer.

PART II—TO FIND WHEN AND WHERE SATELLITE 19..-..... CROSSES REFERENCE LATITUDE ON ....mo ....d, 19....

Schedule D. To Find Minutes Elapsed between Reference Time and a Selected Sweep Time

1. Selected sweep time (from Schedule C, above)	....mo ....d ....h ....m....	ST
2. SUBTRACT: Reference time (from given data)	− ....mo ....d ....h ....m....	ST
3. Elapsed time from reference time to selected sweep time	....d ....h ....m....	
4. ENTER: Minutes from Item 3 (above)	....m....	
5. ENTER: Hours from Item 3 (above) MULTIPLIED BY 60	....m00	
6. ENTER: Days from Item 3 (above) MULTIPLIED BY 1,440, and ADD: Items 4, 5 & 6	+ m00	
7. Time in minutes elapsed since reference time	....m....	

Schedule E. To Find Time when Satellite is Last at Perigee prior to Selected Sweep Time

1. Time in minutes elapsed since reference time (Schedule D, Item 7)	....m....	
2. DIVIDE BY: *Average** perigee-to-perigee period	÷ ....m....	
3. ENTER: *Quotient* (number of periods completed since reference time) *and*	....	
4. ENTER: *Remainder* in minutes	....m....	
5. ENTER: Selected sweep time (Schedule D, Item 1) and SUBTRACT Item 4 from Item 5:	....mo ....d ....h ....m....	ST
6. Time when satellite is last at perigee prior to selected sweep time	....mo ....d ....h ....m....	ST

Schedule F. To Find Time when Satellite Crosses Reference Latitude

1. Number of whole periods completed since reference time (Schedule E, Item 3)	....	
2. MULTIPLY BY: Change in perigee position per period (given)	× +(−) ....°..../period	
3. Change in perigee position since reference time	+(−) ....°....	
4. ADD: Perigee position at reference time (given)	+ ....°....	
5. Current perigee position relative to northbound node	....°....	
6. ENTER: Appropriate central angle between equator and reference latitude, (from Schedule A, Item 8) and SUBTRACT: Item 5 from Item 6, *adding 360° to item 6 if necessary*	....°....	
7. Perigee distance from crossing point, measured within orbit plane	....°....	
8. ENTER: Equivalent fraction-of-period for given orbit eccentricity (from Table III)	....	
9. MULTIPLY BY: *Current** perigee-to-perigee period	× ....m....	
10. Time required for satellite to travel from current perigee position to crossing point.	....m....	
11. CONVERT above to hours and minutes	....h ....m....	
12. *ADD: Time when satellite is last at perigee* (Schedule E, Item 6)	+ ....h ....m.... ST	
13. Time when satellite crosses reference latitude	....h ....m.... ST	....h ....m.... ST

NOTE: If time computed in item 13 differs from selected sweep time by more than one-half perigee-to-perigee period, then determine alternative time as shown below:

14. ADD (SUBTRACT) as appropriate: One whole perigee-to-perigee period (given)		....h ....m....
15. Alternative time when satellite crosses reference latitude	....h ....m.... ST	....h ....m.... ST

To BRING ABOVE UP-TO-DATE, Determine from the most recent data that the satellite will cross reference latitudes ....m.... minutes early, SUBTRACT this amount from Item 13 or 15, and ENTER corrected time in appropriate box. (If satellite is late—ADD)

Schedule G. To Find Relative Longitude of Point Where Satellite Crosses Reference Latitude

1. Time when satellite crosses reference latitude (From schedule F, Item 13 or 15 uncorrected):	....mo ....d ....h ....m....	ST
2. SUBTRACT: Selected sweep time	− ....mo ....d ....h ....m....	ST
3. Time difference (note whether plus or minus)	+(−) ....h ....m....	
4. CONVERT above to minutes	+(−) ....m....	+(−) ....m....
5. MULTIPLY BY: Rate of orbit plane's relative westward motion (Schedule B, Item 3)		×0°...../min.
6. Relative longitude of point where satellite crosses reference latitude. (If time difference in Item 3 is *positive*, the observer's station will be *East;* of crossing point.	+(−) ....°....	+(−) ....°....

To BRING ABOVE UP-TO-DATE, SUBTRACT from time given in Item 4, the correction used in bringing Schedule F up-to-date, and ENTER result in Box. MULTIPLY corrected time by Item 5, and ENTER product in box opposite Item 6.

*See p.9 of text.

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PART III—OPTIONAL ADDITIONAL DETERMINATIONS

Preliminary Preparation of Plotting Grid (for use with any Pass of a given Satellite near Observer's Station)

1. SELECT a plotting grid showing latitude both of observer's station and of reference latitude used in Part II.
2. LOCATE Reference latitude used in Part II on central meridian (0° relative longitude). *This is reference point.*
3. ENTER Heading along satellite track for given orbit inclination and reference latitude (from Table IV) ..... °
4. ALSO ENTER: 180° *less* Item 3, above ..... °
5. DRAW straight line(s) through reference point on heading(s) (measured clockwise from North) shown above. EXTEND the resulting satellite track(s) on both sides of the reference point and MARK satellite direction(s) with arrowhead(s).

Schedule H—To Obtain Azimuth, Elevation, Slant Range and Passage Times

1. LOCATE Observer's relative position on plotting grid using station latitude (given) and relative longitude (from Schedule G, Item 6).
2. SELECT Point(s) of observational interest along satellite track
3. DRAW LINE(S) from observer's relative position to selected point(s)
4. MEASURE clockwise from North the angular distances(s) from observer's position to point(s) of interest, and ENTER as **Azimuth**
5. MEASURE distance(s) from observer's position to point(s) of interest, SCALE OFF on meridian to read in degrees of arc and ENTER as **Distance(s) from observer in degrees**
6. MEASURE along satellite track from reference point to point(s) of interest, SCALE OFF on meridian to read in degrees of arc and ENTER as **adjustment(s) to position**
7. ADD Current perigee distance (from Schedule F, Item 7)
8. **Perigee distance(s) relative to points of interest**

   TURN TO Table III opposite *perigee position(s)* found in Item 8 (above) and under given orbit eccentricity, FIND and ENTER:
9. **Equivalent fraction(s) of period**
10. **Radial distance factor(s)**
11. MULTIPLY radial distance factor (Item 10, above) by radial distance at perigee (given)
12. **Radial distance(s) of satellite from center of the earth**
13. SUBTRACT Mean radius of Earth (3959 mi.) or radius at station *Satellite height(s) above point(s) of interest*
14. USING Satellite heights (from Item 13, above) and distance(s) from observer in degrees (from Item 5, above) ENTER "Chart for Determining Elevation and Slant Range" to OBTAIN { **Elevation(s)** / **Slant range(s)**
15. MULTIPLY **Equivalent fraction of period** (Item 9, above) by ..... m (*Current* perigee-to-perigee period) and ENTER
16. SUBTRACT Time required for satellite to travel from current perigee position to reference point (Schedule F, Item 10)
17. Time interval(s) between satellite passage over point(s) of interest and satellite passage over reference point
18. ADD Time when satellite passes over reference latitude (from Schedule F. Item 13 or 15)
19. Time(s) of satellite passage over point(s) of interest
20. Satellite in sunlight (from Table V)
21. Sky Dark at station (from Table VI)

	Sub-Satellite Point(s) of Observational Interest			
	Point of Nearest Approach	Meridian Passage	Alt #1	Alt #2
4.	...°	000° or 180°	...°	...°
5.	...°	...°	...°	...°
6.	+(−) ...°	+(−) ...°	+(−) ...°	+(−) ...°
7.	+...°	+...°	+...°	+...°
8.	...°	...°	...°	...°
9.	0.	0.	0.	0.
10.	.	.	.	.
11.	× ... mi	× ... mi	× ... mi	× ... mi
12.	... mi	... mi	... mi	... mi
13.	− ... mi	− ... mi	− ... mi	− ... mi
	... mi	... mi	... mi	... mi
14.	...°	...°	...°	...°
	... mi	... mi	... mi	... mi
15.	... m	... m	... m	... m
16.	− ... m	− ... m	− ... m	− ... m
17.	+(−) ... m	+(−) ... m	+(−) ... m	+(−) ... m
18.	+ ... h ... m	+ ... h ... m	+ ... h ... m	+ ... h ... m
19.	... h ... m	... h ... m	... h ... m	... h ... m
20.	Yes No	Yes No	Yes No	Yes No
21.		Yes No		

Form for locating satellite—first within the orbit plane, then relative to observer.

PART II—TO FIND WHEN AND WHERE SATELLITE 19.... - ..... CROSSES REFERENCE LATITUDE ON .....mo.....d, 19.....

Schedule D. To Find Minutes Elapsed between Reference Time and a Selected Sweep Time

1. Selected sweep time (from Schedule C, above)	.....mo .....d .....h .....m.....	ST
2. SUBTRACT: Reference time (from given data)	− .....mo .....d .....h .....m.....	ST
3. Elapsed time from reference time to selected sweep time	.....d .....h .....m.....	
4. ENTER: Minutes from Item 3 (above)	.....m.....	
5. ENTER: Hours from Item 3 (above) MULTIPLIED BY 60	.....m00	
6. ENTER: Days from Item 3 (above) MULTIPLIED BY 1,440, and ADD: Items 4, 5 & 6	+ m00	
7. Time in minutes elapsed since reference time	.....m.....	

Schedule E. To Find Time when Satellite is Last at Perigee prior to Selected Sweep Time

1. Time in minutes elapsed since reference time (Schedule D, Item 7)	.....m.....	
2. DIVIDE BY: *Average** perigee-to-perigee period	÷ .....m.....	
3. ENTER: *Quotient* (number of periods completed since reference time) *and*	.....	
4. ENTER: *Remainder* in minutes	.....m.....	
5. ENTER: Selected sweep time (Schedule D, Item 1) and SUBTRACT Item 4 from Item 5:	.....mo .....d .....h .....m.....	ST
6. Time when satellite is last at perigee prior to selected sweep time	.....mo .....d .....h .....m.....	ST

Schedule F. To Find Time when Satellite Crosses Reference Latitude

1. Number of whole periods completed since reference time (Schedule E, Item 3)	.....	
2. MULTIPLY BY: Change in perigee position per period (given)	× +(−) .....°...../period	
3. Change in perigee position since reference time	+(−) .....°.....	
4. ADD: Perigee position at reference time (given)	+ .....°.....	
5. Current perigee position relative to northbound node	.....°.....	
6. ENTER: Appropriate central angle between equator and reference latitude, (from Schedule A, Item 8) and SUBTRACT: Item 5 from Item 6, *adding 360° to item 6 if necessary*	.....°.....	
7. Perigee distance from crossing point, measured within orbit plane	.....°.....	
8. ENTER: Equivalent fraction-of-period for given orbit eccentricity (from Table III)	.....	
9. MULTIPLY BY: *Current** perigee-to-perigee period	× .....m.....	
10. Time required for satellite to travel from current perigee position to crossing point.	.....m.....	
11. CONVERT above to hours and minutes	.....h .....m.....	
12. ADD: Time when satellite is last at perigee (Schedule E, Item 6)	+ .....h .....m..... ST	
13. Time when satellite crosses reference latitude	.....h .....m..... ST	.....h .....m..... ST

NOTE: If time computed in item 13 differs from selected sweep time by more than one-half perigee-to-perigee period, then determine alternative time as shown below:

14. ADD (SUBTRACT) as appropriate: One whole perigee-to-perigee period (given)		.....h .....m.....
15. Alternative time when satellite crosses reference latitude	.....h .....m..... ST	.....h .....m..... ST

To BRING ABOVE UP-TO-DATE, Determine from the most recent data that the satellite will cross reference latitudes .....m..... minutes early, SUBTRACT this amount from Item 13 or 15, and ENTER corrected time in appropriate box. (If satellite is late—ADD)

Schedule G. To Find Relative Longitude of Point Where Satellite Crosses Reference Latitude

1. Time when satellite crosses reference latitude (From schedule F, Item 13 or 15 uncorrected):	.....mo .....d .....h .....m.....	ST
2. SUBTRACT: Selected sweep time	− .....mo .....d .....h .....m.....	ST
3. Time difference (note whether plus or minus)	+(−) .....h .....m.....	
4. CONVERT above to minutes	+(−) .....m.....	+(−) .....m.....
5. MULTIPLY BY: Rate of orbit plane's relative westward motion (Schedule B, Item 3)		×0°...../min.
6. Relative longitude of point where satellite crosses reference latitude. (If time difference in Item 3 is *positive*, the observer's station will be *East;* of crossing point.	+(−) .....°.....	+(−) .....°.....

To BRING ABOVE UP-TO-DATE, SUBTRACT from time given in Item 4, the correction used in bringing Schedule F up-to-date, and ENTER result in Box. MULTIPLY corrected time by Item 5, and ENTER product in box opposite Item 6.

*See p.9 of text.

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PART III—OPTIONAL ADDITIONAL DETERMINATIONS

Preliminary Preparation of Plotting Grid (for use with any Pass of a given Satellite near Observer's Station)

1. SELECT a plotting grid showing latitude both of observer's station and of reference latitude used in Part II.
2. LOCATE Reference latitude used in Part II on central meridian (0° relative longitude). *This is reference point.*
3. ENTER Heading along satellite track for given orbit inclination and reference latitude (from Table IV) ..... °
4. ALSO ENTER: 180° *less* Item 3, above ..... °
5. DRAW straight line(s) through reference point on heading(s) (measured clockwise from North) shown above. EXTEND the resulting satellite track(s) on both sides of the reference point and MARK satellite direction(s) with arrowhead(s).

Schedule H—To Obtain Azimuth, Elevation, Slant Range and Passage Times

1. LOCATE Observer's relative position on plotting grid using station latitude (given) and relative longitude (from Schedule G, Item 6).
2. SELECT Point(s) of observational interest along satellite track
3. DRAW LINE(S) from observer's relative position to selected point(s)
4. MEASURE clockwise from North the angular distances(s) from observer's position to point(s) of interest, and ENTER as **Azimuth**
5. MEASURE distance(s) from observer's position to point(s) of interest, SCALE OFF on meridian to read in degrees of arc and ENTER as **Distance(s) from observer in degrees**
6. MEASURE along satellite track from reference point to point(s) of interest, SCALE OFF on meridian to read in degrees of arc and ENTER as **adjustment(s) to position**
7. ADD Current perigee distance (from Schedule F, Item 7)
8. **Perigee distance(s) relative to points of interest**

TURN TO Table III opposite *perigee position*(s) found in Item 8 (above) and under given orbit eccentricity, FIND and ENTER:

9. **Equivalent fraction(s) of period**
10. **Radial distance factor**(s)
11. MULTIPLY radial distance factor (Item 10, above) by radial distance at perigee (given)
12. **Radial distance(s) of satellite from center of the earth**
13. SUBTRACT Mean radius of Earth (3959 mi.) or radius at station *Satellite height*(s) *above point*(s) *of interest*
14. USING Satellite heights (from Item 13, above) and distance(s) from observer in degrees (from Item 5, above) ENTER "Chart for Determining Elevation and Slant Range" to OBTAIN { **Elevation**(s) / **Slant range**(s)
15. MULTIPLY **Equivalent fraction of period** (Item 9, above) by ..... m (*Current* perigee-to-perigee period) and ENTER
16. SUBTRACT Time required for satellite to travel from current perigee position to reference point (Schedule F, Item 10)
17. Time interval(s) between satellite passage over point(s) of interest and satellite passage over reference point
18. ADD Time when satellite passes over reference latitude (from Schedule F. Item 13 or 15)
19. Time(s) of satellite passage over point(s) of interest
20. Satellite in sunlight (from Table V)
21. Sky Dark at station (from Table VI)

	Sub-Satellite Point(s) of Observational Interest			
	Point of Nearest Approach	Meridian Passage	Alt #1	Alt #2
2.				
3.				
4.	...°	000° or 180°	...°	...°
5.	...°	...°	...°	...°
6.	+(−) ...°	+(−) ...°	+(−) ...°	+(−) ...°
7.	+ ...°	+ ...°	+ ...°	+ ...°
8.	...°	...°	...°	...°
9.	0. ...	0. ...	0. ...	0. ...
10.	. ...	. ...	. ...	. ...
11.	× ... mi	× ... mi	× ... mi	× ... mi
12.	... mi	... mi	... mi	... mi
13.	− ... mi	− ... mi	− ... mi	− ... mi
	... mi	... mi	... mi	... mi
14.	...°	...°	...°	...°
	... mi	... mi	... mi	... mi
15.	... m	... m	... m	... m
16.	− ... m	− ... m	− ... m	− ... m
17.	+(−) ... m	+(−) ... m	+(−) ... m	+(−) ... m
18.	+ ... h ... m	+ ... h ... m	+ ... h ... m	+ ... h ... m
19.	... h ... m	... h ... m	... h ... m	... h ... m
20.	Yes No	Yes No	Yes No	Yes No
21.		Yes No		

Form for locating satellite—first within the orbit plane, then relative to observer.

PART II—TO FIND WHEN AND WHERE SATELLITE 19..... - ..... CROSSES REFERENCE LATITUDE ON .....mo .....d, 19.....

Schedule D. To Find Minutes Elapsed between Reference Time and a Selected Sweep Time

1. Selected sweep time (from Schedule C, above)	.....mo .....d .....h .....m	ST
2. SUBTRACT: Reference time (from given data)	− .....mo .....d .....h .....m	ST
3. Elapsed time from reference time to selected sweep time	.....d .....h .....m	
4. ENTER: Minutes from Item 3 (above)	.....m	
5. ENTER: Hours from Item 3 (above) MULTIPLIED BY 60	.....m00	
6. ENTER: Days from Item 3 (above) MULTIPLIED BY 1,440, and ADD: Items 4, 5 & 6	+.....m00	
7. Time in minutes elapsed since reference time	.....m	

Schedule E. To Find Time when Satellite is Last at Perigee prior to Selected Sweep Time

1. Time in minutes elapsed since reference time (Schedule D, Item 7)	.....m	
2. DIVIDE BY: *Average** perigee-to-perigee period	÷ .....m	
3. ENTER: *Quotient* (number of periods completed since reference time) *and*	.....	
4. ENTER: *Remainder* in minutes	.....m	
5. ENTER: Selected sweep time (Schedule D, Item 1) and SUBTRACT Item 4 from Item 5:	.....mo .....d .....h .....m	ST
6. Time when satellite is last at perigee prior to selected sweep time	.....mo .....d .....h .....m	ST

Schedule F. To Find Time when Satellite Crosses Reference Latitude

1. Number of whole periods completed since reference time (Schedule E, Item 3)	.....	
2. MULTIPLY BY: Change in perigee position per period (given)	× +(−) .....°...../period	
3. Change in perigee position since reference time	+(−) .....°	
4. ADD: Perigee position at reference time (given)	+ .....°	
5. Current perigee position relative to northbound node	.....°	
6. ENTER: Appropriate central angle between equator and reference latitude, (from Schedule A, Item 8) and SUBTRACT: Item 5 from Item 6, *adding 360° to item 6 if necessary*	.....°	
7. Perigee distance from crossing point, measured within orbit plane	.....°	
8. ENTER: Equivalent fraction-of-period for given orbit eccentricity (from Table III)	.....	
9. MULTIPLY BY: *Current** perigee-to-perigee period	× .....m	
10. Time required for satellite to travel from current perigee position to crossing point.	.....m	
11. CONVERT above to hours and minutes	.....h .....m	
12. ADD: Time when satellite is last at perigee (Schedule E, Item 6)	+.....h .....m	ST
13. Time when satellite crosses reference latitude	.....h .....m ..... ST	.....h .....m ..... ST

NOTE: If time computed in item 13 differs from selected sweep time by more than one-half perigee-to-perigee period, then determine alternative time as shown below:

14. ADD (SUBTRACT) as appropriate: One whole perigee-to-perigee period (given)		.....h .....m .....
15. Alternative time when satellite crosses reference latitude	.....h .....m ..... ST	.....h .....m ..... ST

To BRING ABOVE UP-TO-DATE, Determine from the most recent data that the satellite will cross reference latitudes .....m..... minutes early, SUBTRACT this amount from Item 13 or 15, and ENTER corrected time in appropriate box. (If satellite is late—ADD)

Schedule G. To Find Relative Longitude of Point Where Satellite Crosses Reference Latitude

1. Time when satellite crosses reference latitude (From schedule F, Item 13 or 15 uncorrected):	.....mo .....d .....h .....m	ST
2. SUBTRACT: Selected sweep time	− .....mo .....d .....h .....m	ST
3. Time difference (note whether plus or minus)	+(−) .....h .....m	
4. CONVERT above to minutes	+(−) .....m	+(−) .....m .....
5. MULTIPLY BY: Rate of orbit plane's relative westward motion (Schedule B, Item 3)		×0°...../min.
6. Relative longitude of point where satellite crosses reference latitude. (If time difference in Item 3 is *positive*, the observer's station will be *East;* of crossing point.	+(−) .....°	+(−) .....° .....

To BRING ABOVE UP-TO-DATE, SUBTRACT from time given in Item 4, the correction used in bringing Schedule F up-to-date, and ENTER result in Box. MULTIPLY corrected time by Item 5, and ENTER product in box opposite Item 6.

*See p.9 of text.

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PART III—OPTIONAL ADDITIONAL DETERMINATIONS

Preliminary Preparation of Plotting Grid (for use with any Pass of a given Satellite near Observer's Station)

1. SELECT a plotting grid showing latitude both of observer's station and of reference latitude used in Part II.
2. LOCATE Reference latitude used in Part II on central meridian (0° relative longitude). *This is reference point.*
3. ENTER Heading along satellite track for given orbit inclination and reference latitude (from Table IV) ..... °
4. ALSO ENTER: 180° *less* Item 3, above ..... °
5. DRAW straight line(s) through reference point on heading(s) (measured clockwise from North) shown above. EXTEND the resulting satellite track(s) on both sides of the reference point and MARK satellite direction(s) with arrowhead(s).

Schedule H—To Obtain Azimuth, Elevation, Slant Range and Passage Times

1. LOCATE Observer's relative position on plotting grid using station latitude (given) and relative longitude (from Schedule G, Item 6).
2. SELECT Point(s) of observational interest along satellite track
3. DRAW LINE(S) from observer's relative position to selected point(s)
4. MEASURE clockwise from North the angular distances(s) from observer's position to point(s) of interest, and ENTER as **Azimuth**
5. MEASURE distance(s) from observer's position to point(s) of interest, SCALE OFF on meridian to read in degrees of arc and ENTER as **Distance(s) from observer in degrees**
6. MEASURE along satellite track from reference point to point(s) of interest, SCALE OFF on meridian to read in degrees of arc and ENTER as **adjustment(s) to position**
7. ADD Current perigee distance (from Schedule F, Item 7)
8. **Perigee distance(s) relative to points of interest**

TURN TO Table III opposite *perigee position*(s) found in Item 8 (above) and under given orbit eccentricity, FIND and ENTER:

9. **Equivalent fraction(s) of period**
10. **Radial distance factor**(s)
11. MULTIPLY radial distance factor (Item 10, above) by radial distance at perigee (given)
12. **Radial distance**(s) **of satellite from center of the earth**
13. SUBTRACT Mean radius of Earth (3959 mi.) or radius at station *Satellite height*(s) *above point*(s) *of interest*
14. USING Satellite heights (from Item 13, above) and distance(s) from observer in degrees (from Item 5, above) ENTER "Chart for Determining Elevation and Slant Range" to OBTAIN { **Elevation**(s) / **Slant range**(s)
15. MULTIPLY **Equivalent fraction of period** (Item 9, above) by ..... m ..... (*Current* perigee-to-perigee period) and ENTER
16. SUBTRACT Time required for satellite to travel from current perigee position to reference point (Schedule F, Item 10)
17. Time interval(s) between satellite passage over point(s) of interest and satellite passage over reference point
18. ADD Time when satellite passes over reference latitude (from Schedule F. Item 13 or 15)
19. Time(s) of satellite passage over point(s) of interest
20. Satellite in sunlight (from Table V)
21. Sky Dark at station (from Table VI)

	Sub-Satellite Point(s) of Observational Interest			
	Point of Nearest Approach	Meridian Passage	Alt #1	Alt #2
4. Azimuth	°	000° or 180°	°	°
5. Distance(s) from observer in degrees	°	°	°	°
6. Adjustment(s) to position	+(−) °	+(−) °	+(−) °	+(−) °
7. Perigee distance	+ °	+ °	+ °	+ °
8. Perigee distance(s) relative to points of interest	°	°	°	°
9. Equivalent fraction(s) of period	0.	0.	0.	0.
10. Radial distance factor(s)	.	.	.	.
11. Radial distance factor × radial distance at perigee	× mi	× mi	× mi	× mi
12. Radial distance(s) of satellite from center of the earth	mi	mi	mi	mi
13. − Mean radius of Earth or radius at station	− mi	− mi	− mi	− mi
Satellite height(s) above point(s) of interest	mi	mi	mi	mi
14. Elevation(s)	°	°	°	°
Slant range(s)	mi	mi	mi	mi
15. Equivalent fraction of period × m	m	m	m	m
16. − Time required for satellite to travel from current perigee position to reference point	− m	− m	− m	− m
17. Time interval(s) between satellite passage over point(s) of interest and satellite passage over reference point	+(−) m	+(−) m	+(−) m	+(−) m
18. + Time when satellite passes over reference latitude (from Schedule F. Item 13 or 15)	+ h m	+ h m	+ h m	+ h m
19. Time(s) of satellite passage over point(s) of interest	h m	h m	h m	h m
20. Satellite in sunlight (from Table V)	Yes No	Yes No	Yes No	Yes No
21. Sky Dark at station (from Table VI)		Yes No		