NASA TECHNICAL MEMORANDUM

NASA TM X-64680

HEAO STAR TRACKER SEARCH PROGRAM

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Program Development

March 6, 1972

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

MSFC - Form 3190 (Rev. June 1971)

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. TM X-64680	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE HEAO Star Tracker Search Program		5. REPORT DATE March 6, 1972
		6. PERFORMING ORGANIZATION CODE PD-DO-ES
7. AUTHOR(S) William J. Weiler		8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO.
		13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D.C. 20546		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared by the Navigation and Control Systems Branch, Electronics and Controls Division, Preliminary Design Office, Program Development

16. ABSTRACT

The High Energy Astronomy Observatory (HEAO) requires a highly accurate and flexible control system to accommodate its scientific payload. One of the critical elements of this system is the star tracker subsystem, which defines an accurate three-axis attitude reference. A digital computer program has been developed to evaluate the ability of a particular star tracker configuration to meet the requirements for attitude reference at various vehicle orientations. Used in conjunction with an adequate star catalog, this program provides information on availability of stars for each tracker and on the ability of the system to maintain three-axis attitude reference throughout a representative sequence of vehicle orientations. This program was developed to provide information necessary for the selection of baseline and possible alternate star tracker configurations for the HEAO-C mission. It could be adapted, however, to other missions which utilize star tracker systems.

17. KEY WORDS Star Tracker Star Search Attitude Control Star Catalog HEAO	18. DISTRIBUTION STATEMENT STAR Announcement ERICH E. GOERNER Director, Preliminary Design Office

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	46	$ 3.00

MSFC - Form 3292 (May 1969)

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HEAO STAR TRACKER SEARCH PROGRAM

I. INTRODUCTION

The High Energy Astronomy Observatory (HEAO) requires a highly accurate and flexible control system to accommodate its scientific payload. One of the critical elements in this system is the star tracker subsystem which defines an accurate attitude reference about all three axes. The ability of a particular star tracker configuration to meet the requirements for attitude reference at various vehicle orientations can best be evaluated by a star search computer program in conjunction with an adequate star catalog. Such a program could provide information on star availability, recognition, and occultation. This information is needed to determine tracker system characteristics such as number and orientation of trackers, field-of-view, sensitivity, and gimbaled versus fixed-head trackers. The purpose of this report is to describe a specific star search program used in the HEAO studies, discuss its operation, and present some typical results. This particular program was originally adapted from a Teledyne Brown Engineering Company program and was modified to meet the specific requirements of this study.

II. PROGRAM GENERAL DESCRIPTION

This section will be devoted to a general description of the capabilities, limitations, and use of the star search program developed for this study. This program gives star availability information throughout all or a portion of a year. It is set up for a vehicle which maintains one axis pointing at the sun and may rotate to any angle about this axis. This is the general pattern for HEAO, although the HEAO sunline axis will be permitted to move off the sun by as much as 30 degrees to allow the experiment axis to acquire a target out of plane. The parameters of earth orbit are not considered; therefore, earth occultation is not considered. Since one axis is held along the sunline, sun occultation is avoided by not pointing any trackers within some cone angle of this axis. Star pattern recognition was not attempted because present needs did not require such information. This program was originally intended for fixed-head star trackers. It may, however, be applied to gimbaled trackers if a circular effective field-of-view may be assumed. All of the inputs and outputs would pertain to the effective field-of-view, and no information would be gained on the instantaneous field-of-view.

The star search program is presently set up for the CDC-3200 computer (32 K core). The program can handle a catalog of 7000 stars and up to 10 star trackers in any orientation. This is more than sufficient for a catalog of stars of magnitude 6.00 and brighter. If, however, a larger catalog is required, the program could be modified to accept the catalog in batches.

At the beginning of a set of cases, the user enters the specially prepared star catalog into the computer. The preparation of this catalog is covered in detail in Appendix C. He then enters the number of trackers, program control variables, and specification of each tracker. The program control variables consist of initial and terminating conditions, and program increment sizes. The specification of a tracker consists of the diameter of the field-of-vew, the magnitude of the dimmest star which can be seen, and components of a unit vector along the look direction of the tracker given in a body-fixed reference coordinate system. Then, the number of stars found in the catalog and all of the inputs are printed.

The program begins at the specified initial sunline, and increments the vehicle through a full revolution about this sunline. The direction of the sunline is then incremented, and another revolution is performed. This continues until the specified final sunline direction is reached. At each vehicle orientation, a search through the star catalog is performed for each tracker. At the completion of each sun angle, the following data summarizing the results for this sun angle are printed:

1. Sun angle.

2. Percent fix (percent of vehicle orientations for which at least one star was seen in two or more star trackers simultaneously).

3. For each tracker:

   a. Tracker number.

   b. Percent coverage (percent of vehicle orientations for which this tracker saw at least one star).

   c. Average number of stars seen per look direction.

   d. Greatest number of stars seen at any one look direction.

At the completion of each case, the program prints the following data:

1. Total number of vehicle orientations.

2. Percent fix over entire case.

3. For each tracker: identical data to sun angle print, but computed over entire case.

At the completion of a case, the program will read the set of data for the next case. A blank card following the data for the last case causes the program to terminate.

Since a star search program inherently involves a large number of computations, efforts have been made to reduce computing time and make the program reasonably efficient. A rather elaborate search routine is used, and subscripting is held to a minimum within the search loop.

A discussion of runs which have been made with this program is contained in a later section, and some example runs are given in Appendix D.

III. DEFINITIONS

This section will be devoted to defining the form of the star catalog, the coordinate systems used, and the program variables.

The star catalog is compiled into the required special form and recorded onto magnetic tape by a separate program. The entry for each star contains right ascension, declination, and magnitude information in integer form. The rules for the integer conversion are as follows:

(Star right ascension)	ISTRA=50.*(STRA-180.)
(Star declination)	ISTDC=100.*STDC
(Star visual magnitude)	ISTMG=100.*STMG

where STRA is given in degrees from the ascending line of nodes (0 to 360 degrees), STDC in degrees (±90 degrees), and magnitude in its conventional form. Converting the catalog to integer form reduces computer storage requirements for the catalog by a factor of two. The stars are ordered in the catalog according to increasing declination. This ordering is germane to the search routine. Thus, the integer forms of right ascension and declination have a range of ±9000, integer magnitude has a nominal range of -160 to +900, and the integer declination increases monotonically through the catalog. The details of the program which prepares the catalog, and a discussion of the problems encountered in preparing the catalog which is presently being used are contained in Appendix C.

At the beginning of execution of the star search program, the star catalog is read from magnetic tape into the computer core memory. Because of core size limitations, the catalog may contain no more than 7000 stars. If a larger star catalog is required, the program could be modified to accept the catalog in batches, or the program could be moved to a larger computer. Alternately, the program could be moved to a computer which has fast access mass storage (i.e., disk), and the program modified to perform the search directly from mass storage rather than from core memory. At present a catalog of 4827 stars of magnitude 6.00 and brighter is being used.

Four coordinate systems are used (Fig. 1). A reference coordinate system (X_r, Y_r, Z_r) is body-fixed, with X_r always pointing along the sunline. For HEAO-C, Y_r is taken to be the experiment pointing axis. The orientation of each star tracker is specified by inputing the components of a unit vector in the direction of the tracker in the reference coordinate system. A solar-fixed coordinate system (X_s, Y_s, Z_s) has X_s directed from the earth to the sun in the ecliptic plane, and Z_s perpendicular to the ecliptic plane directed northward. The X_r, Y_r, Z_r system rotates through an angle θ_r from the X_s, Y_s, Z_s system about the $X_s = X_r$ axis (vehicle rotating about the sunline). An inertial ecliptic coordinate system (X_1, Y_1, Z_1) has X_1 directed from the earth along the line of ascending nodes (Aries), and $Z_1 = Z_s$ is perpendicular to the ecliptic plane. The sunline X_s rotates through an angle θ_s from X_1 about the $Z_1 = Z_s$ axis. Thus, θ_s is a measure of the time of year from vernal equinox. A geocentric inertial system (X_g, Y_g, Z_g) has $X_g = X_1$ pointing toward Aries with Z_g perpendicular to the equatorial plane in the northward direction. The X_1, Y_1, Z_1 system is rotated through an angle θ_e of 23.45 degrees from the X_g, Y_g, Z_g system about the $X_g = X_1$ axis. Alternately, a direction in the X_g, Y_g, Z_g system may be given by right ascension from the X_g axis and declination above the equatorial plane. This is the system in which the star catalog is given, and the system in which the star search is carried out.

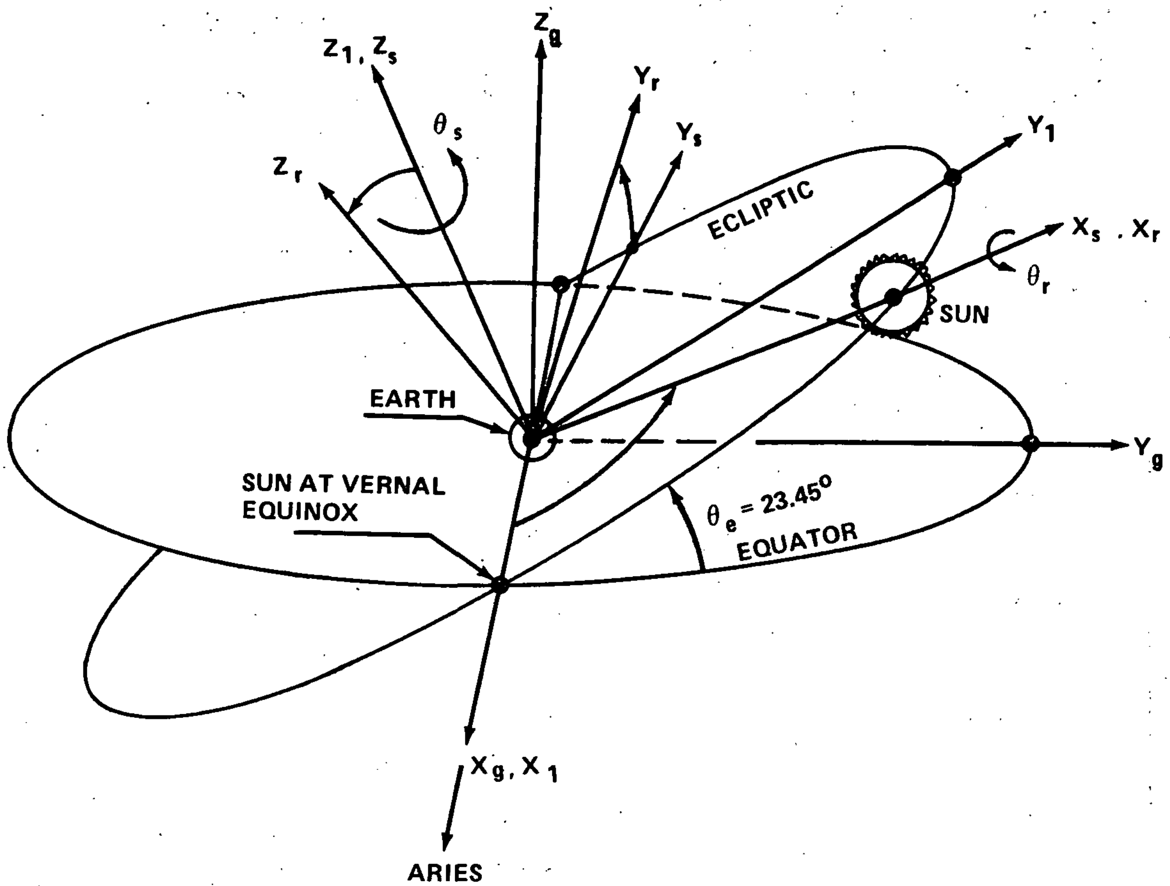

Figure 1. Coordinate systems.

Table 1 is a list of the names and definitions of variables used in the star search program. The dimensions of array variables are given within the subscript parentheses. In general, the variable N is used to refer to the Nth star for the three arrays which contain the star catalog, and M is used to refer to the Mth star tracker for the tracker-related variables. The variables are grouped into the following categories:

1. Constants and Miscellaneous
2. Coordinate System Variables
3. Star Variables
4. Tracker Variables
5. Bookkeeping Variables

Within each group the variables are ordered in approximately the order in which they occur in the program. The implied specification of integer and floating point variables is followed throughout (any variable name beginning with I, J, K, L, M, or N is an integer variable, all others are floating point).

TABLE 1. PROGRAM VARIABLES

Constants and Miscellaneous	
PI	π, 3.1415926536
TOPI	2π
DTOR	degree to radian conversion multiplier, PI/180.
RTOD	radian to degree conversion multiplier, 180./PI
DUM1, DUM2, DUM3	dummy variables used in reading from magnetic tape
JFLG	logic flag variable which controls step search mode
Coordinate System Variables	
THTE	θ_e = 23.45 degrees, angle of inclination between ecliptic plane and equatorial plane
STE, CTE	$\sin\theta_e$, $\cos\theta_e$
THTS	θ_s, angle from line of ascending nodes to sunline
STS, CTS	$\sin\theta_s$, $\cos\theta_s$
PTHS	θ_s converted and saved for print
DELTS	$\Delta\theta_s$, inputed sun angle step size

TABLE 1. (Continued)

Coordinate System Variables (Concluded)	
THTSF	θ_s final, final value of sun angle, used to terminate case
THTR	θ_r, angle reference coordinate system (body-fixed) has rotated from solar-fixed system, measured about sunline
STR, CTR	$\sin \theta_r$, $\cos \theta_r$
PTHR	θ_r converted and saved for print
DELTR	$\Delta \theta_r$, inputed step size for roll about sunline
Star Variables	
NSTRS	number of stars found in catalog
ISTRA(7000) ISTDC(7000) ISTMG(7000)	integer arrays in which the star catalog is stored (right ascension, declination, and magnitude)
N	subscript used with arrays containing star catalog, to specify the nth star
NMIN, NMAX	lower and upper bounds of N, used in successive halving process of the octave search
N0	N_{zero}, used in the step search to retain the original value of N
STRA, STDC	right ascension and declination of a star, converted to floating point
STPJ	projection of a unit vector directed toward a star into the X_g, Y_g plane

TABLE 1. (Continued)

<u>Star Variables (Concluded)</u>	
STXG, STYG, STZG	components in X_g, Y_g, Z_g coordinate system of a unit vector directed toward a star
DOTPR	dot product of a unit vector directed toward a star with a unit vector directed along the look direction of a tracker
<u>Tracker Variables</u>	
NTRKS	number of star trackers for this case (input)
TRXR(10), TRYR(10), TRZR(10)	components of unit vector along look direction of mth tracker in reference (body-fixed) coordinate system (input)
TRMG(10)	limiting magnitude of mth tracker (input)
TFOV(10)	diameter of field-of-view of mth tracker (input)
M	subscript for all tracker-related arrayed variables, to denote mth tracker
TRVL	computed length of inputed vector along look direction of a tracker, used to correct inputed vector to unit length
TRXS, TRYS, TRZS	components of unit vector along look direction of a tracker in solar-fixed coordinate system
TRX1, TRY1, TRZ1	components of unit vector along look direction of a tracker in ecliptic coordinate system

TABLE 1. (Continued)

Tracker Variables (Concluded)	
TRXG, TRYG, TRZG	components of unit vector along look direction of a tracker in geocentric inertial coordinate system
TRRA, TRDC	right ascension and declination of a unit vector along the look direction of a tracker
PTRA(10), PTDC(10)	used to retain TRRA and TRDC of each tracker for an optional print
ITRRA, ITRDC, ITRMG	TRRA, TRDC, and TRMG(M) converted to integer form according to the conversion rules of the star catalog
IRFOV	radius of the field-of-view of a tracker converted to integer form according to the rule IRFOV = (50.*TFOV(M))
SRFOV, CRFOV	sine, cosine of radius of field-of-view
MAXDC, MINDC	upper and lower declination limits (in integer form) of a spherical trapezoid containing the field-of-view of a tracker for present look direction
DLRA	half of the right ascension diameter of a spherical trapezoid containing the field-of-view of a tracker for the present look direction
IDLRA	DLRA converted to integer form according to the rule IDLRA = (50.*DLRA)
MAXRA, MINRA	maximum and minimum right ascension bounds (in integer form) of a spherical trapezoid containing the field-of-view of a tracker for present look direction

TABLE 1. (Continued)

Bookkeeping Variables	
NSEE	number of stars seen by a tracker during search for present look direction
NSEEN(10)	stores the values of NSEE for each tracker so that they are available for optional printout
NSN(10)	running total of number of stars each tracker has seen during the search for the present sunline
NSNT(10)	running total of number of stars each tracker has seen during the entire case
NGNS(10)	greatest number of stars each tracker has seen at any single look direction during the search of the present sunline
NGNST(10)	greatest number of stars each tracker has seen at any single look direction during the entire case
NLD	number of look directions per tracker, or vehicle orientations, which have been searched for the present sunline
NLDT	number of vehicle orientations which have been searched during the entire case
RNLD, RNLDT	NLD and NLDT converted to floating point so that arithmetic operations involving these variables will be performed in floating point
NLHS(10)	number of look directions each tracker had at least one star during the search of the present sunline

TABLE 1. (Concluded)

Bookkeeping Variables (Concluded)	
NLHST(10)	number of look directions each tracker had at least one star during the entire case
LFIX	integer variable used to determine if a fix (two or more trackers having at least one star each) was obtained for the present vehicle orientation
NFIX	number of vehicle orientations for which a fix was obtained during the search of the present sunline
NFIXT	number of vehicle orientations for which a fix was obtained during the entire case
AVNS(10)	for each tracker, the average number of stars seen per look direction during this sunline or over the entire case, as applicable
PCCOV(10)	for each tracker, the percent coverage, or percent of look directions it had at least one star, computed for each sunline, and again for entire case
PCFIX	percent of vehicle orientations at which a fix (two or more trackers having at least one star each) was obtained, computed for each sunline, and again for the entire case

IV. PROGRAM DESCRIPTION

This section will be devoted to a detailed functional description of the star search program. First, the overall flow of the program will be given, as shown in Figure 2. Then the details of the actual search routine will be covered, as shown in Figure 3.

A dimension statement allocates storage for the subscripted arrays for 10 star trackers and a catalog of 7000 stars. The star catalog arrays are stored in COMMON to prevent exceeding core because of temporary storage required by the computer during loading. All of the required format statements are given, and logical unit 6 (assigned to magnetic tape unit 3 at execution time) is rewound. Since the specially prepared star catalog being used is the second file contained on a reel of magnetic tape, a dummy read statement is used to locate the end of the first file. The star catalog is then read, one star at a time, from magnetic tape and stored into the arrays allocated in core memory. The read is terminated when an end-of-file mark is encountered, and the tape is rewound. The integer variable NSTRS contains the number of stars which were contained in the catalog.

The set of data cards for the first case is then read. This data consists of one card containing NTRKS, DELTS, DELTR, initial THTS, and THTSF, and one card per tracker containing TRXR(M), TRYR(M), TRZR(M), TRMG(M) and TFOV(M). The input vectors which specify the orientation of each tracker are corrected to unit length, and all of the input data is printed. For convenience, all angle inputs and outputs from this program are in degrees. Variables are initialized as necessary, initial computations are performed, THTR is set to zero, and the search loop is entered. The search loop finds for the present vehicle orientation how many stars from the star catalog can be seen by each tracker. The outputs of the search routine are updated values of LFX and, for each tracker, NSEEN(M), NGNS(M), NSN(M), and NLHS(M). Upon completion of the search loop, LFX is checked to see if a fix was obtained for this vehicle orientation, and NFIX is updated accordingly. An optional print may be added following statement number 85 to output information at vehicle orientations for which a fix was not obtained. The following information is specifically available for this print: PTRA(M), PTDC(M), NSEEN(M), LFX, PTHS, and PTHR.

A new vehicle orientation is obtained by incrementing THTR by the angle DELTR, and the search process is repeated. This continues until a full revolution about the present sunline is completed. Then bookkeeping variables are updated, statistics for this sunline are computed, and data summarizing the

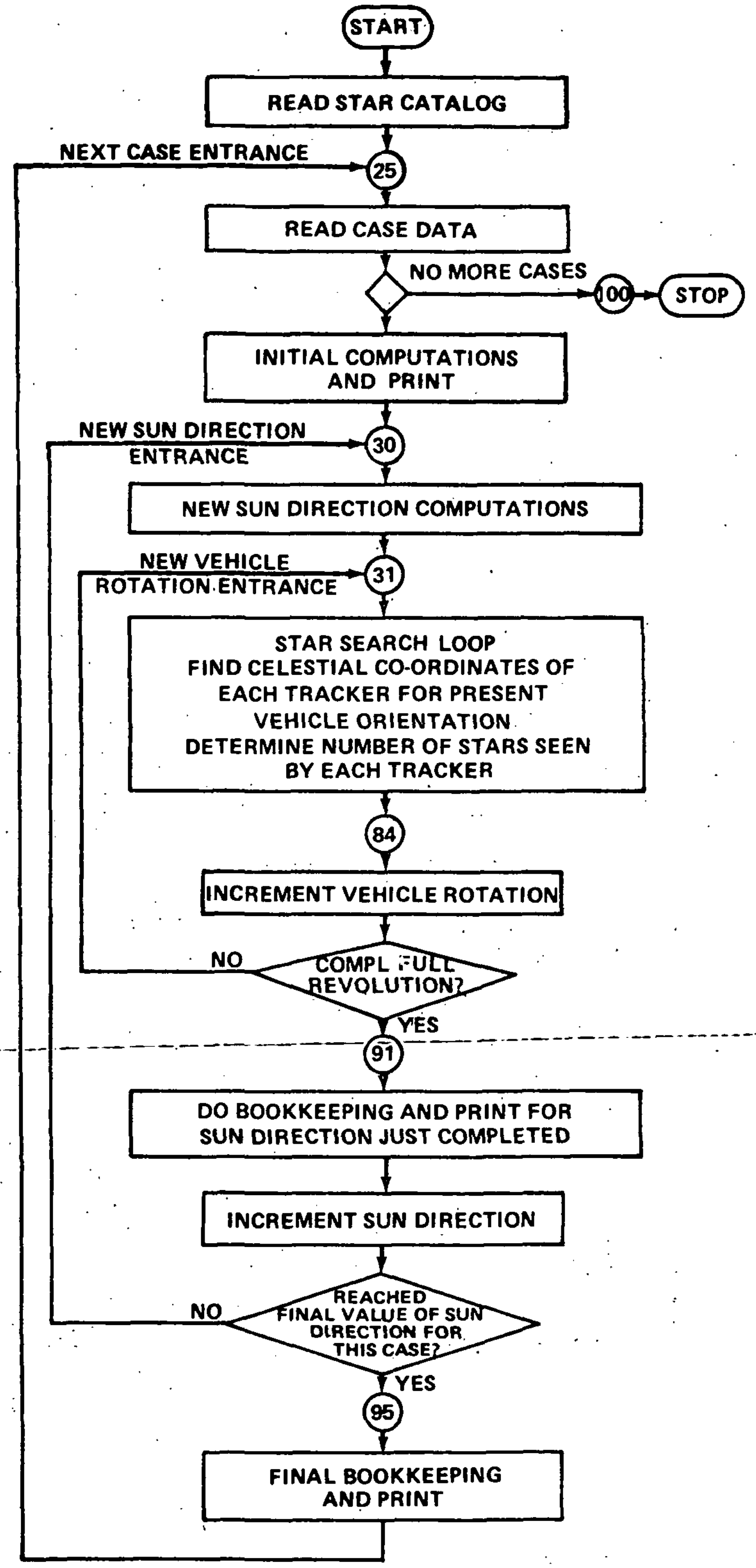

Figure 2. Overall flow diagram.

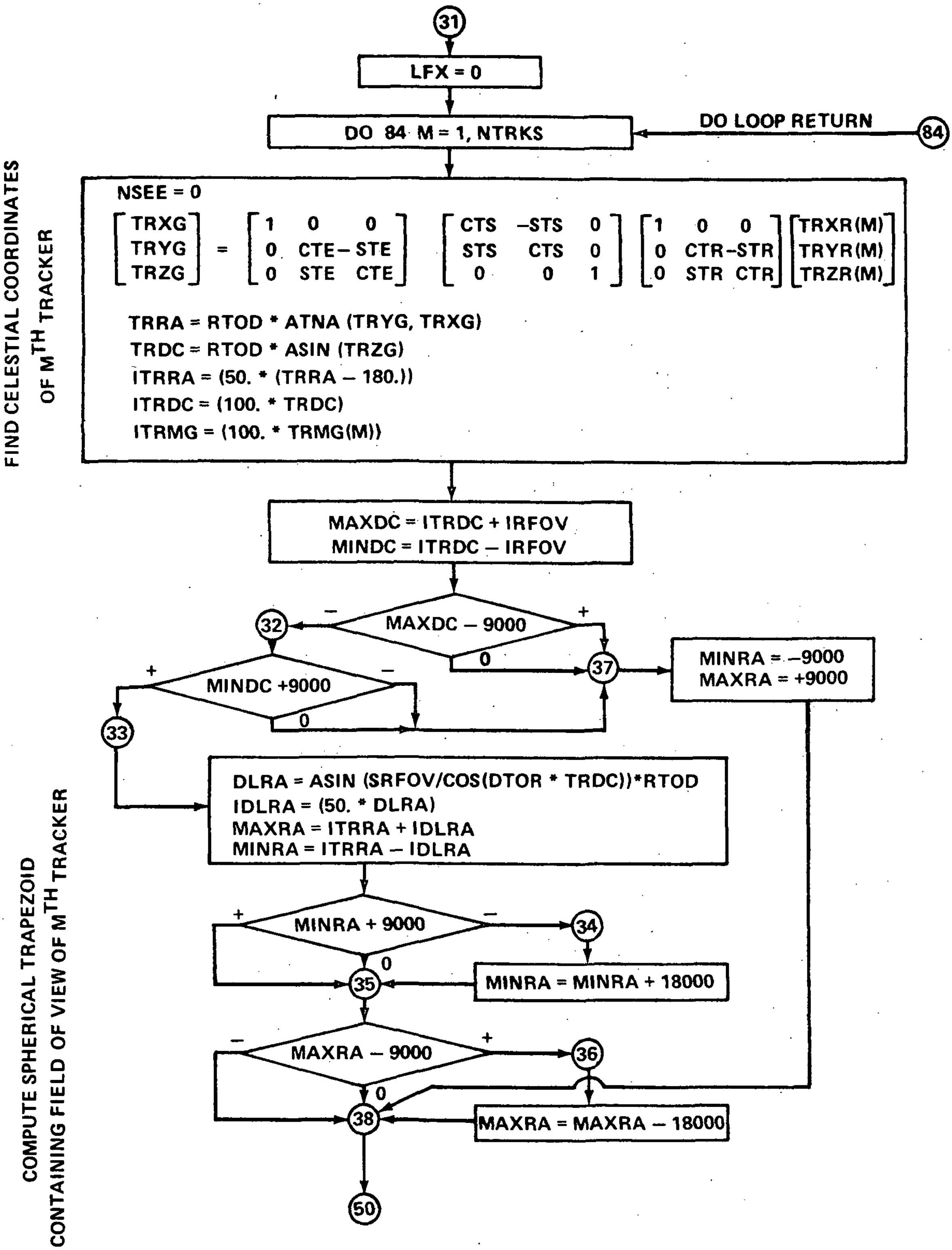

Figure 3. Detailed flow diagram.

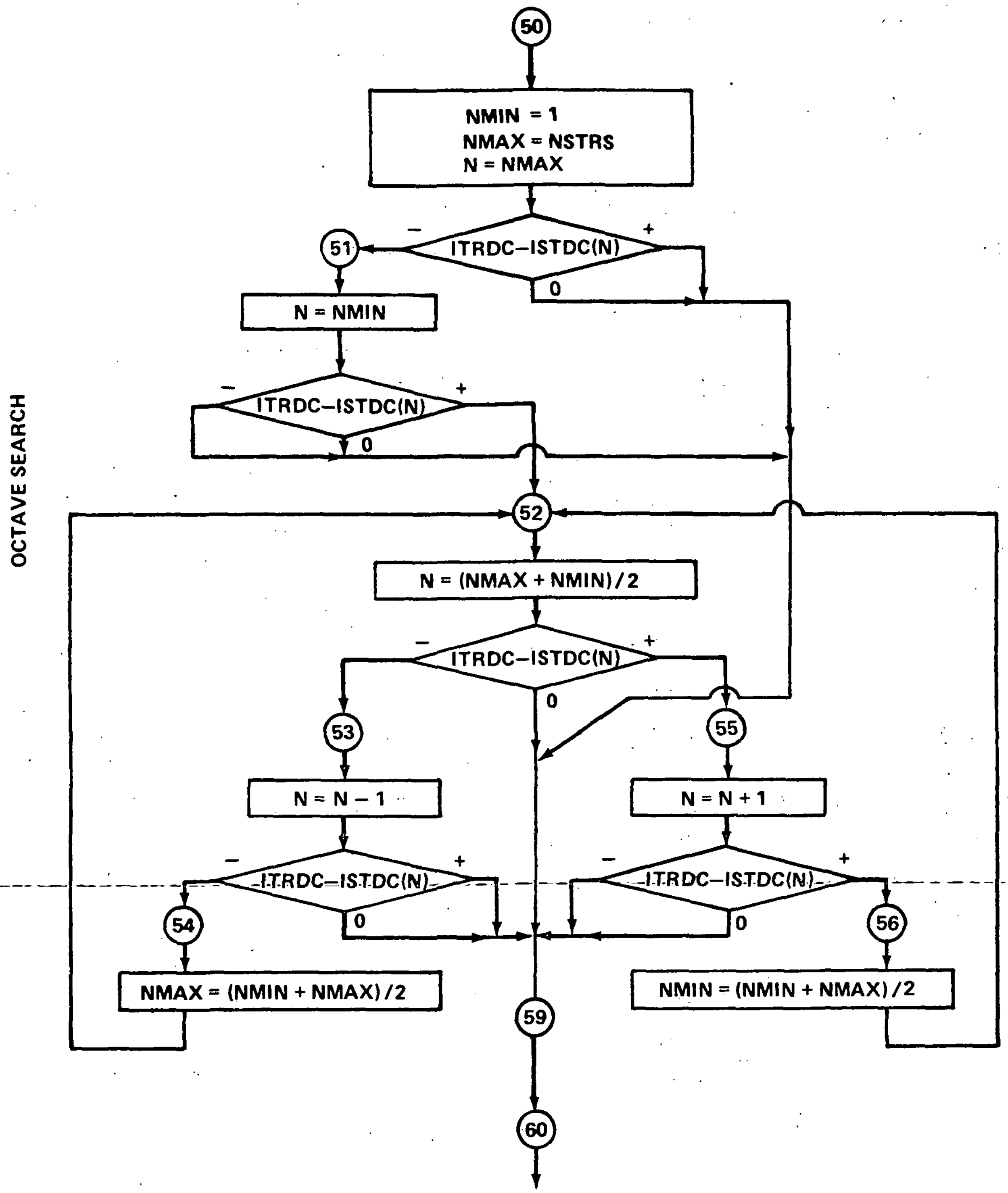

Figure 3. (Continued).

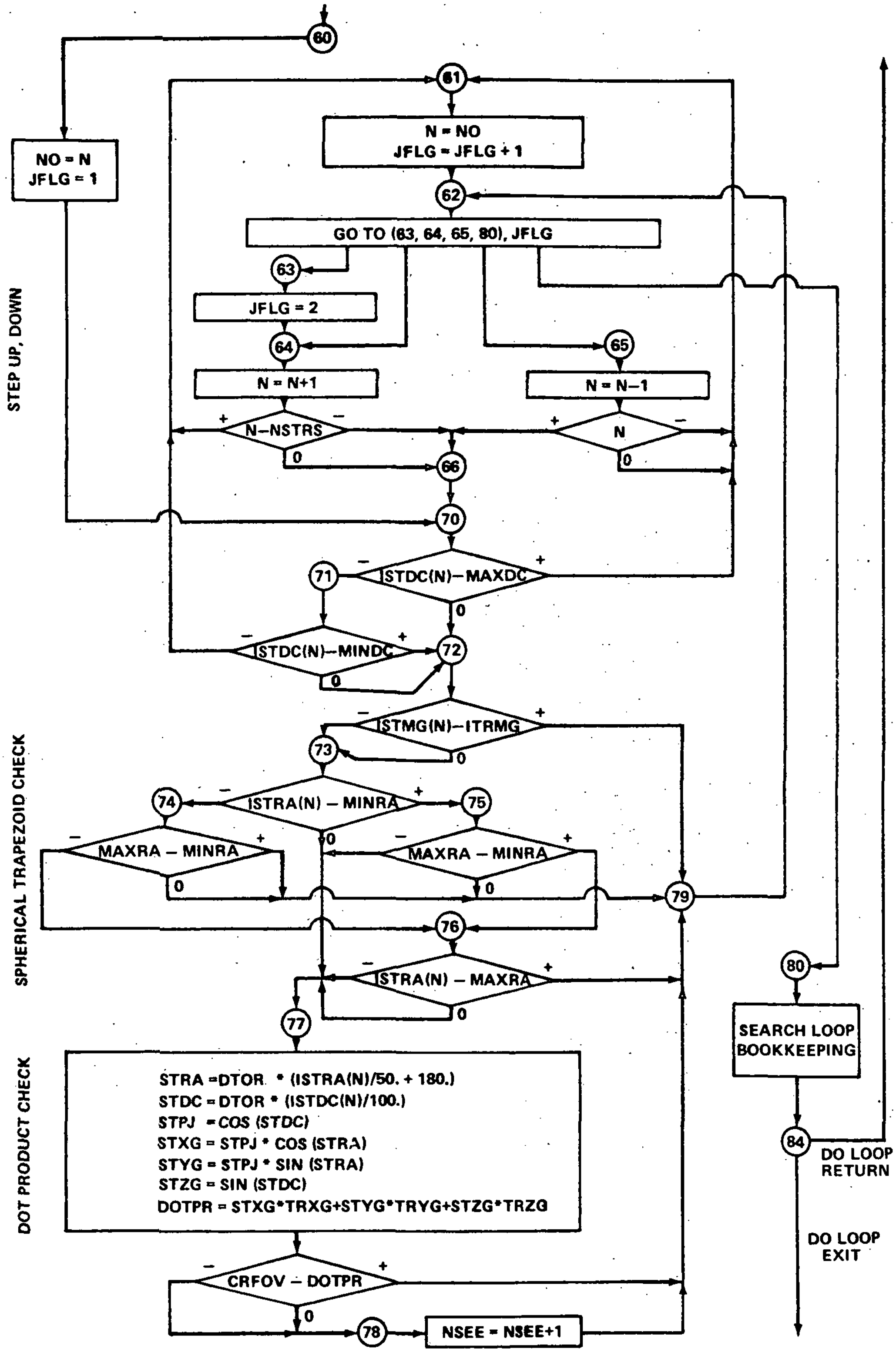

Figure 3. (Concluded).

results of the search for this sunline are printed. The sunline angle (THTS) is then incremented by an angle DELTS, and the preceding process is repeated. This continues until the final sun angle (THTSF) has been reached. Final bookkeeping computations are then made, data summarizing the entire case are printed, and data cards for the next case are read. An invalid data set, consisting of a single card which sets the number of trackers for this case (NTRKS) to zero, or negative, causes termination of the program.

The details of the search loop are shown in flow diagram form in Figure 3. A search is carried out for each tracker in turn under the control of a DO loop. Bookkeeping variables retain the results from which the information to be printed will be derived.

To perform a search for the Mth tracker, the present look direction of this tracker is found in geocentric inertial coordinates (Fig. 3, first page). This is done by rotating the input unit vector components (TRXR(M), TRYR(M), TRZR(M)) through the angles THTR, THTS, and THTE. The rotated components are then converted to a tracker right ascension and declination (TRRA, TRDC) and changed to integer form compatible with the star catalog (ITRRA, ITRDC).

A spherical trapezoid which contains the circular field-of-view is now calculated. The declination boundaries of this spherical trapezoid in integer form are

MAXDC = ITRDC + IRFOV

MINDC = ITRDC - IRFOV

where $IRFOV = 100.*\frac{TFOV}{2}$, and TFOV is the diameter of the field-of-view of the tracker. If the field-of-view is tangent to or encircles a pole (MAXDC ≥ 9000, or MINDC ≤ -9000), the entire range of integer right ascensions (-9000 to +9000) is used. In any other case, the right ascension bounds of the spherical trapezoid are computed as follows:

DLRA = ASIN (SRFOV/COS (DTOR*TRDC))* RTOD

IDLRA = (50.* DLRA)

MAXRA = ITRRA + IDLRA

MINRA = ITRRA - IDLRA .

The derivation of the first step above is given in Appendix B. It is possible for the above computations to yield MAXRA > +9000, or MINRA < -9000, signifying that the field-of-view straddles the 0 degree = 360 degree azimuth. This condition is checked for, and correction made when necessary by adding ±18000 (integer form of ±360 degrees). Note that if this correction is required, it will be true that MAXRA < MINRA after the correction. In any other case MAXRA > MINRA. The bounds of the computed spherical trapezoid will be used later in the search.

It is now desired to find an advantageous starting point in the star catalog from which to begin the search. This is accomplished by an octave search through the catalog, shown in Figure 3, second page. NMIN is set to 1, and NMAX is set to NSTRS. Recalling that the stars in the catalog are ordered by increasing declination, four possibilities exist. The declination of the tracker look direction (ITRDC) is either greater than or equal to the declination of the last entry in the catalog (ISTDC (NMAX)), less than or equal that of the first entry (ISTDC (NMIN)), equal to the declination of an intermediate entry, or between the declinations of two adjacent entries. The first two possibilities are checked. If either is true, the octave search is exited from with N set to NMAX or NMIN, as appropriate. If neither is true, an iterative process follows to determine the catalog number N of a star for which the third possibility is true or either of two stars for which the fourth possiblity is true. The iterative process is one of successive halving of the catalog until one of the possibilites is met. For a catalog of 7000 stars, a maximum of 13 iterations would be needed to complete the process ($7000 < 2^{13}$). In any event, the result of the octave search is a catalog number N which is used as a starting point for the search.

A star by star search, shown in Figure 3, third page, is now made beginning with star NO = N, then incrementing N upward from NO, and then downward. A flag variable JFLG controls the search and will have a value of 1, 2, 3, or 4 depending on whether the program is presently checking entry NO, searching upward from NO, searching downward from NO, or is ready to exit from the search. During the search, each candidate star is checked to see if it is within the spherical trapezoid previously computed. When a star is encountered whose declination is not within the trapezoid, it is known that no more candidate stars lie in the present direction of search, and JFLG is incremented. When applying the right ascension part of the trapezoid test, special attention must be given to the case in which the field-of-view straddles the 0 degree = 360 degree azimuth, as the requirements for passing the test are different for this case. Also, the magnitude is compared with the limiting magnitude of the tracker.

Each star which is found to be within the boundaries of the spherical trapezoid and is of sufficient brightness to be seen by the tracker is then checked to determine if it is within the circular field-of-view. A unit vector directed toward the star is computed. A dot product is formed between this vector and a unit vector along the look direction, yielding the cosine of the angle between the star and the center of the field-of-view. This is compared with the cosine of the radius of the field-of-view to determine if the tracker sees this star. NSEE, the number of stars seen by this tracker in this look direction, is updated accordingly, and the search goes on to the next star. When all candidate stars have been tested, as evidenced by JFLG= 4, the program will update the search loop bookkeeping variables and return to the beginning of the search loop to repeat for the next star tracker. When the search has been completed for all trackers for this vehicle orientation, it will exit from the search loop, perform bookkeeping, increment vehicle orientation, and repeat the search process.

The advantage of the spherical trapezoid test is that only integer subtraction is required to determine if a candidate star is contained therein. Thus, the majority of the stars within the proper declination band of the table are eliminated without the necessity of time-consuming trigonometric calculations.

V. PROGRAM RESULTS

A listing of the star search program and several runs which have been made with the present star catalog are shown in Appendix A. The baseline star trackers (6th magnitude, 6 degree diameter field-of-view) have been used. A run was made with two trackers, one along the Y_r axis (experiment pointing axis) and one along the Z_r axis. This is the baseline HEAO-C configuration. The sunline was stepped from 0 degrees to 180 degrees in 3 degree increments, and the vehicle was rolled about each sunline in 3 degree increments. Since both trackers lie in a plane perpendicular to the sunline, a 180 degree rotation of the sunline covers the entire celestial sphere. For program checkout purposes, a similar run was made with the sunline beginning at 180 degrees and stopping at 360 degrees. The results were identical.

The results of the baseline runs show that through the year each tracker has 95 percent coverage. A two tracker fix was obtained 91 percent of the time. Each tracker had an average of 3.4 stars per look direction, and 20 stars was the greatest number seen by one tracker at any look direction. The poorest coverage was obtained in early June and early December, when the path of the star trackers passes near the galactic poles. Figures 4 and 5 are plots of the star-empty look directions found for a 6th magnitude, 6 degree diameter field-of-view tracker.

Some possibly advantageous alternates to the baseline HEAO-C star tracker configuration have been considered. A computer run is shown in the appendix in which a third star tracker was added in the same plane as the trackers, and pointing midway between their look directions. A two tracker reference was obtained 98.9 percent of the time for this system during the quarter of the year following the equinoxes.

A problem arises with the baseline star tracker configuration if no stars are available within the radius of field-of-view of a desired experiment pointing direction. Since one of the star trackers is aligned with the experiment pointing direction, rotating about this direction will not alleviate the problem. This suggests canting this star tracker a few degrees from the experiment axis so that rolling about the experiment axis will move the look direction of the star tracker and, possibly, acquire a star. The star search program will be used to investigate this and other possible alternates to the baseline configuration.

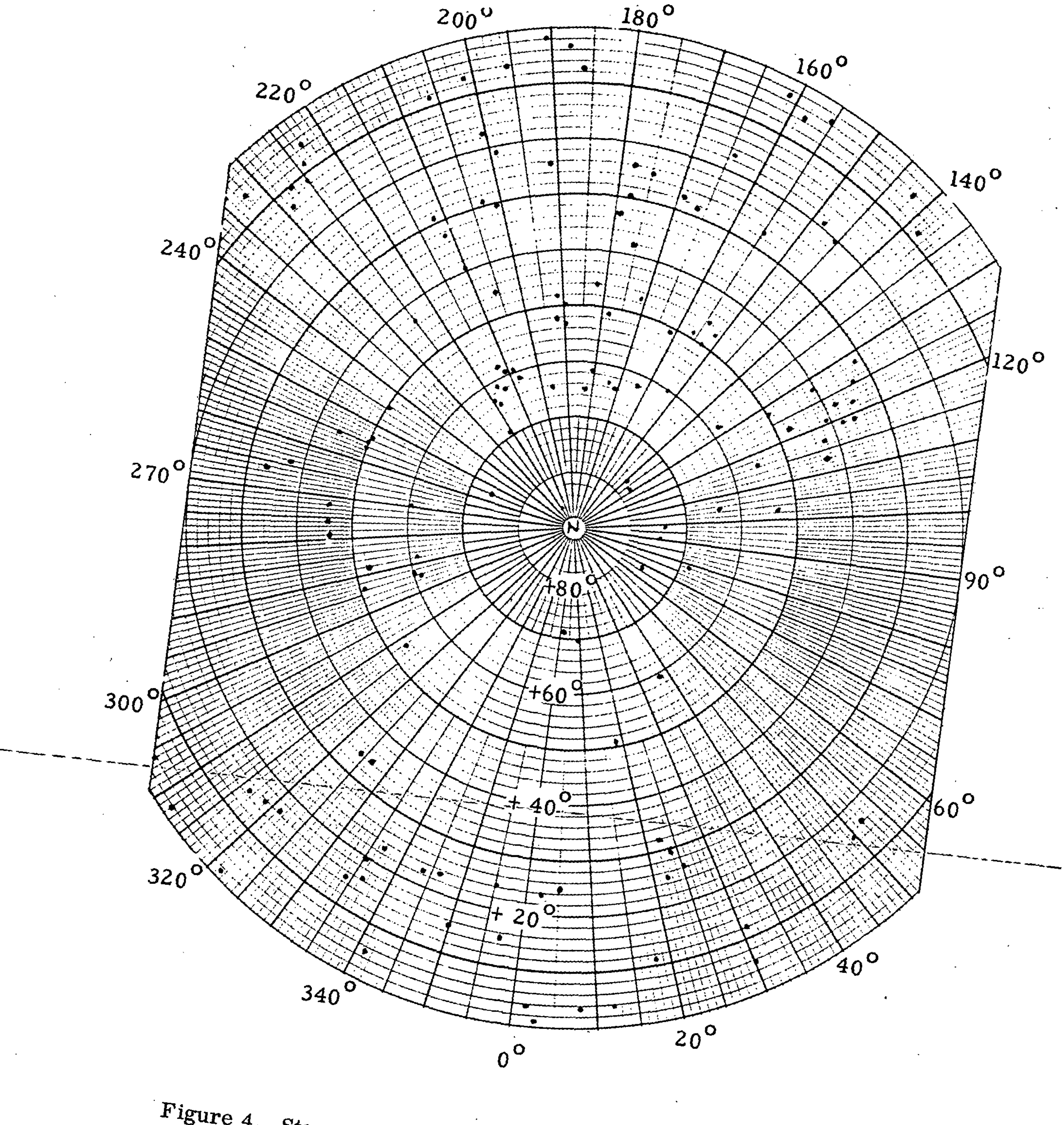

Figure 4. Star-empty look directions, northern hemisphere.

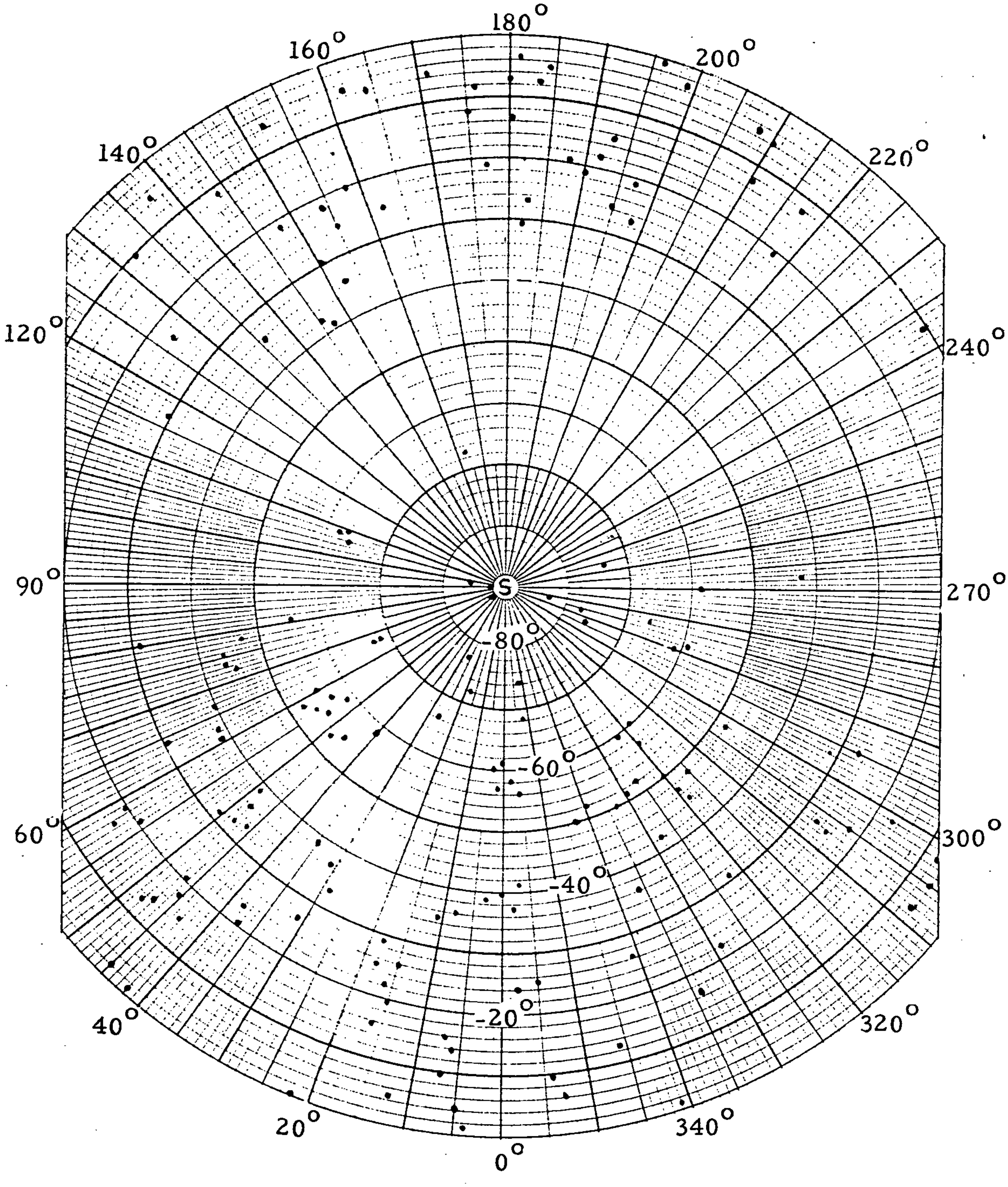

Figure 5. Star-empty look directions, southern hemisphere.

APPENDIX A. STAR TRACKER SEARCH PROGRAM LISTING

This appendix contains a complete listing of the program written in FORTRAN IV for a Control Data Corporation Model 3200 digital computer. This machine configuration includes a 32 K core memory, four magnetic tape units, a card reader, and a printer.

```
                                   3200 FORTRAN (3.0)/RTS            / /

      PROGRAM STRTRKER
      COMMON ISTRA,ISTDC,ISTMG
      DIMENSION ISTRA(7000),ISTDC(7000),ISTMG(7000),TRXR(10),TRYR(10),
     1TRZR(10),TRMG(10),PTRA(10),PTDC(10),NSEEN(10),NSN(10),NSNT(10),
     2NLHS(1 ),NLHST(10),NGNS(10),NGNST(10),PCCOV(10),AVNS(10),TFOV(10)
    1 FORMAT(2F8.3,F6.2)
    2 FORMAT(3I6)
    3 FORMAT(I10,7F10.4)
    4 FORMAT(5F10.4)
    5 FORMAT(1H1,58X,15HCASE INPUT DATA//45X,35HNUMBER OF STARS IN CATAL
     5OG                 =,I7/45X,35HNUMBER OF STAR TRACKERS             =,I7/
     545X,35HINITIAL SUN ANGLE (DEG)               =,F7.2/
     545X,35HFINAL SUN ANGLE (DEG)                 =,F7.2/
     545X,35HSUN ANGLE INCREMENT (DEG)             =,F7.2/
     545X,35HVEHICLE ROTATION INCREMENT (DEG)  =,F7.2/)
    6 FORMAT(14X,7HTRACKER,I2,6X,31HDIAMTR OF FIELD OF VIEW (DEG) =,F7.4
     6,10X,2 HLIMITING MAGNITUDE =,F7.4/29X,33HUNIT VECTOR DIRECTION COM
     6PONENTS ,6X,6HTRXR =,F7.4,6X,6HTRYR =,F7.4,6X,6HTRZR =,F7.4)
    7 FORMAT(1X,4F10.4,I10,2F10.4,I10)
    9 FORMAT(///1X,12HSUNLINE DATA/)
   10 FORMAT(//////1X,10HFINAL DATA/)
   11 FORMAT(2X,5HTHTS=,F7.2,4X,6HPCFIX=,F6.2,2(6X,7HTRACKER,I2,2X,6HPCC
     1OV=,F6.2,2X,5HAVNS=,F5.2,2X,5HNGNS=,I3)/(30X,2(6X,7HTRACKER,I2,2X,
     16HPCCOV=,F6.2,2X,5HAVNS=,F5.2,2X,5HNGNS=,I3)))
   12 FORMAT(2X,5HNLDT=,I7  ,4X,6HPCFIX=,F6.2,2(6X,7HTRACKER,I2,2X,6HPCC
     2OV=,F6.2,2X,5HAVNS=,F5.2,2X,5HNGNS=,I3)/(30X,2(6X,7HTRACKER,I2,2X,
     26HPCCOV=,F6.2,2X,5HAVNS=,F5.2,2X,5HNGNS=,I3)))
      REWIND 6
      PI=3.1415926536
      TOPI=2*PI
      DTOR=PI/180.
      RTOD=180./PI
      NSTRS=
   20 READ INPUT TAPE 6,1,DUM1,DUM2,DUM3
      GO TO(21,20),EOFCKF(6)
   21 CONTINUE
   22 READ INPUT TAPE 6,2,ISTRA(NSTRS+1),ISTDC(NSTRS+1),ISTMG(NSTRS+1)
      GO TO(24,23),EOFCKF(6)
   23 NSTRS=NSTRS+1
      GO TO 22
   24 REWIND 6
   25 READ 3,NTRKS,DELTS,DELTR,THTS,THTSF
      IF(NTRKS)100,100,26
   26 READ 4,((TRXR(M),TRYR(M),TRZR(M),TRMG(M),TFOV(M)),M=1,NTRKS)
      PRINT 5,NSTRS,NTRKS,THTS,THTSF,DELTS,DELTR
      NLDT=0
      NFIXT=
      DO 27 M=1,NTRKS
      NSNT(M)=0
      NLHST(M)=0
      NGNST(M)=0
      TRVL=SQRT(TRXR(M)**2+TRYR(M)**2+TRZR(M)**2)
      TRXR(M)=TRXR(M)/TRVL
      TRYR(M)=TRYR(M)/TRVL
      TRZR(M)=TRZR(M)/TRVL
   27 PRINT 6,M,TFOV(M),TRMG(M),TRXR(M),TRYR(M),TRZR(M)
      THTE=DTOR*23.45
      STE=SIN(THTE)
      CTE=COS(THTE)
      DELTS=DELTS*DTOR
```

```
      DELTR=DELTR*DTOR
      THTSF=THTSF*DTOR
      THTS=THTS*DTOR
      PRINT 9
   30 STS=SIN(THTS)
      CTS=COS(THTS)
      THTR=0.0
      MFIX=0
      MLD=0
      DO 29 M=1,NTRKS
      NLHS(M)=0
      NSN(M)=0
      NGNS(M)=0
   29 CONTINUE
   31 STR=SIN(THTR)
      CTR=COS(THTR)
      LFX=0
      DO 84 M=1,NTRKS
      NSEE=0
      IRFOV=(50.*TFOV(M))
      SRFOV=SIN(DTOR*TFOV(M)/2.)
      CRFOV=COS(DTOR*TFOV(M)/2.)
      TRXS=TRXR(M)
      TRYS=CTR*TRYR(M)-STR*TRZR(M)
      TRZS=STR*TRYR(M)+CTR*TRZR(M)
      TRX1=CTS*TRXS-STS*TRYS
      TRY1=STS*TRXS+CTS*TRYS
      TRZ1=TRZS
      TRXG=TRX1
      TRYG=CTE*TRY1-STE*TRZ1
      TRZG=STE*TRY1+CTE*TRZ1
      TRRA=ATNA(TRYG,TRXG)*RTOD
      TRDC=ASIN(TRZG)*RTOD
      PTRA(M)=TRRA
      PTDC(M)=TRDC
      ITRRA=(50.*(TRRA-180.))
      ITRDC=(100.*TRDC)
      ITRMG=(100.*TRMG(M))
      MAXDC=ITRDC+IRFOV
      MINDC=ITRDC-IRFOV
      IF(MAXDC-9000)32,37,37
   32 IF(MINDC+9000)37,37,33
   33 DLRA=ASIN(SRFOV/COS(DTOR*TRDC))*RTOD
      IDLRA=(50.*DLRA)
      MAXRA=ITRRA+IDLRA
      MINRA=ITRRA-IDLRA
      IF(MINRA+9000)34,35,35
   34 MINRA=MINRA+18000
   35 IF(MAXRA-9000)38,38,36
   36 MAXRA=MAXRA-18000
      GO TO 38
   37 MINRA=-9000
      MAXRA=+9000
   38 CONTINUE
   50 NMIN=1
      NMAX=NSTRS
      N=NMAX
      IF(ITRDC-ISTDC(N))51,59,59
   51 N=NMIN
      IF(ITRDC-ISTDC(N))59,59,52
   52 N=(NMAX+NMIN)/2
      IF(ITRDC-ISTDC(N))53,59,55
```

```
53 N=N-1
   IF(ITRDC-ISTDC(N))54,59,59
54 NMAX=(NMIN+NMAX)/2
   GO TO 52
55 N=N+1
   IF(ITRDC-ISTDC(N))59,59,56
56 NMIN=(NMIN+NMAX)/2
   GO TO 52
59 CONTINUE
60 N0=N
   JFLG=1
   GO TO 70
61 N=N0
   JFLG=JFLG+1
62 GO TO (63,64,65,80),JFLG
63 JFLG=2
64 N=N+1
   IF(N-NSTRS)66,66,61
65 N=N-1
   IF(N)61,61,66
66 CONTINUE
70 IF (ISTDC(N)-MAXDC)71,72,61
71 IF (ISTDC(N)-MINDC)61,72,72
72 IF (ISTMG(N)-ITRMG)73,73,79
73 IF (ISTRA(N)-MINRA)74,77,75
74 IF (MAXRA-MINRA)76,79,79
75 IF (MAXRA-MINRA)77,79,76
76 IF (ISTRA(N)-MAXRA)77,77,79
77 STRA=DTOR*(ISTRA(N)/50.+180.)
   STDC=DTOR*(ISTDC(N)/100.)
   STPJ=COS(STDC)
   STXG=STPJ*COS(STRA)
   STYG=STPJ*SIN(STRA)
   STZG=SIN(STDC)
   DOTPR=STXG*TRXG+STYG*TRYG+STZG*TRZG
   IF (CRFOV-DOTPR)78,78,79
78 NSEE=NSEE+1
79 GO TO 62
80 CONTINUE
   NSEEN(M)=NSEE
   IF(NSEE)84,84,81
81 IF(NSEE-NGNS(M))83,83,82
82 NGNS(M)=NSEE
83 LFX=LFX+1
   NSN(M)=NSN(M)+NSEE
   NLHS(M)=NLHS(M)+1
84 CONTINUE
   NLD=NLD+1
   PTHS =THTS*RTOD
   PTHR =THTR*RTOD
   IF(LFX-2)85,86,86
85 CONTINUE
   GO TO 87
86 NFIX=NFIX+1
87 CONTINUE
   THTR=THTR+DELTR
   IF(THTR-TOPI)31,91,91
91 CONTINUE
   NLDT=NLDT+NLD
   NFIXT=NFIXT+NFIX
   RNLD=NLD
   PCFIX=100.*NFIX/RNLD
```

```
      DO 93 M=1,NTRKS
      NLHST(M)=NLHST(M)+NLHS(M)
      NSNT(M)=NSNT(M)+NSN(M)
      PCCOV(M)=100.*NLHS(M)/RNLD
      AVNS(M)=NSN(M)/RNLD
      IF(NGNS(M)-NGNST(M))93,93,92
   92 NGNST(M)=NGNS(M)
   93 CONTINUE
      PRINT 11,PTHS,PCFIX,((M,PCCOV(M),AVNS(M),NGNS(M)),M=1,NTRKS)
      THTS=THTS+DELTS
      IF(THTS-THTSF)30,95,95
   95 CONTINUE
      RNLDT=NLDT
      PCFIX=100.*NFIXT/RNLDT
      DO 96 M=1,NTRKS
      PCCOV(M)=100.*NLHST(M)/RNLDT
   96 AVNS(M)=NSNT(M)/RNLDT
      PRINT 10
      PRINT 12,NLDT,PCFIX,((M,PCCOV(M),AVNS(M),NGNST(M)),M=1,NTRKS)
      GO TO 25
  100 STOP
      END
```

FORTRAN DIAGNOSTIC RESULTS FOR STRTRKER

```
 NULL STATEMENT NUMBERS
       50          60          7
EQUIP,06=MTC0E0U03
LOAD,56
RUN,10
```

APPENDIX B. EXPLANATIONS AND DERIVATIONS

This appendix contains an explanation of the computer library subroutines and functions used by the program, and explanation or derivation of program algorithms as deemed necessary.

The library functions and subroutines are listed below:

EOFCKF(i) — End-of-file check function, used to determine if an end-of-file was encountered during the last attempted read from logical unit i. A value of 1 is returned if an end-of-file was encountered, a value of 2 if not. In this program, logical unit 6 is used and is defined to be magnetic tape unit 3.

IOCHKF(i) — (Used in the star catalog preparation program.) Checks the status on the last input/output request on logical unit i to determine if a parity error occurred. A value of 1 is returned if an error occurred, a value of 2 if not. Logical unit 6 is used and is defined to be magnetic tape unit 3.

SQRT(x) — Square root of x.

SIN(x) — Sine of x, where x is in radians.

COS(x) — Cosine of x, where x is in radians.

ATNA (s,c) — Arc tangent of $\left(\frac{s}{c} \right)$, where s and c are the sine and cosine of the desired angle or are proportional to the sine and cosine by any positive common factor. The angle returned will be in the range of 0 to 2π radians.

ASIN(x) — Arc sine of x. The angle returned will be in the range of $-\pi/2$ to $+\pi/2$ radians.

Most of the algorithms used in the program are adequately explained in preceding sections. Two points, however, bear some further discussion.

The calculation of the spherical trapezoid containing the circular field-of-view of a tracker for a given look direction involves the use of spherical trigonometry. Referring to Figure B-1, define the following in the celestial sphere:

α	right ascension of look direction
δ	declination of look direction, $\delta \geq 0$
γ	half-cone angle of tracker field-of-view
ϕ	desired spherical angle between meridians NCB and NTA
C	center of tracker field-of-view
N	north celestial pole
T	point of tangency of the tracker field-of-view and meridian NTA

Suppose $\delta + \gamma \leq \frac{\pi}{2}$. (If $\delta + \gamma > \frac{\pi}{2}$, the field-of-view overlaps the north pole and all stars with declination $\geq (\delta - \gamma)$ are tested by the dot product method. Thus, if the field-of-view encircles a pole, a polar cap is used in place of a spherical trapezoid.) The declination limits of the spherical trapezoid are immediately seen to be $(\delta - \gamma)$ and $(\delta + \gamma)$. Also it is obvious that $\gamma \leq \phi \leq \frac{\pi}{2}$, with $\phi = \gamma$ for $\delta = 0$, and $\phi = \frac{\pi}{2}$ for $\delta = \frac{\pi}{2} - \gamma$. From the law of sines,

$$\frac{\sin \phi}{\sin \gamma} = \frac{\sin \frac{\pi}{2}}{\sin \left(\frac{\pi}{2} - \delta\right)} \quad ;$$

thus,

$$\sin \phi = \frac{\sin \gamma}{\cos \delta} \quad .$$

The result is identical for a look direction in the southern hemisphere $(\delta \leq 0)$. This equation is used to calculate ϕ. Thus, for a look direction (α, δ), such that the tracker field-of-view does not encircle a pole, the circular field-of-view is guaranteed to be contained in the spherical trapezoid defined by a

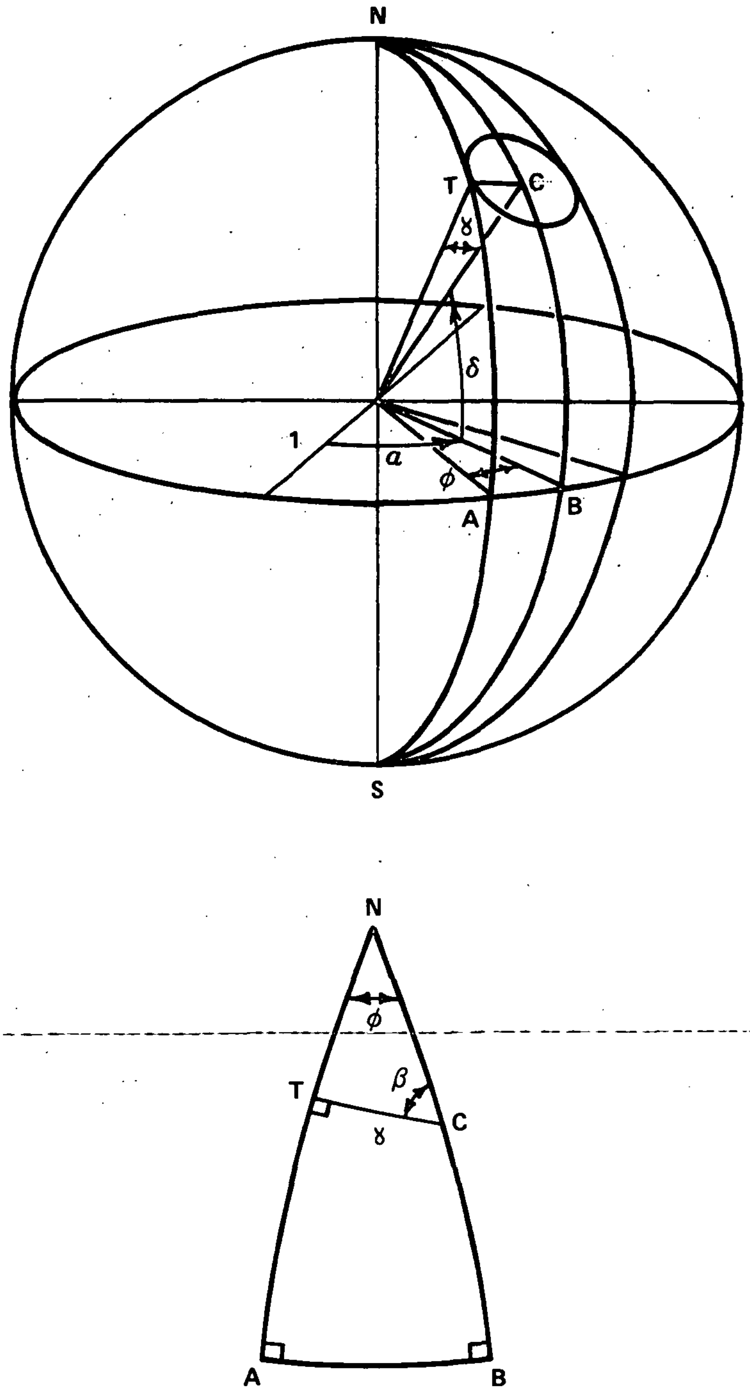

Figure B-1. Spherical trapezoid derivation.

declination range of $(\delta - \gamma, \delta + \gamma)$ and a right ascension range of $(\alpha - \phi, \alpha + \phi)$, where $\phi = \arcsin \dfrac{\sin\gamma}{\cos\delta}$. Each star found to be within this spherical trapezoid is then tested by the dot product method to determine if it is within the circular field-of-view of the tracker.

The dot product method consists of forming a dot product between a unit vector directed toward a star and a unit vector along the tracker look direction. The result of this dot product, which is identically the cosine of the angle between the two vectors, is compared with the cosine of the half-cone angle of the tracker field-of-view to determine if the star is within the field-of-view. It should be realized that because of the magnitudes of the angles involved and the small angular differences which must be detected, the cosine of the half-cone angle and the result of the dot product must each be accurate to at least eight significant figures for a tracker with a field-of-view diameter of one degree. This point must be considered if a tracker with a narrow field-of-view is to be considered, or if the program is to be run on a less accurate computer.

APPENDIX C. PREPARATION OF THE STAR CATALOG

The star catalog presently being used with the star search program was obtained through the Computation Laboratory at Marshall Space Flight Center from a catalog of 259 000 stars compiled by the Smithsonian Astrophysical Observatory[1]. The Smithsonian catalog contains 11 consecutive 36-bit binary computer words per star and is available on two 2400-foot, 7-track tape reels at 556 bytes per inch. This is an extremely comprehensive star catalog and is recommended as a source whenever star catalog information is required.

The Smithsonian catalog was prepared on tape by an IBM 7094 computer. The tapes may be read and interpreted by most computers which have magnetic tape capability. However, due to differences in tape format, coding, and computer word length, some difficulty is involved, and usually a language closer to basic machine language than Fortran will be required. This problem was circumvented by preparing an intermediate magnetic tape written in IBM 7094 BCD (Binary Coded Decimal) format. This tape was written by a program on a computer at the Computation Laboratory which is fully compatible with the IBM-7094 binary coding. This program searched through the Smithsonian catalog and prepared a reduced catalog containing only right ascension, declination, and magnitude for those stars whose magnitude was listed as less than or equal to 6.00. IBM 7094 BCD proved to be directly compatible with CDC 3200 BCD. Thus, the CDC computer was able to read the tape containing the reduced catalog.

An initial look at the reduced catalog showed an obvious error. Nearly 1500 stars were listed as having a magnitude of 0.00. The booklet explaining the Smithsonian Star Catalog was consulted. It was found that for a variable star for which no average magnitude was available, a magnitude of 0.00 was entered in the catalog, and a separate code bit denoted that this was such a star. Since the Computation Laboratory program had not checked these code bits during the search of the catalog, these stars were included in the reduced catalog.

A program was written for the CDC-3200 to read the intermediate star catalog and prepare from it a final star catalog in the form required by the

1. K. L. Haramundanis, SAO Star Catalog Binary Tapes. Smithsonian Institution Astrophysical Observatory, Cambridge, Massachusetts, 1967. Direct inquires to: Star Catalog, Smithsonian Astrophysical Observatory, 60 Garden Street, Cambridge, Massachusetts, 02138, Telephone 617-864-7910.

star search program. This program reads the data for each star and converts the data to integer form according to the rules given for the program. Because of the problem mentioned above, every star whose magnitude is given as 0.00 is eliminated. The remaining stars are then ordered by increasing declination, and the final star catalog is written on magnetic tape in BCD. The intermediate catalog was retained on tape for future reference, and the final catalog is contained on the same reel of tape immediately following the intermediate catalog. A total of 4827 stars are contained in the present final star catalog.

A listing of the computer program used to prepare this catalog is given below.

```
                                    3200 FORTRAN (3.0)/RTS

      PROGRAM STARCAT
      DIMENSION ISTRA(7000),ISTDC(7000),ISTMG(7000)
    5 FORMAT(2F8.3,F6.2)
    6 FORMAT(1X,13HPARITY ERROR ,2I6)
    7 FORMAT(1X,10I10)
    8 FORMAT(3I6)
      REWIND 6
      NSTIN=
      NSTRS=
   10 READ INPUT TAPE 6,5,STRA,STDC,STMG
      GO TO (15,11),EOFCKF(6)
   11 NSTIN=NSTIN+1
      GO TO (12,13),IOCHKF(6)
   12 PRINT 6,NSTIN
   13 CONTINUE
      IMAG=(100*STMG)
      IF (IMAG) 14,10,14
   14 NSTRS=NSTRS+1
      ISTRA(NSTRS)=(50.*(STRA-180.))
      ISTDC(NSTRS)=(100.*STDC)
      ISTMG(NSTRS)=IMAG
      GO TO 10
   15 CONTINUE
      PRINT 7,NSTIN,NSTRS
   20 JFLAG=1
      DO 22 N=2,NSTRS
      IF(ISTDC(N-1)-ISTDC(N)) 22,22,21
   21 JFLAG=2
      JRA=ISTRA(N-1)
      JDC=ISTDC(N-1)
      JMG=ISTMG(N-1)
      ISTRA(N-1)=ISTRA(N)
      ISTDC(N-1)=ISTDC(N)
      ISTMG(N-1)=ISTMG(N)
      ISTRA(N)=JRA
      ISTDC(N)=JDC
      ISTMG(N)=JMG
   22 CONTINUE
      GO TO(25,20),JFLAG
   25 CONTINUE
      DO 26 N=1,NSTRS
   26 WRITE OUTPUT TAPE 6,8,ISTRA(N),ISTDC(N),ISTMG(N)
      ENDFILE 6
   30 REWIND 6
      STOP
      END

                    FORTRAN DIAGNOSTIC RESULTS  FOR    STARCAT


NULL STATEMENT NUMBERS
     30
EQUIP,06=MTC0E0U03
LOAD,56
```

APPENDIX D. EXAMPLE RUNS

Several example computer runs made with the HEAO Star Tracker Search Program are given in this appendix. A discussion of some of the results is contained previously in this document.

CASE INPUT DATA

NUMBER OF STARS IN CATALOG	=	4827
NUMBER OF STAR TRACKERS	=	2
INITIAL SUN ANGLE (DEG)	=	0
FINAL SUN ANGLE (DEG)	=	180.00
SUN ANGLE INCREMENT (DEG)	=	3.00
VEHICLE ROTATION INCREMENT (DEG)	=	3.00

TRACKER 1 DIAMTR OF FIELD OF VIEW (DEG) = 6.0000 LIMITING MAGNITUDE = 6.0000
UNIT VECTOR DIRECTION COMPONENTS TRXR = 0 TRYR = 1.0000 TRZR = 0

TRACKER 2 DIAMTR OF FIELD OF VIEW (DEG) = 6.0000 LIMITING MAGNITUDE = 6.0000
UNIT VECTOR DIRECTION COMPONENTS TRXR = 0 TRYR = 0 TRZR = 1.0000

SUNLINE DATA

THTS=	PCFIX=	TRACKER	PCCOV=	AVNS=	NGNS=	TRACKER	PCCOV=	AVNS=	NGNS=
0	91.74	TRACKER 1	95.87	3.51	8	TRACKER 2	95.87	3.49	8
3.00	93.39	TRACKER 1	96.69	3.75	11	TRACKER 2	96.69	3.73	11
6.00	98.35	TRACKER 1	99.17	3.69	10	TRACKER 2	99.17	3.70	10
9.00	90.08	TRACKER 1	95.04	3.55	12	TRACKER 2	95.04	3.54	12
12.00	92.56	TRACKER 1	95.87	3.45	11	TRACKER 2	95.87	3.42	11
15.00	95.87	TRACKER 1	97.52	3.68	10	TRACKER 2	97.52	3.65	10
18.00	94.21	TRACKER 1	96.69	3.77	12	TRACKER 2	96.69	3.74	12
21.00	96.69	TRACKER 1	98.35	3.64	15	TRACKER 2	98.35	3.64	15
24.00	91.74	TRACKER 1	95.87	3.71	17	TRACKER 2	95.87	3.71	17
27.00	91.74	TRACKER 1	95.87	3.50	16	TRACKER 2	95.87	3.50	16
30.00	90.08	TRACKER 1	95.04	3.60	13	TRACKER 2	95.04	3.60	13
33.00	81.82	TRACKER 1	90.91	3.59	12	TRACKER 2	90.91	3.57	12
36.00	90.08	TRACKER 1	95.04	3.37	13	TRACKER 2	95.04	3.36	13
39.00	91.74	TRACKER 1	95.87	3.65	18	TRACKER 2	95.87	3.65	18
42.00	95.04	TRACKER 1	97.52	3.57	18	TRACKER 2	97.52	3.56	18
45.00	83.47	TRACKER 1	91.74	3.22	12	TRACKER 2	91.74	3.23	12
48.00	93.39	TRACKER 1	96.69	3.39	11	TRACKER 2	96.69	3.40	11
51.00	91.74	TRACKER 1	95.87	3.32	17	TRACKER 2	95.87	3.32	17
54.00	83.47	TRACKER 1	91.74	3.26	17	TRACKER 2	91.74	3.25	17

THTS= 57.00	PCFIX= 91.74	TRACKER 1	PCCOV= 95.87	AVNS= 3.12	NGNS= 13	TRACKER 2	PCCOV= 95.87	AVNS= 3.12	NGNS= 13
THTS= 60.00	PCFIX= 90.08	TRACKER 1	PCCOV= 95.04	AVNS= 3.07	NGNS= 12	TRACKER 2	PCCOV= 95.04	AVNS= 3.06	NGNS= 12
THTS= 63.00	PCFIX= 95.04	TRACKER 1	PCCOV= 97.52	AVNS= 3.07	NGNS= 13	TRACKER 2	PCCOV= 97.52	AVNS= 3.07	NGNS= 13
THTS= 66.00	PCFIX= 93.39	TRACKER 1	PCCOV= 96.69	AVNS= 3.03	NGNS= 14	TRACKER 2	PCCOV= 96.69	AVNS= 3.01	NGNS= 14
THTS= 69.00	PCFIX= 84.30	TRACKER 1	PCCOV= 91.74	AVNS= 2.93	NGNS= 14	TRACKER 2	PCCOV= 91.74	AVNS= 2.92	NGNS= 14
THTS= 72.00	PCFIX= 73.55	TRACKER 1	PCCOV= 86.78	AVNS= 2.66	NGNS= 16	TRACKER 2	PCCOV= 86.78	AVNS= 2.66	NGNS= 16
THTS= 75.00	PCFIX= 68.60	TRACKER 1	PCCOV= 83.47	AVNS= 2.68	NGNS= 15	TRACKER 2	PCCOV= 83.47	AVNS= 2.66	NGNS= 15
THTS= 78.00	PCFIX= 77.69	TRACKER 1	PCCOV= 88.43	AVNS= 2.85	NGNS= 11	TRACKER 2	PCCOV= 88.43	AVNS= 2.84	NGNS= 11
THTS= 81.00	PCFIX= 88.43	TRACKER 1	PCCOV= 94.21	AVNS= 3.07	NGNS= 12	TRACKER 2	PCCOV= 94.21	AVNS= 3.06	NGNS= 12
THTS= 84.00	PCFIX= 93.39	TRACKER 1	PCCOV= 96.69	AVNS= 3.06	NGNS= 9	TRACKER 2	PCCOV= 96.69	AVNS= 3.06	NGNS= 9
THTS= 87.00	PCFIX= 96.69	TRACKER 1	PCCOV= 98.35	AVNS= 3.19	NGNS= 12	TRACKER 2	PCCOV= 98.35	AVNS= 3.20	NGNS= 12
THTS= 90.00	PCFIX= 85.95	TRACKER 1	PCCOV= 92.56	AVNS= 2.97	NGNS= 13	TRACKER 2	PCCOV= 93.39	AVNS= 2.98	NGNS= 13
THTS= 93.00	PCFIX= 81.82	TRACKER 1	PCCOV= 90.91	AVNS= 2.79	NGNS= 12	TRACKER 2	PCCOV= 90.91	AVNS= 2.79	NGNS= 12
THTS= 96.00	PCFIX= 81.82	TRACKER 1	PCCOV= 90.91	AVNS= 2.85	NGNS= 12	TRACKER 2	PCCOV= 90.91	AVNS= 2.85	NGNS= 12
THTS= 99.00	PCFIX= 83.47	TRACKER 1	PCCOV= 91.74	AVNS= 2.98	NGNS= 14	TRACKER 2	PCCOV= 91.74	AVNS= 2.98	NGNS= 14
THTS= 102.00	PCFIX= 86.78	TRACKER 1	PCCOV= 93.39	AVNS= 3.07	NGNS= 11	TRACKER 2	PCCOV= 93.39	AVNS= 3.08	NGNS= 11
THTS= 105.00	PCFIX= 85.12	TRACKER 1	PCCOV= 91.74	AVNS= 2.98	NGNS= 11	TRACKER 2	PCCOV= 91.74	AVNS= 2.98	NGNS= 11
THTS= 108.00	PCFIX= 85.12	TRACKER 1	PCCOV= 92.56	AVNS= 3.22	NGNS= 11	TRACKER 2	PCCOV= 92.56	AVNS= 3.22	NGNS= 11
THTS= 111.00	PCFIX= 90.08	TRACKER 1	PCCOV= 95.04	AVNS= 3.18	NGNS= 11	TRACKER 2	PCCOV= 95.04	AVNS= 3.18	NGNS= 11
THTS= 114.00	PCFIX= 95.87	TRACKER 1	PCCOV= 97.52	AVNS= 3.18	NGNS= 11	TRACKER 2	PCCOV= 97.52	AVNS= 3.17	NGNS= 11
THTS= 117.00	PCFIX= 90.08	TRACKER 1	PCCOV= 95.04	AVNS= 3.23	NGNS= 12	TRACKER 2	PCCOV= 95.04	AVNS= 3.22	NGNS= 12
THTS= 120.00	PCFIX= 88.43	TRACKER 1	PCCOV= 94.21	AVNS= 3.21	NGNS= 16	TRACKER 2	PCCOV= 94.21	AVNS= 3.21	NGNS= 16
THTS= 123.00	PCFIX= 87.60	TRACKER 1	PCCOV= 93.39	AVNS= 3.53	NGNS= 16	TRACKER 2	PCCOV= 94.21	AVNS= 3.55	NGNS= 16
THTS= 126.00	PCFIX= 91.74	TRACKER 1	PCCOV= 95.87	AVNS= 3.60	NGNS= 19	TRACKER 2	PCCOV= 95.87	AVNS= 3.60	NGNS= 19
THTS= 129.00	PCFIY= 88.43	TRACKER 1	PCCOV= 94.21	AVNS= 3.61	NGNS= 16	TRACKER 2	PCCOV= 94.21	AVNS= 3.62	NGNS= 16
THTS= 132.00	PCFIX= 91.74	TRACKER 1	PCCOV= 95.87	AVNS= 3.64	NGNS= 14	TRACKER 2	PCCOV= 95.87	AVNS= 3.64	NGNS= 14
THTS= 135.00	PCFIX= 98.35	TRACKER 1	PCCOV= 99.17	AVNS= 3.51	NGNS= 10	TRACKER 2	PCCOV= 99.17	AVNS= 3.50	NGNS= 10
THTS= 138.00	PCFIX= 95.04	TRACKER 1	PCCOV= 97.52	AVNS= 3.50	NGNS= 11	TRACKER 2	PCCOV= 97.52	AVNS= 3.50	NGNS= 11

THTS= 141.00	PCFIX= 90.08	TRACKER 1	PCCOV= 95.04	AVNS= 3.36	NGNS= 12	TRACKER 2	PCCOV= 95.04	AVNS= 3.36	NGNS= 12
THTS= 144.00	PCFIX= 95.04	TRACKER 1	PCCOV= 97.52	AVNS= 3.17	NGNS= 9	TRACKER 2	PCCOV= 97.52	AVNS= 3.13	NGNS= 9
THTS= 147.00	PCFIX= 93.39	TRACKER 1	PCCOV= 96.69	AVNS= 3.33	NGNS= 14	TRACKER 2	PCCOV= 96.69	AVNS= 3.31	NGNS= 14
THTS= 150.00	PCFIX= 95.04	TRACKER 1	PCCOV= 97.52	AVNS= 3.74	NGNS= 15	TRACKER 2	PCCOV= 97.52	AVNS= 3.69	NGNS= 15
THTS= 153.00	PCFIX= 93.39	TRACKER 1	PCCOV= 96.69	AVNS= 3.69	NGNS= 14	TRACKER 2	PCCOV= 96.69	AVNS= 3.64	NGNS= 14
THTS= 156.00	PCFIX= 96.69	TRACKER 1	PCCOV= 98.35	AVNS= 3.70	NGNS= 20	TRACKER 2	PCCOV= 98.35	AVNS= 3.66	NGNS= 20
THTS= 159.00	PCFIX=100.00	TRACKER 1	PCCOV=100.00	AVNS= 3.87	NGNS= 15	TRACKER 2	PCCOV=100.00	AVNS= 3.89	NGNS= 15
THTS= 162.00	PCFIX=100.00	TRACKER 1	PCCOV=100.00	AVNS= 3.74	NGNS= 9	TRACKER 2	PCCOV=100.00	AVNS= 3.73	NGNS= 9
THTS= 165.00	PCFIX= 95.04	TRACKER 1	PCCOV= 97.52	AVNS= 3.81	NGNS= 10	TRACKER 2	PCCOV= 97.52	AVNS= 3.79	NGNS= 10
THTS= 168.00	PCFIX=100.00	TRACKER 1	PCCOV=100.00	AVNS= 3.98	NGNS= 9	TRACKER 2	PCCOV=100.00	AVNS= 3.98	NGNS= 9
THTS= 171.00	PCFIX= 95.04	TRACKER 1	PCCOV= 97.52	AVNS= 4.11	NGNS= 16	TRACKER 2	PCCOV= 97.52	AVNS= 4.07	NGNS= 16
THTS= 174.00	PCFIX= 95.04	TRACKER 1	PCCOV= 97.52	AVNS= 3.81	NGNS= 17	TRACKER 2	PCCOV= 97.52	AVNS= 3.80	NGNS= 17
THTS= 177.00	PCFIX= 93.39	TRACKER 1	PCCOV= 96.69	AVNS= 3.31	NGNS= 9	TRACKER 2	PCCOV= 96.69	AVNS= 3.31	NGNS= 9

FINAL DATA

NLDT= 7260	PCFIX= 90.66	TRACKER 1	PCCOV= 95.25	AVNS= 3.38	NGNS= 20	TRACKER 2	PCCOV= 95.28	AVNS= 3.37	NGNS= 20

CASE INPUT DATA

NUMBER OF STARS IN CATALOG	=	4827
NUMBER OF STAR TRACKERS	=	2
INITIAL SUN ANGLE (DEG)	=	180.00
FINAL SUN ANGLE (DEG)	=	360.00
SUN ANGLE INCREMENT (DEG)	=	3.00
VEHICLE ROTATION INCREMENT (DEG)	=	3.00

TRACKER 1 DIAMTR OF FIELD OF VIEW (DEG) = 6.0000 LIMITING MAGNITUDE = 6.0000
UNIT VECTOR DIRECTION COMPONENTS TRXR = 0 TRYR = 1.0000 TRZR = 0

TRACKER 2 DIAMTR OF FIELD OF VIEW (DEG) = 6.0000 LIMITING MAGNITUDE = 6.0000
UNIT VECTOR DIRECTION COMPONENTS TRXR = 0 TRYR = 0 TRZR = 1.0000

SUNLINE DATA

THTS=	PCFIX=		PCCOV=	AVNS=	NGNS=		PCCOV=	AVNS=	NGNS=
180.00	91.74	TRACKER 1	95.87	3.51	8	TRACKER 2	95.87	3.49	8
183.00	93.39	TRACKER 1	96.69	3.75	11	TRACKER 2	96.69	3.73	11
186.00	98.35	TRACKER 1	99.17	3.73	10	TRACKER 2	99.17	3.70	10
189.00	90.08	TRACKER 1	95.04	3.59	12	TRACKER 2	95.04	3.54	12
192.00	92.56	TRACKER 1	95.87	3.49	11	TRACKER 2	95.87	3.42	11
195.00	95.87	TRACKER 1	97.52	3.69	10	TRACKER 2	97.52	3.65	10
198.00	94.21	TRACKER 1	96.69	3.76	12	TRACKER 2	96.69	3.74	12
201.00	96.69	TRACKER 1	98.35	3.64	15	TRACKER 2	98.35	3.64	15
204.00	91.74	TRACKER 1	95.87	3.71	17	TRACKER 2	95.87	3.71	17
207.00	91.74	TRACKER 1	95.87	3.49	16	TRACKER 2	95.87	3.50	16
210.00	90.08	TRACKER 1	95.04	3.60	13	TRACKER 2	95.04	3.60	13
213.00	81.82	TRACKER 1	90.91	3.59	12	TRACKER 2	90.91	3.57	12
216.00	90.08	TRACKER 1	95.04	3.38	13	TRACKER 2	95.04	3.36	13
219.00	91.74	TRACKER 1	95.87	3.67	18	TRACKER 2	95.87	3.65	18
222.00	95.04	TRACKER 1	97.52	3.58	18	TRACKER 2	97.52	3.56	18
225.00	83.47	TRACKER 1	91.74	3.25	12	TRACKER 2	91.74	3.23	12
228.00	93.39	TRACKER 1	96.69	3.40	11	TRACKER 2	96.69	3.40	11
231.00	91.74	TRACKER 1	95.87	3.34	17	TRACKER 2	95.87	3.32	17
234.00	83.47	TRACKER 1	91.74	3.28	17	TRACKER 2	91.74	3.25	17

THTS= 237.00	PCFIX= 91.74	TRACKER 1	PCCOV= 95.87	AVNS= 3.12	NGNS= 13	TRACKER 2	PCCOV= 95.87	AVNS= 3.12	NGNS= 13
THTS= 240.00	PCFIX= 90.08	TRACKER 1	PCCOV= 95.04	AVNS= 3.07	NGNS= 12	TRACKER 2	PCCOV= 95.04	AVNS= 3.06	NGNS= 12
THTS= 243.00	PCFIX= 95.04	TRACKER 1	PCCOV= 97.52	AVNS= 3.07	NGNS= 13	TRACKER 2	PCCOV= 97.52	AVNS= 3.07	NGNS= 13
THTS= 246.00	PCFIX= 93.39	TRACKER 1	PCCOV= 96.69	AVNS= 3.00	NGNS= 14	TRACKER 2	PCCOV= 96.69	AVNS= 3.01	NGNS= 14
THTS= 249.00	PCFIX= 84.30	TRACKER 1	PCCOV= 91.74	AVNS= 2.91	NGNS= 14	TRACKER 2	PCCOV= 91.74	AVNS= 2.92	NGNS= 14
THTS= 252.00	PCFIX= 73.55	TRACKER 1	PCCOV= 86.78	AVNS= 2.67	NGNS= 16	TRACKER 2	PCCOV= 86.78	AVNS= 2.66	NGNS= 16
THTS= 255.00	PCFIX= 68.60	TRACKER 1	PCCOV= 83.47	AVNS= 2.67	NGNS= 15	TRACKER 2	PCCOV= 83.47	AVNS= 2.66	NGNS= 15
THTS= 258.00	PCFIX= 77.69	TRACKER 1	PCCOV= 88.43	AVNS= 2.85	NGNS= 11	TRACKER 2	PCCOV= 88.43	AVNS= 2.84	NGNS= 11
THTS= 261.00	PCFIX= 88.43	TRACKER 1	PCCOV= 94.21	AVNS= 3.05	NGNS= 12	TRACKER 2	PCCOV= 94.21	AVNS= 3.06	NGNS= 12
THTS= 264.00	PCFIX= 93.39	TRACKER 1	PCCOV= 96.69	AVNS= 3.06	NGNS= 9	TRACKER 2	PCCOV= 96.69	AVNS= 3.06	NGNS= 9
THTS= 267.00	PCFIX= 96.69	TRACKER 1	PCCOV= 98.35	AVNS= 3.21	NGNS= 12	TRACKER 2	PCCOV= 98.35	AVNS= 3.20	NGNS= 12
THTS= 270.00	PCFIX= 86.78	TRACKER 1	PCCOV= 93.39	AVNS= 2.98	NGNS= 13	TRACKER 2	PCCOV= 93.39	AVNS= 2.98	NGNS= 13
THTS= 273.00	PCFIX= 80.99	TRACKER 1	PCCOV= 90.08	AVNS= 2.77	NGNS= 12	TRACKER 2	PCCOV= 90.91	AVNS= 2.79	NGNS= 12
THTS= 276.00	PCFIX= 81.82	TRACKER 1	PCCOV= 90.91	AVNS= 2.84	NGNS= 12	TRACKER 2	PCCOV= 90.91	AVNS= 2.85	NGNS= 12
THTS= 279.00	PCFIX= 82.64	TRACKER 1	PCCOV= 90.91	AVNS= 2.96	NGNS= 14	TRACKER 2	PCCOV= 91.74	AVNS= 2.98	NGNS= 14
THTS= 282.00	PCFIX= 86.78	TRACKER 1	PCCOV= 93.39	AVNS= 3.08	NGNS= 11	TRACKER 2	PCCOV= 93.39	AVNS= 3.08	NGNS= 11
THTS= 285.00	PCFIX= 85.12	TRACKER 1	PCCOV= 91.74	AVNS= 3.00	NGNS= 11	TRACKER 2	PCCOV= 91.74	AVNS= 2.98	NGNS= 11
THTS= 288.00	PCFIX= 85.12	TRACKER 1	PCCOV= 92.56	AVNS= 3.23	NGNS= 11	TRACKER 2	PCCOV= 92.56	AVNS= 3.22	NGNS= 11
THTS= 291.00	PCFIX= 90.08	TRACKER 1	PCCOV= 95.04	AVNS= 3.17	NGNS= 11	TRACKER 2	PCCOV= 95.04	AVNS= 3.18	NGNS= 11
THTS= 294.00	PCFIX= 95.87	TRACKER 1	PCCOV= 97.52	AVNS= 3.16	NGNS= 11	TRACKER 2	PCCOV= 97.52	AVNS= 3.17	NGNS= 11
THTS= 297.00	PCFIX= 90.08	TRACKER 1	PCCOV= 95.04	AVNS= 3.23	NGNS= 12	TRACKER 2	PCCOV= 95.04	AVNS= 3.22	NGNS= 12
THTS= 300.00	PCFIX= 88.43	TRACKER 1	PCCOV= 94.21	AVNS= 3.21	NGNS= 16	TRACKER 2	PCCOV= 94.21	AVNS= 3.21	NGNS= 16
THTS= 303.00	PCFIX= 87.60	TRACKER 1	PCCOV= 93.39	AVNS= 3.53	NGNS= 16	TRACKER 2	PCCOV= 94.21	AVNS= 3.55	NGNS= 16
THTS= 306.00	PCFIX= 91.74	TRACKER 1	PCCOV= 95.87	AVNS= 3.60	NGNS= 19	TRACKER 2	PCCOV= 95.87	AVNS= 3.60	NGNS= 19
THTS= 309.00	PCFIX= 88.43	TRACKER 1	PCCOV= 94.21	AVNS= 3.61	NGNS= 16	TRACKER 2	PCCOV= 94.21	AVNS= 3.62	NGNS= 16
THTS= 312.00	PCFIX= 91.74	TRACKER 1	PCCOV= 95.87	AVNS= 3.64	NGNS= 14	TRACKER 2	PCCOV= 95.87	AVNS= 3.64	NGNS= 14
THTS= 315.00	PCFIX= 98.35	TRACKER 1	PCCOV= 99.17	AVNS= 3.53	NGNS= 10	TRACKER 2	PCCOV= 99.17	AVNS= 3.50	NGNS= 10
THTS= 318.00	PCFIX= 95.04	TRACKER 1	PCCOV= 97.52	AVNS= 3.50	NGNS= 11	TRACKER 2	PCCOV= 97.52	AVNS= 3.50	NGNS= 11
THTS= 321.00	PCFIX= 90.08	TRACKER 1	PCCOV= 95.04	AVNS= 3.37	NGNS= 12	TRACKER 2	PCCOV= 95.04	AVNS= 3.36	NGNS= 12

THTS= 324.00	PCFIX= 95.04	TRACKER	1	PCCOV= 97.52	AVNS= 3.14	NGNS= 9	TRACKER	2	PCCOV= 97.52	AVNS= 3.13	NGNS= 9
THTS= 327.00	PCFIX= 93.39	TRACKER	1	PCCOV= 96.69	AVNS= 3.30	NGNS= 14	TRACKER	2	PCCOV= 96.69	AVNS= 3.31	NGNS= 14
THTS= 330.00	PCFIX= 95.04	TRACKER	1	PCCOV= 97.52	AVNS= 3.72	NGNS= 15	TRACKER	2	PCCOV= 97.52	AVNS= 3.69	NGNS= 15
THTS= 333.00	PCFIX= 93.39	TRACKER	1	PCCOV= 96.69	AVNS= 3.68	NGNS= 14	TRACKER	2	PCCOV= 96.69	AVNS= 3.64	NGNS= 14
THTS= 336.00	PCFIX= 96.69	TRACKER	1	PCCOV= 98.35	AVNS= 3.74	NGNS= 20	TRACKER	2	PCCOV= 98.35	AVNS= 3.66	NGNS= 20
THTS= 339.00	PCFIX=100.00	TRACKER	1	PCCOV=100.00	AVNS= 3.92	NGNS= 15	TRACKER	2	PCCOV=100.00	AVNS= 3.85	NGNS= 15
THTS= 342.00	PCFIX=100.00	TRACKER	1	PCCOV=100.00	AVNS= 3.73	NGNS= 9	TRACKER	2	PCCOV=100.00	AVNS= 3.73	NGNS= 9
THTS= 345.00	PCFIX= 95.04	TRACKER	1	PCCOV= 97.52	AVNS= 3.82	NGNS= 10	TRACKER	2	PCCOV= 97.52	AVNS= 3.79	NGNS= 10
THTS= 348.00	PCFIX=100.00	TRACKER	1	PCCOV=100.00	AVNS= 4.01	NGNS= 9	TRACKER	2	PCCOV=100.00	AVNS= 3.98	NGNS= 9
THTS= 351.00	PCFIX= 95.04	TRACKER	1	PCCOV= 97.52	AVNS= 4.09	NGNS= 16	TRACKER	2	PCCOV= 97.52	AVNS= 4.07	NGNS= 16
THTS= 354.00	PCFIX= 95.04	TRACKER	1	PCCOV= 97.52	AVNS= 3.83	NGNS= 17	TRACKER	2	PCCOV= 97.52	AVNS= 3.80	NGNS= 17
THTS= 357.00	PCFIX= 93.39	TRACKER	1	PCCOV= 96.69	AVNS= 3.31	NGNS= 9	TRACKER	2	PCCOV= 96.69	AVNS= 3.31	NGNS= 9
THTS= 360.00	PCFIX= 91.74	TRACKER	1	PCCOV= 95.87	AVNS= 3.51	NGNS= 8	TRACKER	2	PCCOV= 95.87	AVNS= 3.49	NGNS= 8

FINAL DATA

NLDT= 7381	PCFIX= 90.67	TRACKER	1	PCCOV= 95.24	AVNS= 3.38	NGNS= 20	TRACKER	2	PCCOV= 95.29	AVNS= 3.37	NGNS= 20

CASE INPUT DATA

NUMBER OF STARS IN CATALOG	=	4827
NUMBER OF STAR TRACKERS	=	3
INITIAL SUN ANGLE (DEG)	=	0
FINAL SUN ANGLE (DEG)	=	90.00
SUN ANGLE INCREMENT (DEG)	=	3.00
VEHICLE ROTATION INCREMENT (DEG)	=	3.00

TRACKER 1	DIAMTR OF FIELD OF VIEW (DEG) = 6.0000	LIMITING MAGNITUDE = 6.0000		
	UNIT VECTOR DIRECTION COMPONENTS	TRXR = 0	TRYR = 1.0000	TRZR = 0
TRACKER 2	DIAMTR OF FIELD OF VIEW (DEG) = 6.0000	LIMITING MAGNITUDE = 6.0000		
	UNIT VECTOR DIRECTION COMPONENTS	TRXR = 0	TRYR = .7071	TRZR = .7071
TRACKER 3	DIAMTR OF FIELD OF VIEW (DEG) = 6.0000	LIMITING MAGNITUDE = 6.0000		
	UNIT VECTOR DIRECTION COMPONENTS	TRXR = 0	TRYR = 0	TRZR = 1.0000

SUNLINE DATA

THTS=	PCFIX=		PCCOV=	AVNS=	NGNS=		PCCOV=	AVNS=	NGNS=
0	98.35	TRACKER 1	95.87	3.51	8	TRACKER 2	95.87	3.50	8
		TRACKER 3	95.87	3.49	8	TRACKER			
3.00	98.35	TRACKER 1	96.69	3.75	11	TRACKER 2	96.69	3.74	11
		TRACKER 3	96.69	3.73	11	TRACKER			
6.00	100.00	TRACKER 1	99.17	3.69	10	TRACKER 2	99.17	3.71	10
		TRACKER 3	99.17	3.70	10	TRACKER			
9.00	100.00	TRACKER 1	95.04	3.55	12	TRACKER 2	95.04	3.55	12
		TRACKER 3	95.04	3.54	12	TRACKER			
12.00	99.17	TRACKER 1	95.87	3.45	11	TRACKER 2	95.87	3.42	11
		TRACKER 3	95.87	3.42	11	TRACKER			
15.00	99.17	TRACKER 1	97.52	3.68	10	TRACKER 2	97.52	3.66	10
		TRACKER 3	97.52	3.65	10	TRACKER			
18.00	99.17	TRACKER 1	96.69	3.77	12	TRACKER 2	96.69	3.74	12
		TRACKER 3	96.69	3.74	12	TRACKER			
21.00	100.00	TRACKER 1	98.35	3.64	15	TRACKER 2	98.35	3.66	15
		TRACKER 3	98.35	3.64	15	TRACKER			
24.00	100.00	TRACKER 1	95.87	3.71	17	TRACKER 2	95.87	3.77	17
		TRACKER 3	95.87	3.71	17	TRACKER			
27.00	100.00	TRACKER 1	95.87	3.50	16	TRACKER 2	95.87	3.52	16
		TRACKER 3	95.87	3.50	16	TRACKER			
30.00	98.35	TRACKER 1	95.04	3.60	13	TRACKER 2	95.04	3.60	13
		TRACKER 3	95.04	3.60	13	TRACKER			
33.00	96.69	TRACKER 1	90.91	3.59	12	TRACKER 2	90.91	3.56	12
		TRACKER 3	90.91	3.57	12	TRACKER			
36.00	98.35	TRACKER 1	95.04	3.37	13	TRACKER 2	95.04	3.36	13
		TRACKER 3	95.04	3.36	13	TRACKER			
39.00	100.00	TRACKER 1	95.87	3.65	18	TRACKER 2	95.04	3.64	18
		TRACKER 3	95.87	3.65	18	TRACKER			
42.00	100.00	TRACKER 1	97.52	3.57	18	TRACKER 2	97.52	3.58	18
		TRACKER 3	97.52	3.56	18	TRACKER			
45.00	98.35	TRACKER 1	91.74	3.22	12	TRACKER 2	91.74	3.26	12
		TRACKER 3	91.74	3.23	12	TRACKER			
48.00	100.00	TRACKER 1	96.69	3.39	11	TRACKER 2	96.69	3.42	11
		TRACKER 3	96.69	3.40	11	TRACKER			
51.00	100.00	TRACKER 1	95.87	3.32	17	TRACKER 2	95.87	3.34	17
		TRACKER 3	95.87	3.32	17	TRACKER			
54.00	96.69	TRACKER 1	91.74	3.26	17	TRACKER 2	91.74	3.25	17
		TRACKER 3	91.74	3.25	17	TRACKER			

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THTS=  57.00   PCFIX=100.00   TRACKER 1  PCCOV= 95.87  AVNS= 3.12  NGNS= 13   TRACKER 2  PCCOV= 95.87  AVNS= 3.12  NGNS= 13
                              TRACKER 3  PCCOV= 95.87  AVNS= 3.12  NGNS= 13   TRACKER
THTS=  60.00   PCFIX= 98.35   TRACKER 1  PCCOV= 95.04  AVNS= 3.07  NGNS= 12   TRACKER 2  PCCOV= 95.04  AVNS= 3.06  NGNS= 12
                              TRACKER 3  PCCOV= 95.04  AVNS= 3.06  NGNS= 12   TRACKER
THTS=  63.00   PCFIX=100.00   TRACKER 1  PCCOV= 97.52  AVNS= 3.07  NGNS= 13   TRACKER 2  PCCOV= 96.69  AVNS= 3.05  NGNS= 13
                              TRACKER 3  PCCOV= 97.52  AVNS= 3.07  NGNS= 13   TRACKER
THTS=  66.00   PCFIX=100.00   TRACKER 1  PCCOV= 96.69  AVNS= 3.03  NGNS= 14   TRACKER 2  PCCOV= 96.69  AVNS= 3.00  NGNS= 14
                              TRACKER 3  PCCOV= 96.69  AVNS= 3.01  NGNS= 14   TRACKER
THTS=  69.00   PCFIX= 97.52   TRACKER 1  PCCOV= 91.74  AVNS= 2.93  NGNS= 14   TRACKER 2  PCCOV= 91.74  AVNS= 2.91  NGNS= 14
                              TRACKER 3  PCCOV= 91.74  AVNS= 2.92  NGNS= 14   TRACKER
THTS=  72.00   PCFIX= 98.35   TRACKER 1  PCCOV= 86.78  AVNS= 2.66  NGNS= 16   TRACKER 2  PCCOV= 86.78  AVNS= 2.65  NGNS= 16
                              TRACKER 3  PCCOV= 86.78  AVNS= 2.66  NGNS= 16   TRACKER
THTS=  75.00   PCFIX= 93.39   TRACKER 1  PCCOV= 83.47  AVNS= 2.68  NGNS= 15   TRACKER 2  PCCOV= 83.47  AVNS= 2.65  NGNS= 15
                              TRACKER 3  PCCOV= 83.47  AVNS= 2.66  NGNS= 15   TRACKER
THTS=  78.00   PCFIX= 95.87   TRACKER 1  PCCOV= 88.43  AVNS= 2.85  NGNS= 11   TRACKER 2  PCCOV= 88.43  AVNS= 2.84  NGNS= 11
                              TRACKER 3  PCCOV= 88.43  AVNS= 2.84  NGNS= 11   TRACKER
THTS=  81.00   PCFIX=100.00   TRACKER 1  PCCOV= 94.21  AVNS= 3.07  NGNS= 12   TRACKER 2  PCCOV= 94.21  AVNS= 3.05  NGNS= 12
                              TRACKER 3  PCCOV= 94.21  AVNS= 3.06  NGNS= 12   TRACKER
THTS=  84.00   PCFIX=100.00   TRACKER 1  PCCOV= 96.69  AVNS= 3.06  NGNS=  9   TRACKER 2  PCCOV= 96.69  AVNS= 3.07  NGNS=  9
                              TRACKER 3  PCCOV= 96.69  AVNS= 3.06  NGNS=  9   TRACKER
THTS=  87.00   PCFIX=100.00   TRACKER 1  PCCOV= 98.35  AVNS= 3.19  NGNS= 12   TRACKER 2  PCCOV= 98.35  AVNS= 3.21  NGNS= 12
                              TRACKER 3  PCCOV= 98.35  AVNS= 3.20  NGNS= 12   TRACKER



FINAL DATA
NLDT=   3630   PCFIX= 98.87   TRACKER 1  PCCOV= 94.74  AVNS= 3.33  NGNS= 18   TRACKER 2  PCCOV= 94.68  AVNS= 3.33  NGNS= 18
                              TRACKER 3  PCCOV= 94.74  AVNS= 3.32  NGNS= 18   TRACKER
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APPROVAL

NASA TMX-

HEAO STAR TRACKER SEARCH PROGRAM

By William J. Weiler

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

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

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